MOLDS FOR CASTING VEHICLE PARTS

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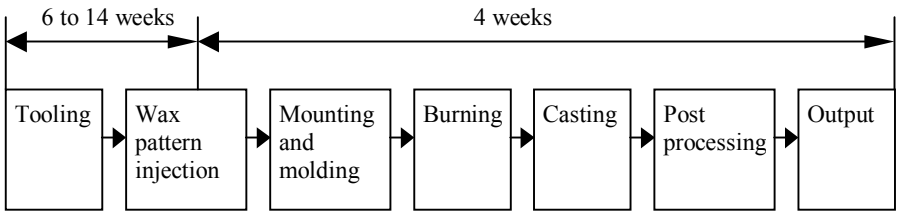
Abstract

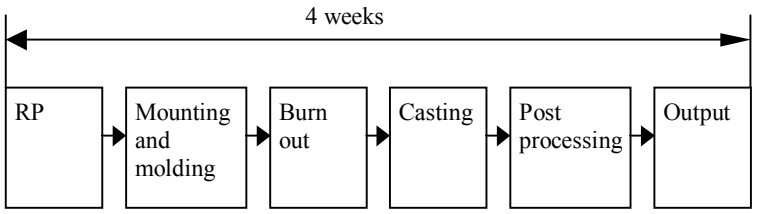
Casting metals and alloys makes most of the parts for vehicles. To shorten the time to market and get a satisfied quality new design approach have to be involved.
New CAD based technologies are giving an opportunity to make molds faster and cheaper with a high quality than previously using classical methods.
In this paper master mold design process including decision about materials is presented. All principals for rapid tooling molds are applied at the mold for iron casting part for trains.

INTRODUCTION

Products in automotive and vehicle industries must reach the highest quality to provide safe usage. Most of the parts of the breaking system and many other parts are made by casting. Especially plastic parts of the outside items of the vehicles are made by injection molding. Materials used for these purposes are aluminum alloys and steel as well as other materials (plastics, polystyrene, rubber, etc.).
To increase productivity and to shorten the time of a new product development, special attention have to be paid to the casting molds. In many cases prototype cast metal parts are required to be tested before approval in the mass production.
Their quality primarily depends on molds. In fact, procedure for making a rapid prototype of a part is the same as procedure for rapid tooling for making molds. Rapid prototyping (RP) and rapid tooling (RT) are relatively new methods. These methods became common for making molds. The choice of the method depends on type of the mold or it's usage. Rapid techniques in mold making are usually used in developing complex geometry vehicle parts. These techniques shorten a time for castings up to four weeks. Duration of time depends on used method and complexity of the part. Comparison between traditional methods and RP in investment casting process are shown in Figure 1.



a) Traditional method



b) RP investment casting

Figure 1. Comparison between traditional methods and RP in investment casting process

TECHNIQUES FOR RAPID TOOLING MOLDS

Techniques for mold making can be subdivided into:

- Subtractive processes in which material is removed from the solid block to reach desired mold,
- Additive processes in which material is added and generate desired pattern or mold,
- Formative processes where forces are applied to form a desired mold.

Rapid tooling techniques comprises of two distinct types: transfer and direct. Transfer or replicast process starts with a physical pattern to copy mold. Pattern shape transfer can be accomplished by casting, mechanical tracing and electrode discharge machining (EDM).

Direct methods used 3D CAD (solid or surface) virtual computer programmed set of instructions. Digital data is used to control machine tool's movements. Machine tool could use additive layer-by-layer technology or CNC machining.

Traditional tool making methods often combine transfer and direct methods.

Transfer-replicast or reverse tooling

In the process of mold making replica of the part is produced. These methods can be denoted as:

- Single
- Double and

- Triple reverse methods.

Single reverse methods were used to convert RP patterns directly into castings with other materials. Single reverse methods are:

- Investment casting,
- Sand casting,
- Spray metal molding,
- Silicon RTV rubber molding.

Single reverse process is illustrated in six steps (Figure 2)

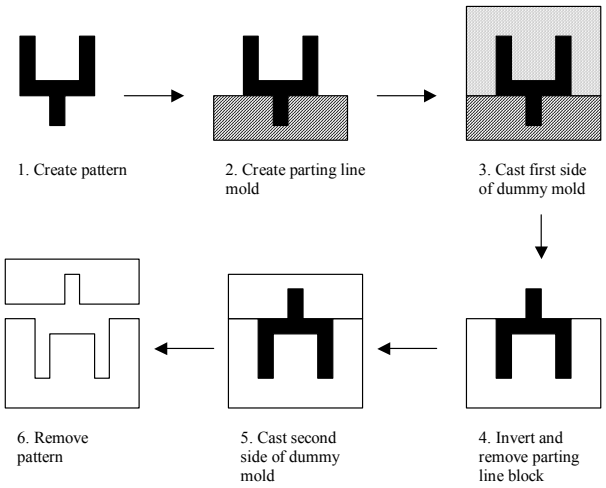


Figure 2. Single reverse process

Investment casting is a precision casting process used to produce metal parts from almost any alloy. Unlike sand casting where a single pattern can be used to produce a large number of molds, a new pattern is required for every investment casting. These patterns are produced in injection molding machines, and they are made of wax or ABS-special material for the process of RP. Replicast method is very useful for large castings up to 750 kg without any restrictions on a wall size. Replicast prototype approach has two key benefits; cheap production of polystyrene pattern comparing to traditional permanent pattern for sand casting. Here is an opportunity to design, check and make changes on the pattern.

In replicast processes patterns can be made of resin or laminated fiberglass instead of polystyrene. Polystyrene foam is cheap and comfortable for soft machining. CNC milling machines are used to produce patterns or molds automatically without handcraft. This approach allows exceptionally complex geometries to be produced with high quality. The main characteristic of replicast process is possibility to fabricate a series of prototypes of the same design.

Sand casting is used to produce metal parts when surface high quality is not demanded. It is a high volume production technology, which requires patterns, cores and core boxes. Casting are frequently high volume and a prototype used in this case is made by LOM. This prototype is used as pattern in cases when 100 or more products are needed. The LOM pattern is used directly to create impressions in the sand.

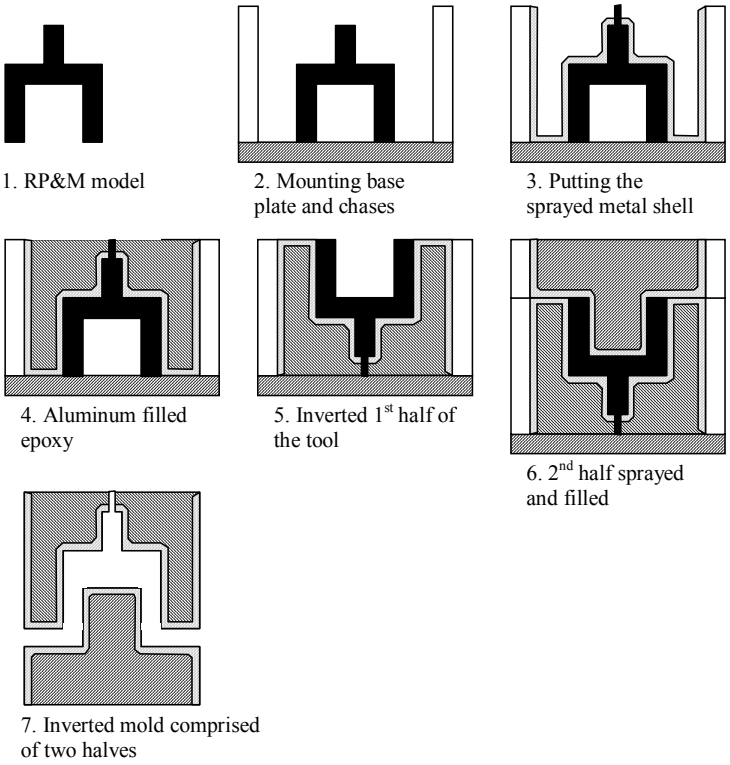


Figure 3. Spray metal molding process for tove production

Spray metal molding is used to create tooling for low volume prototype injection molding. Master pattern is sprayed with a thin coating resistant to high temperature and agence. After forming a shell over the master and half of the box is created, epoxy is poured (Figure 3). Such kinds of molds are capable to produce 1000 injection molded parts. Materials used for molded parts are usually thermoplastics.

Silicon room temperature vulcanizing (RTV) rubber molding is a quick and inexpensive process used to create plastic components. Most of outside parts in automotive design are made of plastic materials. After process of mold preparing, taking care of minimizing distortion in a period of cooling, molds are used for polyurethane resins vacuum casting.

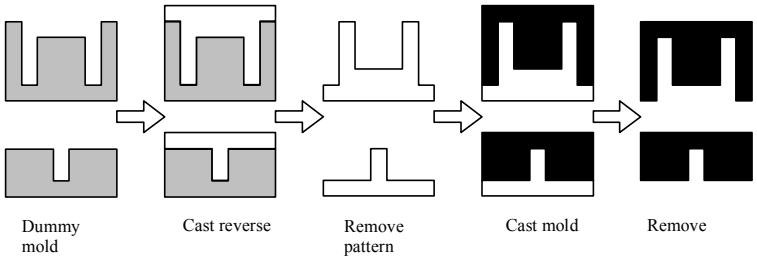
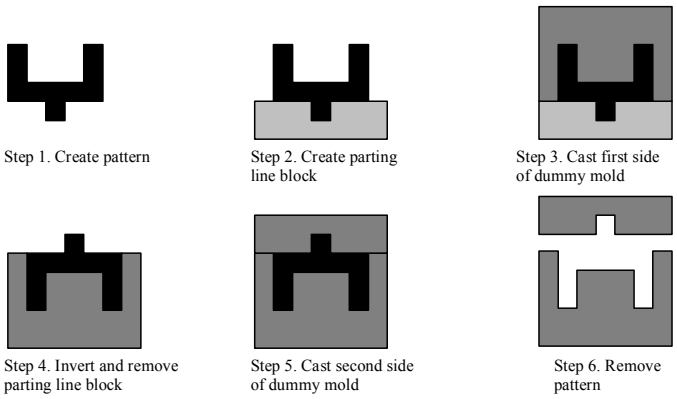
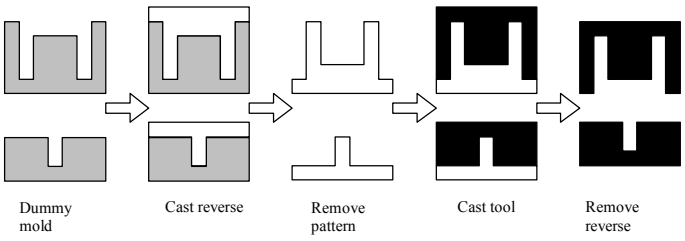


Figure 4. Double reverse tooling method

Double reverse method is mainly used to produce thousands parts. Cores and cavities can be converted to hard plastic patterns produced by using a rubber molding or aluminum and steel patterns in investment casting process. Figure 4. illustrates double reverse tooling method.
All mentioned methods could be included into subtractive RT processes. Aluminum mold can be used for the patterns including inversion of the part shape to produce cavity shape.
Triple reverse method comprises of two steps. A mold pattern is produced by single reverse tooling and converted into a casting mold (Figure 5).



a) Single reverse to create dummy molds



b) Double reverse to create tooling

Figure 5. Triple reverse process

Plaster mold casting is used to manufacture highly complex aluminum components with a higher surface finish than sand casting can provide. RP pattern is duplicated as a flexible rubber pattern, which is used to make expandable plaster molds into which molten metal can be poured. Flexible rubber can be easily removed from the fragile plaster molds. RP pattern is used to create silicon rubber molds for epoxy casting. It is set up in a mold box and molding material poured and hardened. After partition on the two halves multiple mold sections can be made. This first mold is used to make a flexible rubber pattern that is than set up in the mold box and in a similar process foamed plaster is poured around it. Rubber pattern can be easily removed without breaking a plaster. Plaster molds are dried and harden. In a dried plaster molds molten aluminum magnesium and zinc can be poured. After a metal has cooled plaster mold is broken off. Rubber patterns are capable for producing up to 100 plaster molds.
The new replicast process developed recently for making molds are 3D Keltool. This method is mold-making solution that produces cores and cavities up to 8 days. It is ideal for casting complex part geometries and inserts up to 150 x 215 x 145 mm, for injection molding and die casting applications.

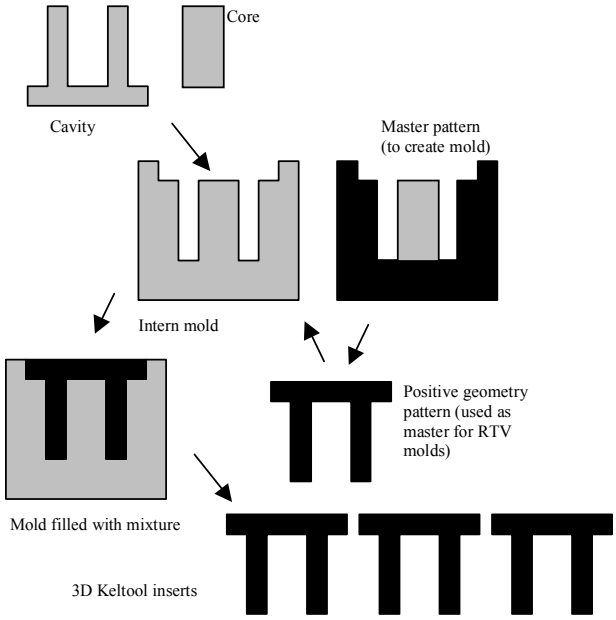


Figure 6. 3D Keltool technology

The mold (tool) design has been created in 3D CAD. STL files of cavity and core are used to make cores and cavities by layered methods, mainly stereolitography. These are master patterns used for producing RTV silicone rubber molds. The molds are filled with a mixture of steel powder, tungsten

carbide powder and epoxy binder. Binder is used to bind powders together to form slurry. The material has cured in the most. These "green parts" are melt and sintered. The binder material is burned off and part became "brown part". The final step in the process is to infiltrate copper in the free spaces of the porous part. Resulting part is fully dense insert comprises of 70% tool steel and 30% cooper. Tool steel provides wear -resistance and low distortion, tungsten carbide ceramic provides hardness and durability and copper thermal conductivity. 3D Keltool technology is limited on the small sizes. It is flexible tooling solution for creates prototype or production molds. Steps in this process are shown at Figure 6.
Once the production mold is finished the tool would be capable to produce thousands of parts. In a low volume production it can be a production tooling.

DTM-Direct tooling manufacturing

Direct tooling methods can be classified as additive rapid tooling methods. These methods are:
Stereolitography (SL), Solid Ground Curing (SGC), Selective Laser Sintering (SLS), 3D printing, Laminate Object Manufacturing (LOM), Fused Deposition Modeling (FDM). All methods have the same characteristics to build a mold putting layer by layer. Using a specialized software 3D model is sliced into very thin layers (cross sections). Depending on the specific method used, the RP machine constructs a solid part layer by layer until a replica of the CAD model is generated.
Stereolitography uses liquid resin, which is cured under laser acting. This process is expensive cause of resins. Laminate Object Modeling is a process of laser cats the slices from the sheet of paper, which is than attached to previously cut layers. The model is definitely finished by hand. This process is cheap and good for large parts. Most of the very complicated LOM models are models for sand casting for automotive parts.
Selective Laser Sintering is a process in which the powder is fused by heat. The process has similarities with SL. Instead of liquid resin the powder is exposed to laser acting to fuse particles of powder. This process is available for polycarbonate, nylon and wax powders. It is limited with powder materials. In spite of that it is prospective process. In this method DTM can be included. It uses a ferrous alloy with a low carbon content in particles that are coated with polymer. The polymer layer of powder is melted under laser acting. The result is a green part in which infiltrate polymer. In this state components posses very little dimensional stability. The part is dried in the oven and sintered. Brown part is reinforced with a copper alloy. This is procedure for mold making for injection molding.
3D printing is just appropriate technology for mold making from the CAD file to the physical part. Direct shell production casting (DSPC) patternless

casting process that yields functional metal parts such as automotive cylinder heads in days instead of months. In this process ceramic molds are created for casting metal parts. Many identical molds can be produced using the same CAD file. Cavity file is used to generate automatically the ceramic casting mold. The ceramic mold is created in layers comprises of three steps per layer. First one, the ceramic shell mold is sliced to yield a cross section of the ceramic mold. Second step, a powder is spread over the surface. Third, multijet print head moves across the section of the mold. The binder attached the particles of the powder and it becomes a rigid part. The process is repeated until all layers of the mold are built. The DSPC mold is cleaned, heated and poured with molten metal. Any molten metal can be cast in DSPC molds. Automotive parts of aluminum, magnesium, ductile iron and stainless steel have been manufactured.

MOLDS FOR IRON CASTING PARTS FOR TRAINS

In everyday practice the cheapest way to make a casting mold has to be chosen. At the same time vehicle part in a form of fork, symmetrical on the axial plane was the part for casting. After the part has been analyzed the process started with 3D virtual model of the part (figure 7.)

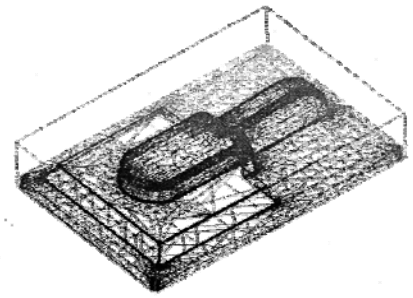


Figure 7. Foundry models

Model was designed in I-deas software and translated into STL file. The decision was to make a part obeying economic parameters. Time was short and a budget for design for a new product was so low. The foundry use sand casting process and need master pattern.
Master pattern was prepared in a form of rapid prototype. Rapid prototype was made of BM 5460 Ciba Tool material, which satisfied drown demands. First of all it is cheap material with good characteristics for master molds. All material properties are defined in ISO (604, 178, 75, 868) and DIN 53752 standards. Material is appropriate for CNC milling. Used machine can reach a rotation speed up to 26000 rpm. It is a range of HSM machining area. Using CPM 3020 milling machine with it's technical characteristics manufacturing took 0, 5 hour for roughing and 2, 0 hours for finishing. This

way of making master pattern is a directly tooling process. The master pattern was initial for preparing several foundry models. Foundry models should have good wear resistance and surface hardness to endure a series if imprints into sand box. Materials used for models are plastic resins. Material for foundry models can be ureol 5146 A or ureol 5146 B. The foundry models are shown, figure 8.

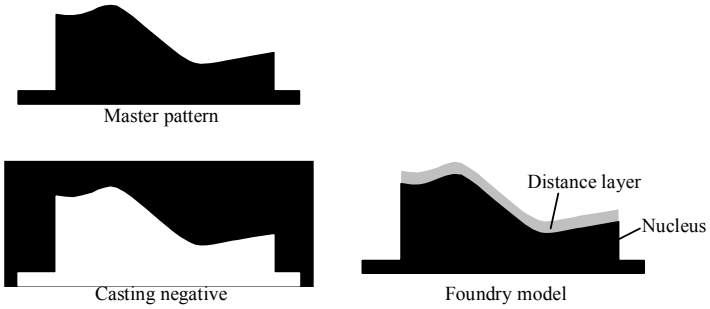


Figure 8. Plastic Resin casting scheme

CONCLUSIONS

This paper deals with molds for castings for vehicles. New methods in designing parts for vehicles are contributed in a minimizing of costs and new materials, which are appropriate for that applications allow the very unusual design for outside parts of the vehicles.
RP and RT processes in vehicle industry are very important and will be developed in the future. This approach was tested in a case of a small part for trines. Comparing to the traditional methods for mold making the time was shortened eight times, and new designed mold was more accurate without any dimensional mistakes.

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