WOOD CONVERSION BY MACHINERY.

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BY

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PREFACE.

THE present series of articles on "Wood Conversion by Machinery" was originally published in the *Timber Trades Journal* during 1875, and at the request of many of the readers it was decided to reproduce them in a more permanent form, more especially as writings pertaining to Wood Conversion are few enough and incomplete enough to justify the preservation of whatever will be of use in developing this important industry.

The subject is, for the most part, treated in an historical and economical way, and hence what is presented will apply to wood manufacturing industry independently of those changes in minor details which are constantly going on

The number of saw-mills which is commonly employed as a basis for estimating the extent of wood manufacturing, conveys but a limited idea of that branch of industry which may be classed as wood converting.

Wheel carriages, furniture, hollow ware, with many other things which could be named, are vast and important branches of our manufacturing industry, the main processes in which are converting and shaping wood.

Processes so diversified do not of course admit of compendious treatment, and hence the necessity of generalizing in a work like the present one. Wood converting is rapidly changing, improvements are constantly being made, and the same reasons which prevent specific descriptions of processes argue the necessity of closely following such changes and improvements.

That the next few years will bring about a more extended application of machines in various kinds of wood work there can be no doubt; such a result is not so much, however, to be expected from improvements in machinery as from a concentration of manufacture enabling a "duplication of parts," and consequently the employment of special machines.

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WOOD CONVERSION BY MACHINERY.

CHAPTER I.

MACHINE TOOLS FOR WOOD CONVERSION.—THEIR ECONOMIC EFFECT.

Nearly all articles of manufacture, if not the direct product of what are called machine tools, are a secondary product—that is, machinery of whatever kind employed in manufacturing is a product of machine tools; and when we trace back a particular manufacture, whether of iron, wood, or fibrous material, we shall always come to a first stage wherein machine tools have enabled, and not unfrequently been the means of suggesting the manufacture.

It is not an easy matter even for the skilled to define the difference between what are called machine tools, and manufacturing machinery. The term in an engineering sense is mainly confined to implements for converting iron and wood, and in this sense it is proposed to employ it here, yet there is no reason why the name should not apply as well to any implement to which machine power is applied, especially when such implements have supplanted hand tools.

Some manufactures are possible only by the application of machinery, but by far the greater part have in some manner been carried on previous to the application of motive power and machines. It is easy to see whether a manufacture can be performed by hand or not, that the expense of production must become the true measure of practicability, or to state it otherwise, the importance of machine tools in any manufacture may be just the same whether such manufacture could be performed by hand or not.

Builders' materials, for instance, such as doors, window sashes, floor boards and so on, can all be prepared by hand, and even are to some extent at this time, but in an open market and with fair competition, it is impossible to prepare such material by hand labour as it would be to convert trees with handsaws.

Among the many causes which tend to the employment of wood converting machines, the principal one has been the great expense of handwork, and the amount of such machinery employed in various countries is very regularly as the rate of wages paid to workmen. Economy of labour having introduced machines into a manufactory, the price of the product is at once lowered, so as to effect a ready sale, and in other manufacturies a similar course has to be adopted to maintain a place in competition. It is both curious and interesting to trace the rise and development of wood manufacture in different places, and note the time required for machine work to displace handwork,and also the influencs exerted by such changes upon workmen.

It may be noted that without exception whenever the product of wood manufacture goes to a common market, and is not protected by any kind of monopoly, such as patents, secret processes, or the still more onerous restriction called in trade "exclusiveness," machinery has been generally and soon adopted for every process to which it can be applied.

The Baltic country, for example, has what we may call a common market for wood and wood products; the competition is an open and equal one, except as the cost of production may be influenced by concessions given to certain persons or firms by the Scandinavian governments. The result is, that to manufacture either lumber or finished building material, machinery of the best class must be employed. Ten, or even five per cent. of difference in the cost of production may under such circumstances build up or break down a manufactory, especially if labour constitute a considerable part in the cost of production. The effect of such competition is at this time best seen in the United States, where the price of doors, sash, flooring, mouldings, and other building material is as fixed, and governed by the same conditions as other staples. The result is, that all manufacturers are compelled not only to employ machines, but must have machines of a given capacity; a day's work of planing, mortising, or tenoning by machines is as well known, and has a fixed standard, the same as a day's work of hand labour once had. So that such manufacture has become regular, losing from year to year a speculative character, and becoming beneficial to the interests of the country in the same degree.

Another result of wood manufacturing becoming regular and uniform has been to divide the preparation of builder's material from the building trades, a change now rapidly gaining ground in Europe, and which, for obvious reasons must soon become complete. This subject is only alluded to here, and will be treated of at greater length in a future place.

The influence of machine work upon the wages and interests of skilled workmen in some cases is one of those complex problems of which no solution is likely to be reached even by a generalization of facts and results.

In respect to wood manufacture in all its branches we can, however, well dispense with the philosophy which would explain the effects of machinery upon the interests of workmen; the facts are so complete, and the beneficial results of machine application so well known that the opposition to machinery, once so common in Europe, has almost ceased.

Everywhere workmen have been raised, and benefited in a social and educational point of view. Wages have increased, so also has the amount of work to be done, and generally in proportion to the extent which machinery has supplanted hand labour. If the number of skilled workmen required in any particular branch of wood manufacture has been reduced, other and new branches have been opened up, while, contrary to the opinions of many and in some cases of our wisest men, the demand for manufactured products keeps pace with the power of producing.

To cheapen a product even in a small degree, seems at once to lead to its more extended use, and in most cases to new purposes, until the whole is absorbed; if for instance the cost of planing lumber was by some new improvement reduced one-half, such a result would for a time disturb the manufacture, causing fluctuations in prices, and perhaps reduce the number of operators engaged in tending planing machines, but in a short time, and as soon as such improvement became generally adopted by millowners, the effect would be a good one for all. Time would be required for the influence of the cheaper product to be felt in the rent paid for houses, the price of food and other necessaries of life, but such effect would be inevitable, and it is only foolish to regard the effect of labour-saving machines as detrimental to the interests of workmen because a manufacturer, or a patent owner may reap the earliest reward. By "exclusiveness" in wood manufactures, mentioned in a former place, is meant that considerable portion of our wood manufacture which is not subject to open competition; cases where builders, cabinet makers, coach makers, and so on, are able to continue hand work, because of higher prices obtained by prestige or reasons other than the real value of what is produced.

This relic of old times, supported by the specious argument of keeping up the quality of products, is fast disappearng. The number of people who will purchase an article of manufacture at a higher price than that for which another manufacturer would furnish the same thing, are each year becoming less; the effect of books and journals devoted to technical industry is fast educating the public in the quality and value of every kind of manufactured products, and the blind dependence upon persons skilled in certain callings must soon give way to a fair competition.

Of this no higher evidence is wanting than the popular efforts now making for educating the young in technology as well as in classics, and perhaps in no branch of industry will such education avail more than in wood conversion.

In the pages to follow there will be given some explanation of the principles upon which woodworking machine tools operate, with some notice of the progress and development of wood manufactures in Europe and America, also of some special machines and manufactures such as are thought to be of general interest.

The existence at this time of a single journal in Great Britain devoted to the timber and wood manufacturing interests is perhaps a sufficient evidence of the narrow source open for information to those who write upon the subject; it also shows a necessity for more being written, and there is no one conversant with the facts who will not admit that if wood manufactures had been supported and encouraged by books and scientific journals as many other less important interests have been, improvement, great as it has been, would be still more rapid and thorough.

CHAPTER II.

THE INVENTIONS OF SIR SAMUEL BENTHAM PERTAINING TO WOOD-CUTTING.

In each branch of the manufacturing arts, or at least in such branches as have some prominence, there is a pleasure and sometimes a gain in going back over their early history, and noting the difficulties and doubts which had to be combated, the risks and self-denial through which early inventors and improvers fought their way.

The gain which may be derived in this way is that it enables us to estimate the degree and value of the progress made down to our time, and from this to form some opinion as to what the future may bring forth. Such research also does but due justice to those who were early promoters and workers in our industries.

In reference to early inventors, and especially as respects the one of which some notice is to be given here, it should be pointed out that the measure of honour and fame meted out to such men is by no means to be taken as indicating the importance of their works.

A person may invent a whole train of processes, constituting a branch of manufacture of first importance, and receive for such a work less renown than a person who discovers some comparatively trifling matter, but one which is brought to the general notice of the public.

The credit received for inventive improvements is naturally as their popularity, and as the number of people brought in contact with such improvements; and as any invention in technical industry is confined to the knowledge and understanding of but a small number of people, it is but natural that by a popular standard the inventor of umbrellas, velocipedes, or sewing machines should rank the same with those who have founded railways, steam navigation, or the most intricate of our manufactures.

Invention may be divided into two branches, in some respects quite distinct; one, the conception of principles, or the mode of processes; and the other, the invention of mechanical means of carrying out such processes. The first belongs to the field of true engineering; the second, to that of the mechanician or contriver; and in order to form a true estimate of any invention, so far as it may represent ability and talent, this division must be kept in mind.

In a book by the writer published some time ago * there was given a brief notice of Sir Samuel Bentham, with some account of his connection with the origin and rise of wood-cutting machines. Such a notice in a technical book was of course very brief, and failed to include many things which at this time cannot fail to have a considerable interest to those engaged in wood manufacturing.

It will also in the present case be impossible to enter upon any history of Sir Samuel Bentham; his works as engineer and inventor could scarce be detailed, no matter how

* "A Treatise on the Construction and Operation of Wood-Working Machines." 1872.

briefly, at the space here at command, and it is proposed only to review his connection with the origin of woodcutting machines as set forth in his patent of 1793 (No. 1951).

The specification of this patent is perhaps at this time the most remarkable example existing of how far the power of words alone can go in conveying ideas of practical mechanism; there is no kind of composition which so taxes the power of language as descriptions of machinery and machine-processes, even when drawings are employed to assist explanation, yet in reading the specification referred to not only is the want of drawings not realized, but we even have a more clear and comprehensive idea of the nature of the inventions described because of the absence of such specific mechanism as drawings would necessarily represent.

This remark may not apply to the case of those who are altogether unskilled in the processes set forth and explained, but will, no doubt, be admitted by those who have had occasion to examine the patent, and to determine its scope and meaning, either in a mechanical or a legal way.

Bentham's first patent in wood-working machinery for cutting and planing (No. 1838), dated 1791, deserves some notice before his later and more important one of 1793; not that the planing machinery described therein deserves much notice, but because of the language of the specification which gives a most distinct clue to the method of reasoning and development which enabled Bentham to proceed successfully and boldly in improvements connected with nearly every branch of industry practised at the time.

On page 2 of the Specification (1791) he says, in reference to the employment of machines for planing wood, "By this means machinery may take the place of human skill in this operation to as perfect a degree as in any of the manufactures on which invention has been employed.

"Hence arise three capital advantages:—

"First.—The quantity of force employed, and hence the quantity of work done at a time, may be increased at pleasure.

"Second.—Even the force of men may be exerted in this way to a greater advantage than while confined, as in present practice, to a particular mode, by the necessity of care and dexterity.

"Third.—The labour not only of the awkward and unpractised, but of the blind and lame, may be called in, and a value given to it little, if any, short of that which the most skilled and experienced artist bears at present.

"This invention," he continues, "is, properly speaking, not of a mode, but of a principle."

There has been some attempt to place the invention of Hatton, 1776, patent (No. 1125) as preceding and anticipating Bentham's wood-planing machine described in the specification quoted from. Nothing can be more unfair; the machine of Hatton is evidently one of those crude mechanical contrivances, of which we have no lack at the present day, in which there is no definite object followed, nor any definite result expected; it was merely a scheme, such a one as any ordinary mechanic could have hit upon without the exercise of what may be called the powers of invention.

Bentham's machine of 1791, as a mechanical agent, was perhaps but little better than Hatton's, yet the mechanism was but a small and even unimportant part of the invention; his real invention consisted in discovering and evolving a principle which, as subsequent events will serve to show, soon led to the abandonment of reciprocating cutters for those having rotary motion, and founded our present mode of wood-planing.

Referring now to the patent of 1793, it is proposed to follow through the specification and to compare the various suggestions and propositions there laid down, with modern practice. In doing this no fair estimate of the ability of the inventor can be had, without at the same time considering the state of the mechanic arts at the period. Seventy-five years ago there were but few machines for cutting wood known or employed. Reciprocating saws and turning lathes were nearly all. Circular saws were employed to a limited extent here and in Holland, but the mechanical difficulties connected with high speed, both in respect to the bearings of spindles and the means of driving them, were so great, that any plans looking to the employment of rapid motion had to include not only the operation of tools on materials, but also an even greater problem of how to support and drive spindles at a high speed.

Even the manufacture of circular saws was a matter of great difficulty and expense; they were plated out by hand hammers and were made only of small size.

Veneer Cutting.

The first proposition in Bentham's patent is to form boards, tubes, or other forms from thin veneers, cut with knives from blocks of wood, wet or steamed so as to render them soft. The description of the process of cutting veneers or scales, on pages 2 and 3 of the specification may be said to comprehend all that has since been developed in such cutting. The wood paper, or scales of wood so thin as to be employed like paper for covering walls, are at this time cut most successfully by means of reciprocating planes, precisely in the manner described in the specification of Bentham.

The proposition to form tubes from wood by winding successive layers glued or cemented together, we may claim is not a matter of common practice, only because paper, gutta-percha, and metals are employed, and because tubes can be made, at less expense of such materials than from wood; yet even now many boxes and tubes are made from scale boards, in the manner described in the patent.

On page 8 are described gang saws for cutting stone, nearly corresponding to modern practice, and following this comes a careful and comprehensive description of the wedge or spreading guard, now a common feature of all wood sawing machinery employed for cutting thin pieces.

The Rotary Wedge.

A "rolling wedge" is commonly employed with large saws in America. Veneer saws with a metal disc bevelled from the axis, and circular saws ground off thin from their centres, are also nothing more than modifications of what was proposed and described by Bentham. Any skilled person after reading the specification, page 9, would not only have no difficulty in foreseeing the application of this wedge principle, and could not thereafter, in the true sense of the term, "invent" either a rolling wedge, or a wedge running with a saw; it is all the same thing, parts of one mode of operating which is clearly and amply set forth by Bentham.

Saw Guides.

Stationary guides bearing directly on saws to keep them in a true line, are described as follows:—

"To confine the saw better to its direction, and prevent its being twisted by the above or any other cause, I sometimes employ a pair of guides, consisting of hard wood or metal. . . . One of these guides is fixed as near as possible above the upper surface of the piece (to be sawed), the other as near as possible below the under surface."

The application of such guides, as well as other devices pertaining to sawing, are of course spoken of in connection with reciprocating saws; circular saws, except of small diameter, were then unknown, and could not have been made even if their application had been understood; this, however, only renders the improvements of Bentham the more remarkable, because had he foreseen that circular saws of large diameter, and for the largest pieces, would have come into use in future, he would no doubt have given hints which might even now be of use. In proof of this last proposition it may be mentioned, that while in almost all cases our circular saws are provided with guides, or packing-boxes beneath the lumber, guides above the lumber are seldom provided, and such guides are in most cases of more importance than those placed beneath. Packing guides in the top of a saw bench or beneath the lumber serve to keep a saw in line "after" it has passed through the lumber, but guides above the lumber direct a saw "before" it enters the wood.

The American Muley saw-mills and band-saws also furnish examples of the importance of top guides, the lower or bottom guides being sometimes dispensed with altogether. With circular saws, however, the guides or packing-boxes have other objects besides keeping the plate in line; they are employed for lubricating, keeping the saws rid of pitch, and serve also to diffuse the heat which may arise either from the saw rubbing against the wood or come from the bearings of the spindles.

Reciprocating cross-cutting saws are next described with careful minuteness, including carriages with automatic stop motion, to be employed in cutting the shoulders of tenons. Two saws to cut both sides of a tenon at one operation are mentioned, a plan which was for a long time, and even down to a recent date followed in cutting tenons for joinery and cabinet-work.

Lumber Guides.

The radial or swing gauge for cutting out curved pieces, afterwards shown in the patent of Newberry (band-sawing, 1808), was no doubt the invention of Bentham applied in connection with the new process of sawing.

On page 12 of Bentham's specification will be found a clear description of what is sometimes called a "tracing guide," employed for sawing out irregular forms; these guides consist in grooves formed in the top of a table and under a sliding plate or carriage, on which the pieces to be sawn are fastened. Pins are inserted in the sliding carriage fitting into the grooves beneath, and as the lumber progresses to the saw these grooves direct it, the same as would be done by hand if the lumber were free to move in any direction. As there are two of these grooves, one at each end of the sliding piece, and two pins to guide it, there will obviously be but little correspondence between the form or course of the grooves and the piece sawed out.

The form of such guiding grooves is determined by experiment; pencils or scribing points are inserted at the ends of a finished piece; this piece is then carefully moved along at the side of the saw as nearly as possible in a proper course for sawing out similar pieces; the marks produced by the pencils or scribing tools show the position and form of the guiding grooves.

This mode of presenting and guiding wood to receive the action of saws or cutters was adopted by *Slater and Tall,* and is shown in their patent of 1854, for improvements in machinery for making wooden planes; a patent which, next to that of Bentham, contains perhaps a greater amount of original and practical invention in woodcutting than any other ever granted in this or any other country.

Curvilinear Sawing.

Spiral or irregular bevel sawing, such as cutting out ship timbers, is carefully described by Bentham; descriptions are given of how machines for such purposes should be constructed; and it is not a matter of wonder that a patent granted for machines of this kind was in 1848 the subject of a trial at law in which the proceedings were for a repeal of the patent. (Crown *v.* James Smith's patent for sawing machinery.)

Machines to cut winding forms are now extensively employed in American shipbuilding yards, and have been the subject of many patents relating to the details and mechanism required for various operations, but still the principles are the same as those set forth in Bentham's specification.

In this connection it will be proper to say that a "principle," or "a mode of operating," which is as near a definition of what a principle means as our courts have been able to arrive at, may or may not be subject-matter of an invention.

When a "principle" or mode of operating is conceived of only, there is no invention in the legal nor accepted sense of the term. The mechanical agents required to perform the "mode of operating" in a practical way must also be invented, otherwise incompetent persons might forestall and monopolize "modes of operation" which they themselves were unable to turn to practical use.

Bentham's inventions are clearly within the line which excludes theoretical scheming; his inventions were not alone of principles or general methods, but in each case is described a practical mode of operating, so that in all the accounts of his improvements in woodcutting machines is found that minuteness and clearness of detail which was mentioned at the beginning, and which would in every instance enable a workman of ordinary skill to construct the machines described.

Wave Moulding.

Section III. of Bentham's specification is remarkable as giving a clear and exact description of "scraping," or fixed tool moulding machines, such as are at the present time employed for making what are known as wave mouldings.

Not a single detail is wanting to constitute the specification (pages 14 and 15, No. 1951) a complete description of all the essential features of modern machines for making wave mouldings, and the reason why mouldings with an irregular surface, such as are now common, were not mentioned is probably because such disfigurement was not thought desirable.

Waved mouldings are at best a questionable kind of ornament, both as a matter of taste and the inconvenience of keeping them clean; but the longer curves or irregular forms mentioned in the specification, as well as parallel configuration of pieces having square or enlarged sections preventing the employment of moulding planes, shows that no essential feature of this process or mode of operating was overlooked by the inventor.

Saw Grinding.

In connection with a "Reciprocate Lathe," as it is called, is mentioned that the same mode of operating can be applied to the grinding of saws, and it is a very singular fact that the most improved machinery for grinding straight saws, invented within a dozen years past, is substantially an application of what Bentham proposes. In the Keystone works at Philadelphia, where there is no doubt the most improved machinery in the world for saw-making, the thicker kinds of plate or straight saws are ground when stretched in reciprocating frames, precisely on the plan described by Bentham more than eighty years ago; even the employment of two grindstones one acting on each side of the saw-plate, a feature of the new machinery alluded to, did not escape Benthams' attention, but is set forth in words which might form a portion of the specification of a patent granted for the modern machines referred to.

Wood Bending.

In Section IV., relating to bending wood, is given a description of the now common plan of slitting the wood into several pieces parallel with its length or grain. It is not known whether this had been practised before in other countries, but as Bentham says it was new, and as his opportunities of observation were greater perhaps than those of any other person of his time, there can be but little doubt that the invention of dividing wood for bending began with him.

That part most to be noted in the description of wood-bending given is what relates to what are now called "back straps."

No success was attained in wood-bending until such straps came into use; they consist in a strong plate or strap of steel or iron, which follows and is firmly pressed against the convex sides of the pieces bent, preventing the fibres from breaking or raising. Another office of such straps in bending curved pieces is to give "end pressure," as it is called, that is, prevent an elongation of a piece while it is being bent, and, by end pressure, causing a compression of the concave side equal to or exceeding the elongation on the convex side. We now come to what is the most important part of the inventions contained in the patent of 1793.

Rotary Tools for Woodcutting.

The fifth section relates to shaping material by rotary tools. The inventor says "the idea of adapting the rotative motion of a tool with more or less advantage, to give to all sorts of substances any shape that may be required, is my own, and as I believe, entirely new."

In another place the processes of sawing, boring, grinding, and also cutting mortises in ships' blocks by rotary tools and appliances, are referred to, and if we classify ordinary machine operations into dividing, as with saws; abrading, as with grindstones, and cutting to shape with rotary cutters, as in planing and moulding, we shall be compelled to admit, the principles or mode of operating on plane surfaces with rotary tools as the invention of Bentham.

For those not skilled in or acquainted with the nature and extent of the various operations in wood-conversion which come under the head of shaping with rotary cutters, it will be difficult to convey an idea of the importance of the invention here set forth; it includes, indeed, nearly all operations in wood-working, and as an original invention may be said to consist in the discovery of the fact that flat surfaces or surfaces of any contour, can be properly prepared by the action of rotating tools.

It is not to be wondered at that such an operation should not have been sooner discovered, for even at the present time there are few processes in treating material which seem so anomalous as that of planing a flat surface with cutters revolving in a circle of a few inches in diameter.

In the first part of the section relating to rotary tools in Bentham's patent he gives a very lucid description of the various appliances commonly employed in connection with circular saws for grooving, rebating, notching, cross-cutting, slitting, and so on, devices which were more than thirty years later described by Professor Willis, Holtzapfel and others, and with other things the patent describes the process of preparing dovetail joints with conical cutters, a plan which is yet followed, and is the principle upon which most of the dovetailing machines now in use are constructed.

In reference to planing mouldings it is said, "If the circumference of a circular cutter be formed in the shape of any moulding, and projecting above the bench no more than necessary, the piece being shoved over the cutter will thus be cut to a moulding corresponding to the cutter; that is, the reverse of it, just as a plane iron cuts the reverse.

"If a plain cutter such as that above spoken of for cutting a groove in the breadth of a piece, be made so thick, or as we might be apt to say now, so broad, or so long, as to cover the whole breadth of the piece, it will present the idea of a roller. This I call a cutting roller; it may be employed in many cases with great advantage to perform the office of a plane."

The cutting roller of Bentham is the present cutter "block" of England, or the cutting "cylinder" of America, and after what has been quoted it may be seen that the idea of rotary planing and moulding machines had been fully grasped by Bentham. He goes on as usual to the various conditions which attach to the process of planing.

"A waving or a winding surface can be produced," says he, by such means as have been suggested in connection with reciprocating machines; and farther, "if a cutting roller of this sort be placed with its axis horizontal and the bench beneath, it may be made to rise and lower. The bench (machine) may be very readily adjusted, so as to determine the thickness to which a piece will be reduced by *being passed under the roller.*"

"To gain time cutters may be applied *to different sides of a piece at once*, and such of them as make parallel cuts may be mounted on the same spindle.

These extracts would not be out of place in an explanatory lecture or essay on wood-cutting at the present day, and cannot help awakening surprise that they should have been written eighty-three years ago, when there had, so far as we know, been no precedents, nor even suggestions from previous practice.

The section on rotary cutting tools ends with a description of segmental saws, not only describing a mode of constructing such saws, but giving the reasons why segmental saws should be made, and the advantages gained from having saws made in that manner.

The following extract may have some interest to modern inventors of saws with inserted teeth:—"Another mode of composition is to make the teeth distinct from each other, as well as from the cylinder from which they project; they will thus be separately bedded in the cylinder, and taken on or off as occasion may require."

Wood-boring.

Pages 25 and 26 of *Bentham's Patent* of 1793 contain an elaborate description of various boring appliances for wood.

The various tools and processes explained not only comprehend nearly every common form of boring or perforating tools, but also core-boring and tubular augers, which, so far as their application, may be regarded as implements of modern discovery; tubular augers for boring long pieces, such as pump tubes, wooden pipes, and for holes which require to be true and straight, as in boring the axes of waggon hubs, are now or have been down to a recent time licensed and manufactured under patents granted fifty years after Bentham's description of the tools. Rotary mortising machines, and machines for relief work, called at this day moulding and recessing machines, were included among and fully described with Bentham's inventions. Reciprocating mortising machines, float machines or tools, slide rests, gauge turning,—in short, there is no modern machine or process, or at least no important one in wood cutting which might not have been drawn from the specification of Bentham. Nor is this all that can be said; so replete with useful and practical suggestions is the specification of 1793, that it will be no exaggeration to say that as a technical treatise on wood-cutting it has high claims as a text-book even for our day.

In contemplating the inventions of Bentham, or indeed any improvement of a former time which failed to become known or used, there is a lesson to be drawn, one which points out the advantages which we now enjoy. Had the improvements of Bentham in wood-cutting machines been as broadly published and disseminated at the end of the last century as the most trivial inventions are at the present time, there can be scarcely a doubt that wood manufactures of all kinds would much sooner have attained the place they now hold.

To follow chronologically various improvements which followed those of Bentham would be a matter of but little interest to most persons. Following his time there was a long period in which there seemed to be no advancement made, owing no doubt in a great measure to an impression that Bentham's patents comprehended the whole art of machine wood-conversion, an opinion which would naturally be strengthenedby the fact of his machines being for the most part employed in the Government dockyards and penitentiaries, and not open to public inspection as they would have been in more accessible places. There were then no blue-books as now to explain what a patent consisted in, nor what it included and excluded; the days of monopolies independent of invention were then too fresh in the public mind to permit such views as are now held of patented improvements.

CHAPTER III.

PATENT MONOPOLY IN WOOD CONVERSION.

No branch of industry, at least no one of so great extent, has been more hampered and injured by patent grants than that of wood-conversion. Nearly every principle or mode of operating has at some time been in the thralls of patent monopoly. There have also no doubt been many improvements called out by the inducement of an exclusive right to their use; but upon the whole it is questionable whether the art of wood-cutting, all things considered, would not have progressed quite as fast independent of patents during forty years past.

It would be a specious argument to adduce certain facts either in support or contradiction of the proposition that patents on wood machines have not been beneficial; at the same time there has been in a few instances so gross a violation of public rights, and such an unmistakable contravention of the intended effects of patent privilege that some notice of two cases will be admissible.

About the year 1836—the precise date is not at hand—was granted the celebrated, or, as we should say, the notorious patent on wood-planing machines, known as the "Woodworth" patent in the United States. The patent was for a combination of rotary cutters with feeding rollers which fed the lumber to the cutters; a combination of two elements, both well known at the time, and, as it proved, of so great importance in America that the patent in effect became a most grievous burden and a wrong, the remembrance of which lasts to the present time.

The combination of feeding-rollers with planing-cutters was not, as every one who examines the matter must admit, a discovery; hundreds of mechanics would no doubt have supplied such an expedient as soon as its want was felt; but down to the date of this patent there had been but little if any need for machines acting on the principle of Woodworth's.

To explain what is meant by this last proposition some detail must be entered into.

Woodworth's machine was intended for and only capable of planing lumber flexible enough to be forced into contact with a platen and the planing-cutters, independently of its general shape; that is, the lumber if bent could notwithstanding be passed through the machines and reduced to a parallel thickness, and within certain limits made square upon its edges at the same time; but the operation was one which, previous to this time, had been thought inadmissible, because imperfect, and was besides quite unnecessary, except for thin boards.

It is not meant to claim that previously to the time mentioned machines for thicknessing boards would not have been useful, and have saved much time and labour; but the fact was that but little was then known of what may be called box framing which permits nearly every part of a building to be made of boards one inch in thickness. Planing machinery had previously been constructed mainly with a view of planing true and straight pieces after the manner of Bramah's.

As a sequence of circumstances, and not, as has been claimed, because of Woodworth's machines, thin flexible boards planed to a parallel thickness became the staple form of dressed stuff for nearly all purposes in joinery. As said a whole house except the framing, and sometimes even this included, it was found could be made with boards from one to one and a half inches thick; and the slow process of moving the lumber on carriages, as with the older planing machines, was found unnecessary, a continuous feed being all that was required.

This of course applied only, or at least mainly, to the American lumber system of that or even the present time. The stuff for doors, sash-blinds, and so on, is now for the most part planed on continuous or roller-feeding machines; and the "unit," as it may be called, of the American lumber system is a board one inch thick. An evidence of this is the manner of computing by the square foot of one inch thick which is common throughout the States.

Planing lumber on roller-feeding machines was in Europe but an unimportant matter, and is so even now when compared with American practice. No lumber except floor boards and other flexible stuff which can be sprung into shape in erecting, is planed in this manner, and I think it is but fair to assume that had Bentham with many others foreseen or imagined that lumber planed on roller-feeding machines could be made so generally available, they would have provided feeding-rollers without imagining that an invention was made in so doing. The patent was, however, granted, and scarcely granted, when people, from a sense of suffering an injustice rather than any spirit of pirating invention, disregarded the claims, or sought to obviate them, and began to construct continuous feeding machines.

A court of law, ignorant alike of the mechanical nature of the patent, and no doubt the effect which the decision would have, confirmed the Woodworth claim to a combination of feeding-rollers and rotary cutters, giving foothold to a monopoly which lasted for nearly thirty years.

More than sixty suits at law followed the first decision, the decisions in nearly every case being based upon the first one, which from an impartial view, or an intelligent acquaintance with a history of the art, was not tenable.

That popular opinion did not support the views of the courts is but too well proved by the successive trials, and the large sums of money which were lost by litigation.

Another case, still more flagrant, because happening at the present time, when our courts are presumed to be better informed in patent matters, is that of the J. P. Woodbury patent on the pressure-bars of wood-planing machines. The claim is for the combination of "a rotary cutter with yielding pressure-bars;" and the whole case, even to the name of the patentee, bears so strong an analogy to the old Woodworth monopoly that no little excitement has grown out of the matter during a few years past.

Woodbury filed his claims for a patent at Washington in the year 1848; the patent office rejected the claim as containing nothing new or patentable, and the matter ended for a term of twenty years, during which time nothing was heard of it.

During this long interval, and during the time when continuous feeding planing machines were coming rapidly into use, thousands were made, all having pressure-bars between the feeding rollers and the cutters. In 1870 there was an attempt made to resuscitate the Woodbury claim; this failing, a third attempt was made, and a patent finally issued in 1873—an act alike contrary to all precedent in England and America, and to the disgrace of the American patent office, which has placed itself in a position of collusion with a scheme to tax and hamper one of the main industries of the country. The resuscitation of the claim was based upon some vague technicality of a law (subsequently enacted), and to the public mind presents no other idea than that of a scheme for extortion.

There is no want of evidence that pressure-bars as claimed in this patent were employed by others long before the alleged invention of Woodbury: Burnet's patent (English) on planing machinery, 1839, shows such appliances; and the summary action of the American office in 1848 was fully supported alike by facts and the conditions of the case.

To guard against this new danger to the timber-planing interest, an association of millowners and others interested has been formed; lawyers have been retained, and already, without paying the claimed royalties, the expense and trouble has been considerable. What the issue may be no one can at this time say; * the ruling of the courts in the Woodworth case is still fresh in people's minds, and they are distrustful.

These are two instances where patents have tended to distract and hinder the lumber-working interest in America. Others could be named of scarcely less importance, so that upon the whole there are at least good and sufficient grounds for questioning whether the lumber-working interest has upon the whole been most hindered or promoted by patented inventions.

While speaking of the subject it will be but fair to point out that no harm, and nearly always useful results have followed the granting of patents for improved mechanism for working wood; it is only in cases where the claims of patents have gone beyond specific mechanism, and included a "principle" or a "mode of operating," that injustice has been done. This point, aside from its legal phase, is one of some interest to those employing wood-cutting machines, and deserves some explanation in addition to what was given in a previous place.

A principle or some general mode of operating cannot, according to the spirit of the law, be subject-matter for a patent. A strained construction of this rule is often necessary in order to grant legitimate patents for processes, but in the case of machines and implements it is clearly the purpose of the patent laws to limit claims to specific mechanism. Thus Woodworth was no doubt entitled to a patent for his manner of constructing feeding-rolls for planing machines, the manner of driving, supporting, and adjusting the rollers, or to any specific or novel arrangement of rollers with rotary cutters, but not broadly to the "use of feeding rollers." Woodbury

* July 1875.

no doubt had also a legitimate claim to any novelty existing in his plan of constructing and arranging pressure-bars, but not to every kind of device, except rollers which can be employed for holding down the lumber in front of or behind the cutters of a planing machine.

It would be uncharitable to charge upon our courts the fault of being unable to define clearly the difference between "devices" and "principles" as elements of invention. One is so blended with the other, and the connection so intimate, that even the most skilled engineers as well as judges and lawyers in many cases form opinions widely at variance.

The difficulty lies primarily in the attempt to found personal rights where no natural rights exist; and mistakes with controversial opinions and frequent oppressive monopolies will no doubt ever be one of the results of any patent system, no matter how carefully founded or impartially administered.

CHAPTER IV.

FACTORY BUILDINGS FOR WOOD MANUFACTURERS.

The diversified character of wood manufacture prevents, to a great extent, the application of general rules to the form or arrangement of buildings. There is, perhaps, no other branch of industry which presents such a variety of products and processes; between the appliances for shaping and handling such minute pieces as matches, bobbins, button-moulds, and the conversion of huge logs into lumber, there is, of course, a wide field for adapting buildings as well as the general appurtenances of factories.

There are, however, some general conditions, which run throughout, such as the high speed of machinery, the bulk of material and offal, danger from fire and accidents, dust, difficulty of heating, and so on, and while, for the reasons before given, it is not expected that any rule in respect to buildings can be given which can have general application, it is believed that which may be said will be of value to those who construct wood factories.

Massive walls, which are important for buildings in many kinds of mannfacture, especially when heavy weights are lifted with cranes, are by no means so important as strong floors for wood factories; walls, of course, should always be strong enough to carry with safety all the weight which may ever be loaded upon them, and to resist the strongest storms, but when the investment in a building has, as is often the case to come within prescribed limits, it sometimes happens that by taking something from other details and adding to the strength of floors, a building may be better adapted to the purposes of wood manufacturing.

In America, where joists 14 inches, or even 16 inches deep, are a staple in the lumber trade, it is an easy and inexpensive matter to construct floors of great rigidity by bridging with diagonal struts between joists; but when floor timbers of shallow depth only can be procured, it becomes a matter of both difficulty and expense to secure rigidity enough in floors to withstand the jar and vibration of machines, and avoid deflection when heavy loads are shifted from one place to another.

In a new factory in Sweden the writer has seen a very ingenious and efficient plan of stiffening floors by means of diagonal braces, nailed and bolted to the joists, extending from the walls and centre girder, and meeting so as to form what might be called a truss frame, twenty to twenty-four inches deep in the centre; these trussed joists placed at intervals of six to eight feet, with others of good depth, but not trussed between, make a floor of surprising strength.

A plan of employing the roof framing of a factory to assist in supporting and adding rigidity to floors is sometimes adopted, and we may claim is too often overlooked. The pitch of roofs permits or necessitates the employment of deep truss framing, which, by adding a little to the dimensions of the timbers, can be employed to support floors with almost any load which is required. Suspending rods from roof frames can, in almost any factory, be carried down through several stories, without impeding the movement of material, or causing obstruction to belts or machinery. In such an arrangement, the weight falls vertically upon the walls of a building, and distributes the whole load more equally than if, as is too often the case, three-fourths rested on a row of central columns.

CHAPTER V.

FOUNDATIONS FOR RECIPROCATING MACHINES.

Earth foundations are generally thought of as the only permanent and reliable support for machines which cause jar and vibration; yet a proper attention to the conditions of setting and arranging, will enable almost any rotary machine, and many reciprocating machines, to be operated on upper floors with safety and satisfaction.

There are pertaining to the fixing and supporting of machines, principles which are not only obscure, but have received apparently no attention at the hands of those who have written instructions and rules for erecting and operating machinery, and as the matter is one of special importance in wood manufacture, and has to do with buildings as well, some consideration of the subject will not be out of place here.

The subject divides itself into two branches; one pertains to machines with reciprocating motion, and the other to machines with rotary motion only.

In respect to reciprocating machines, such as frame saws, jig saws, mortising machines, and so on, earth foundations resist vibration mainly by the inertia of their weight; that is, an iron machine frame, when firmly bolted to a mass of masonry, becomes part of a whole, consisting of the foundations and the superstructure. A machine frame of one ton weight, bolted to five tons of mason work is in effect much the same as though the same machine frame contained six, instead of one ton of iron. It is, therefore, not the earth attachments which give solidity and firmness to machinery set on stone foundations so much as it is the weight which is attached to machine frames, and such a proposition at once suggests certain conditions in constructing foundations which are often neglected. Presuming a foundation to be an integral part of a machine, the value of such a foundation will be as its solidity, and depend upon how firmly it is bound together, and how near the whole mass, including a machine frame, approaches a solid.

To excavate a hole in the earth and fill it with loose stones will not make a foundation, and to attach holding down bolts to pieces of timber buried beneath masonry is to provide elasticity where rigidity is required. Anchor pieces for holding down bolts should be of iron, and in all cases be placed beneath masonry, so that the whole mass will be bound together. Such anchors require considerable surface, and should never be of narrow pieces of wrought iron, but broad castings of sufficient strength to ensure against their breaking with the utmost strain which can fall on them. Such suggestions by no means relate alone to the difference between good and bad foundations. First-class foundations are often prepared with holding down bolts to embrace but a part of the masonry, and no attention given to binding the stone work together.

In cases where such rigidity leads to the destruction of bolts, bearings, and so on, and when some degree of elasticity is essential it is obviously wrong to place the elastic medium, whatever it may be, between a machine frame and its foundation or to provide for the elasticity in a foundation; the proper place for introducing a yielding or elastic connection in such cases is between the crank shaft bearings and the machine frame. In this way the desired result is attained in a more effectual manner and the evil results of jarring and vibration avoided.

In England, where concrete foundations are generally employed, some of the difficulties attending the construction of stone work, or more especially brick work, are avoided, but it must not be forgotten that in most parts of the world where machinery is employed foundations are made of masonry.

The vibration of reciprocating machines, such as frame saws, is seldom, even when the greatest care is had in erecting, altogether overcome; the tendency to vibration increases with the speed of machines, and as the highest practical speed at which recipocrating saws can be run is not more than one-eighth part of what the conditions of cutting would admit of, it is easy to see the importance of adding to the speed of movement in every way possible.

The vibration of recipocrating machines may fall either in a vertical or a horizontal plane, a matter always to be taken into account in considering the foundations and attachments of machinery having reciprocating motion.

When any reciprocating machine, such as a frame saw or mortising machine, has its reciprocating parts balanced—that is, when a weight equal to the reciprocating parts is attached to the opposite side of the crank—the vibration will be changed from a vertical to a horizontal plane; if the reciprocating parts are not balanced vibration will fall mainly in a vertical plane.

The reasons for this are obvious: when a weight equal to a saw frame and its connections is applied opposite to the crank of such a machine, we say such a machine is balanced. But the term although commonly employed, is by no means correct; the gravity of the saw frame and its attachments is of course balanced, but these parts have only rectilinear movement, whilst the counterweight itself has a rotary movement, and the result must be that a counterweight will be as much out of balance in a horizontal plane, as the saw frame and connections would be in a vertical plane if no counterweight was employed. From this it follows that if the vibration of a reciprocating machine can be changed at discretion from a vertical to a horizontal plane, or *vice versa*, the counterweighting of such machines should, in all cases, have reference to, and be arranged for, the kind of foundations or attachments employed in erecting the machines.

It is, perhaps, safe to claim that little or no attention is given to this matter by those who construct and erect reciprocating machines, and that vibration, which is often a matter of serious annoyance and expense, is generally set down as some inherent evil connected with the machinery over which the ingenuity of man has no control.

To show how varied are the conditions under which reciprocating machines may have to operate, and the difference in foundations and supports, we have only to consider how very unlike are masonry foundations and floors.

Earth foundations oppose vibration by gravity or by inertia due to their weight, consequently resist mainly the vertical vibrations of machinery; floors, on the contrary, resist vibration from the rigidity of their horizontal attachments, and can never be made sufficiently strong to oppose vibration in a vertical plane; the conditions are directly opposed in the two cases; masonry is the strongest possible foundation for machines with vertical vibration, and the floor of a strong building constitutes a very effective foundation to resist horizontal vibration.

Reciprocating machines to stand on earth foundations will therefore operate with less vibration, and can be driven at a greater speed without counterweighting, while machines which are to stand on floors, especially when the cranks are near to the plane of the floor, should have a full counterweight applied.

So obvious is this difference between vertical and horizontal vibration, that nothing more than simple experiment is required to demonstrate it; on jig saws for example, a counterweight can generally without much trouble be attached or removed, and the effect noted.

From what has been explained of the resisting power of floors in a horizontal plane it follows, that the crank shafts of reciprocating machines which stand on floors should be as near as possible in the plane of the floors, otherwise a rocking vibration of the machines is produced, which, with a rate of speed within certain limits, will produce a kind of measured vibration, far exceeding what is due to the direct effect of unbalanced weight.

For this reason a great advantage results from placing the crank shaft of any reciprocating machine at its base, or point of attachment to a foundation or floor. In the case of earth foundations, the strains from unbalanced weight are in this way brought nearer to the centre of the mass or weight which has to resist them; and, as explained in the case of floors, such strains fall nearer in the plane of resistance.

In experiments conducted some years ago by the writer, to determine the most effectual means of resisting vibration in a peculiar kind of sawing machines, driven at from one thousand to fifteen hundred revolutions a minute, it was found that a heavy crank wheel gave good results. This in effect was employing the inertia of a heavy mass to resist rapid reciprocating motion, the effect of vibration, not being permitted to pass through the crank shaft bearings and be communicated to the machine frame. The experiments were such as to induce a belief that if, in designing deal and log saw frames, a portion of the metal put into the framing, was transferred to the cranks or fly wheels, a higher speed could be attained. The introduction of an elastic medium, such as a spring or block of wood, between the bearings of a crank shaft and a machine frame, although seldom done, is one of the most effectual means of avoiding jar and vibration in reciprocating machines.

To sum up the means of avoiding vibration in reciprocating machines we have—

(1.) Solid foundations, the machine framing rigidly attached so that the whole becomes in effect one mass, to resist vibratory strains.

(2.) Counterweight arranged with reference to the plane in which vibration can best be resisted.

(3.) An elastic medium placed between the bearings of crank, shafts and machine frames.

(4.) Heavy crank or fly wheels, with the crank pins inserted at or near the centre of percussion.

With a proper attention to these several conditions, and by reducing the weight of reciprocating parts to a minimum, it is safe to claim that at least one-third can be added to the speed of ordinary reciprocating machines, such as are employed in wood manufacture.

It may be remarked, that while the laws of physics deal with, and explain the various problems connected with moving weights, the gap between physics and wood conversion is so wide, that our text books have heretofore, and no doubt will for the future, fail to bridge over the space. Even if this were possible, no general rules could ever be applicable. The construction and fixing of reciprocating machines must always remain more a matter of experience and judgment than the application of scientific rules, however, far such rules may reach in explaining the difficulties to be contended with.

CHAPTER VI.

FOUNDATIONS FOR ROTARY MACHINES.

In reference to rotary machines such as circular saws, planing, turning, boring machines, and so on, the problem of how to construct foundations and supports is altogether different, and involves none of the difficulties to be contended with in the case of reciprocating machines. As, however, the action of machines is to some extent governed by the nature of the supports or foundations for machines,the subject is thought sufficiently important to be briefly treated of in the present connection.

Presuming the cutters, spindles, and framing of a rotary wood-working machine to be one and the same body, that is, the whole to be rigidly combined, and the vibration and jar due to the action of the cutters, or from any other cause, to be common to both the cutters and frame, there would in that case be strong reasons for employing massive frames and foundations for rotary as well as reciprocating machines.

The cutters and the framing of wood-working machines are however, two separate, and in some respects independent parts, connected only by running contact, and this contact, or connection as it may be called, is of such a nature that the jar or vibrations of cutters and their spindles which causes rough work, may be, and generally is, from causes quite independent of the framing.

With spindles moving at a low speed, and when bearings are formed with great care, as in metal-working machine tools for example, the connection between the cutting or acting details, and the fixed framing of such machines may be more rigid and perfect, that is, the bearings of spindles or sliding parts can be set up so close that little or no loose play will exist, and whatever jar the moving parts may have is communicated more or less fully to the framing. The strains upon the details of metal-cutting machine tools are, however, slow, constant, and altogether different from those to contend with in wood-cutting machines, and the parallel can be one of illustration only, because the rapid speed of the running parts of wood-cutting machines prevents that intimate connection between the spindles and framing which is generally supposed to exist. Bearings moving at a high velocity must run loose, and in practice there is generally enough play in such bearings to cause many times the irregularity of the cutting action so often attributed to weak frames.

A want of proper balancing, which generally has most to do with the perfection or imperfection of cutter action, is a fault to be considered quite independent of machine frames or their foundations. A frame can hardly be made strong enough, or the bearings of spindles be kept close enough, to avoid the effect of unbalanced cutters; on the other hand, a frame can scarcely be so light, or bearings so loose, as to prevent smooth working of rotary cutters, if they are properly balanced and no resistance offered except that of the cutting action. This remark of course applies only to machines having great speed, and when the inertia of the moving parts, the cutter blocks and so on, is sufficient to resist the effects of intermittent cutting, a rule which applies, however, to almost every machine having rotary motion.

The massive frames with foundations of masonry, which has in some parts of Europe become a characteristic of wood-machine engineering, is one of those plausible deviations from ordinary practice which may be supported by specious arguments, and is generally much more advantageous to those who construct than those who buy and operate machines.

It may be said that massive frames do no harm, which is true in respect to the working of a machine; but extra and useless weight enhances the cost of machinery, while it adds nothing to its real value, and indirectly becomes a reason for continuing machines in use after they should be set aside for improvements. Too much weight also unfits machines for upper floors, where a great share of wood cutting machinery must operate, and generally interferes with that facility of adjustment and operation on which depends to a great extent what a machine will perform. This subject will be again reverted to in a future place, and is only introduced here as far as having to do with foundations and supports.

The main argument in favour of strong foundations for rotary machines is found in the manner in which their frames are usually constructed; the object in many cases seeming to be how many separate legs can be provided, and how long a foundation base can be secured. It adds to the apparent stability of a machine frame to have a long base, and no doubt it has such effect if a foundation is considered immovable; but it is evident that with foundations not immovable and such as a great share of wood machines have to be set upon, any settling or change of the foundation is communicated to the machine frame, which is thereby warped and strained out of truth in proportion to the weight of the foundation and the power of resistance which the frame offers; in this way a machine frame instead of being supported by, may be said to support a foundation. It is not unusual to see machines with four, six, or more legs fastened down at as many points to upper floors, or other foundations which yield from unequal loads and from settling; tenoning machines are especially affected by being fastened in this manner, and their carriage ways out of truth, and the frames warped.

A remedy for this difficulty is to mount machines on three bearing points instead of four or more, a matter which every one understands, and a plan of construction well adapted to many, if not most, wood-cutting machines, yet for some reason not adopted. A machine with three legs may require more rigidity in its framing than if four or more legs were employed, that is, if we are to consider the theoretical conditions under which strain, jar, and so on, are resisted, but in so far as keeping a machine in truth, and without settling strains, its performance will in most cases, be improved by reducing the number of legs or supports.

CHAPTER VII.

THE EFFECT PRODUCED IN CUTTING BY FOUNDATIONS AND FRAMES.

The action of rotary cutters as affected by foundations, or the problem of whether the solidity of a foundation can affect the smoothness and regularity of surfaces produced by rotary machines, such as planing, moulding, shaping machines, lathes, and so on, is a subject upon which various opinions exist; it is easy, however, to see that the jar or vibration of a machine frame, the result of a weak foundation, can at best be but a remote cause of rough work. The material being acted upon when passing between feeding rollers, or moved upon carriages, may be considered as a part of, or connected to, a machine frame, while the cutters and their spindles are in a sense another and independent part of the same machine, connected with the framing and the material by running or loose joints; consequently any imperfection of the work produced is most likely to occur from a want of maintaining a perfect connection between the cutters and the machine frame; in other and plainer words, rough cutting is the natural result of imperfect balancing, loose bearings or spindles, or cutters so weak as to spring and bend, and is rarely caused by of a movement of machine frames or their foundations.

This matter is not an easy one to be made clear by words alone, but will be well understood by those practically skilled in operating machines, and who have, by their experience found out under what conditions cutters work smooth or rough.

So important indeed are balancing, stiff spindles, strong cutters, and true bearings for wood-cutting machines, that in those countries where the highest efficiency has been attained in constructing and operating such machines, we find that massive frames and foundations are regarded as matters of secondary importance in the attainment of good work, and that our most perfect wood-working machinery, such as that employed in the Government Armoury at Enfield for example, is constructed with frames of moderate weight.

There is no purpose here of arguing against strong foundations, nor even against heavy frames for machines, when there can be anything gained by either; the object is to explain that many machines which are thought to require masonry foundations can as well be operated on upper floors, as on earth foundations and great convenience be thus attained in many cases, besides avoiding useless expense in preparing special foundations.

It is, moreover, believed that in arranging wood-factories and machine foundations, there is a want of a proper understanding as to the difference between reciprocating and rotary machines, all being looked upon as the same, and as requiring similar foundations and supports. "Have a good foundation for the planing machines; mortising machines and sweep saws can go on the upper floors," is not an uncommon remark to hear in arranging a wood factory; and a very correct one, considering only the convenience of operation, and the general course of lumber in a factory, but in reference to foundations and the effect on a building, it is a bad rule indeed which places rotary acting machines on the earth floors, and reciprocating machines on upper floors.

CHAPTER VIII.

THE ARRANGEMENT OF WOOD-WORKING FACTORIES.

In a general way questions of arrangement in wood-factories should give way to the handling of material, and its course through a building during the processes of conversion; this is especially important in manufacture of building materials, because of the shape of the material.

Pieces fifteen to twenty feet long cannot be carried about in boxes, nor sent up or down through hatchways by means of lifts, as in most kinds of manufacturing; and rules which apply to buildings for other purposes will be found altogether at fault in the case of wood-working factories.

Confining what is said at present to the arrangement of buildings for sawing and planing, that is, for manufacturing or operating on long lumber, ground room is of paramount importance, and should in all cases be secured, even at the sacrifice of conveniences which in many other operations would seem of greater consideration. The value of ground room is governed to a great extent by its frontage; a piece of ground one hundred feet square with an open front on a street or wharf, is generally worth as much for sawing and planing operations as twice the amount of ground would be if its frontage and width were but fifty feet instead of a hundred feet. The reason of this is that the operations carried on in a sawing and planing mill are not regular, nor performed on the same material; different operations, quite independent, are usually going on at the same time, so thatmaterial cannot with convenience be received and passed out through one doorway, or a narrow front. Another reason in favour of wide frontage is that the normal course of the lumber in a sawing and planing mill is across a building, and not parallel with its length, as in almost every other kind of manufacturing.

For planing and sawing, floor room is required equal to two and one half times the length of the lumber, with width depending upon the amount operated upon at one time; that is, there should be room for piling material alongside its course through machines, unless, as is often the case, worked lumber can be discharged from machines through openings in the walls of a building, and into storing sheds. The old system in saw-mills was to construct a long building parallel with the course of the lumber, a plan yet followed for water-power saw-mills, and suitable in many cases, but the modern system, especially where lumber manufacture is extensively carried on, is to construct buildings with their greatest dimensions across the course of the lumber. Of this examples can be seen in Glasgow, Gothenburg and Chicago, where long narrow buildings with a single lumber course have given way to broad ones, the lumber moving across in one or more lines, as the extent of the business done may require.

The Arrangement of Saw Mills.

Saw-mill arrangement can be classed into three divisions. One with the driving gearing overhead, another with the driving gearing placed on the floor, and a third where the gearing is placed beneath the saw frames, either in a lower story or in a pit prepared for the purpose.

The plan of placing crank shafts overhead for heavy saw frames is one which should never be adopted when the gearing can be placed beneath, or at least it may be said, that such an arrangement, to have anything near the same steadiness and freedom from vibration, must cost much more to erect without offering corresponding advantages. Strong earth foundations are in any case necessary, and when constructed they should be employed as a means of resisting or absorbing vibration, which by the overhead arrangement of crank shafts is transferred from the foundations to a building. The strains from unbalanced parts falling so far above the base of the framing causes an oscillating motion in framing which nothing but top bracing can overcome. As a fact, but few, if any, mills arranged with overhead gearing have given satisfaction; the faults inherent to such an arrangement together with a neglect to arrange counterbalances as they should be, leads to "shaking mills" and a consequent derangement and destruction of machinery.

A Swedish firm have adopted plans for saw frames of the lighter kind, which in some degree obviates the vibration common to mills with overhead gearing. Two saw frames having opposite and coincident movement, are employed in what is called the equilibrium machines, that is, the rectilinear movement of the frames is arranged one to balance or counteract the momentum of the other, in so far as this possible without both moving in one plane. A still farther advantage is gained by employing a short crank shaft with a heavy wheel on each end, the bearings of the shaft being so arranged as to fall well within the base of the whole structure.

Placing the bearings and the belt pullies between the cranks of course widens a double machine when arranged on the plan described, and thereby destroys in a degree the balancing effect of the saw frames moving in opposite directions; yet the general appearance, as well as the actual working of these Swedish mills gives evidence of their arrangement having been well studied. With overhead crank shafts there need be no problem as to counterweights, in so far as such weights may be employed to resist vibration. Heavy crank wheels or fly wheels, in such cases are to be recommended and counterweights avoided. The vibration is best resisted in a vertical plane and by means of posts and foundations; yet in avoiding this difficulty another is incurred, because of the saw frames always stopping at the bottom of their stroke, an inconvenience in respect to adjusting or sharpening saws, serious enough to cause mill owners in most cases to accept the counterweights and shaking together.

It may be here remarked that what is said of reciprocating saws will seem to readers very much like treating of different plans of arrangement and finding fault with all. There is indeed but little hope of doing more. Reciprocating movement in machinery of all kinds is unnatural, and gives rise to various and serious difficulties which we can at best only hope to remedy in a degree. Yet because in constructing and operating such machinery insurmountable difficulties are met with is no reason why the principles and operative conditions should not be carefully studied; on the contrary the little which can be gained by careful and intelligent arrangement is magnified in importance by the amount of that which remains without a remedy. General opinion among those who own and operate reciprocating machines, or at least among those who have not made careful investigation, is commonly divided between two suppositions, both wrong; one that the vibrations arising from reciprocating parts can be avoided by certain devices such as balancing or counterweighting; the other, that such vibration is an inherent, an unavoidable difficulty which arrangement or devices cannot affect. In this as in most cases when widely divergent opinions exist, the truth can be found somewhere between.

If it is necessary to employ overhead gearing in arranging a saw-mill, the best plan is construct a rigid floor of framing overhead, not a narrow frame of truss work eight to ten feet wide, extending over the tops of a row of frames as is sometimes seen, but the whole area of a building is none too large for such framing. To so connect a whole floor so as to constitute it a frame to resist vibration seldom costs as much as to construct a special truss over the top of a saw frame, or a row of frames, and as horizontal strains, under an arrangement of whatever kind, must fall upon a building nothing is gained in trying to avoid the walls.

Wooden framed millhouses are often chosen when overhead gearing is employed for fear that walls of masonry will not stand the vibration. Such a reason for wooden buildings seems plausible enough in one sense, yet whenever a masonry wall is likely to be injured from the jar and vibration of machinery there exists at the same time the strongest reasons for providing such walls. Vibration and jar must be resisted and absorbed somewhere, and by some means; like matter or force such strains are indestructible, and to provide elastic walls or floors is merely to shift the evil from one place to another.

A wall of masonry is never in danger from the jar and vibration of machinery until such a wall is sensibly moved by the strains, that is, it will either resist continually and safely, or be in a short time destroyed, and all that is wanting in any case is masonry perfect enough and walls heavy enough to resist the duty they are called upon to bear. These remarks are made with a knowledge of the arguments in favour of elasticity so commonly presented in favour of wooden-framed buildings for saw-mills employing reciprocating saws, and with no intention of claiming that elasticity is not an essential condition in many cases to prevent the destruction of machinery. The same rules which apply to the permanent way of our railways apply also to reciprocating or other jarring machinery; as already pointed out the proper place to provide for such elasticity is not in buildings nor foundations, but between the running parts and the fixed framing of machines.

CHAPTER IX.

SAWING FRAMES AND THEIR SUPPORTS.

As sawing frames constitute the greater share of machinery with reciprocating motion, some further consideration of the subject of supports will not be out of place. Saw frames having their crank shafts placed at the floor line or in pits, have little to do with buildings, at least with that part which is above the sawing floor. The superstructure in such cases is merely a weather shed unless upper floors are provided for other purposes than the sawing operations. The construction of such buildings is generally governed by the price of ground and the amount of room at disposal. It would be a want of economy to erect a mere shed over a sawing floor when the machinery is supported on earth foundations, if the upper floors of a strong building can be employed or rented. A shed may burn without seriously injuring the machinery of a mill, and sky-lighting may often be an object, but these things are trivial compared to the rent of land in cities, but may in the country be of more importance than the price of land.

Sawing frames with their crank shaft at the floor line, although for many reasons favoured and recommended by saw-mill engineers, have not met with the favour to be expected; either double or forked connections of short length have to be employed, the cranks, shafts, and other machinery are placed in an exposed and inconvenient position—it is, in short, an arrangement to secure portability at the expense of convenience in operating. The plan may be said to look better on paper than it performs in a mill; yet to gain portability and have a sawing machine self contained are objects which may, in exceptional cases, more than compensate for the inconveniences of floor line crank shafts. If a mill is to be a permanent one, and the machinery to be continually employed on severe duty, the old plan of a pit crank shaft is without doubt the best; a long connection can be employed, and the vibration is transferred from the mill floor to earth foundations and low down so as to be successfully resisted, while the driving gearing, except being exposed to sawdust, is as much shielded and out of the way as if it were mounted overhead.

In purchasing and arranging sawing machinery due attention must be had to the local conditions in each case, if for instance it is considered best to arrange driving gearing beneath and independent of a sawing floor, it does not always follow that the machinery must be placed in a pit; on the contrary pits should always be avoided when possible in erecting machinery of any kind, and especially such as is driven at high speed, and there is sawdust or other *débris* to make its way into a pit.

When the price of land is high, and when for this or other reasons a mill-house has to be erected on the edge of a wharf or on a street, it is of course impossible to have inclined drag-ways to haul timber up to a floor, and by this means keep the driving gearing above ground; but whenever there is room to operate in this way, and have a sawing floor from nine to eleven feet above the ground there are many conveniences gained. Sawed lumber is more readily distributed, or discharged we may call it, from an elevation of one story than from a ground level. Trucks are more easily loaded and lumber can be slid away in different directions by its gravity instead of having to be lifted and carried. Besides these advantages is that of room, light, and the greater safety for machinery in a basement story above ground; there is also, in other cases, a saving of the extra room required for a steam engine which can be spared from a ground floor.

There is something strange in the aversion to elevating timber and sawing on upper floors which is met with in many parts of Europe, and especially in England; and when the small size of the timber sawn is taken into account, this prejudice seems stranger still. It is easy to understand why heavy sawing machinery is always placed on the ground, but the frame, log carriage and upper details of saw-mill machinery, such as could be operated on an upper floor, is not that part of the machinery which requires attachment to earth foundations; in fact the steadiest mills, those which have the least jar and motion communicated to saws, saw frame supports, timber and carriages, are those wherein there is no connection between the sawing floor and the foundations which support the crankshafts and driving gearing.

In America reciprocating saw-mills are never built as self-contained machines but constitute a kind of permanent plant connected in most cases with the framing of buildings. The fact that self-contained machines are mostly made in Europe has led to an opinion that the construction of such machinery is not well understood in America; but one who will stop to consider the vast amount of timber sawn in America, with which we can only compare the product of all Europe, and the ingenuity displayed in constructing machinery of all kinds, it will seem most improbable that advantage is not taken of every possible improvement in sawing machinery. This is certainly the case as any one practically acquainted with the matter must admit. Self-contained frames are not made for several reasons. Such machinery is not made for sale abroad, nor is a saw-mill regarded as a machine; a pair of friction wheels such as are employed in the gang-mills of Michigan would in bulk and importance equal what we call a log frame, such as is manufactured for European timber The parts of American saw-mills are supplied by engineers or millwrights who do not furnish plans for complete mills, and are constructed with reference to the special arrangement of each mill. The building, as before mentioned, becomes in a sense an integral part of the machinery, that is, the framing of the building is employed to support machinery; the proportions throughout are on a scale corresponding to the difference in the size of the timber in America and Europe, perhaps on the whole as two to one in respect to shafts, belts, power, and so on. The common opinion as to the employment of thick saws in American gang-mills is also one of those mistakes apt to arise when local circumstances are not understood, and requirements are not the same in different countries. Saws of No. 14 to 16 gauge are operated in some of the gang mills, and there is no doubt whatever that every improvement enabling the employment of thin blades is as well understood in the American timber districts as anywhere in the world.

To construct self-contained machines adapted to the timber of America according to the European system, and with a capacity such as is demanded there, would treble the cost of their machinery and add nothing to its efficiency. The gang mills of Michigan, Minnesota, Pennsylvania, and Maine, and the Pacific coast, have often been inspected by European engineers, and the excellence and proper adaptation of the machinery conceded; there are, however, few ideas applicable to European timber-sawing to be drawn from these mills; they are produced by wants which are local and peculiar. Some of the causes which have led to so great a difference between the timber manufacture of Europe and America, and between the machinery employed in the two countries, will be explained at more length in a future place.

In erecting saw-mills of the smaller class, such as are generally employed in Europe, it often happens when there is water to contend with, that pit driving gearing can be mounted in iron tanks, at less expense than cemented masonry can be provided. The expense of a riveted tank, even if it should exceed the cost of masonry, will be compensated in several ways which might not at first appear. Such a tank, of sufficient size to surround the base of a saw-frame can be furnished with, and constitute a part of the plant prepared by engineers; the machinery or framing can be fastened to the plates, and the tank itself may constitute the real frame downward from the sawing floor. A rectangular box tank provided with iron girts to support a crankshaft and the base of a saw-frame requires but little more material than a continuous frame, extending from the foundation to the top of the saw guides, and will at the same time avoid the expense of a watertight pit of masonry otherwise required. A foundation is of course required, piles being in most cases all that is wanted. Angular flanges should be riveted on the outside of a foundation tank, or, what is equally as good, beams of wood bolted on, so that by packing firmly around the outside with clay or gravel the structure will be held in the earth with a firmness surpassing that of masonry, because foundations of stone or brick owe their strength to their gravity rather than to what may be called earth attachment, and depends also upon how firmly the structure as a whole is bound together.

In a saw-mill examined by the writer sometime ago, the pit work was mounted in a tank about 12 × 8 × 8 feet of $\frac{3}{8}$ and $\frac{1}{2}$ inch plates of wrought iron; the seams were well riveted, and calked on the outside. This tank when completed—the attachments for supporting machinery fitted and "anchors" bolted to its outside—was lowered to rest on the top of piles driven to a good depth, sawn off so as to form a level bed for the iron structure. The tank was easily set and adjusted, after which a space of two to three feet around the outside was packed and rammed with clay, broken bricks, and stone. This tank was set at a distance of about 100 feet from the water, which at high tide was several feet above the tank floor, and although the earth beyond the packing was loose and porous, no floating action or other cause has disturbed the structure, which proved to be of great solidity, and was erected at a less expense and without many of the inconveniences which would have attended on the construction of a pit of cemented masonry.

CHAPTER X.

DIFFERENT SYSTEMS OF WOOD MANUFACTURE.

In a former place mention was made of the difference between the lumber systems of Europe and America.

In speaking of European practice, however, it must be understood that the wood manufacturers of the Scandinavian countries are not included. Their system is a strange and marked exception to rules otherwise quite general throughout Europe, and in fact differs more from the European than it does from the American system.

It is proposed to explain some of these differences in the plans of sawing, manufacturing, and so on, and to point out, as far as practicable, some of the causes which lead to such a difference in wood-working processes when nearly all other branches of manufacturing are quite uniform—at least are uniform in the production of most staple articles from iron, fibrous material, and so on.

Different countries have adapted their practice to the various local conditions which exist in each, and as this difference is of a commercial rather than a mechanical nature, it may be assumed that there are sufficient reasons for the various methods.

The system of lumber manufacturing in England, or more especially in South Europe, being a shorter remove from hand-work, and principally confined to supplying local demands, the influences of an extended and competing market for wood products which has forced into use the systems of America and Scandinavia are wanting.

What may be learned by some examination of the matter does not depend so much upon what is right and what is wrong in practice as upon what plans are most likely to obtain in future if building material and other wood products are to become staple instead of special manufactures.

In the prospective opening of new sources for lumber in Finland and Russia there will be more analogy to the conditions which exist in America than there is in the present trade with Swedish and more western ports; and presuming that timber of larger size is to be dealt with, the cost of transporting to increase, and the value of forests to be less than herotofore, there will no doubt be hints from American and Scandinavian practice which may be here studied with advantage.

One thing fast making its way in the Baltic region is the manufacture of finished wood products, at or near places where the timber is procured, and instead of transporting logs and deals, to send finished doors, sash flooring, mouldings, and so on, to the great markets of London, Paris, Hamburg, and other points of distribution.

The reasons which favour manufacturing in the Northern timber districts are neither few nor unimportant, and it is idle to suppose that those engaged in lumber manufacture will not avail themselves of such plans as afford the largest profit, especially in the case of Finland or Russia, where the forests will be worked no doubt for the most part by English or German companies and firms. It is therefore important to watch the practice or modes of manufacturing adopted, because with equal or better facilities there can be but little hope of successful competition on the part of manufacturers in England.

One of the principal if not the most important advantage which manufacturers in Scandinavia enjoy, is in a separation of building from the preparation of material. In America the business of building and the preparation of building material, except in small villages, are completely separated: builders do not manufacture and manufacturers do not build; the two things are in their natures as completely separated as the manufacture of iron and the manufacture of machinery. Their combination in Europe is the result of circumstances, and controlled by conditions which may be expected soon to pass away.

The progress of all industrial interests is marked by a more complete division of labour, and the difference in cost between building material prepared by a manufacturer and that prepared by a builder is now quite enough to separate the two branches, were it not that a great share of building is done without open competition in estimates and prices; but, setting this reason aside, the preparation of building material in America and in Sweden also, necessarily comprehends a kind of skill and knowledge which the building interest itself has no use for, and is not likely to attain.

Taking the trade in finished material between Sweden and Germany, for example. It began some years ago, not more than twelve we may say, by orders for finished doors, sash, mouldings, and so on, the form and dimensions of which were specified by German builders. The Swedish manufacturers, in seeking a more extended market, had to prepare diagrams and drawings to illustrate their products, and this led to the establishment of draughting departments in the various works. The numerous and excellent technological schools existing in Sweden, in which the science of architecture forms a prominent part of the studies, furnished a class of well, if not practically learned architects and draughtsmen, who through the want of sufficient opportunities for practice in that country were and are still employed for very low wages.

From doors, mouldings, blinds, and so on, orders began to come for finished houses, not only from Germany but even from India, the plans being after a time prepared in Sweden and forming a part of estimates sent out.

Skilled architects are continually at work scheming new plans, and so thorough has become their knowledge of buildings and the manipulation of wood, and so large the collection of drawings, precedents, and examples, that the business, although but a dozen years old, has a completeness and a connection which in most other branches of manufacture has required five times as long to attain. Young men, the sons of architects and especially the sons of manufacturers, are sent first to America to study wood manipulation, the manufacture of doors, sashes, blinds, mouldings, furniture turning, and so on; they are then sent to Germany to study architecture, and especially of those parts which has thus far formed the principal market for the Swedish product. The present founders of the manufacture of building material on the west coast began without the advantages which an incoming generation will command; yet such has been the industry and skill brought to bear that their tools and processes are without doubt far in advance of anything beside on the continent of Europe.

The progress made is not confined alone to skill in architecture and the processes of manufacture, but includes another and equally important element, which is, the management of labour, of which some explanation here will not be out of place. Taking the factories of Gothenburg as an example, the workmen of the skilled class nearly all belong to the *Arbetareforening*, a kind of trades union, but wanting in many of the characteristics as well as aims which marks similar organizations in other countries. They own a beautiful and expensive hall, where their meetings are held; a restaurant, library, conversation rooms, and so on, occupying the ground floor, the great hall being above. This "Forening" (association) has a strong moral power compared with the manufacturing interests with which it is connected; for the men to strike would at once and wholly stop and disorganize the wood manufacturing interest, yet a strike is something which does not seem to be thought of, or at least forms no part of the plans upon which the society was organized and is maintained.

A stranger making such investigation as the writer of this article has done is forced to the conclusion that through a thorough and carefully directed education, the true relations between capital and labour have come to be understood by the workmen, and by this, with other causes of less importance, the social disturbance resulting from the labour war has this far been sucessfully avoided.

A characteristic of this association, or rather of its influence on workmen, is that it does not destroy individuality, a result probably the worst which has ever resulted from such combinations. The workmen strive to attain individual proficiency and distinction in their calling, and do not care to regard themselves as units of a whole, the stability of which depends on connected aims and acts; each man speaks for himself and acts for himself, so that in the shop there is no standard for a day's work, no arbitrary rules to fetter and destroy self-respect.

When visiting one of the Swedish joinery works, the writer of this was asked if he had seen the *Barn Werkstadt* (child's workshop), and was invited to go through this unheard of department. Although well acquainted with the works for more than a year, the existence of this department was never known, and it was with no little astonishment as well as interest that this "work school" was inspected.

In a long room, separated from the main buildings, was a row of work benches, twenty or more in number. At each was a boy from ten to sixteen years old, busy constructing wheel-barrows, boxes, toys, and other articles of wood. A master was presiding over the school, and the degree of skill manifested by children so young was marvellous. There was a forge for preparing the irons required, such as hinges, handles, tires for wheels, and so on; the "factory" was complete. At certain hours work stopped and "school" began, the two alternating as was thought expedient. The children were orphans collected throughout the city, and were here housed, clothed, fed, and instructed, with the understanding that at a certain age, and when a certain amount of proficiency had been attained, an entrance into the main works would be allowed.

The scheme, as now remembered, is one of co-operation between the city authorities and the manufacturing company, under whose charge the school is in some respects placed.

To compete successfully with the manufacturers of building materials in the Baltic provinces, the machines employed must perform as much and cost no more than theirs; men must be trained under some liberal system of apprenticeship to what is in many respects a new calling; factories must be as large, complete, and without connection with building matters. To Mr. James Brownlee, C.E., of Glasgow, we are indebted for perhaps the most extensive and complete experiment in the independent manufacture of building material made in this country, and are especially indebted to him for that liberal and enlightened spirit which prevents him from trying to conceal and mystify his processes and machines, most of which are in a greater or less degree original, and planned by himself. An extended observation, coupled with high engineering skill, and an experience in manufacturing abroad as well as at home, has in his works furnished an example from which many might profit.

CHAPTER XI.

THE SEPARATION OF SAWING AND FINISHING PROCESSES.

The separation of sawing mills from wood factories is a result of separating manufacturing from building, and it is to this cause the lumber systems of America and the Scandinavian countries may be ascribed. This separation of timber-sawing from finishing processes may be right or may be grown in a small works, where the principal business is to prepare special orders as in builders' mills. A full sawing plant is necessary in such cases because it is impossible to keep a stock of lumber on hand large enough to select orders from without preparing them especially; but in a large business it is different, and it is an object to have prepared sawed lumber received in a form as near as possible ready for finishing machines.

Sawing timber, and manufacturing joiner or other woodwork, are as different as two manufactures employing unlike material. The plant and machinery is different, and the skill required in the two things has but little in common. Between sawing and finishing comes the process of drying, which stops and for a considerable time hinders the progress of material. The time and distance, we may call it, between timber-sawing and finishing is so long, that orders in most cases cannot wait to pass through the whole course; and there is nothing more natural, when all circumstances are taken into account, than that the two things have been separated wherever a large business is attempted.

In the works of Mr. Brownlee, at Glasgow, before referred to, the sawing mills are a separate department and at some distance from the joiner works. In one of the largest establishments in Sweden (Strömman and Larsson, Gothenburg) no round timber is ever used; while, as before remarked, in North America saw-mills and planing-mills are rarely ever connected together.

As sawing round timber and finishing are distinct as processes they generally become separated, even when conducted by one firm, or as parts of one business. There cannot of course be any reason why one business should not include both, if they are kept separate. Finishing can be regular and continuous throughout the year; sawing in most climates where timber is procured, has to be suspended during winter months. Sawing requires a large reserve capital, so that a great supply of timber can be purchased at certain seasons and held through the remainder of the year; but in finishing the lumber supply can be regular and controlled by the demand as in other manufactures.

CHAPTER XII.

ENGINEERING SKILL IN CONSTRUCTING WOOD FACTORIES.

Another thing causing diversity of practice and a matter to which some attention might be given with advantage, is, the conditions under which wood-working factories are usually constructed. In almost every other kind of manufacturing, and many branches not having one-fourth the importance of wood-conversion, the arrangement and construction of factories is placed in the hands of skilled and experienced engineers. If an iron-works, a cotton mill, or other factory except one for wood-working is to be built, no one thinks of relying upon unskilled opinions and plans, nor even upon those who construct machinery or tools to be employed in the factories ; but in the case of woodwork, demanding more special skill perhaps than any other branch of common manufactures, an engineer is seldom employed. The constructors of wood-working machines have generally much and valuable knowledge of the nature of the processes which their machines are to perform ; but such knowledge is not always complete, and besides, must be general and not applicable to such local conditions as exist in every case when a factory is to be constructed. Such knowledge is, besides, scarcely ever from practical experience, but gleaned from information given by customers in ordering machines, and explaining the processes to be performed.

Plans for wood-working factories prepared by those who construct machinery naturally include an equipment of their own machines, which in many cases may lack in adaptation. To furnish machinery is indeed the object for which such plans are usually prepared, and as they often involve a considerable expense to those who make them, it is unreasonable to expect such service for nothing. There is no purpose of unfairly criticising the method of machine makers furnishing designs for factories; such plans may be and often are valuable, especially when a full plant is to be erected regardless of expense, and when the designers have a considerable experience in constructing machines for some special line of work; yet the diversity of practice and continual change in wood-conversion, with which manufacturing engineers as a rule have only local acquaintance, often leads to mistakes.

It may also be said that the preparation of plans, and superintending the construction of factories, is a business which most of our machine-manufacturing firms would willingly avoid, one thrust upon them by circumstances instead of by choice, except in so far as to determine intermediate driving, gearing, speeds, and other special matters pertaining to their own machines.

That wood-conversion has not become a regular and recognised branch of mechanical engineering, in a measure independent of the manufacture of machines, is to be accounted for in other ways than because there is no need of such a branch, and perhaps mainly because engineers have not adopted this as they have other classes of manufacture for special study.

Wood factories are too often constructed by adding incongruous wings and sheds to a nucleus which the business had outgrown; shafts are mounted at various angles, machines set wherever floor-room is found; the lumber goes on a tortuous round to receive the various operations of planing, mortising, and so on, sometimes "doubling" on its course until handling costs more than machine processes. Nothing of this kind will be found in the factories of Sweden and Norway, where as a rule careful attention is given to arrangement, and the construction of such factories is generally placed in the hands of competent engineers, who have no interests to serve other than to add to their reputation by completing a creditable work.

One exception to this rule was met with in Sweden, where a "patched-up" factory was constructed some years ago. Instead of following the precedents around them the proprietors sent abroad and purchased a set of massive, awkward machines, in no way suited for the light work and rapid manipulation of Sweden. The result is, as might have been easily foreseen, this factory can no more be operated against its competitors than a handworkman can compete with a planing machine. The investment is "permanent," and the factory silent.

As remarked in a previous place in the course of these articles, nothing can so effectually improve wood manufactories as emulative competition, and uniform prices for the product of factories. When manufacturers obtain the same price for what they produce, then their profits must depend upon the completeness and skill with which their factories are constructed and operated, then we can look for better arrangement; and as in the case just described, if a factory is not up to a proper standard of efficiency it falls, to make room for another and a better one.

CHAPTER XIII.

SAWS AND SAWING.

In the present article it is proposed to treat of sawing, and as there may be some who will question the expediency of searching after the principles of tool operation and attempting to classify them as a mode of investigation, some explanation will not be out of place.

There is no operation, no matter how apparently simple, involving force and motion, that is not worthy of careful investigation, and there is no mode so reliable, nor so likely to lead to improvements as that of tracing out even the most minute relations between cause and effect by a separation into details. The economic conditions attending on machine processes are often as important to understand as the mechanical details of operation; indeed, the relation between the result produced by machines, and the commercial objects for which they are employed, is so apparent as to scarcely require mention, and must continually be apparent in any investigation likely to lead to useful results.

The great advancement in the machine arts made during the past fifty years, which may be said to embody more than had been learned in all time before, has been mainly due to methodical instead of unmethodical investigation, to rational and scientific study instead of chance or accidental discovery.

Constructive ingenuity has in time past stumbled upon many useful improvements, and has added no little in improving and perfecting the details of machine tool operations, but the amount of benefit derived from such inventions has been gradually diminishing, until in many branches of industry accidental discovery has at the present time almost ceased.

The methodical and logical manner of investigation pursued by Bentham has already been pointed out, and were it possible to ascertain the mode of reasoning pursued by such men as Bentham, Stephenson, Bodmer, or Whitworth, there is no doubt but that one plan was common to all, that of following principles, and by induction foreseeing new results.

Believing that this mode of investigation is applicable to every tool process, and that a clearer understanding may be had, even of the most simple operations, by analyzing them and considering the principles which lie at the bottom, it is trusted that such a treatment of the present subject will not be construed as pedantic, or as an attempt to mystify that which is of itself plain.

A mechanic of considerable skill was once asked what the difference was between slitting and cross-cutting saws. The answer was ready enough: "Why, in the shape of the teeth and the manner of filing them." A second question followed "*Why* are the teeth of a different shape for slitting and cross, cutting?" This question was not answered, and might as well have related to conic sections in so far as being understood by the workman. He knew by accident that saw teeth required to be of a different shape for cross-cutting and slitting; he had long known the fact by observation and experience, but had went no farther; his education in the matter required years, involved experiments, mistakes, and no little effort of observation, all of which would have been saved by going one step farther at the beginning.

The object of the question asked was to learn the proper form of saw teeth for cutting paper, a matter of which the workman had not even an opinion, because he had never sawn paper, and his knowledge of saws was only experimental or accidental.

Many years ago, when saws were but little understood, and when methodical investigation in connection with such commonplace matters was not thought of, such a mechanic had some chance of making improvements in saws and sawing, or might even now stumble upon some new thing of value by accident; but the chances are he will leave the art of sawing very much as he found it, and that his life will include many an hour of wasted labour, which logical investigation could have saved.

With this much in reference to a method the subject of sawing will now be taken up.

The various operations performed in working wood consist either in dividing it into parts, or in giving shape to such parts after they are divided. The first operation is performed by means of saws, and the second by cutters.

So far as a principle of operating there is no difference between sawing and cutting; but, as explained, sawing being directed to dividing, and cutting to the shaping of wood, it is more convenient to treat of the two separately.

Saws are employed for dividing various kinds of material as well as wood, such as stone, metal, bone, and other materials soft enough to be cut, but not soft enough to be compressed, and thus admit cutting instruments without removing material to make a path for them. Wood, stone, metal, and bone, for example, are too solid to admit of a direct acting knife or cutter passing through them; but cotton, paper, cloth, or leather can be so cut, and without any waste of material. To classify in another way, material having granular structure can be divided by sawing, and fibrous material by direct cutting.

Wood partaking both of a granular and a fibrous structure, a kind of link between the two classes of material named is divided by both sawing and cutting as the grain may determine. By dividing is not meant paring, as in cutting shavings from such material as wood or iron, but separating into two or more parts, each of which will be complete or useful, and not constitute waste. If, for example, a block of wood is to be reduced one-third in a direction parallel with the fibre, this one-third may be split, cut, or sawn off, and remain a valuable piece of lumber; but if the same block is hewn to the required dimensions with an axe, or planed with a plane, the part removed is reduced to chips or shavings, and is only waste.

If a cutting instrument be employed to divide such a block, the waste is as the amount of wood reduced to shavings or dust in order to clear a path for the cutting instrument, and hence every effort is made to reduce the width of this path, which is technically called a "kerf."

The width of a kerf formed by cutting instruments employed in dividing material is not regulated by the width or length of the edges required, as these may be very short or narrow, but such edges have to be supported and guided by some rigid mechanism which follows them through the material to be cut, and the rigidity or strength of this supporting mechanism must be in proportion to the depth or size of the material to be divided. Such mechanism is illustrated by the blade of a chisel, the handle of an axe, the stem of an auger, or the plate of a saw. The teeth of a saw are the cutting tools, the saw-plate is the supporting or guiding agent, corresponding to the handle and shank of hand tools.

As a means of supporting and guiding cutters a saw-plate, which must be considered independent of the saw teeth, is one of the most perfect which can be imagined, and for reasons which will presently be explained requires less room for its passage through material, and consequently causes less waste than any other mechanism for operating cutters of which we at this time have knowledge. Keeping in mind the plates of saws as the guiding and supporting agent in a class of cutting instruments, we may see that every condition pertaining to the plates enables them to be reduced to the narrowest or thinnest dimensions. The material, for instance, is usually fine steel, tempered to that degree of hardness which gives the greatest strength; but this alone by no means provides enough rigidity to enable saw-plates to drive and guide the teeth or cutters. In most cases another means is employed to increase the rigidity of saw plates, which is tension or straining, and by the aid of these two things, the strong material of which saw-plates are composed, and the rigidity imparted by tension, a saw-plate one-tenth of an inch in thickness can drive a set of cutters through, and divide a block of wood of almost any size, the kerf or waste not exceeding one-eighth of an inch in width.

So great was the necessity for an economical means of dividing material, and we may say so simple is the saw as an implement, that its invention goes so far back into the past that there are no easy means of tracing the history; nor need we concern ourselves about the early invention of saws except in tracing the historical development of mechanical industry.

CHAPTER XIV.

ABRADING SAWS.

Before coming to the subject of various kinds of saws for wood dividing, some mention may be made of another class, which may be called abrading saws, such as are employed in dividing material too hard to be cut with steel implements. Such saws can be divided into two classes,—those which have fixed teeth, or cutting tools consisting of diamond points, and the other operating by means of detached cutting agents, such as sand, emery, diamond powder, and more recently spherical pellets of chilled cast iron, and saws without teeth of any kind.

Diamond teeth, or diamond-pointed teeth, have been applied to reciprocating, rotary, and endless or band saws, and have been applied to dividing granite, and especially the softer kinds of stone, with considerable success. If we can believe the facts and claims adduced by various inventors, there has been attained a success in the use of such saws which will warrant us in assuming their employment profitable in cutting friable varieties of stone, but not granite.

It is perhaps well that new inventions of this kind should remain for a time, and throughout their incipient period, in the hands of patentees and advertisers, without receiving those crucial and disinterested tests which alone can determine what is of value and what is not. Extravagant claims for new improvements may convince a certain class of people, and serve the object for which such claims are put forth; but to the more cautious, and those who in the end will be called upon to decide the merits of new inventions, exaggerated statements are merely a warning. It will be no disparagement of diamond-sawing to say that at this time the process is mainly in the hands of patentees or experimenters, and that longer and more thorough tests will be wanting before the economic value of the process is proved.

Abrasive saws, acting by means of what may be called detached teeth, such saws as we see employed in cutting building stone, marble, and so on, may be classed among the standard implements for converting material. Such sawing as a process is old and so well understood as to scarce require notice, were it not for some recent improvements which may add to the speed at which cutting on hard material can be performed. Such saws generally have blades of soft iron instead of tempered steel, and rely upon tension alone to impart rigidity and direct their course. The sand, emery, or other abrading substance coming between the hard material and the soft iron saw-blade, adheres to the latter, and is dragged through the kerf, cutting, or abrading, like the teeth of a wood saw, or pulverizing by what may be called rolling abrasion.

Saws without teeth driven at a great speed, so as to melt fusible material by friction, have often been tried for practical purposes, but have not come into general use. The action of such saws presents an apparent anomaly. Soft iron or steel is found to be the best material to make them from, and hardened steel is cut with nearly the same facility as iron. The greater the speed the more rapid the cutting; in fact but little can be done without a speed of 8,000 feet or more at the periphery of the saw.

The material being softened by heat appears to be rubbed away by the saw, which may be said to melt its way. The operation is one more curious than useful, and can never supplant direct cutting or shearing tools for dividing metal.

The invention of Moigneux for dividing material by means of a platinum wire, heated by electricity, may be called the most novel, and at the same time analogous operation to sawing which has ever been proposed. By this process a small strained wire, heated to a high degree by electricity, is passed through combustible or fusible material, burning or melting its way, creating a kerf but little wider than the diameter of the wire employed. Such a process, if not too expensive, may have some useful application in the industrial arts; but the waste of heat by radiation must render the operation an expensive if not an impossible one in dividing many kinds of material.

CHAPTER XV.

SAWS FOR WOOD—THE FORM OF TEETH.

In treating the subject of wood saws it will be divided into two branches, one relating to the cutting action and form of saw teeth, and the other to the different modes of operating with saws.

In the form of teeth for slitting-saws there are several conflicting conditions to be contended with. The cutting action, if that alone were to be considered, would call for one form of teeth, to maintain the set of the teeth demands another and a different shape; while to provide room for the sawdust cut away may call for a form and arrangement of teeth different from what either cutting or setting suggests; so that a kind of compromise between the forms demanded by these different conditions is the best that can be done.

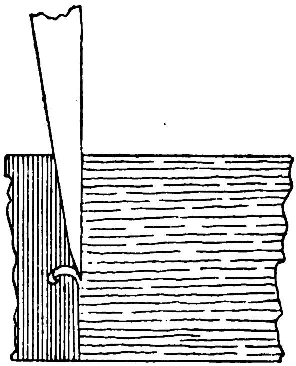

Fig. 1.

Fig 2

A slitting-saw tooth considered as a cutting instrument may be likened to a chisel, and the form of teeth which would operate with the least power would be the same as that of a mortising chisel shown in Fig. 1; and in every case where clear lumber is sawed, and when long experience has demonstrated what form of teeth operate with least power, there has been an approach to what is called chisel teeth, as shown in Figs. 1 and 2.

Knots, hardwood, and rapid feed are conditions which call for rigid teeth, rendering the chisel form impracticable; and it is only in sawing clear lumber, and with a high degree of skill in filing and setting, that such teeth can be employed to advantage.

The limit of endurance, with such steel as must be employed for saws, will not permit thin pointed teeth, they will break in cutting through knots and hardwood; and whatever besides is taken into account, no form of saw-teeth which permits their points to crumble and break should ever be adopted.

In actual practice, in establishments where a high degree of skill is employed, there is a tendency to acute-pointed saw-teeth; when there is a want of skill the tendency is the other way, and teeth unnecessarily blunt are common.

It would seem that even considering the conflicting conditions before pointed out, standard forms for saw-teeth should be fixed so as to relieve operators from the trouble and risk of using their own judgment in the matter; but in ages of experience we have come but little nearer to any standard, although the adaptation of saws to special kinds of work is constantly improved.

One reason, not always thought of, why saw-teeth cannot be the same even for cutting wood of uniform quality, is the varying depth of the lumber. As mentioned, one of the conditions of sawing is to provide recesses between the teeth to carry off the sawdust cut away by each tooth as it passes through the kerf. Now such a recess, when large enough to accommodate the dust formed in passing through a piece one foot in depth, would be only one-half large enough if a piece two feet in depth were being sawed, the rate of feed being the same in both cases.

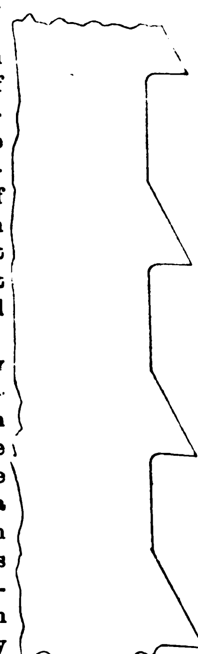

Fig. 3.

This is but one of many things which prevents the adoption of standard forms of saw-teeth, and among the varied conditions of saw operation is no doubt the one least understood, and to which least attention is directed. Nor is this want of attention because the dust space between saw-teeth is not a matter of importance; it is, in fact, one of the most frequent among many causes which have rendered the operation of band-saws so difficult.

It is not uncommon to see the freshly sawn surfaces, as they came from power-feeding band-saw mills, coated over with fine sawdust, packed firmly on the face of the lumber, so that considerable force is required to scrape it off. This is a result of insufficient dust-room between the teeth, and in the case of band-saws especially, a fault easily remedied by spacing the teeth at a greater distance, as in Fig. 3, a plan recommended and generally adopted for power-feeding saws by M. Perin, of Paris, whose experience with band-saws entitles his opinions to great weight.

Long spaces between the teeth, as said, is an arrangement especially applicable to band-saws, because the tooth movement or speed of such saws can be regulated at pleasure, so that a certain number of teeth may act in a given time, whether they be near together or wide apart.

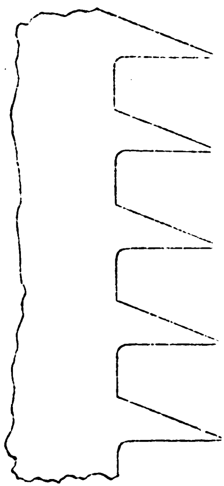

Fig. 4.

An extreme example of providing dust-space in saws, and in the adaptation of saw-teeth to certain conditions, is found in the reciprocating lumber saw-mills of North America. Fig. 4 shows the form of teeth, and Fig. 5 an enlarged tooth with its point hammered as it is called, to give a cutting instead of a scraping position to the edge. This example, which most persons would at first glance set down as one of bad practice, is indeed one of the best that can be cited to show how experience through a long and expensive school will at last reach what is required.

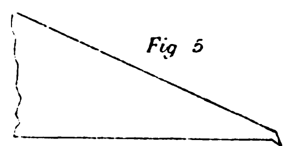

Fig 5

Taking into account the circumstances attending on the operation of these saws, we need be at no loss to account for so unusual a form of teeth.

(1) The great depth of the timber, often reaching three or more feet, requires the largest possible amount of dust-room between the teeth.

(2) The speed of the saws not exceeding 400 feet of cutting movement, the teeth require to be close together, and the dust-space secured by cutting deep into the plate between the teeth.

(3) The wood being generally free from knots, and the saws left with a soft temper, the teeth can be long and thin without danger of breaking, and thus permit wider spaces between.

(4) Long thin teeth, if set in an inclined or hook position, would not retain the set, and would deviate from the kerf and be broken; hence they stand out almost perpendicular from the plate, as shown in the figure.

(5) As teeth of this form would only scrape instead of cut, an edge is turned down with a hammer, as shown in Fig. 5, which not only gives a good cutting angle, but tends to throw the dust back into the bottom of the dust-spaces, and thus to fill them uniformly.

These, then, are some of the reasons for employing so singular a form of teeth; and as some of the facts connected with the use of such saws will not be out of place and of interest to the reader, they will be briefly given.

A single saw, with a stroke of 30 inches, strained in a frame, operated by a 10-inch steam cylinder, geared directly to the same shaft as the saw, will cut from 500 to 1,000 superficial feet of poplar lumber in one hour.

The saws employed are about one-fifth of an inch in thickness when new, from seven to eight inches wide, and are sometimes composed of alternate layers of thin plates of iron and steel welded together in rolling. The iron gives tenacity to the teeth, permits the hammering operation before alluded to, and does not seem to injure the cutting quality of the edges.

Such saws are usually given a "rake" equal to one inch for twelve teeth, or one half-inch to a foot; and the feed in extreme cases equals *twenty inches* of area at each stroke, and is seldom less than ten inches—that is, in sawing a log 30 inches deep the feed will be from ⅜ in. to ¾ in. at each stroke.

3,000 to 5,000 superficial feet of lumber is sawn in a day from fir, poplar, and other soft wood; the quantity depending on handling logs and lumber, and filing the saws, which are never removed for the purpose.

These remarks relate to saw-mills in the valley of the Ohio River, where the gang-mill system has not until recent times been introduced, and are based upon personal investigation, and from witnessing experiments.

The deviation of saws from a true line, or "running," as it is generally called, is that difficulty in operating to which nearly all knowledge of sawing is directed. Deviation cannot be considered a fault in saw operation, which is to be avoided by precaution; it is a normal result to which nearly every fault in saw operation tends. It is the limit we can say of capacity, determining how fast a saw can cut, also how thin saws can be made, and how long they can be run without sharpening.

The causes of saws deviating or "running" can, therefore, be said to include nearly the whole art of sawing, and should not, as it generally is, be considered one of the faults resulting from a specific cause, but should be considered as the general effect of nearly every difficulty to which saws or sawing is liable.

Deviation may be caused by unequal setting of the teeth, improper filing, from the teeth bending when cutting, the shape of the teeth not being suited to the work to be performed, want of dust space between the teeth, overfeeding, saws being too thin, from their being improperly hammered or strained, from saws becoming unequally heated; in short, from so many causes that, as before said, to understand the deviating of saws, and how to remedy it, includes the art of making and operating saws.

Referring to a proposition laid down at the beginning, we attempt to operate the teeth of saws with the thinnest possible supporting mechanism so as to save material, and their deviation of course determines thickness and kerf.

Imperfect or unequal setting is one of the most common causes of saws deviating. To set the teeth of a long saw so that each tooth shall project alike on either side of the plate, and remain in that position, is a mechanical operation of the greatest difficulty, and one not often attained. It can scarcely be called a difficult operation to bend a set of teeth so that a gauge will indicate a true and equal set on each side of a saw; but to have the teeth remain in this position is another matter, and one not so easily attained.

If a tooth is sprung with a key just enough to give the required set, and another tooth is bent too much and sprung back so as to meet the gauge, the two teeth are by no means left in the same condition; the first will be liable to straighten or lose its set under circumstances which would not affect the second, so that a gauge after all may fail to indicate whether a saw has been properly set.

Rough sawing comes generally from bad setting; and bad setting from unequal bending of the teeth, or from different teeth or parts of a saw having varying temper; and also from teeth being more or less rigid because of their shape.

In iron cutting it is common to employ what is called spring tools, or dragging tools. Such tools have their edges behind the supporting shank, so that undue pressure against the edge tends to lift the tool and diminish its work. The same principle in a modified way, applies to saw teeth; the cutting edges can be arranged to stand behind or in front of the base or support of the tooth, as shown in figs. 6 and 7. With a dragging tooth, as in fig. 6, moving in the direction of the arrow, it is evident that the propelling force will tend to drag the tooth into its proper path in a kerf, and prevent deviation; but in the form fig. 7, the propelling force and base of the tooth being behind the cutting edge, there is not this tendency to draw the tooth into line with the plate, and if a tooth of this form once bends, it is usually broken. In operating thin band-saws at high speed, when their teeth stand forward—that is, the edge forward of their base,—it is a common thing for the teeth to be driven into the timber and broken off. This danger, of course, comes as well from the

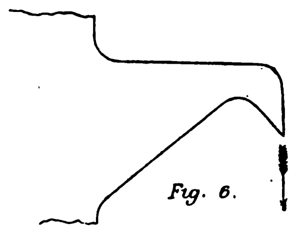

Fig. 6.

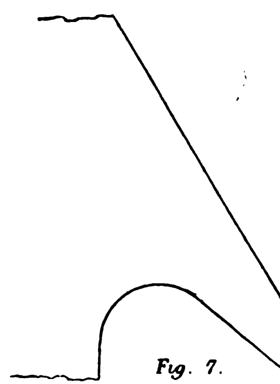

Fig. 7.

length as from the form of the teeth, because of the thin saw-plates and a want of rigidity to resist bending.

One of the difficulties in band-sawing has been how to provide sufficient dust-room between the teeth and yet have them short. Fig. 3 on a preceding page shows a plan commonly resorted to, that of long spaces and short teeth; but this has its objection in the fact that the dust spaces fill only for a short distance below the base of each tooth; the rapid movement of the saw, the friction of the dust particles against the sides of the kerf, and their inertia, all tend to pack them in a solid mass in the top of the space between the teeth, commonly called a "throat."

This packing of sawdust leads, sometimes to results in sawing which are unexpected, and often not understood. A saw may for instance, fail to operate in cutting elm wood, or even soft fir, and yet run true in cutting the hardest wood. In fact, rosewood, banyan, cocoa, box, mahogany, and other kinds of hard wood with a granular structure, are more easily sawn true than softer woods, because the dust is free and does not pack between the saw-teeth.

It would no doubt be possible at this time, through the means usually adopted in such cases, to establish a standard for the form and arrangement of the teeth of saws that would have considerable value; but so thoroughly empirical are opinions relating to the matter, that such a standard would no doubt receive but little attention. Any attempt at the best adaptation to various kinds of work, and for different kinds of saws, would of necessity lead to a considerable diversity in the form and arrangement of sawteeth, and such diversity would for a time complicate the manufacture and sale of saws—would benefit those who employ saws, but be a disadvantage to those who make them; so that, upon the whole, what may be done in writing of saws or their operation is only to promote investigation and direct attention to such observation as may sometimes assist in forming a basis for standard rules as to the mode of constructing them.

The various forms of saw-teeth which have come to notice in a public way during a few years past are, in fact, not new at all. In the *Ichonographic Encyclopædia*, a German work much older than any of the late patented saws, can be found drawings of nearly every kind of teeth; and what is equally strange, this work, although twenty or more years old, contains some of the best examples of tools that can be referred to.

CHAPTER XVI.

THE OPERATION OF CIRCULAR SAWS.

The subject of saw-operating, and the adaptation of saws of different kinds to various purposes, having been already treated of to a considerable extent in several publications, it is proposed here to review some of the economical conditions connected with sawing, thus following out the original proposition of generalizing instead of particularizing as a mode of investigating.

The expense of sawing can be divided into—(1) Wages of attendants; (2) Power; (3) Interest on the capital invested in plant; (4) Wear and deterioration in value from use; (5) The consumption of supplies, such as saws, files, oil, and belts; (6) Management.

To form an estimate of these expenses we will choose for example what is called a Deal Bench, as the most commonly known among our sawing machines.

Referring to the first item named, the attendance, benches as now arranged, when employed in splitting deals, require two men, one of whom must be skilled in the care of saws, and also understand the cutting of lumber for different purposes. The wages of these two men may be estimated at £200 for a year.

Assuming that 5-horse power is consumed in driving such a saw, and that the fuel required in generating this power is or should be mainly furnished by the sawdust, the expense may be set down at £10 for each horse-power per annum, or £50 for a deal bench consuming 5-horse power.

This is of course estimating the power as a part of that employed in an establishment where other machinery is operated; or, to assume a fair example, the 5-horse power may be considered as one-fifth of the duty of an engine of 25-horse power.

The machine, with its connections, foundations, and so on, if estimated at a value of £100, would cost as an investment at interest of five per cent., £5 each year.

In ordinary manufactures, such as are not undergoing rapid change, machine tool deterioration does not exceed 5 per cent. in iron manufactures, or 7½ per cent. in wood manufactures. Sawing machines, being less liable to change and improvement than most other machines employed in woodwork, do not exceed this estimate, and deterioration may be set down at £7 per annum for such a bench as we have assumed.

Supplies for a deal bench, as before named, include saws, oil, sharpening tools, and belts. Of these things it is hard to arrive at an estimate; the destruction of belts, for example, is an item which may be from £2 to £10 per annum.

If belts are wide enough to perform their duty without overstraining, and are not driven at a destructive speed, the wear is not much, but on most of the saw benches as now arranged the belts are only one-half wide enough, and consequently must be strained very hard, and driven at a speed nearly equal to that of the saw-teeth. The same remark applies to some other machines.

Presuming one belt 50 ft. long and 6 inches wide to cost £5, and last a year, and that oil, files, and saws will cost £8 more, it will give a sum of £13 per annum for supplies.

Managing expense does not, perhaps, exceed £20 to each workman; so that a deal bench should be charged with £40 per annum for such expense.

There are other items of expense, such as tax, insurance, commercial risk, and so on, which should be included in attempting to ascertain the exact cost of operating a machine, but this is only a secondary object here, the purpose being to ascertain with some certainty how far the total expenses of operating a saw bench may be affected by circumstances within control.

To sum up,—

Attendance of two men for one year ...	£200
Steam power, one-fifth of 25-horse power ...	50
Interest on investment	5
Deterioration of value...	7
Supplies, including saws, files, oil, and belts	13
Management and office expense	40
	£315

—giving in all £315, or for present purposes it may be called £300 per annum, as expense for operating and maintaining a five-horse power deal sawing bench.

In considering these items of expense, be they more or less than what is here set down, it must be remembered that nearly all of them are constant, so long as a machine is kept in operation; and some of them, such as management, interest, insurance, and even deterioration go on just the same, whether a machine is operating or still.

To compensate this expense of £300, is the duty performed by the machine, and it would be an axiom to repeat that the expense of this duty is inverse as the amount performed. That is, if 2,000 superficial feet is cut in one day, the expense rated per foot is very near twice as much as though 4,000 instead of 2,000 feet had been sawn in the same time.

In sawing the larger amount there would of course be consumed more oil, power, belts, saws, and so on; but these are small items compared to labour, which is near two-thirds of the whole, so that the actual expense is much the same whether 2,000 or 4,000 ft. is sawn in a day.

The performance of a machine (its working capacity) is therefore the main element in determining the expense of splitting deals, and to this some attention will now be given. The criticisms on common practice, when made, must not be construed as an intended attack on machines in common use, nor the mode of operating them. The conclusions drawn may be in some cases erroneous; it is asked, however, that they be accepted as candid.

Splitting deals is perhaps the most regular among the sawing operations of a wood factory; even planing is subject to more changes; and if there are any among the standard machines in common use which admit of specific adaptation, a deal-splitting machine is among them; yet when we come to examine the usual manner of constructing and operating these machines, there appear many features which, to say the least, do not suggest adaptation.

The amount of work performed by a sawing machine is as the cutting time; that is, a saw acting continuously for one hour will perform twice the work that one will when acting but thirty out of sixty minutes, and running idle during the remaining half-hour.

The expenses of operating a deal bench are not much different when the saw is acting and when it is not. When running idle there is the same wear and general expense; even the amount if fully employed is the same, because a saw when cutting usually furnishes its own fuel.

The attendance, which would seem to be double as much when a double amount of work is performed, is in fact no more with a continuous acting saw than it is when one-half the time is lost by intervals. To state this another way, the expense of attendance is measured by time, and not by the amount of work performed, presuming of course that a continuous acting machine is so arranged as to demand no more hand labour than one which operates but half the time.

These propositions every one acquainted with machine operations must admit; how far our practice conforms to what they suggest will next be examined.

A deal bench is generally arranged with a winding drum at one end; a rope is employed to pull the lumber to the saw; two men, one at either end, walk along with the lumber as it passes the saw, guiding the deal by hand.

When a cut is completed these two men walk back again to the starting-point; the rope is unwound, the hook placed on the end of the deal, the men wait until the slack is wound up, and then start on a new walk the length of the lumber, and so on the operation proceeds.

If the time of cutting is noted by means of a watch, and at the end of an hour the cutting time is subtracted from the whole, most of our mill proprietors would be astonished to find that their deal sawing machines are operating less than one-half the time, and that the cost of sawing is double what it might be.

The labour of attending a sawing machine when operated in this manner is very great, and severe also. The men are engaged for the most part in performing functions which the machine should do; they are continually walking, have to drag back heavy deals, and are so engaged that there is not a moment left to inspect the work as it goes on, or examine the surfaces as they come from the saw, unless such time is taken from the cutting intervals.

How this rope-winding or hand-feeding system of sawing has ever made its way so far is one of those strange things which want rational explanation. A bench for jobbing, or one applied to such a variety of uses that power-feeding mechanism could not well be applied, might have a winding rope to help an attendant feed the lumber, but in sawing deals which are measurably uniform as to width and thickness, such a plan of feeding can only be considered a rude attempt to avoid a part of the physical exertion required in handwork, and without gaining the least advantage in effect.

Saws for splitting deals should always have continuous self-acting feed; the saw should never cease cutting until it is dull. The feeding duty of the head sawyer should be to start the deals, but not to walk after and guide them; his time is required for other things; each piece wants inspection before it is sawn; there are continually things to perform and see after, which can be attended to in the intervals between entering or starting deals on a power feed machine.

At the delivering end of a machine having continuous feed, there is no duty to perform except to remove pieces and return those to pass through a second time; there is no occasion to press the lumber against a gauge by means of a hand lever, nor to drive wedges in the kerf to clear the saw, as is often done in sawing wet spongy lumber.

Machines that have a continuous duty, which is measurably uniform, should be fitted with a return feed to bring back pieces which have to pass through twice. This can consist of rollers only, so that a piece can be "shot" back without walking after it, or can be operated by power, which is best in most cases.

In America machines arranged to make several cuts in one piece, are either constructed on an angle so that the lumber runs back by gravity. or an endless belt is employed to carry pieces back.

There is, however, no sawing in America, or at least not much, corresponding to what has been called deal-splitting; the planks or deals being generally sawed into two pieces only. Such sawing is done at the rate of 60 to 70 feet a minute on what are called power-feeding machines, which cost less and require less hand labour than deal benches.

In the north countries of Europe power-feeding deal-splitting machines have come into use as a matter of necessity. A hand-feeding or rope-winding bench, it was found, although making one and a half or two boards at each cut, would not supply a planing machine; the saw would fall behind, and the planing had to be stopped until the saws "caught up," this, as said, led to the adoption of power feed, not only for splitting, but also for edging deals.

One mode of increasing the performance of deal benches which has been attempted, is to employ two saws making three pieces at each cut. Of this system it need only be said that two circular saws cannot be successfully operated in this manner; the theory is well enough, so is the appearance of such a machine, but its performance is another matter. A gang of circular saws can be operated on one spindle when their peripheries only are buried in the wood, and when the depth of the lumber sawn is not more than twice the depth of the teeth, under other conditions the plan is not one to be recommended. All such gang or multiple machines, whether for deals or logs, have failed in practical use.

Another point of some importance in sawing deals is the kerf waste. The dimensions of deals has naturally been reduced to the lowest point, and the amount cut away in splitting and planing, often has a considerable effect upon the market worth of the finished work, as it may be above or below certain standards of thickness.

In sawing there are two things which determine the waste, the thickness of saws, and how closely the lumber is confined or kept against the gauge.

In reference to the first matter it is well known that the thinness of circular saws depends mainly on supporting guides. A saw of 14 gauge provided with proper guides will run true when one of 12 gauge without such guides will deviate and cause trouble.

To apply guides at the top of a bench or at the bottom o the lumber is certainly of assistance in guiding or supporting a saw, but is by no means enough. A guide above the lumber to direct and hold the saw true as it "enters the lumber" has double the effect of a guide which directs a saw "after it has come through the lumber." For deal sawing top guides should be employed whenever thin saws are an object; such guides are easily applied, can be instantly swung out of the way, or set up and down as the width of the lumber may vary. As to guides behind the spindle, at the rear side of a saw, as it is generally called, they of course serve to direct a saw as it enters the kerf, and prevents scratching the sawed surfaces when no spreading wedge is employed; but with a wedge or "knife," as it is called, to open the lumber behind the saw, the rear guides can as well be dispensed with.

These spreading knives are important devices in many kinds of sawing, and as they are seldom employed in this country, and consequently not well understood, some notice of them will not be out of place.

Their object is threefold: to prevent scratching the sawed surfaces by the entering teeth as they pass into the kerf; to prevent the lumber from cramping a saw by springing together, as is common when green or wet stuff is sawn; and to prevent danger from the teeth catching, so as to "throw pieces over."

The principle of sawing or splitting such pieces as are in any degree flexible should be to clamp them as firmly as possible near the cutting point, and then to release and open them behind this point so as to free the saw, prevent friction, and allow the dust to escape. A spreading knife serves this second object, and will in practice be found a valuable adjunct on any bench, and for almost every kind of work. The knives should be of tempered steel, carved to follow the saw as shown in fig. 8; the thickness should be from one-fourth to

Fig. 8.

one-third more than the kerf at the front of the saw, or where the teeth act; the front next to the saw, should be a dull edge, and the section of the knife a tapering wedge from the back to the front.

The convenience gained and the danger avoided in drawing pieces away from a saw after they have passed the gauge is quite enough to compensate for the expense of spreading knives, if there were no other objects for them to serve.

It may be explained that the foregoing remarks on deal sawing benches were at first suggested by an observing saw-mill proprietor in Lancashire, who a short time since remarked to the writer. "When I sit in my office listening to my deal sawing benches and note the cutting time, I find it is less than one-half; the men work very hard, yet the work done is not one-half what it should be or could be if the machines were acting continuously."

CHAPTER XVII.

RECIPROCATING SAWS FOR DEAL SPLITTING.

THERE are many, if not a majority, of saw-mill proprietors who consider reciprocating saws best for splitting deals. Yet there are but few who are altogether satisfied with the performance of such machines, and are anxious about improvements to lessen expense or save material.

The adaptation of reciprocating or frame saws for sawing deals, in order to be fairly understood, must be considered on economic instead of mechanical grounds, and the diversity of opinion which exists is in nearly every case traceable to different reasons from those which would be advanced to show how a frame saw or a circular saw would in a given time perform a greater or less amount of work.

In comparing the mechanical effect produced in the two cases, therefore, we do not reach those conditions which should mainly govern a mill-owner in his choice of the two plans, yet there are suggestions to be gathered from both views, and it is proposed to first consider the mechanical performance of frame saws, and afterwards notice what may be called the economic conditions which attend on the use of such machines for sawing deals.

A circular saw machine is one with a fixed or determinable capacity. Its performance, measured by the surface sawed, is tolerably constant. A profitable or a proper employment of a machine demands that a certain amount of surface be cut during the running time, and the only means to regulate the amount sawn is by the cutting time; that is, a saw moving at a certain speed must have a constant amount of cutting to do in order to have the teeth act properly. Frame-sawing machines have no fixed or determinable capacity; what they perform is dependent upon the number of saws operated at one time.

A frame capable of operating sixteen saws, if employing but four, is working at from one-third to one-fourth its capacity. In sawing deals with two cuts in each, a double frame—that is, two frames combined—operate but four saws. If more than two deals are sawn at once, the feeding mechanism is independent for each deal and the difficulties arising from complication and the want of uniform action between the different parts of the machine is quite enough to outweigh what is gained by the added cutting capacity, so that two deals and four cuts can be assumed as the average capacity of double-frame saws, or machines having two sets of feeding mechanism. The aggregate of cutting movement with four saws, making two hundred revolutions a minute at a stroke of twenty inches, which is a high estimate to assume, gives something over 3,000 feet a minute of cutting movement for all the saws taken together; perhaps something less if the exact conditions are taken into account, but in no case exceeding more than one-half the cutting speed of the teeth of a circular saw.

It may be remarked that while not constant in all cases, the rate which the teeth of saws move is the best exponent of capacity that can be assumed, and if applied in practical tests will be found tolerably correct in the case of reciprocating and circular saws when applied to deal cutting.

The best performance known to the writer is for a double frame saw, that is, a machine feeding two deals at once, about 4,000 lineal feet in ten hours; this, with two cuts in each deal, makes 16,000 feet, or with three cuts in each piece, 24,000 lineal feet of cutting in ten hours, the deals averaging nine inches wide. This equals a continuous feed of 40 feet a minute for ten hours, and is equal to the cutting capacity of a power-feeding circular saw, even if acting without intermission throughout the time, which is not possible.

This example in frame sawing is an extraordinary one, and not at all to be assumed for the purposes of a comparison with circular saws. The amount is no doubt twice what is performed in ordinary practice, and 8,000 feet with four saws, or 12,000 feet with six saws, is nearer the true performance of a good frame feeding two deals, so that the cutting capacity of a frame saw compared to a circular sawing machine (not a saw bench) is as one to two.

Taking this view of the case—that, is that a circular sawing machine has twice the capacity of a frame saw—it would seem that the expense of sawing would be as two to one also; but another and a very different standard must be assumed if we include the economic conditions, as will be seen.

Keeping in view the expenses attending the operation of saws enumerated in a previous article, namely, attendance, power, interest, deterioration, supplies, and management, and applying them in comparing frame and circular saws, we will find some points of advantage in favour of frame saws, which may and does in many cases more than balance the difference in operative capacity.

First may be named the knowledge and skill required in the two cases. Frame saws are old and well understood; there is no trouble in procuring men to operate them, while circular saws for power-feeding purposes are but little understood. A circular saw-bench is, of course, a familiar machine, but a continuous feeding one is another matter, and as past experience has proved, there is but one means of introducing improvements in such machinery,—that is, to wait until people become skilled through experience. Power-feeding circular saws have been for twenty years making their way in America, where everything favours rapid development; and while it may be claimed that for most purposes analogous to deal sawing, such machines have superseded reciprocating saws, still there is much to learn now, and wide differences, both of opinion and practice, yet exist.

A second point is attendance. The feeding movement when three cuts are made in one deal is, if we count running back, five times as much with a circular sawing machine as with a frame saw. If two cuts only are made in each piece, the feeding movement counted in the same way would be as three to one in favour of a frame saw, or, to assume an average the distance which the lumber has to be moved in the two cases, as four to one.

Presuming that a circular sawing machine has feeding mechanism for returning deals as well as feeding them forward, still there would remain the difference that each piece would require to be adjusted and started four times instead of once, so that attendance, the most expensive item of all, would be much less in the case of frame saws. There is not at hand any facts from which a comparison can be made, but it is believed that the attendance would be not far from as two to one in favour of a frame saw.

Kerf waste would, perhaps, be something more with a circular saw, but the cutting would be more exact. There is often a considerable loss by frame saws deviating, and this can be fairly balanced against the greater kerf waste with circular saws.

Other items among those named in the list of expenses, on a previous page, except management, would be much the same in the two cases.

These points of difference. although considerable, do not by any means make up for the double cutting capacity of a circular sawing machine, if we assume that the work can be continuous,—that is, if a frame saw or a circular saw can be kept constantly cutting throughout the year on one class of work. In that case a circular saw would be the most profitable and the best adapted to the purpose; but it is only in the largest mills where there is business enough to keep a deal-splitting machine in continuous operation; and this brings us to the main point of difference in the two cases—the adaptability of the machines to different purposes, so that they may be continually employed.

A frame saw can be employed for sawing deals or logs as occasion may require, but a circular saw arranged for deal sawing cannot well be applied to other purposes.

This is one of the few cases where a combination machine may be employed to advantage. The changes required in altering a frame saw from log to deal sawing, or *vice versa*, are not many in the most improved machines, and the adaptation in the two cases is very good, or at least better than in almost any example that can be named.

There is also in favour of such combination some other conditions which do not apply to other machines, such as the large amount of floor space occupied, the investment, which is considerable, and the number of attendants, which demands that such machines be kept continually at work.

It must also be pointed out that a combination saw frame does not compare with most other machines to which the name combined is applicable; it is, in fact, not a combined machine, but one applicable to two purposes. Most of the mechanism is adaptable to and used for both purposes; and if two separate machines were employed, one for deals and the other for log sawing, most of the parts in one would be duplicates of the other; on the contrary, machines for boring, sawing, planing, cutting tenons, and so on, consist for the most part of separate details mounted on one frame, the frame and counter-shaft being nearly all that is employed in common for the different operations.

The conclusions to be drawn from the premises laid down are that in any mill where a deal-sawing machine cannot be kept continually running, a combined frame saw is preferable, because such a machine can be employed in cutting logs when not required for deals; but in any case when there is enough to do so that a deal saw may be kept continuously at work, a circular saw is preferable and less expensive.

There is one more condition to be taken into account in comparing reciprocating and circular saws for deal-splitting. In the case of frame saws it is safe to assume that they all have now reached a point of efficiency which will not likely be much surpassed by future improvements. It is hard to conceive of any means to increase the amount of work which such machines perform, unless by adding to the speed at which they are driven. There has been every effort made in this direction by various makers of sawing machinery, and the speed of saws has been wonderfully increased during some years past. Greater speed is no doubt attainable by a proper attention to the causes which produce vibration, and in providing larger and better surfaces for crank shafts and crank bearings; yet there is not much to be expected from such improvements.

Frame saws may therefore be considered among those machines which are well understood and tolerably perfect. Circular sawing machines, on the contrary, are by no means so well understood, and the improvements which would follow a more extended use of power-feeding machines of this kind are difficult to foresee.

A circular saw supported above and below a deal by efficient guides could no doubt be as thin as or thinner than strained reciprocating saws, and might also by reason of such guides be driven at a speed of ten or even twelve thousand feet a minute.

A circular saw might also be driven by friction wheels applied near to the teeth and beneath the wood, so as to impart some tension to the cutting edge, and thus avoid that weakness or want of rigidity in the plate which is a result of driving saws from their axial centre, and the reason that saw-plates must be so thick. This is not mentioned as a scheme of any practical value, but merely to illustrate how various inventions and improvements might follow a more extended employment of circular saws for purposes where frame saws have hitherto been employed.

Band saws may, however, render such improvements unnecessary.

CHAPTER XVIII.

BAND SAWS FOR DEAL SPLITTING.

Four years ago the following was written:*—

"The future of band saws is hard to predict; judged upon general principles, and by the laws which govern sawing, we are at once led to conclude that band sawing must supplant every

* Treatise on the Construction and Operation of Wood-cutting Machines, page 149.

other method. The advantages are so many and so obvious, that nothing but insurmountable mechanical difficulties can prevent their becoming the standard saws for every kind of use. Analyzing the principles of their action, we may be said to have blades of superior thinness, capable of tension in varying degrees, moving in right lines through the material, at a speed that is almost unlimited, and can exceed that of circular saws; operating, too, by machinery consisting only of rotating parts, and of the most simple construction, the sawdust all carried down through the lumber, offering no obstruction in following lines."

The opinions then expressed are yet entertained, and it may be fairly claimed that in four years past the progress of band sawing has been all that could be expected, even if we grant the possibility of this method eventually superseding all others for every kind of work where band saws can be employed. It will, however, be proper to explain here, before considering band saws as deal-sawing machines, that there is no intention of recommending mill-owners to adopt them instead of frame or circular saws.

The manufacture of band-saw blades and the construction of band-sawing machinery, as well as the operation of band saws, are all new arts, yet far from perfect; and while this should deter no one from adopting snch machinery where there is skill to operate it, and where there are conditions to favour such saws, yet it must not be thought that there is no more to do than to procure a machine and set it at work. As mentioned in a former place. special knowledge of certain kinds of machines is slowly developed, and grows up as a kind of gradual progress from failure to success. Nearly all kinds of skill or handicraft have come through such a stage. At first a skilled man here and there was all that could succeed; after a while the number increased, the special skill became general skill, and still farther on, common skill, so that the processes, whatever they might be, lost their mystery, admitted of exact treatment, and produced constant results. This will no doubt apply to band saws and band sawing.

The process is now in its first stage; like others, this art must go through its regular changes, but with one difference from most machine processes. Band sawing is not likely to advance rapidly from discoveries and inventions.

Everything thus far points to it as a thing of slow development; inventions and discoveries will be made; by them, indeed, must progress go on, but the improvements will be many and little, instead of few and great. It is a work of time and patience, but is now beyond that stage when practicability was the main problem; adaptation and expense are now the points to be dealt with.

The advantages gained by band sawing are so great that nothing but insuperable difficulties can now stop the progress which is going on; if such difficulties had existed we are now far beyond the point where they would have appeared.

The destruction of blades, the most formidable among those difficulties which stand in the way of band sawing, is owing to causes which we may reasonably expect some time to control. It is often said a saw will bend only a certain number of times before it breaks, and that the time that a saw will operate without breaking is dependent on some inherent condition of the steel, which fixes a limit of service.

This can be true only in so far as the proposition applies to certain saws, and under certain conditions. It is well known that steel ribbons and springs in many cases are not limited to a certain amount of bending, but last for a lifetime without breaking. It is true there are no examples where the frequency of bending compares with band-saw blades, but to balance this the severity of bending in the case of many kinds of springs is much greater than with saws.

It is to be regretted that there exists at this time no data by which the bending capacity of steel springs or ribbons can be determined. It is also difficult to see how any exact knowledge of the matter is to be obtained, because there must in all experiments, no matter how carefully made, be one condition of uncertainty, namely, the quality and condition of the steel.

By examining a piece of steel we cannot determine its quality farther than indicated by granular structure; its chemical qualities can only be reached by assaying; of temper, which seems more than anything else to determine the bending endurance, is so far beyond our means of determining, that it is not too much to say there is but little known.

If, added to this, we consider the rough and inexact processes of saw manufacturing, and the equally irregular and inexact conditions in the modes of operating saws, it may be easily imagined that future experience will add the required endurance for band-saw blades.

The writer in a case under his charge employed a saw two inches wide and thirty feet long (when new) at intervals for more than a year. The saw was used for a considerable time in experiments, working under severe and irregular strains in lumber from twelve to thirty inches deep, heated by friction sometimes until the back was blue for the whole length. This saw was worn away by filing until it was not more than one and one-fourth inches wide, and cut certainly more than 50,000 feet of lumber, yet never broke until torn in two by excessive tension. The blade was then sheared to one inch in width, a new set of teeth were cut, the saw was set to work on hand-feeding machines, and lasted out the usual term of a new saw of similar width. In this case there was certainly no limit of endurance which would interfere with the economic results of band sawing. It should be explained that during the experiments referred to various other saws were tried, mainly to test endurance and the form of teeth; one, which to all appearance was as good as the one that lasted so long, never exceeded four hours' service without breaking. Others lost their "hammer setting"—that is, would become crooked if heated by friction. The case of long endurance mentioned is the most remarkable, but by no means the only one which could be referred to, where saws have been worn out without breaking—that is, reduced by filing to such narrow dimensions as to break from tension.

As in the case of frame and circular saws, the first thing to be considered is the mechanical effect of band saws compared with other machines to perform the same work, and afterwards the economic conditions which govern the commercial advantages and disadvantages which belong to band sawing.

The first matter need not require much attention; it involves no intricacy, and can be disposed of by saying that a band saw can move at an equal or greater speed than a circular saw, and would require the same attendance as to labour, but more as to skill. The amount of work performed measured by time will be about the same with a band or circular saw; if any difference, it will be in favour of a band saw.

The economical conditions, however, are very different in the two cases, much more different than would be supposed, and to these belong most that can be explained here.

A band sawing machine fitted for deal-sawing for lubmer twelve inches or less in width, like a combined frame saw, can be applied to various purposes when not required for deal-sawing.

Such a machine will operate the finest saws required in sweep cutting, and by changing the feeding table for one with a flat top the machine will in all respects be the same as if arranged for hand feeding only.

With a gauge for slitting such a band sawing machine is one of the most convenient of jobbing saws, and is in practice preferred by workmen to any kind of saw bench for that class of work to which there is given the name of "jobbing and cropping."

With feeding mechanism attached such a machine can be employed for slitting, moulding battens, sawing panel stuff from thick pieces,—in fact, any kind of straight slitting requiring accuracy and speed. These are the principal working advantages gained.

The saving of material, an item which in many kinds of work is equal to the expense of sawing, is also an advantage of band saws, one that has special importance in deal-sawing, and in cutting out battens for mouldings from the more valuable kinds of lumber.

The kerf, compared to either frame or circular saws, need never be more than two-thirds as much, and in most cases can be half as much.

Among the economic conditions favouring band saws can also be named some saving in the investment, especially in foundations which are scarcely required, also in the amount of power required to drive the saws, and in the avoidance of jar, vibration, and danger to attendants.

These last items perhaps require some explanation. The investment in a band saw adapted for deal-sawing alone is near the same as for a power-feeding circular saw, but not more than one-half what a frame saw of equal capacity would cost if foundations and the expense of driving connections are included.

Investment as an item of expense in machine processes is, however, a small one, as has been before pointed out.

The saving of power due to the thinner blades employed in band sawing is considerable, but is a matter of importance only when the sawdust is not employed as fuel to generate power; the saving of material is of course more important, every one knows that lumber even at modern prices is an expensive kind of fuel.

Comparing one band saw with another, or one circular saw with another, the difference in the power required to drive them might be set down as one-half the difference in the thickness of the saws,—that is, a saw $\frac{4}{10}$ in. thick would require one and one-half times as much power to drive it as a saw $\frac{2}{10}$ in. would. The rubbing friction of saw-plates against the wood consumes much more power than is generally supposed; besides, in slitting, the particles have to be split off parallel to the kerf just the same whether a thick or a thin saw is employed. I incline to the opinion, however, that in comparing a band saw with a circular saw the amount of power required is very nearly as the thickness of the saws, other things being equal,—that is, if both saws are equally sharp, have the same amount of set, and operate at the same speed. This would make a great difference, because band saw blades are on an average but little more than half as thick as circular saws.

The avoidance of jar and vibration is a consideration of considerable importance, in so far as enabling a band saw to be set on a floor instead of on foundations; but this advantage exists only in comparing band with frame saws. In the matter of danger to attendants, band saws compare with frame saws. A common opinion prevails that the blades are liable to come off the wheels or fly when they break, but no serious accidents from these causes have occurred, so far as at present known.

To summarize these several points will give an argument of some strength in favour of band saws for deal-sawing; but, as at first mentioned, there is no intention of recommending mill-owners to adopt such machines without very carefully considering both sides of the case.

CHAPTER XIX.

SHAPING WOOD.

Wood conversion, as before explained, consists in cutting out, and shaping; the first performed by saws, and the second by cutters. It is surprising that in an art so extensive and varied the processes should be so few and simple in their nature when stated in this way; but if the matter be followed farther to the different modes of cutting and shaping we meet with a diversity of operations which wants a parallel in the treatment of metal even.

To include smelting processes the conversion of metal, of course will include a greater number of processes, and those of greater intricacy and importance than exist in wood converting, but if we confine comparison to dividing and shaping, the modes of operating are much more numerous in wood manufactures.

This may be accounted for because the property of melting, common to metals, enables them to be shaped into almost any form which ingenuity can devise; while, in the treatment of wood as well as nearly all material except metal, forms must be cut out from solids.

An exception to this, but one of no great importance, is in the permanent bending of wood. There are but few varieties which have the required flexibility and tenacity to be treated by bending; the particles, if we may so speak of a fibrous material, do not as in metal assume a permanent 'set' but are ever ready to assume their natural position when disturbed by moisture or bending a second time.

The shaping of wood consists in two operations which are in many respects distinct, or at least may be so treated, for the purpose of investigating the economical and also the mechanical conditions which attend on wood converting. These two operations are, the action of cutters, and presenting material.

The "presentment of material"—a phrase to be found in Bentham's patent of 1793,—includes the greater part of what may be termed machine processess, not only in working wood but other material to which a positive shape is given. The tools or agents employed to remove surplus material, with all problems connected with the manner of supporting, propelling, guiding, and maintaining them, do not, present as much intricacy as the "presentment of material;" and it is a matter of no little interest to know that these two things, with nearly all the economic conditions connected with them, should have been so clearly conceived of by Bentham. It is also a wonder that Babbage in his "Economy of Manufactures" published in 1832, did not in his investigations of machine action adopt a similar classification, and point out the distinction between the action of implements and the presentment of material.

In shaping wood, the mode of operating cutters, whether rotary, reciprocating, or direct acting, is familiar to every one who has to do with wood converting, that is, the general mode of operating with cutters, if we leave out problems of speed, angles, proportions and so on, is very well understood; but the various devices for presenting material, considered aside from cutting is, as before said, a subject of some difficulty.

The different modes of presenting wood to receive the action of cutters, or to be shaped, as it may be called, can be classified as follows:

1. By sliding over fixed surfaces.
2. By being carried in straight lines on carriages.
3. By being carried in curved or irregular lines on carriages.
4. By true or eccentric rotation.
5. By means of models.

These different modes of operating can be illustrated by the following machines.

1. Planing and moulding machines, with all that have rollers or chains to feed the lumber.

2. Planing machines or others having running carriages moving in a straight line.

3. Machines for jointing the staves of casks, planing the fellies for waggon wheels, shaping machines with undulating carriages, and so on.

4. Common turning lathes for cylindrical forms, and excentric lathes for turning oval picture frames and similar work.

5. Duplicating machines for forming gun stocks, shoe lasts, tool handles, and so on.

These modes of operating or presenting material are with tolerable uniformity applied to certain kinds of work, but as might be expected the classification of the work, or the articles produced, is by no means so easy to determine as the processes. Many kinds of work may be performed by two or more of the modes explained, and in the problem of which to adopt lies one of the most difficult which engineers and manufacturers have to deal with.

The framing of a door, for example, can be planed on a roller feeding machine, on a trying-up or a carriage machine; in some cases one plan is right, in other cases it will be wrong. There are factories in England, where one or the other of these different plans of planing framing is practised exclusively, and no doubt to the best advantage, in either case. An oval picture frame can be made in an excentric lathe or moulded on a shaping machine; sometimes such frames are cut out and formed by the movement of the cutters only; each plan is practicable; the problem is which is best, and what mode of operating does the particular conditions in a given case render most suitable.

It is evident that however important it might be to have some general rules to guide in selecting and determing processes for shaping wood, that such rules are impossible because of the varying conditions under which work is performed. The nature of material, the amount of skill, and the quantity to be done, may each modify a choice of processes; so that the most which can be done is to point out, as well as possible, the peculiarities of each of the different modes of presenting material.

CHAPTER XX.

LONGITUDINAL AND TRANSVERSE PLANING.

WOOD-PLANING machines which act transversely, across instead of lengthwise the fibre, having in all their modifications grown out of the invention of Bramah (1808), it is proper to call such machines by his name.

It is a matter of common knowledge that the disturbing strains incident to cutting are, in machines of this kind, very much less than with cylinder machines, or as they are generally called, "trying-up machines."

A clear distinction between the principles of operating can be made by saying that in one case the plane in which the cutters rotate is parallel to the face of the lumber or the surface acted upon, while in the other case the plane of rotation is at a right angle to the face of the lumber. This difference in the mode of operating, with some other reasons of less importance, has kept the two processes quite distinct, and although the mode of planing by a Bramah machine is much slower, and consequently more expensive, yet a large number of such machines continue in use, and probably always will.

Such a machine, with the cutters arranged to revolve in a circle 30 inches in diameter, running at a speed of 1,500 revolutions in a minute, has a cutter movement of nearly 12,000 feet in the same time. Excepting circular saws, and these only in exceptional cases, this is the highest speed found among standard wood-cutting machines.

A machine operating on pieces eight inches wide is cutting but one twelfth part of the whole time, and the action of the cutters can be considered as abrupt blows given at speed of 12,000 feet a minute.

The inertia of pieces being planed is mainly depended upon to keep them steady, that is with carriage feeding machines, and when we consider that the blows given by cutters are resisted as the speed and duration of the blows, we arrive at one of the causes which enables long flexible pieces to be planed on Bramah machines without being jarred or forced out of position by the cutters. In many cases when the wood being planed is heavy, and the pieces not too small, they are laid upon the carriage without any kind of fastening, and are not disturbed by the cutter action.

The cutting of a cylinder planiug machine it is true, is analogous in so far as the action of the cutters being a series of intermittent blows ; but here the analogy ends, and tracing out the several distinctions between the two modes of operating, there appears not only sufficient reason for the difference of disturbing action, but reasons which, by theoretical inference, will lead us to suppose this difference greater still. In the example chosen, a piece eight inches wide, the length of edge, would with a cylinder machine be eight inches ; with a Bramah machine from $\frac{1}{8}$ to $\frac{3}{8}$ inch, owing to the depth of the cut or the amount of wood removed. These edges act under conditions as to the grain of the wood, their maintenance, and so on, which will permit it to be assumed that the strains arising in the two cases are as the length of the edges.

With a Bramah machine the cutting time would be, if two cutters are employed on pieces 8 inches wide, one-sixth of the whole; but on a cylinder machine this time is shortened, and with two cutters moving in a circle of 8 inches at 3,500 revolutions a minute, the cutting time is on an average not more than one-twelfth part, so that the intensity of the blows is greater, because of longer duration. But leaving this out, and assuming the disturbing strains to be as the length of the edges, and inverse as the velocity, the difference would be in favour of a Bramah machine as 1 to 25 or 30, and I have reason to think that with edges equally sharp, and presuming two machines to be performing the same duty, the difference in cutting strain would be in this proportion.

This is, however, not all that is in favour of the Bramah mode of planing, on material likely to be disturbed by cutter action. In planing with a cylinder machine, the blows given by the cutters are in most cases across the thin section of the lumber.

The general dimensions of lumber planed on carriage machines are a breadth equal to three or more times the thickness, as in the case of deals. As said, a cylinder machine, although acting in a measure lengthwise the lumber, nevertheless delivers its blows on the flat sides, while with a Bramah machine the cutting strain is transverse to the deep section, or edgewise the pieces, and is this reason more effectually resisted.

One objection to transverse planing, an insuperable one, is the expense and difficulty of maintaining edges; their length can only equal the depth of the cut, that is if one-fourth of an inch in depth is being removed at one cut, the length of the edges must be the same. In practice it may seem that edges much longer than this can be, and are, employed, but it must be remembered that the main work is cross-serving the fibre, and that splitting of the chips is an unimportant matter in comparison. If in cutting away one-fourth of an inch in depth, edges one half-inch long are employed, they must of necessity be set at an angle of 45°, and the result is merely that of severing the fibre at an angle instead of vertically from the face ot the lumber. In practice edges much longer than the depth of the cut are always used, but the amount of edge scarcely bears comparison to what is employed in a cylinder machine, which, with three cutters, multiplied by the width of the lumber, have usually two feet or more of edge, and will consequently run a much longer time, and perform a much greater amount of work without sharpening.

The character of lumber is so varied, as well as the quality of cutters and the mode of their application that we can hardly expect to ever have any exact data as to the performance of planing machines. In practice, however, the difference between Bramah and cylinder machines is not less than as one to two in respect to the amount of work that can be done.

This great difference in expense of the work, and also in the price of the machine, which is much more for those which have transverse action, has not prevented them from being extensively employed for the more accurate kinds of planing.

The difference in result is much greater than is generally supposed; so great indeed that one operation may be called true planing, and the other, with trying up machines, a kind of compromise between carriage and roller feeding. If cutters are kept sharp and the lumber wedged up so as to lay solid on a carriage, tolerably true, planing can be done with a cross cylinder; but in general practice and especially for long flexible framing, the Bramah machine will no doubt long hold its place among standard machine tools.

The general dimensions of such machines are as to height and width are much larger than for cylinder machines, consequently iron framing becomes expensive. The carriages when long become heavy, and "awkward to handle," if made of iron, and when we consider how insignificant the strains are in a machine of this kind, it is a matter of doubt whether a wooden frame machine is not both economically and mechanically the best, the expense is nearly as two to one, and as a rule the wooden frame machines have an equal capacity.

Planing Carriages.

In reference to the nature of the functions performed by sliding or rolling carriages for presenting material, it may be said that such devices consist in supplying artificial outlines to pieces planed or cut.

If a piece of lumber has two straight sides at a right angle to each other, there is no need of employing a carriage to plane the remaining two sides true; they have only to be made parallel to the first two sides to produce a finished piece, true in all respects; hence a common custom in both joinery and cabinet work, is to plane two sides on a carriage machine and then finish the remaining two sides by passing the lumber through a roller or continuous feeding machine.

The same rule of course applies to planks or boards to be planed on two sides only; the first side can be planed on a carriage machine, and the second on a roller-feed machine, gaining thereby considerable time because of the more rapid performance of the latter.

Referring to a plank to be planed on two sides, it is easy to see that to plane the first and second sides are operations which may be quite different, and in this difference obviously consists the functions of a carriage; if a piece has a true straight surface no carriage is required: from these two conclusions, two things are deducible, namely, that lumber to be planed straight must have one or more straight surfaces to guide it; second, that carriages supply this want by providing what has been termed an artificial surface.

A carriage is then, to be regarded as a true side temporarily fastened to the lumber, to supply a want of straightness, and must be so conceived of in order to understand the principles of planing operations. The difference in size between a piece of lumber and a carriage on which it is planed is usually such as to prevent one from conceiving of the two as being for the time combined and one body, that is, a carriage seems of too great importance both as to size and apparent functions, to be considered as merely an auxiliary straight side fastened to the bottom of a piece of lumber in order that it may be guided in a straight line by sliding over fixed surfaces, yet this is the purpose to which planing carriages are directed.

Pursuing this matter still further, the distinction between carriage-feeding and roller-feeding planing machines may be traced to the same principle.

If a carriage is considered as merely an auxiliary surface supplied to pieces to be planed, the query arises, Why are such carriages reciprocating? and, Why cannot the operation of planing be continuous when performed in this manner, as well as with machines having roller feed? The reason is, that a separate carriage cannot be furnished with each piece to be planed, the same one has to be employed for every operation, and consequently must be brought back to the starting point each time that a piece is passed through a machine. There are in fact some exceptions to this rule; carriages are made sometimes to operate continuously in one direction. A series of short carriages connected together in the manner of a chain, are sometimes employed to plane short pieces, thus securing a continuous and rapid feed without abandoning the principle of carriage planing. There is, however, a difficulty in machines constructed to operate in this manner, which prevents their employment for the more exact kinds of work. A series of independent carriages, liable to unequal wear in use, soon lose their uniform action: it is a matter of extreme difficulty to construct a chain carriage so that when new each platen will be precisely the same, and produce work of uniform thickness, while from exposure to grit and dust, which is unavoidable, the ways and bearings are sure to work unequally.

An example of chain carriages, which may be referred to in this connection, is in what is called Farrar's planing machine, extensively employed in America for parallel planing. This carriage, if it may be so called, consists of a series of flat bars placed transverse to the lumber, and linked together to form a continuous chain. These bars being not more than three and a half inches wide can scarcely be termed carriages in the common acceptation, but the whole chain may be considered a flexible carriage.

When lumber is fed continuously through a machine, the cutter acting on opposite sides, or on one side only, the other passing over a bed or roller, the effect is in some degree to produce straightness, but only in a degree, because the imperfections or irregularities will exist after planing nearly the same as before. If lumber is slid over a straight surface of some length, and not exposed to pressure great enough to straighten bends, such planing will in a still greater degree improve the truth of pieces. In practice, this effect is of but little importance, and is generally dependent upon the rigidity or size of the lumber; in preparing stuff for framing, or for any purpose where it cannot be sprung into shape by fixing, there is but little dependence to be placed in the straightening effect produced by roller or continuous feeding machines. This statement seems like repeating an axiom, but so far from this being the case, it is a matter of common occurrence even among experienced mechanics to find them of the opinion that lumber can be planed true on continuous feeding machines When lumber is straight-grained, and has been carefully seasoned without springing, there is no occasion to employ carriage planing machines to prepare joiner work. In America it is as exceptional to find carriage machines employed for such work, as it is in Europe to find roller-feeding machines applied to the same purpose.

From the conditions thus far pointed out, it will seem that the main object of carriages is to produce good work, while by continuous feed imperfect work only can be performed, or, in other words, that a continuous feed in planing is only a makeshift operation, having speed alone for an object. If this were the case, it would be hard to account for the excess of roller feeding machines in use and the work which they perform; straightness produced by carriages is however but one object and often a secondary one in planing.

The term "truth" as thus far employed, has been applied to general dimensions, that is, straightness and squareness, but there are other requisites in planing in many cases more important than either straightness or true rectangular sections.

In Bentham's old patent, so often alluded to in the course of these articles, he employs the two terms "presentment" and steadiment" usually in conjunction; in his analytical way of investigating machine processes, nothing seems to have escaped his notice, and we cannot in our language at the present time employ a phrase which more clearly and completely compasses the subject under consideration than "presentment and steadiment."

It is one thing to present a piece of lumber to receive the action of cutters, and quite another thing to steady it while being operated upon. By means of a carriage a scantling may be moved in a straight and be planed true as to general dimensions, but the surfaces may be rough and uneven, and the dimension irregular as to short lengths, mouldings for instance cannot be planed on a carriage machine unless pressure rollers were employed to clamp the stuff firmly at the point of cutting, and the pressure thus applied will bend the piece, if flexible, so as to fit it to the top of the carriage at the point of cutting; the straightness of a piece would in that case be the same after moulding as before, and nothing be gained by reason of the carriage.

There is this principle to be noted throughout all planing operations. Lumber cannot be planed true as to general dimensions if firmly clamped in planing; it must in order to be planed true, be in a state of rest and not strained by clamps. The only means of employing steadying devices when true planing is wanted, is to have the clamps hold in but one direction, vertically for example, and be free to slide in a horizontal plane; but even in this case, or by "wedging up" under lumber the supports can only be at intervals, and not of a kind to secure such "steadiment" as is secured by feeding rollers and elastic pressure pads.

By roller feed the timber can be firmly held at the point of cutting, and this way receive an accurate profile and smooth surface; hence in all cases where these two last-named conditions are more important than the truth of general dimensions, it is necessary to employ a continuous or roller feed, which not only secures the steadiment required, but enables a great amount of work to be done, and at a small expense.

The importance of straightness in nearly all cases varies as the flexibility of pieces; this applies especially in joinery, where pieces rarely stand alone, but constitute parts of a whole. The mouldings in a house are all straightened by fixing them, and it is not of the least consequence when they are small and flexible whether they are straight or not. The framing of doors, sash, or any movable part not being held straight by permanent fixing, require to be planed straight, and to remain so.

Opposed to true planing, especially with carriage machines, there is the strain and disturbance of the cutting action, a matter which is of considerable importance in designing and constructing machines for planing wood. Such strain may be disregarded in roller-feeding machines where it is easily opposed by unyielding beds or abutments, but in planing long flexible framing on carriage machines, it is impossible to do true work without the expense and trouble of numerous clamps, if there is much strain arises from the cutting action. The strain of cutting comes from three causes—the state of edges as to sharpness; the angle at which they act; and the speed of movement. A trying up machine, with a cross cylinder and long cutters; and a Bramah machine with a disc-rotating parallel to the surface of the lumber, furnish two examples of cutting strain. It is well known that with a Bramah machine the disturbing effect of the cutters is very slight, and that long flexible pieces can be planed with slight, or even without any fastening except their weight, and the friction between the lumber and carriage. On the other hand we find trying up machines arranged with clamps to hold lumber and also with rollers and pressure bars to keep it down at the point of cutting. There is a marked difference in the two operations, nearly as great in fact as that between carriage and roller-feeding machines, and as the question often arises as to which plan is best for certain kinds of work, it will be proper to notice the matter in connection with presenting and steadying material.

PRESENTING WOOD BY ROTATION.

Among all the various modes of operating in wood conversion, by none can such true smooth surfaces be produced as by turning. So accurate is the cutting, and so attractive the result, that wood-turning has ever been the principal among amateur mechanical operations. Considered as a mode of presenting material, we must therefore look for some principles in turning which are peculiar to the process and do not exist in planing or other operations where moving tools are employed. In attempting to trace out these distinctions, Sir Samuel Bentham's phrase of "presentment and steadiment" must be kept in mind. Among the various mechanical expedients to produce a perfect movement in running joints, there are two which we find in nearly every case where great accuracy and true "steadiment" is secured; one is a sliding joint depending on gravity to keep the surfaces in contact, the other is conical points or pivots so small in diameter, and the speed so slow that considerable pressure can be maintained, so as to prevent jar or lateral movement. A lathe is an example of point support; the material is held so firmly, and with so little chance of jar or irregular movement that forms cut out by rotation are geometrically true. The smoothness of work produced by turning is in part due to this perfect steadiment, and partly to the perfection of the tool presentment, which being usually performed by hand, guided by the eye, and felt as the work progresses, is altogether different from automatic machine action.

In the case of a machine acting automatically, there are presumed to be, or should be, in order to secure perfect work, a set of constant conditions; cutters should be constantly sharp, the material should be uniform in texture and hardness, and so on. This is not, however, the case, and no machine with automatic action can operate even for a few minutes under conditions precisely the same.

In hand operations, human intelligence meets these varying conditions, and adapts the operation of tools to the changing circumstances.

The senses stand as sentinels to watch for and detect the slightest changes; if a tool becomes dull or breaks, we at once see or feel the result, and apply a remedy, the work progresses slow or fast as its smoothness may require or the hardness of material will permit; an automatic machine on the contrary goes on the same, regardless of such things.

Hand turning as a process in wood conversion includes therefore those two essentials of perfect performance of the tools, steadiment of the material, and a control of the cutting action by the senses of an operator.

In machine turning the material has a similar support, and the tools also are so held as to produce movements the truth of which are dependent only upon the accuracy of guides or ways, that is, if contact between the sliding surfaces can be continually maintained,

To contrast turning with rotary planing, for example :—The tools, instead of being held and guided by joints which, because of slow movement can be kept in close contact, are dependent shafts running at a high speed in their bearings, such joints must be loose and have play, the variations of temperature demand this. If the spindles of a wood-cutting machine are examined when they are cold, it will be found that when the fit is as close as it dare be, still there will be play, and the journals can be moved laterally in the bearings.

The journals being the means by which the tools or cutters are guided, can be contrasted with slide-rests of lathes; both are to support tools and guide their action. What these conditions point to we find verified in practice; a lathe, whether for wood or iron is a very perfect acting machine tool compared to one where cutters are supported by rapidly revolving journals.

To produce turning absolutely true, it is well known that fixed centres at both ends of a piece are necessary, and that even the running points of lathe-spindles cannot be relied upon for reasons just pointed out.

Underlying every process in wood converting is a train of principles which, if followed out, will explain all the phenomena connected with machine performance, and by such generalization is often reached those simple practical improvements which chance may stumble over for a lifetime. The degree of improvement reached in various branches of mechanical industry is, in fact, very constantly as the amount of logical investigation which has been bestowed upon them.

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