Identifying a Candidate for Conversion to Casting

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Michael A. Gwyn, Advanced Technology Institute, North Charleston, South Carolina
Alfred T. Spada, Executive Editor

This article originally appeared in Engineered Casting Solutions, the magazine for designers and purchasers of castings. Although it was written with the casting end-user in mind, it contains valuable information for every foundry that participates in casting conversions. Think of it as an opportunity to see the kind of process your customer may be taking as he identifies potential conversions to castings.
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How do you spot a conversion opportunity for casting? On the floor of your manufacturing and assembly operation, you undoubtedly have seen components currently made up of several stamped, wrought or machined metal parts. Could they be redesigned to a single cast metal component for improved performance? How do you determine if the potential performance gain or cost savings would make the redesign viable?

The choice of whether a component is best manufactured as welded, assembled, machined or cast component is based on the component’s geometry, production costs and requirements in application. This article looks at these issues and provides a framework for analyzing weldments and assemblies as possible conversion candidates.

When to Look to Change

The focus for design engineers often is time to market. Because of delays elsewhere, components often are designed to be manufactured by the process(es) that will deliver them with the shortest lead time. This leads to OEMs designing and manufacturing weldments and assemblies of weldments in-house, utilizing their available capacity and labor and eliminating the demands of sourcing a component (such as design changes and pattern costs). Design engineers generally feel more comfortable designing “building blocks” of simple wrought shapes. This is the method commonly taught in structural design, and manufacturing engineering and purchasing colleagues are comfortable with bringing weldments and assemblies of weldments into production.

Another quick-to-market option is to hog-out (machine) a shape from stock to produce a required component, simplifying the sourcing process to a one-step machining operation. Although both approaches deliver the product to the customer in a time-efficient manner, they may not deliver it in the most cost-effective manner, particularly when volume increases.

Weldments and assemblies of weldments create a significant volume of part numbers to produce (or buy), schedule and track. They require high levels of labor to fixture (weld, bolt, align, etc.) and typically aren’t as dimensionally or structurally consistent due to the inherent variabilities in manufacturing.

On the other hand, hog-outs have the advantage of known wrought stock mechanical properties (making them a popular choice for critical aerospace applications) but suffer from high costs because a large percentage of the bar stock they are borne from ends up on the machining room floor. Because mechanical properties of casting alloys are not as well defined nor as widely available in properties literature (casting’s mechanical properties depend on the process and involve liquid flow and solidification gradients), some structural designers feel more comfortable with wrought metal properties. As a result, however, the opportunity to learn more about the casting structural properties is often missed, along with the prospects of lighter, stronger and more cost-effective parts.

In prototype situations when time is of the essence, weldments, assemblies and/or machining are sometimes selected over casting to bring the product to market quickly. The key is to convert these fabricated components to the most efficient manufacturing method once volume production is ready to begin.

What to Look For in a Conversion Candidate

The first thing to look for in a possible conversion to casting is a component with a complex geometry. This could be a single component that was machined or forged, but more often than not the most impressive cost/weight savings is with a series of stampings and/or other wrought shapes that are welded and/or bolted together.

Components often are designed with the building-block mindset during the proto-

This D357 aluminum alloy main landing gear door uplock support sheet metal assembly for the Boeing 777 aircraft (shown installed at l) was converted to a one-piece casting (ctr) for the 767 aircraft. The conversion eliminated 27 part numbers from Boeing’s inventory and reduced internal manufacturing flow by 65%. The cast component is shown installed at right.
The process of converting weldments to castings at Oshkosh Truck begins by identifying candidate weldments. A “walk around” is performed on a vehicle with representatives from:

- **Engineering**—those who understand the form, fit and function of the weldment;
- **Purchasing**—someone who has knowledge of the weldment’s quantities and cost;
- **Metalcasting official**—who can identify the castability of the weldment and what (if any) geometric changes must be performed to enable casting of the part’s geometric envelope, from both a castability and structural standpoint.

Forming a team, these individuals work together to understand components that are candidates for conversion. Not all weldments are good conversion candidates. Poor candidates are weldments that have a low annual use (unable to accommodate the pattern costs of casting), rely on specific materials characteristics that are unavailable with ductile iron and whose geometries aren’t readily castable.

In any design conversion to casting, overall part geometry must be explored with structural, casting and downstream manufacturing in mind. This 60-lb hitch housing casting for U.S. military tow and cargo trucks was converted from a 35-piece, bolted-and-welded assembly to a 10-piece component at a cost and weight savings. Cast in 8630 steel in green sand, the component was redesigned with vertical alignment bosses, rib stiffeners and bosses to improve the strength required to withstand 15,000 lb of stress. The new design also eliminated 5 hr of alignment on the assembly lines.

Therefore, the team must work together and look at all aspects of the part to determine if the weldment is an appropriate conversion candidate. These candidates are typically complex weldments that consist of several pieces, have a castable geometry and are welded from a material whose engineering material properties can be approximated by the foundry.

The tensile properties of the weldment only are a fraction of the possible material characteristics that must be considered when evaluating conversion candidates. Table 1 shows a comparison of material characteristics that may need to be considered for any application. For a typical 1020 steel weldment with a minimum tensile strength of 48 ksi, 27 ksi yield strength and hardness ranging from 96-140 Bhn, the conversion to a 65-45-12 or 60-40-18 grade of ductile iron increases tensile properties.

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Normally, components are designed to yield strength characteristics with an added safety factor. But, because most failures occur from repeated application of loads (fatigue) that generate stresses below the material’s
ponent performance. The well-known mechanical properties of wrought metals are directional (stronger in the wrought direction, weaker in the transverse direction) and may be compromised significantly by welding. A properly produced, high-integrity casting with isotropic mechanical properties (equal in all directions) enjoys uniformity of properties in continuous sections as well as junctions. In addition, visual appearance must be evaluated. While fabrications offer smooth surfaces, their welded junctions are not as pleasing to the eye as the continuity of a complex cast shape.

**Is the Conversion Feasible?**

If a component or series of components have been identified for possible conversion to casting, the next step is to bring in a metalcaster to determine the component’s castability and possible cost/weight reductions. Typically, redesigns to casting aims for a 40% cost reduction from the weldment, assembly or manufacturing.

The greater the inches of weld needed to make up a component from several smaller components, the more likely it is a candidate for conversion to casting.

**Number of parts**—Is the component made up of several smaller parts that have been attached together? If it is, would a single casting reduce the cost associated with part number inventory as well as free up in-house operations for other more important manufacturing tasks?

**Dimensional consistency**—How tight are the tolerances for the component? Is warping ever an issue? The inherent dimensional inconsistency with castings is eliminated with a single cast component.

**Scrap rates**—Are scrap rates high for the component during in-house fabrication? If so, the component may be better manufactured out-of-house via a different production method.

**Appearance**—Is the component visible? Does it require a clean, streamlined appearance with a fine surface finish?

**Field problems**—Does the component fail in use? Are the stresses exerted on it too great? Castings provide consistent properties throughout each component, eliminating much of the variability found in assemblies and weldments.

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**7 Considerations for Potential Casting Conversions**

When examining a weldment or assembly for a possible conversion to casting, following are seven considerations to determine the feasibility of the redesign:

- **Geometry**—Is the component complex enough to warrant a redesign to casting?
- **Inches of weld**—The greater the inches of weld needed to make up a component from several smaller components, the more likely it is a candidate for conversion to casting.
- **Number of parts**—Is the component made up of several smaller parts that have been attached together? If it is, would a single casting reduce the cost associated with part number inventory as well as free up in-house operations for other more important manufacturing tasks?
- **Dimensional consistency**—How tight are the tolerances for the component? Is warping ever an issue? The inherent dimensional inconsistency with fabrications is eliminated with a single cast component.
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**at Oshkosh Truck Corp.**

Yield strength, notch geometries and microstructural transitions inherently present in a weldment become the critical factor in the survivability of the component. In most cases, the casting offers increased durability and resistance to fatigue failure by reducing or eliminating these discontinuities.

Although lower in ductility and toughness than steel, ductile iron offers significant toughness, a slight reduction in density and some damping characteristics. In addition, the elimination of weldments provides the component with improved function through more uniform loading in the casting cross section.

**Optimizing Design**

Examination of a weldment for potential casting conversion also provides an opportunity to optimize the component’s design. As part of the casting conversion process, a finite element analysis should be performed and confirmed with actual testing. During this activity, the design can be optimized for load-carrying capability.

Time may not have been available during the prototype stage to perform this type of in-depth analysis. Instead, reliance was placed on experience and a liberal safety factor. Hence, examining it for a casting conversion provides a unique opportunity to reinvestigate the part. A redesign may improve its function or merely improve cosmetic appearance.

Casting the weldment also will result in fewer internal stresses, depending on how it is cooled, which results in less distortion during subsequent machining operations. This will aid in more accurate dimensional conformance.

Weldments inherently contain residual tensile stresses that can approach the material’s yield strength. Removing material during machining operations has the tendency to relieve these residual stresses and generates distortion. Only if the weldment is stress-relieved before machining can the distortions be eliminated. These benefits lend justification to converting the weldment into a casting.

—Robert M. Hathaway, Material Process Engineer, Oshkosh Truck Corp., Oshkosh, Wisconsin

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**Table 1. Rolled Steel vs. Ductile Iron Material Comparisons**

<table>
<thead>
<tr>
<th>Properties</th>
<th>Hot Rolled Steel: AISI 1020, ASTM A830</th>
<th>Ductile Iron: Grade 65-45-12, ASTM A536</th>
<th>Ductile Iron: Grade 60-40-18, ASTM A536</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength (ksi)</td>
<td>48 min.</td>
<td>65 min.</td>
<td>60 min.</td>
</tr>
<tr>
<td>Yield Strength (ksi)</td>
<td>27 min.</td>
<td>45 min.</td>
<td>40 min.</td>
</tr>
<tr>
<td>Elongation in 2 in. (%)</td>
<td>36</td>
<td>12 min.</td>
<td>18 min.</td>
</tr>
<tr>
<td>Hardness [BHN]</td>
<td>96-140</td>
<td>156-217</td>
<td>143-187</td>
</tr>
<tr>
<td>Modulus of Elasticity [x 10^6 psi]</td>
<td>29.5</td>
<td>24.4</td>
<td>24.5</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>0.33</td>
<td>0.29</td>
<td>0.29</td>
</tr>
<tr>
<td>Specific Damping Capacity</td>
<td>1.5</td>
<td>≈9.9</td>
<td>≈9.9</td>
</tr>
<tr>
<td>Density [lb/cu in.]</td>
<td>0.2839</td>
<td>0.2565</td>
<td>0.2565</td>
</tr>
<tr>
<td>Machinability Rating (%)</td>
<td>78 at feed of = 0.17 mm/rev</td>
<td>42-83 at feeds of 0.25-0.50 mm/rev</td>
<td>67-108 at feeds of 0.25-0.50 mm/rev</td>
</tr>
</tbody>
</table>
hog-out to overcome the labor and lead-time benefits associated with the other manufacturing methods.

The first step in identifying a casting partner is to determine the material in which the redesigned component could be made. Weldments and assemblies of weldments often are fabricated from wrought steel shapes because carbon and low-alloy steel is the most easily weldable of metals and provides high toughness, strength, ductility, yield stress and stiffness. The problem is that steel often is chosen solely on its weldability. If the component is going to be a casting instead of a weldment, then weldability may not be as important. Therefore, other materials should be considered.

Potential questions to ask to determine the correct material include: What material is required for the application from a physical and mechanical property standpoint? Will the component be used in a severe service application with high fatigue and impact resistance or is it a cosmetic part? Does it need to adsorb vibration? Does it need to control sparks? Does it need to resist corrosion? Does it need to be lightweight?

Steel is the material of choice when high impact resistance and fatigue life are required for severe service applications. In addition, if the cast component is going to be welded to another component, then steel is a logical choice. Generally, however, the opportunity exists to replace a steel weldment with a casting from another alloy family, such as iron or aluminum.

If the component is going to be used in a fatigue application, but isn’t a severe service application, then iron may be the logical choice because of its castability (ease of casting). Ductile iron in particular has made a name for itself in the conversion of steel fabrications to castings because it combines excellent castability with reasonable toughness.

When weight is an issue without severe service application, aluminum often is the casting material choice. With new technology in alloying and molding, aluminum is increasingly becoming a material of choice in important fatigue applications, such as replacing stamped steel fabrications with squeeze-cast aluminum in automotive suspension components.

Regardless of choice of alloy family, the most significant factor in the success of castings in structural applications is the use of geometry to control stress and stiffness. Only the casting process offers so much variety in shape at low cost. Even though some alloys are stiffer than others (for example, steel is 3 times stiffer than aluminum), it is stiffness from shape that makes castings a breakthrough metal product form.

Once a material is selected, design engineers must then go to their purchasing colleagues to begin the search for a casting partner to assist in the redesign of the component to casting. Ask your purchasing colleagues to find casting sources who appreciate the importance of structural geometry in casting design. Such a casting producer will offer the most overall capability in cost reduction and component improvement when converting stamped steel fabrications, weldments and weldment assemblies to metal castings.

For More Information

Cost-Effective Casting Design, a Cast Metals Institute course, Des Plaines, IL.


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