Introduction

Principles of centrifugal castings
When it comes to metal forming, casting metal can be one of the simplest, most cost-effective routes to a near net shape manufactured good. Centrifugal casting in particular has the capability of utilizing these desirable benefits during the production of cylindrical stainless steel products.

Centrifugal casting is a process where molten metal is funneled into a rotating mold (commonly 700 to 1300 rpm). The rotation of the die creates centrifugal force which thrusts the metal towards the mold wall.

Benefits

Process Control
Significant cost savings can be a result of process control. At Spuncast raw materials purchased are received and the chemistry evaluated. The chemistries are acquired through one of three methods: auditing pieces from various locations in that lot on the spectrometer, the purchased scrap comes with a certified chemistry, or a 100lb sample of material is melted down and a chemistry slug evaluated. This known/averaged chemistry creates the necessary control needed when working with low carbon alloys (such as Duplex). Charge sequence and temperature control also play a large role in controlling process variables. Charge sequence can control the amount of elemental recovery, as well as the cycle time of each melt. Temperature control allows the melter opportunity to avoid superheating the melt, ultimately affecting the chemistry, and tap the furnace with the exact amount of temperative increase needed to pour the casting above but close to its liquidus temperature. Another way temperature control plays a key role is during the casting solidification process. Centrifugal casting promotes directional grain growth during solidification, as shown in the pictures below.

Secondary Refining
The centrifugal forces promote metal cleanliness by forcing the non-metallic’s (less dense) to the inner diameter of the casting. As solidification takes place, the inner surface acts as a riser feeding the outer diameter with the metal it needs to produce a solid, dense casting. The less dense materials (the dirt, dross, or slag) that were forced to the bore of the casting can now be subsequently machined off. Since the use of gating and risers are eliminated, the productions of these castings have an extremely high casting yield.

Shapes and Sizes
Centrifugal casting is most appropriate when producing relatively simple cylindrical shaped parts. The list that follows shows the size ranges and limitations for the production of parts using this unique casting process.
Size Limits: [1]

Diameter: Up to 3 m (10 feet)
Length: 15 m (50 feet)
Wall Thickness: 2.5 mm to 125 mm (0.1 - 5.0 in)
OD Tolerance: as fine as 2.5 mm (0.1 in)
ID Tolerance: can be 3.8 mm (0.15 in)

Figure 3: Size Limitations for Centrifugal Casting

Utilizing a vertical casting orientation, more complex shapes are quite possible by the use of either chemically bonded sand inserts or investment (lost-wax) shell inserts.

**Advantage and Limitation**
Centrifugal castings can be more cost effective than forgings and have properties that surpass those of most other casting processes. This centrifugally cast dense structure creates castings with a longer life. These parts can withstand greater loads and impacts without fracturing.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forged Tool (Billet)</td>
<td>High residual cost</td>
</tr>
<tr>
<td>Low Filling Choke</td>
<td>Dense Casting Costs</td>
</tr>
<tr>
<td>Improved Properties</td>
<td>Long Manufacturing Costs</td>
</tr>
<tr>
<td>Duplicate Casting</td>
<td>High material cost</td>
</tr>
<tr>
<td><strong>Strength Limitations</strong></td>
<td>Density Limitations</td>
</tr>
<tr>
<td><strong>Inherent Inclusions</strong></td>
<td>Micro-porosity</td>
</tr>
<tr>
<td><strong>Inherent Mismatch</strong></td>
<td>High mismatch of mechanical properties</td>
</tr>
</tbody>
</table>

Table 1: Above is a list of advantages and limitations to acknowledge when selecting a form of product manufacturing.

Two samples of centrifugally cast Duplex Stainless Steel parts:

**Decanter Centrifuges**

Solids Discharge Main Effluent

Figure 4: Decanter Centrifuges - Separating solids from liquids plays a key role in countless industrial, food and waste treatment processes.

**On-ship Hydraulic Accumulators**

Figure 5: On-ship Hydraulic Accumulators - Energy storage basin in which hydraulic fluids are held under pressure by a peripheral source.

**Duplex Stainless Steel Property Comparison**

**Mechanical Property Comparison: Wrought vs. Centrifugally Cast**

The primary U.S specification for cast duplex stainless steels is ASTM A890. There are eight grades within this specification. To date there is no accepted specification for a cast lean duplex. The following data is a comparison of achievable cast properties to wrought specifications for duplex grades 4A and 1B. These two were selected because they both have an abundance of history and data available. There are other duplex grade properties available, but the information is fairly limited.

**Grade 4A**

2205 - J92205

**Grade 1B**

2530 - J92205

Table 2: Mechanical property summary for 70 cast and heat treated tensile bars (1120°C Water Quench)

<table>
<thead>
<tr>
<th></th>
<th>UTS (MPa)</th>
<th>UTS (ksi)</th>
<th>Yield (MPa)</th>
<th>Yield (ksi)</th>
<th>Elongation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spun cast Avg.</td>
<td>1015.3</td>
<td>148</td>
<td>977</td>
<td>142</td>
<td>26.9</td>
</tr>
<tr>
<td>Wrought Spec. (S32550)</td>
<td>730</td>
<td>106</td>
<td>620</td>
<td>90</td>
<td>12.6</td>
</tr>
</tbody>
</table>

Table 3: Mechanical property summary for 16 cast and heat treated Tensile bars (1120°C Water Quench)

<table>
<thead>
<tr>
<th></th>
<th>UTS (MPa)</th>
<th>UTS (ksi)</th>
<th>Yield (MPa)</th>
<th>Yield (ksi)</th>
<th>Elongation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spun cast Avg.</td>
<td>231</td>
<td>33.8</td>
<td>198</td>
<td>29</td>
<td>13.3</td>
</tr>
<tr>
<td>Wrought Spec. (S32205)</td>
<td>150</td>
<td>22.1</td>
<td>110</td>
<td>16</td>
<td>8.5</td>
</tr>
</tbody>
</table>

Table 4: SCLean - Spuncast’s Cast Grade of Lean duplex

**SCLean**

SCLean - Spuncast’s Cast Grade of Lean duplex

Several wrought material grades have recently been introduced that accomplish cost saving by lowering the amount of Ni, but none of these were designed for castability (specifically centrifugal casting).

**As stated earlier, maximizing mechanical properties while minimizing the use of expensive raw materials was the primary objective. One without the other (mechanical properties / lower cost per kg) is of no use.**
The previously shown mechanical properties were made at the following price:

SCLean = $1.67 / Kg (based on $44.31/Kg Ni - LME)

For reference: That same week had the following prices:

CD4MCuN = $ 3.88 / Kg
Duplex4A = $ 4.54 / Kg

Conclusion
Centrifugal castings use directional solidification and pressure from the centrifugal force to create castings with a denser more sound structure exhibiting superior physical properties to that of statically poured castings.

It has been made clear that centrifugal casting is a versatile process with benefits in the areas of mechanical properties and overall process cost-effectiveness. The utilization of this process can be beneficial when producing a variety of products. One particular example shown was the specific development of SCLean as a “castable” lean duplex.

Reference(s)

About the authors

Shawn Martin
Academic Education & Degrees:
Bachelors of Science - Material Science & Engineering, Michigan Technological University
Current Position:
Metallurgist,
Spuncast, Inc, Watertown, WI USA

Greg Mooren
Academic Education & Degrees:
Bachelors of Science - Material Science & Engineering, Michigan Technological University
Current Position:
Metallurgist, Spuncast, Inc, Watertown, WI USA

Alan Holtz
Academic Education & Degrees:
Bachelor of Arts - History, University of Pennsylvania
Bachelor of Science - Metallurgical Engineering, University of Missouri - Rolla
Current Position: Vice President - Sales & Engineering, Spuncast, Inc, Watertown, WI USA