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Tub support Structure Micro Porosity and Flatness prediction through casting and thermo structural simulation.

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Abbreviations: *FEA-Finite element method , VA Vertical Axis, HPD- High pressure die casting*

Keywords: *Washing machine, Tub support structure, Casting simulation, Inspire click 2 cast, OptiStruct.*

Abstract

A washing machine is an appliance that washes and cleans the clothes. Some of the parts used in the washing machine are manufactured using casting processes. During manufacturing processes, these casted parts may have defects like porosity, voids, warping, etc. Due to manufacturing defects, these parts get failed in the field which leads to quality issues. The objective of the present work is to predict manufacturing defects using Inspire based Click2Cast and OptiStruct solver.

During manufacturing, it was found that the four legs of the bracket were not in the same plane due to which there is a problem with the mounting and tilting of the associated parts. Also, failure was observed in one of the screw bosses in the part. Initial investigation in the lab suggested failure occurred due to porosity. In the present study, a methodology was developed to predict the porosity and flatness problem of the tub mount bracket. The major challenge was to get process parameters for the casting process from the manufacturing supplier. The same process parameters were used in Click2Cast solver for the casting simulation. Another challenge was to predict the warpage of the part. Further analysis was done by mapping the casting temperature of the bracket in OptiStruct solver to predict the warping of the part. Good correlation was found in the simulation with the manufacturing defects.

Introduction

Casting is one of the oldest manufacturing processes. In this process, the material is first liquified by properly heating in a furnace and then the liquid is poured into a previously prepared mold cavity where it is allowed to solidify. Subsequently, the product is taken out of the mold cavity, trimmed and machined to shape. There are different casting process such as gravity die-casting, pressure die-casting, etc. The present study focuses on simulation approach based on high pressure die-casting to predict casting defects such as porosity, air entrapment, mold erosion, and warpage, using the commercially available Altair Inspire cast simulation software. Casting simulation normally involves the design of the runner, riser, mold cavity, material selection, initial velocity, the direction of filling, etc.

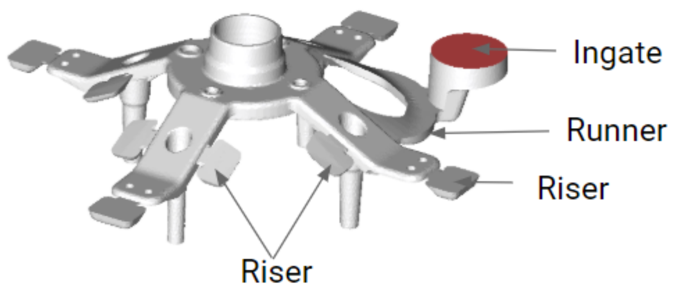


Figure 1: Major elements of Tub support bracket gating system

The main objective of this work in addition to detecting the casting defect in the washing machine tub support bracket is to develop a simulation Methodology to predict warpage in the component using co-simulation of Casting with FEA thermal structural methods.

1.1. VERTICAL AXIS WASHING MACHINE CONSTRUCTION

Vertical Axis (VA) washing machine popularly known as Top Load washing machines in which the wrapper and stationary tub mounts vertically and cloth loading is through the top door. Agitation is supplied by the back-and-forth rotation of the basket. This motion flexes the weave of the fabric and forces water and detergent solutions to pass through the clothes. At the end of the washing machine cycle, the spin cycle is used to remove water from clothes by rotating the drum at higher speed causing clothes to push on to the wall of the drum by centrifugal action. The process generates an unequal distribution of clothes inside drum surface. This causes an unequal distribution of clothes as an unbalanced mass in the system.

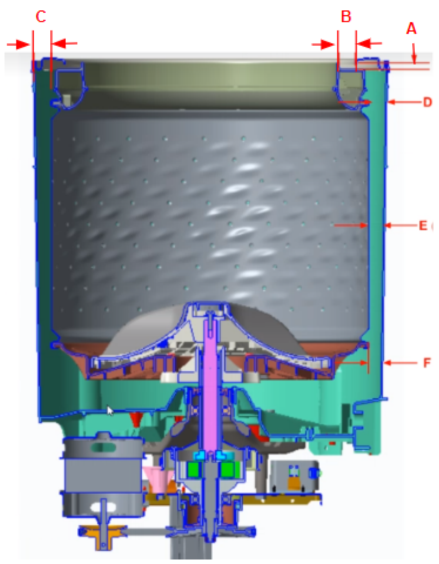


Figure 2: Washing machine construction (section view) highlighted with gap in subsystem

During manufacturing, it was found that the four legs of the bracket on which the stationary tub and entire subsystem is mounted considering the gap between subsystem as shown in Figure 2 were not in the same plane. Due to which there is a problem with the mounting and tilting of the associated parts in the assembly by 10 degrees creating uneven gaps. Tilting causes problem of drum rotation hitting the *associated parts. This caused flatness issue and is measured after the machining process. Also, porosity failure was observed in one of the screw bosses in the part.*

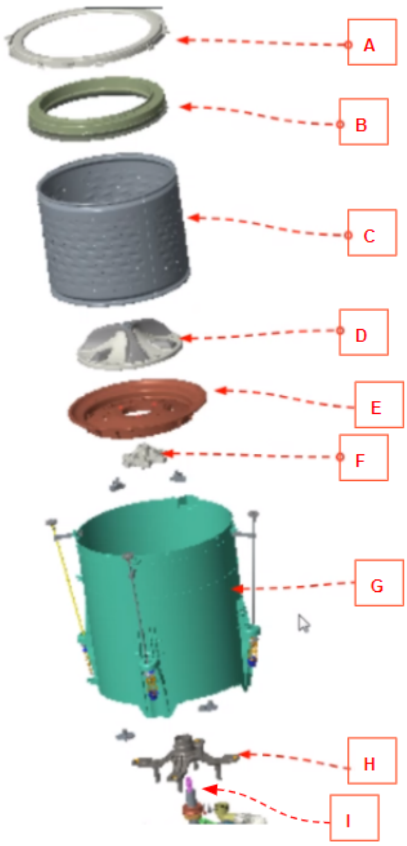


Figure 3: Wash unit exploded View

Figure 3 shows an exploded view of the subsystem of VA washing machine wash unit.
A- Tub Ring, B- Balance Ring, C-Wrapper, D- Agitator, E- Tub Base, F- Agitator Bracket, G- Stationary Tub, H- Tub support bracket, I -Shaft

The shaft (I) is supported in bearing mounted on Tub support bracket (H) passages to hold agitator (D). The stationary tub (G) is mounted on a tub support bracket (H) in which the rotating tub (C) get hold by spinning shaft (I). The Tub support bracket (H) is manufactured by casting process at the supplier end.

Process Methodology (details with figures)

In addition to the porosity and Air entrapment, casting manufacturing defects related to flatness (warpage) is also involved with the washing machine tub support bracket components. Using Inspire casting simulation *tool does not directly provide output in terms of warpage. It demands appropriate thermal-structural simulation methodology to develop in which the solidification temperature results from casting simulation will be mapped on structural FEA mesh. Below figure gives step by step approach for evaluating warpage in the component.*

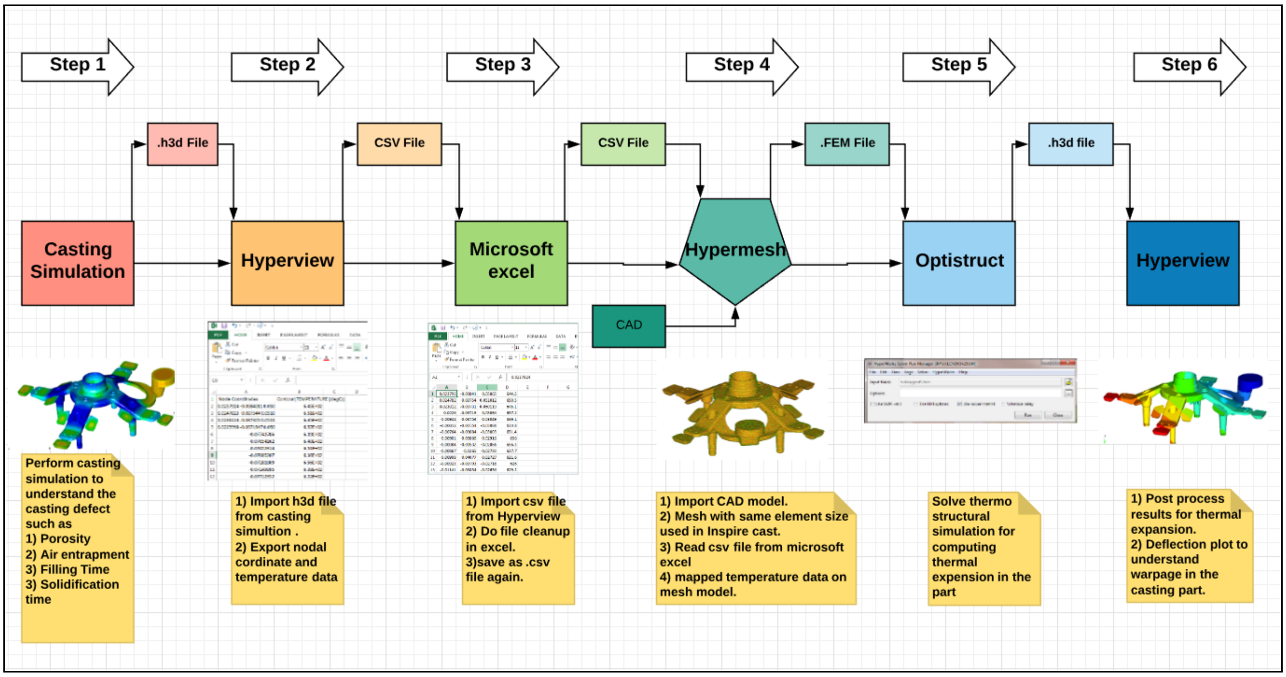


Figure 4: Thermo structural Simulation process flow

The above simulation methodology developed from step 1 to step 6 where two different solvers Inspire cast and OptiStruct is used in addition to Hyperview, HyperMesh and Microsoft excel to export & map the results.

Results & Discussions

Casting simulation was used to identify the causes of porosity and flatness defect in the Tub support bracket of VA washing machine. The simulation results for both porosity and flatness is very well correlated with the manufactured part. Manufacturing Defects identified in casting simulation results are discussed subsequently.

Porosity Defect

Figure 5 shows images of porosity in an aluminum Tub support bracket and the porosity location from computer simulations. The porosity region shown in Figure 5a, which is encircled for clarity, is in the exact location as the location shown in Figure 5c. In fact, the simulation correctly predicted the location of each of the macro-pores in this casting, which were nested between the Screw bores in this casting.

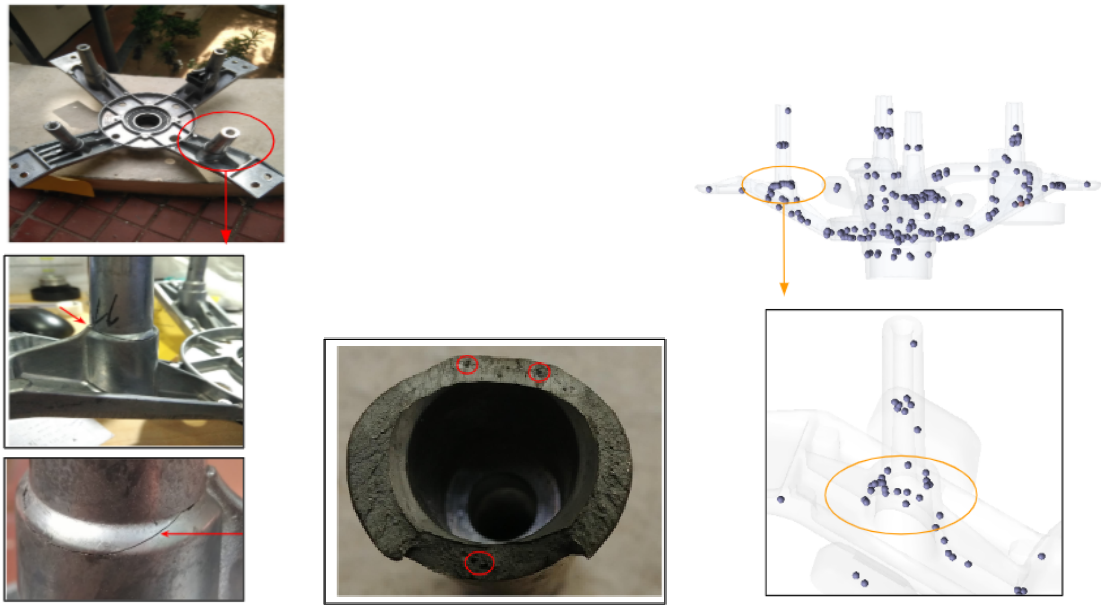
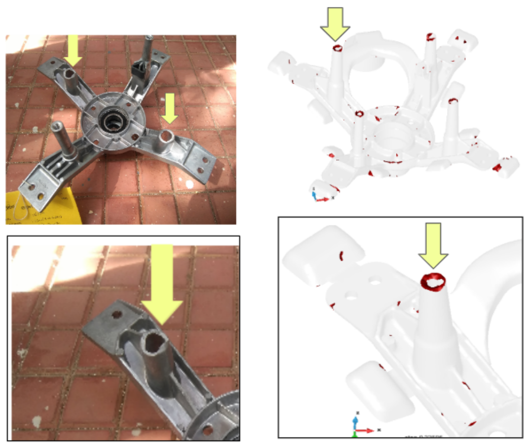


Figure 5: Image of a crack in straight leg of the HDP Tub support bracket (a) casting slice from straight leg (b) and a simulation image from the same area (b). The encircled areas in the simulation image represent the predicted macro-porosity.

Figure 5b shows slices from Tub support bracket. Simulation results shown in Figure 5c showed that there were large regions of porosity between the straight screw bosses and bracket legs. After slicing the casting in these regions, macro-porosity was discovered and similar location indicated in simulation as well.

Flatness (warpage) Defect

In order to identify the possible reason of flatness issue (warpage) in simulation, casting simulation results and thermal structural simulation results are studied. Tub support bracket encountered defect due to air entrapment in the molten metal during the injection process in die-casting. Air entrapment shows the amount of Air entrapped in the straight and taper bosses of the bracket because it gets filled last in the injection process. Figure 6a showing air entrapment in the Tub support bracket which is shown encircled is in the same location as in the simulation shown in Figure 6b. So for flatness, the bosses are extra filled with material and precisely machined to the required tolerances. So there is less chance of flatness issue in brackets under air entrapment.



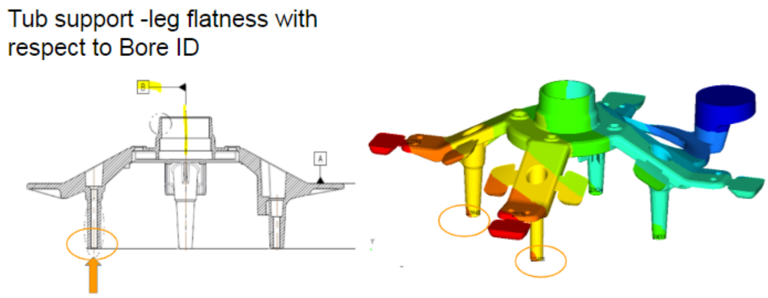
(a) *(b)*

Figure 6: Casting showing air entrapment in experimental casting (a) and in a computer simulation of the same casting (b).

Another possible reason for out of flatness issue is warpage in the part. Inspire casting simulation tool does not directly provide output in terms of warpage in the part due to thermal expansion under elevated temperature. So a simulation methodology was developed as shown in Figure 4 to address the warpage in the simulation. This thermal structural simulation process flow is followed for identifying the warpage in the bracket.

Warpage Defect

Solidification temperature from casting simulation is mapped on to structural mesh as a thermal load and simulated in OptiStruct to evaluate the thermal expansion of the bracket under temperature load.



(a) *(b)*

Figure 7: Warpage in tub support bracket

Figure 7b shows warpage shown by encircled in tub support bracket with respect to bore ID , is in the same location as encircle in CAD drawing shown in Figure 7a.

Benefits Summary

The casting simulation performed on the tub mount bracket will reduce design cycle time during the manufacturing process and cost of prototype building during the design stage. Thus quick decisions can be taken about the feasibility of a product during the product development life cycle.

Challenges

The major challenges observed during the simulation was to get the process parameters from the manufacturing supplier and decide on gate locations to support manufacturing for getting defect-free parts.

Future Plans

Future simulation work will focus on more accurate prediction of porosity, warpage, and other casting defects in HPD castings. This simulation work is intended to assist our designer and foundries suppliers in minimizing scrap rates by accurately simulating design risk before tooling begins to minimize on time, cost & effort.

Conclusions

A method was developed to increase the accuracy of simulating macro-porosity and Flatness issue in aluminum alloy castings produced by HPD casting. The simulations methodology developed showed better accuracy in predicting macro-porosity and warpage in the tub support bracket which is much closer matching between manufactured part and simulated results. The casting defects observed during the simulation will help to reduce cycle time during the design process and reduce the cost of manufacturing.

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