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Pattern Making, Clay, Plaster and Wax
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In Pattern Making Part One we explored the use of wood and putty in pattern making. We traced the use of wood as a pattern making material back almost 6000 years, to the beginning of the Bronze Age. We didn't mention, however, that dried clay, pottery, and bee's wax were also sometimes used as casting patterns by early artisans. This article will examine the use of tooling wax, styling clay, and gypsum plaster by more modern pattern makers.

As noted in the previous article, many pattern makers utilize more than one type of pattern making material... even on the same pattern. All three materials discussed in this article can be, and often are, used in conjunction with other pattern materials. With regard to wax this is especially the case. In a recent Closed Molders Forum I discussed the use of sheet wax as a means to duplicate part thickness during the construction of closed molds. In addition to tooling wax in sheet form, pattern waxes are also available in an extensive array of extruded profiles, as well as machinable or extrudable blocks.

Before discussing the actual uses of tooling waxes in pattern making, it should be noted that a wide range of wax formulations are available, each intended for a specific purpose. Typically, tooling waxes are derived from petroleum based micro-crystaline waxes that contain varying amounts of oils or plasticizers to adjust hardness and flexibility. Natural waxes such as bees' wax are also used in certain products. The various ingredients and additives are blended to achieve the desired properties. Waxes can be formulated to be hard and rigid or soft and flexible. They can also be formulated for higher temperature applications that might involve exothermic resins or curing ovens.

One of the more common uses of wax in pattern making is for creating fillets and other features on patterns made of harder materials. Pattern makers can purchase extruded wax fillets or extrude their own to produce smooth professional looking radii on inside corners or joints. Contact cement or low melt temperature wax-based adhesives (sticky wax) hold the wax fillets in place. Special filleting tools are available for applying and smoothing the fillets. These tools are often heated before use so as to soften the wax for better workability. As an example, cultured marble molders often use wax to mate sink bowl molds to counter top molds. The wax creates a smooth radius between the bowl and the top, and hides the joint between the two molds. Pattern makers and molders who use large quantities of extruded wax profiles can save money and time by using in-shop extruding equipment to make profiles on demand from extrudable wax sticks.

Many other details can be added to patterns using wax. Features such as resin flow channels and groves for sealing gaskets can also be easily created out of extruded wax. Draft angles on vertical pattern surfaces can be quickly accommodated using tapered sheet wax. Embossed logos and arm of fine detail can be cast from wax in silicone rubber or flexible urethane molds and then applied to the pattern, thus saving the pattern maker hours of detail labor. Lettering or serial numbers can be quickly cast into a wax plaque using plastic or metal type. When applied to the pattern, the plaque will transfer the lettering to the mold. Softer modeling waxes can also be hand carved for this purpose.

Wax can also be used as a stand-alone pattern material. Historically, solid wax patterns have not been used extensively in the FRP industry, but they are commonly used in other industries. For instance, in the foundry industry, the lost core method of metal casting uses wax patterns that melt away when the molten metal is poured. Having said that, however, patterns machined from blocks of solid wax are becoming more common as a method for rapid prototyping/pattern making. Solid wax patterns can be quickly and easily machined directly from a CAD file using low cost CNC router equipment. (CNC routers cut softer materials well, and are much lower in cost than CNC mills that are used to machine metal) An added benefit of this process is that there is no wear on the cutting tools, and much of the wax, including shavings, can be remelted and reused if desired. Engineering changes and repairs are also easily accommodated on wax patterns.

For some applications the previously mentioned soft modeling waxes can also be used for pattern making, allowing almost unlimited free-form creativity. For example, a sculptor can carve or hand shape his or her original art work in wax, take a mold off the wax original, and then cast or laminate unlimited reproductions. (A bust of Bill Clinton might be a popular item) Modeling clay is frequently used in much the same way, and that leads to our next topic, styling clay.

Skilled machinists and skilled pattern makers share many of the same talents. They must be able to render a dimensionally accurate, three-dimensional object from two dimensional drawings or prints. In pattern making, however, some artistic creativity is often necessary, something not demanded of machinists. That is especially true when styling clay is the pattern maker's medium. For many years styling clay (a cousin to modeling clay) has been the pattern material of choice in the auto industry and other industries where aesthetics play an important role in product or part design. The folks who design these objects tend to be more artists than engineers. They often refer to themselves as stylists. The pattern makers that work with these stylists must also have an artful eye.

Clay as a pattern making material reportedly got its start in 1914 when GM design engineer Harley Earl began sculpting scale models of new automobile designs from clay that he dug from a stream bank. Nearly ninety years later, and despite dire predictions that clay patterns would be made obsolete by CAD drawings and CNC patterns, clay is probably more popular as a pattern material than it has ever been. The wonders of 3D CAD not withstanding, the ability to work in a full size, hands-on medium still has a lot going for it. If a stylist doesn't like a curve or a line, the pattern maker can change it in real time right before their eyes. They can run their hands over it, stand back and look at it from all angles, add some material here or remove some there to achieve the desired look. No other pattern media offers that level of freedom of expression. Needless to say, pattern makers who are adept a working in clay are true artisans, and are very much in demand.

The clay itself has come a long way since Harley Earl's day. Modern styling clays typically are composed of approximately 10% Kaolin clay, 30% oil, and 60% powdered sulfur. The actual formulas are closely held, and are modified in various ways to create an extensive range of clays with specific properties for specific applications. Hardness and workability are the two main variables, but shelf life, durability, surface texture, density, odor, polishability, machinability, and compatibility with post finishes are additional formulation considerations. In addition, sulfur free versions are available for use in environments where the presents of sulfur might be a problem (i.e. around expensive electronic equipment). Unlike sulfonated clay, sulfur free clay can also be melted and cast much like wax. Also like wax, styling clay is fairly firm at room temperature, so it must be warmed to about 130' F in order to be soft enough to be hand applied to the model. The clay is usually stored in a bun warmer or heated container to keep it ready for use. Understanding the role of temperature is very important to the successful use of clay as a pattern material.

As is the case when building larger wood patterns, clay patterns begin with the construction of a slightly undersized frame to support the clay. This frame, which is usually referred to as an armature or buck, is usually sized so that the clay is typically between 1/4 and 2 inches thick on the finished pattern. Thicker sections often can't be avoided and aren't a major issue, but add cost, weight, and a slightly greater risk of subsequent cracking. One inch is considered optimum. This buck can be made of wood, metal, low- density foam, or any combination thereof. Styrofoam has generally become the material of choice because it is easily shaped, and can be quickly trimmed if a design change requires the buck to be modified. As with other pattern construction methods, it is critical that the armature be rigid and dimensionally stable. In most cases the finished buck is mounted on a flat base plate. For smaller projects the base plate can be a properly braced sheet of heavy plywood. In the auto industry, where projects tend to be larger, a perfectly flat steel platform is used. It should be noted that since the base plate is the reference for all measurements, the dimensional tolerances of the finished pattern can be no more accurate than the tolerances (flatness) of the base plate.

When construction of the armature is completed, it is completely coated with shellac to provide a good bonding surface for the clay (and to seal any wood from moisture adsorption). The clay, which has been pre-warmed, is then rubbed by hand onto the armature in successive thin layers. (This minimizes the possibility of shrinkage cracks as the clay cools to room temperature.) The objective here is to build up the thickness to slightly beyond the desired dimensions of the finished pattern.

At this point the pattern is ready for final shaping. The shaping can be done either by CNC machine or by hand. If it is to be done by hand, the pattern maker begins the process of shaving the cooled and firm clay back to the required shape. A popular time saving trick is to use a custom crafted 'drag template' made out of plastic or metal sheet stock to remove excess clay from the last layer while it is still warm and soft. For example, a pattern maker building a pattern for a car fender can transfer the desired curvature from the design drawing to a drag template, which in turn is used to remove excess material from the last layer of clay, thus greatly reducing the amount time required for final shaping.

Contour gauges and templates are also very useful as guides for the hand removal of excess material from the pattern. The actual work of scraping and carving the pattern to its finished shape is done with a wide range of hand tools. Experienced pattern makers often have a toolbox filled with homemade tools, many of which were originally crafted for a specific project.

As a final touch, the surface of the clay can be brought to a fairly high luster by rubbing with a combination of light oil and water. This process is closely akin to creating a spit shine on a pair of leather shoes.

When it has been determined that the desired shape of the clay pattern has been achieved, the pattern makers job is largely done. At this point the pattern can be put to a variety of possible uses. It can be digitized to create CNC tool paths for cutting a metal tool, it can be surfaced with a variety of materials for the purpose of making a composite mold or master, or it can be used unsurfaced to make a quick and inexpensive plaster prototype mold. (Using our previously defined terms, it should be noted that this methodology is also often used for making engineering or presentation models, rather than actual patterns. For instance, concept cars shown at auto shows are often nothing more than clay models with a cosmetic surface.)

If a class 'A' surface is required on the pattern, or if a composite production mold will be made from the pattern, the preferred surfacing regimen is a four step process beginning with an adhesion promoter, and followed by a water-based barrier coat, a sandable primer, and finishing off with a polishable top coat or tooling gelcoat. A fast and low-cost alternative for smaller projects is the direct application of Krylon TM sanding primer from a spray can.

Our last topic of discussion, touched upon briefly in a previous paragraph, is the use of gypsum plaster as a pattern making material. This family of material dates back to the sixth century (560 BC) when Plaster-of-Paris came on the scene as a casting material. Plaster as a tooling material had its beginning in the 1930s when gypsum cement, known as Alpha Gypsum, was developed. Alpha Gypsum plasters are commonly used for casting master patterns from patterns made of other materials (production molds are then made from the master pattern), and for making quick and inexpensive prototype molds.

They are also often used for making fixtures for holding, checking, or trimming molded parts. Typically they are one-part systems using plain water as a catalyst. Burlap or hemp is often used as a reinforcement to strengthen the plaster. When hemp is used it is generally mixed into the wet casting plaster. A burlap reinforced plaster pattern is constructed in much the same way as a laminated pattern or mold... using multiple layers of fabric that have been impregnated with plaster. Cure time for these materials is nominally two hours.

A new generation of more sophisticated gypsum products has come upon the scene recently. These products have resolved some of the shortcomings of the traditional gypsum plasters. The first of these products is a castable and machinable pattern media. It can be easily cast into a slightly oversized form, and then either manually or digitally machined to the finished shape. A sprayable version is also available which can be gun applied to an existing pattern, or to a slightly undersized foam buck such as described earlier during our discussion of day patterns.

The sprayable material is a two component system, and is applied like a thermoset resin, with a two component gun. The additional component is an excelerator that speeds up the cure in thin sections. The second product of this new generation of materials is referred to as 'model duplicating media.' This material is a low exotherm plaster system that was originally developed for making prototype molds from clay patterns, but has been found to be suited to other tooling applications as well. It is referred to as a system because it actually consists of two complimentary products. The first is a surface coat that is normally applied about

1/8th of an inch thick, and the second is a glass fiber reinforced backing that is applied 3/4 to I inch thick.

The primary advantages of this new generation of materials are that they are machinable and exhibit zero shrink (they expand .0 1 5%). The advantages of gypsum products in general are that they are lower in cost, faster, safer, and easier to use than most other pattern materials. They contain no hazardous materials or VOCS, and plain water is used as the catalyst.

Larger patterns and molds made of gypsum may require a metal or composite frame for structural support. This frame can be attached by bedding it in additional plaster. In addition, plaster patterns or molds must be sealed before use (a specific sealer is available for the purpose).

Once the surface has been properly sealed, a mold release can be selected based on the subsequent material that will be used. The durability of plaster molds generally limits their use to prototype and short run production. Typically I to 25 parts can be expected. Under ideal conditions several hundred parts may be possible. Several suppliers have developed hydrophobic epoxy surface coats that, when used in conjunction with plaster casting materials, can greatly extend a plaster tool's life. The less porous and more durable working surface of epoxy surfaced plaster molds and patterns, along with their very low cost, has enabled plaster tooling to find a home in many limited production environments.

This concludes part two in this series on pattern making. In the next installment we will explore the use of polymer based tooling materials including the use of high-density foams. -CFA

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