

Creating Casting Patterns Utilizing 3D CAD Data, Z-Corp 510 3D Printer and xlaFORM Resin Infiltration

**New technologies combine to
create casting patterns quickly
and less expensively.**

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Why create casting patterns utilizing 3D CAD data, ZCorp 510 3D printer and xlaFORM resin infiltration?

As is typical in the creation of prototype castings, traditional pattern manufacturing costs can easily be more expensive than the actual costs of pouring all the parts associated to a short prototype casting run. In addition, the lead time for the creation of these patterns can often be measured in weeks.

In the following example, a new drive pinion flange design is taken from concept 3D CAD model to final prototype pattern pieces in the matter of 3 days. Resulting in the patterns being used to create 250 rapid prototype cast iron castings at a fraction of the cost and time associated with traditional patterns.

1. Starting with the 3D CAD data.

Accurate 3D CAD data is where it all starts. If the base CAD model contains errors, those errors will carry through to the final cast iron parts, ensuring that the CAD model is at the appropriate release level and has been thoroughly designed and checked is of utmost importance.

Figure A shows the final machining CAD model of the new concept flange design.

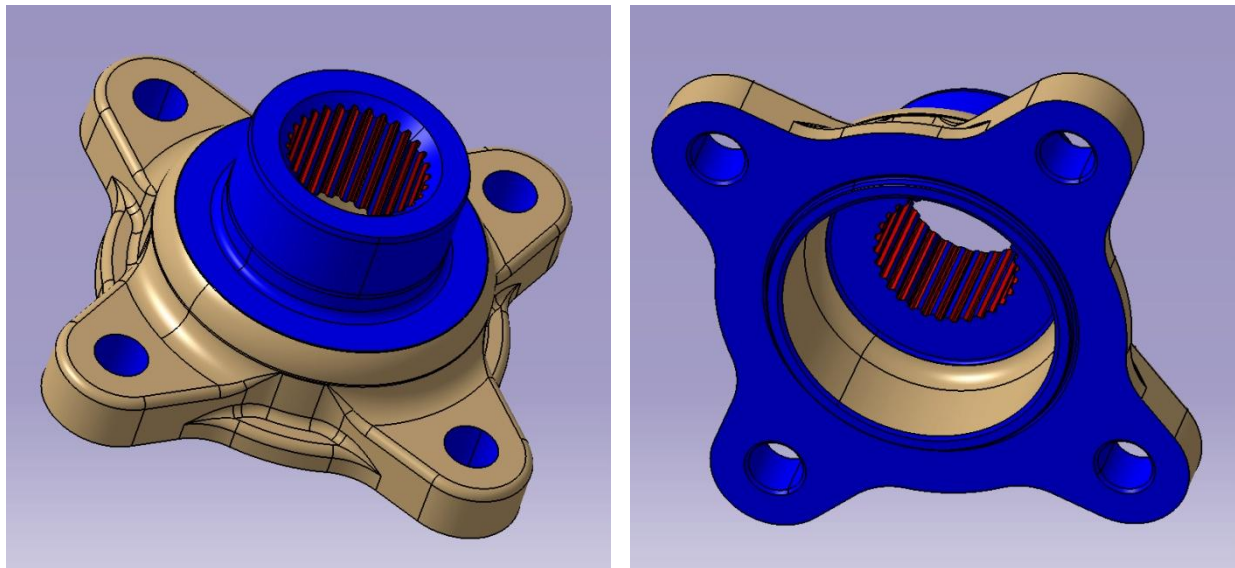


Figure A

In this machined CAD model, blue represents the machined surfaces and tan represents the remaining cast surfaces. The casting CAD model, shown in **Figure B**, reflects the part geometry of the actual final prototype cast iron flange that will be received from the foundry.

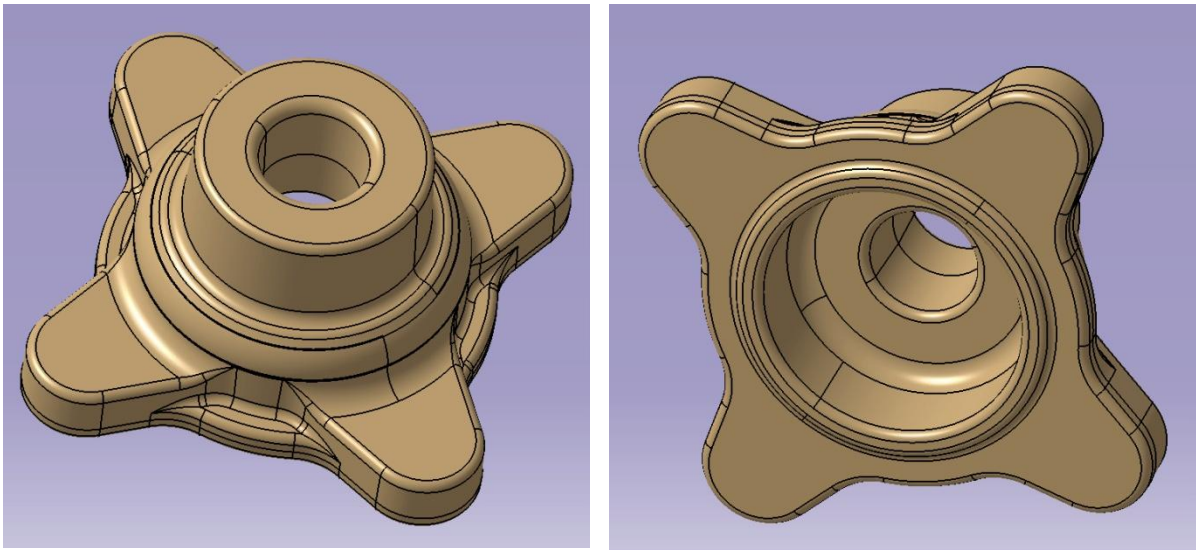


Figure B

The casting model has all four lug holes filled in, 2.3 mm machining stock added to all machined surfaces, 2 to 3 degree draft and an external and internal parting line as indicated in **Figure C**.

The draft angles help the sand casting mold pull away from the patterns without breaking. The draft is split at the parting line with the parting line acting as the neutral plane where the top part of the casting pattern (the 'cope') is separated from the bottom part of the casting pattern (the 'drag'). The patterns used to create the prototype castings are made more complex because of the offset parting lines and the fact that no sand insert (the 'core') will be used to create the center hole of the flange.

Once the casting model is finalized, work can begin on creating the casting pattern CAD models.

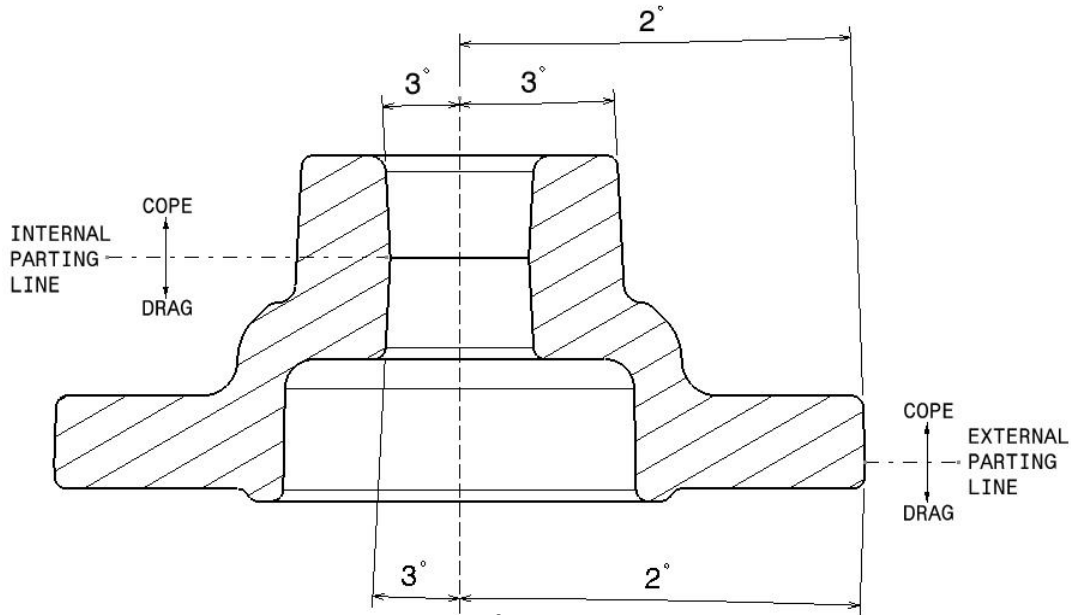


Figure C

To start with, because of the size and type of metal (ductile iron) the foundry recommended adding just a small shrink factor of 1/16" per foot or .6%. This was accomplished by scaling the CAD model 1.006 from a point located at the intersection of the external parting plane and the center axis.

Next, because of the offset parting lines, the casting was cut along the external parting plane, up through the part to the internal parting line, to create the cope and drag halves of the pattern, see **Figure D**.

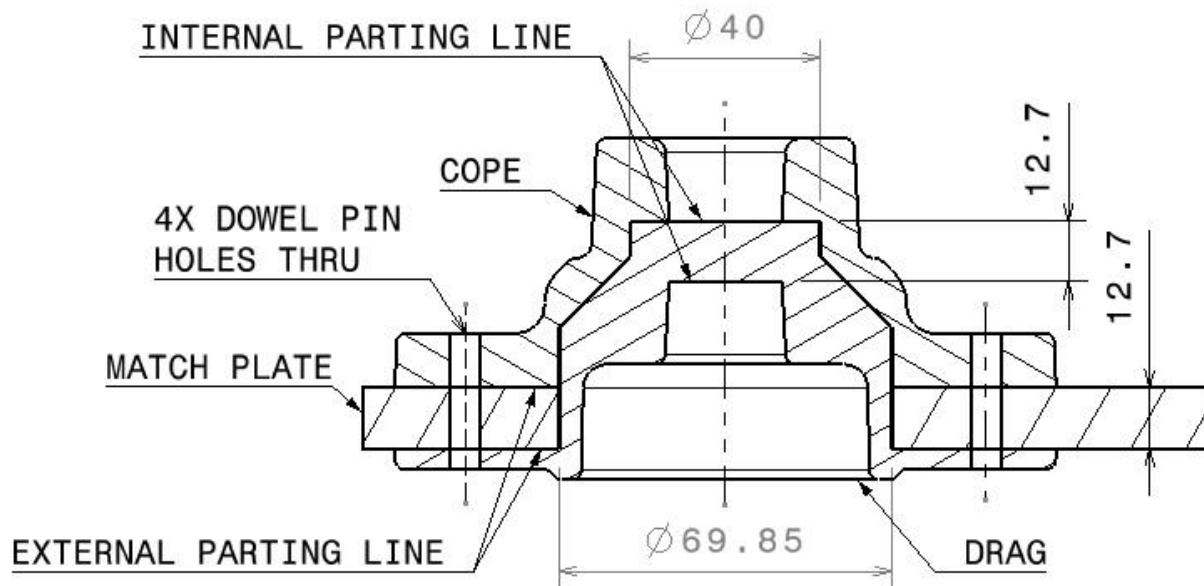


Figure D

The match plate was machined such that a 70mm hole could accept the drag half of the pattern. The cope half of the pattern was then fitted onto the drag and both patterns were clocked and doweled together through the match plate.

To create a mold that does not require a core, the center diameters of 69.85mm and 40.0mm were extended by 12.7mm (1/2") and the center hole was capped on the drag half. The 12.7mm extension matches the thickness of the match plate, thus when the two halves of the sand mold are pulled away from the patterns and the two sand mold halves are fitted together, the external and internal parting lines will match up.

The key item here is that both the cope and drag patterns incorporate one half of the center thru hole of the flange casting such that when the two halves of the sand mold are put together, there will be one solid sand 'core' already present in the mold.

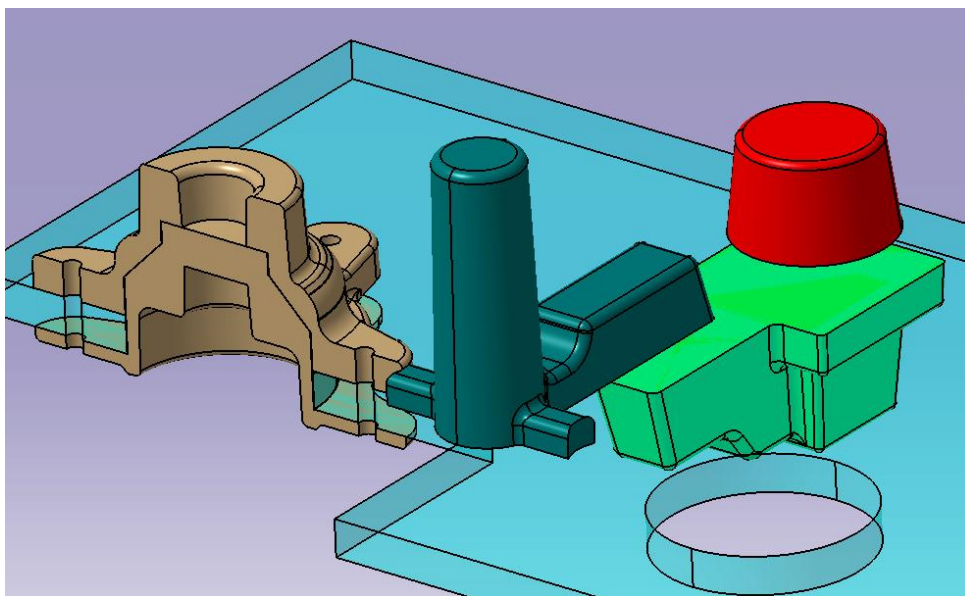


Figure E

Figure E shows an isometric view of the CAD pattern/match plate assembly. The match plate has been cut away and made translucent. Only one casting pattern is shown and it is cut in half to show how the drag fits through the hole in the match plate and how the cope fits over top of it. Adjacent to the casting pattern are the ingates which allow casting material from the feeder (shown in grey) to be drawn in the casting as it cools.

Underneath the match plate is the filter block (shown in light tan), which after the mold halves are pulled away from the patterns, holds a filter to help extract impurities from the cast iron as it is poured. Lastly, the sprue is attached (shown in red) and is where the cast iron pour is started.

The match plate holds two complete sets of patterns. This is referred as a two-on pattern.

2. The Z-Corp Spectrum Z510 process.

To create the rapid prototype models, the 3D CAD data was exported into the Z-Corp, Z-Print software from the native CAD software. The parts (cope and drag pattern halves, feeder, filter block and sprue) were exported in VRML (Virtual Reality Modeling Language) format. VRML allows for the color of the CAD models to carry over to the Z-Print software. There is an increased cost associated to printing 3D prototypes in color as apposed to printing them in monochrome. However, in this instance a solid color was applied to some parts.

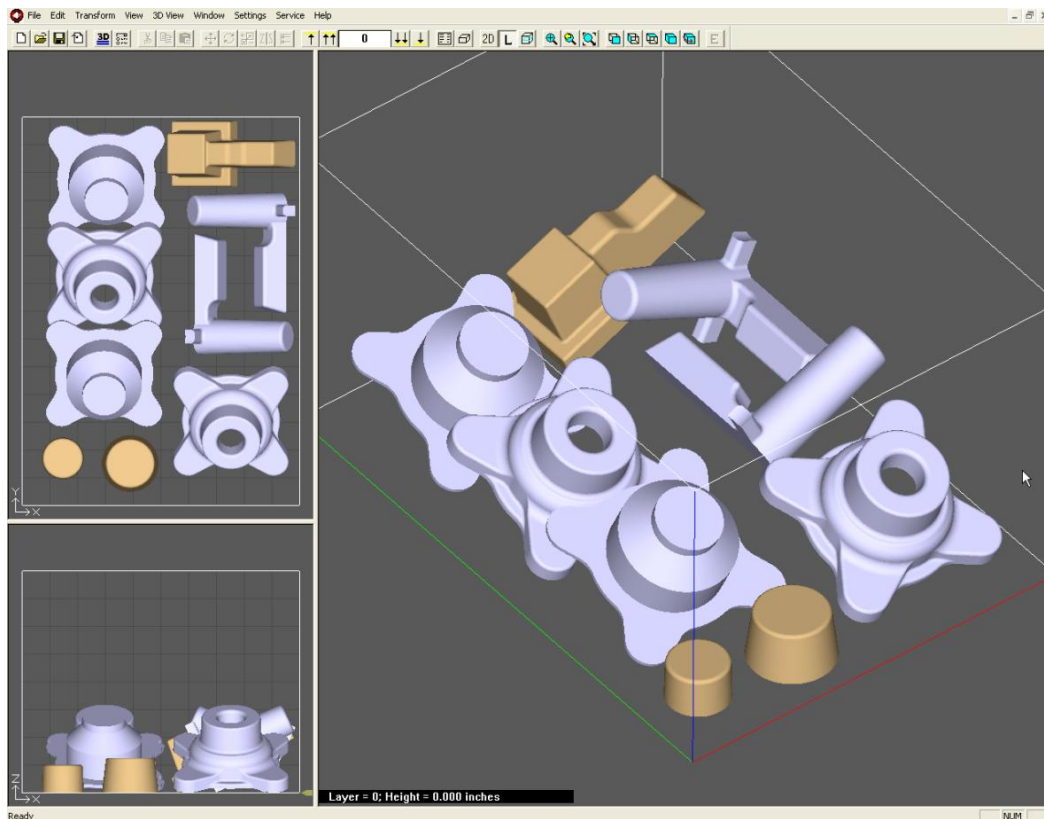


Figure F

When exporting the CAD models from their native CAD package, it was important to set the screen resolution of the CAD models as high as possible to ensure that the export is as accurate as possible. Once all the pieces

were imported into the Z-Print software, they were tilted. The X and Y plane is the build plane. By tilting the parts, each printed section of the CAD models are smaller in area than if the CAD models were printed flat, thus there is a reduction in shrinkage in the X/Y plane which helps overall accuracy of the build. **Figure F** shows an image of the Z-Print software and all the parts placed into the build envelope. The build envelope of the Z510 is 10" X 14" X 8".[1] As can be see in **Figure F**, the Z510 can build, in one shot, as many parts, in any multiple color, as can fit inside this build envelope.

When the Z510 begins building the parts the Z-Print software sections the CAD data into multiple horizontal build layers (the X/Y plane) from 0.0035" to 0.008" thick.[1] In this case the 0.0035" thickness was selected to maximize the number of build layers and increase the accuracy of the build. As the liquid binder prints each layer, each following layer 'binds' to the next until the final solid part is complete within the build hopper.

Once the Z510 machine and Z-Print software begin building parts, they do so unattended. The length of time to run is dependant on the surface area of each build layer times the number of layers in the Z axis. In this case, all of the parts needed for this pattern ran on the Z510 machine all at the same time, overnight for approximately 7 ½ hours. **Figure G** shows the rapid prototype parts laying on the Z-Corp build plate, in the build hopper, with all of the excess dust moved back into the feed hopper.

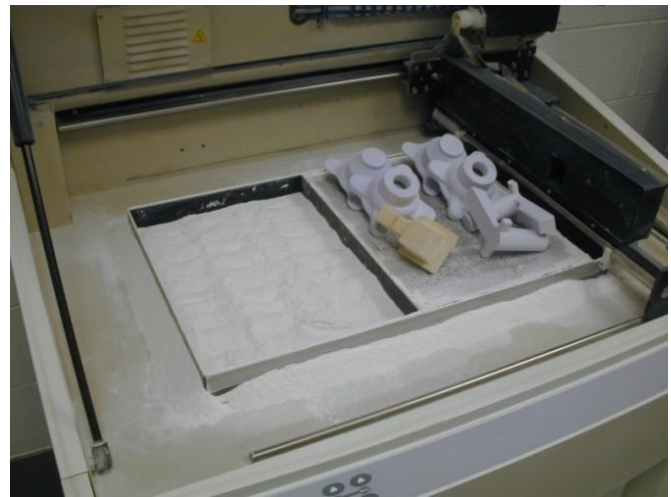


Figure G

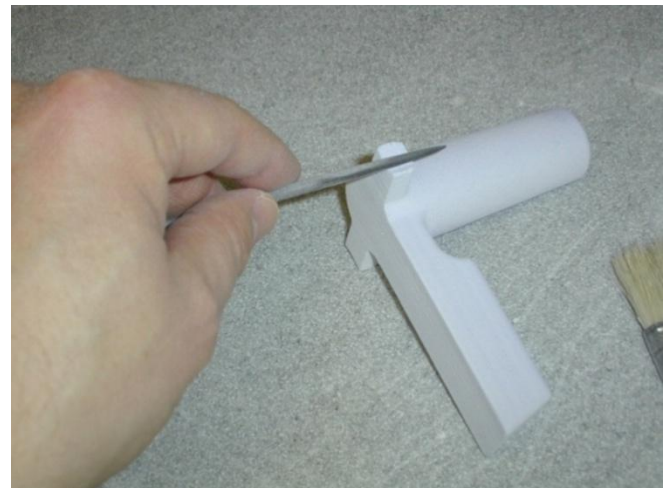
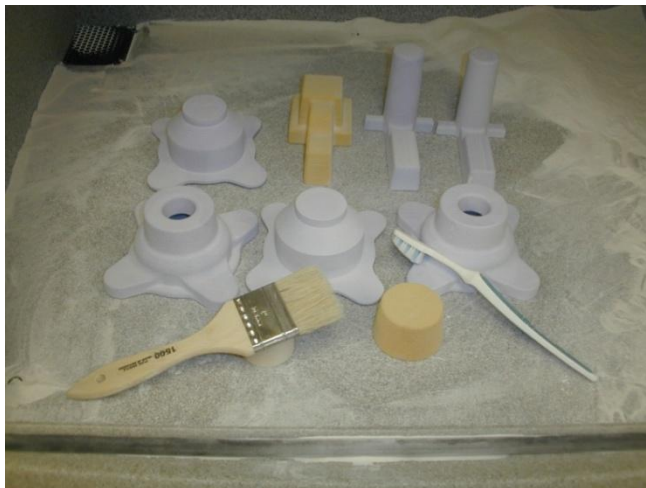


Figure H

Once the parts are removed from the Z510 machine they were placed in a de-powdering station, see **Figure H**. In the de-powdering station, high pressure air/brushes were used to remove any fine loose dust, while under vacuum in the station. While the parts are in the 'green' state, they can still be easily altered (if required). In this case the radius of the ingates was increased manually by using a metal file to remove material. The parts are now ready for hardening.

3. The xlaFORM Resin Infiltration process.

The xlaFORM process has two parts, first is the infiltration of the parts in the resin vat and second is the curing of the resin by the application of a heat source.

To begin the process, the parts are placed onto the platform of the xlaFORM machine, see **Figure I**. Before the parts are submerged into the resin a number of conditions/variables must be set. First the resin must be heated to the ideal temperature for infusion, typically between 120 and 140°F. When this temperature is achieved, with the parts on the platform, the chamber door is secured creating an air tight chamber within the machine.



Figure I

At this point the 'dry soak' time and 'wet soak' time must be set. The dry soak time controls the length of time the chamber degassing cycle lasts before submerging the parts into the resin vat. The wet soak time controls the length of time the resin infusion cycle lasts. Typically the wet soak time is twice that of the dry soak time.

The dry and wet soak times are determined by the thickness of the parts being infiltrated and the desired depth of infiltration required. In this case the patterns need to be 100% infiltrated, so once cured they would withstand the compression pressure applied to them during the creation of the sand casting molds. So to ensure 100% infiltration, a dry soak time of 45 minutes and a wet soak time of 90 minutes were used.

The second part of the xlaFORM process is to cure (harden) the infiltrated parts. Because xlaFORM utilizes a thermoset resin, a heat source needs to be applied to the parts. To accomplish this, the parts were placed into a convection oven and heated at 280°F for a couple of hours (curing times/temperatures vary depending on wall thickness/overall size of part). During the first ½ hour or so of curing, it is required to occasionally remove the parts out to damp off excess resin before it hardens into droplets.

Once the parts are fully cured they can be machined, drilled, tapped and sanded. In this case, the two pattern halves had 3/16" holes drilled through the lugs so that when the cope and drag halves of the patterns were fitted into the match plate they could be clocked and a dowel pins pushed through the two pattern halves and the match plate.

In addition to drilling the pattern halves, all the parts were sanded to smooth the exterior surfaces so that the sand mold would pull away from pattern with out sticking and breaking.

Once cured and fixed to the match plate, the patterns can withstand compression up to 30,000 psi.[2] This is enough strength to allow for the creation of sand casting molds. **Figure I** shows the final cured parts assembled with out the match plate.



Figure J

4. The Pattern Assembly and Sand Casting Mold.

Upon completion, the parts need to be mounted to the match pate. In this case, all the pieces were sent to the foundry where they proceeded to assemble, dowel and fasten all the parts onto the match plate. In addition, they applied more sanding/material to smooth the pattern surfaces to ensure that no sand would stick during the sand mold creation, see **Figure K** for final pattern assembly pictures.

One item to note is that after running a few sample parts to test out the pattern, it was discovered that there was porosity in the sample prototype castings. To alleviate this issue, more material was made available to the parts to draw from during cooling by the addition of an extra feeder, also shown in **Figure K**.

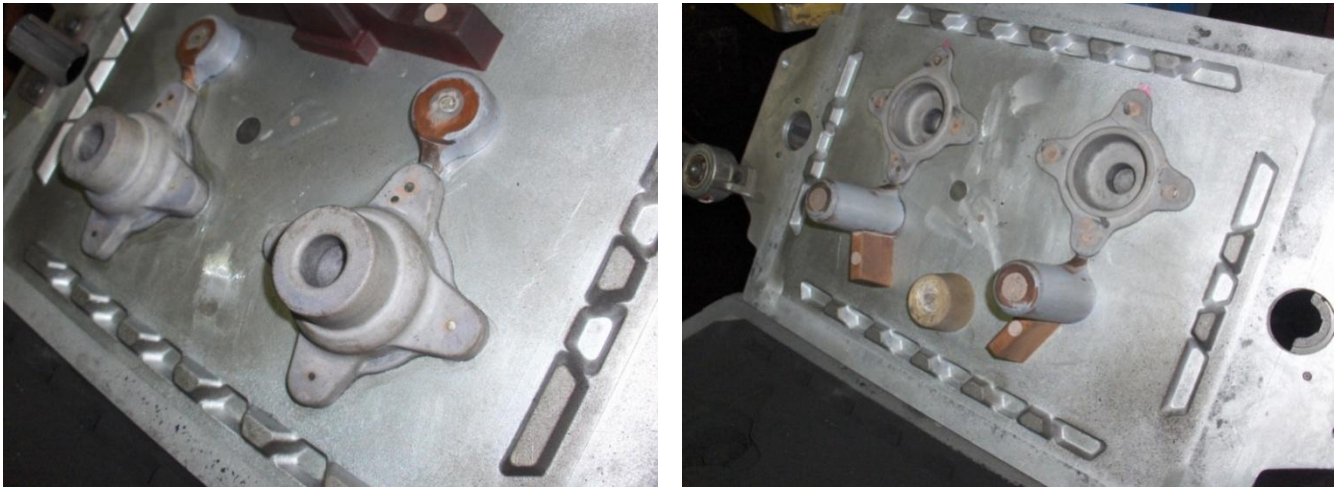


Figure K

Another item to note is that the foundry made one other change to help alleviate the porosity issue and that was to turn the two part patterns upside down so that the heavier end that was originally on the cope (up) side of the pattern along with the feeder is now on the drag (down) side of the pattern. This way as the castings cooled they would draw metal down from the feeder. This can be seen in both **Figure K** and **Figure L**.

Lastly it is important to note that if during the sample process it was discovered that there was a problem with the part patterns such that it was required to modify them to change a diameter or increase a radius and/or modify a draft angle, all these modifications could have been made in the CAD data, exported and run on the Z510 over night, cleaned up and hardened in the xlaFORM and delivered to the foundry in two days.

Figure L shows the completed sand cast molds, the drag half is shown on the left and the cope is shown on the right. The match plate is removed once the sand is compressed and then the two mold halves are placed one on top of the other and the metal frames are removed. What is left is a solid block of sand with the voids for the runner system and cast parts in place, ready to receive the cast iron pour.

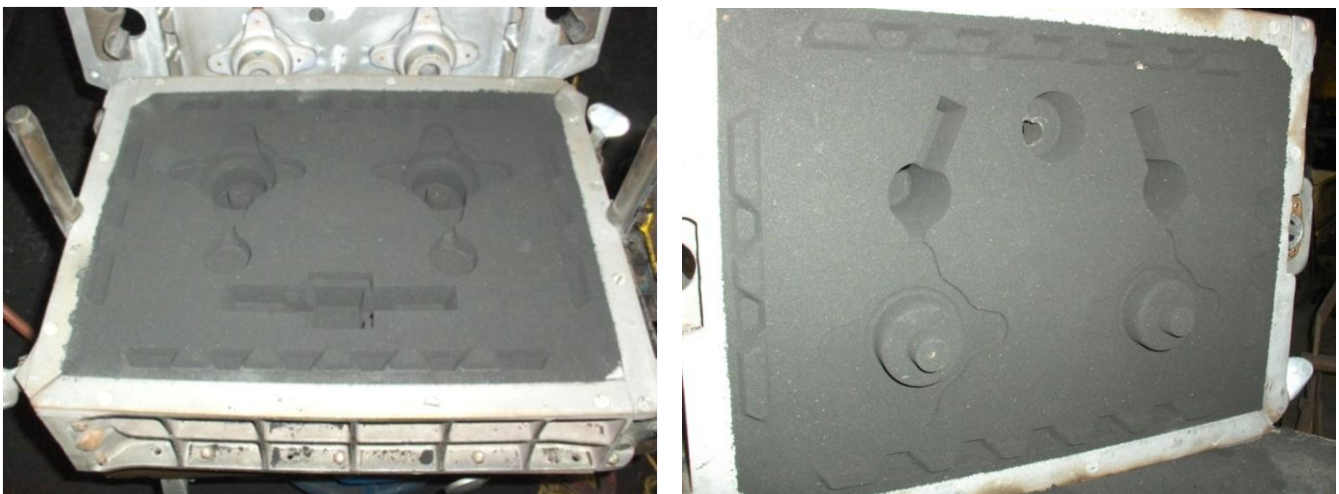


Figure L

5. The Final Result.

Figure M shows the completed machine flange (left) and one of the 250 rapid prototype castings received from the foundry (right). The castings machined perfectly and exceeded all of the customer’s specifications.

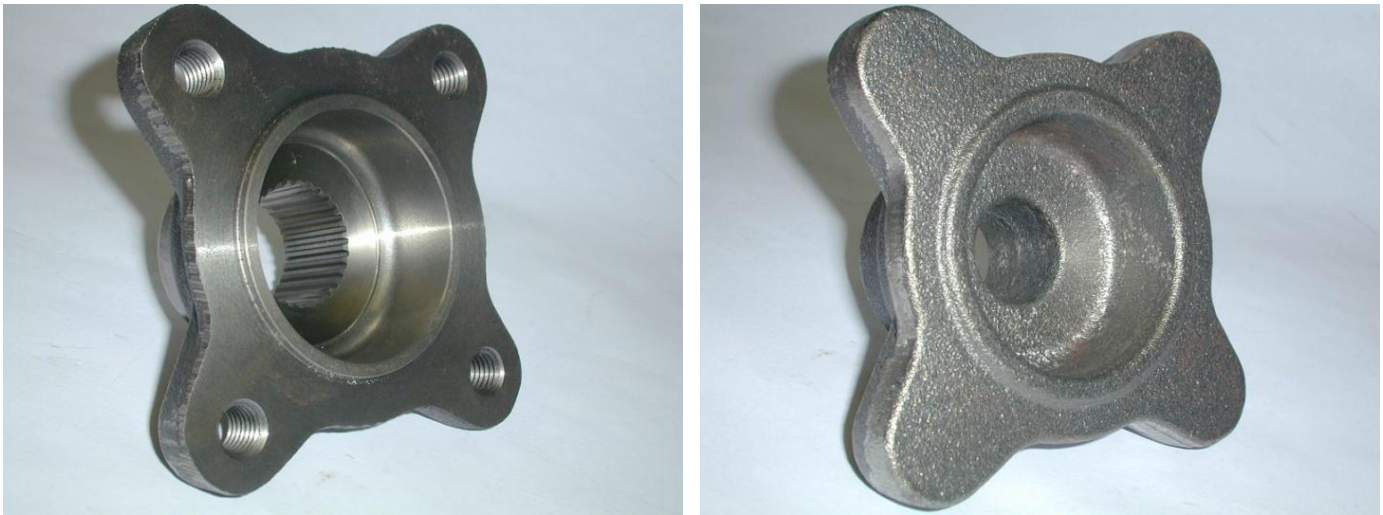


Figure M

Table A illustrates the breakdown of actual cost of material and time to delivery for CAD/Z-Corp/xlaFORM rapid prototype patterns vs. the quoted costs/delivery time to have traditional patterns manufactured.

<i>Drive Pinion Flange Z510/xlaFORM Costs and Delivery Time</i>		<i>Drive Pinion Flange Quoted Traditional Pattern Price and Delivery Time</i>	
Z-Corp Material Costs -----	\$85.50	Quoted Traditional Pattern Price -----	\$4,000
XLA Resin Costs -----	<u>\$110.00</u>		
Total Material Costs -----	\$195.50		
Delivery Time For Patterns ----- (CAD Operator and Z510/xlaFORM Time)	3 Days	Quoted Delivery Time For Patterns ----	4 to 5 Weeks

Table A

The final result shows that the combined technologies of 3D CAD, Z-Corp 3D printing and xlaFORM resin infiltration achieved great time and costs saving over the creation of traditional patterns, while allowing for quick reworking/replacement of patterns, when required.

In today’s incredibly competitive market place, as technologies are developed that cut cost and delivery time substantially, helping to facilitate better customer service, that technology needs to be embraced and exploited to its fullest extent.

References

1. Z Corporation; <http://www.zcorp.com/Products/3D-Printers/Spectrum-Z510/Technical-Specifications308/spage.aspx>
2. xlaFORM; <http://www.xlaform.com/performance/performance.php>