Green Sand Casting in the Home Shop

Introduction

Do you remember how much fun it was to play in the sandbox when you were a kid? It was so much fun to take a shovel and a bucket and build castles and fortresses. Now all you can do is watch the children playing in the sandbox, unless you don't care what the neighbors think.

There is a hobby that will give you the opportunity to play in the sand again: green sand casting in the home shop. Casting aluminum at home may seem like an odd hobby, but it can be a safe way to make the metal objects that you need or want.

The process is fairly straightforward: you make a pattern of what you want to cast, then use the pattern to make a sand mold, and then pour molten metal into the mold. After the metal freezes you end up with the piece that you want. Usually. Some of the time it takes a couple tries to find the technique that works best for a particular piece.

My journey into metal casting started because I wanted a metal lathe but couldn't afford one. A man named Dave Gingery wrote a series of books in the 1980s showing how to cast aluminum and zinc, and to use the castings to build a metal lathe, metal shaper, horizontal mill, drill press, and several accessories (See Sources). After finishing the series I continued to find items that I could cast, such as decorative items, drawer pulls, and sundials.

One of the most difficult things about operating a foundry at home is obtaining the proper materials. If you happen to have a foundry supply company locally, chances are they really don't want to deal with a hobbyist (trust me on that one). They don't seem to like dealing in small quantities or they have reservations about their legal liability if you hurt yourself. And the shipping costs associated with buying items such as sand from distant vendors can be prohibitive.

That's why Dave Gingery offered alternatives to actual foundry supplies. Coarser sand can be used, and fire clay and water can be used to make green sand instead of using oil based binders. Baby powder or foot powder can be used instead of parting dust. There are a lot of alternatives available. The downside to alternatives is that sometimes the quality of your casting could suffer. But this can often be solved with a little time and a file.

Safety

Safety is very important when casting metal in the home shop. The typical injuries of any shop (cuts, bruises, foreign matter in the eyes, etc.) still pertain, but the risks of burns, fire, asphyxiation, and disease are added in.

The furnace has to be insulated from any combustible surfaces since the outside can get very hot. It also has to be operated outside since a great deal of carbon monoxide (CO) and carbon dioxide

(CO_2) will be produced. My propane furnace is installed in my garage, but I have a hood and exhaust fan to remove the CO and CO_2 to the outside.

Another danger is with spilled metal. If a crucible breaks or is dropped the metal will flow like water until it starts to freeze. If the metal ends up on something combustible it will cause a fire. It's also not safe to pour over concrete since the concrete can explode if molten metal is spilled on it. And the metal will hitch a ride on the concrete shrapnel, which will start a lot of small fires.

The material that is used most extensively is silica sand, which can contain dust. If the dust is inhaled and settles in the lungs it can eventually lead to a lung disease called silicosis. This is why it's important to use a respirator when working with dry sand.

Patterns

Making a pattern is similar to making the piece in wood, with some differences of course. The first difference is that the pattern must be made bigger than the final piece. When the metal melts it expands, and it will contract after being poured into the mold. For aluminum this expansion rate is approximately 1/8" per foot. So a piece 6" long would require a pattern that is 6-1/16" long. On smaller parts the contraction can be ignored though.

Another difference is that any vertical surface, as viewed when the pattern is in the mold, must be tapered. The taper is required to make it easier to remove the pattern from the mold. Once the pattern starts to come out of the mold it will release from the walls of the mold cavity, allowing its removal without scraping sand from the walls. A taper of 4° is usually sufficient.

The edges of the pattern also need special consideration. Where the two halves of the mold come together is called the *parting line*, even though it's actually a plane. Any edges that are not on the parting line must be rounded. Outside corners must be rounded and inside corners must have a fillet. Rounding outside corners can be as easy as sanding the edges of a wood pattern. Creating the fillets on inside corners requires a filler such as wood putty or auto body filler.

Patterns do not have to be made of any particular material. Wood is an easy material to work with, which makes it a good choice. But any material that is rigid enough to hold its shape will work. Some of the patterns that I've used are aluminum pieces that my grandfather cast in his foundry before I was born. Patterns can also be made of wax or foam, but the processes used to make castings this way is outside the scope of this article.

After the pattern is made it is sanded smooth and sealed. It is coated with varnish, shellac, or a spray-on clear coat to keep it from absorbing moisture. The green sand has water in it and an unsealed pattern will absorb the water in the sand. This will lead to a weaker sand mold if too much water is removed from the sand.

Making the Mold

For the illustrations in this article I decided to make two caps for a project that I'm working on. Figure 1 shows the patterns that I made. Each one is 1¼" wide, $2^3/_8$" long, and 1½" tall. The problem with casting this part is that there will be quite a bit of shrinkage. The shrinkage will be in the center of the top. These parts will be bored later, so I can make the mold so that the shrinkage will be in the area that will be removed, so the shrinkage will not cause any trouble.

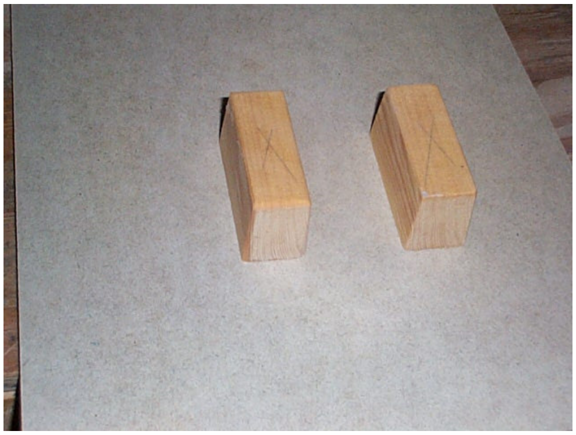

Figure 1 Patterns

The mold is made in a box called a *flask*. A flask is made with two or more interconnecting parts. Figure 2 shows a two-part flask. The piece on the left is the bottom and it is called the *drag*. The piece on the right is the top, and it is called the *cope*. When the parts are put together the *pegs* in the cope will fit into the *sockets* on the drag. This assured the flask goes together the same way each time. The edges of the cope and drag shown in the picture are where the parting line of the mold will be.

Figure 2 Flask

Since neither the drag nor cope has a bottom, boards must be used to hold the sand in the flask. The two boards in the picture are the *molding board* and *bottom board*. The only difference between the boards is that the first one I use is the molding board. All the surfaces of the flask and boards that will touch the molding sand are sealed so they will not absorb moisture.

To start the mold, the drag is placed upside-down on the molding board and the patterns are places on the board with the parting lines down (Figure 3). This places all the parting lines on the same plane.

Figure 3 Starting the Mold

Sand is then shoveled into the flask with a trowel and is rammed firmly with a *rammer* (Figure 4). The sand is built up in layers until the drag is filled. After filling the drag the bottom (which is the top at this point) is leveled off and the mold is vented. A wire is poked into the sand to make holes that will allow the air and steam in the mold to escape when the metal is poured into the mold (Figure 5).

Figure 4 Ramming the Sand

Figure 5 Venting the Sand

After venting the sand some loose sand is sprinkled on the mold and the bottom board is rubbed into the sand. The object is to have solid contact between the sand in the drag and the bottom board. If the sand does not have adequate support it will break when the cope is rammed up. This will result in a distorted casing.

When the bottom board is in place the drag is rolled over. Since the halves of a mold can easily weigh 40 to 60 pounds each this has to be done carefully. The molding board is removed to reveal the parting line of the drag (Figure 6).

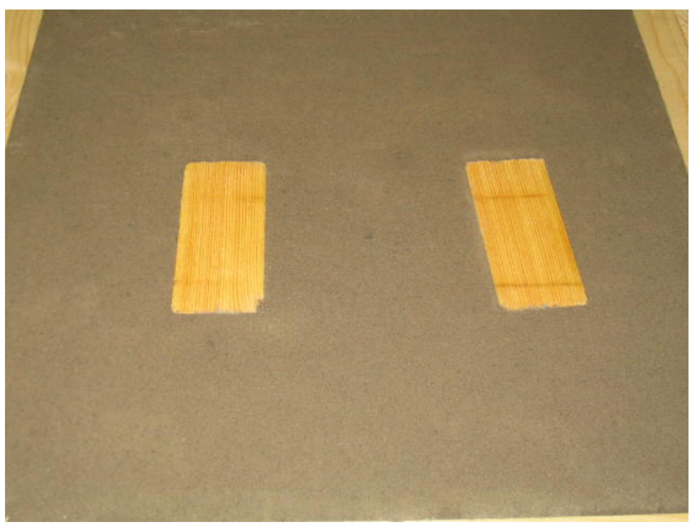

Figure 6 The Parting Line

At this point provisions have to be made for the metal to enter the mold (Figure 7). The hole that the metal is poured into is called the *sprue*, and it is made by placing a *sprue pin* in the mold. The halves of the mold also have to be isolated from each other so the mold will come apart cleanly. In Figure 7 parting dust is being sprinkled on the face of the sand. Parting dust will not absorb moisture, so it creates a barrier that keeps the sand in the cope from adhering to the sand in the drag.

Figure 7 Applying parting Dust

After the parting dust is applied the cope is placed on the drag. The cope is filled with sand, rammed, and vented just like the drag. The next step is to cut a funnel shape around the sprue pin as shown in Figure 8. The funnel shape provides a larger target when pouring the metal.

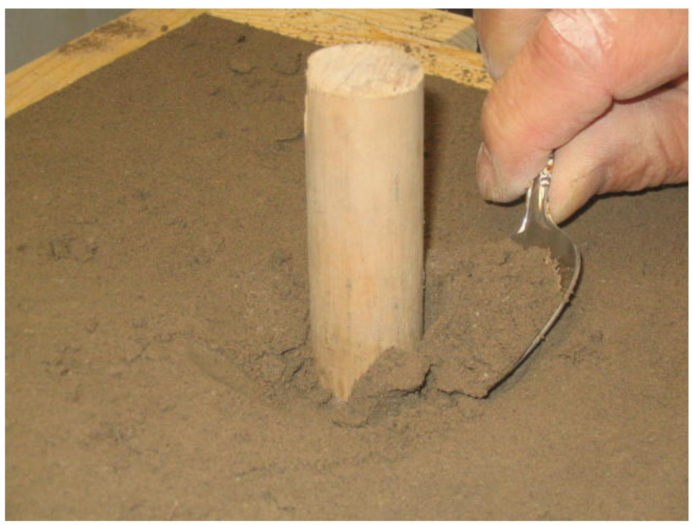

Figure 8 Cutting the Funnel Around the Sprue Pin

Then the mold is opened and the cope is placed behind the drag (Figure 9). The patterns now have to be removed from the mold. This is done by screwing an eyescrew into the pattern and rapping against the screw with a *rapper* (Figure 10). I use a 1" box-end wrench for a rapper. Rapping the pattern makes the cavity a fuzz larger to help remove the pattern, and it also strengthens the walls of the cavity. When the pattern is loose it is pulled out of the sand.

Figure 9 The Open Mold

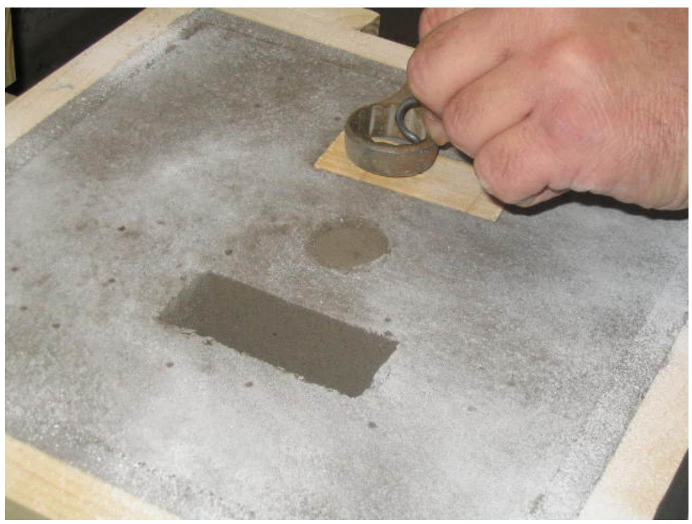

Figure 10 Rapping the Pattern

The final step in creating the mold is to cut *gates* from the sprue to the cavities (Figure 11). The gates complete the path that the metal will follow from outside of the mold to the cavities.

Figure 11 Cutting the Gates

The mold is then moved to the casting area and reassembled.

Furnaces

The central piece of equipment in a foundry is the furnace. A furnace has a lining of *refractory* that holds in the heat while the fuel heats the crucible and metal being melted. There are commercial blends of refractory available, but the linings can also be made from homebrewed mixes of sand, fire clay, and cement. Some people have even used fire brick as a lining with success. Refractory linings can incorporate fillers such as sawdust or Perlite® that will burn out of the lining to leave a void. The voids will increase the insulating ability of the lining.

The biggest difference in furnaces is the fuel used. The fuels can be separated into three general classes: solid, gas, and electricity. Solid fuels include charcoal, coal, coke, and wood. Gas fuels include natural gas (methane) and propane. Of course, electricity uses electricity.

Each type of fuel has its advantages and disadvantages. Solid and gaseous fuels require an air source to burn the fuel fast enough to release enough heat to melt the metal, but a hair dryer can be used for this. Solid fuels leave a lot of ash after they are burned, so the furnace has to be cleaned out after it has cooled. Gaseous fuels require piping and regulators, and the fuel source must be isolated from the heat of the furnace. The biggest disadvantage to electricity is the possibility of electric shock, so the heating elements must be shut off before entering the heating chamber with any tools or scrap. One advantage that electricity has over both solid and gaseous fuels is that it is quiet since no air source is required. But this can also be a disadvantage since you could leave the furnace on without noticing or, more importantly, you can be lulled into feeling it's completely safe.

The construction of a furnace depends on the type of fuel used. The first furnace I built was for charcoal. It was made in a metal five-gallon bucket with a 2" thick refractory lining on the sides and bottom. A hole has to be made in the bucket and refractory lining, called a *tuyere* (pronounced tweer), toward the bottom of the heating chamber to admit the air blast. A 2" thick lid filled with refractory sits on top of the furnace to complete the heating chamber. The lid has a hole in the middle for a vent, and a handle is added to lift the lid off the body of the furnace.

To use the charcoal furnace a layer of charcoal is placed in the bottom of the heating chamber. The crucible sits on top of this layer and the layer is made thick enough to keep the top of the crucible just below the top of the body of the furnace. The fire is started before the crucible, filled with scrap, is put in place. The charcoal is doused with starter fluid and lighted with a match. When the flame is well established the air blast is started. The crucible is placed in the furnace and the charcoal is put between the sides of the crucible and the refractory. Finally, the lid is put on top and the metal is allowed to melt. From starting the fire to having the metal melted takes roughly 30 to 45 minutes for aluminum.

A gas furnace is similar to a solid fuel furnace in regard to the refractory and tuyere, but a mixing chamber attached goes into the tuyere. The gas and air mix in the mixing chamber and ignite when they enter the heating chamber. Another difference is that the crucible sits on a *plinth* instead of the refractory or a bed of fuel. The gas furnace that I built, which was designed by Dave Gingery, has a two-piece body and a lid. A pedal at the base of the furnace raises the lid so it can be swung out of the way to add scrap. A handle is attached to the middle section to raise this section and the lid so the crucible can be removed.

To use the propane furnace the crucible is placed on the plinth. The fan is turned on, which also opens a solenoid valve in the gas line. A torch is place in the air stream while a hand valve is opened to admit the gas into the mixing tube. Once the fire is established the furnace is closed. The melt time on this furnace is about 20 to 35 minutes.

An electric furnace is the most compact. The one I built is made in three pieces: a base, a middle section with the heating element, and a lid. A groove is formed in the refractory lining on the inside of the middle section for the heating element, and a control is mounted on the outside to control the electricity to the element. While I don't use this furnace to melt aluminum because it is slow, it can be used for melting metals that melt at a lower temperature like zinc, pewter, and lead. It can also be used to melt wax out of molds, heat treat carbon steel, and carburize mild steel.

Melting the Metal

Now the fun begins. The first thing to do is fill the crucible with scrap (Figure 12). The scrap that I used was a frame that I didn't like, and decided to redesign, after it was cast. The important thing to remember is to not jam the scrap in the crucible. When the metal expands it could damage the crucible.

Figure 12 Crucible Filled with Scrap

Figure 13 shows the crucible in the furnace. Notice that the entire area is covered by a 2½" thick layer of sand. The sand will protect the concrete floor in case of a spill.

Figure 13 Furnace

I use a torch to light the furnace (Figure 14). The blower is turned on and placed in the air stream. Then I open the hand valve on the gas line until the gas lights. Then the furnace is closed to allow things to heat up. The first five to ten minutes gives me time to sweep the floor since nothing much happens during that period.

Figure 14 Lighting the Furnace

When the metal starts to melt it will settle in the crucible. This leaves room on top for more scrap. The lid of the furnace is swung out of the way, as shown in Figure 15, to allow scrap to be placed in the crucible. But the scrap can't be dropped in. It has to be held above the furnace for a short period of time to dry it out. If a piece of scrap, like a beer or pop can, has moisture in it and is pushed into the molten metal, the moisture can turn to steam and blow the metal out of the furnace.

Figure 15 Opening the Furnace

When the crucible has enough metal for the casting, it is removed from the furnace. At this point the temperature of aluminum will be in the 1400°F to 1600°F range, even though aluminum melts at 1200°F. The metal has to be superheated so it won't freeze before it is in the mold.

After the crucible is removed it is placed on some bricks next to the furnace (Figure 16). Any impurities that were on the metal have floated to the top of the metal and formed a mass called *dross.* The dross is skimmed off with a *skimmer* and discarded so the impurities won't be poured into the mold.

Figure 16 Skimming the Dross

Now the metal is poured into the mold (Figure 17). The metal has to be poured quickly, but steadily. If the flow is stopped for any reason, the metal that is in the mold could freeze before the pour starts again. After the mold is full, the excess metal is poured into an ingot mold (Figure 18). This mold is one that I made at work, but an old muffin pan can also be used.

Figure 17 Pouring into the Mold

Figure 18 Pouring into an Ingot Mold

The casting is now allowed to cool for a while. Thin castings don't require much cooling time, but heavier castings should cool for up to an hour. This cooling period is a good time to wipe off all the sweat and replenish bodily fluids. The heat from the process can cause sweat even on a cold day.

Once the casting has cooled the mold is destroyed (Figure 19). The sand is broken up and put back in the bin. Some of the water has been boiled off, so more is added and the sand is mixed so it will be ready for the next time. Figure 20 shows the caps as they came out of the mold, ready for machining. The picture also shows the shrinkage on each cap.

Figure 19 Destroying the Mold

Figure 20 The finished Casting

Conclusion

Casting metal at home may seem like a very daunting task. The temperatures high enough to melt aluminum or brass can be extremely dangerous if proper precautions aren't taken. I've heard of two cases of amateur foundry men hurting themselves. One man was wearing sneakers when he spilled some aluminum. He ended up with major burns on his feet. Another man had a pan of paint thinner in the shed where his furnace was. When he started his furnace, the resulting explosion put him in a burn unit for months.

But these are the exceptions and not the rules. In the eleven years that I've been casting aluminum I have never been burned. I have had a couple of incidents, like aluminum running of a flask at the parting line. The aluminum pooled in the sand below the mold and froze, and what little aluminum stayed on the flask created a lot of smoke. But this type of incident is planned for so it won't cause a fire.

Figure 21 shows the caps after they were installed on another part, also cast in my garage, and then bored and counterbored. If I were not able to cast parts like these at home my only option would be to buy a chunk of aluminum and machine away most of it. This would not only be time-consuming, it would be very wasteful. And it also lets me play in the sand as an adult without risking institutionalization.

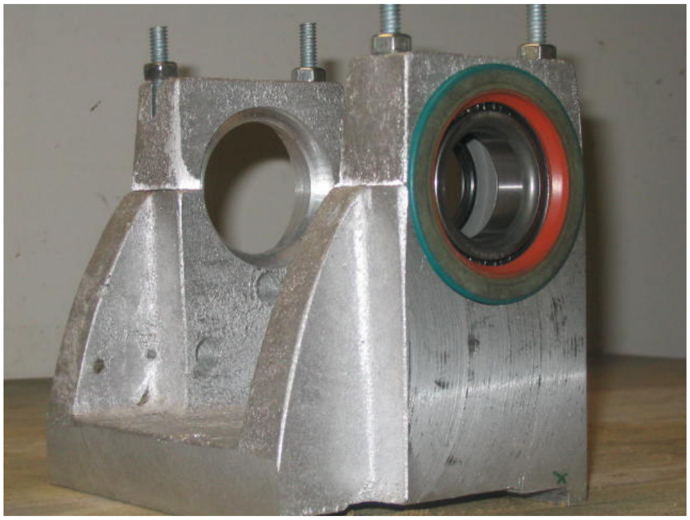

Figure 21 Caps After Machining

Sources:

David J Gingery Publishing
http://www.lindsaybks.com/dgjp/

Lindsay Publications
http://www.lindsaybks.com/

Author's Homepage and Website
http://home.earthlink.net/~jschwytzer/workshop.html
http://www.johnschwytzer.com/