Lessons in Manufacturing and Prototyping

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This blog series documents how I leveraged my manufacturing experience, materials science knowledge, mechanical engineering and prototyping skills to resolve real-life production or quality issues. The blogs are meant to crystallize the learnings, to educate, and to start conversations.

The previous blog reported that polyester was not an adequate material for the redesigned chair brackets. Even though the modification of the design was a success, Highly Accelerated Life Test a.k.a HALT showed that failure could still happen (albeit at another location). This blog described the process of casting the parts out of metal using the lost wax casting method.

The first step in lost wax casting (also called investment casting) is to create a copy of the final part out wax. For high-precision parts, care needs to be taken to make the wax part slightly bigger to account for shrinkage of the metal during solidification. Because the chair brackets are not high-precision parts, we used the near-net shape rubber molds to cast wax copies.

Figure 1. A wax copy of a chair brackets

The second step is to create a tree-like structure (called sprue) using wax, to create paths for the metal to flow-in and for the air to escape. A wax cup is placed on top of the sprue to pour the molten metal in, and also to act as a reservoir of molten metal to feed the thicker areas as they cool and shrink (thereby avoiding voids in the final product).

The third step is to create a mold (we used plaster). Since the mold will be broken to take the metal parts out, the mold can be made in one piece. Only the pouring cup and the vents are visible. In industrial settings, different slurries are used to make the mold. Each slurry has different properties (the slurries used in the early layers enable a high level of detail to be achieved, the later layers are designed to give strength to the molds.

Once dried, the mold is heated upside down, and the wax from the parts and sprues come out (they are considered "lost", hence the name of the process). Again, in industrial environments, the wax is recuperated out of the autoclave. In my workshop, I heated the molds just enough to be able to pour the wax out outside the oven to avoid making a mess (or worse, a fire).

Metal is then poured in the hot mold and left to solidify. One needs to make sure the cup is filled enough to keep feeding the parts as they shrink.

Figure 2. A plaster mold after having poured the metal (notice the vents on the left)

Then a fun (and messy) step takes place, namely the breaking of the mold and retrieval of the parts. This can feel a bit like archeology (see Figure 3).

Figure 3. Metal parts and pieces of mold prior to cleaning

The last steps consist of cutting out the sprues, vents, and possible flash and of inspecting the parts for defects. Examples of defects are inclusions (foreign material that could have made its way into the mold), trapped air bubbles, voids, cold shuts, unfilled areas, etc.
The first batch of parts revealed that we should increase the temperature to reveal more details (either the temperature of the mold or of the metal, or both). These parts were however good enough to test for function.

Figure 4. First batch of metal cast parts after cleaning

We assembled a few chairs and tested over a period of a few weeks. Not a single bracket failed. This was good news but it would be better to push the test further to know where in the assembly the weakest point is.

We shared the result with our customer who decided to use the parts and to inform us if any failure were to happen. Months have since gone by without failure.

This concludes the series of blogs on the failing chair brackets.