CASTING NO DOUBTS

COMPARING COST AND QUALITY OF A COMPLEX INVESTMENT CAST PUMP IMPELLER MADE FROM MOLDED WAX AND QUICKCAST PATTERNS

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Designing a pump impeller that performs well is challenging. The fluids being pumped are often multi-component, and the flow velocities and volumes are high, which make predicting performance analytically very difficult. Performance is best optimized experimentally using an iterative process: design an impeller, cast the design, test the performance, make a design change, cast the new design, and retest, and so on until an optimum design is reached.

In practice, however, optimizing performance in this manner has been prohibitively expensive. Tooling costs for impellers are significant because they often require cores, either soluble or ceramic, to create the internal flow-paths. Consequently, multiple tools must be built encompassing cores, gating and the main pattern. It simply is not practical to modify or rebuild tooling to evaluate design changes. As a result, pump manufacturers accept suboptimal performance rather than spend the time and money to optimize performance.

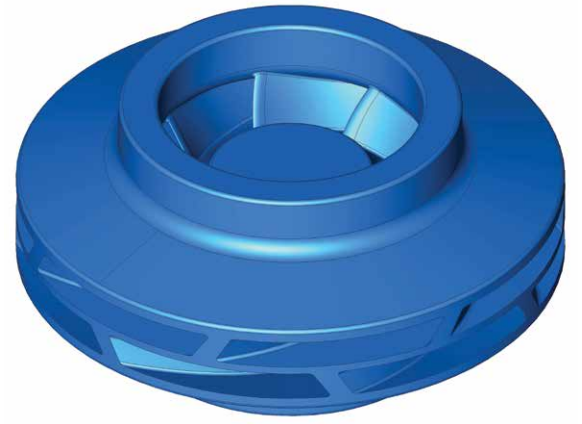
QUICKCAST PATTERNS

Tech Cast, LLC, a leading supplier of high quality investment castings, has pioneered the use of QuickCast patterns in the development of pump impellers. One of their specialties is large complex pump impeller castings up to 350 pounds (158 kilograms) and 36 inches (91 centmeters) in diameter.

Figure 1: QuickCast Pattern

QuickCast patterns, introduced over the past several years, provide increased design versatility without physical constraints of conventional tooling. QuickCast patterns are hollow stereolithography parts, as seen in figure 1, which can be used as investment casting patterns. Because QuickCast patterns are created using an additive manufacturing technology, the process requires no tooling enabling prototype pattern creation at a fraction of the cost and time required for tooling. Tech Cast Direct patterns enable Tech Cast's customers to evaluate several design alternatives inexpensively and reach a better performing impeller. In addition, QuickCast patterns allow for several design alternatives to be evaluated simultaneously, shortening the time needed to reach the final design.

Figure 2: Test Geometry



WORK WITH 3D SYSTEMS

In 2012, Tech Cast worked with 3D Systems to compare the quality, cost, and time requirements of castings created with QuickCast patterns to those created by conventional wax patterns. The study had several objectives:

- Determine the quality of castings created with QuickCast patterns relative to those created with wax patterns. Included in the quality evaluation will be dimensional accuracy, surface roughness, and surface quality

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- Determine the relative total cost to create the first casting.
- Determine the time required to create the first casting with each method.

Table 1: QuickCast Pattern Comparison

Dimension ID	Target	Actual	Deviation	% Deviation
1	15.955	15.959	0.004	0.03%
2	7.782	7.779	-0.003	-0.04%
3	3.03	3.032	0.002	0.07%
4	9.745	9.747	0.002	0.02%
Average Absolute Percent Deviation				**0.04%**

Test Geometry

Tech Cast chose a double suction impeller roughly 16 inches (40 centimeters) in diameter, pictured in figure 2 as the test geometry. The conventional wax injection tooling for this design cost $40,000 and had a lead time of eight to ten weeks. 3D Systems supplied the QuickCast pattern for the study.

Test Procedure

Tech Cast processed the QuickCast pattern, using the best practices according to their experience and recommendations from 3D Systems. Tech Cast documented labor hours at each step of the process and compared the casting results between QuickCast patterns and conventional wax patterns.

ASSESSING THE RESULTS

Dimensional Accuracy

Tech Cast measured critical dimensions on both the patterns and their respective castings.

Table 1 shows measurements of the patterns which are scaled to compensate for shrinkage. The accuracy of the QuickCast pattern was comparable to the wax pattern. The largest deviation from an individual measurement for the QuickCast pattern was 0.004 inches (0.1 millimeters). All deviations were less than one tenth of a percent compared to the nominal value and insignificant when compared to the tolerances of the casting requirements.

Dimensional inspection of the castings is shown in table 2. Both castings showed similar deviations to the intended casting target with an average dimensional error less than 1 percent. From a dimensional accuracy viewpoint, the QuickCast pattern demonstrated the capability of producing a predictable, precise casting.

Surface Roughness

Surface roughness was measured on each of the castings as shown in the table below. The casting from the QuickCast pattern had a rougher surface but remained within limits for the casting application.

Table 2: Casting Comparison

Dimension ID	Casting Target	Casting from Wax Pattern			Casting from QuickCast Pattern		
		Actual	Deviation	Percent Deviation	Actual	Deviation	Percent Deviation
1	15.75	15.880	0.130	0.83%	15.728	-0.022	-0.14%
2	7.63	7.560	-0.070	-0.92%	7.615	-0.015	-0.20%
3	2.93	2.933	0.003	0.10%	2.949	0.019	0.65%
4	9.62	9.648	0.028	0.29%	9.581	-0.039	-0.41%
Average Absolute Percent Deviation		**0.53%**			**0.35%**		

Surface Quality

Surface quality refers to the absence of surface imperfections that detract from the appearance and functional performance of the component and may require repair. Such imperfections can include negatives to the surface such as pitting or cracks, or positives to the surface that could result from shell imperfections. The casting made from the QuickCast pattern exhibited an increase in negative areas on the casting, however, the severity of the surface defects did not impact casting performance.

Table 3: Surface Finish Comparison

Pattern Type	Surface Roughness (µin Ra)
Wax Pattern	122
QuickCast Pattern	159

CASTING PROCESS

Once the pattern is obtained, the casting process generally takes one to two weeks depending on casting size and

Table 4: Process Comparison

Step	Description	Wax Pattern	QuickCast Pattern
CAD Modeling	Incorporate pattern shrink, solidification modeling and gating into the casting design.	0-1 week	
Pattern	Obtain soluble core and pattern tooling or QuickCast pattern	7-9 weeks	1-2 weeks
Foundry Processing	Process the pattern through the foundry and clean the casting.	1 -2 weeks	
Time to First Casting	Time from receipt of order to shipment of first casting. (Casting complexity and value added services may affect this time)	9-12 weeks	2-5 weeks
Cash Expenditure	Purchases required to obtain first pattern. (This pricing excludes casting cost)	$40,000	$3,150

complexity. The processing time consists of such things as drying time in the shell building process, time in the oven to preheat the mold before pouring and time for the casting to solidify and cool. The process requires about the same amount of time whether QuickCast or wax patterns are used. There is extra time for molding the wax pattern but it is balanced against the time required to process the QuickCast patterns due to an additional burnout oven cycle necessary to completely remove the pattern material. Table 4 compares the processes between wax and QuickCast patterns.

Figure 3: Casting from QuickCast Pattern

CONCLUSIONS

Casting Quality
While not quite as good as a casting made from a wax pattern, the quality of a casting made from a QuickCast pattern is good enough for all but the most demanding applications.

Cost of the First Pattern
The foundry must invest $40,000 into tooling before obtaining the first casting when using wax patterns. If they choose to use QuickCast patterns, they need only invest $3150, less than 10 percent of that required for molded wax patterns. In this example, casting costs have been excluded from both cases.

Labor Content of Castings
Casting a QuickCast pattern requires similar labor compared to a wax pattern.

Time to First Casting
QuickCast patterns allow the foundry to deliver the first casting 6-8 weeks faster than wax patterns.

Applications

- **Direct manufacturing** – QuickCast patterns reduce the total costs of finished casting for limited runs or low volumes without significant sacrifice to casting quality.
- **Repair Parts** – No investment of injection tooling for one-off repair or legacy items.
- **Concurrent Designs** – A QuickCast pattern ordered simultaneous with wax tooling allows the foundry to prove out processing during tool construction.
- **Research and Development** – Multiple variations may be tested at the same time without incurring tool alteration costs.

A number of pump manufacturer applications can be fulfilled using precision castings created from QuickCast patterns. In fact, using QuickCast patterns may allow for evaluation of two iterations of a design in less time than it would take to build wax pattern tooling. The time and cost required to evaluate an iteration of the design using a QuickCast pattern is roughly equivalent to the average time and cost of making a design change to a tool. QuickCast patterns provide the perfect solution for delivering low volume, dimensionally accurate castings in a condensed time frame without significant capital investment in tooling. ■