A New Approach to Casting Impellers Using 3D Printing

Following the need to replace a power plant's worn out impeller, experts chose to use a combination of 3D sand printing and standard sand casting to shorten lead-times and replace the damaged application. This resulted in a better understanding of the two casting approaches, and ultimately improved the pump's overall performance.

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When a power plant needed to replace a worn out impeller, on a pump provided in the 1980s for the plant's cooling system, it was faced with three main challenges:

- Getting the pump back in service in the shortest possible time,
- Remanufacturing the impeller without having the original pattern, and
- Improving the performance of the pump by reviewing the design.

Rather than following a more conventional method of replacing the impeller, a new approach was proposed to meet the challenges faced by the facility in question. The proposal was to combine the use well known aluminium bronze sand casting with 3D sand printing technology.

3D Sand Printing Technology

The use of 3D sand printing technology in foundries is now considered a mature technology and is slowly entering the industrialization phase. As opposed to direct part printing, this technology consists of printing a mold in which a selected alloy will be poured, making it adjustable to existing and recognized alloys. The technology that is used for this process is called Binder Jetting. Binder Jetting is a process in which a liquid binder is deposited on a layer of sand which has been heated beforehand to enable polymerization. The binder then bonds these areas together to form a solid part one layer at a time. The complete printing is done by successive layers of approximately 250 µm, which are carried out until the mold and core are finished. The materials commonly used in Binder Jetting are: metals, sand, and ceramics that come in a granular form.

In order to meet the replacement impeller's requirements, personal with expertise in mixing casting and experience with new 3D systems were necessary. The process of replacing the impeller involved the following sequence:

- Scanning the old impeller to create a new 3D file,
- Improve the design of the hydraulics,
- Use the new 3D file to « print » the sand mold, and
- Casting.

For this project, a large size printer which could accommodate a 970 x 555 x 460mm volume, was required. The size of the printer is a criteria of importance, as it limits the size of the components; for larger parts it is, however, always possible to proceed by sub-assemblies to reach desired volume.

The Combination of Standard Casting Methods with 3D Printing Systems

By combining the two technologies, different steps are required to achieve a successful outcome; the different steps need to coordinate with different knowledges. The following is a list of the necessary steps:

a) Designing the various 3D files

Component 3D File

The initial step consists of creating a 3D file of the component to be casted; new parts are usually readily available with 3D files. For existing components, the use of scanning technology is necessary. The designer can then decide either to touch up the model or improve it depending upon his requirements.

Mold/Core 3D File

Based on the component 3D file, a casting engineer then decides what position the part will be casted in by:

- Defining the mold parting line,
- Adding machining overstock,
- Adding extra thickness for contraction/shrinkage (a specific rate for each material), and
- Designing the running system, the risers and the chiller positions.

Without this knowledge, it is impossible to use a 3D file to print a mold. As each file is application sensitive, knowledge of which criteria is necessary for each 3D print is gained with experience.

b) Molding

Once the 3D files are finished, the sand printing of the various parts of the mold can be launched. For this specific project, the mold was created in three parts: the bottom, top and core. If standard casing technology had been used, each part would have needed a separate wooden tooling.

At this point the use of modern 3D printing technology reverts back to the more conventional casting process. Assembly of the mold needs to be handled by an experienced operator who will carefully position the various components such as coolers, isothermal sleeves and air channels before closing the mold completely.

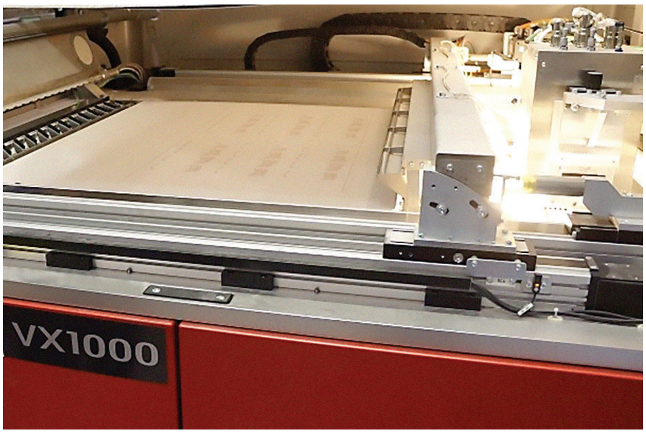
Bottom of mold.

Core (hydraulics).

c) Completion, machining, and controls

Following the completion of the mold, liquid aluminium bronze is poured. Once it has cooled the operators knocks out the part before cutting the risers and grinding the surface.

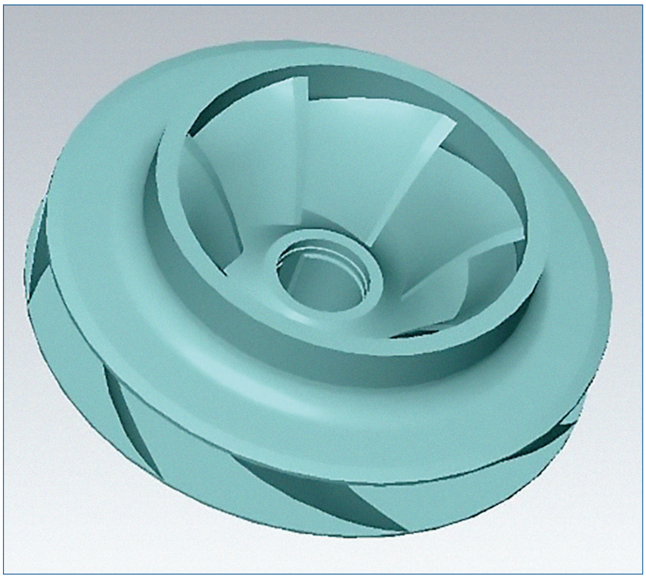
As quality is a major requirement for each parts of an application, several controls are used, including: base material conformity by chemical analysis and tensile test, dimensional control, and surface roughness



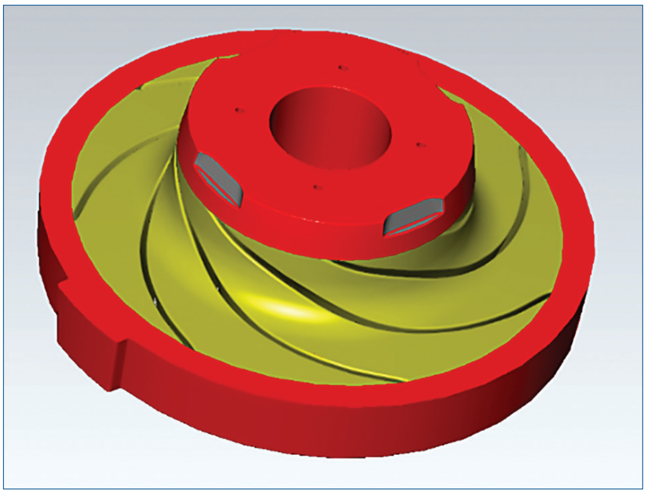
3D printing in layers.

control. The use of surface roughness control ultimately helps reduce the time spent on the grinding phase.

At this stage, the impeller is ready for final machining, including slotting and balancing. Final controls include dimensional and dye penetrant tests.



Impeller 3D file.



3D file used for printing the core.

	Lead Times	Cost	Patterns	Batch Size	Design Complexity	Storage Costs	3D Files
Standard Sand Casting	++	+++	Needed	Small & medium size	+++	+++	No
3D Sand Printing	++++	+	Not needed	Prototype & small size	++++	0	Yes
3D Sandbloc machining	+++	+	Not needed	Prototype & small size	++	0	Yes
Combined: Standard + 3D Printing	+++	++	Needed	Small & medium size for complexe parts	++++	+	Partially

INOXYDA has now led several projects combining both technologies and has gathered experience and knowledge to establish a first comparison chart of possible solutions.

Comparison and Limits of 3D Technology

The successful replacement of the impeller for this project provided a unique opportunity for a comparison between standard sand casting and 3D sand printed casting. The use of the two methods together proved to be fully complementary and resulted in reduced lead-time. The primary complications arose from having a number of trades with different backgrounds working together: Design Engineer, 3D Programmers, Molders, Founders/Melters, and Machining Operators were all required to make the project successful. In terms of the quality of the impeller, all of the criteria was reached using the 3D method; surface roughness was even improved.

As all technologies have limits that must be identified in order to find the right solution, the following issues were taken into consideration at early stages of the project:

- Batch size: 3D sand printing is, today, not competitive for simple parts where patterns exist,
- Cost of 'Risk': Cost of printing is still high. Any problem after closing the mold could lead to significant extra costs, and
- Dimensions: For large sizes the cost of the 3D printer is still significant and leads to long printing time.

Note on Using of 3D Sand Printing Technologies

Based on a number of different projects that have been carried out, INOXYDA has chosen to continue using existing pattern based sand casting for simple parts, or when patterns are already readily available. When more complex parts are required, such as in the case of multiple cores and/or for spare parts where patterns are no longer available, the 3D sand printing is preferred.

Mold fully assembled.

About the Authors

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