MACHINE FORGING

A TREATISE ON BOLT, NUT AND RIVET FORGING AND THE APPLICATION OF FORGING MACHINES TO FORMING, WELDING AND UPSETTING OPERATIONS ON MACHINE PARTS

BY

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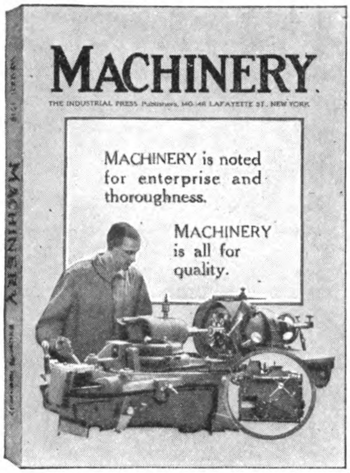
MACHINERY
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MACHINERY

PREFACE

FOR many years inventors rarely crossed the threshold of the blacksmith shop. Hand-manipulated tools formerly were used for many forging operations which are now performed in a small fraction of the time entirely by mechanical means. In fact, a great deal has been accomplished during recent years in developing forging machines and various other classes of power-driven equipment for forge shops. The forging of bolts and rivets by machinery is an old method, but the use of machines adaptable to forging, welding and upsetting operations on machine parts of numerous shapes and sizes, is a relatively modern development.

Since the making of bolts, nuts, and rivets is a very important and specialized branch of machine forging, the construction and use of the machines and dies employed for this work have been described in this treatise, as well as the application of machines designed for general forging operations. As the dies used for giving forgings the required shape are an essential feature of forging machines, dies designed for various typical operations have been illustrated and described in connection with this treatise.

D. T. H.

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MACHINE FORGING

CHAPTER I

BOLT HEADING MACHINES

THE bolt and nut industry in America started in a very small way in Marion, Conn., in 1818. In that year Micah Rugg, a country blacksmith, made bolts by the forging process. The first machine used for this purpose was a device known as a heading block, which was operated by a foot treadle and a connecting lever. The connecting lever held the blank while it was being driven down into the impression in the heading block by a hammer. The square iron from which the bolt was made was first rounded, so that it could be admitted into the block. At first Rugg made bolts only to order, and charged at the rate of sixteen cents apiece. This industry developed very slowly until 1839, when Rugg went into partnership with Martin Barnes; together they built the first exclusive bolt and nut factory in the United States in Marion, Conn. The bolt and nut industry was started in England in 1838 by Thomas Oliver, of Darlston, Staffordshire. His machine was built on a somewhat different plan from that of Rugg's, but no doubt was a further development of the first machine; Oliver's machine was known as the "English Oliver."

As is generally the case with a new industry, the methods and machines used were very carefully guarded from the public, and this characteristic seems to have followed the industry down to the present time, judging by the scarcity of information available on the subject. Some idea of the methods which were at first employed to retain all information in the factory in which it was originated is well

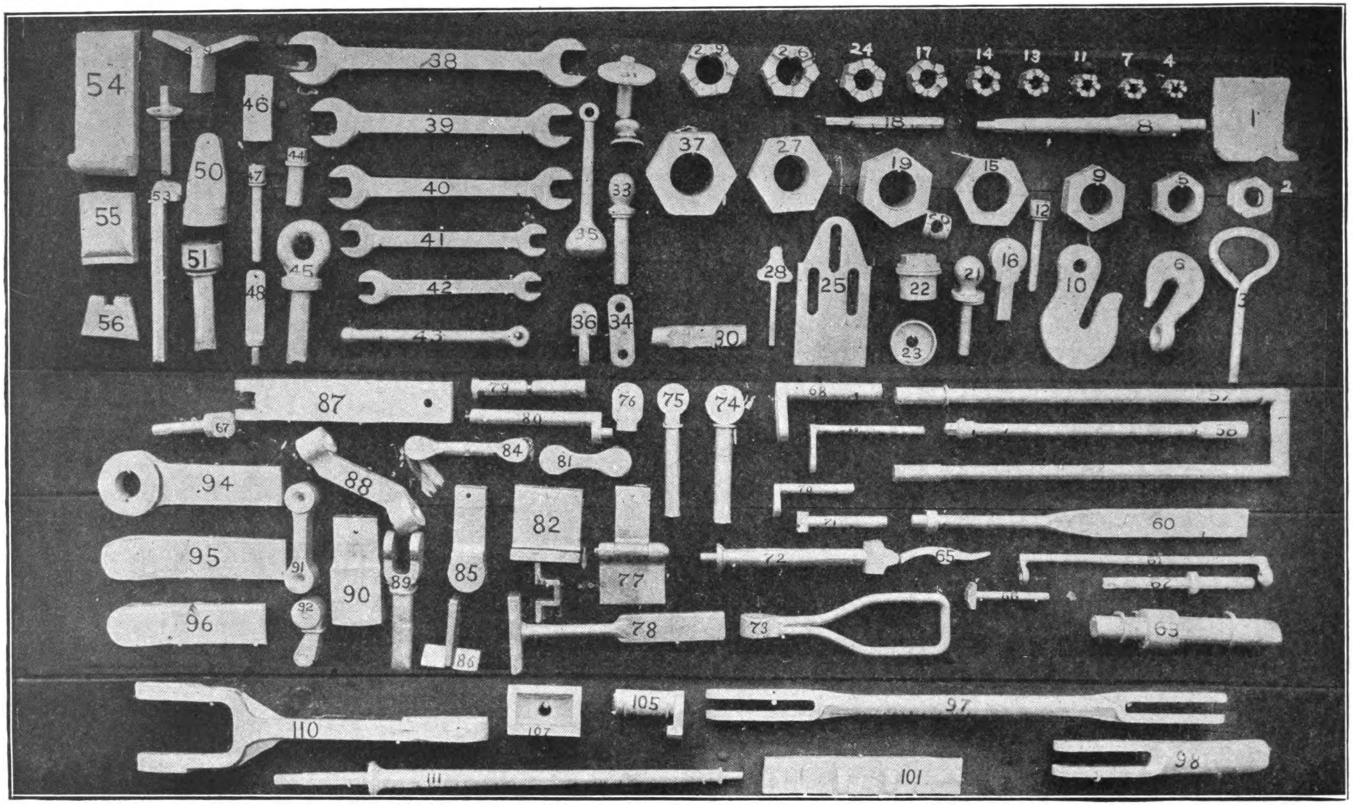


Fig 1. Examples of Forged Parts produced in the Collinwood Shops of the L. S. & M. S. Railway on Ajax Forging Machines

brought out by the following instance: In 1842, when the industry was beginning to be generally known, it is stated that a Mr. Clark, who at that time owned a bolt and nut factory in New England, and had devised a special machine for use in this manufacture, had his forging machine located in a room separated from the furnaces by a thick wall. A hole was cut through this wall, and the man who operated the machine received the heated bars from the furnace through the small hole in the wall. The only person who ever got a glimpse of the machine was the operator. The forge man was not permitted to enter the room.

Machine forging, as we know it today, is of wide application, embracing a large number of machines and processes that apply, in a measure, to almost any manufacturing plant. Machine parts hitherto made from castings are now made much more economically by the use of the drop-hammer or forging machine, and give much more satisfactory service.

Types of Machines. Upsetting and heading machines are divided into two general classes; namely, stop-motion and continuous-motion headers. The stop-motion headers have the greatest range, and are primarily used for heading bolts and for all kinds of upset forgings. The continuous-motion headers are used only for heading rivets, carriage bolts and short lengths of hexagon- and square-head machine bolts; they produce these parts at a much faster rate than is possible with a stop-motion header, but their range of work is limited. The universal practice is to shear the bars cold when working a stop-motion header, and only in special cases, when the shank at the headed piece is very short, is the side shear used.

Rivets, etc., forged in the continuous-motion header, are made by the process known as "off the bar;" that is, a bar is heated for a distance of approximately four feet, and is then pushed into the machine where the moving die acts as a shear and cuts off the blank. The latter is immediately gripped against the stationary die, whereupon it is headed and ejected. This whole cycle of movements is accomplished in one revolution of the flywheel.

Operation of Plain Bolt and Rivet Machines. Briefly stated, a plain bolt and rivet machine comprises two gripping dies, one movable and the other stationary, and a ram which carries the heading tool. The heated bar is placed in the impression in the stationary gripping die, and against the gage stop; the machine is then operated by pressing down the foot treadle shown in front of the

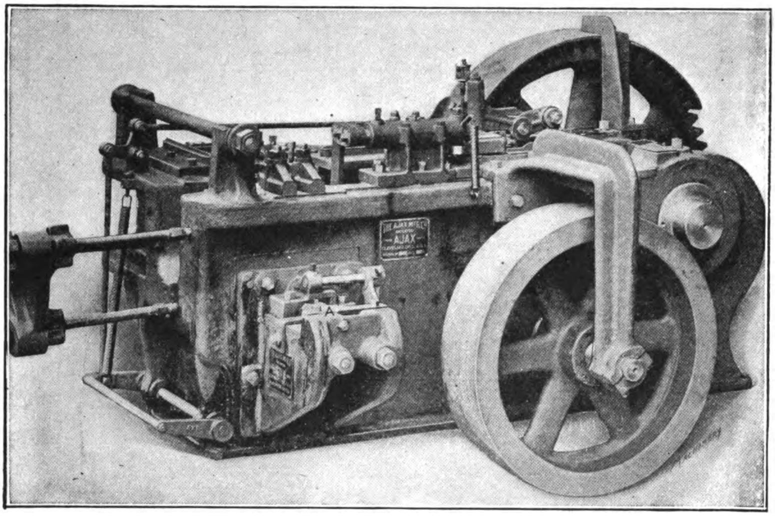


Fig. 2. Ajax Bolt Heading Machine suitable for all Types of Machine Bolts and Upset Forgings

machine in Fig. 2. As already mentioned, the stock is generally cut to the desired length before heading on this type of machine, especially when it is long enough to be conveniently gripped with the tongs; but it can be headed first and afterward cut off to the desired length in the side shear. It is also possible, in some makes of machines, to insert a cutting tool to cut off the blank before heading, when the work is not greater in length than the capacity of the machine.

There are several methods used in making bolts and rivets in a regular forging machine. In Fig. 3 is shown a diagrammatical view of a set of forging dies which have a wide range of application. In this type of dies the head on the bolt is formed by rotating the bar between the grip-

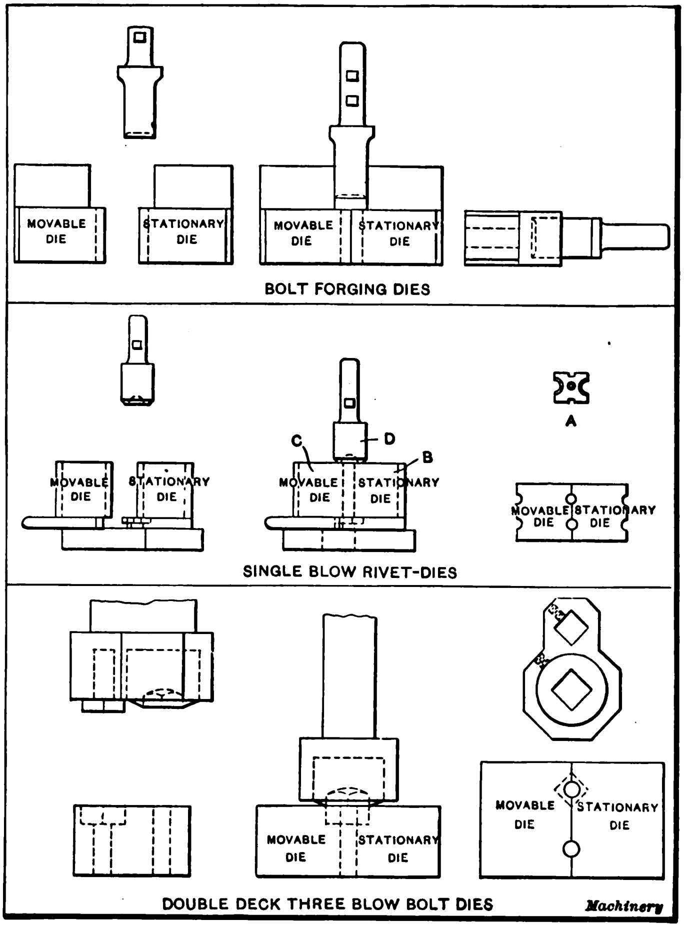


Fig. 3. Plain Bolt Forging Dies of Universal Application. Fig. 4. Single-blow Rivet Dies. Fig. 5. Double-Deck Three-blow Dies

ping dies after each blow of the plunger. For a square-headed bolt, the bar is turned twice through a space of 90 degrees, and is generally given two or more blows in each position. A hexagon-head bolt usually requires at least six blows to complete one bolt, and the shape of the head depends to a large extent on the skill of the operator. The wide range of work, however, which can be handled in dies of this type, makes them of almost universal application, especially in a railroad shop.

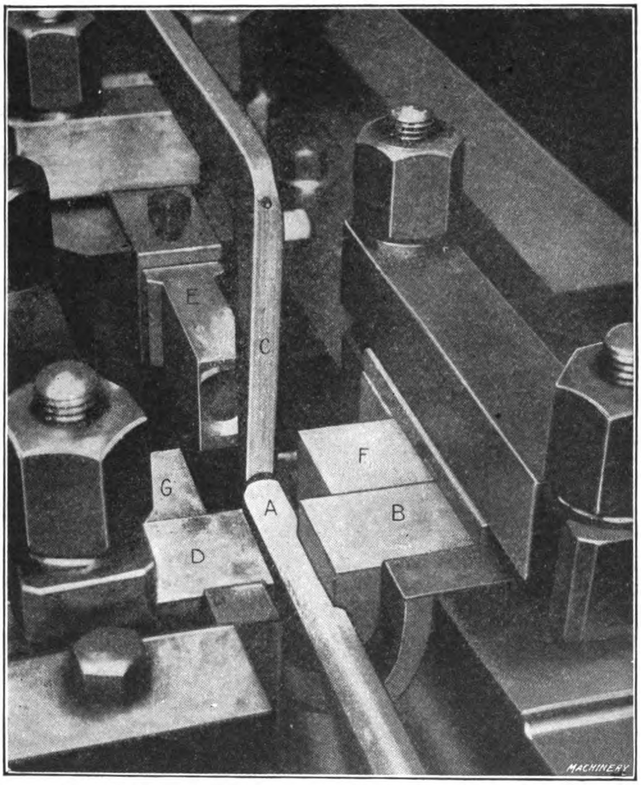


Fig. 6. First Step in the Production of Bolt Heads in Plain Forging Dies of the Type shown in Fig. 3

Fig. 4 shows a set of single-blow rivet dies which are used in a continuous-motion rivet header, and illustrates how these dies are operated in the making of a rivet in one blow. The heated stock is fed in and cut off to the exact length by a shear *A*; it is gripped between dies *B* and *C* while being cut off. Tool *D*, held in the ram of the machine, then advances, upsetting the head to the shape shown, whereupon the movable die backs out, allowing the formed rivet to drop out and the bar to be inserted to the stop, ready for the next piece. The type of bolt heading tool illustrated in Fig. 5 is known as a double-deck three-blow bolt die; its use and operation will be explained later.

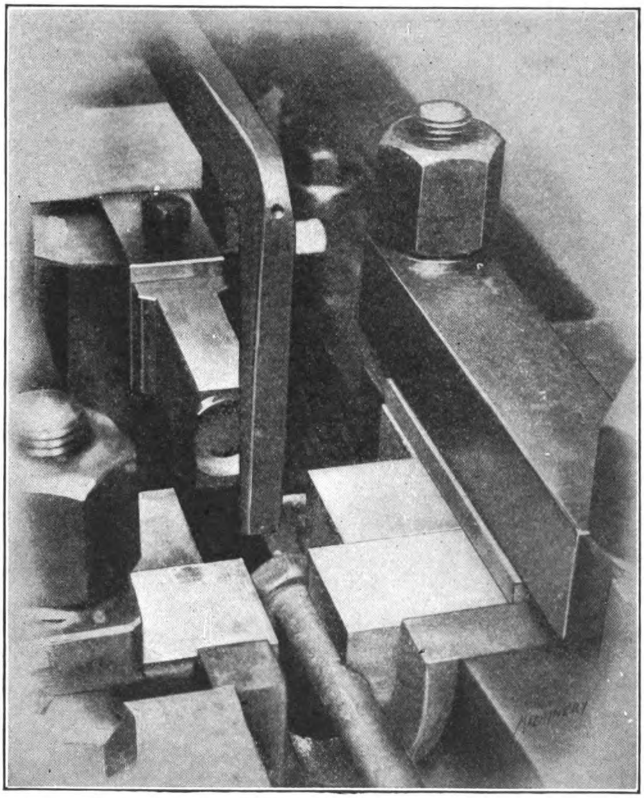


Fig. 7. Second Step in the Production of Bolt Heads

Successive Steps in Heading Bolts. Figs. 6, 7 and 8 show the successive steps followed in the forging of a hexagon-head bolt in the type of bolt forging dies illustrated in Fig. 3. Bar *A*, which is heated for a portion of its length, is placed in the impression in the stationary gripping die *B*, as shown in Fig. 6, and is gaged to length by the lifting stop *C*. The machine is then operated, and the movable die *D* closes in on the bar, gripping it rigidly. The stop now rises, and, as the ram of the machine advances, the plunger *E* upsets the end of the bolt, the blocks *F* and *G* forming a flat on each side of the upset end. The operator keeps his foot on the treadle, and as the movable die

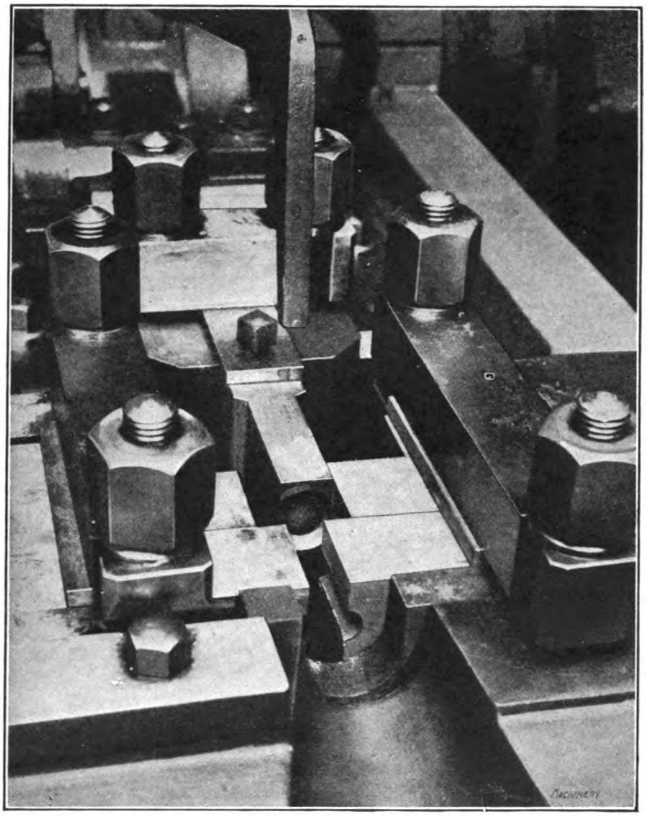


Fig. 8. Third Step in the Production of Bolt Heads

backs out, he rotates the rod one-sixth of a turn. This operation is repeated until the head has been correctly formed. The operator now removes his foot from the treadle, stopping the operation of the machine, when the dies remain in the open position, allowing him to remove the completed bolt as shown in Fig. 7. This view shows the stop down and the dies open ready for the rod to be inserted again, while Fig. 8 shows the dies open and the plunger on its return stroke.

Fig. 9 shows how the furnace and forging machine are arranged for making bolts and machine forgings in the Cleveland shop of the L. S. & M. S. Railway. The bars in this case are long enough to be gripped with the tongs, and are therefore cut off to the desired length in a power shear before heading. From the power shear the bars

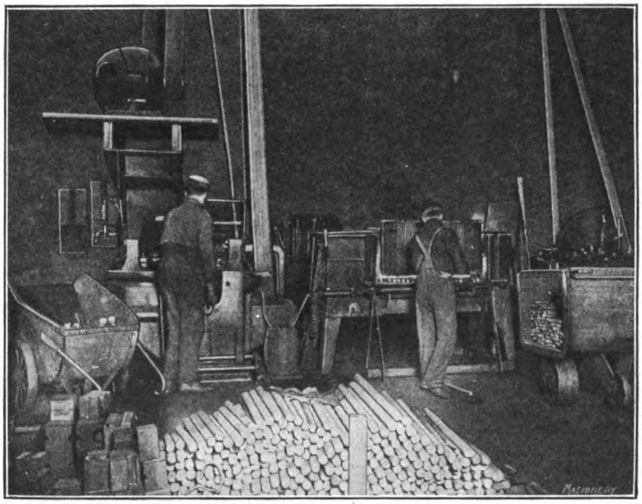


Fig. 9. Heading Bolts in a 2-inch Ajax Forging Machine

are brought to the heating furnace, in the truck shown to the right in the illustration, where one end of the bars is heated to the desired temperature. This furnace is heated by oil and is placed as close to the forging machine as possible. The man who attends to the heating of the stock places the rods in a row, and as soon as the end to be headed reaches the proper temperature, he quickly removes the heated bar and passes it to the forging machine operator, who immediately places it between the dies, operates the machine, and forms the head. In this particular example the bolt is $1\frac{1}{4}$ inches in diameter by 12 inches long, and is formed in three blows in double-deck dies of the type illustrated in Fig. 11. The dies and heading tool are kept cold by means of a constant stream of water. As soon as the bolt is headed it is thrown in the truck to the left, which is used for conveying the bolts to the threading machines.

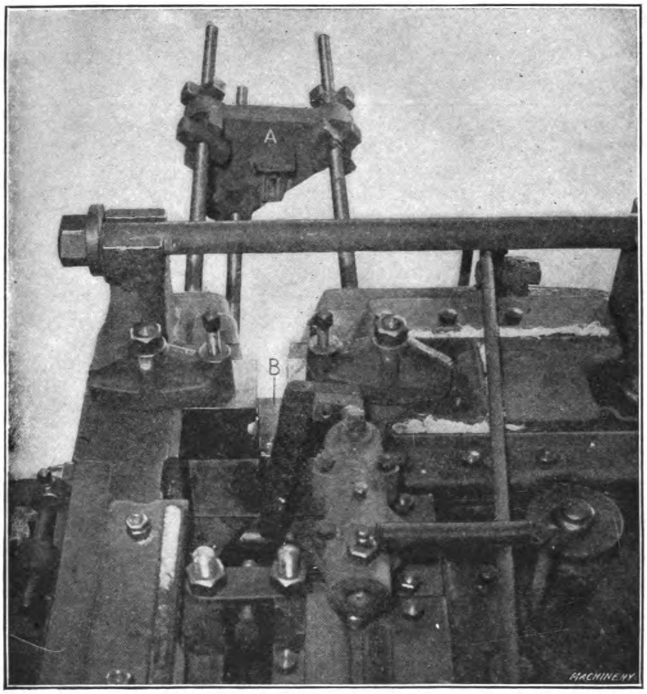


Fig. 10. View looking down into the Die Space of Bolt Forging Machine

Fig. 10 shows a view looking down into the die space of the Ajax bolt header, from which an idea of the relation between the working members can be obtained. The back stop *A* is used for locating the bar in the correct position. This stop is sometimes used instead of the swinging stop *B*. This view also shows how the gripping dies are held in the die space; a heel plate fastened to the frame of the machine and to the movable die-slide by studs and nuts, carries set-screws which bear down on the die blocks, holding them tightly in the die space.

Types of Bolt Header Dies. Fig. 11 shows a type of bolt heading dies known as double-deck three-blow bolt dies, which are used for finishing hexagon-head bolts. The two gripping dies *A* and *B*, as a rule, are made from blocks of tire steel; each gripping die is made from three pieces to facilitate machining. The lower header punch *C* is cupped out to form a hexagon, and is held in the heading tool-holder which is attached to the ram of the machine. The upper punch *D* is held in the same manner as the lower

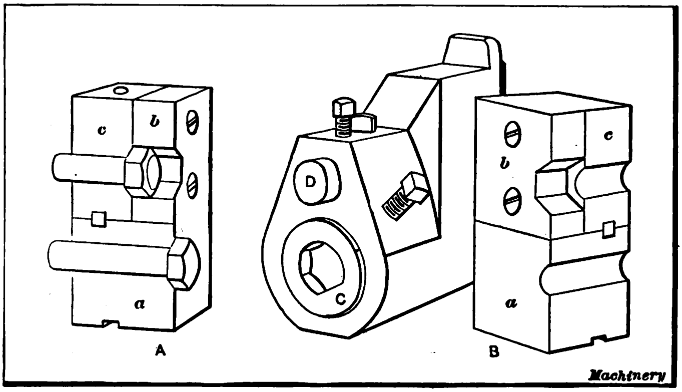


Fig. 11. Type of Double-deck Dies used in producing Bolt Heads without Fins or Burrs in Three Blows

heading punch, and forces the bolt into the hexagon impression in the dies after it has been roughly formed in the lower impression. This type of die produces a bolt free from fins and burrs, and accurate as regards size and shape. The bolt is given one blow in the lower position and then raised to the upper die impression, where it is generally given two blows.

A combination set of double-deck gripping dies for making square- and hexagon-head bolts is shown in Fig. 12. The construction of these dies is similar to that of the dies shown in Fig. 11, with the exception that these dies can be used for making both square- and hexagon-head bolts.

The punches for forming the hexagon- and square-head bolts are shown at the right and left, respectively. A general idea of the class of work turned out in a bolt and rivet header may be obtained from Fig. 13.

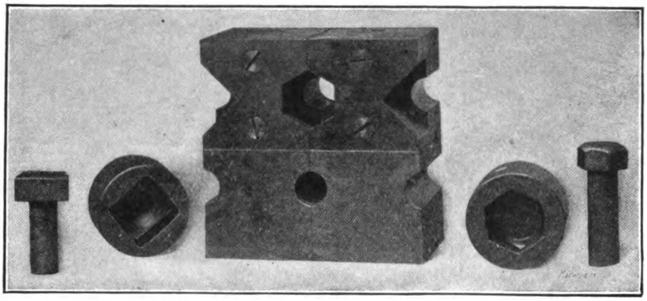


Fig 12. Combination Square and Hexagon Double-deck Bolt Dies

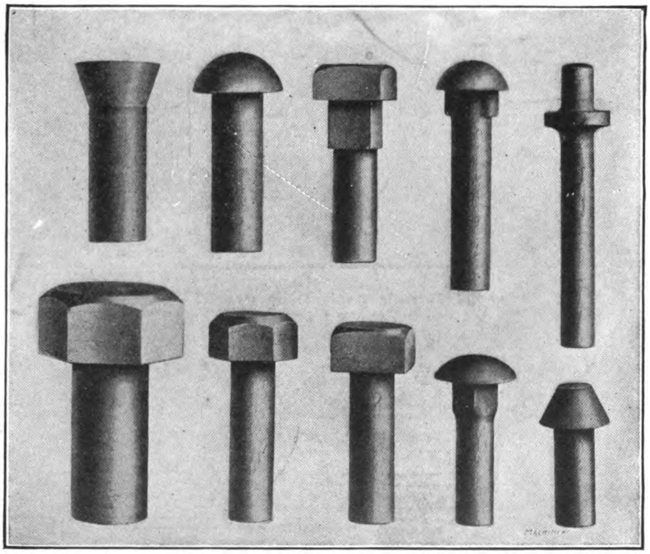


Fig. 13. Some Examples of Work turned out on National Wedge-grip Bolt and Rivet Header

Construction of National Wedge-grip Bolt and Rivet-Header. Fig. 14 shows a view of a two-inch National wedge-grip bolt and rivet header which is used for making bolts, rivets and miscellaneous forgings. There are a number of interesting features connected with this machine, one of which is the wedge-grip and automatic relief mechanism. In operating a bolt and rivet header it is necessary that the work be placed directly in the impression in the gripping dies and not between their opposing faces. Both of these dies must come tightly together, and are made to do so by the mechanism of the machine; therefore any foreign body preventing the correct movement

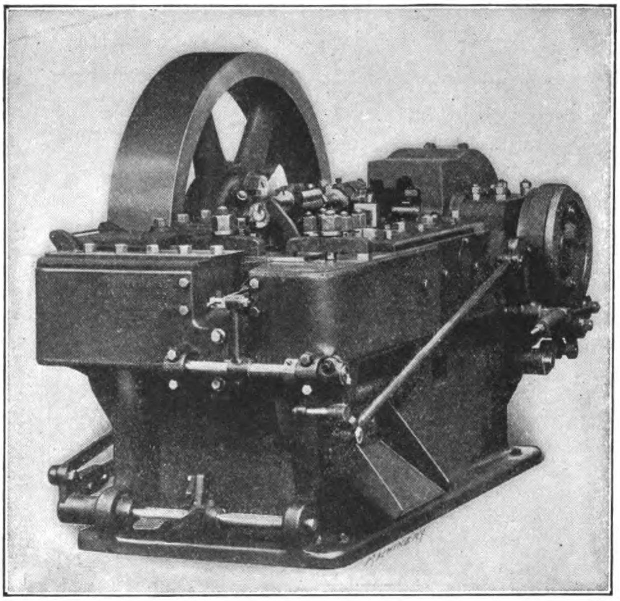


Fig. 14. Two-inch Wedge-grip Bolt and Rivet Header

of these dies would cause trouble by breaking the machine, if no special means to safeguard against this were provided. Various methods have been used, however, for obviating this difficulty, one of which is the application of a shearing pin in the movable gripping die slide, which, when the foreign body is placed between the dies, is sheared off without causing any damage to the machine. Another method, which is a special feature of the National wedge-grip header, is a spring relief, which throws the

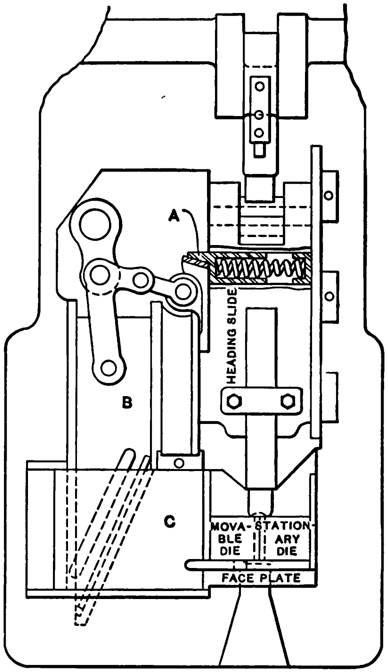


Fig. 15

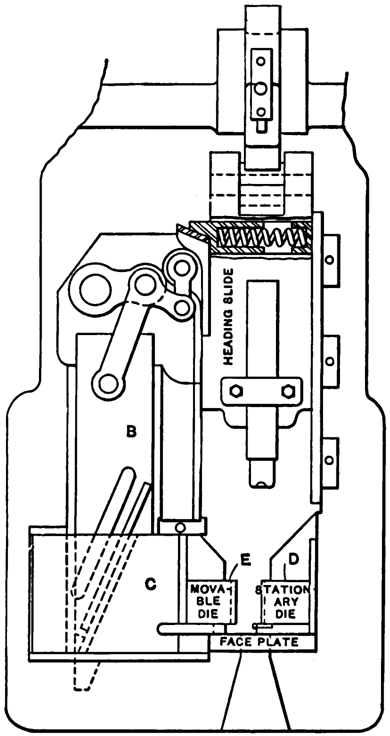


Fig. 16

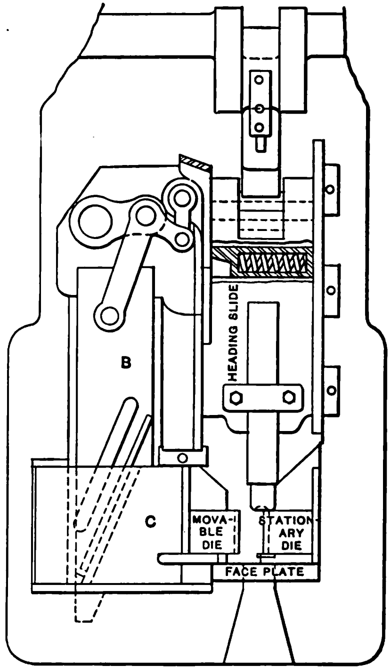


Fig. 17

Machinery

Figs. 15, 16 and 17. Diagrams Illustrating Construction and Operation of Wedge-grip Bolt and Rivet Headers

entire gripping mechanism out of action should the stock or any foreign body be caught accidentally between the dies and prevent them from closing. The action of this relief is indicated in Figs. 15 to 17. In Fig. 15 the gripping dies are shown closed and the relief mechanism does not operate. In Fig. 16, the gripping dies are shown open and the ram is at its extreme backward stroke, while in Fig. 17 the dies are open, but with the ram at the forward end of the stroke. The latter view shows what happens when a foreign body is caught between the gripping dies and prevents them from closing.

The relief mechanism consists of a spring plunger *A*, the front end of which is beveled, and which is kept in the "out" position by a coiled spring. This plunger, as indicated in Fig. 16, presses against an angular projection on the movable gripping slide. Now when a foreign body comes between the gripping dies and prevents them from closing, this spring plunger is forced back and the toggle joint operating the wedge-gripping slide remains stationary; this allows the dies to remain open, although the ram completes its full forward travel. This relief will operate up to the time the dies are closed, but when the dies are closed, the gripping pressure is positive.

An important feature of this machine is the wedge-grip for the movable slide. This consists of a slide *B* to which the toggle lever is attached, and which is moved back and forth by the latter through the movement of the crankshaft. The forward end of slide *B* is beveled and forms a solid metal backing when the gripping slide *C* is in the forward or gripping position—when the dies are closed. This means of locking the movable die during the heading operation prevents any rocking or wobbling of the slide and causes an even pressure to be exerted over the entire working surface of the dies. The stationary die *D* and movable die *E* are set so that their working faces merely touch, and the rigidity of the grip prevents any spring, so that the work can be produced without fins and burrs. By not having to set the dies ahead, the pounding or battering and premature wearing out of the dies is prevented. Fig. 18 shows more clearly how the movable and stationary dies are retained in the die space, and how they are backed up by steel liners. From an inspection of this illustration it will be seen that with this sliding wedge mechanism it is practically impossible for the dies to give or spring when in operation on the work.

Hammer Type of Bolt Header. In the type of bolt and rivet making machines so far described, the head is formed

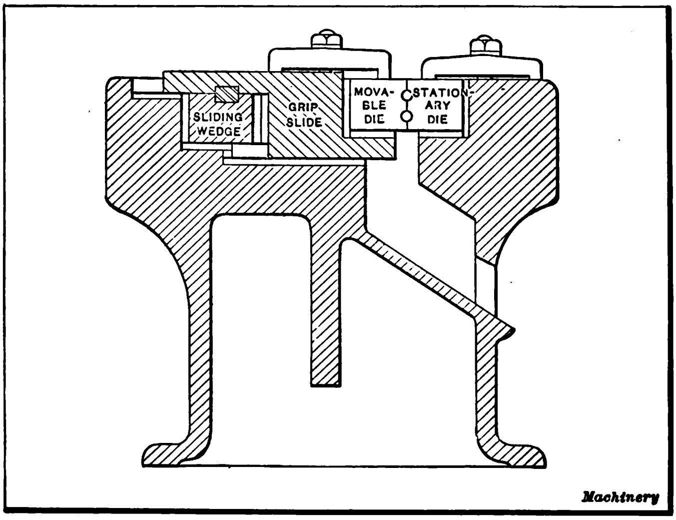


Fig. 18. Section through Die Box of the Wedge-grip Bolt and Rivet Header

by hitting the heated bar on the end and forcing it into suitably shaped impressions in the gripping dies. In the following, attention will be given to a type of bolt heading machine in which the end of the bar is first upset and the head then formed to the desired shape by the combined action of the upsetting punch and hammer dies operating from all four sides.

In the hammer type of bolt header, made by the National Machinery Co., Tiffin, Ohio, which is shown in Figs. 19, 20 and 21, the head of the bolt is formed by an end-

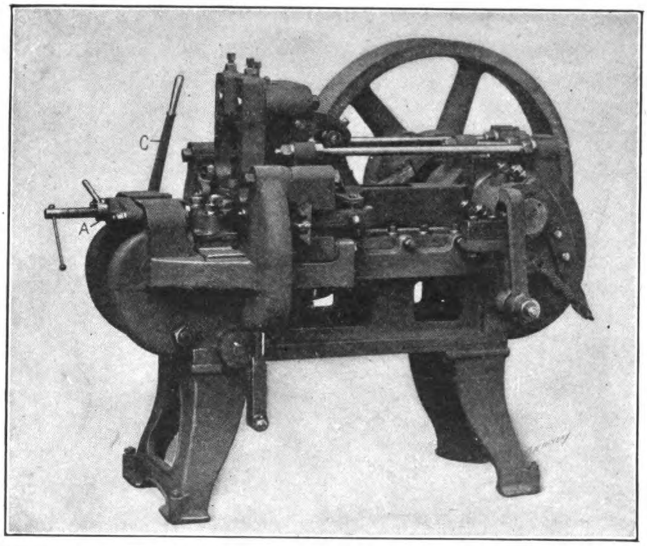


Fig. 19. Type of Hammer Header

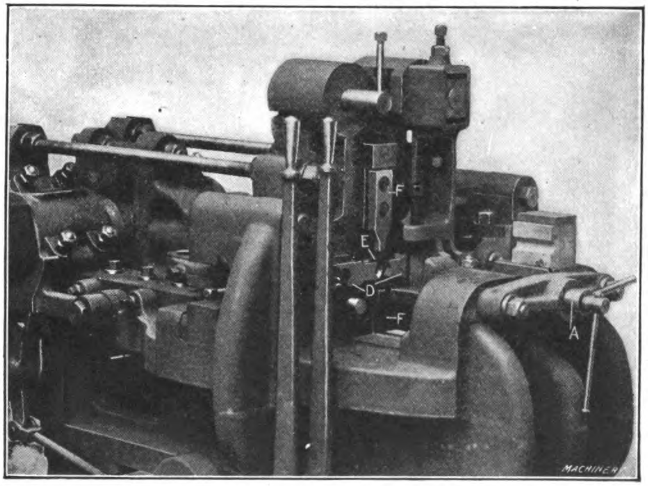


Fig. 20. View of Hammer Header showing Both Gripping Dies removed, and One Die Hanger

working upsetting punch and four hammers operated from all four sides at right angles to the axis of the bolt. In operation, the heated blank, which has previously been cut to length, is placed in a seat (when the bolt is long enough to be thus accommodated) and between the gripping dies, being located lengthwise by the adjustable stop *A*. Then by a movement of the hand-lever *C*, the dies (one of which

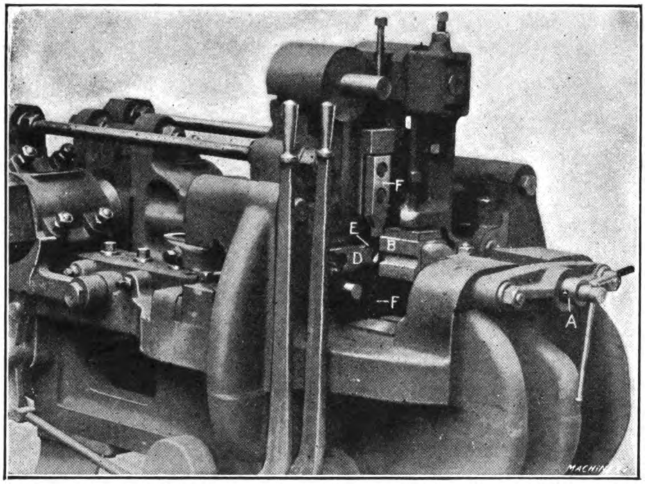


Fig. 21. View of Hammer Header showing Left-hand Die Hanger removed, and One Gripping Die in Place

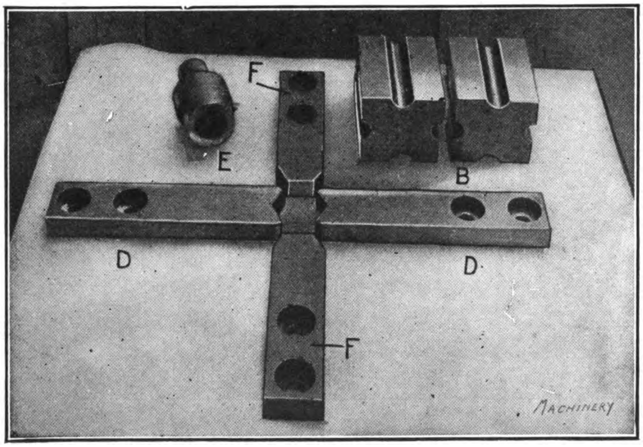


Fig. 22. Type of Dies, Hammers and Heading Tool used in the Hammer Type of Bolt Header shown in Fig. 19

is shown at *B* in Fig. 21) are closed and the machine is started. The stock is not moved during the forging operation, but is kept up against the adjustable stop, and the gripping dies are not opened until the head is completely formed. From three to five blows are struck, depending upon the size of the bolt and the finish desired, whereupon the machine is stopped and the dies are opened by operating the hand-lever, allowing the finished work to drop from the machine. The side-forming hammers *D*, Fig. 20, give two blows to every blow struck by the heading tool *E* and the vertical hammers *F*.

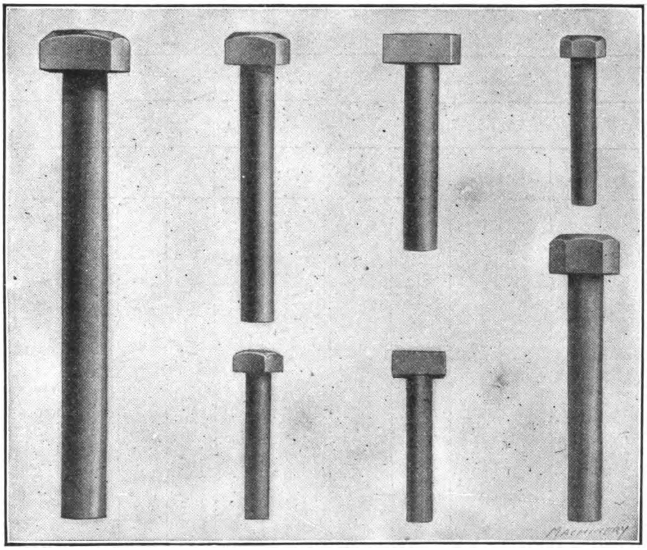
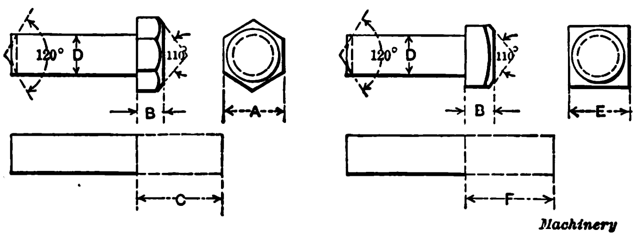


Fig. 23. Some Examples of Work produced in National Hammer Headers

The 1½-inch size of this type of hammer header is provided with two hand controlling levers, as shown in Figs. 20 and 21. One of these levers operates the arms carrying the gripping dies, and the other operates the clutch for starting and stopping the machine. On the smaller sizes of machines, one lever controls both of these movements. Fig. 20 shows one of these hammer headers with the gripping dies and the left-hand gripping die hanger removed; this view also shows clearly the upsetting punch and the four forming hammers. Fig. 21 shows the same machine with one of the gripping dies in place, but with

Proportions of U. S. Standard and Manufacturer's Standard Hexagon and Square Head Bolts and Approximate Amount of Stock Required to Form Head



United States Standard						Manufacturers' Standard					
Dimensions in Inches						Dimensions in Inches					
D	A	B	C	E	F	D	A	B	C	E	F
1/4	1/2	1/4	1 3/32	1/2	1 9/32	1/4	7/16	3/16	23/32	3/8	17/32
5/16	19/32	19/64	1 3/16	19/32	1 3/8	5/16	17/32	1/4	3/4	15/32	11/16
3/8	11/16	11/32	1 1/4	11/16	1 1/2	3/8	5/8	9/32	15/16	9/16	13/16
7/16	25/32	25/64	1 3/8	25/32	1 5/8	7/16	23/32	21/64	1	21/32	31/32
1/2	7/8	7/16	1 1/2	7/8	1 23/32	1/2	13/16	3/8	1 3/32	3/4	1 1/16
9/16	31/32	31/64	1 5/8	31/32	1 13/16	9/16	29/32	27/64	1 1/4	27/32	1 7/32
5/8	1 1/16	17/32	1 11/16	1 1/16	2	5/8	1	17/32	1 13/32	15/16	1 11/32
3/4	1 1/4	5/8	1 15/16	1 1/4	2 7/32	3/4	1 3/16	9/16	1 9/16	1 1/8	1 5/8
7/8	1 7/16	23/32	2 5/32	1 7/16	2 1/2	7/8	1 3/8	21/32	1 7/8	1 5/16	1 7/8
1	1 5/8	13/16	2 3/8	1 5/8	2 3/4	1	1 9/16	3/4	2 1/32	1 1/2	2 5/32
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2 1/2	3 7/8	1 15/16	5 3/16	3 7/8	5 15/16	2 1/2	3 13/16	1 7/8	4 13/16	3 3/4	5 3/8
2 3/4	4 1/4	2 1/8	5 1/2	4 1/4	6 7/16	2 3/4	4 3/16	2 1/16	5 3/8	4 1/8	5 29/32
3	4 5/8	2 5/16	6 1/16	4 5/8	7	3	4 9/16	2 1/4	5 11/16	4 1/2	6 7/16
3 1/4	5	2 1/2	6 1/2	5	7 9/16	..	..	..	..	..	..
3 1/2	5 3/8	2 11/16	7	5 3/8	8 1/8	..	..	..	..	..	..
3 3/4	5 3/4	2 7/8	7 1/2	5 3/4	8 11/16	..	..	..	..	..	..
4	6 1/8	3 1/16	8	6 1/8	9 5/16	..	..	..	..	..	..

the left-hand gripping die hanger removed. The tools used in this machine are more clearly illustrated in Fig. 22; the various members are denoted with the same reference letters as used in connection with the description of the machine. For making a square-headed bolt, the side-working hammers, of course, are of the same shape as the vertical hammers.

The type of hammer header illustrated in Figs. 19, 20 and 21 is limited in its scope to the production of square, hexagon and tee-headed bolts as shown in Fig. 23. These, however, can be produced in large quantities at a low cost, and what is more important, the product is entirely free from fins and burrs, and is shaped as accurately as is possible by the forging method. The fact, however, that it takes longer to change the dies from one size to another in this type of machine is a point against its installation in preference to the other types of bolt headers, where frequent changes in the sizes of dies are necessary.

Stock Required for Bolt Heads. In forming a head on a bolt or rivet, the heated metal on the end of the bar is upset or formed into the desired shape by a plunger held in the ram of the forging machine. To produce the head requires considerably more metal than the thickness of the head—because of the increase in diameter—and hence it is necessary to allow a certain amount of excess stock to form the head. The accompanying table gives proportions of U. S. standard and Manufacturers' standard hexagon and square bolt heads, and also the approximate amount of stock required to form the head—this information being listed in Columns "C" and "F." The excess amount of stock given is not exact, but is close enough for starting the machine, as the stop can afterward be adjusted to suit.

CHAPTER II

CONTINUOUS-MOTION BOLT AND RIVET HEADERS

CONTINUOUS-MOTION bolt and rivet headers are made in two types, one being hand-fed and the other provided with an automatic roll feed. A machine of the hand-fed type, built by the National Machinery Co., is shown in Fig. 1. In operating this type of machine, the bar, which has been heated for a length of four or five feet, is fed through a shear in the faceplate block of the machine, and as the movable gripping die closes on the bar, a blank of the required length is cut off and held rigidly in the gripping dies. The head is then formed by the forward movement of the ram which carries the heading tool. After heading, the ram of the machine recedes, the gripping dies open, and a kicker, actuated by a connecting-rod C from a cam on the main shaft, ejects the finished work from the dies, depositing it, through a chute, into a box. As the dies open, the operator again pushes in the heated bar until it strikes the stop, and as the movable die advances, another blank is cut off and headed as before. The machine runs continuously until the heated portion of the bar has been exhausted, when the operator takes a newly heated bar from the furnace and proceeds as before.

A bolt or rivet made in a machine of this type receives only one blow, and, therefore, for work within the capacity of this machine, the production is greatly increased over that obtained from the plain type of forging machine. One of the chief requisites in a machine of the continuous-motion type is that of securing a rigid grip on the work while the head is being formed. If the grip is not satisfactory, that is, if the dies separate, it causes the shank of the bolt or rivet to become tapered or out of round, and also re-

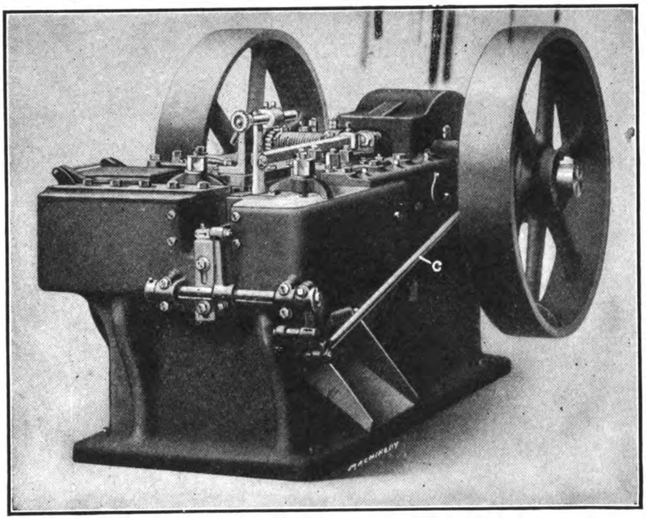


Fig. 1. Continuous-motion Wedge-grip Bolt and Rivet Header

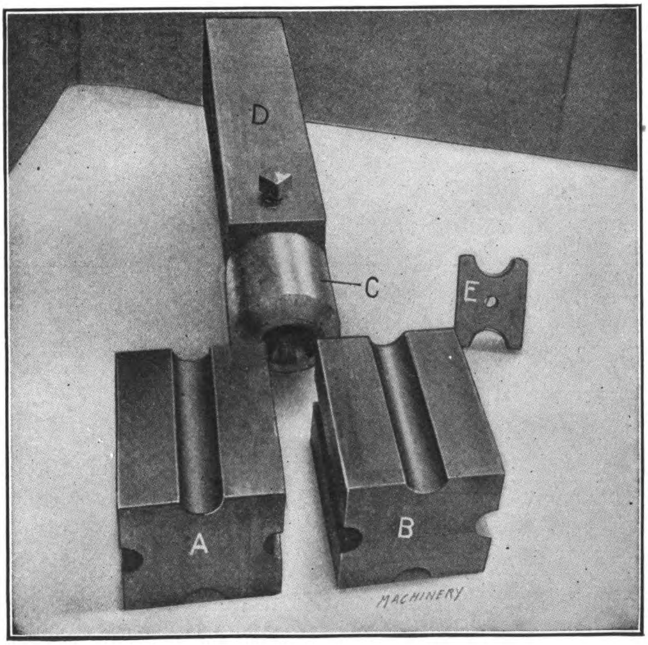


Fig. 2. Type of Dies and Tools used in the Continuous-motion Bolt and Rivet Header shown in Fig. 1

sults in fins being produced on the shank and under the head. Furthermore, unless the machine is provided with suitable slides which can be kept in proper alignment, it is difficult to secure work on which the heads are centrally located with the shanks, and also to keep the shear and movable die in correct working relation.

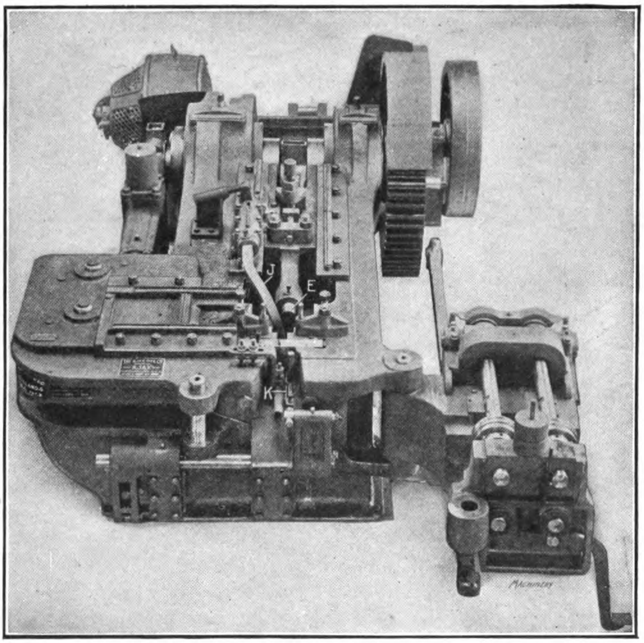


Fig. 3. Continuous-motion Bolt and Rivet Header equipped with Roll Feed Attachment

The type of tools used in the bolt and rivet machine of the continuous-motion type is illustrated in Fig. 2. The two gripping dies A and B are held in the die space of the machine by heel clamps as shown in Fig. 1. The gripping dies are provided with four interchangeable grooves, so that when one groove wears out, it is only necessary to turn the blocks. The heading punch C, which is held in the holder D in the ram of the machine, is cupped out to suit the shape of the bolt or rivet head, and is so arranged that it will be in perfect alignment with the gripping dies.

The shearing blade *E* is held in the faceplate block, and is used in cutting off the stock to the desired length. The length of the gripping dies is governed by the length of the bolt required; they are made shorter than the blank from which the bolt is made, thus allowing for sufficient extra stock to form the head.

Continuous-motion Bolt and Rivet Header with Automatic Feed. Fig. 3 shows a continuous-motion bolt and rivet header, built by the Ajax Mfg. Co., Cleveland, which is furnished with a roll feed attachment, consisting of four rollers provided with suitably shaped grooves in their peripheries. This view shows the roller feed attachment

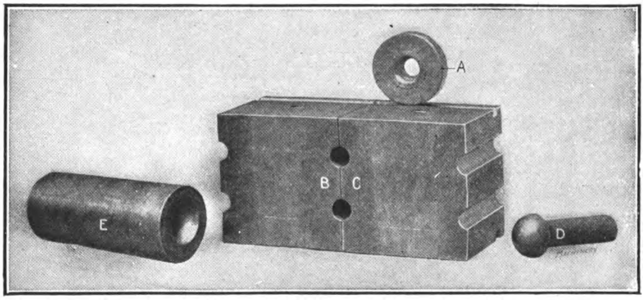


Fig. 4. Type of Dies and Tools used in Bolt and Rivet Making Machine shown in Fig. 3

swung back out of the way in order to exhibit the dies and tools. This machine is similar to the one shown in Fig. 1, with the exception of the roll feed attachment for handling the bars automatically. The tools used are shown in Fig. 4, together with an example of work produced in them. The shearing die *A*, in this case, is steel bushed and is circular instead of oblong in shape. The gripping dies *B* and *C* are provided with four grooves each, as previously described, but to change the blocks for presenting a new groove, they are turned end for end, there being no grooves in the top faces. *D* is a ¾- by 4-inch track bolt; *E* is the heading tool that is held in the ram of the machine.

A close view looking down into the die space of the machine shown in Fig. 3 is illustrated in Fig. 5. This view shows the relative positions of the feed rolls, shearing die, gripping dies, etc. The heated bar is fed by the rolls *F* through the guide pipe *G* held by bracket *H*, and through the shearing bushing *A*. This bushing is retained in the faceplate *I* which is held in grooves in the machine bed. The bar is fed directly through the cut-off bushing *A* and is gaged to length by the swinging stop *J* (see also Fig. 3). The movable die *C* then advances, cuts off the blank and carries it into the groove in the stationary die *B*, gripping

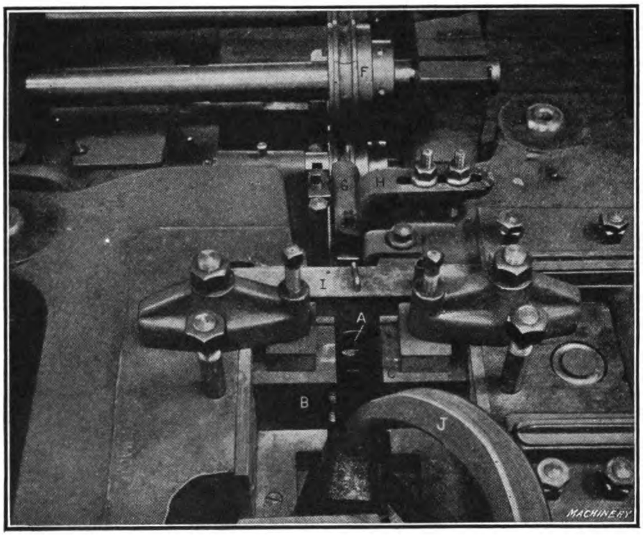


Fig. 5. View looking down into Die Space of a Continuous-motion Bolt and Rivet Header

it while the heading tool (*E*, Fig. 3) advances and upsets the end of the bar, forming the head. The stationary and movable gripping dies are held in place by straps, and are located by tongues fitting in grooves in their lower faces. The length of feed is governed by the travel transmitted to the rolls by the feed mechanism, which receives power from the main crankshaft through a connecting-rod, ratchet, pawl, gears, etc., and is adjustable at the operator's will.

The various steps in the production of a round-head rivet by the continuous-motion single-blow bolt and rivet

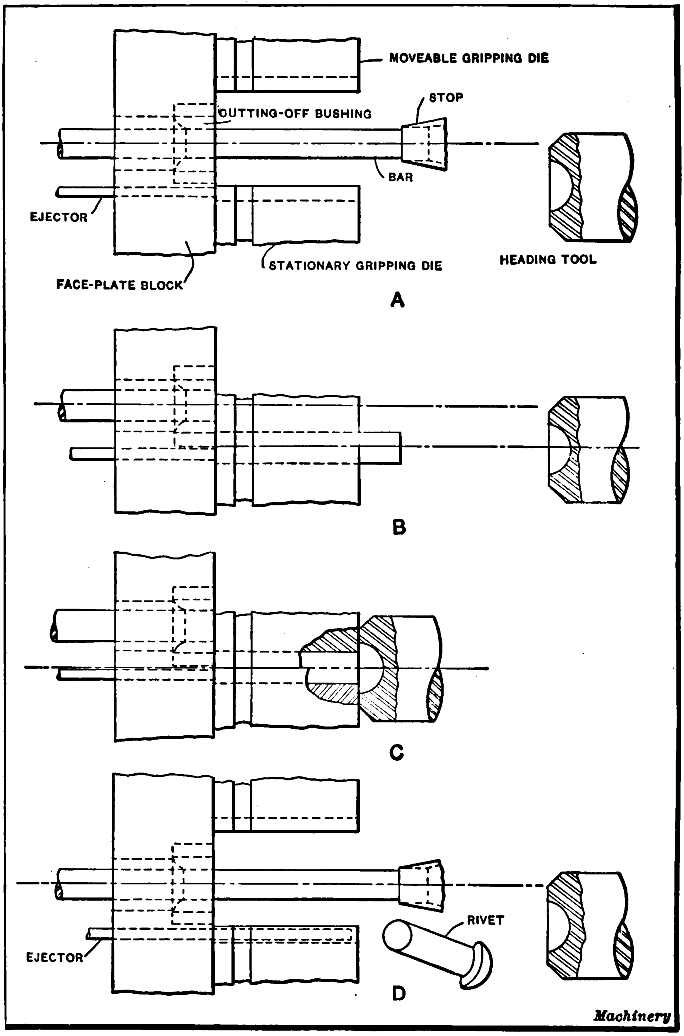


Fig. 6. Successive Steps in the Formation of a Round-head Rivet in a Single-blow Rivet Machine of the Continuous-motion Type

machine, are clearly illustrated in the diagram, Fig. 6. At *A*, the feed rolls have operated and have fed the heated bar out against the gage stop; at *B*, the movable die has advanced, sheared off the end of the bar (projecting through the shearing bushing), and carried the blank into the groove in the stationary die. When the blank is held rigidly, or in other words, when the movable die has reached the end of its forward movement, the heading tool advances, as shown at *C*, and upsets the end of the bar, forming the head. At *D*, the movable die and heading tool have retreated, the ejector pin (see *K*, Fig. 3) has advanced, pushing out the completed rivet, and the bar has been fed out again ready for a repetition of the operations.

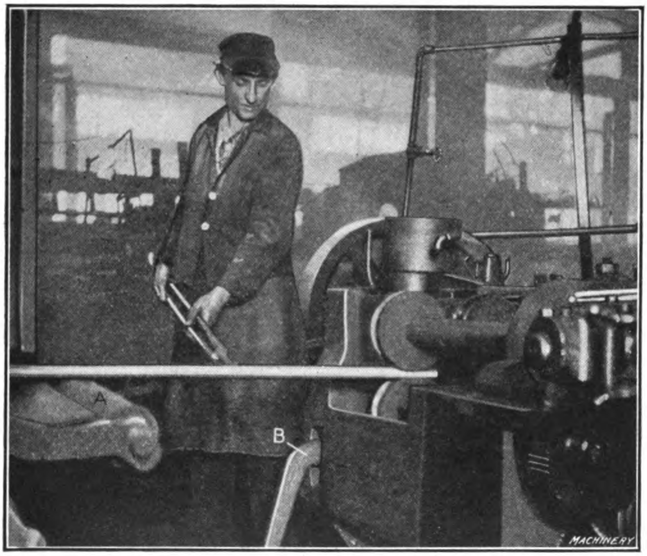


Fig. 7. Continuous-motion Bolt and Rivet Machine in Action making 1 ½-inch Rivets

Some idea of the methods pursued in the making of bolts and rivets by the continuous-motion machine process can be obtained from Fig. 7, which shows an operator attending to one of these automatic machines. The furnace in which the bar is heated (in the condition in which it comes from the mill) is located anywhere from 3½ to 4 feet from the feed rolls of the machine, and is provided in front with a roller *A*, over which the heated bar passes. The heating furnace, as a rule, is 30 feet long, so that the entire length of a bar can be accommodated.

As soon as the bar in the furnace has reached the proper temperature, the operator grips it with a pair of tongs, as indicated in Fig. 7, draws it out, and places it between the feed rolls. Then he presses down the foot-lever *B*, thus starting the machine. The heated bar is then drawn in by the rolls, fed through the cutting-off die, gripped in the gripping dies, headed and ejected at the rapid rate of forty to seventy pieces per minute.

In the manufacture of rivets, as a rule, steel containing from 0.10 to 0.12 per cent carbon is more frequently used than wrought iron, although the latter material is used in considerable quantities in some manufacturing establishments. Wrought iron for making rivets is heated to almost a white heat, but steel which contains from 0.10 to 0.12 per cent carbon is heated to only about 1400 degrees F.—a bright red color. When the head of a rivet is so shaped that it is necessary to carry the stock down far into the heading tool, the temperature to which the bar is heated must be increased, in order to make the metal flow more readily and prevent buckling.

In making rivets with long tapered heads, the operator generally finds it necessary to change the length of feed, so that a rivet having a full head without flash is formed. The reason for this is that the bars sometimes vary in size and temperature, which makes this adjustment necessary. A National continuous-motion bolt and rivet making machine is provided with means for taking care of the fluctuations in size and temperature of stock. In this machine the position of the stop is controlled by a handwheel within convenient reach of the operator, which he adjusts either way, depending upon the size of the bar, temperature of the metal, the shape of the part to be produced and the material from which it is made. When an over-size bar is encountered, the operator shortens the length of feed, as it is evident that too much stock would otherwise be supplied. When the bar is under-size, the reverse is the case. Again, when the bar is too hot, it is upset more on the end by the rolls forcing it against the stop, and of course more metal is provided than when the bar is not so hot, and consequently harder. The operator watches the pieces as they drop from the machine, and then adjusts the stop to keep the work as uniform as possible—having a full head and without flash. The feed rolls of this machine are made of chilled iron castings, and are kept cool by water jackets, insuring even temperature and minimum wear. They are operated from the main-shaft of the machine, through a

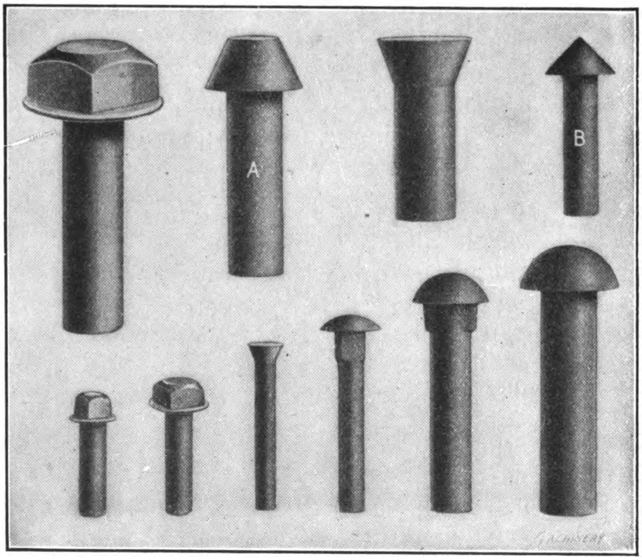


Fig. 8. Some Examples of Work which come within the Range of the Continuous-motion Type of Bolt and Rivet Headers

ratchet feed, by a connecting-rod, which is adjustable for securing variations in the feeding time of the rolls. The movements of the machine are timed so as to allow the gripping dies to remain open a comparatively large part of the revolution, thereby allowing more time for the stock to be fed in and gaged, and the dies to be well flooded and cooled at the completion of each stroke.

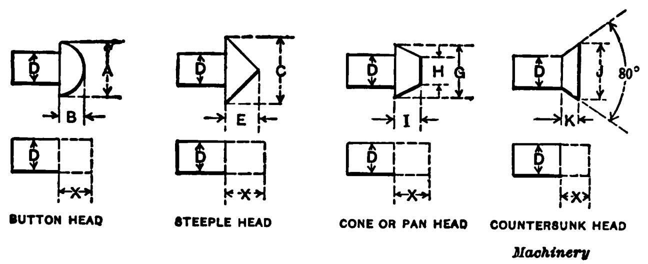
Examples of Continuous-motion Bolt and Rivet Work. Inasmuch as only one blow can be struck in a continuous-motion bolt and rivet making machine, it is impossible to produce parts which cannot be completed in one blow. Fig. 8 shows a representative group of bolts and rivets for which the continuous-motion machines are especially adapted. These machines will also handle a great variety of special work, such as square and hexagon head single-blow bolts, track bolts, etc. The cone-shaped rivets *A* and *B* illustrate the point mentioned in a previous paragraph regarding the difficulty encountered in producing work which is carried down far into the heading tool. These examples serve to illustrate the point.

Making Bolt and Rivet Dies. Bolt dies which are used in a forging machine are as a rule made from steel containing from 0.60 to 0.80 per cent carbon, and are hardened and drawn. The gripping dies are tempered hard, so that the sharp corners on the edges of the dies will not wear away rapidly. It is customary to harden these dies in either oil or water, and then draw the temper so that a file will just take hold. The heading tool, which is comparatively small in diameter, and is called upon to perform heavy duty, must be much tougher than the gripping dies. Ordinarily the heading tool is made from a tough steel containing from 0.40 to 0.50 per cent carbon, and is drawn considerably more than the gripping dies.

In making the impressions in the gripping dies for heading ordinary sizes of bolts, no allowance is made for the shrinkage of the metal. However, in drilling the hole in the dies which grip the stock when it is being headed, a liner is placed between the two halves of the die, so that when they come together on the stock, the latter will be securely held. For dies with a 1/4- to 5/8-inch hole, a liner 1/64 inch thick is placed between the opposing faces, when drilling the hole. For holes larger than 5/8 inch and up to 1 inch, a liner 1/32 inch thick is used; for holes from 1 inch up to 1 1/2 inches in diameter, a liner 3/64 inch thick is used; and from 1 1/2 inches up to and including 3 inches in diameter, a liner 1/16 inch is employed. The double-deck type of dies are made from six blocks of steel bolted and keyed together to facilitate machining.

In making bolt and rivet dies which are used in continuous-motion machines, it is customary when making rivets from ½ to 1 inch in diameter, to use bar stock which is rolled 1/64 inch under size. The dies referred to are shown in Figs. 2 and 4. The holes in the gripping dies are

Dimensions of Rivet Heads of Various Shapes



Dimensions in Inches

D	A	B	C	E	G	H	I	J	K
1/4	7/16	3/16	1/2	1/4	7/16	1/4	7/32	29/64	1/8
5/16	35/64	15/64	5/8	5/16	35/64	5/16	17/64	37/64	5/32
3/8	21/32	9/32	3/4	3/8	21/32	3/8	21/64	11/16	3/16
7/16	49/64	5/16	7/8	7/16	49/64	7/16	3/8	51/64	7/32
1/2	7/8	3/8	1	1/2	7/8	1/2	7/16	29/32	1/4
9/16	1	13/32	1 1/8	9/16	1	9/16	1/2	1 1/32	9/32
5/8	1 3/32	15/32	1 1/4	5/8	1 3/32	5/8	17/32	1 5/32	5/16
11/16	1 3/16	1/2	1 3/8	11/16	1 3/16	11/16	19/32	1 1/4	11/32
3/4	1 5/16	9/16	1 1/2	3/4	1 5/16	3/4	21/32	1 3/8	3/8
13/16	1 7/16	19/32	1 5/8	13/16	1 7/16	13/16	23/32	1 1/2	13/32
7/8	1 17/32	21/32	1 3/4	7/8	1 17/32	7/8	3/4	1 19/32	7/16
15/16	1 5/8	11/16	1 7/8	15/16	1 5/8	15/16	13/16	1 11/16	15/32
1	1 3/4	3/4	2	1	1 3/4	1	7/8	1 27/32	1/2
1 1/16	1 27/32	25/32	2 1/8	1 1/16	1 27/32	1 1/16	15/16	1 15/16	17/32
1 1/8	1 31/32	27/32	2 1/4	1 1/8	1 31/32	1 1/8	1	2 1/16	9/16
1 1/4	2 3/16	15/16	2 1/2	1 1/4	2 3/16	1 1/4	1 3/32	2 9/32	5/8
1 3/8	2 13/32	1 1/32	2 3/4	1 3/8	2 13/32	1 3/8	1 3/16	2 17/32	11/16
1 1/2	2 5/8	1 1/8	3	1 1/2	2 5/8	1 1/2	1 5/16	2 3/4	3/4

drilled to exact size (not 1/64 inch under size, which is the diameter of stock used), and the expansion of the iron in heating gives sufficient grip, as it is only necessary to prevent the rivets from being pulled out of the dies by the return stroke of the heading tool. The reason for this is that in the continuous-motion type of bolt and rivet machine, the work is supported on the sides by the gripping dies, and is backed up by the shear, so that it is practically held in a box while the head is being formed. The same grade of steel is used for making rivet tools as for making tools for producing bolts, and the heat-treatment is also carried on in a similar manner.

Stock Required for Rivet Heads. In making rivets in a continuous-motion rivet machine, the amount of excess stock (X, in the accompanying table) required is generally obtained by trial, but when definite shapes and proportions of rivet heads have been decided upon, the amount of excess stock required can be calculated approximately. The great difficulty in giving tables covering the amount of excess stock required is that no standard for rivet heads is universally followed, with the result that a slight difference in the curve or height of the head changes the amount of stock necessary. In addition to this, the scale of the furnace, depending upon whether gas, oil or coal is used for heating, so changes the amount of stock required that a special setting of the stop in different cases is required. This is one reason why up-to-date continuous-motion rivet making machines are provided with stops which can be adjusted while the machine is in motion. It is evident, therefore, that the exact amount of stock required is a question of some nicety, and it is surprising to what extent even the scaling off in the furnace will affect the stock required for the rivet head. What are considered in some shops standard shapes and sizes for rivet heads are given in the accompanying table.

CHAPTER III

NUT FORGING MACHINES

THE plain type of upsetting and forging machine which is used to a certain extent in the manufacture of bolts and rivets, especially the larger sizes, is also used for producing the ordinary square and hexagon nuts in sizes from 2 inches up. In making nuts by this process, the diameter of the round bar from which the nut is made should not exceed the root diameter of the thread in the finished nut, so it is evident that an extremely large upset is required to produce a full nut. When large nuts are produced in a plain forging machine, the usual method is first to form an upset on the end of the bar and then pierce the hole in the nut by punching the bar back, the metal removed to form the hole in the nut being attached to the bar. This operation requires considerable pressure, and as little, if any, material is wasted, it is a very successful method of producing nuts 2 inches and larger on a commercial basis. In the following, two types of machines, especially built to produce square and hexagon nuts, will be described. One of these machines is known as the hot-pressed center-feed nut machine, and the other as the hot-forged type; the latter is applicable only to the production of square nuts.

Hot-pressed Center-feed Nut Machine. The hot-pressed center-feed nut machine, as its name implies, produces nuts by pressing a heated blank of iron or steel into the required shape, the latter first being cut off as the bar is fed into the machine. The bar stock, which is rectangular in shape, is fed in from the side through a recess in the center of the machine and placed in front of the face of the dies. Fig. 1 shows an Ajax center-feed hot-pressed nut machine that works on the principle just stated. This machine consists

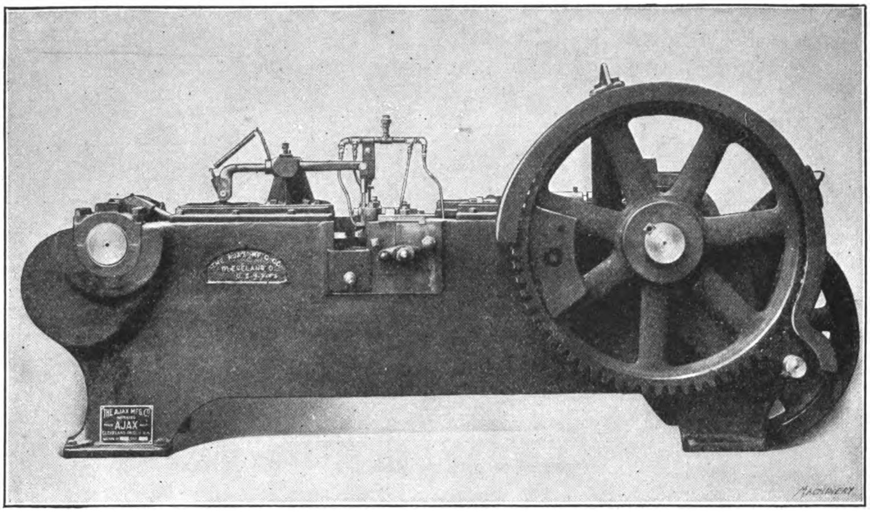


Fig. 1. Side View of Ajax Hot-pressed Center-feed Nut Machine showing Operating Side and Water Pipes for cooling Dies and Tools

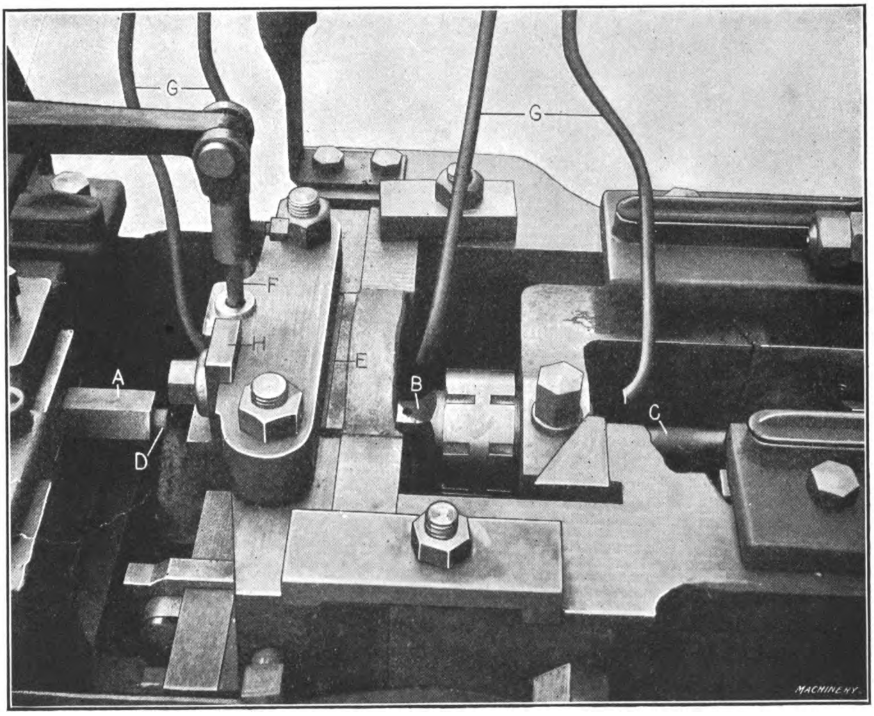


Fig. 2. Detail View of Machine shown in Fig. 1 showing Dies, Punching, Piercing, Crowning Tools, etc.

essentially of two movable rams or slides which carry the cutting-off, crowning, piercing and wad-extracting punches, respectively. One ram is operated directly from the main crankshaft, while the other is operated by eccentrics and a connecting-rod.

Fig. 2 shows a detail view of this machine, and gives some idea of the construction of the dies, tools, etc. Here

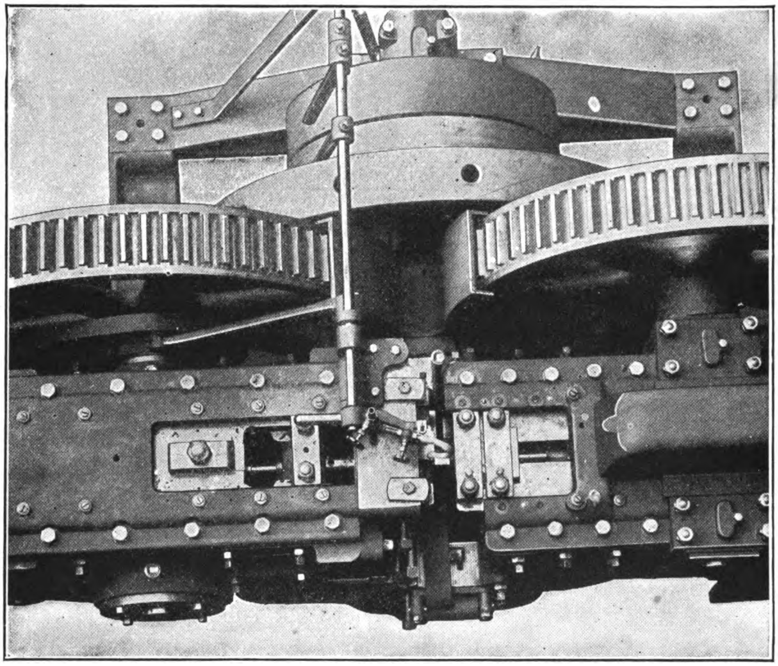


Fig. 3. Top View of another Type of Hot-pressed Center-feed Nut Making Machine

A is the cutting-off punch, *B* the crowning punch, *C* the piercing punch, *D* the wad extractor, *E* the nut dies and *F* the ejector. The pipes *G* furnish a copious supply of water to keep the dies and tools cool when in operation. A device for centering the bar in relation to the dies and tools is shown at *H*.

A National center-feed hot-pressed nut machine, which produces hexagon and square nuts in the same manner as that shown in Fig. 1 is shown in Fig. 3. In this machine, however, both rams or sildes are operated directly from the source of power by a pinion and two large gears, one gear driving each slide. The majority of manufacturers produce nuts from a material known as soft, mild, open-hearth steel, which has a comparatively fine grain, and conse-

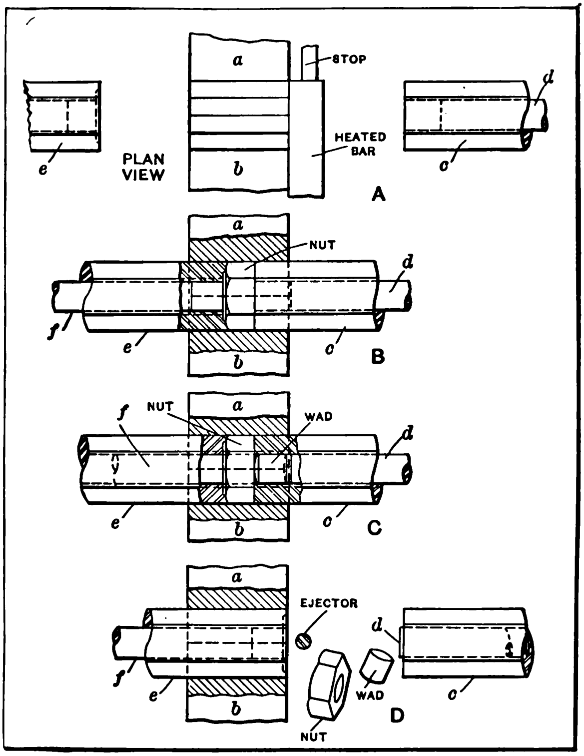


Fig. 4. Diagram of Sequence of Operations in making Nuts in a Hot-pressed Center-feed Nut Machine

quently, when forged, has less tendency to crack than does wrought iron. It can also be threaded more easily and with a smoother finish than wrought iron, owing to the fact that great difficulty is met with in working the latter material, because the grain opens up, thus making it difficult to thread. Wrought iron, however, has one point in its favor—it can be worked at a much higher temperature than steel without affecting its structure, and hence does not need to be handled quite so carefully.

Operation of a Center-feed Hot-pressed Nut Machine. In operating a center-feed hot-pressed nut machine, the rectangular bar is heated to the correct temperature for a length of four or five feet. It is then brought to the machine and fed in from the side in front of the face of the main dies, as indicated at *A* in Fig. 4. The cut-off tool *c* then moves up and shears the blank from the end of the bar, carries it into the main dies *a* and *b*, and presses it against the crowning tool *e*, which has also advanced, as indicated at *B*. The piercing tool *f* now advances, punches the hole in the nut, and carries the wad into the cutting-off tool,

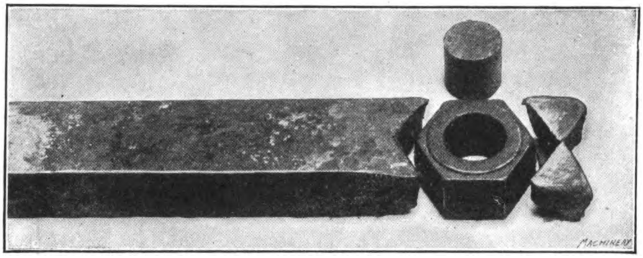


Fig. 5. Showing how a Hexagon Nut is produced from Rectangular Bar in a Hot-pressed Nut Machine

as shown at *C;* then the cutting-off and piercing tools *c* and *f* recede, and the crowning tool *e* advances, forcing the nut out of the dies. As the cut-off tool *c* recedes, the extractor *d* forces the wad out of the punch at the same time as the nut is ejected from the dies. The ejector, which is operated by a lever and cam, as shown in Fig. 3, is provided to prevent the nut from adhering to the crowning tool; this very seldom happens, however. A completed nut is produced at each revolution of the large gears.

The operations just described are repeated until the heated portion of the bar has been used up, after which the operator places the bar in the furnace to be re-heated, takes a freshly heated bar from the furnace, and proceeds as before. The machine is run continuously, and is not stopped for the insertion of a newly heated bar. Finished nuts are turned out at the rate of from 40 to 70 per minute, depending upon the size of the machine and the skill of the operator. Fig. 5 shows how a hexagon nut is produced from a rectangular bar of stock in a center-feed hot-pressed nut machine. It will be seen that considerable scrap is lost in the production of a nut of hexagon shape, viz., the wad removed to form the hole, and the triangular pieces which are removed to form the corners. On a square nut the material wasted is not quite so great, as in

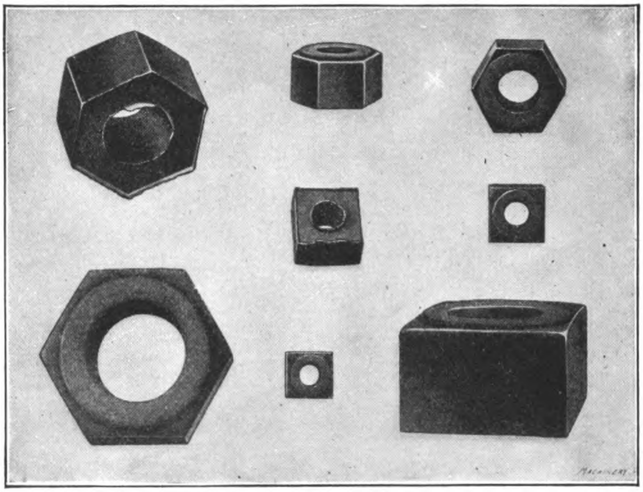


Fig. 6. Group of Square and Hexagon Nuts, showing Character of Work turned out in Hot-pressed Nut Machine

this case only the wad and a slight amount of stock, sheared off the end of the bar to form a square corner, are removed.

There are two common methods in use in nut forging. One is to set the stop so that the rounded corner of the bar is sheared off, leaving a square corner. This, of course, wastes somewhat more stock than the other method, yet to be described, but has the advantage of producing a perfect nut. The rounded corner is caused by the cut-off tool which, in removing the block of metal from the end of the bar to form the nut, rounds over the end of the bar, due to the hot metal drawing over, and thus makes this waste of stock necessary if a full-shaped nut is to be secured.

Another method in common use to save stock and at the same time produce a practically full nut, is to invert the bar after each stroke of the machine. By this method opposite sides of the bar are alternately presented to the dies, which overcomes, to a large extent, the effect of the fin on one side and the rounded corner on the other, and produces a full nut without shearing any material from the

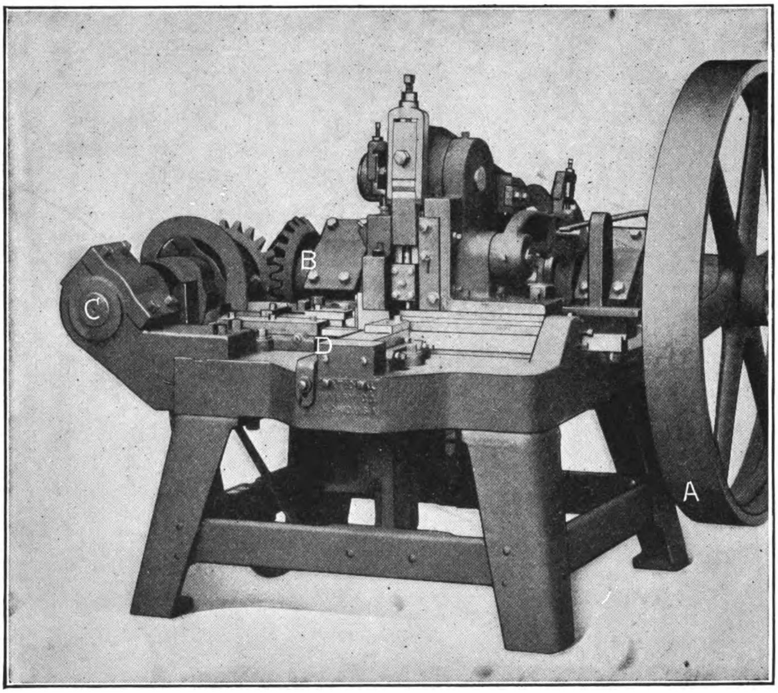


Fig. 7. Hot-forged Nut Machine used exclusively for the Manufacture of Square Nuts from Rectangular Bar Stock

end of the bar. The only objection to this method is the necessity of turning the bar, which, if heavy, soon tires the operator. On the larger sizes of nuts, the first method is used, as the bars are quite heavy and the operator would find it difficult to turn them and keep up with the operation of the machine.

Fig. 6 shows a typical group of nuts which can be produced economically and on a commercial basis in the center-feed hot-pressed nut machine. In this illustration two of the nuts show fins on the under side, both around the outer edges and the hole. This is caused by the sharp edges of the cut-off tool becoming rounded and allowing the hot metal to "leak" past the edges. The clearance allowed between the cut-off punch and dies also tends to produce a slight fin. When the tools are new the burr or fin produced is very slight, but it increases as the tools wear. These fins are removed in a succeeding operation in a burring machine.

Hot-forged Nut Machine. Fig. 7 shows a National nut making machine which is applicable only to the manufacture of square nuts, but produces this class of nuts free from fins and burrs at a rapid rate. Nut manufacturers who produce in great quantities are extensive users of this type of machine, but a concern making a variety of nuts in small quantities should not attempt to use it, owing to the delay incident to changing the dies and tools from one size to another. Briefly stated, the machine consists principally of a suitable mechanism for operating a shearing and crowning tool, four horizontal hammers which form the four sides of a square nut, and piercing and flattening punches. Power is transmitted from pulley *A* to the two shafts *B* and *C* located at right angles to each other and connected by miter gears. Shaft *C* carries eccentrics and cams which operate the left-side hammer and sizing tool for gripping the bar while it is being sheared; and shaft *B*, through cams, levers and eccentrics, operates the blank shearing tool, nut ejector, front and rear hammers, piercing punch and flattening tools.

Operation of Hot-forged Nut Machine. In order to illustrate how this hot-forged nut machine produces square nuts, the diagrams shown in Fig. 8 are included. These views show plan and sectional elevations which illustrate the relative positions of the various dies and tools, and the stages through which the nut passes before being ejected. In operating this machine, rectangular bar stock heated

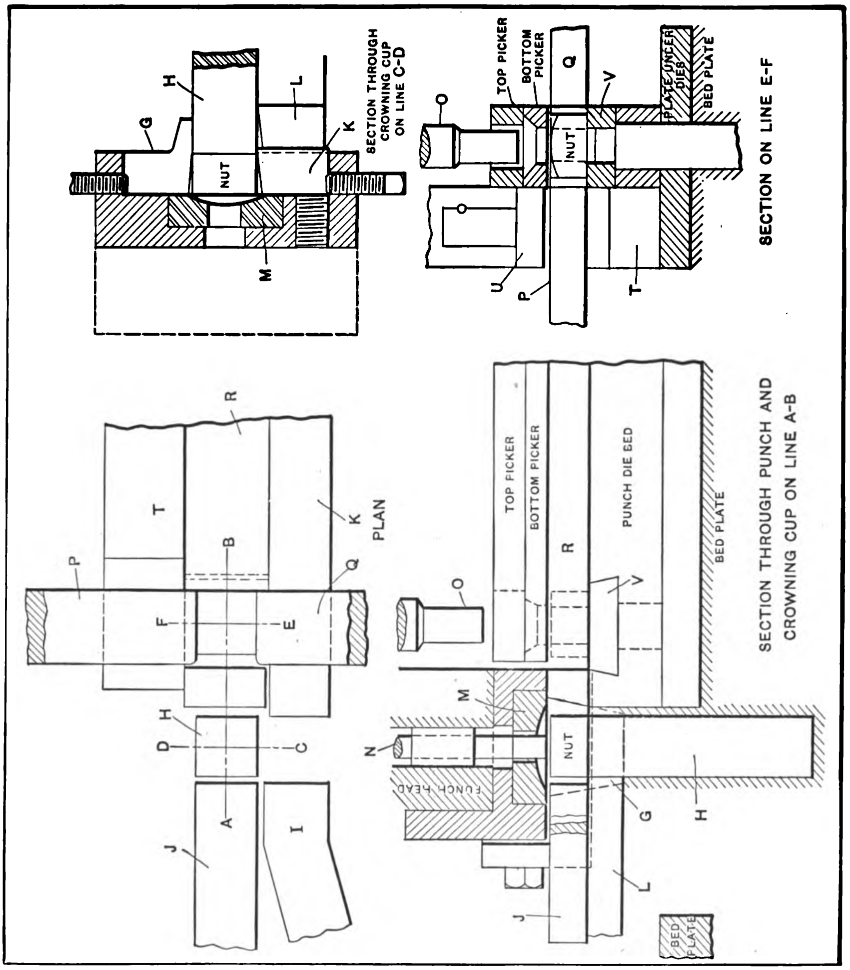


Fig. 8. Construction of Tools and Operation of the Hot-forged Type of Nut Machine Shown in Fig. 7

to a length of four or five feet is fed into the machine (see *D*, Fig. 7) along the line *CD*. The stock is equal in width to the diameter of the nut across the flats, and of the same thickness as the nut. It is fed into the machine with the greatest width horizontal and is located by the gage *G*.

As the heated bar is fed in, a shearing tool *H*, operated from the bottom of the machine, forces the heated end of the bar against the knife *K* and cuts off a suitable blank; as this tool continues to rise, it presses the nut blank into the crowner cup *M*, which is located directly above the shearing tool. While the shearing operation is taking place, the sizing tool *I*, which moves in a line parallel with the side hammer *J*, holds the bar tightly against the stationary sizer *K*.

Gripping the bar in this manner tends to give a better shearing cut. The shearing tool *H* is now lowered until its top face is in line with the bottom of the side hammer *J*, and at the same time the kickout *N*, operated through a hole in the crowner *M*, ejects the nut, preventing it from sticking in the cup. The shearing tool now remains in its "down" position while the side hammer *J* carries the nut along line *AB* until the center of the nut is in line with *EF* and directly under the piercing punch *O*.

As the side hammer *J* moves the nut blank under the piercing punch, the rear hammer *P* advances and presses the nut into the square box formed by the side hammer *J*, rear hammer *P*, stationary hammer *R* and front hammer *Q*. This tends to square up the sides of the nut and form it to the proper shape. While in this position, the punch *O* pierces the hole in the nut, forcing the wad through the die *V*, and immediately withdraws. The rear hammer *P* and side hammer *J* then return to their original positions, and the front hammer *Q* moves the nut back to the flatter bed *T*, which is located directly under the rear hammer *P*. While the nut is located on the flatter bed, the flattening tool *U*, which is over the rear hammer, comes down on the nut, gives it a slight squeeze, which corrects any distortion of the top and bottom faces caused by the squeezes between the four hammers previously described, and also serves to flatten any fins resulting from the piercing operation. The flattening tool *U* then rises, and the flatter bed *T* withdraws, allowing the finished nut to drop out of the machine. A completed nut is made at each revolution of the flywheel, and the machine is operated at from 60 to 90 revolutions per minute, depending upon its size.

Some idea of the character of the work turned out by the hot-forged nut machine can be obtained from Fig. 9, which shows a representative group of square nuts just as they come from the machine. The nuts produced by these machines are entirely free from fins or burrs, are of excellent finish, and ready for tapping directly after being forged.

Dies and Tools Used in Hot-pressed Center-feed Nut Machines. The type of dies and tools used in the hot-pressed center-feed nut machine shown in Fig. 3 is shown in Fig. 10. The reference letters used here are the same as those in Fig. 4. The dies *a* and *b*, which are reversible, are

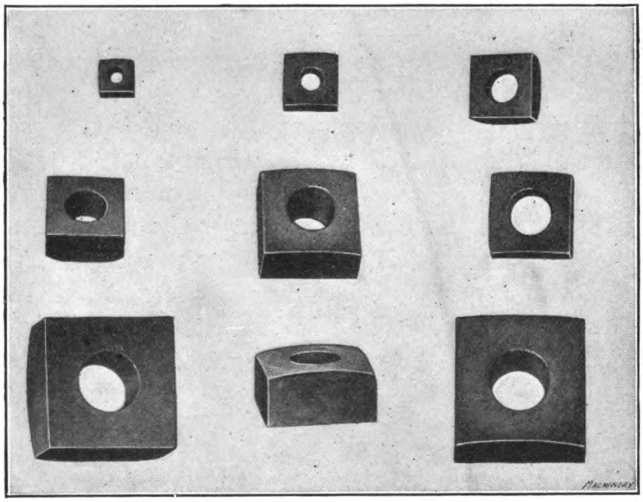


Fig. 9. Samples of Square Nuts produced on Hot-forged Type of Nut Machine—Note Absence of Burrs or Fins

usually made from chilled iron castings, and are ground to size. Dies made from this material, it is claimed, will last fully eight times as long as those made from ordinary carbon steel, but as it is somewhat of a problem to get the proper amount of "chill," many manufacturers are using a good grade of open-hearth steel instead. A crucible steel which has been found to give good results for this class of work contains from 0.90 to 1.10 per cent carbon. Some nut manufacturers have found that a certain grade of vanadium alloy steel having a carbon content of from 0.15 to 0.30 per cent gives excellent results when used for nut dies. In all cases, of course, it is necessary to harden the dies, and those made from crucible tool steel are hardened and drawn so that they can just be touched with the file, or in other words, the temper is drawn to a light straw color.

The composition of vanadium steel used for dies varies. Two grades of vanadium tool steel are recommended for forging machine dies by the American Vanadium Co., of Pittsburg, Pa. One is composed of carbon, 0.50 per cent;

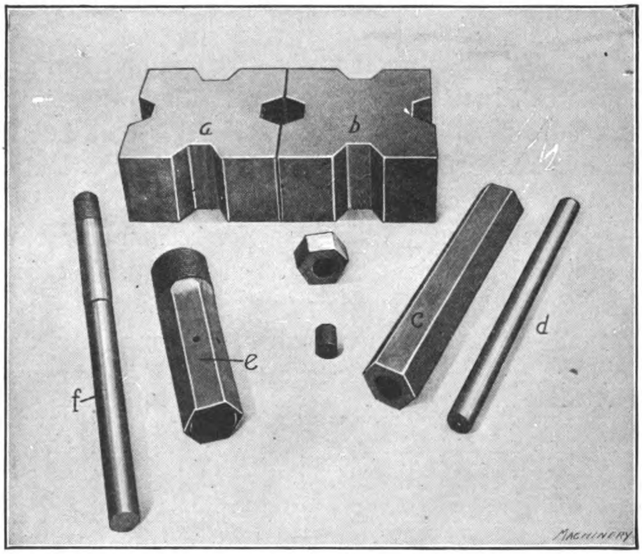


Fig. 10. Type of Dies and Tools used in making Hexagon Nuts in Center-feed Hot-pressed Nut Machine shown in Fig. 3

chromium, 0.80 to 1.10 per cent; manganese, 0.40 to 0.60 per cent; vanadium, not less than 0.16 per cent; silicon, not more than 0.20 per cent.

The heat-treatment recommended for this steel is as follows: Heat to 1550 degrees F. and quench in oil; then reheat to from 1425 to 1450 degrees F., and quench in water, submerging the face of the die only. When this method is used, the die is drawn by the heat remaining in the body and is thus tempered, and the life of the die increased.

The second kind of vanadium tool steel recommended has the following analysis: Carbon, 0.65 to 0.75 per cent; manganese, 0.40 to 0.60 per cent; vanadium, not less than 0.16 per cent; silicon, not more than 0.20 per cent. The heat-treatment for this steel should be as follows: Heat to 1525 degrees F. and quench in water with the face of the die only submerged.

The length of life of vanadium steel dies is stated to be about six times the life of dies made from ordinary high-carbon tool steel.

The cut-off tool *c* is generally made from ordinary carbon tool steel, hardened and drawn. Some attempts have been made to use high-speed steel for this tool, but as this material is rather expensive, and as this particular tool wears away very rapidly, a cheaper brand of steel is generally adopted. The piercing tool *f* when made from "Rex A" high-speed steel has been found very satisfactory for hot punching. The crowning tool *e* and wad extractor *d* can be made from carbon tool steel, hardened and drawn.

In order that the tools in a center-feed hot-pressed nut machine may work freely, it is necessary to provide a certain amount of clearance, especially between the cut-off tool, crowning tool and dies. On nuts from ½ to 2 inches in diameter (this is the size of the bolt for which the nut is used), 1/64 inch clearance is allowed. On sizes smaller than ½ inch, 0.010 inch clearance is allowed, whereas for tools used in making nuts larger than 2 inches, a clearance of from 0.020 to 0.060 inch is provided. The hole formed by the junction of the two halves of the dies is made perfectly straight, but the piercing tool is slightly tapered—being smaller at the front end. This enables it to withdraw more easily from the hole in the nut, and also increases its life. It is evident, of course, that after the hole is punched in the nut, the chilling effect of the dies (which are kept cool by water flowing over them) tends to "freeze" the nut on the piercing tool, but the slight taper on the piercing tool prevents this.

There is no allowance made in the hole of the nut to provide for shrinkage, as the holes regularly punched in nuts are made considerably larger than the root diameter of the threads on the tap. The nuts can then be more easily tapped, and the percentage of tap breakages is reduced.

In Fig. 11 is shown the shape of the dies used for making square nuts in a center-feed hot-pressed nut machine. It will be seen that these dies are made in four pieces, and it is possible to raise or lower the outside blocks *A* and *B*,

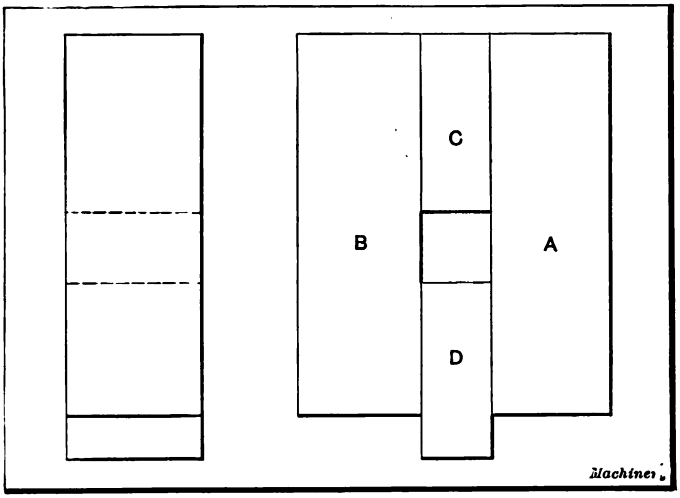


Fig. 11. Type of Dies used in making Square Nuts in Machine of the Type shown in Fig. 3

so that new cutting edges are secured. In addition to this the top and bottom dies *C* and *D* can be reserved, and also the two side pieces, thus giving long life for one redressing of the dies. As a rule, this type of dies is made from ordinary crucible tool steel containing from 0.90 to 1.00 per cent carbon, hardened and drawn, and ground all over.

Dies and Tools Used in Hot-forged Nut Machines. The four hammers used in the hot-forged nut machines are made from rectangular blocks of steel, shaped as shown in Fig. 8. The rear, front and stationary hammers are made wider than the nut, but of approximately the same thick-

Proportions of U. S. Standard and Manufacturers' Standard Hexagon and Square Nuts and Sizes of Rectangular Stock Required to Produce Them. (See notation on Fig. 12.)

United States Standard

Dia. of Bolt	A	B	C	D	E	F	G	H	I
	Dimensions in Inches								
$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{13}{64}$	$\frac{17}{64}$	$\frac{15}{32}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{17}{64}$	$\frac{15}{32}$
$\frac{5}{16}$	$\frac{5}{16}$	$\frac{19}{32}$	$\frac{1}{4}$	$\frac{11}{32}$	$\frac{9}{16}$	$\frac{5}{16}$	$\frac{19}{32}$	$\frac{11}{32}$	$\frac{9}{16}$
$\frac{3}{8}$	$\frac{3}{8}$	$\frac{11}{16}$	$\frac{5}{16}$	$\frac{13}{32}$	$\frac{21}{32}$	$\frac{3}{8}$	$\frac{11}{16}$	$\frac{13}{32}$	$\frac{21}{32}$
$\frac{7}{16}$	$\frac{7}{16}$	$\frac{25}{32}$	$\frac{23}{64}$	$\frac{15}{32}$	$\frac{23}{32}$	$\frac{7}{16}$	$\frac{25}{32}$	$\frac{15}{32}$	$\frac{23}{32}$
$\frac{1}{2}$	$\frac{1}{2}$	$\frac{7}{8}$	$\frac{27}{64}$	$\frac{17}{32}$	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{7}{8}$	$\frac{17}{32}$	$\frac{13}{16}$
$\frac{9}{16}$	$\frac{9}{16}$	$\frac{31}{32}$	$\frac{15}{32}$	$\frac{19}{32}$	$\frac{29}{32}$	$\frac{9}{16}$	$\frac{31}{32}$	$\frac{19}{32}$	$\frac{29}{32}$
$\frac{5}{8}$	$\frac{5}{8}$	$1\frac{1}{16}$	$\frac{17}{32}$	$\frac{21}{32}$	1	$\frac{5}{8}$	$1\frac{1}{16}$	$\frac{21}{32}$	1
$\frac{3}{4}$	$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{41}{64}$	$\frac{13}{16}$	$1\frac{3}{16}$	$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{13}{16}$	$1\frac{3}{16}$
$\frac{7}{8}$	$\frac{7}{8}$	$1\frac{7}{16}$	$\frac{3}{4}$	$\frac{15}{16}$	$1\frac{3}{8}$	$\frac{7}{8}$	$1\frac{7}{16}$	$\frac{15}{16}$	$1\frac{3}{8}$
1	1	$1\frac{5}{8}$	$\frac{55}{64}$	$1\frac{1}{16}$	$1\frac{9}{16}$	1	$1\frac{5}{8}$	$1\frac{1}{16}$	$1\frac{9}{16}$
$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{13}{16}$	$\frac{31}{32}$	$1\frac{3}{16}$	$1\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{13}{16}$	$1\frac{3}{16}$	$1\frac{3}{4}$
$1\frac{1}{4}$	$1\frac{1}{4}$	2	$1\frac{3}{32}$	$1\frac{3}{8}$	$1\frac{7}{8}$	$1\frac{1}{4}$	2	$1\frac{3}{8}$	$1\frac{7}{8}$
$1\frac{3}{8}$	$1\frac{3}{8}$	$2\frac{3}{16}$	$1\frac{7}{32}$	$1\frac{1}{2}$	$2\frac{1}{16}$	$1\frac{3}{8}$	$2\frac{3}{16}$	$1\frac{1}{2}$	$2\frac{1}{16}$
$1\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{3}{8}$	$1\frac{11}{32}$	$1\frac{5}{8}$	$2\frac{1}{4}$	$1\frac{1}{2}$	$2\frac{3}{8}$	$1\frac{5}{8}$	$2\frac{1}{4}$
$1\frac{5}{8}$	$1\frac{5}{8}$	$2\frac{9}{16}$	$1\frac{27}{64}$	$1\frac{3}{4}$	$2\frac{7}{16}$	$1\frac{5}{8}$	$2\frac{9}{16}$	$1\frac{3}{4}$	$2\frac{7}{16}$
$1\frac{3}{4}$	$1\frac{3}{4}$	$2\frac{3}{4}$	$1\frac{17}{32}$	$1\frac{7}{8}$	$2\frac{5}{8}$	$1\frac{3}{4}$	$2\frac{3}{4}$	$1\frac{7}{8}$	$2\frac{5}{8}$
$1\frac{7}{8}$	$1\frac{7}{8}$	$2\frac{15}{16}$	$1\frac{21}{32}$	2	$2\frac{13}{16}$	$1\frac{7}{8}$	$2\frac{15}{16}$	2	$2\frac{13}{16}$
2	2	$3\frac{1}{8}$	$1\frac{49}{64}$	$2\frac{1}{8}$	3	2	$3\frac{1}{8}$	$2\frac{1}{8}$	3
$2\frac{1}{4}$	$2\frac{1}{4}$	$3\frac{1}{2}$	$2\frac{1}{64}$	$2\frac{3}{8}$	$3\frac{3}{8}$	$2\frac{1}{4}$	$3\frac{1}{2}$	$2\frac{3}{8}$	$3\frac{3}{8}$
$2\frac{1}{2}$	$2\frac{1}{2}$	$3\frac{7}{8}$	$2\frac{15}{64}$	$2\frac{5}{8}$	$3\frac{3}{4}$	$2\frac{1}{2}$	$3\frac{7}{8}$	$2\frac{5}{8}$	$3\frac{3}{4}$
$2\frac{3}{4}$	$2\frac{3}{4}$	$4\frac{1}{4}$	$2\frac{31}{64}$	$2\frac{7}{8}$	$4\frac{1}{8}$	$2\frac{3}{4}$	$4\frac{1}{4}$	$2\frac{7}{8}$	$4\frac{1}{8}$
3	3	$4\frac{5}{8}$	$2\frac{11}{16}$	$3\frac{1}{8}$	$4\frac{1}{2}$	3	$4\frac{5}{8}$	$3\frac{1}{8}$	$4\frac{1}{2}$
$3\frac{1}{4}$	$3\frac{1}{4}$	5	$2\frac{15}{16}$	$3\frac{3}{8}$	$4\frac{7}{8}$	$3\frac{1}{4}$	5	$3\frac{3}{8}$	$4\frac{7}{8}$
$3\frac{1}{2}$	$3\frac{1}{2}$	$5\frac{3}{8}$	$3\frac{11}{64}$	$3\frac{5}{8}$	$5\frac{1}{4}$	$3\frac{1}{2}$	$5\frac{3}{8}$	$3\frac{5}{8}$	$5\frac{1}{4}$
$3\frac{3}{4}$	$3\frac{3}{4}$	$5\frac{3}{4}$	$3\frac{3}{8}$	$3\frac{7}{8}$	$5\frac{5}{8}$	$3\frac{3}{4}$	$5\frac{3}{4}$	$3\frac{7}{8}$	$5\frac{5}{8}$
4	4	$6\frac{1}{8}$	$3\frac{5}{8}$	$4\frac{1}{8}$	6	4	$6\frac{1}{8}$	$4\frac{1}{8}$	6

Manufacturers' Standard

Dia. of Bolt	A	B	C	D	E	F	G	H	I
	Dimensions in Inches								
$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{7}{32}$	$\frac{17}{64}$	$\frac{15}{32}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{17}{64}$	$\frac{15}{32}$
$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{9}{32}$	$\frac{11}{32}$	$\frac{19}{32}$	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{11}{32}$	$\frac{19}{32}$
$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{11}{32}$	$\frac{13}{32}$	$\frac{23}{32}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{13}{32}$	$\frac{23}{32}$
$\frac{7}{16}$	$\frac{7}{16}$	$\frac{7}{8}$	$\frac{13}{32}$	$\frac{15}{32}$	$\frac{13}{16}$	$\frac{7}{16}$	$\frac{7}{8}$	$\frac{15}{32}$	$\frac{13}{16}$
$\frac{1}{2}$	$\frac{1}{2}$	1	$\frac{7}{16}$	$\frac{17}{32}$	$\frac{15}{16}$	$\frac{1}{2}$	1	$\frac{17}{32}$	$\frac{15}{16}$
$\frac{9}{16}$	$\frac{9}{16}$	$1\frac{1}{8}$	$\frac{1}{2}$	$\frac{19}{32}$	$1\frac{1}{16}$	$\frac{9}{16}$	$1\frac{1}{8}$	$\frac{19}{32}$	$1\frac{1}{16}$
$\frac{5}{8}$	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{9}{16}$	$\frac{21}{32}$	$1\frac{3}{16}$	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{21}{32}$	$1\frac{3}{16}$
$\frac{3}{4}$	$\frac{3}{4}$	$1\frac{3}{8}$	$\frac{21}{32}$	$\frac{13}{16}$	$1\frac{5}{16}$	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{13}{16}$	$1\frac{7}{16}$
$\frac{7}{8}$	$\frac{7}{8}$	$1\frac{5}{8}$	$\frac{25}{32}$	$\frac{15}{16}$	$1\frac{9}{16}$	$\frac{7}{8}$	$1\frac{3}{4}$	$\frac{15}{16}$	$1\frac{11}{16}$
1	1	$1\frac{3}{4}$	$\frac{7}{8}$	$1\frac{1}{16}$	$1\frac{11}{16}$	1	2	$1\frac{1}{16}$	$1\frac{15}{16}$
$1\frac{1}{8}$	$1\frac{1}{8}$	2	$\frac{15}{16}$	$1\frac{5}{16}$	$1\frac{15}{16}$	$1\frac{1}{8}$	$2\frac{1}{4}$	$1\frac{5}{16}$	$2\frac{3}{16}$
$1\frac{1}{4}$	$1\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{3}{32}$	$1\frac{1}{2}$	$2\frac{3}{16}$	$1\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{3}{8}$
$1\frac{3}{8}$	$1\frac{3}{8}$	$2\frac{1}{2}$	$1\frac{3}{16}$	$1\frac{5}{8}$	$2\frac{3}{8}$	$1\frac{3}{8}$	$2\frac{3}{4}$	$1\frac{5}{8}$	$2\frac{5}{8}$
$1\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{3}{4}$	$1\frac{5}{16}$	$1\frac{3}{4}$	$2\frac{5}{8}$	$1\frac{1}{2}$	3	$1\frac{3}{4}$	$2\frac{7}{8}$
$1\frac{5}{8}$	$1\frac{5}{8}$	3	$1\frac{7}{16}$	$1\frac{7}{8}$	$2\frac{7}{8}$	$1\frac{5}{8}$	$3\frac{1}{4}$	$1\frac{7}{8}$	$3\frac{1}{8}$
$1\frac{3}{4}$	$1\frac{3}{4}$	$3\frac{1}{4}$	$1\frac{9}{16}$	2	$3\frac{1}{8}$	$1\frac{3}{4}$	$3\frac{1}{2}$	2	$3\frac{3}{8}$
$1\frac{7}{8}$	$1\frac{7}{8}$	$3\frac{1}{2}$	$1\frac{11}{16}$	$2\frac{1}{8}$	$3\frac{3}{8}$	$1\frac{7}{8}$	$3\frac{3}{4}$	$2\frac{1}{8}$	$3\frac{5}{8}$
2	2	$3\frac{1}{2}$	$1\frac{13}{16}$	$2\frac{1}{4}$	$3\frac{3}{8}$	2	4	$2\frac{1}{4}$	$3\frac{7}{8}$
$2\frac{1}{4}$	$2\frac{1}{4}$	$3\frac{3}{4}$	2	$2\frac{3}{8}$	$3\frac{5}{8}$	$2\frac{1}{4}$	$4\frac{1}{4}$	$2\frac{3}{8}$	$4\frac{1}{8}$
$2\frac{1}{2}$	$2\frac{1}{2}$	$4\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{5}{8}$	$4\frac{1}{8}$	$2\frac{1}{2}$	$4\frac{1}{2}$	$2\frac{5}{8}$	$4\frac{3}{8}$
$2\frac{3}{4}$	$2\frac{3}{4}$	$4\frac{1}{2}$	$2\frac{7}{16}$	$2\frac{7}{8}$	$4\frac{3}{8}$	$2\frac{3}{4}$	$4\frac{3}{4}$	$2\frac{7}{8}$	$4\frac{5}{8}$
3	3	$4\frac{3}{4}$	$2\frac{11}{16}$	$3\frac{1}{8}$	$4\frac{5}{8}$	3	5	$3\frac{1}{8}$	$4\frac{7}{8}$
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..

ness, and the front and rear hammers are rounded on the forward corners, to facilitate the insertion of the nut. The side hammer, which carries the nut into the "box-shaped impression" formed by all four hammers, is of the same width and thickness as the nut. The crowner, flatter tool and the four hammer blocks are all made from ordinary crucible steel, hardened and drawn, whereas the shearing tool and piercing punch and die are usually made from high-speed steel. The brand of steel known as "Rex A" has been found very satisfactory for this purpose. The

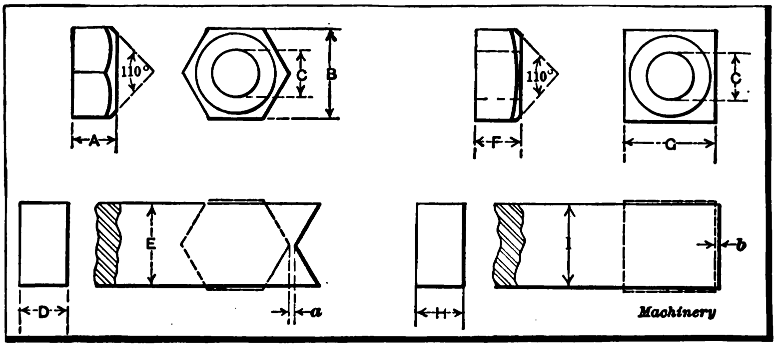


Fig. 12. Proportions of Standard Hexagon and Square Nuts; see Table on Opposite Page

tools used in the hot-forged nut machine do not wear out nearly so quickly as those used in the hot-pressed type of machine, owing to the fact that there is not the same scraping action against the surfaces of the tools.

Sizes of Rectangular Stock Used in Making Square and Hexagon Nuts. In making nuts in center-feed hot-pressed nut machines of the types shown in Figs. 1 and 2, rectangular bar stock as shown in Fig. 5 is used. To allow for upsetting the stock slightly and pressing it into the desired shape, a rectangular bar is used which is slightly thicker than the finished nut, and slightly less in width than the diameter of the nut across the flats. As explained in a previous paragraph, in order to produce a perfectly shaped nut it is necessary to waste a certain amount of stock as indicated at *a* and *b* in Fig. 12. The amount of stock wasted depends upon the size of the nut and to a slight extent upon the temperature at which the bar is being worked.

In producing a hexagon nut, only the front triangular corner is rounded (owing to the drawing over of the hot metal), whereas on a square nut, the entire front corner of the nut is rounded. A considerable saving of metal can be effected by turning the bar after each stroke of the machine, thus presenting opposite faces of the bar to the dies, as was previously explained. This can easily be done in making the smaller size of nuts where the bar does not exceed 40 to 80 pounds in weight. For large nuts, instead of turning the bar, a small amount of stock is wasted, as indicated at *a* and *b* in Fig. 12, which varies from 1/16 to ¼ inch, depending upon the size of the nut.

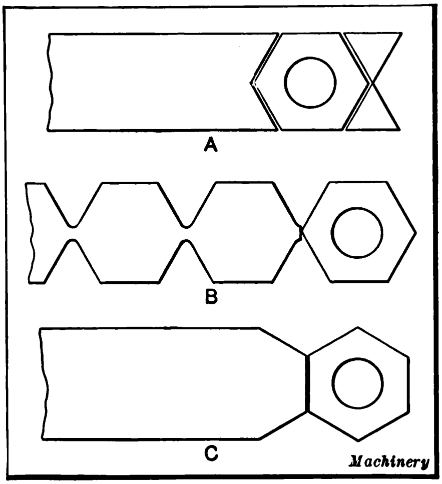


Fig. 13. Three Methods of forging Nuts

The hot-forged type of nut-making machine shown in Fig. 7 has the advantage over the center-feed hot-pressed machine of not wasting any stock. The hot-forged nut machine, however, is only suitable for the manufacture of square nuts, and is only used where this type of nut is made in large quantities.

The Indenting Method of Forging Nuts. In forging nuts, it is desirable to produce well-formed sharp-cornered nut blanks without subjecting the machine to excessive stresses, and also reduce the waste or scrap to a minimum. The common method of forging nuts is illustrated at *A*, Fig. 13. The nuts are cut or sheared from the end of the heated bar of rectangular stock and then the hole is punched in the blank. With this method, there is considerable waste, the slug which is removed from the center to form the hole and the triangular-shaped pieces which are cut from the bar between successive blanks, being scrap. In order to reduce the amount of scrap, attempts have been made to use bars of stock having V-shaped notches rolled into them, as indicated at *B*, instead of cutting away the stock and thus removing the triangular shaped pieces.

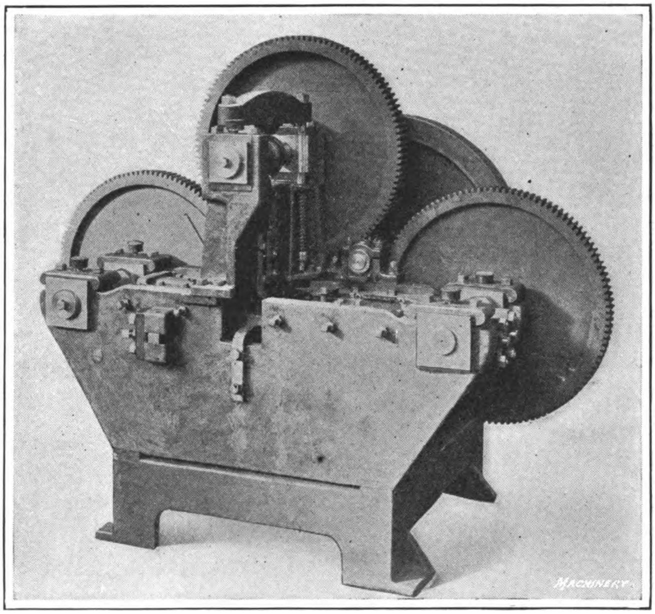


Fig. 14. Nut-forging Machine

Another plan that has been tried is shown at *C*. In this case, the V-shaped notches are formed by indenting tools on the nut-forging machine, which compress the metal on each side of the bar. Both the notched bar method and the use of indenting tools have been tried extensively during the past thirty years in the United States, England, and Germany. The use of notched stock and of indenting tools on the forging machine were both unsuccessful, partly because the machines were faulty in design and did not operate satisfactorily. When using notched bars, the entire bar of stock would usually be spoiled if one nut were spoiled. The indenting type of forging machine that formerly was experimented with also proved unsatisfactory, as stock of rectangular section was used and the indenting operation distorted the nut blanks so much that the pressures necessary to form sharp-cornered blanks were beyond the limit of endurance of both the tools and the machine.

Indenting Type of Nut-forging Machine. The Hollings nut-forging machine illustrated in Fig. 14, in conjunction with the special shape of stock used, makes it possible to produce well-formed blanks without excessive pressures and with much less waste in the form of scrap. In fact, it is claimed that the consumption of stock in an ordinary nut-forging machine operating on the principle illustrated at *A*, Fig. 13, may be as much as 50 per cent greater for the same production of nuts than in the indenting type of machine to be described. According to production figures, 3200 pounds of stock were required by the old method to produce 10,000 ¾-inch hexagonal nuts, there being 1100 pounds of scrap. By the new method only 2300 pounds of stock were required for the same number and size of nuts, there being only 200 pounds of scrap. In this case about 40 per cent more material was required by the old method.

In the operation of this machine, the heated bar of stock is fed in from the side and the V-shaped notches are first formed by the indenting tools (see Fig. 15). The cutting-off tool then moves up, severing a blank which is pushed into the die; then a punch advances rapidly and thins the slug as the stock is forced against an opposite punch which also expands the blank in the die. The first punch then recedes and the nut is compressed against the crowning tool. The hole is next pierced as the second punch continues its stroke, the slug being forced inside the cutting-off tool. The cutting-off tool and the second punch referred to now recede and as the crowning tool is advanced by cams, the nut is pushed out of the die. When the cut-off tool moves backward, the slug is ejected and at the same time the nut blank is ejected by the "nut kicker." The latter has a diagonal motion downward and outward, which insures the nut being removed from the crowning tool, as it passes clear across the face of the tool.

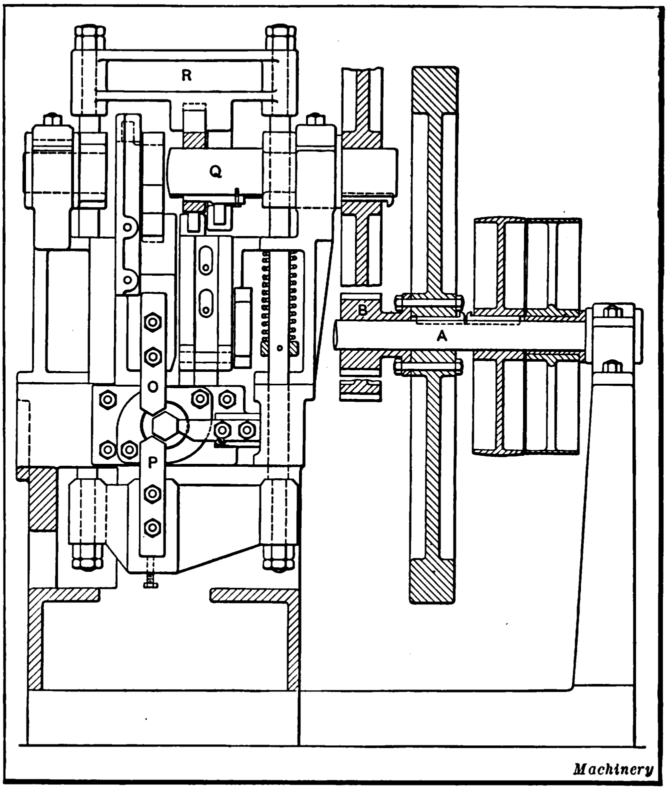


Fig. 15. Detail View of Indenting Tools and their Operating Mechanism

The cutting-off tool is held positively in its holder instead of depending on a friction grip. The punch for ejecting the slug and the piercing punch are provided with adjustable brass sleeves which are free to slide through the rear ends of the respective tool-holders, so that by piping the water to the hollow space within the crowning and cutting-off tools, water is pumped through these spaces by the action of the machine, thus cooling the tools and increasing their durability.

The driving pinion *B* is secured to the flywheel by two bolts as shown in Fig. 15, so that if a cold bar should be placed between the indenting tools, the bolts will shear off and prevent damage to the gears or other parts of the machine. The main thrust of the machine is exerted against a thrust bar which passes straight through the machine. One end of this bar is supported by spring, and the other end bears against a small cross-bar which acts as a safety breaker in case two nuts should accidentally get into the die. The tension of the spring can be regulated to give the correct pressure. The machine is so designed that the principal members are subjected to almost a plain straight tension, the twisting and side strains having been reduced to a minimum. The strain resulting from the indenting operation is also taken by vertical tie-rods and throughout the entire machine the strains are largely balanced.

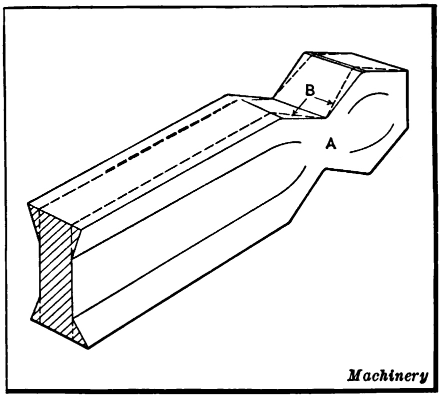


Fig. 16. Special Patented Shape of Bar used in Conjunction with Nut-forging Machine shown in Fig. 14

Special Form of Stock Used with Indenting Type of Nut Forging Machine. The special form of bar stock used in conjunction with this machine is illustrated by the perspective view, Fig. 16. The central part of the bar is of rectangular section, but the ends flare outward as the illustration shows. The object of using this special shape is to make it possible to secure well-formed sharp-cornered nut blanks and still keep the necessary pressures within commercial limits—not simply experimental limits. While it is possible to make nuts by the indenting method when using stock of plain rectangular section, such a severe blow is required that the method is impracticable as a commercial proposition. The rolling of the section illustrated in Fig. 16, therefore, is the first step in this patented process of nut forging. When the machine is operating on a bar of this shape, the indenting tools, in compressing the metal, force it outward, thus filling up the narrower section at *A*. The result is that the sides of the nut blank are approximately flat, except in the center, where the hole is to be pierced; consequently an excessive blow or pressure is not necessary in flattening the nut. When an attempt is made to form nuts from plain rectangular stock, the indenting tools force the metal outward as indicated by the dotted lines at *B*. The result is that the blank is narrow at the top and bottom and the machine is subjected to severe stresses while forming the blank. This machine may be used on rectangular stock, the same as the ordinary center-feed type, by simply removing the indenting tools. This process of forging nuts, including the machine and the special form of bar, is covered by patents which have been granted in most countries throughout the world. Ernest Hollings, 5 Kelvin Ave., Sale, Cheshire, England, is the inventor, and the process is operating on a commercial basis in Manchester, England.

CHAPTER IV

MACHINES AND DIES FOR GENERAL FORGING OPERATIONS

POSSIBLY the greatest development in forging is the application of machine methods to the production of engine and machine parts. It is now possible to forge many parts from steel and wrought iron, which formerly could be made only from castings. This means a great saving of time and expense, as not only are machine forged parts much more rapidly made than those made from cast iron or steel castings, but they also cost considerably less to manufacture in large quantities. In the following, interesting examples of different types of upsets, bending and forming operations, etc., will be illustrated and described, together with a general description of the dies and tools used. This will give an idea of the remarkable possibilities of the upsetting and forging machine in its present-day development.

The Upsetting and Forging Machine. The upsetting and forging machine might be considered to a certain extent as a further development of the bolt and rivet making machine, which was originated almost a century ago; but forging machines are built much heavier than bolt and rivet machines and are designed especially to meet the demands in the production of difficult-shaped and heavy forgings. For the heavier types of machines, the base or main frame, as a rule is made from one solid steel casting.

A typical upsetting and forging machine, made by the National Machinery Co. and designed for heavy service, is shown in Fig. 1. The bed of this machine is made from one solid casting of semi-steel. In order to provide against breakage caused by accidentally placing work between the dies, upsetting and forging machines generally have various safety devices in order to prevent serious damage to the machine. The safety device in this machine consists of a toggle-joint mechanism for operating the movable gripping-die slide. The gripping-die slide *A* is operated by two cams *B* and *C* on the main crankshaft *D*. Cam *B* serves to close the dies which grip the work; cam *C* oper-

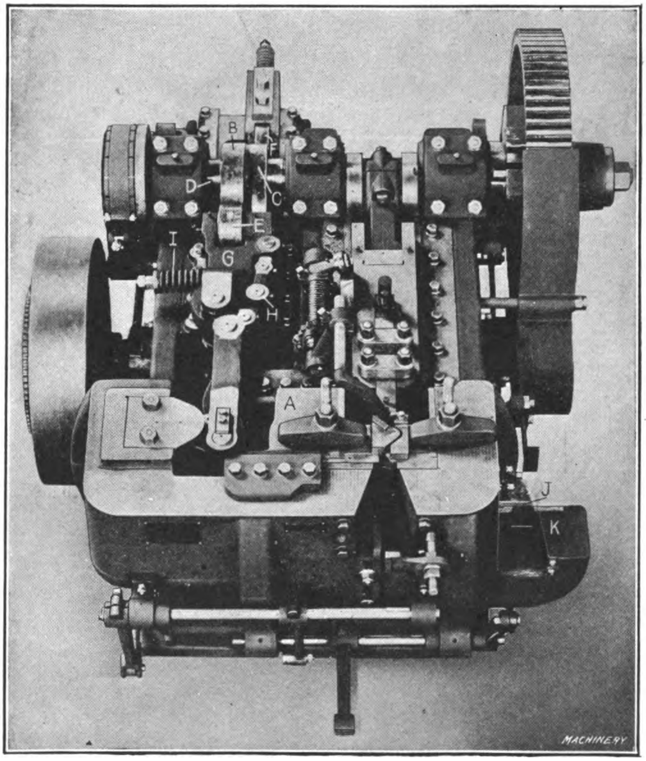


Fig. 1. Upsetting and Forging Machine having a Safety Relief Mechanism for Operating the Gripping Dies

ates the opening mechanism for the dies. These cams are in contact with chilled cast-iron rolls *E* and *F* carried in the toggle slide *G*. The automatic grip relief is controlled by the by-pass toggle *H* and heavy coil spring *I*. This toggle does not come into play until the strain is such that it would cause damage to the working mechanism of the machine, or in other words until the maximum power required to hold the movable die from springing away, is attained. The relief resetting automatically on the back stroke makes a second blow possible without delay.

Some idea of the gripping pressure exerted before the relief mechanism operates is indicated in Fig. 2. This piece, which has been flattened between the opposing faces of the gripping dies, is a 2-inch round bar of from 0.10 to 0.15 per cent carbon steel, $9\frac{5}{8}$ inches long. The flattened portion is $3\frac{5}{8}$ inches wide by 5 inches long and 23/32 inch thick. The piece, of course, was heated to a forging temperature before being placed between the opposing faces of the dies and was flattened to the condition shown in one squeeze. This illustrates a feature peculiar to this type of machine in that it can be used for squeezing or swaging operations, these being carried on between the opposing faces of the gripping dies. In many cases this allows work to be handled that is generally formed or flattened by the side shear *J*, which is operated from the movable die slide, being a continued arm of the same casting. As a rule, the side shear is used for cutting off stock, and is also sometimes used for bending operations, suitable dies or cutting tools for this purpose being held in the movable slide *J* and stationary bracket *K*.

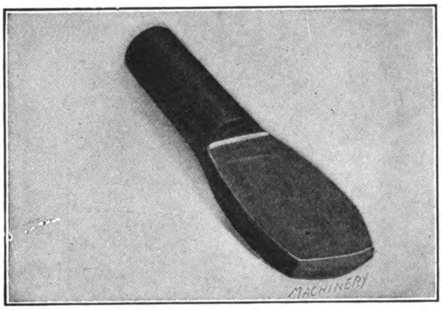


Fig. 2. Extent to which a Bar is flattened between Gripping Dies of Forging Machine before Relief operates

An Ajax upsetting and forging machine in which the working mechanism of the machine is protected from serious injury in a different manner, is shown in Fig. 3. In this machine the safety device consists of a bolt *A* connecting the die slide *B* and the slide *C* operating it. When any foreign body intercepts the gripping dies, the bolt *A* is sheared off, thus providing for a positive grip and at the same time furnishing a safety device that protects the working mechanism of the machine against the possibility of serious injury.

A good example of an upset forging operation which can be handled successfully in an upsetting and forging machine, is the castellated nut shown at *A* in Fig. 4, produced in an Ajax forging machine. This type of nut is pro-

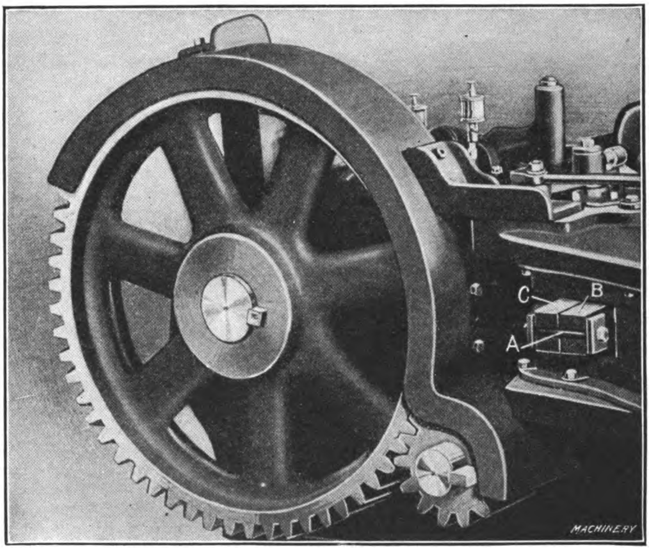


Fig. 3. Another Type of Upsetting and Forging Machine showing Safety or Shear Bolt providing a Safety Relief for the Gripping Dies

duced practically without waste of stock in from two to three blows. The gripping dies and tools used are shown in Fig. 4, and also in detail in Fig. 5, where the construction of the tools can be more clearly seen. Referring to the latter illustration, it will be noticed that the dies *C* and *D* are made in two pieces. This is done in order to facilitate the machining operations, and in many cases it enables the dies to be made at a much lower cost because of the simplicity in construction. These dies are made from scrap driving-axle steel which contains about 0.60 per cent carbon, and are hardened in the usual manner, the temper being drawn to a light straw color.

The plunger *E* which upsets the end of the bar into the lower impression in the dies, is made in three parts; this facilitates its construction and the method of manufacture. The body is made from a piece of soft machine steel, on the front end of which a hardened bushing *F* is held by a pin. The inside of this bushing is of a hexagon shape to form the sides of the nut. Screwed into the body of the

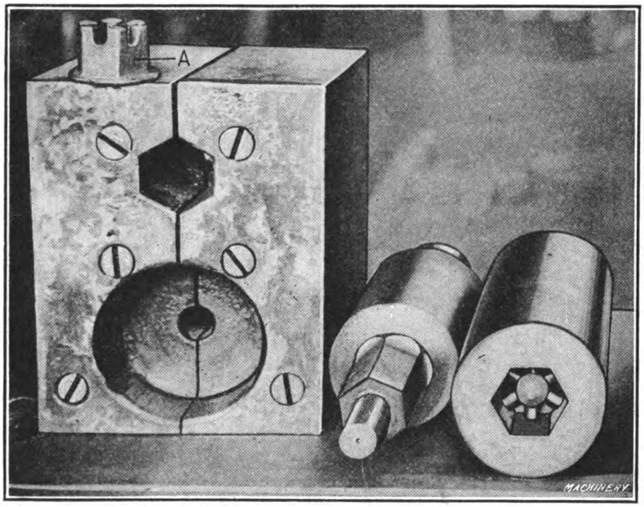


Fig. 4. Dies and Tools used in making a Castellated Nut in a Forging Machine

punch is a former *G* which is machined to such shape that six "wings," as shown, are formed around its periphery, these producing the castellated grooves in the head of the nut. The former *G* is pointed, and rough forms the hole in the nut. The top punch which is used for completely punching the hole in the nut and at the same time severing it from the bar is also made from a machine steel body *H* into which is screwed a hardened steel punch *I*, this being prevented from loosening by a pin driven through it.

The method of producing a hexagon castellated nut in a forging machine is as follows: A bar of the required size (which must not exceed the root diameter of the thread in the finished nut) is heated in the furnace to a temperature of from 1400 to 1600 degrees F., depending upon the material, and is then brought to the forging machine and placed in the lower impression of the gripping dies. Then as the machine is operated, the lower plunger advances, upsetting the end of the bar and forming the excess metal into a nut of the required shape. The bar is now quickly removed from the lower impression, placed in the upper

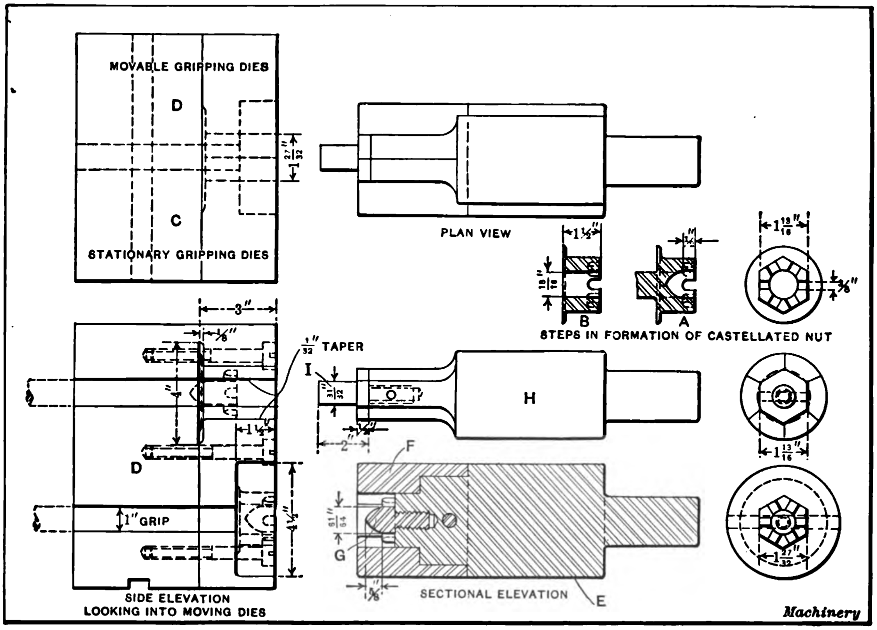


Fig. 5. Details of the Dies and Tools used for making the Castellated Nut shown in Fig. 4.

impression, and the machine again operated; whereupon the top plunger advances, completing the hole in the nut and attaching the metal thus removed to the end of the bar. These two operations are indicated at *A* and *B* in the illustration. This interesting method of making castellated nuts is used in the Collinwood shops of the L. S. & M. S. Railway. The only material wasted in the production of a castellated nut of this character is the slight excess of stock formed into a fin, which must be removed, of course, in a subsequent operation.

Another interesting example of castellated nut forging in which the excess metal is used in the formation of a washer on the nut and thus eliminates all waste of material, is shown in Fig. 6. The construction of the tools here illustrated is almost identical with

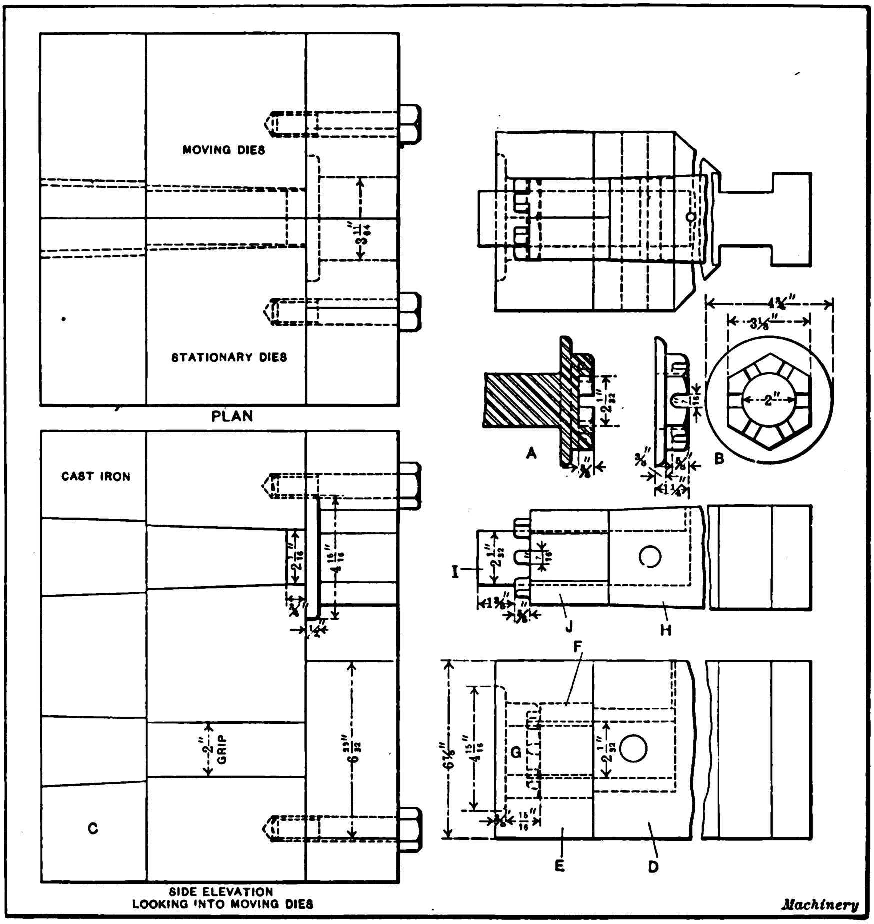


Fig. 6. Dies and Tools used for making a Combination Washer and Castellated Nut which is produced without any Waste of Stock

that shown in Figs. 4 and 5 with the exception of the punches and also the utilization of a cast-iron block *C*, for partly completing the construction of the gripping dies. The part of the gripping dies which is made from cast iron is not used as a gripping mé-dium and hence does not need to be made from steel to provide for wear. The lower punch *D* is in this case made from machine steel and is provided with a tool-steel head *E* which is bored out and formed to a hexagon shape. Inserted in this is a sleeve *F* for forming the castellated portion of the nut. A punch *G* rough-forms the hole in the nut. The upper plunger *H* carries a punch *I* which completely

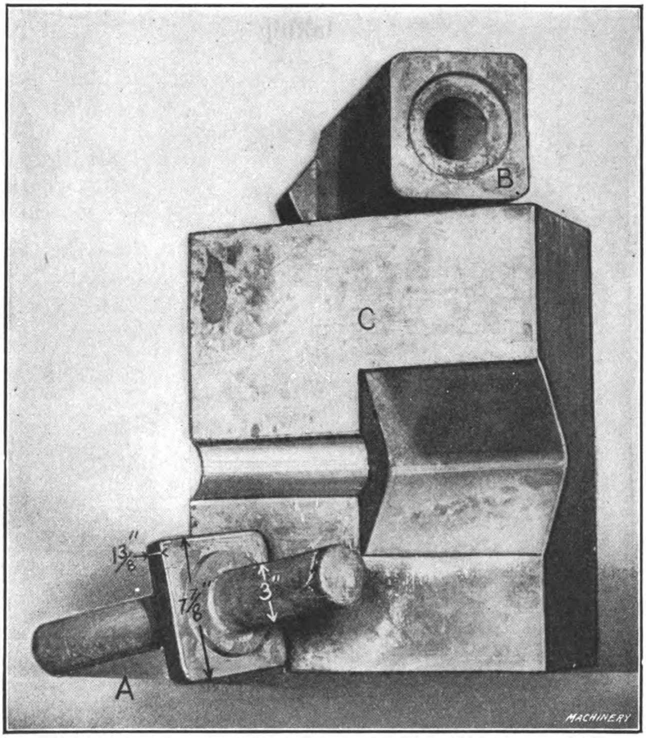


Fig. 7. Dies and Tools used in making an Enormous Upset in a 6-inch Universal Forging Machine

forms the hole in the nut by punching the bar back, and by means of the castellated washer *J* finish-forms the castellated grooves in the nut. The steps followed in the production of this combination castellated nut and washer are shown at *A* and *B* in the illustration. A 2-inch bar of wrought iron is used, and it requires a length of 4 inches to form the nut and washer.

Dies and Tools Used for Making a Locomotive Trailer Pin. The locomotive trailer pin shown at *A* in Fig. 7 represents about the maximum amount of upset which can be satisfactorily made in a forging machine and, in fact, is much greater than that usually recommended. This work was done in the Chicago shops of the C. & N. W. Railway, on a 6-inch Ajax universal forging machine. This trailer pin is made from a 3-inch round wrought-iron bar, 26 inches

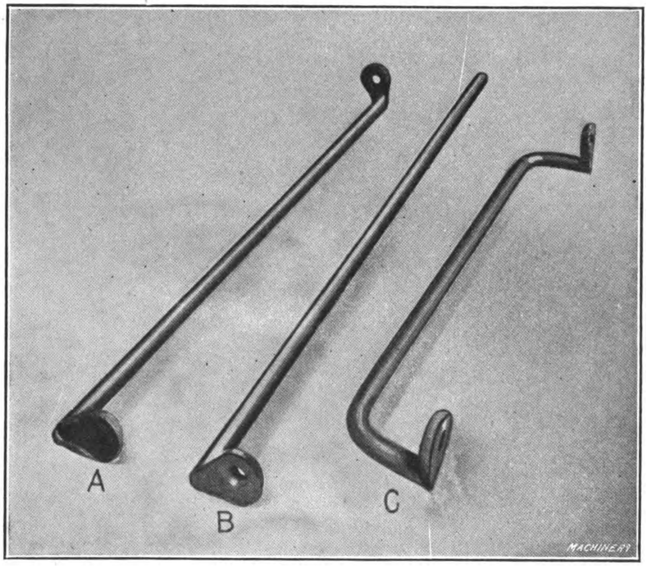


Fig. 8. Three Steps in the Formation of Ladder Treads for Freight Cars

long, and an excess amount of stock equal to 10¾ inches in length is put into the upset in one blow. The dimensions of the upset square flange are 7⅞ inches across the flats and 10 5/16 inches across the corners, by 1⅜ inches thick. The circular flange is 5⅞ inches in diameter by ⅝ inch long. After the work is given the first blow with the plunger *B*, it is reheated and the work is again placed between the gripping dies *C*, only one of which is shown. The machine is again operated and the part given another blow which serves to close up the texture of the steel and eliminates the defects caused by the structure of the steel pulling apart during the upsetting operation.

Bending and Forming Operations. The making of ladder treads for freight cars is a good example of bending and forming operations that can be handled successfully in the upsetting and forging machine. Fig. 8 shows three of the steps in the production of a ladder tread which is com-

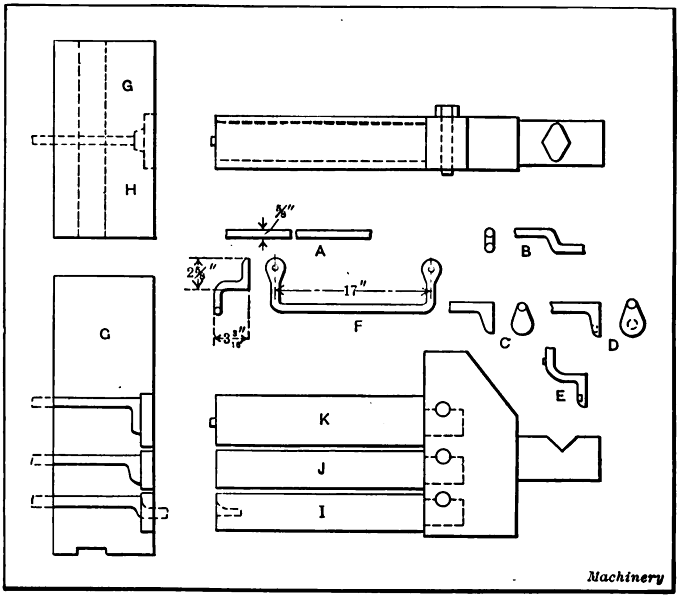


Fig. 9. Dies and Tools used in forming the Feet of Ladder Treads

pleted to the shape shown at *C* in five operations, on a National forging machine.

The dies and tools used for forming the feet of the ladder tread are illustrated in Fig. 9. The first operation is indicated at *A* and consists in cutting off a bar of ⅝-inch iron to the required length. This is heated on one end, placed in the lower impression in the gripping dies *G* and *H* and given a blow by the plunger *I* which forms the end of the rod into the shape shown at *B*. In this operation, the stock is upset just far enough so that it will not buckle in front of the dies.

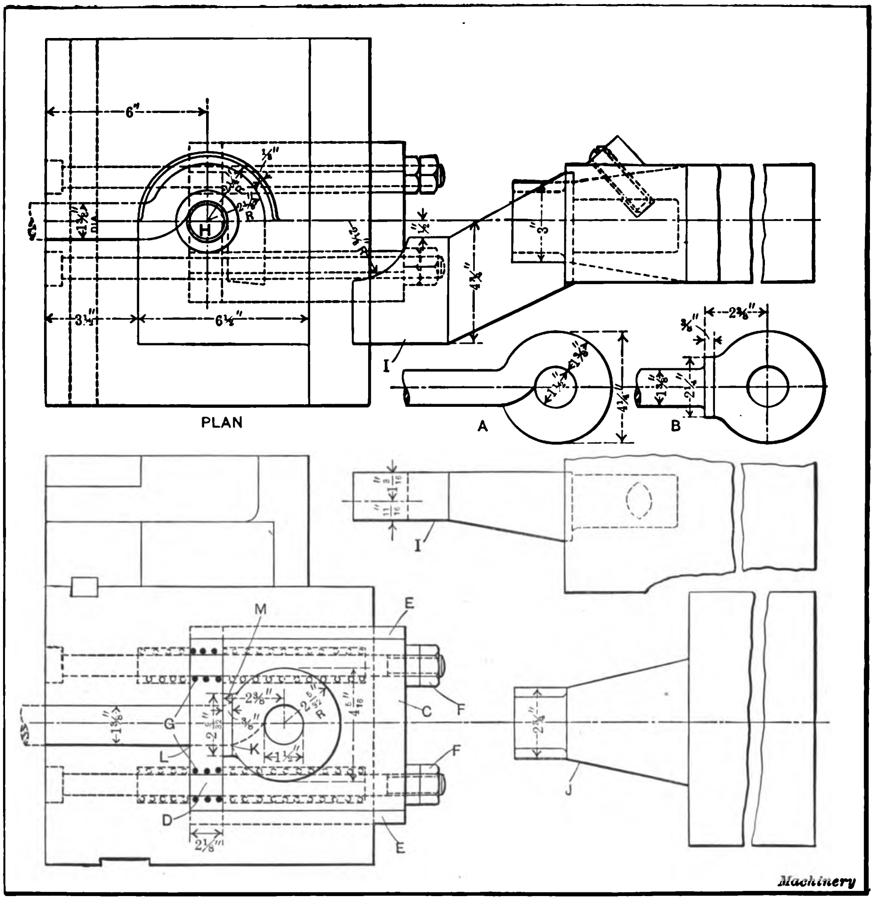


Fig. 10. An Interesting Set of Dies and Tools used in a 3-inch Forging Machine for forming Eye-bolts in Two Blows

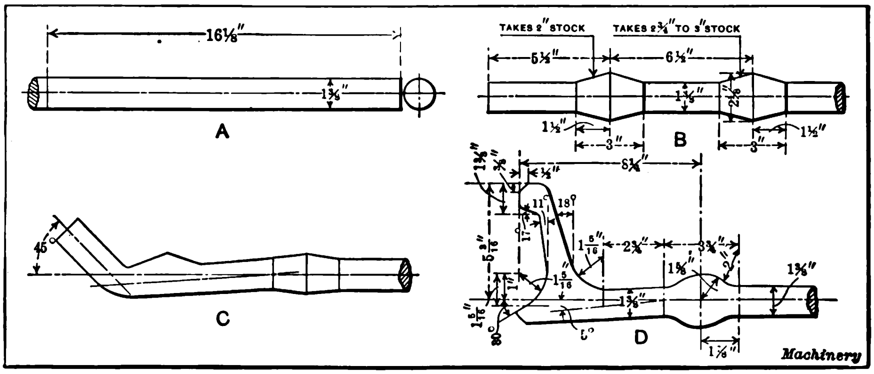


Fig. 11. Sequence of Operations on Automobile Front Axle accomplished in 3½-inch Forging Machine

The second operation bends and forms the stock back into a solid forging as indicated at *C*, this being accomplished in the second impression in the gripping dies by plunger *J*. The final forging operation, the result of which is shown at *D*, completes the foot, the upper impressions in the dies being used for this purpose; these are made the exact shape of the foot, and the plunger *K* has a pin in it which punches the hole in the foot to within 1/16 inch of passing through the 9/16-inch stock. The final operations which are performed in a bulldozer or other bending machine consist in bending both ends of the tread to the required shape. This requires two operations, which are indicated at *E* and *F*, respectively. Before the final bending, the forging is taken to an emery wheel to remove the burrs formed when forging the feet.

The eye-bolt shown in two stages of its formation, at *A* and *B* in Fig. 10, is another example of a bending and forming operation accomplished in a forging machine. This eye-bolt is made from a 1⅜-inch round wrought-iron bar, and is completed in two blows in a 3-inch Ajax forging machine, using the dies and tools illustrated. The construction of the gripping dies is rather unusual and interesting. The lower impression in the dies consists of two movable members *C* which slide on four rods *D* and are provided with tongues *E* which fit in corresponding grooves in the movable and stationary gripping dies. The pins, of course, act as mediums for holding these sliding members *C* in the gripping dies. The blocks *C* are kept out against the adjustable lock-nuts *F* by open-wound coil springs *G*.

The method of operation is as follows: The stock is first heated for a portion of its length to the correct temperature, then placed in the upper impression of the stationary die, being located in the correct endwise position by the stop of the machine. The machine is then operated and when the movable die closes on the work, it grips it and at the same time forces the heated end of the stock around pin *H* held in the stationary die. Just as soon as the dies close tightly on the work, punch *I* comes in contact with the bent end of the bar and forms it around the pin *H*, bending the work into the shape shown at *A*. The dies now open and the work is removed and placed on the pin forming the center portion of the impression in the blocks *C*. The machine is again operated and as the dies close, the ram *J* advances and forces the blocks *C* forward, carrying the "eye-end" of the work along with it.

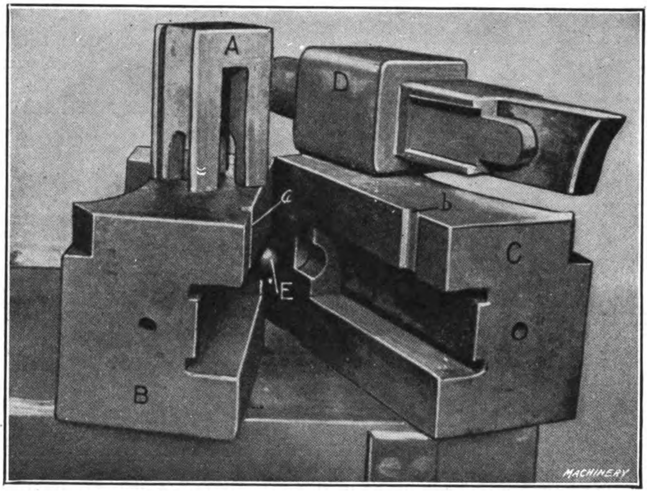


Fig. 12. Dies and Tools used for forming a Driver Brake Adjusting Rod Block in a 5-inch Forging Machine

Now as both parts of the bar—"eye-end" and body—are rigidly held in the gripping dies and movable blocks *C*, it is evident that the part of the bar at point *K* must be upset. The result of this displacement of the stock causes the formation of a shoulder on the bar at the base of the eye, formed by the circular impression *M* in the blocks *C*. The amount of stock required to form the boss at the base of the "eye" is governed by the position of the locknuts *F*. The ram *J* and gripping dies are made from steel castings. The four compression springs *G* are 10¾ inches long when extended, of ¼ inch pitch; 5/32-inch diameter wire is used and the outside diameter of the spring is 1 3/16 inches.

Dies and Tools for Forming a Driver Brake Adjusting Rod Block. A difficult forming operation accomplished in the forging machine is shown in Fig. 12. The part *A* is a driver brake adjusting rod block, used on freight cars. It is made of wrought iron and is completed in two blows in a 5-inch Ajax forging machine. The method of procedure in making this piece is first to cut a piece of rectangular bar iron to the required length and then bend it into a U-shape in the bulldozer. It is then taken to the furnace where it is heated to the proper temperature, and a "porter"

Fig. 13. A Heap of Finished Forged Coupler Pocket Filling Blocks

bar, about 3/4 inch in diameter, is also heated. This is joined to the bent piece (which is to form the block) and the latter is placed between the gripping dies, the bar being used simply as a means of handling. The dies shown at *B* and *C* are provided with half-round impressions shown at *a* and *b* through which the "porter" bar projects. As the machine is operated, the front end of plunger *D* cuts off the "porter" bar and forces the bent piece into the impressions in the gripping dies. While the piece is still held in the dies, the machine is again operated and the work given a second blow, this, of course, all being done in the one heat. The round-ended plug *E* at the end of the impression in the stationary die forms an impression in the end of the block, and serves as a spot for a subsequent drilling operation. Work of this character demands a forging machine in which a rigid gripping mechanism is provided, if excessive fins on the work are to be avoided. The reason for this is that the plunger, in forcing the metal into the dies has a tendency to separate them.

Fig. 13 shows a forging made in practically the same manner as that illustrated in Fig. 12. This part, a coupler pocket filling block, is used on freight cars by the L. S. and M. S.

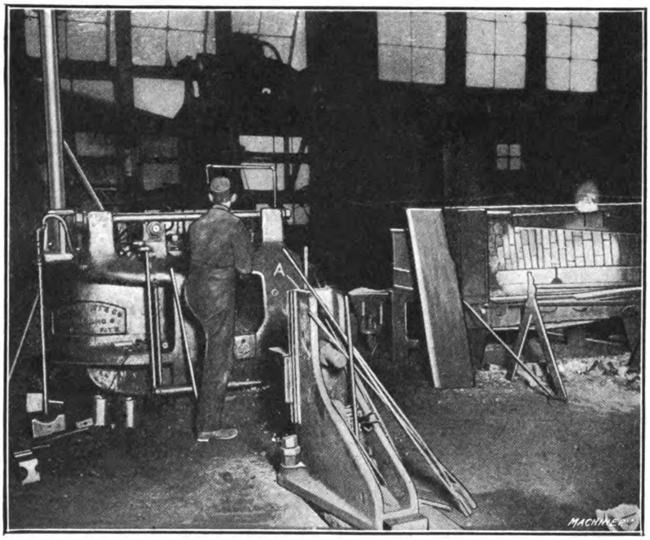


Fig. 14. Ajax 5-inch Forging Machine set up for making Coupler Pocket Filling Blocks for Freight Cars

Railway, and is made from scrap arch bars cut up into pieces of the desired length. These pieces are first formed into a U-shape in a bulldozer and are then brought to the furnace shown to the right in Fig. 14. Here they are heated to the desired temperature, then gripped with the tongs and placed on the shelf of the back stop *A*. The forging machine operator then lifts the piece from the shelf by means of a "porter" bar, and places it between the gripping dies, where the forging is given two blows and then thrown down in the sand to cool off. Fig. 13 gives some idea of how this coupler pocket filling block is produced. The piece of arch bar which has been formed to a U shape in the bulldozer still forms the end of the block, the sides or webs being formed by bending in the arch and lapping up the open ends. This can easily be seen by referring to the piece *A* in the illustration, where the joint formed in this manner is clearly shown. The burrs formed on these pieces are removed in a subsequent operation.

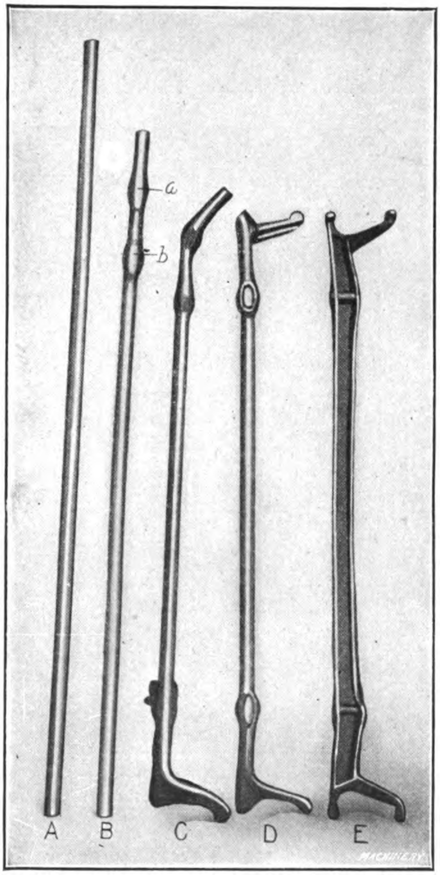


Fig. 15. Sequence of Forging Operations on the Automobile Front Axle

Forging an Automobile Front Axle. The making of the Ford automobile front axle by forging machine methods is an excellent example of the general adaptability of the upsetting and forging machine to the manufacture of miscellaneous parts from carbon and alloy steels. When used in conjunction with a steam hammer or bulldozer, there is practically no limit to the range of work which can be successfully handled. One development in forging-machine methods of unusual interest to many manufacturers is the application of forging machines to the welding of machine and engine parts. This in many cases permits the utilization of scrap metal, thus converting practically valueless material into expensive machine parts. Some interesting forging operations employed in the production of the Ford front axle and other parts, will be described in the following:

In Fig. 15 is shown a series of operations performed in the 3½-inch "National" forging machine shown in Fig. 16, the work being the front axle for the Ford automobile. This front axle is made from a vanadium steel bar 1⅜ inches

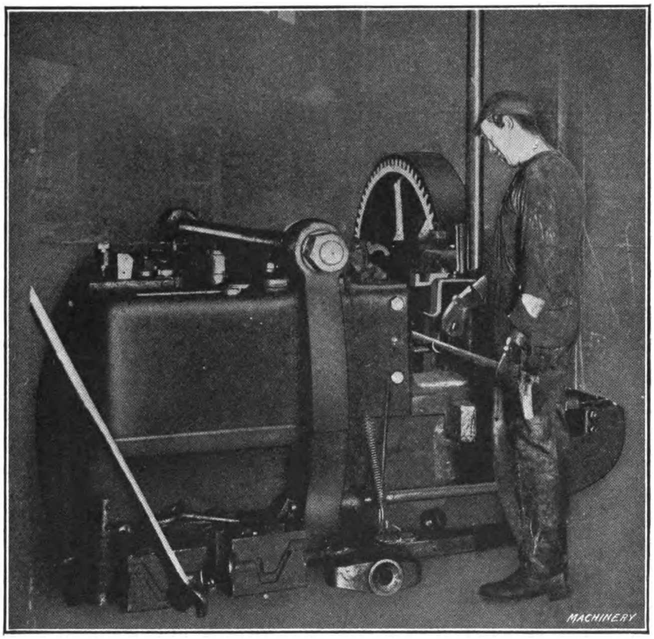


Fig. 16. National 3½-inch Forging Machine used for the Preliminary Operations on the Automobile Front Axle

in diameter by 67¾ inches long, as shown at *A* in Fig. 15. The first forging operation consists in forming the two bulges *a* and *b*. Both ends of the bar are formed in this manner, but in separate heats. This operation, which is also indicated at *B* in Fig. 11, shortens the ends of the bar from a length of 16⅛ inches to 13½ inches, which means that 2⅝ inches of stock is put into the bulges. The forging machine dies for performing this operation are shown

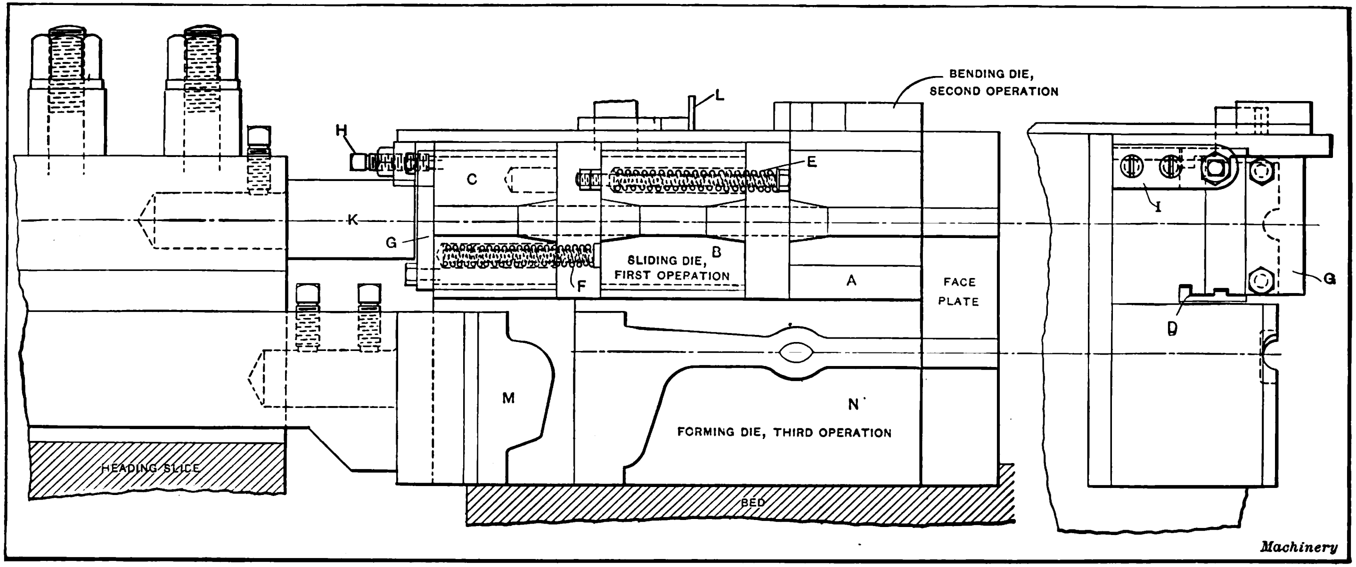


Fig. 17. Construction of Dies and Tools used in Forging Machine for making Automobile Front Axle

in Fig. 17, the bulging being accomplished in the top members. In order to form both bulges at once it is necessary to have the top members of these dies constructed in such a manner that the blocks carrying the impressions are free to slide forward when acted upon by the plunger held in the ram of the machine.

As will be seen by referring to this illustration, one half of the larger bulge is carried in block *A*, while the other half of the impression is carried in the sliding block *B*. In the opposite end of the sliding block *B* is provided one-half the impression for the smaller bulge, the other half being formed in the sliding block *C*. The sliding blocks *B* and *C* are held by tongue plates *D* to the main body of the top forging die in which they are free to slide. They are held in their outward positions by coil springs *E* and *F*. Coil spring *E* is carried on a stud held in sliding block *B*, while coil spring *F* is carried on a stud screwed into block *B* and fitting in a clearance hole in sliding block *C*. The stock when heated to the correct temperature, is located in the proper position in the dies by block *G*, which is fastened by cap-screws to block *C*, and covers the hole in the dies as indicated in the end view. Block *C* is located in its proper "out" position by adjusting screw *H*, held in block *I*, fastened to the top member of the die.

The stock which has been heated for a distance of about 18 or 20 inches is placed in the impressions in the upper member's of the stationary gripping dies. The machine is then operated; the gripping-dies hold the work rigidly, while plunger *K* advances and forces sliding block *C* forward until it is in contact with block *B*. The forward movement of the ram continues until block *B* is forced up against block *A*, when the ram recedes, the dies open, and the forging is removed. It is evident that as the work is held rigidly between the opposing faces of the gripping dies, the advance of these sliding members upsets the excess metal and expands it into the impressions provided in the dies.

The next operation on the front axle, which is indicated on the top of the axle at *C* in Fig. 15, and also at *C* in Fig. 11, consists in bending the end around in order to locate the material in the required position for forming the knuckles of the axle. This operation is handled in the dies shown in Fig. 17, that member which accomplishes the work being formed on the top face of the top members of the dies. The bar which is still in its initial heat, is laid on top of the dies and in contact with the stop gage *L*. The machine is then operated, and as the dies close, the impressions formed on the projection of the top die twist the end of the bar around and form it to the desired shape.

The bar is now placed in the furnace and again heated to the proper temperature. Then it is brought to the forging machine and placed in the lower impression in the gripping die shown in Fig. 17. The forging machine is then operated, and as plunger *M* advances, it upsets and forces the work into the impressions in the lower gripping dies *N*,

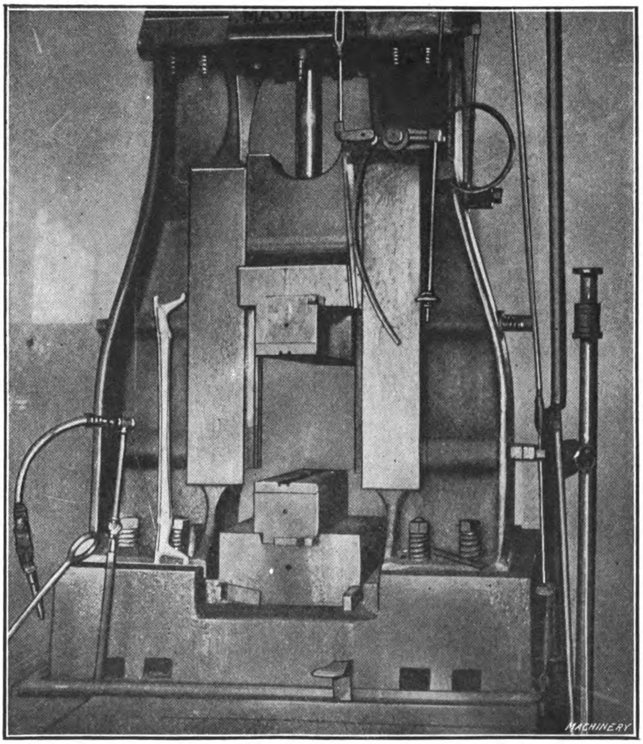


Fig. 18. "Massillon" Steam Hammer used for bringing the Automobile Front Axle to Final Shape

forming the front axle to the shape shown at *D* in Figs. 11 and 15. This completes the operations on the front axle which are handled in the forging machine. After one end of the bar has been formed to the desired shape, the other end of the bar is heated and passed through the same operations. Before the front axles are passed on to the final drop-forging operations, the burrs and fins formed in the forging machine dies are removed.

The final forming of the front axles is done under a steam hammer of the type shown in Fig. 18, the dies illustrated in Fig. 19 being used. Only one end is completed at a time; this will be seen by referring to the dies shown in Fig. 19. The axle is heated for a little over one-half its length and is placed on the lower die in the steam hammer. The oper-

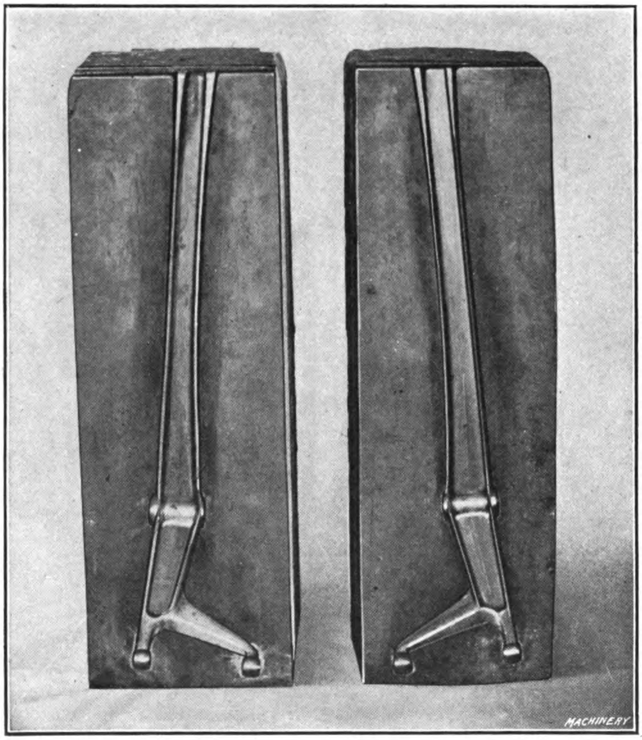


Fig. 19. Upper and Lower Dies used in Steam Hammer shown in Fig. 18 for finish-forming the Automobile Front Axle

ator is careful to locate the end of the bar so that the stock to form the knuckles is in the proper position in relation to the impression in the die before the first blow is struck; then ten successive blows are struck and the axle is removed and taken to a punch press holding a shearing die which removes the fins. It is then brought back to the steam hammer given a final blow and laid down to cool off in the sand.

After one end of a batch of front axles has been finished in this manner the other end is heated and carried through the operations described. The axles are then again taken to the furnaces, heated and placed in a fixture held in a

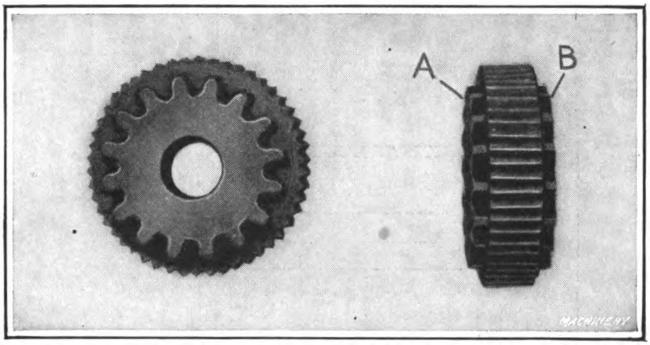


Fig. 20. Steel Disk with Forged Pinions

punch press, where they are stretched to the exact length—52½ inches.

Forming Dies for Special Steel Pinions. The making of steel disks like the one shown in Fig. 20 involves the use of forming dies of interesting design, such as were developed

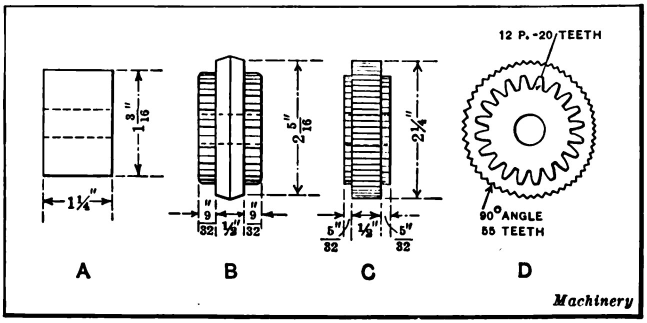


Fig. 21. (A and B) Blank before and after forging. (C and D) Finished Pinion

at the Craftsman Tool Co.'s plant, Conneaut, Ohio, where these parts are made in large quantities. Cold-rolled bar stock which is drilled and cut into blanks of the dimensions shown at *A*, Fig. 21, is used in making the disks. After the

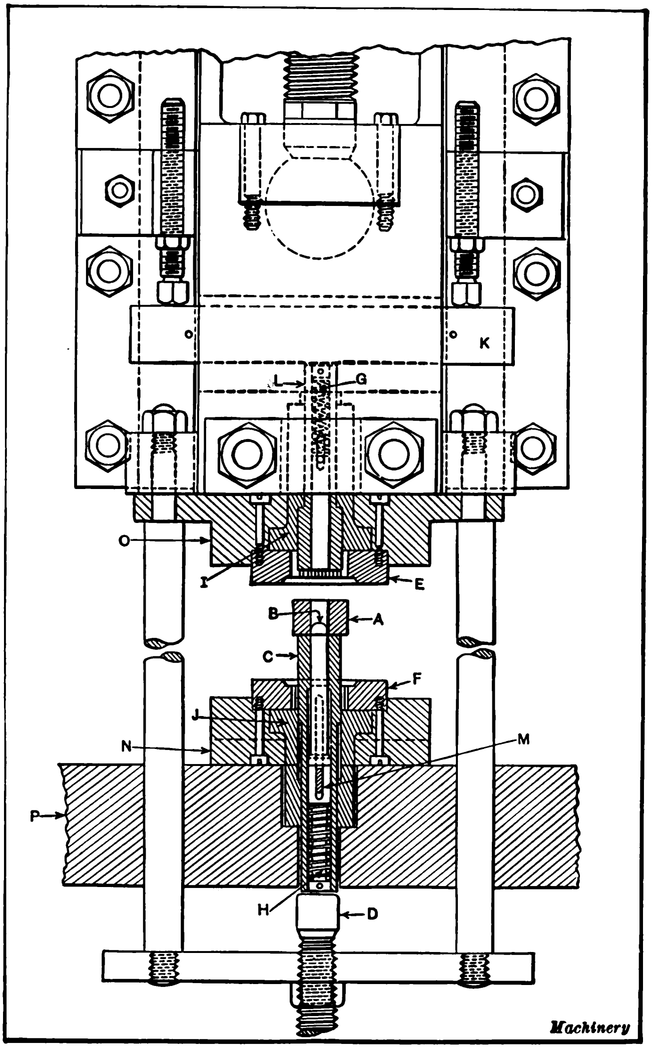


Fig. 22. Special Dies for forming Pinions

blanks have been heated to a high forging temperature, the pinion sections of the disks (*A* and *B*, Fig. 20) are formed in a back-geared forging press equipped with the special forming dies shown at *E* and *F*, Fig. 22. The condition of the blank as it comes from the dies is shown at *B*, Fig. 21.

After the forging operation has been completed, the blanks are faced to obtain the correct thickness. The saw teeth on the circumference of the disk are then milled in an automatic machine, using a forming cutter which cuts five teeth at a time. In Fig. 21 the principal dimensions of the finished disk are shown in the views of the side and face, at *C* and *D*, respectively.

The tooth sections, or pinions, *A* and *B*, Fig. 20, are formed in special dies which are constructed from steel bolster plates and bored out to receive high-speed steel forming dies *E* and *F*, Fig. 22, in which the internal teeth which form the pinion teeth of the disk have been cut. The upper and lower plungers *L* and *C* serve as strippers for the upper and lower dies. These plungers are constructed to allow for adjustment, and this feature enables the dies *E* and *F* to be ground upon their faces when the teeth become so rounded at the end as not to form perfect teeth in the pinions. Thus the cost of renewal is kept at a minimum.

In operation, the blank *A*, which has been previously brought to a high forging heat in a furnace, is placed over the pilot *B* so that it rests on the end of the lower plunger *C*. As the slide of the press moves down plunger *C* and the knock-out rod *D* both travel downward, while the pilot *B* is held stationary by means of a key *M*, which is driven through and securely held in socket *J*, and which passes through the slot in plunger *C*. The downward movement of plunger *C* is caused by the action of spring *H* which, being held in compression by a pin through the lower end of the plunger, is allowed to expand when the knock-out rod *D* is moved downward. This action, of course, forces the plunger *C* down against the end of rod *D*. The downward stroke of the press slide brings the two high-speed steel dies *E* and *F* nearly in contact, thus squeezing the hot metal blank *A* into the dies and forming the pinion teeth, as shown in Fig. 20. The springs *G* and *H*, shown at the upper and lower ends, respectively, of the plungers, serve to prevent excessive shock when striking against the shoulders in sockets *I* and *J*, that is, the springs *H* and *G* force the plungers to become seated in the sockets before the forming operation takes place. On the upward stroke of the press slide, the knock-out rod *D* comes into contact with plungers *C*, which strips the blank *A* from pilot *B*. To prevent the blanks from occasional sticking in the top die *E* on the upward stroke, the top knock-out *K* is so located as to come into contact with plunger *L*, thus forcing the blank from die *E*. When the blank comes from the press, the center hole is in perfect condition due to the accuracy of pilot *B*. Dies *E* and *F* are held in steel die-bolsters *O* and *N* by dowels and cap-screws. A heavy bed-bolster *P* is used to support the bottom die-bolster, and the top die is attached to the press slide.

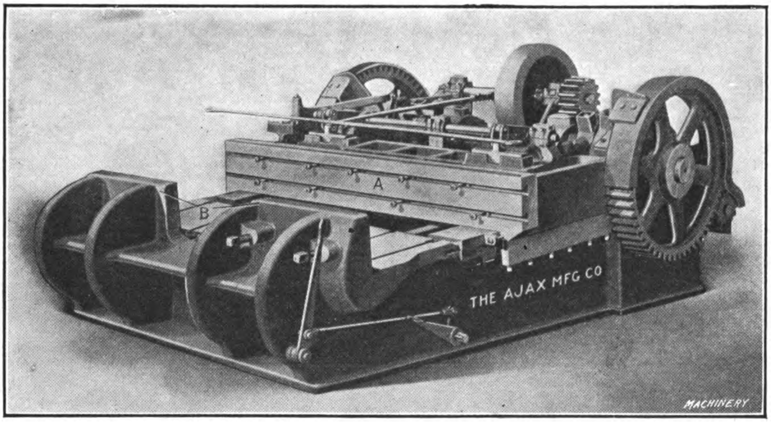


Fig. 23. No. 7 High-speed Bulldozer—an Adjunct to the Forging Machine

The Bulldozer. The bulldozer is especially adapted for bending operations and is closely allied to the forging machine; in fact, many operations can be done successfully on forging machines only when the bulldozer is used for performing a preliminary operation. This type of machine contains a cross-head which carries one member of the forming dies; the other member of the dies is held against a die-seat which is formed integral with the main base of the machine. The stock to be formed is placed between the dies and, as the cross-head moves forward, the stock, which may or may not be heated, is bent to the shape of the dies.

One design of bulldozer is shown in Fig. 23. The machine consists primarily of a moving cross-head *A* which carries one member of the forming dies, the other member of the forming dies being held against the "toes" *B* of the machine. The operations are accomplished by the forward travel of the crosshead, the work as a general rule being completed in one travel of the head. While the machine is fairly simple in construction and operation, many types of interesting forming tools are used.

The forming tools for the bulldozer can generally be made cheaper and more conveniently from cast iron, especially when they are provided with hardened steel plates where any friction takes place—that is, those parts of the tool which actually do the forming or shaping should, as a general rule, be reinforced with hardened steel plates. This enables the tools to be renewed very cheaply, as the plates when worn out can be replaced by new blocks of steel. The

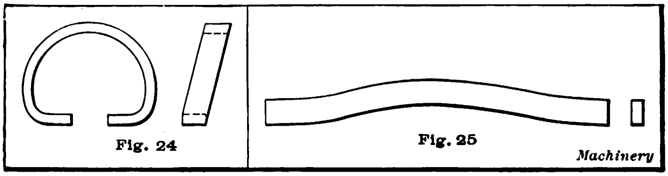


Fig. 24. The Finished Stirrup

Fig. 25. Blank after the First Operation has been performed

roller type of tool which is carried and operated by the crosshead is the best for saving material and power when it is possible to use this type. However, the type of tool to use depends largely on the shape to be formed and other requirements. In all cases where hot punching or cutting is done, high-speed self-hardening steel should be used for the working members of the tool.

Bulldozer Dies for Forming Steel Stirrups. In certain of its products, the General Electric Co. uses steel stirrups of the form shown in Fig. 24. These stirrups are made of high carbon steel of approximately $3/4$ by $3/8$ inch in cross-section. As a rather large quantity of these parts is required and as no forging machine was available, it was decided to make dies in which these stirrups could be produced on a standard bulldozer. As the dimensions must be within 1/64 inch of uniform, it was necessary to make dies that would produce work within these limits without requiring any subsequent forging which would leave hammer marks.

The sequence of operations involved in making these stirrups is as follow: A bar of steel is sheared into blanks of the required size, which are first bent to the form shown in detail in Fig. 25, this form being a development of the finished stirrup. Suitable allowance is made for the spring of the steel in order to obtain the required dimensions. The blanks are bent to the form shown in Fig. 25 between the dies *A* and *B* (Fig. 26) which are shown in the operating position, and also in cross-section in order to illustrate the construction more clearly. The die *A* is fastened to a stationary base, which is, in turn, bolted to the ways of the bulldozer and backed up by adjusting screws. It will be seen that the plates *A* and *B* overlap in order to prevent distortion of the work while it is being bent into shape. The die *B* is bolted to a supporting plate which is carried by a second plate *F* bolted to the ram of the bulldozer. The gage *G* provides for locating the blanks in the proper position.

The next step is to complete bending the work to bring it to the form shown in Fig. 24. When the ram recedes after performing the preliminary operation between the dies *A* and *B*, the work is taken out and laid edgewise on the shelves *H* and *J* of die *K*. The gage *X* provides for locating the work in the required position. When the ram comes forward, it pushes the wedge *L* against the slide *M* which travels on ways provided in the block *N*. During the first part of the operation performed in this die, the block *N* is held stationary by a locking-pin; but after the slide *M* has completed its travel, the locking-pin is released and the block *N* moves forward. A more complete explanation of this part of the work will be given in a subsequent paragraph. The slide *M* carries a form *P*, and as the slide moves to the right this form comes into contact with the work and forces it into the die *K*, thus bending the piece to a U-shape.

When the operation has proceeded to this point, the wedge *Q* located on the under side of the base pulls out the locking-pin *R* thus leaving the block *N* free to move. As the ram continues its forward movement the die *S*, which is fastened

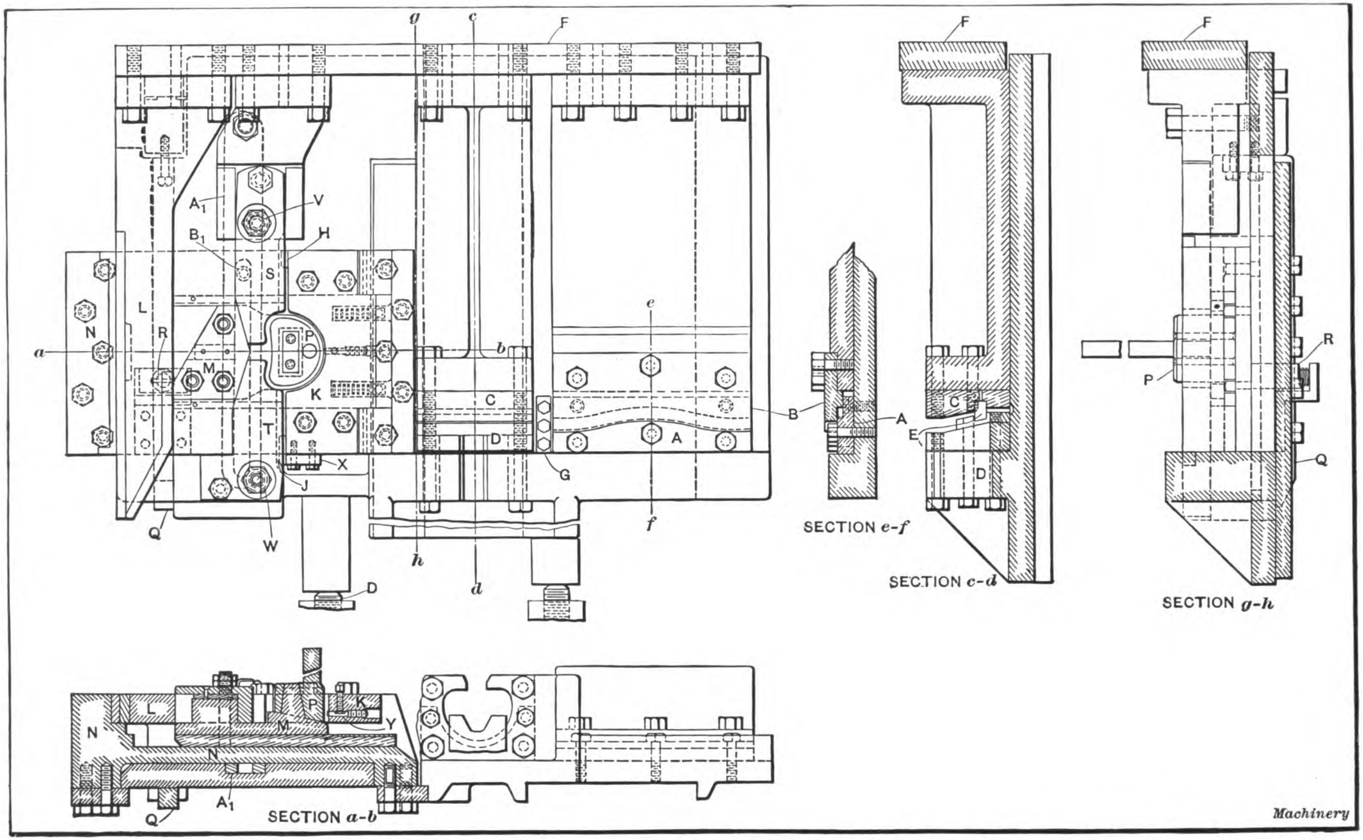


Fig. 26. An Interesting Set of Bulldozer Dies for Forming Stirrups of the Form shown in Fig. 24.

to the ram, comes into contact with one arm of the U-shaped piece on the form *P* and bends it around the form. At the same time the ram continues to move forward and pushes the slide *M* and the block *N* with it. In so doing, the other arm of the U-shaped work is pushed into the stationary die *T*, which bends it around the form *P*. At the end of the forward movement of the ram, both the dies *S* and *T* come in contact with the wedge-shaped end of the slide *M*, which forces the dies against the form *P*, thus setting the work on the form. The dies *S* and *T* are pivoted at the points *V* and *W*, respectively, to enable the dies to be moved by the tapered surfaces on the slide *M*. While this forming operation is being performed, the work is pushed against a stamping device *Y* set in the die *K*, which produces the necessary marking on the part. When the ram returns, the die is released and the slide *M* is pushed back by the springs in the block *N*; then a link draws the block *N* back.

The form *P* is now taken out of the slide with the work in place around it. The third operation consists of setting the work in the dies *C* and *D*. The purpose of this operation is to overcome the elastic limit of the material so that the piece will be set to exactly the required form. After this final operation has been completed, the form is pushed out of the work by means of the ejecting-pin *E*, leaving it in the shape shown in Fig. 24.

CHAPTER V

WELDING IN THE FORGING MACHINE

THERE are three methods in general use for welding or joining pieces in a forging machine. The selection of the one to employ depends largely on the shape of the work and other requirements. The most common method in general use is lap-welding, of which there are several applications. The next in importance is pin-welding. Butt-welding is as a rule used only where it is impracticable to handle the work in any other way.

In regard to the materials that can be handled, wrought iron can be very readily welded in the forging machine, and when proper care is taken this can be successfully done without resorting to the use of fluxes, except in unusual cases. Machine steel does not weld so readily as wrought iron, and usually it is advisable to use a welding compound on the faces of the parts it is intended to join. The following ingredients make a satisfactory flux for steel welds: To one part of sal-ammoniac add twelve parts of crushed borax. Heat slowly in an iron pot until the mixture starts to boil, then remove and reduce to a powder. Then apply the powder to the welding faces of the work shortly before removing it from the furnace, putting the work back in the furnace for a short period after applying the flux. Alloy steels, while they can be worked successfully in a forging machine, cannot be successfully welded. As a rule, parts made from alloy steels can be worked into shape only by upsetting and forming.

Lap-welding and Forming Operations. A simple example of lap-welding in conjunction with a forming operation is shown on the Ajax forging machine, Fig. 1, the various steps in the making of a draw-bar hanger being illustrated at *A*, *B* and *C*. The first operation consists in cutting a 2¼-

by ¾-inch bar of wrought iron to a length of 19¾ inches—this allowing a sufficient amount of excess material to form the two bosses, one on each end. The bar is then heated in the furnace and placed in the side shear of the machine as shown at *D*. The forging machine is now operated and the tools held on the side shear arrangement partly cut off the bar and bend the nicked end around about one-quarter turn. It is then removed from the machine, placed on an anvil, and the bent end lapped over as shown at *B*, after which it is again put in the furnace and heated to the proper temperature; it is then removed and placed in the lower

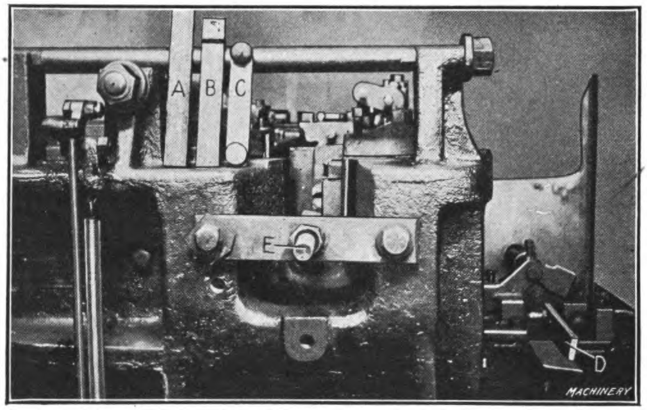


Fig. 1. Making Draw-bar Hangers in a 3-inch Forging Machine

impressions in the gripping dies, being properly located for length by the back stop *E*. The machine is then operated, completing the weld and forming the upset square boss on one end of the bar in one blow. After performing the operations described on all of the bars the other end is handled in practically the same manner, using the upper impressions in the gripping dies and subjecting the bar to three heats instead of two.

Dies and Tools for Making Locomotive Ash-Pan Handle. Fig. 2 shows a locomotive ash-pan handle that is produced in a similar manner to the draw-bar hanger shown in Fig. 1, the operations on this piece being indicated at *A*, *B*, *C* and *D*, respectively. The first operation is to cut off a bar *A* of the required length, as before mentioned, and bend one end over into the shape at *B*, putting it into the required condition for welding, forming and piercing in the forging machine. The welding and forming operations indicated at *C* are handled in the lower impression of the dies shown to the left of the illustration, the position of the work before forming being indicated by the dotted lines *E*. The lower impression is formed as shown in the end view of the dies at *F*, being provided with a draft in the impression of 1/16 inch on the diameter in order to facilitate the "flow" of the

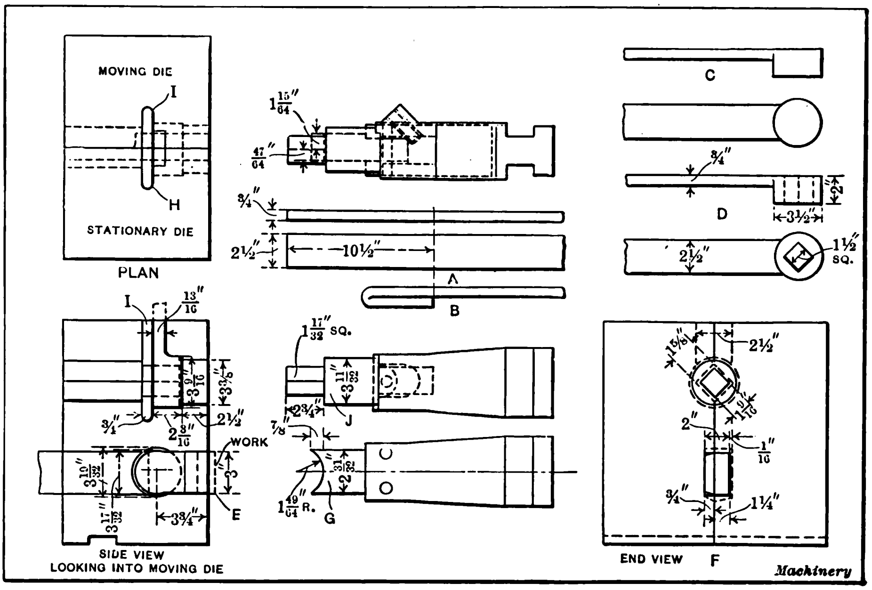


Fig. 2. Dies and Tools used in making a Locomotive Ash-pan Handle

metal and the removal of the forging from the dies. The punch *G* is made with a concave end which forms a portion of the boss and upsets the material into the desired shape at the same time.

After being welded and formed, the work is removed from the power impressions and placed in a vertical position in the upper impressions in the dies. Here the square hole, as indicated at *D*, is punched. As the gripping dies are made from steel castings, they would not stand up satisfactorily for a piercing operation, so in order to punch a clean hole two steel plates *H* and *I* are inserted in the movable and stationary members of the dies. These are so shaped that a square hole is formed when the dies come together. The hole is pierced by the punch *J*, the construction of which is shown in the illustration. Both punches *G* and *J* are made from steel forgings and hardened.

Dies and Tools for Making Car Float Stanchion Foot. Another interesting example of lap-welding which is used for the purpose of enlarging a 2-inch bar to 6 inches in diameter to form the head on a car float stanchion foot is illustrated in Fig. 3. This car part, as indicated at *A* and *B*, is made from a wrought-iron bar 2 inches in diameter, to

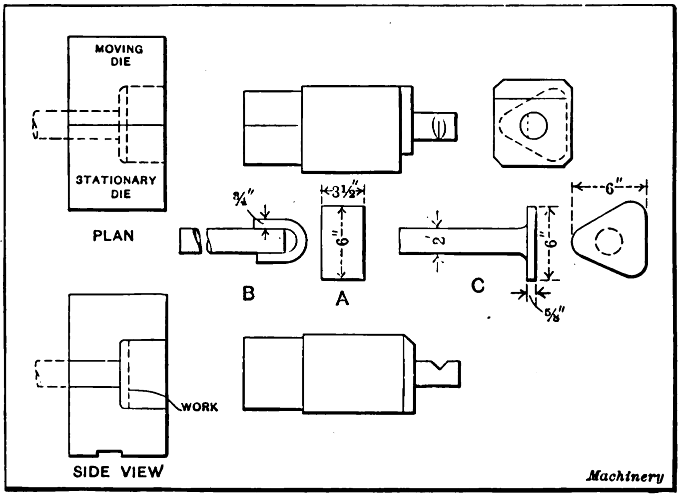


Fig. 3. Forging Machine Dies and Tools for making a Car Float Stanchion Foot

which a rectangular block *A*, 6 by 3½ by ¾ inch, is welded. Block *A* is first cut to the required length, and bent into a U-shape in the bulldozer. Then it is placed on the round bar as indicated at *B* and the two parts are put in the furnace where they are heated to a welding temperature. The parts are now quickly removed, given a tap to stick them together, placed in the forging machine, and with one blow are formed to the shape shown at *C*. The dies and tools used for this operation, which are also shown in the illustration, are of simple construction, consisting only of two gripping dies and one plunger.

Dies and Tools for Making Locomotive Spring Bands. A lap-welding operation which is handled in a different manner from those previously described is shown in Fig. 4. This piece, which is a spring band for a steam locomotive is made from a rectangular wrought-iron bar 2¼ by ⅜ by 19 inches long. It is first bent into a U-shape as indicated by the full lines at *B*, in a bulldozer. After being bent in the bulldozer, the work is again put in the furnace and heated to the proper temperature. It is then removed from the fur-

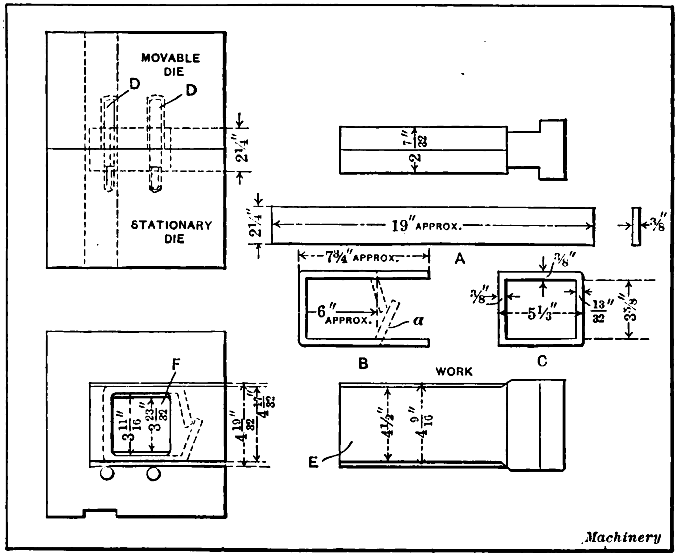


Fig. 4. Forging Machine Dies and Tools for making Locomotive Spring Bands

nace and by means of bending dies held in the side shear of the forging machine, the ends are bent into the shape shown by the dotted lines *a*—partly overlapping each other. After this operation, the piece is again placed in the furnace, heated to a welding temperature, and quickly removed and placed between the gripping dies shown to the left. The stationary gripping die carries two pins *D*, which serve as a means for supporting the work before the dies close on it. The welding and forming operation is accomplished by plunger *E*, which forms the work around the square impressions F in the dies, and at the same time welds the two ends together, forming the spring band into one piece. A particularly interesting feature about this job is the fact that the excess amount of stock formed by the overlapping ends is distributed equally along the front side of the forging, making it 1/32 inch thicker than the original rectangular bar, and thereby increasing its strength at this point.

Dies and Tools for Making Extension Handle for Grate Shaking Lever. An interesting example of lap-welding is illustrated in Fig. 5, where the dies and tools used for forming an extension handle for a grate shaking lever are illustrated. This part, as shown at A and B, is made from two pieces—a rectangular bar of wrought iron 2½ by ¾ inch, which has been sheared to an angular shape on one end, and a loop B formed from a piece of ⅝-inch rectangular bar iron bent into a U-shape in the dies illustrated to the left. The trimming of piece A and the bending of piece B is carried on at the same time with special shaped formers held to the top faces of the gripping dies. To do this, the operator first places a piece of rectangular stock of the required length in the impressions in the rear member D of the stationary gripping die; he then takes bar A, which has been previously cut to the required length and places it in the impression at the front end of the gripping die. Upon operating the machine, the moving die advances and as it carries a plunger E, it forces bar B into the suitably shaped impression in the stationary gripping die. At the same time that this operation is being accomplished, the shearing plates F and G carried in the stationary and movable gripping dies, respectively, shear off the end of bar A.

The welding of these two parts is accomplished in the lower impression in the gripping dies which hold the pieces in position while punch H advances and upsets and welds the parts together. The two pieces are placed together and put in the furnace, heated to a welding temperature, then removed and given a tap, so that they will stick together. They are then put in the lower impression of the gripping dies and the machine operated. Then as the plunger H advances it enters the loop in part B, expanding it into the

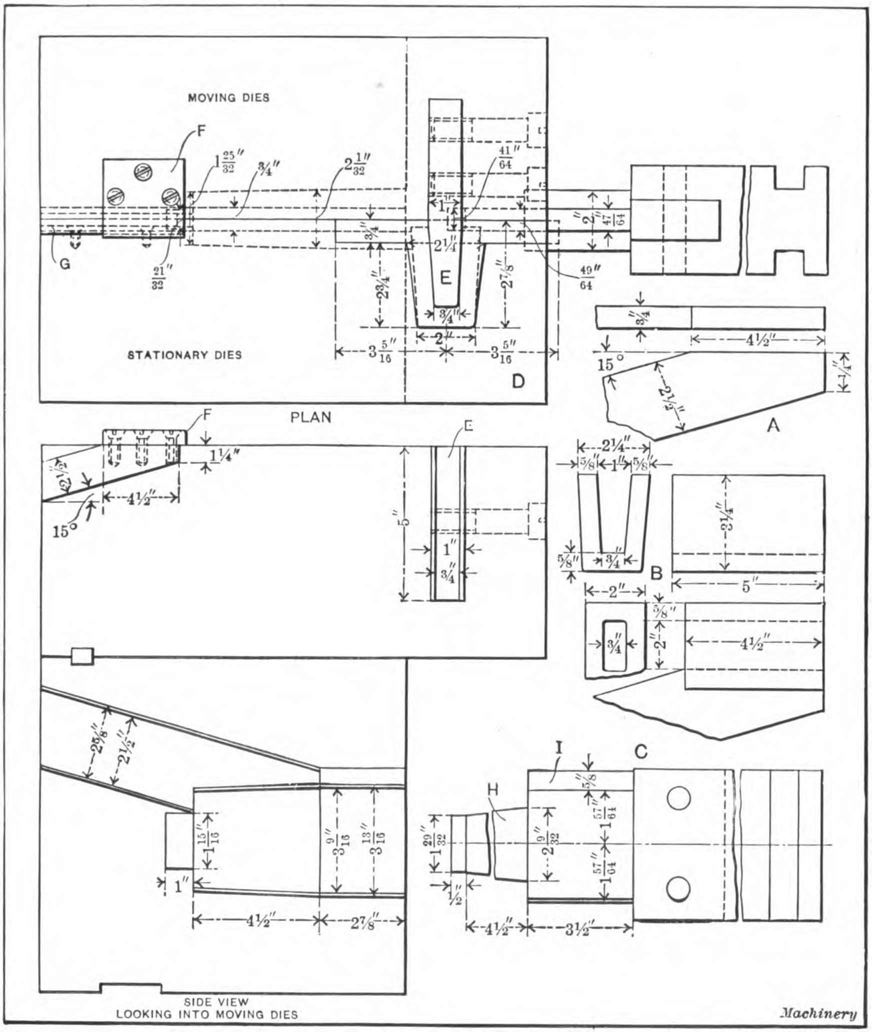


Fig. 5. Forging Machine Dies and Tools for making Extension Handles for Grate Shaking Levers

impression in the gripping dies, and at the same time, by means of the shoulder on the punch, carrying forward the excess stock and distributing it equally throughout the forging, thus joining the two parts and producing a perfectly welded joint. Punch *H* is guided when in operation by a tongue *I*, sliding in a groove in the gripping dies, and preventing side movement of the punch.

Universal Type of Upsetting and Forging Machine. The miscellaneous welded and formed parts shown in Fig. 6 were forged in the Chicago shops of C. & N. W. Railway. The forging dies and tools shown in the following illustrations constitute a few of the many interesting examples to be found in the shop mentioned. All of the examples shown in Fig. 6 were produced on the 6-inch Ajax universal forging machine shown in Fig. 7.

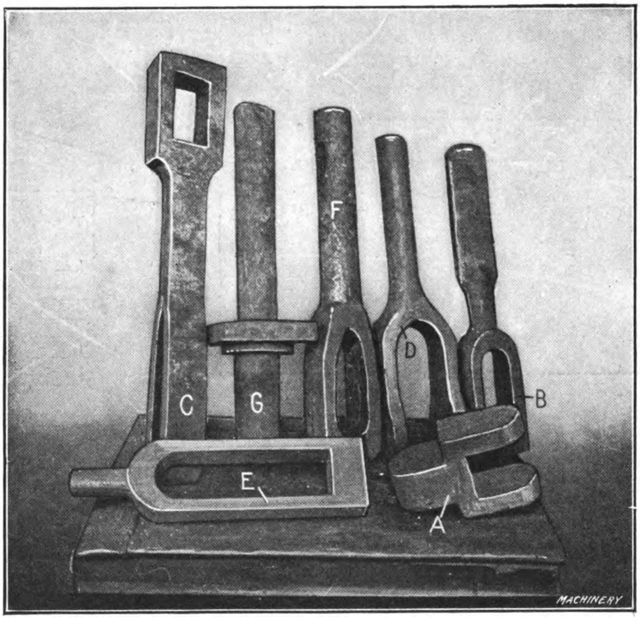


Fig. 6. Miscellaneous Examples of Lap-welding and Forming Operations accomplished on a 6-inch Universal Forging Machine

The universal type of upsetting and forging machine shown in Fig. 7 has a much greater range of possibilities for producing machine made forgings than the regular upsetting and forging machines previously described. This machine has all the features common to the regular forging machine in combination with those of a powerful vertical press operated independently of the other part of the machine. The universal forging machine is designed especially for forming such forgings as require squeezing, punching or trimming operations before or after upsetting. This often makes it possible to prepare and complete large upsets and difficult shaped forgings in one handling, and thus utilize the initial heat.

It consists mainly of a double-throw crankshaft from which are operated two header slides—one for the standard upsetting mechanism and the other for the vertical press. The upper die-holder *A* of the vertical press is op-

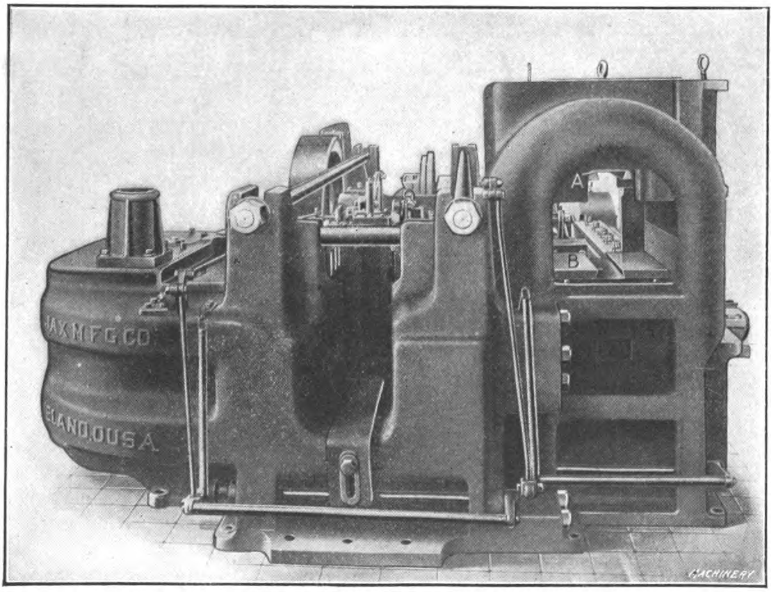


Fig. 7. Six-inch Universal Forging Machine used for making the Forged Parts shown in Fig. 6

erated by two heavy steel side links, the lower ends of which connect with eccentrics on an oscillating shaft. This die-holder is provided with means of adjustment so that the squeezing dies can be brought together or separated as requirements demand. The lower member of the dies used in this auxiliary part of the machine is held on the stationary die-holder *B*.

Dies and Tools for Making Spring Hangers. An interesting example of the utilization of scrap metal for making engine parts is the spring hanger *A*, Fig. 6. This part is made from old arch bars 1 by 4 by 5 inches with the dies and tools shown in Fig. 8. Six blocks cut off from the arch bars are piled together and riveted as shown at *A* in Fig. 9, the old holes in the arch bars serving as a means for riveting them together. This is done to hold the separate blocks in place while reaching a welding heat. After the parts have reached the proper temperature they are taken to the universal forging machine shown in Fig. 7, and placed between squeezing dies held in the vertical press. The machine is then operated, welding the pieces together

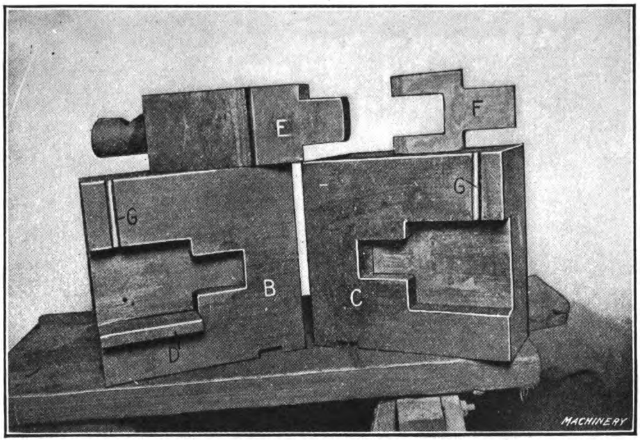


Fig. 8. Dies and Tools for making Spring Hangers in a 6-inch Universal Forging Machine

and converting them into a solid block as shown at *B* in Fig. 9.

After the separate pieces have been welded and shaped, the solid block is again taken to the furnace and heated to a welding temperature. Then it is removed and placed between the opposing faces of the gripping dies *B* and *C*, Fig. 8, these being held in the forging machine shown in Fig. 7. The stationary gripping die *B* is provided with the shelf *D* on which the heated block is placed, this serving to hold it while the dies are coming together. As soon as the dies close on the work, plunger *E* advances and displaces the stock in such a manner as to form the tail on the end of the forging *F* by simply forcing the center portion of the block back into the rear impressions in the gripping dies. This is accomplished in one heat, and when the piece is removed from the dies it is finished complete. Vent holes *G* are provided in the opposing faces of the dies to allow the excess metal to escape.

Another example of a spring hanger forging is shown at *B* in Fig. 6, the dies and tools used being shown in Fig. 10. The first operation in the forging of this spring hanger is to draw the 2-inch wrought-iron bar *A* down to the shape

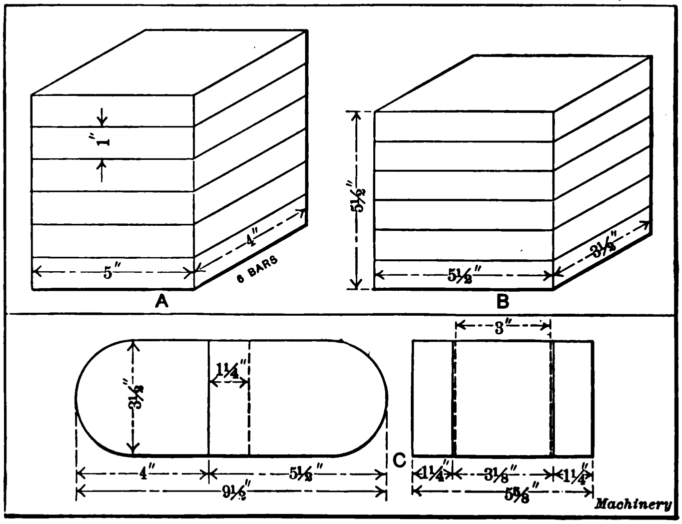


Fig. 9. Sequence of Operations on Spring Hanger shown at A in Fig. 6 and also in Fig. 8

shown at *B*, Fig. 11, in a Bradley steam hammer. This piece, after being drawn down, is heated and placed in a bulldozer, where it is bent into a U-shape as shown at *C*, the heaviest part of the piece being located at the bent end. The one-inch hole is punched through the bent end at the same time that the work is being formed. The body or shank of the hanger is made from a 1- by 4-inch piece of round edge iron *D* which is swaged down on a 4-inch forging machine to $1\frac{3}{4}$ inches round for a length of about 7 inches on one end, as shown at *E*. The bar is then heated, placed in the forging machine and upset to 2 inches in diameter in order to form completely the reinforced portion on the flat part, and at the same time reduce the end to one inch in diameter. The reduction on the end of the bar is accomplished with the plunger held in the ram of the machine.

The loop *C* is now placed on the reduced end of the rod as shown at *G* and is riveted cold, just enough to hold the two pieces together while heating for welding. The work

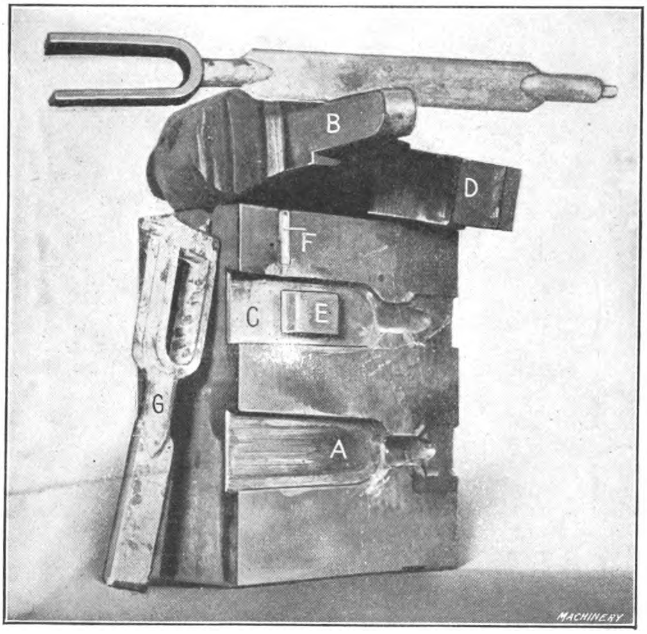


Fig. 10 Dies and Tools used in making Spring Hanger shown at B in Fig. 6—also Illustrating Pin-Welding Operation

is then raised to a good welding heat, and is quickly placed in the lower groove *A* (see Fig. 10) of the dies held in the 6-inch forging machine shown in Fig. 7, where the work is formed by the plunger *B* (Fig. 10). The reason for doing this work in a 6-inch forging machine is that the plunger travel necessary is 14 inches, and this would be impossible on a smaller machine than that having a 6-inch capacity. This 14-inch travel, of course, is after the dies have been closed on the work. After the two pieces are welded together as shown at *H* (Fig. 11) a block *a* of 2-inch square iron 3 inches long is placed in the U-end of the forging as shown at *I* and a welding heat taken. The work is then placed in the upper groove *C*, Fig 10, of the dies and as the plunger *D* advances it upsets the forging to the proper shape around the embossed center portions *E*, the excess metal flowing up through the vent holes *F* provided in the gripping dies. The finished forging is shown at *J* in Fig. 11.

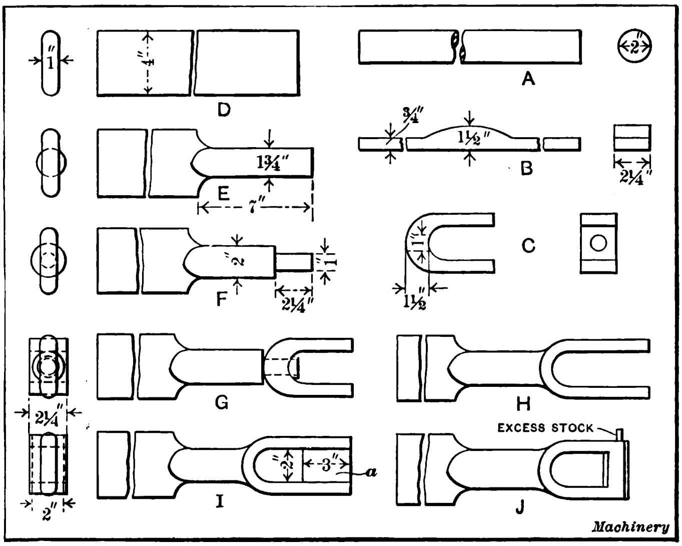


Fig. 11. Sequence of Operations performed on the Spring Hanger B shown in Figs. 6 and 10

Still another type of spring hanger which is completed in the forging machine is shown at *C* in Fig. 6. This is made from a rectangular bar of wrought iron which is first lapped over and then welded, after which the eye-end is formed to shape on the forging machine. The square hole is rough-formed by the vertical press of the universal forging machine shown in Fig. 7, and is then finished in the upper impression in the dies held in the horizontal part of the forging machine. No material is removed to form the square hole, the metal simply being expanded, increasing the width of the bar.

Dies and Tools for Making Fork End of Main Driver-Brake Pull Rod. The fork end of the main driver-brake pull rod shown at *D* in Fig. 6 is made from a 2¼-inch bar or round wrought iron which is first squeezed down flat on one end until the flattened end is 3 inches wide by 14 inches long. This operation is handled in the vertical head of the machine shown in Fig. 7. A piece of ½ by 3 by 14-inch wrought iron is laid on the flattened portion of the bar (both pieces, of course, being heated) so that they can be stuck together by the dies held in the vertical head of the universal forg-

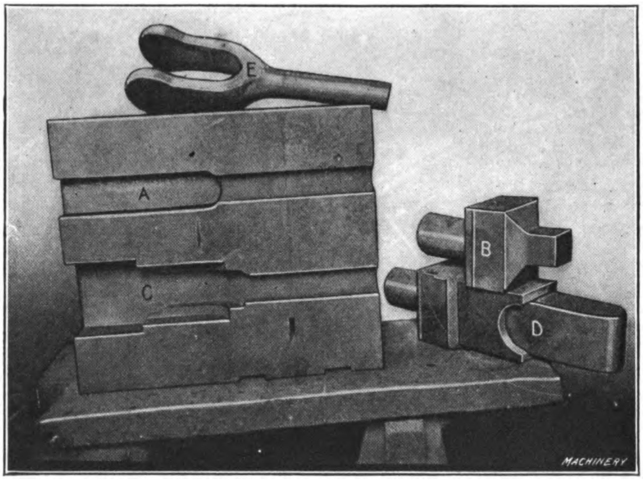


Fig. 12. Dies and Tools for making Fork End of Main Driver-brake Pull Rod shown at D in Fig. 6 in a Forging Machine

ing machine, thus holding them while the welding heat is being taken. The next step in the forging of this fork is to increase the diameter of the rod from 2½ to 3 inches square. This operation is accomplished in the upper grooves *A* of the dies shown in Fig. 12, using the plunger *B* for upsetting. The 3-inch squared end is now split for about 9 inches of its length with suitable tools held in the vertical head of the machine, and at the same time is opened up slightly. The piece is then taken to the furnace and heated after which it is placed in lower grooves *C* of the dies. One blow of plunger *D* brings it to the final shape shown at *E*.

Dies and Tools for Making Slot End of Main Driver-Brake Pull Rod. The slot end of the main driver-brake pull rod shown at *E* in Fig. 6 is made as shown in Fig. 13 from two pieces *a* of 1 by 2½-inch flat bar iron 27 inches long, one piece *b* of 3-inch square iron 3½ inches long, and one piece *c* of 2½-inch square iron 5 inches long. The two pieces *a* are clamped by a pair of tongs on the end where the block *c* is located and a welding heat is taken on the other end. The work is then removed from the furnace by the tongs

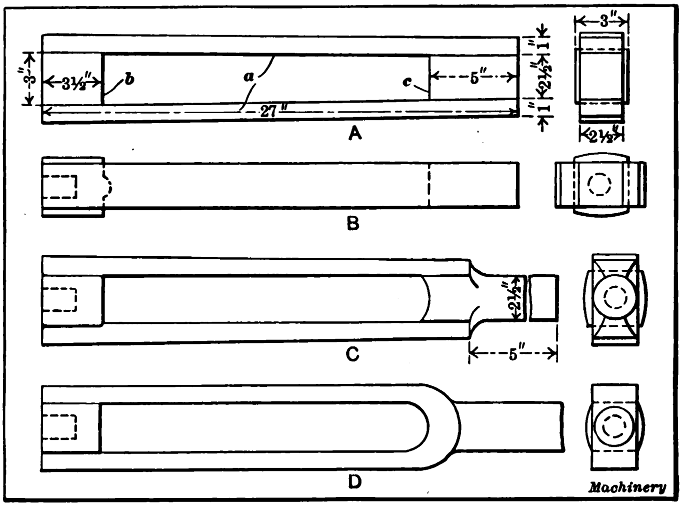


Fig. 13. Sequence of Operations performed on the Slot End of the Main Driver-brake Pull Rod shown at E in Fig. 6

and quickly place in the top groove of the dies. The machine is operated, and as the plunger, which has a punch on its front end, advances, it punches a hole in the work and displaces the stock, forming a boss on each side as indicated at *B*. The position of the tongs on the work is then reversed and the other end of the forging is heated, after which it is swaged to 2½ inches in diameter for a distance of 5 inches on this end to the shape shown at *C*. This operation is handled by the gripping dies which are provided with circular grooves located between the upper and lower impressions. The forging is again heated and placed in the lower impressions of the dies, the round part entering the plunger. The machine is then operated, forming the forging to the shape shown at *D*.

Butt-welding Bottom Connecting-Rods for Freight Cars. Butt-welding is seldom done on forging machines, owing to the difficulty generally experienced in successfully making this type of weld. The bottom connecting-rods shown at *F* in Fig. 14, are, however, produced satisfactorily by butt-welding in the Collinwood Shops of the L. S. & M. S. Railway. The stock for the forked ends *A* is sheared off from a bar of 2½ by ¾-inch wrought iron and bent to a U-shape in the bulldozer. The center portion of this connecting-rod

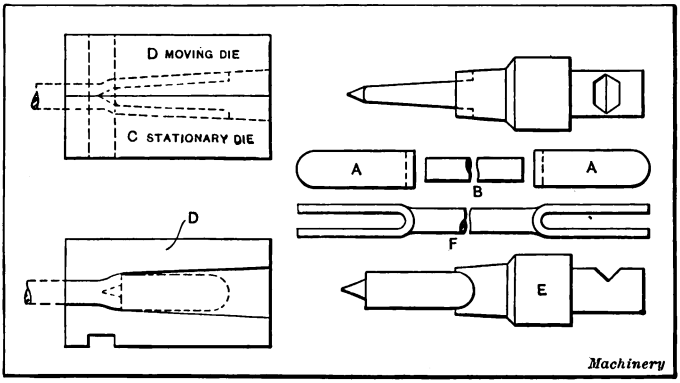


Fig. 14. Illustrations showing Sequence of Operations in the Butt-welding of Bottom Connecting-rods

is made from 1¾-inch round wrought-iron bars which are also sheared to the required length before coming to the forging machine.

The U-shaped pieces *A* and bars *B* are now placed in a furnace where they are heated to a welding temperature. The operator then removes a rod and also a U-shaped piece and butts them together; he then places the pieces which are stuck together in the impressions in the gripping dies *C* and *D*, and operates the machine. Now as plunger *E*, which has a pointed end, advances, it forces itself through the fork into the round stock, thus intermingling the grain of the material and insuring a solid weld. To prevent scale from forming on the pieces to be welded, a small jet of compressed air is made to play on them just before and while the machine is operating.

After welding, the work is removed from the gripping dies and placed between suitably shaped forming dies held in the side shear. The machine is then operated, forming the U-shaped end to the proper shape, after which the piece is thrown down in the sand to cool off. After all the rods have been completed in this manner, the other or straight end is placed in the furnace and the same procedure

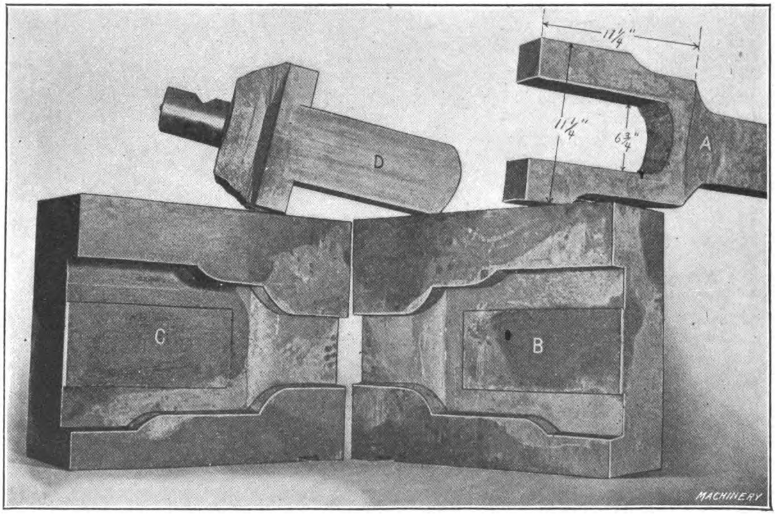


Fig. 15. Dies and Tools used in making Locomotive Main Rods in the 6-inch Universal Forging Machine

repeated. The completed bottom connecting-rods are shown at *F*. To prove that this type of weld was satisfactory, numerous tests were made to break it at the welded joints. This was not accomplished until the testing machine registered a pull of 74,000 pounds, which is equivalent to a tensile stress of approximately 30,000 pounds per square inch. As the tensile strength of wrought iron seldom exceeds 48,000 pounds per square inch, it will readily be seen that this type of weld would be satisfactory for the general run of forged work.

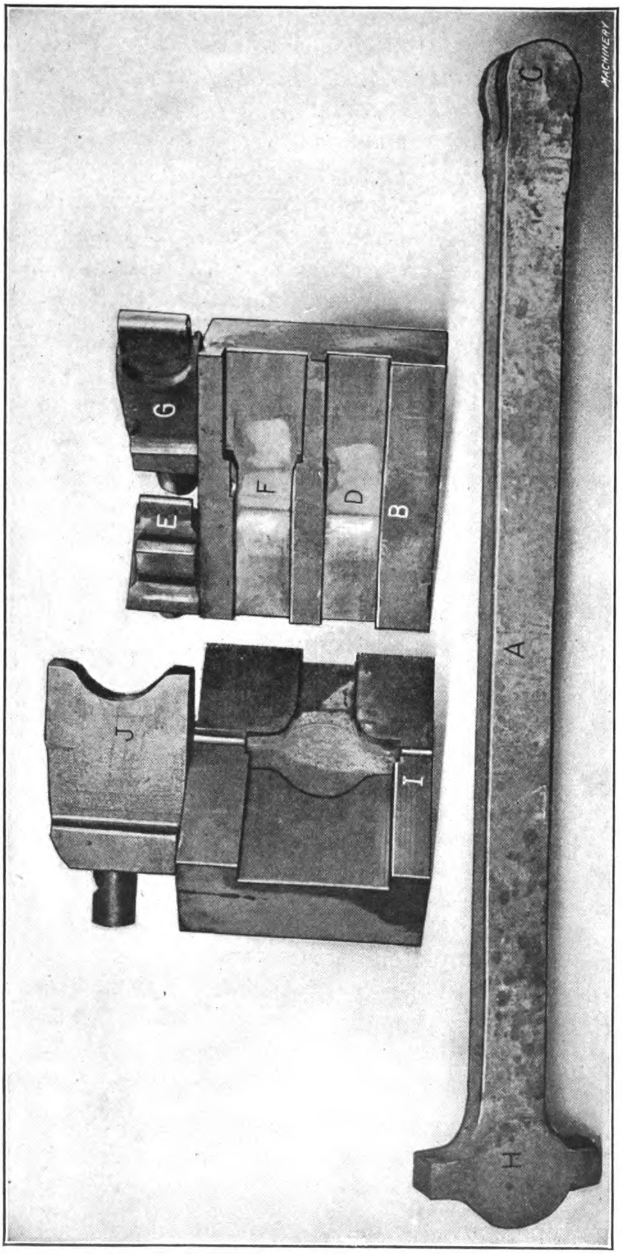


Fig. 16. Dies and Tools used in a Universal Forging Machine for making Locomotive Side Rods

Tools for Making Engine Main and Side Rods in the Forging Machine. The locomotive main rod shown at *A* in Fig. 15 is an exceptionally large piece of work made in a 6-inch Ajax forging machine in the Chicago shops of the C. & N. W. Railway. The main rod is first roughed out under a steam hammer and the end split before it is brought to the forging machine shown in Fig. 7. The roughing out of the slot and the finish-forming in the forging machine are done in one heat. In the forging machine the work is gripped by the dies *B* and *C*, and is upset and formed to shape by the plunger *D*.

Another good example of heavy forging done in the Ajax 6-inch universal forging machine is the locomotive side rod shown at *A* in Fig. 16. This side rod is made from square stock drawn down to the required size under the steam hammer and is upset and formed on each end in the forging machine shown in Fig. 7. The gripping dies, only one of which is shown at *B* in Fig. 16, are used for forming the end *C* of the rod. It requires two operations to complete this end. The first operation is performed in the lower groove *D* of the dies and consists in rough-forming the slot with the plunger *E*. The work is then placed in the upper groove *F* and completely formed to shape by means of plunger *G*.

The other end *H* of the side rod is upset and formed to shape by another set of dies—only one of which is shown at *I*. The rod, which is heated to a welding temperature, is placed in the impressions in the gripping dies and is upset and formed to the required shape by means of the plunger *J*. These two examples of machine forging illustrate very well the adaptability of the forging machine to locomotive building.

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