

Understanding Metal Clay and the Firing Process

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When I started my blog, I predicted that within a year many brands of metal clay would be available. This has become true, and it seems to create a lot of confusion. Different sets of instructions have become available, along with different firing schedules, etc. Teachers tend to vary in their choice of brand and may not be fully aware of how to handle other brands.

To help clear up this confusion, I thought it might be best not necessarily to clarify the differences between the brands, but rather to establish what they have in common. My hope is that by gaining an understanding of how metal powder sinters, individual users may find it easier to arrive at their own optimal firing schedule.

I am by no means a scientist. Everything I am about to write is based on a lot of reading, as well as on my personal experience. I have found that reading material about the theory of sintering may not necessarily be helpful, since practice rarely goes hand in hand with theory. However, things that I have read have given me ideas of what may be worth trying, and through trial and error I have arrived at a certain level of understanding. That is all I have to share.

Sintering means the bonding of loose particles together below their melting point. The term sintering applies not only to metal powder but also to ceramics. Perhaps a good example of sintering is ice cubes. Ice melts at 32°F/0°C. The temperature in the freezer is way below that. What happens if we raise this temperature without reaching the melting point? The ice cubes will start sticking to each other until we are able to pick them up as one solid unit. However, since they don't touch each other at every point of their surface, there are spaces between them and this whole mass is porous.

The sintering process consists of 2 main phases:

1. Removal of the binder
2. Densification of the particles

The Binder

The role of the binder is to give the metal powder the consistency of clay, so we can shape it or press it into molds. For the clay to turn into pure metal, the binder needs to be removed completely before the sintering process begins. If it is not completely removed, whatever is left of it prevents the metal particles from adhering to each other.

If the binder is completely removed, it does not matter what type it is. The type may affect the working condition of the clay but not the sintering results.

Densification

Once the binder is removed, the particles are allowed to get closer and closer. As far as I know, the particle shape of most metal powder used for the different brands of metal clay is spherical. The spheres get closer and closer, their contact areas grow, but since they don't reach their melting point and they don't turn into liquid, they don't lose their shape completely and there are still spaces between them.

Here is a link to a short video clip that I posted on my blog a while ago. About halfway through the clip you can see a good illustration of it.

<http://artinsilver.com/blog/2009/03/08/powder-metallurgy/>

So what needs to happen in order for us to have a successful firing?

Precious metals such as pure silver and gold are fired exposed to air. They don't react with the oxygen in the air, and the oxygen ensures the complete removal of the binder.

Base metal clays such as copper and bronze, when fired exposed to air, react with oxygen to create oxides, which, like the residue of the binder, prevent the particles from bonding. Pure copper can be fired exposed to air for a very short time before it oxidizes internally. However, longer or repeated exposure to heat and air will enhance the oxidation and eventually the copper will disintegrate. This is true not only for copper clay but also to solid copper, such as plumbing pipes and sheets.

Copper alloys, such as bronze, cannot be fired exposed to air. If they do, a large chunk of them will come off, taking with it the texture and details.

So, base metals are fired buried in activated carbon, which reduces the amount of oxygen in the kiln and inhibits this reaction. Gold granulation is done this way since it involves the use of copper. The carbon creates a “reducing atmosphere” by burning; while burning, it consumes the oxygen present in the kiln chamber.

However, most organic binders used in metal clays need oxygen to burn off. If there is not enough oxygen (because it has been reduced by the carbon), the binder will not burn off completely. If the binder is not completely removed, there will be no proper sintering.

So in a way, the activated carbon is both a blessing and a curse. On the one hand it enables sintering; on the other it interferes with the removal of the binder. In industry, vacuum or gasses are used to create a reducing atmosphere.

If we manage to burn the binder before the carbon catches fire, we increase our chances of successful sintering.

From my experience, the binder burns at around 1000°F/538°C in a top loader kiln or 1100°F/593°C in a front loader kiln (I refer to the most popular kilns, that are about 8"x 8" x 8"). At this temperature the carbon does not burn yet. Some brands of clay have more binder in them than others and may require staying at this temperature for a certain amount of time for the binder to burn off completely.

If you have problems sintering your clay, no matter which brand you use, it is always a good idea to hold at this temperature between 30 to 60 minutes before going on to the goal temperature. Large and thick pieces have a lot of binder to burn, so holding at this temperature will always be helpful. Holding at this temperature will not affect thin or small pieces that may be present in the batch.

Firing Time

The amount of carbon in the box will determine the firing time. The more carbon present, the more time it takes for the binder to burn. Thin and small pieces require very little carbon (1" below and on top) and can be fired for 1:00 hour once the carbon is removed. In this case, no hold time at 1000°F/538°C or

1100°F/593°C. Thick and large pieces require more carbon and therefore more time, usually 2:00 hours. As I said before, holding at 1000°F/538°C or 1100°F/593°C can only help.

Firing Temperature

Copper clay has a wide range of sintering temperature. If you fire copper alone (preferably in carbon), you can go up to 1800°F/980°C and fire for 1:00 hour.

Bronze will swell and warp if you fire it at over 1470°F/800°C (top loader) or 1550°/843°C (front loader). It is ok to fire copper at this temperature.

White bronze will swell and warp above 1200°F/648°C (top loader) or 1280°F/693°C (front loader).

These temperatures are not absolute numbers. They depend on the size, age, and condition of your kiln, and tests are required before determining your individual firing schedule.

The best test would be to fire bronze or white bronze clay at the suggested temperatures. If the pieces snap at these temperature you need to increase it. If they swell or curl you need to reduce it.

Other Tips

- The smaller the kiln, the better. Otherwise you are wasting energy on heating air. (Lower temperatures than suggested may be required, though).
- Use a firing box that is not made out of a poor conductor of heat, such as stainless steel. Stainless steel also oxidizes during firing and contaminates your kiln. I find a fiber blanket box or just a kiln shelf surrounded with kiln posts very effective.
- Make sure there is some space under and above the box to allow heat flow.
- Make sure the kiln is vented. The binder, fumes, and contaminants need to escape. If they don't, they are most likely to inhibit sintering. If you don't have a venting hole, you can either drill one or fire with the door a crack open.

- For the same reason, don't use a lid. The carbon will stay contained in the box and will not contaminate your kiln.
- Use coconut shell carbon, acid washed, size 12 x 40.
- After every firing, clean the carbon from the ash that has been generated while it was burning. This way you can re-use it.
- Unless absolutely necessary, it is best to fire in carbon, starting with a cold kiln and finishing in a cold kiln. Taking pieces out hot may cause oxidation.

This file will be updated as necessary and is downloadable as a PDF file from the right-hand pane of my blog.