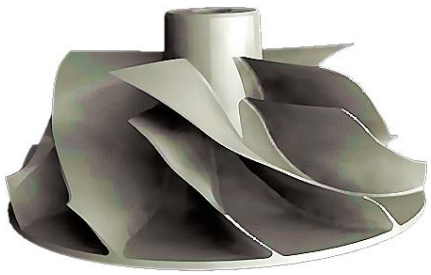
QUEEN CITY FORGING CO.
People who make the process work

Case Study

Queen City Forging Solutions in Aluminum **Turbocharger Impeller**



The Problem:

TURBOCAM International's OEM customer, a major turbocharger manufacturer, sought competitive advantage in the market by extending the warranty of its diesel turbochargers. The aluminum casting process, used to create a near net shape, could not provide the durability required for compressor impellers, a high speed rotating component subject to severe service challenges. To develop a new approach to manufacture a more durable impeller, TURBOCAM and the OEM turned to a process called "MFS" or "Made From Solid".

TURBOCAM's Manufacturing facility in Barrington, NH.

In the original design, an impeller blank was cast in an aluminum alloy prior to 5-axis machining of the final net shape. Porosity and inclusions inherent in the aluminum casting process limited structural integrity and fatigue properties that were needed to meet a new standard for reliability.

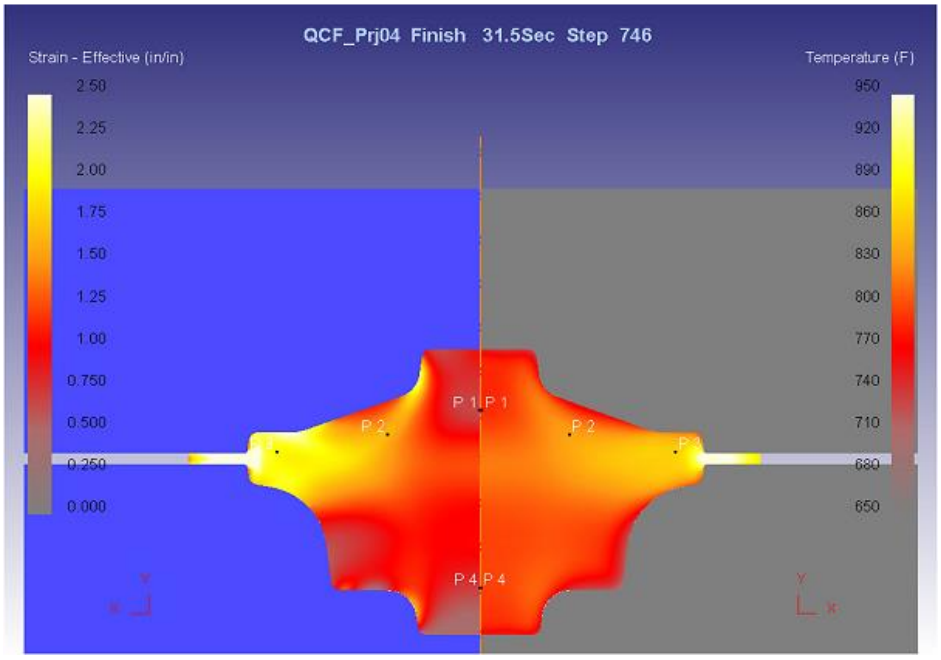
To address this deficiency, TURBOCAM explored several alternatives to casting. This included the option of CNC machining the impeller's net shape from solid aluminum alloy extruded bar stock. Although this approach improved part durability, the significant increase in machining time, and scrap in the form of chips removed in the machining operations added an unacceptable cost burden to the production process.

At the OEM's direction, TURBOCAM explored the use of aluminum alloy forgings as an alternative to casting the impeller or machining it from extruded bar. For this challenging automotive application, where requirements were similar to the demands of aerospace rotating parts, there were concerns with some traditional forging approaches. Aero engine rotating components are typically produced in forge shops where high costs would mean high price. Such shops are not geared to volume production. A limited number of conventional shops forge aluminum and use volume production techniques that cannot provide full benefit of the MFS process. In their

exploration, TURBOCAM discovered Queen City Forging, a forging producer with the innovating thinking and forging expertise to help develop the right solution to this problem . . .

The QC Forge Solution:

QC Forging's team started the process by collaborating with TURBOCAM and their OEM's engineering team, using computational modeling to simulate the functional requirements of the impeller over its product life. This included examination of the forces the OEM had identified through laborious destructive testing, targeting critical structural/fatigue properties that impacted the performance of the finished component in service. Engineering the deformation process to optimize the metallurgy was the key.



Computational modeling was used to simulate the functional requirements of the impeller

Providing the icing on the cake for TURBOCAM and its customer, QC Forge had been working with Oak Ridge National Laboratory on the development of a new, Rapid Infrared (IR) furnace that uses infrared radiant heating to assure rapid, uniform heating for the aluminum forging process. Along with energy savings, this patented heating process had already produced remarkable metallurgical improvements in aluminum, including increased strength and improved fatigue properties in a 2000 series alloy aluminum forging, comparing conventional convection oven heating with results from the rapid IR process.

A series of tests revealed that the metallurgy of IR heated aluminum forgings had a finer grain structure, superior tensile and higher hardness values than those processed conventionally, as shown in Table 4 and Figure 8 (below). In addition, the faster heating

ramp up of the IR furnace was shown to quadruple productivity, while consuming one-third less energy than traditional aluminum heating methods.

Table 4. Process conditions, grain size and hardness of AA2618 forgings

Specimen	Forging	Solution Heat Treatment	Aging	Grain Size[1]	Hardness[2]
	425 °C	530 °C	200 °C	(μm)	(HRB)
I	Conventional	Conventional	Conventional	40	59.5
II	IR-preheating	IR, 40 mins	Conventional	27	67.7

[1]Grain size measured by linear interception. Listed are transverse cross-section grain sizes.
[2]Determined on transverse cross-section.

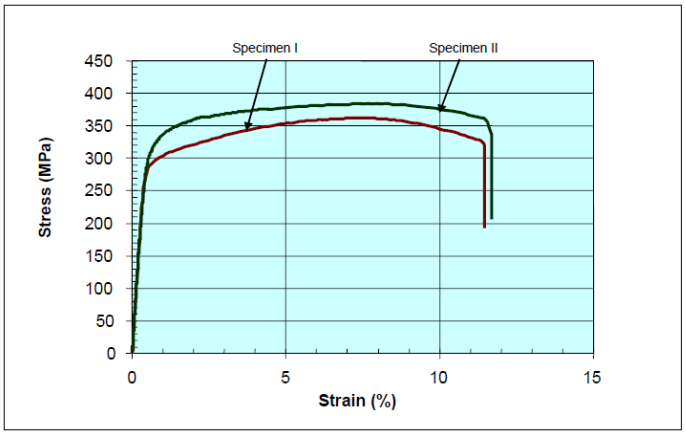


Figure 8. Stress-strain curves of specimens I and II. The tensile tests were performed at room temperature using 2.5 mm thick flat specimens 6.0 mm in width and 15 mm in gage length, cut longitudinally from the center of the forgings.

With two (2) infrared aluminum forging ovens built and installed at Queen City Forging, this unique heating technology[1] turned out to be the ideal solution to the challenging requirements for durable impellers. QCF's forging process achieved grain refinement and enhanced part durability, while improving process uniformity and throughput enough to cost-competitively produce the impellers at the production levels needed by the turbocharger OEM.

After forging at QCF, the aluminum impellers were then Inspected, trimmed, and heat treated in preparation for subsequent delivery to TURBOCAM for high speed CNC machining of the finished impellers.

[1] **This technology is exclusively available at Queen City Forging.** U.S. Patent 7,544,256B2

The Results:

Queen City Forging's approach and innovative IR aluminum forging process delivered impellers with enhanced durability - properties so good, the cost effective aluminum impeller replaced a significant quantity of impellers previously offered in a titanium alloy. A win for the OEM and a win for their customers! The forgings also provided unanticipated benefits over aluminum castings as the improved uniformity reduced time consuming bench work, often required by castings during finishing processes.

Although the impeller forgings required more 5-axis machining of the blades than a near net casting, the forged shape provided an additional advantage for TURBOCAM, allowing them to use forgings to produce a variety of end products, including several finished part designs from one forging blank and prototypes with improved operating efficiency. New experiments carried all the metallurgical advantages of a proven process, allowing confidence the results depended only on the change in machining and finishing.

QC Forging produced over 300,000 aluminum turbocharger impeller forgings for TURBOCAM by the end of 2012 and has continued to meet their production volumes with the strict requirements set forth by the OEM. QCF's innovative solution helped TURBOCAM meet this critical challenge and grow their business with the OEM, supporting the company's position as a global leader in the development and manufacturing of turbomachinery components.

Best of all, this impeller manufacturing solution helped the turbocharger OEM realize the strategic goal of extending their product warranty and retaining their reputation as leader in the market.

…a solution forged by innovation.

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