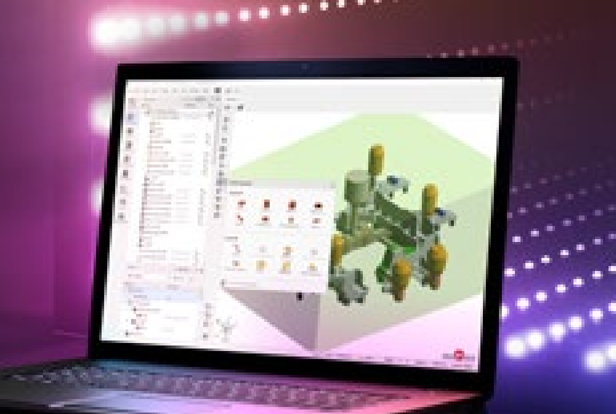
How Does Casting Support Impact Distortion During Heat Treatment?



INTRODUCTION

Heat treatment is a common practice to achieve higher mechanical properties in the component not reached during the casting process. Typical Heat treatment involves heating and cooling a casting after shakeout/ejection. Most heat treatment processes aim to 1) alleviate residual stresses left over from the casting process and 2) Improve the mechanical properties (e.g., Tensile Strength, Elongation, Hardness, Etc.) of the casting. Often, with complex castings, the component is placed on a rack of fixtures for part or all of the heat treatment processes to hold the casting in place, avoiding the formation of defects like distortion and cracking as the casting responds to thermal changes. The following study evaluated the impact of this support structure's design on the final casting quality.

SETUP

Figure 1. Geometry considered to evaluate support structures.

MAGMASOFT® tested three designs. Design one (Left) has a rack supporting the outer edge of the casting. Design 2 (Middle) supports the center hub. Design 3 (right) is of a similar rack structure to Design 1 with the casting rotated 180°.

In this experiment, the only variables were the rack designs and casting placement. All other process parameters were consistent between the three scenarios. The simulated cast alloy was 356 aluminum, and the rack was H13 tool steel, with an initial temperature of 30°C at the start of the heat treatment process simulation.

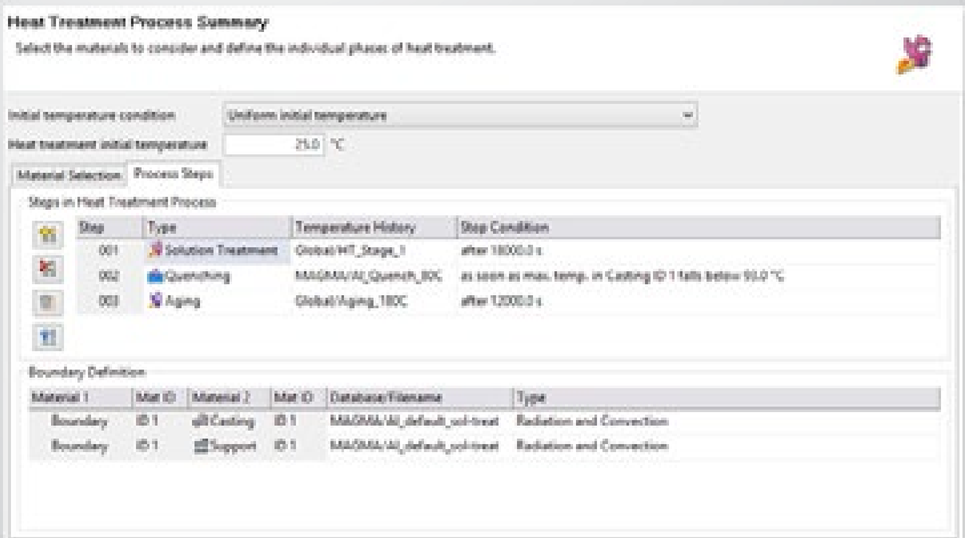


Figure 2. Heat Treatment recipe used for designs

The simulation replicated a T6 heat treatment process typical for aluminum castings. The steps considered were as follows:

Solution Treatment – The oven heats from 30°C to 538°C (1,000°F) over 3600 seconds (1 hr). Then the oven remains at 538°C (1,000 °F) for the remaining 14,400 seconds of this step.

Quenching – The casting is quenched in a bath of water at 80°C (176°F) until the maximum temperature in the casting falls below 93°C (200°F).

Aging – The casting is placed in an oven at 180°C (356°F) for 12,000 seconds (3.33 hr).

After the completion of the aging process, the casting is cooled naturally to ambient air at room temperature. At this point, distortion measurements were obtained.

RESULTS

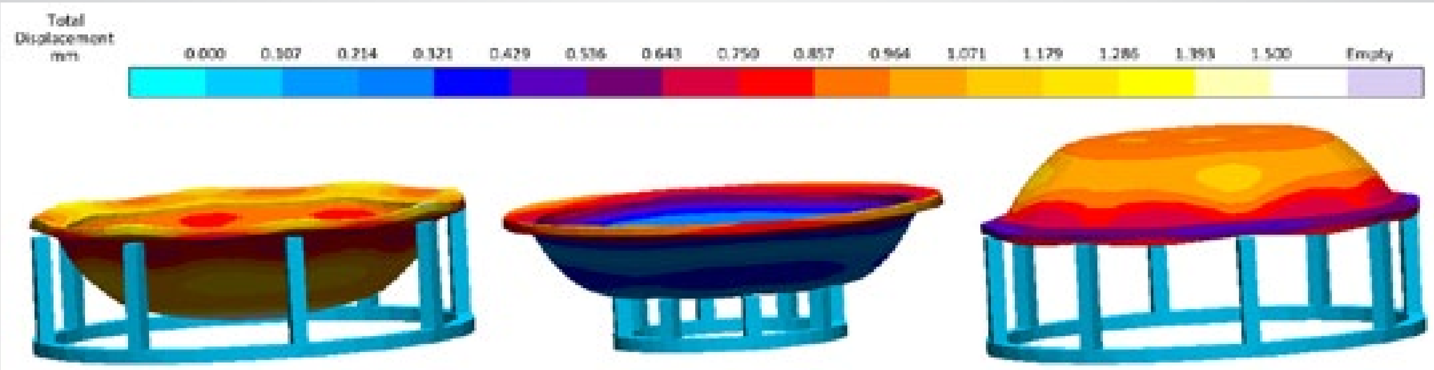


Figure 3. Comparison of distorted castings for 3 designs (D1 Left, D2 Middle, D3 Right)

Figure 6 shows the total displacement of the castings at the end of heat treatment at ambient temperature. The distortion viewing is activated and amplified ten times (10x) for better visibility.

Design 1 has the highest tendency for distortion of the three designs due to the support position being far from the center of mass of the part. The result is that the part tends to sag in the middle and between the support posts around the flange. The maximum displacement of the casting is in the center, where the warpage exceeds 2.5 mm.

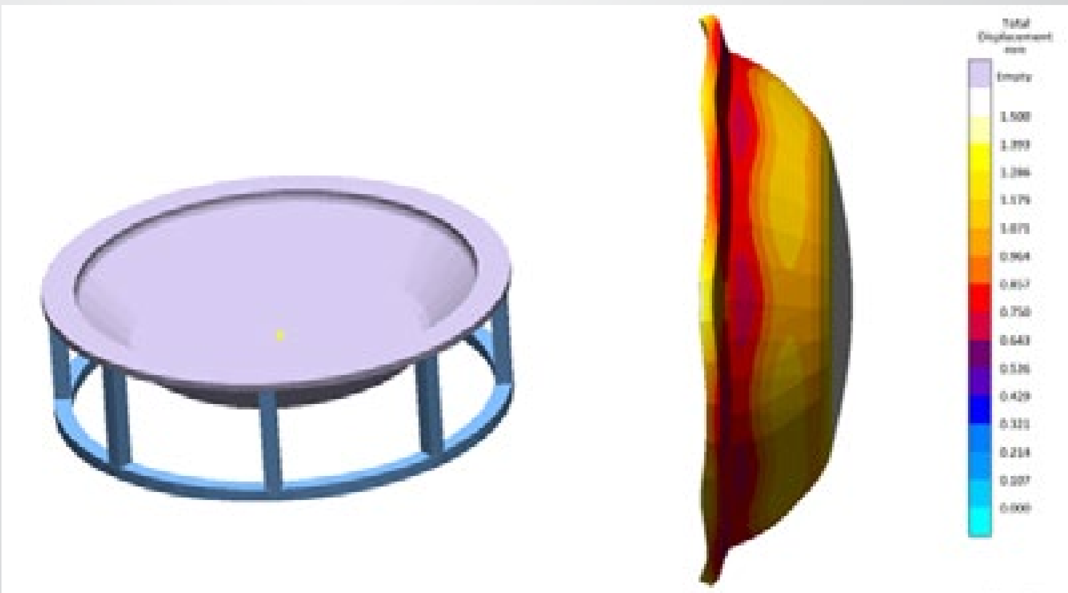


Figure 4. Total Displacement with distortion amplified x10 of Design 1

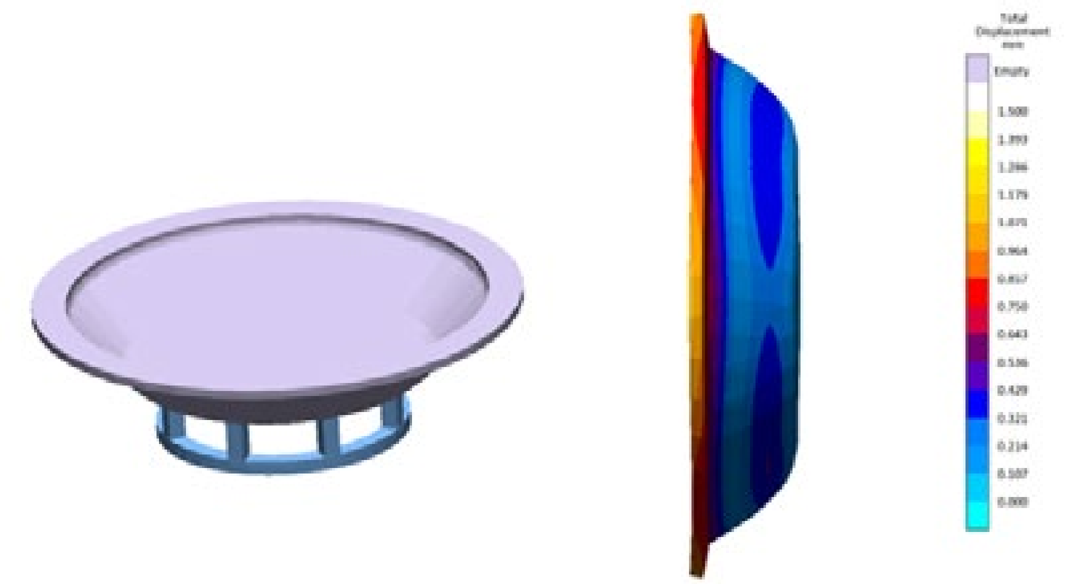


Figure 5. Total Displacement with distortion amplified x10 of Design 2

Design 2 had the lowest distortion tendency of the three designs. This design placed supports under the center of mass while the outer edge was unsupported. The maximum displacement of the casting is around the outer flange. However, this displacement is less than 1 mm.

Design 3 shows improvement compared to Design 1, as both have the same support structure. However, Design 3 flips the casting 180 degrees, combating some of the sagging observed in Design 1. This design falls short because the center of mass of the part still needs to be supported, and the existing supports need to be closer together. For this reason, there is a high distortion tendency at the areas of the outer edge where supports are present. The maximum displacement in this part is around the sides, exceeding 1 mm but far less than the 2.5 mm displacement of Design 1.

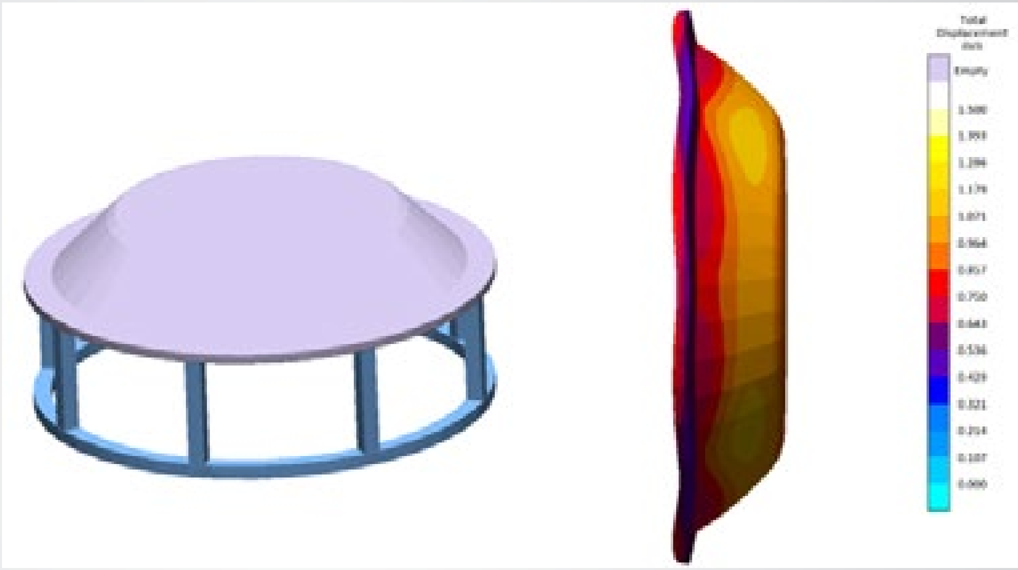


Figure 6. Total Displacement with distortion amplified x10 of Design 3

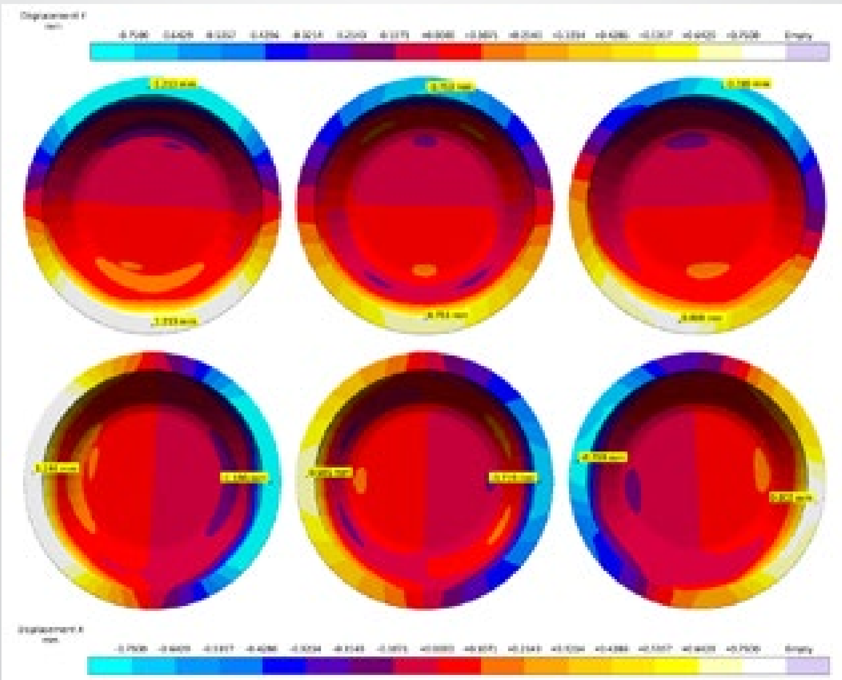


Figure 7. Displacement in X and Y for D1 (Left), D2 (Middle), and D3 (Right)

Design 1 had the highest displacement in the X and Y axis of the three designs, primarily due to the insufficient support placement leading to the part warping. The displacement in the X and Y axis is around 1.2 mm. Design 2 had the lowest displacement in the two axes of the three designs showing that supporting the parts‘ center of gravity is vital to promoting success during heat treatment. This design‘s displacement in the X and Y does not exceed 0.75 mm. As mentioned above, Design 3 showed improvements compared to Design 1. However, the support placement still leads to higher displacement in the X and Y than in Design 2. The displacement for design 3 in these axis reaches but does not exceed 0.80 mm.

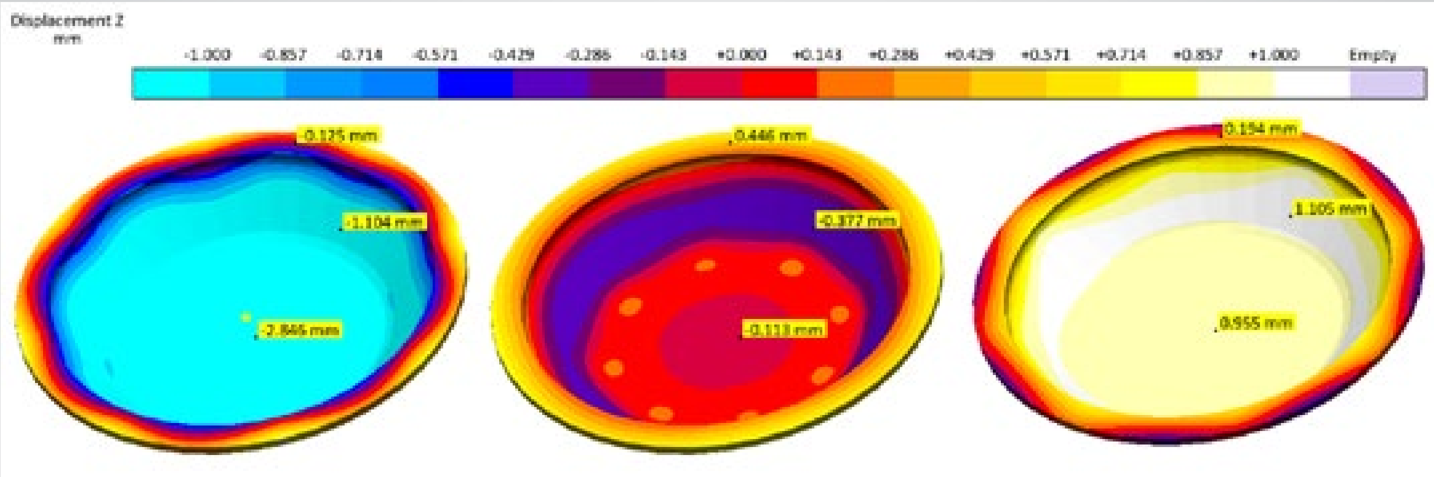


Figure 8. Displacement in z for D1 (Left), D2 (Middle), and D3 (Right)

Displacement in the Z axis shows the sagging tendencies. Design 1 has the highest tendency for displacement of the three designs, exceeding 2 mm in the center of the part where sagging is observed. Design 2 has the lowest tendency for displacement in the z axis, with the maximum displacement around the flange of the casting not exceeding 0.45 mm. By flipping the casting displacement in is cut in half from Design 1 to Design 3 in the center of the part. However there is still high displacement around the side of the casting in this design, exceeding 1 mm.

The analysis above shows that Design 2 has the highest tendency to have the casting within tolerance after the completion of the heat treatment process. Design 3 ranked second, where displacement was low; however, distortion was high around the edge due to non-optimal support placement. Design 1 was the worst of the three designs, as the center of mass had no support, which promoted the part to sag in the center.

CONCLUSIONS

A heat treatment rack needs to be optimized to minimize distortion risks during the solution phase of heat treatment. Considerations such as part geometry, part orientation, the center of mass, restriction of movement, and goals for the end casting quality should influence the design of the fixture or rack that supports the casting through the heat treatment process. Using MAGMASOFT® simulation, these support racks can be analyzed and optimized to help generate a quality heat treatment process from the start.