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Volume 4, Issue 5

Build This...

Reloadable Fan Cake

October, 2004 Issue

Build This:
Reloadable Fan Cake

Technique:
Core-less Microstars

Technique:
Mixing with Screens

Tool Tip:
Making Screens

Class C Corner:
Wreckless, Home of the Brave

Summary:
Half the work in building cake items is in fabricating the cake shot tubes and tediously fusing them together. The cake shown here uses PVC and an innovative design for creating a 25 shot fanned comet cake that can be quickly reloaded and fired again and again!

Materials:

- (25) 5" long 3/4" I.D. 100 PSI PVC pipe
- (25) 7/8" O.D. x 3/4" long dowel rod segments
- (50) 3/4" long nails or tacks
- (5) 6" long 1/4" O.D. brass tubing
- (1) 5" x 10" piece of 3/4" thick wood
- (4) 4" long strip of 3/8" x 3/4" wood

Tools:

- Drill press
- Hack saw or cutoff saw
- Band saw or jig saw
- Deburring tool
- 1/4" drill bit
- 3/32" drill bits
- Hand reamer
- Clamps
- Hot glue gun
- Vice grips or vice
- Hammer

Unmeasured Materials:
Electrical tape, PVC cement, hot glue

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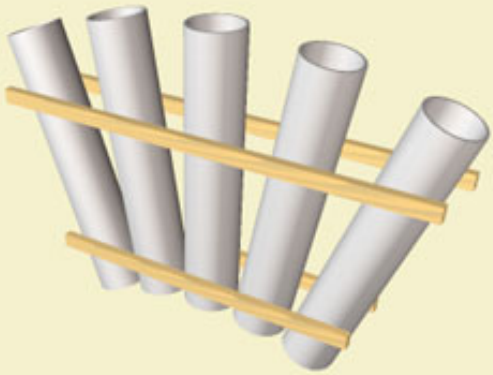

Figure 1: A conventional fanned mortar configuration.

Figure 2: A more efficient fan configuration aligned on a common axis.

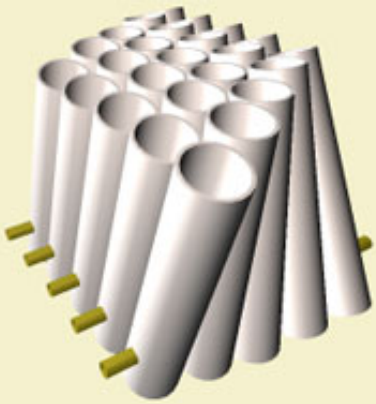

Figure 3: A block of five fanned rows.

Introduction

Firing groups of comets in a fanned formation is a great way to fill the sky both vertically and horizontally, giving a curtain of effects rather than just a central column. Achieving this effect requires two things: 1) having a group of mortars fixed at the proper firing angles and 2) making sure all the mortars fire at the same time.

Figure 1 shows how most commercial cakes construct their mortars to fire in a fanned configuration. Wooden braces or sometimes thin cardboard tubes are used to fix a row of mortars at the proper angles. Each successive row in the cake would share the braces from the previous row, such that you would have only one set of braces between each row of mortars. The shots are fused with black match that either feeds into a common piece of quickmatch running across the bottom of each row, or through just raw black match feeding in through holes directly across from each other in a straight line.

With so much manufacturing effort going into the fabrication of the mortars and their framed layout, one almost feels guilty throwing the spent carcass in the trash after use. For the hobbyist who has to do all the work constructing and arranging the mortar box himself, it is hard to justify the amount of work involved for 15 seconds of glory if the mortar box is only good for one use. It is for this reason that I have designed a fanned mortar box that is both reusable and easily reloadable, not to mention less complex, more compact and easier to construct.

While the method shown in Figure 1 works fine for commercial one-time use cake items, it presents a problem if the cake is intended to be reloaded. Once the rows of mortars are boxed together, you would have to pull them apart to get at the internal holes to re-fuse each row. Figure 2 shows the alternate configuration that makes re-fusing very simple. Instead of the mortars being aligned side by side, they are stacked onto a central piece of brass tubing that serves as a quickmatch pipe, a pivot point and a support rod. The tubing is perforated with holes that lead into each mortar, then fused by inserting a single piece of black match from end to end. The tubing is constricted at one end and ignited at the other end, resulting in instantaneous jets of fire from each passfire hole upon ignition.

The twisted arrangement shown in Figure 2 is a little unwieldy to use as a single shot fan, but when blocked together with many identical rows, they nest solidly to form a compact cake block as seen in Figure 3. The tubes are all glued to each other, so there is no need for a complex frame of cross supports.

Figure 4: A vertical bandsaw makes cutting PVC mortars fast and easy.

Figure 5: Using a deburring tool to trim the rough edges inside the tubes.

Figure 6: Drilling 1/4" fuse pipe holes 1-1/8" from bottom of pipe. Note use of stop block to eliminate the need to measure each hole location.

Rather than firing in a left-right orientation to the audience, this new method fires front to back. However, the effect looks identical to the viewer. The finished cake block looks a bit like a modern art sculpture, or perhaps a cake that was twisted up in one of Florida's recent hurricanes!

Constructing the Cake:

Like many things in pyro, building this project entails fabricating many small tubes. However, at least we won't be rolling the tubes from scratch this time. PVC makes an ideal mortar for shooting comets and other items that don't contain flash powder. Because PVC fragments into small pieces when blown apart, the rule of thumb is not to launch anything from PVC that will blow up the tube if it fails to lift.

The cake shown here is designed for 3/4" diameter loads, so a piece of 1" O.D. thin wall 100 PSI PVC works well. The inside diameter of this pipe is about 7/8", making it an ideal fit. I cut the tubes to 5" lengths, but you may up it to 6" if you want to conserve on lift powder. The longer the tube is, the more sensitive it will be to excesses in your lift measurements, which can result in comets getting blown blind if you are not careful.

This cake uses five rows of a five shot fan configuration, thus you will need to cut 25 tubes. While a pipe cutter can be used to do this, it is much faster to use a thin kerf Japanese handsaw or, even better, a vertical cutoff saw as seen in Figure 4. The one disadvantage to the sawing methods is the ragged edges left on the tubes, so some extra time will be spent sanding them and cleaning out the dust. Figure 5 shows a simple deburring tool that makes cleaning the inside edges of all the tubes quick and clean.

With all the tubes cut and cleaned up, the next task is to drill the pivot hole where the brass passfire tube will pass through. The diameter of this hole will naturally be the O.D. of whatever tubes you find to use as the passfire. I used 1/4" thin walled brass tubes from the "K&S Metal Center" displays found in some hardware or craft stores.

Figure 6 shows a drill press with a stop block clamped to the table surface, eliminating the need to measure out and mark the hole center point on each tube. The holes will need to be 1-1/8" from the end of the tube, and will run all the way through both sides of the pipe.

Once all the holes are drilled, the tubes are ready to be plugged. I used segments cut from a 7/8" O.D. dowel rod to form 3/4 thick bottom plugs. Unfortunately the dowel rods are typically undersized and have a considerable gap when placed in the tubes. This problem is overcome by wrapping each plug with about 4 to 5 turns of electrical tape, which enables them to fit snugly in place.

The mortar plugs are held in place by two small nails hammered in from opposing sides of the tube. The nails will not split the PVC or the wood plug, so there is no need to drill pilot holes. Be sure the nails are not placed directly under the passfire holes, since they would prevent the tubes from making good contact.

Figure 7: Plugging bottom of tubes with 3/4" long wood plugs cut from a 7/8" dowel rod. A snug fit is obtained by wrapping 4-5 turns of electrical tape around each plug.

Figure 8: Using two small nails to hold each plug into the tubes.

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Figure 9: One end of each 6" long brass tube is pinched closed using a vise or pliers.

Figure 10: Aligning fuse tubes in front of mortars and marking passfire holes to be drilled.

With the mortars finished, the next step is to fabricate the metal quickmatch tubes. I am using 1/4" O.D. brass tubes with less than a 1/32" wall thickness. Using tubes smaller than this makes it difficult to drill holes in the side, while going larger is not really necessary unless you plan to use some very thick black match inside. Because the black match will be completely protected from bending, I only use a single strand of thin cross matching black match to fuse the tubes. This allows one continuous piece of match to run directly through the time fuse and down the entire length of the brass tube.

The K&S tubes are 12" long, which allows you to get two 6" tubes from each one. You will need one 6" long tube for each fan row in your cake box (5 in this case). One end of each tube is pinched closed as seen in Figure 9. This is best done by placing a solid rod inside the tube, leaving a 1/4" space at the end to be crimped, then crushing the end closed in a vice. The internal solid rod limits deformation near the end of the tube that would otherwise be caused if not supported internally.

Once all the tubes are crimped at one end, line them up in front of five mortar tubes as seen in Figure 10. Use a marker to mark where the center point of each mortar falls on the tubes. Be sure to position the crimped end to the left of the last tube, since it will be located on the outside once installed.

Next you will need to drill a 3/32" diameter hole at each of the marks you made. Because the drill bit will slide around and "skate" while trying to drill the side of a smooth tube like this, you will need to indent each mark with a center punch before drilling. Figure 11 shows the fluted match pipe being drilled out.

Now you are ready to install the brass tubes into each set of five mortars. Because each tube will likely be a tight fit, it helps to ream out the passfire holes very slightly with a hand reamer as shown in Figure 12. Be careful not to remove too much material though, because you do not want air gaps that would allow hot gases to escape around the brass tubes and potentially side ignite adjacent rows.

The brass tubes are inserted into the first mortar and pulled tightly so that the crimped end wedges into the hole, as seen in Figure 13. The passfire holes are aligned so that they point toward the bottom plug where the lift powder will be sitting. The comet or other insert will be sitting on top of the brass tube when the cake is loaded.

Once all five sets of mortars are assembled, you are ready to glue

Figure 11: Drilling passfire holes with a 3/32" bit.

Figure 12: Slightly enlarging fuse pipe holes with a hand reamer prior to assembly.

Figure 13: Sliding mortars on to the fuse pipes.

them into their firing positions. This requires a set of alignment jigs to be made from scraps of wood, as seen in Figure 14. Because there are five tubes in the fan, there are three angles that need to be set. The first angle is zero degrees for the center tube, which fires straight up. The second angle is 10 degrees for the tubes on either side of the center tube, measured from the vertical position. The last angle is 20 degrees from vertical for the two outside tubes.

This is about the minimum spread that you would want for a fan. For a wider spread, an angle set of 0, 15 and 30 works good. ShowSim can be used to experiment with the appearance of various fan angles using the effect front generator. The ShowSim simulator adds random drift so that you will get a better feel for what your cake is likely to look like in real life. It is good to be sure you are setting the angle you really want before proceeding beyond this point, since it is difficult to rip the tubes apart if you change your mind later.

The three angles are measured onto 3/4" thick scraps of wood that are 2" wide by 5" tall, then cut out on a band-saw. Two additional 3/8" thick spacers are required between each angle block in order to keep the angles aligned with the mortars. These spacer blocks must be 4" tall to keep them from getting in the way. All five pieces are sandwiched together and held with a clamp as seen in Figure 14. It is not necessary to glue the pieces together, since this is only a temporary fixture for the alignment process. It is necessary to make sure that each block sits flat against the table when in use of course, otherwise your angles will be off.

Figure 15 shows how two sets of alignment fixtures are used to hold the tubes in their proper position. After making sure that each tube lies flat against the angled surface of each block, a bead of hot glue is applied between each tube to hold them together. The hot glue must be allowed to solidify before removing the tubes from the fixture. Hot glue provides a strong bond between the PVC, but also allows some flexibility that is needed when gluing the twisted rows together to form the final cake block.

It is a good idea to trial fit your five fan rows together before applying any glue, as seen in Figure 15. This helps detect any alignment errors before it is too late. The hot glue can be cut off and re-assembled if any gross alignment problems are discovered.

Lastly, PVC cement is used between the tubes of adjacent rows in order to lock the cake into one solid assembly. Care must be taken to insure that the center tube always points straight up during this process, as it is easy for the rows to skew side to side and mess up the collective alignment.

At this point the hard part is done, and the good news is that you will get many uses out of your cake before you ever have to go through this again!

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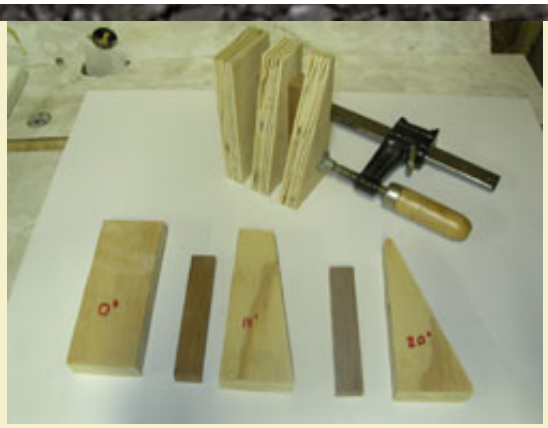

Figure 14: Building the angle fixture used to hold the mortars at the proper angles during gluing.

Figure 15: Two angle fixtues are used to align the tubes while hot glue is applied to fix them in place.

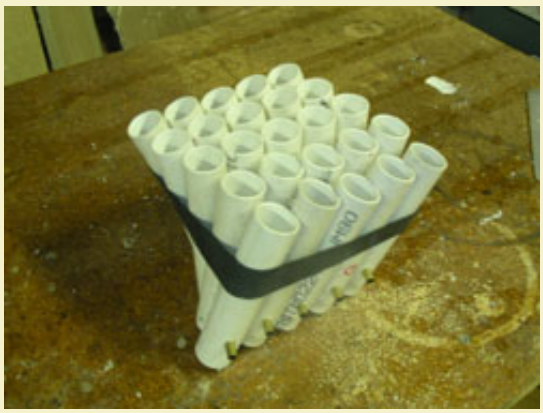

Figure 16: The five rows of angled tubes are finally banded together using PVC cement between the tubes to secure them into one solid block.


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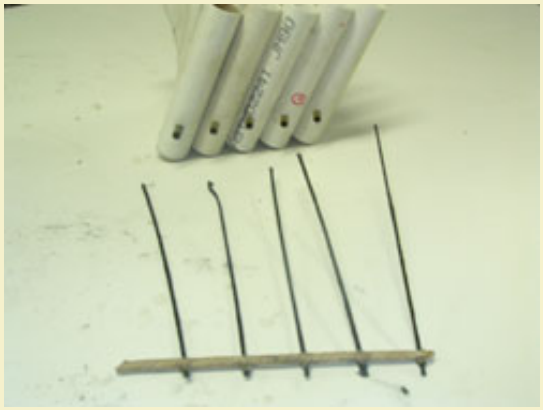

Figure 17: Crossmatching one continuous piece of time fuse.

Figure 18: Inserting parallel blackmatch sticks into brass pipes.

Figure 19: Protecting bare match joints with

Loading the Cake:
This cake is probably the easiest cake to fuse you will ever see. A single long piece of time fuse is punched and cross-matched at five locations with sticks of black match that fit all the way down the length of the brass tubes. I have used 1-1/4" spacing between the match holes for this cake, which will give about a 3 second delay between each of the five fanned shots. Leave at least two inches of time fuse extended before the first shot, which will be the ignition point for the cake.

Once the time fuse is cross-matched, the black match pieces are inserted into all five tubes at once and slid all the way in as seen in Figure 18. Strips of foil tape are then used to seal around the exposed black match to prevent cross-ignition. Be sure that there is some bare time fuse exposed between the tapped joints, otherwise hot gases from the cross-match ignition can shoot down under the tape and set off the next fuse simultaneously. Also be sure that the tape is sealed firmly around the time fuse for this same reason. The tape on the last ignition point should also cover the back end of the time fuse, since there is an exposed powder core there. If there were a Murphy's Law of fireworks, it would be "anything that can take fire, will." With this in mind, cover the ignition end of the time fuse with a piece of masking tape until it is time to fire the piece.

The best types of comets to fire from a fan cake will have very long tails, thus visually showing the fan shape from the ground up. In this example I am using silver flitter comets made using the Dixon Flitter from the formula database. This is a potassium nitrate based flitter that is considerably easier to ignite than perchlorate varieties. However, it is not as intensely bright as the perchlorate flitter formulas such as the Bleser White Flitter.

Once you have pumped the flitter comets, you will want to prime them only on one end. This is because flitter formulas burn very fast, so you want them to burn only from one end rather than from all sides at once. This at least gives you a little extra air time. It is not necessary to paste in the non primed part of the comet because it will not take fire from the lift charge.

The prime used here is ball milled meal with 5% dextrin mixed with 1 part aluminum flake per 40 parts meal. The flake can be bright aluminum, medium flitters, fine flitters-- it doesn't matter too much. The aluminum is just there to heat up the prime, and you could use other metals such as silicon or titanium as a substitute. The prime slurry shown in Figure 20 is made by adding 15 g of water w/20% alcohol to 25 g of prime. This is stirred to form a thick, muddy slurry

foil tape.

Figure 20: Slurry priming the ends of some 3/4" silver flitter comets.

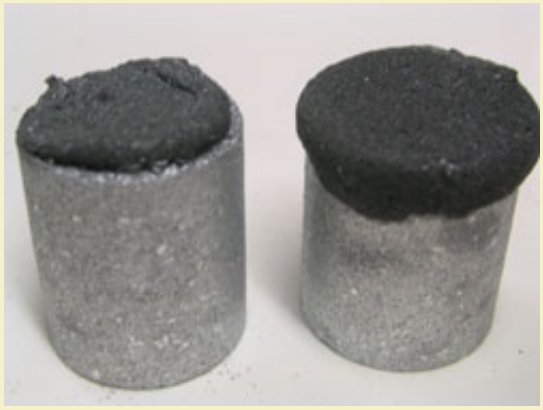

Figure 21: Inadaquate priming compared with effective priming.

Figure 22: Pushing in paper sheets to form fire protection plugs.

that the comets will be dipped into.

When dipping the comets, it is important that the prime cover the corner edges of the comets, such as shown on the right-hand comet in Figure 21. The comet primed only on the end surface in Figure 21 will fail to ignite, since fire will not reach the corner edge of the comet where ignition temperature is the lowest. The end prime is also more likely to come dislodged from the comet surface during lift than is the fully dipped example. Care must also be taken not to let the prime get so thick on the sides that the comet won't fit into the cake tubes.

These comets will require about 1.5g of 2Fg in each tube for the lift charge. This could be more or less depending on the strength of your lift as well as how tight your comets fit into the tubes.

Once all the lift charges and comets have been loaded into each tube, a 2" square sheet of 30lb virgin kraft is pressed into each tube using a 7/8" dowel rod as seen in Figure 22. If recycled paper is used then it won't be strong enough for the tight fit and it will tear. This paper plug is a fire wall that prevents sparks from one row from falling down into unlit tubes and prematurely setting off adjacent rows ("anything that can take fire, will"). The plug does not need to be pushed all the way down into the tubes if you are going to fire the cake immediately. If the cake will be transported and potentially getting turned upside down, then you will need to push the plug all the way down to insure that the lift charge does not leak around the comet and pile up on the other side where it will do no good.

Use and Reuse:
When firing the cake, the position is orientated so that the brass tubes face the audience. It is a good idea to stake the cake down to the ground to prevent it from bouncing onto its side, especially if fired on a grassy lawn. Make sure any stakes used to not fall into the line of fire of some of the angled mortars.

After use, there will be a water-absorbing black slime inside the mortars that you will need to wash out with soap and water before firing again. Before getting the cake wet, try to extract the burnt black match strings from inside the brass tubes by dumping them out. Otherwise they can get wet and be difficult to extract.

There you have it, the worlds most compact and easy to use fan cake! 🔥



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