3D Printing Tough, Durable Parts

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It is not uncommon for a designer to require a 3D printed part which is functional, exhibits superior strength, has excellent temperature resistance, excellent humidity resistance and is a part which can be machined. When such a designer seeks these characteristics from a Z Corporation infiltrant, Z-Max Epoxy is the infiltrant which meets these requirements.

Strength is often one of the highest requirements for a designer when it pertains to functional prototypes. and as a result, we are often asked just how strong Z-Max really is. An absolute answer is not simple, since it depends on so many factors such as part geometry and infiltration application. Like any prototyping process, experimentation and variation of design is often required to yield desired results.

For the purposes of exhibiting Z-Max's superior strength characteristics, we decided to model and print a functional prototype skateboard. We chose to infiltrate the skateboard with Z-Max and then machine it to support hardware.

Not only is this prototype aesthetically pleasing for prototype display purposes (or proof of concept), it is also a full, functioning skateboard! Although this skateboard is not recommended for actual everyday use, nor is it recommended for actual skateboard park use, it is a display of Z-Max's strength which allows for full prototype functionality.

Here I am (~150 lbs) riding the completed skateboard outside of Z Corporation headquarters!

To view the Z-Max Skateboard Video, please visit the Z Corporation 3DP User Website

***** IMPORTANT WARNING *****

This board is not intended for actual use by children, young adults or adults.
It is not to be substituted for that of a fully manufactured, tested, commercial skateboard.
Its intent is solely for rapid prototype functionality and display purposes only.

Modeling & Printing the Skateboard

There are many 3D modeling software programs which produce solid 3D models for rapid prototype printing. This particular skateboard model was created and textured using NewTek's LightWave Modeler software. The completed LightWave .lwo model file was later converted to a VRML97 file (with textures) within LightWave Layout, and then imported into ZPrint. Due to the length of this board (23"), and the desire to produce the longest board possible, we chose to print this skateboard deck on Z Corporation's Z810 printer using ZP130 powder. The Z810 printer has the largest build plate offered on a Z Corporation platform making it perfect for this type of part.

Infiltrating with Z-Max

Z-Max is a high strength epoxy infiltration system specifically formulated for Z Corporation. Z-Max epoxy is a low viscosity, high strength, infiltration system designed to fortify parts built on all of Z Corporation's three-dimensional printers. Z Corporation parts infiltrated with Z-Max epoxy can also be easily machined, sanded and painted.

All epoxy infiltration systems benefit from the use of an oven to dry the printed part prior to infiltration. Driving off the excess moisture makes the part more porous, allowing for easier penetration of the epoxy into the part. Z-Max infiltrant penetration depths of 0.25" are possible with a fully dried part.

In order to insure maximum penetration of Z-Max, the skateboard deck was placed into a convection oven at 160^{o}F after removal from the Z810 build. In this case, the board was left in the oven overnight; however 2 hours would have been sufficient to remove the moisture.

A general rule of thumb for determining how much Z-Max a printed part will absorb is 7 grams of Z-Max per cubic inch of part to be infiltrated. Using Z-Print, the board deck volume was calculated to be 83.5 cubic inches of part which corresponds to 580 grams of Z-Max for 100% infiltration. When working with Z-Max, it is recommended not to mix more then 250 grams of resin at once to maintain a comfortable working time. Larger quantities of Z-Max will cure in a significantly reduced time, generating considerable amounts of heat.

Two applications of 250 grams of Z-Max were immediately applied to the entire board deck while it was still warm from the oven. The elevated temperature of the board reduces the viscosity of the Z-Max once it is applied, allowing it to wick deeper into the part. After the application of the epoxy, the board was allowed to "gel" at room temperature for one hour.

The best practice, once the part is infiltrated, is to first let the epoxy cross link (completely solidify or gel), then place the part into an oven for the final cure. Oven curing Z-Max parts at 160°F (70°C) for two hours will improve the final strength and hardness characteristics by up to 20%.

Be sure to well support large parts while applying Z-Max, and during the gel time. Once fully infiltrated with the uncured resin, the part will soften and deformation is possible. A good way to insure that your part remains as dimensionally accurate as possible, is to print using the fixture option. During infiltration the part can be placed on the fixture after the gel time. During the final cure at room temperature, or in an oven, the part will be well supported, and settle into its original shape.

After 2-3 hours in the oven at 160^{o}F, the board was removed from the oven and an additional application of Z-Max was applied to the warm board deck. This coat will not wick into the part the same way the first coats did. This coat was applied to give the board an even, glossy appearance and to seal the surface. After an hour at room temperature (following the application of Z-Max), the board was again returned to the oven for a 2 hour final cure.

Machining and Assembling the Board

Although the holes for mounting the skateboard trucks could have easily been created within LightWave Modeler, we chose, for this example, to machine the holes after the infiltration process. When machining post infiltration, ensure that sufficient infiltration depth is achieved in the location where the part will be cut/drilled. If the cut penetrates into the part deeper than the infiltrant (white powder will be visible), the area can be sealed and strengthened with the application of additional Z-Max in the cut hole.

Parts infiltrated with Z-Max can be used for many machining operations such as, milled, lathed, reamed, drilled and even tapped. In our experience when machining Z-Max, the use of a 600-1000 RPM machining speed produces the best results. The chip cut from the infiltrated material tends to have a “gummy” quality that can be felt particularly during hand tapping operations. Because of this characteristic, be sure to securely fixture the work piece to prevent the tool from grabbing and moving the work piece. A drill press is recommended over a hand drill due to the brittle nature of the material; when using a hand drill, it is difficult to keep a steady angle on the drill; if the part is thin walled in the area of the cut, it is possible to crack the piece without much warning due to the wander of the drills angle. Breaks, if they do occur, can often be repaired with the use of a fast cure epoxy.

After the board had sufficiently cooled to room temperature, eight through holes, for the fasteners to mount the skateboard trucks, were drilled and countersunk. With skateboard trucks and wheels obtained from Toys-R-Us, the board was assembled.

Conclusion

Once the board was completed, and since nothing like this had ever been printed at Z Corporation, many folks here were eager to see the board ridden. I have had some experience skateboarding in my youth and was eager to ride the board. With board, helmet and video camera in hand, we set out to the Z Corporation parking lot and had some fun.

Having ridden the board for ~45 minutes, the board held up great under this rider. In fact, we hope to put it through some more vigorous skateboard testing in the near future.

This particular Z-Max infiltrated skateboard model is just one example of the superior strength which can be obtained from parts infiltrated with Z-Max.