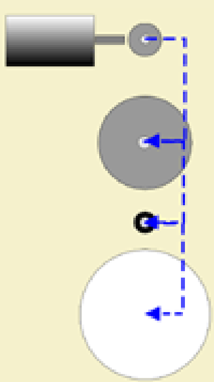
Design Notes...

Star Roller Design

Introduction:
Star rollers are a simple yet essential tool in every pyrotechnicians workshop. Rolling stars by hand in a large bowl is so tedious and slow that I find little value in the experience even for the beginner. I was personally driven away from making round stars by the experience of rolling them by hand early in my pyro endeavors, and it wasn't until I built a machine to roll stars years later that I realized what I had been missing out on. Rolling stars using a simple machine to rotate a drum full of stars is without question the most efficient way to make stars of any kind. There is good reason why the round star is preferred by manufacturers who are engaged in large scale production, such as the Chinese, Japanese and even Maltese shell builders. It is simply the most flexible and efficient star to produce compared with cut, pumped or any other method of star production.

Drive Train Calculator:

Enter values for five of the six parameters below in order to solve for the missing parameter. You can use this to calculate the required motor speed by entering all drive train diameters plus the desired bucket RPM.



Motor Speed: [ ] RPM

Pulley #1 Dia.: [ ]

Pulley #2 Dia.: [ ]

Drive Roller Dia. [ ]

Bucket Outside Dia.: [ ]

Bucket Speed: [ ] RPM

Calculate

Speed Selection:
One of the most common questions regarding star roller design is "what speed should the drum rotate?" Well, there is no magic number of RPMs that can be applied to all star rollers. This is because speed is dependent on the diameter of the rolling drum, as well as on the personal preference of the person doing the rolling. The faster you roll the stars, the faster they will pick up composition (up to a certain point anyway). But if you rotate too fast, you start having problems with stars getting thrown from the bucket. Higher speeds can also cause the star pile to slide as one big pile with no tumbling action occurring.

For a 14" diameter drum, 30 RPM works good for the range of stars beginning with cores up to about 1/2" diameter. For the 24" diameter tire roller shown on the next page, I also rotate at about this same speed. The rolling action in the 24" diameter tire moving at 30 RPM is much more aggressive than the 14" diameter drum. Since there is no concern for stars getting thrown out of my tire roller and the traction inside the tire prevents the sliding star pile problem, I can get away with a higher speed than a conventional design would allow. Note that even though both the 14" roller and the 24" roller are rotating at 30 RPMs, the 24" roller is "faster" because there is more drum wall passing under the stars each minute than there is with the 14" drum. To keep the rolling action the same for larger and smaller drums, you would have to slow down the speed as the drum diameter increases or speed up the RPMs as the diameter decreases.

You can actually figure out the desired speed for your own rolling bucket using the 30 RPM number for a 14" diameter drum given above. You have to convert this spec into a number that corresponds to the linear amount of bucket wall passing under your stars per minute, which would be 1320 inches in this case (PI x 14 x 30rpm). You can use this number to solve for the RPM of any size bucket given its diameter using the following formula: RPM = 1320/(3.14 x Dia). Keep in mind that this speed is a little on the slow side but will work for a larger range of star sizes than if you went with a higher speed.

Since most star roller designs employ a motor with a pulley on the drive shaft linked to a second pulley on another drive shaft that drives the actual rolling bucket, the drive train calculator shown above can be used to determine the size of any one component after typing in all other values including the desired RPM of your rolling bucket. The Passfire tire star roller uses this exact same drive train as well, so replacing the word "bucket" with "tire" will allow you to calculate the drive train for a tire based roller. If your star roller design has fewer pulleys, you can effectively remove pulleys from the calculator by setting two connected components to the same value. For example, if you had a 2" pulley driving a 12" pulley that was directly connected to the rolling bucket as shown in Figure 2, you would enter 2 for "Pulley #1 Dia", then 12 for "Pulley #2 Dia" and also 12 for "Drive Roller Dia" as well as "Bucket Outside Dia."

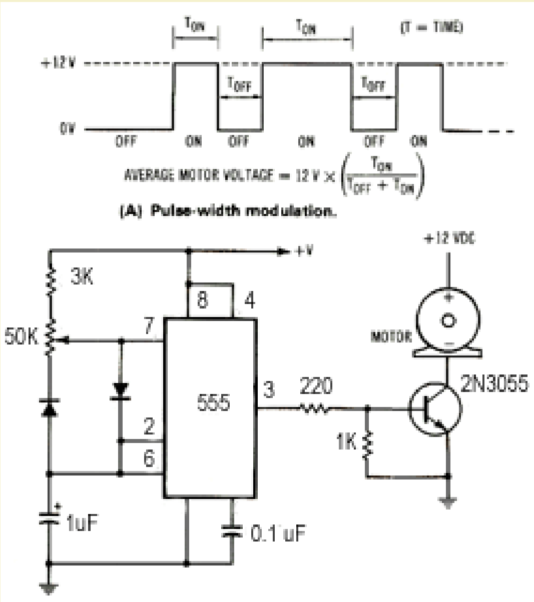


Figure 1: A simple PWM DC motor speed control circuit.

Speed Control:
The use of DC motors allows easier speed control circuitry compared with AC motors. Figure 2 shows a DC speed control circuit based on pulse width modulation (PWM), which can control the speed of a motor without losing torque at lower speeds. Trying to control motor speed by lowering the voltage applied to a DC motor will result in an undesirable loss in output torque as the speed is lowered. Since lower speeds are usually only needed when rolling large stars or large batches, this loss in torque occurs at a time when high torque is needed most!

The circuit in Figure 2 is based on a 555 timer chip, which used to be sold in any Radio Shack store in the form of an 8 pin DIP chip. The 2N3055 power transistor needs to be a TO-3 package mounted to a heat sink if you plan to build this.

The hazard with using DC motors in the presence of any pyrotechnic materials are the sparks generated by the motor brushes. An enclosed "explosion proof" type motor must be used for this application, which is a sealed type of motor where flammable materials or vapors can not be ignited by the brush sparks.

While DC motors allow easier speed control, they still require DC power supplies in addition to the speed control circuitry and are thus circuit intensive compared with AC motors, which can simply be plugged into a wall outlet. The simpler operation of AC motors, combined with the higher torque and brushless operation they feature, make them my personal preference for driving star rollers or any other kind of pyro machine. While dialed in speed control is a nice feature, it is not an absolute necessity. You will generally do most of your rolling at one speed, from cores up to about 1/2" size stars, then have a second slower speed for making larger stars. I find that using two different size pulleys on the drive shaft is all the speed control I need. The nice thing about pulleys is that they are simple, torque actually goes up at lower speeds and there are no electronic parts to assemble and maintain.

More...

Star Roller Design...

Figure 2: A simple 5 gallon bucket roller.

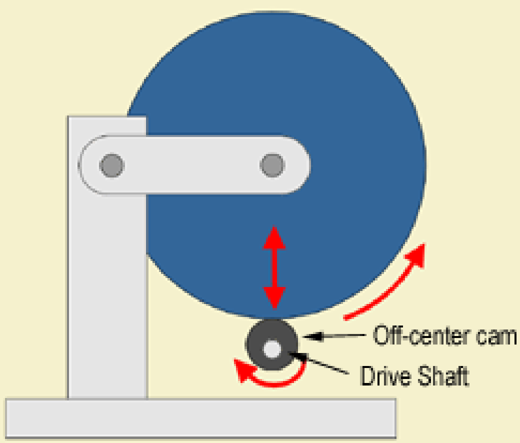


Figure 3: Off-center cam drive method of drum agitation.

Figure 4: The mechanics of a Hobby

Machine Design:
Figure 2 shows a typical home-brew roller that uses a 5 gallon bucket as the rolling drum. Note the clever use of an improvised "pulley" made from circular wooden disks behind the bucket. This allowed the designer to control his speed reduction without the need to locate what would otherwise be an uncommonly large pulley wheel. A DC gear motor can be seen attached to a sliding plate that allows belt tension to be adjusted.

Rolling buckets invariably must be fastened to a spinning back plate or drive shaft. This usually results in the fasteners sticking out on the inside of the bucket, which presents problems when rolling stars. The bucket bottom must be flat and free of protruding fasteners, otherwise the fragile stars will rub against them and become damaged. Many rollers, including the one shown in Figure 2, get around this problem by doing the actual rolling in a second bucket that is inserted into the first bucket. This double bucket method also makes it easier to remove and transport the stars when rolling is completed, since you can simply pull the bucket full of stars out and put in a new bucket. Cleaning the buckets between rolling sessions is also easier with this design. This works quite well when the rolling drum is a beveled type bucket that is actually designed to fit inside other buckets for stacking and storage. Many flower pots and plastic buckets allow this technique to be used, while most cooking pots have straight sides and will not work this way.

Another feature commonly used in many star roller designs, including the Hobby Fireworks star roller, is the use of an off-center drive shaft to drive the rolling bucket. The bucket must be mounted on a hinged arm, as seen in Figure 3, so that it is free to move up and down as it sits on the drive shaft. The purpose of this design is to create a rapid shaking motion in the bucket, which serves to bounce the stars as they are being rolled. This helps break up clumps of stars in the early stages of rolling where stars tend to get stuck to each other due to their small size. Figure 4 shows how the Hobby Fireworks roller has cleanly implemented this design. Note the use of the PVC housing on the motor as a way to create an explosion proof motor from a cheaper standard motor.

As your thirst for round stars increases, your desire to roll larger batches increases as well. This is because it takes the same amount of time to roll a given batch of stars regardless of if it is a two pound batch or a fifteen pound batch. In fact, it is actually easier to roll larger batches than small batches. For large scale production of round stars, a converted cement mixer has been a tried and true method. The mixing fins must first be removed from the drum, and

Fireworks star roller.

Figure 5: Cement mixers are popular high-volume rollers.

Figure 6: Closeup of a typical cement mixer star batch size.

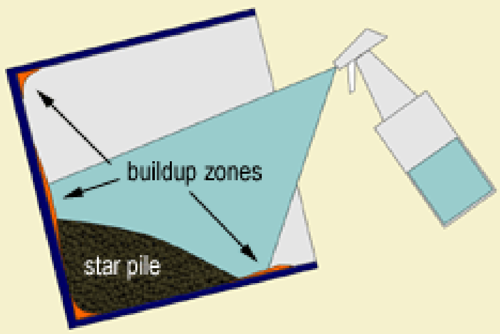


Figure 7: Common areas where composition collects in a drum type roller.

the resulting holes filled in. The mixing drum shown in figure 5 also has a seam inside the drum that must be covered with a strip of duct tape to keep powder from caking in the groove. Figure 6 shows a batch of 1/4" stars in production. Note the bolts visible at the back of the roller, which could cause problems when rolling larger stars or large batches of small stars. Be sure to select a mixer with minimal internal hardware or other crevices that will trap powder when going this route.

Conventional Roller Problems:
One of the biggest hassles with rolling stars using the type of setup shown in Figure 7 is the composition that sticks to the drum walls. This is less of a problem when using smooth metal drums, but is a big pain with many types of plastic drums. If the back of the drum meets the sides at a sharp angle, then comp will compact in this corner and slowly build up as you roll the stars. The Hobby Fireworks roller uses the cut-off bottom of a plastic 40 gallon drum, which has a nice rounded transition from side to bottom to eliminate this buildup zone.

Another cause of comp buildup occurs when the mister overshoots the star pile and wets the back and front edge of the rolling bucket. Stars do not contact the back of the drum, so the wet spots will collect loose powder and continue to build up until you scrape it off. Comp that builds up on the sides of the drum can be picked up by the stars if the buildup is sprayed directly and allowed to roll for a while. However, this technique doesn't always work and wastes time that you could otherwise spend adding more comp to the stars.

Once comp starts to build up in your roller, it will continue to grow and rob composition from your stars. If the stars can't pick it up, then you eventually have to scrape it out manually. Sometimes considerable amounts of composition will be wasted this way, or force you to pump it into comets in order to utilize your expensive materials!

Another problem that occurs in star rolling is the tendency for the small stars to work their way to the bottom of the roller while the larger stars make their way to the top. This results in the larger stars being first to receive new composition, while the smaller stars are starved. Thus the size inequity between the large and small stars continues to grow, resulting in undesirable size inconsistency that can only be controlled through frequent screening. Various techniques can be used during rolling to reduce this problem, such as stirring the pile by hand, spraying the drum wall in order to wet the bottom stars and only applying composition to the top edge of the star pile. However, all these techniques slow down the production process and still do not eliminate the need for frequent screening.

An Unconventional Roller Solution:
In my search for the ultimate star roller, I can honestly say that the simple and economical design shown in Figure 8 is also the best performing star roller I have ever used. It's the kind of simplicity that leaves you saying "why didn't I think of that sooner?" Perhaps it is a mental block that prevents us from deviating too far from conventional star roller designs that prevents this kind of thing from being discovered. Anyway, your next star roller undertaking should

Figure 8: The Passfire star roller using a tire as the rolling drum.

Figure 9: High volume and star uniformity achieved with the tire roller.

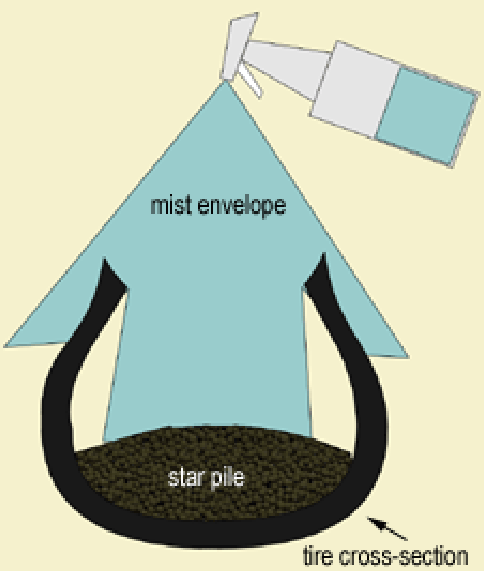


Figure 10: Tire roller greatly reduces misting the container walls.

begin at your county tire dump, because this is the future of star rolling in my opinion.

Figure 10 shows how the shape of a typical car tire helps guide your sprayer mist to the stars instead of the sides of your roller that you want to remain dry. The 24" diameter tire shown here is rotating at 30 RPM, which is pretty fast for such a large diameter roller. You can start with a cup of very small husked millet cores and have very little problems with them sticking together in the early stages of rolling. The high RPM and ribbed inner tire surface really keeps them bouncing around similar to the way the off-center drive shaft method already mentioned.

I originally believed that the ribbed inner surface found in almost all tires would be problematic and result in composition getting trapped in all the grooves. I went through great efforts to figure out a way to eliminate or fill in this pattern to form a smooth inner surface, only to find out later that the roller actually performs much better as-is! Figure 11 shows how the small ribbed texture eliminates star pile slippage, which would normally be a big problem in large diameter rollers.

The internal ribbed tire texture also tends to circulate stars from the bottom of the star pile and deposit them onto the top of the pile, as seen in Figure 11. This gets rid of the problem previously described where the small stars hibernate at the bottom while the large stars rise to the top. The stars are continually mixed by the tire roller without any effort on the part of the operator. Screening is still required occasionally to remove small stars that form on their own, but no where near as often as required with traditional star rollers. When making the 15 pound batch of 1/4" round stars seen in Figure 9, only one screening was required.

The amount of skill required by the operator to produce consistently sized stars without getting clumps in the early stages is greatly reduced by this roller. Surprisingly, problems with composition sticking to the walls of the tire are very minimal. The only noticeable problem with this type of roller is that it does tend to carry some dry comp up to the top of the tire and drop it down. The falling comp tends to drift outside the tire and collect underneath it, which means care must be taken to isolate the motor from the falling dust.

While this roller does produce slightly more airborne dust than a typical drum roller, it has the advantage of being open to air flow so that a fan can be placed behind the operator to insure that airborne dust is blown out the back of the tire and away from the operator. This works so well that outdoor star rolling can essentially be done without the need for wearing a heavy, sweaty respirator for hours on end!

This design is really nothing more than a variation of a ball mill that takes a large tire as the milling jar. It is very simple and cheap to produce, as described in full detail in this months tool tip. I produced the one shown here in just one weekend using about $80 in materials!

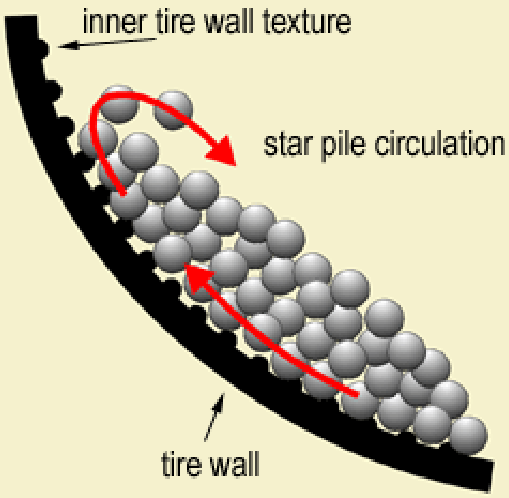


Figure 11: Textured inner tire surface eliminates sliding star piles and circulates stars from bottom of pile.

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