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Casting Design Optimization for Steam Turbine Emergency Stop Valve (ESV) Housing with Computational Casting Simulation Method

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Abstract— *Design optimization casting emergency stop valve steam turbine, has been done with casting simulation using Magmasoft v5 software. By simulation, some casting design parameters are changed to get more optimal results. Optimization of the design of castings in this study, obtained by improving the design through changes in pouring system using bottom pouring and optimization of riser design. The result of four design casting simulation ESV housing versus filling velocity, solidification, and porosity have the same trend of location defect that is in the flange and middle body valve connection area. However quality of the simulation results, in design # 4 has a better quality of casting results based on the color gradation seen in the range of 80-90%. Although, there is still a potential defect in critical areas that have low castability. This results can be used as input for the further casting improvement and NDT inspector guidance.*

Keywords*— *Design optimization, Casting simulation, Filling Velocity, Solidification, Porosity.

I. INTRODUCTION

One part of the steam turbine that has a vital function is the Emergency stop valve (ESV). Emergency stop valve (ESV) steam turbine has the main function as a valve (throttle valve). This component must be able to drain and stop the vapor flow quickly and completely, either automatically or manually when needed. ESV components are enclosed by an ESV housing that serves to maintain pressure to prevent leakage and as a protective part of ESV from foreign objects. The ESV housing material is made from JIS G5151 Grade SCPH2 steel which is resistant to pressure and high temperature. While the manufacturing process of ESV Housing steam turbine is done by using the casting method (sand casting) and its completion with machining process. ESV housing is divided into 4 (four) segments top, middle, bevel and lower casing. Of the four segments, middle ESV housing is a critical part because of its slightly complicated contour form, so it often fails when foundry. One of the causes of the failure of the cast process is the error in designing the foundry system, thus impacting the defects resulting product, whether it is a defect dimensional, pores, or crack. The failure of the cast process will have an impact on quality, cost and delivery.

Fig.1: ESV Housing

With the advancement of computing technology today, many developed software that can be used to help the design process and simulation of casting. This computational method of product development is very advantageous than the use of conventional methods (trial & error) [1]. The current casting simulation software has been widely accepted as an important tool in the design and development process of casting products that can improve casting yield and casting quality [2] [3]. In this research, the optimization of ESV housing design will be done by using Magmasoft software v5. Some design parameters still follow the user's design, and some other parameters will be optimized by reference to the standards required for JIS G5151 Grade SCPH2 and ASTM A 609 quality level materials. Its main focus is on improving cast quality against crack and porosity defect.

II. RESEARCH METHOD

This research is a design development of ESV product castings that have been manufactured but there are still defects (rejected) crack and porosity in some parts. Therefore, the approach of optimizing the design of the castings (improvement) is done by using the comparison method between the initial castings with the product castings optimization results using software Magmasoft V5. In this case, it will be done three alternative design improvement and optimization of the best design alternative. The steps that will be done are:

- Design review: perform analysis of design drawings. From this picture can be done analysis, which parts need to be modified so that the casting process is more optimal.

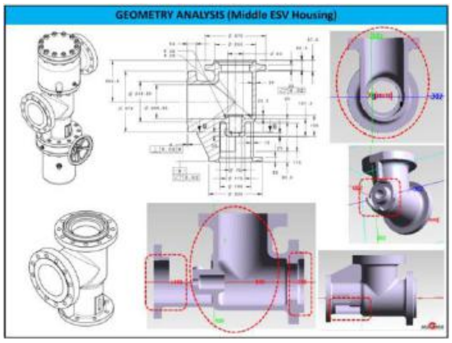


Fig.2: The ESV part needs to be done modification

- Design modifications: modify the system or parts of parts that could theoretically improve the performance of the casting process. Some of the improvements made are [4][5]:
    - Gating system
    - Position and height of riser
    - The sharp geometry shook me
    - Profile flange
- Design optimization: through the utilization of Magmasoft v5 software, simulation of modified design is done until the optimum design results are obtained. The effect of pouring system change with bottom up system and reduction of riser height up to less than the tip of shrinkage that occurs in riser area will be analyzed its effect on casting quality. As illustrated in Figure 3.

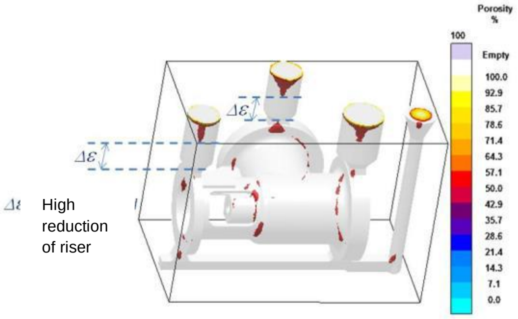
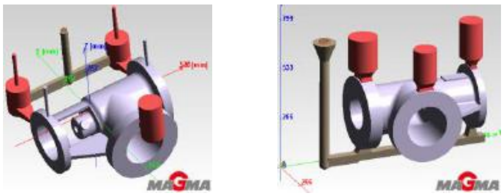


Fig.3: Potential area for improving yield casting

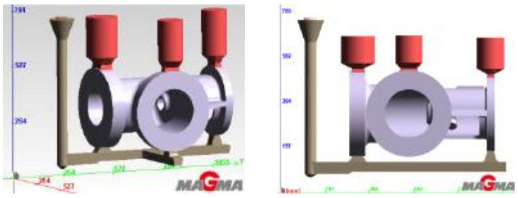
III. DESIGN AND ANALYSIS CASTINGS SIMULATION

Design Optimization, includes design and castings simulation for:

- Design # 1: initial casting (rejected)
- Design # 2: the first design improvement alternative
- Design # 3: second improvement design alternative
- Design # 4: optimization of design improvements



(a) Design #1 (b) Design #2



(c) Design #3 (d) Design #4

Fig.4: 3D Gating System Design

In this study there are four designs analyzed, as shown in Figure 4. Design # 1 is the initial design, where the product from the ESV middle housing has been casted, without casting simulation and the result fails. The initial design drawings were analyzed using magmasoft and the results were compared with non-destructive test results - Ultrasonic Test (NDT-UT) casting products, as shown in Figure 5.

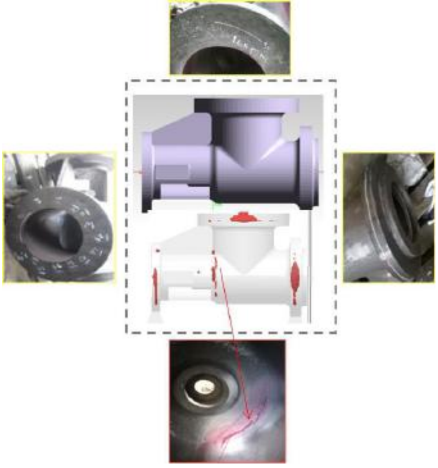


Fig.5: NDT-UT Product vs Magmasoft Comparation

Comparative analysis can be seen that the suitability of location of NDT-UT porosity cavity with potential location of Magmasoft simulation result defect, that is in third area of radial flange direction and area of body valve center. Porosity is a type of defect that is commonly encountered in the presence of cavities in casting products that can be caused by:

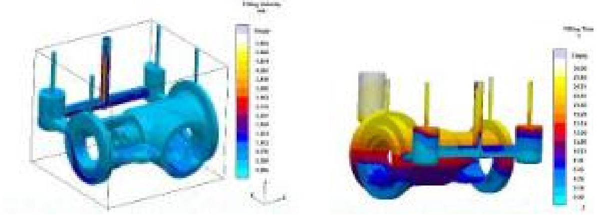
- Gas content of the melt
- Gas and air entrapments due to filling
- Shrinkage of metal during solidification and cooling
- Combination of these

Initial analysis results need to be changed pattern with consideration of flow improvement to minimize turbulence during liquid metal filling by changing side pouring to bottom pouring and castability design improvement by providing additional machining allowance in flange area. In addition, different wall thickness variations lead to varying cooling rates, to compensate for shrinkage and to seek for directional solidification to require an adequate riser system.

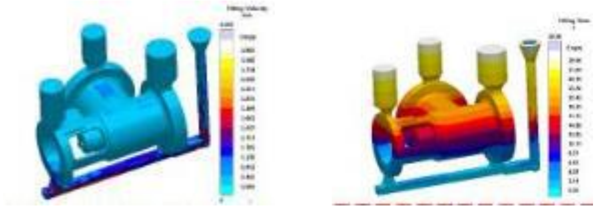
The concept of design change is poured into Design # 2 (using 2 ingate) and Design # 3 (using 3 ingate). The simulation results of Design # 2 and Design # 3 are almost the same in quality but Design # 2 has higher yield casting. So Design # 2 was chosen to be optimized again to increase its casting yield to Design # 4.

3.1 Filling Velocity Analysis

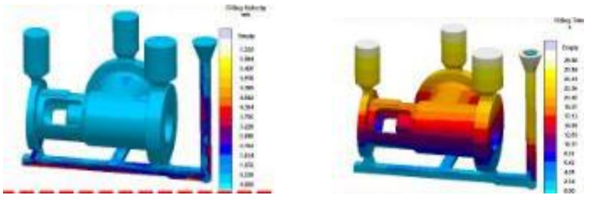
In general, casting filling velocity causes gas wrapping and slag inclusion, and it influences quality of casting parts directly [6]. In this paper, filling velocity of three design casting ESV housing was researched on with magmasoft, and the simulation results were analyzed. The best filling effect can be gotten, when the velocity (v) is equal to filling time (t). As a result, it could offer better casting parameters for design casting ESV housing.



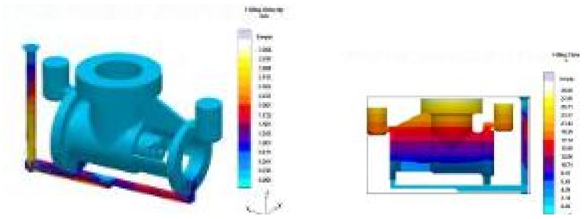
(a) Velocity and Time Filling design #1



(b) Velocity and Time Filling design #2



(c) Velocity and Time Filling design #3



(d) Velocity and Time Filling design #4

Fig.6: Velocity and Time Filling

Tapper runner design # 2 and # 3 still cause slight turbulent flow, this can be solved by extending the tapper, beyond the first ingate (design # 4).

3.2 Solidification Analysis

When the liquid metal is poured into the mold, it immediately fills the cavity in the shape of the mold and there will be compaction / hardening of the metal liquid [7]. Solidification begins at a temperature indicated by liquidus and is completed when the solidus is reached [8][9]. As shown in Figure 7.

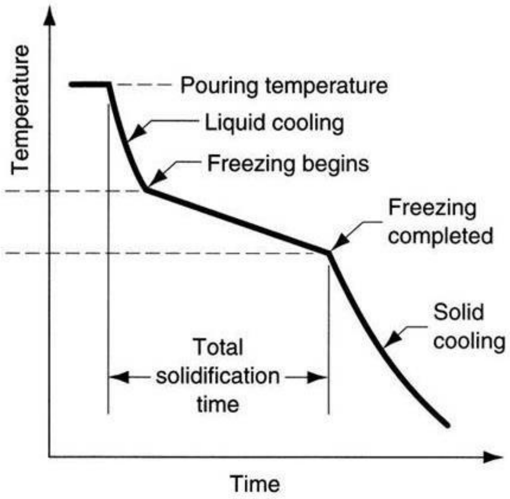
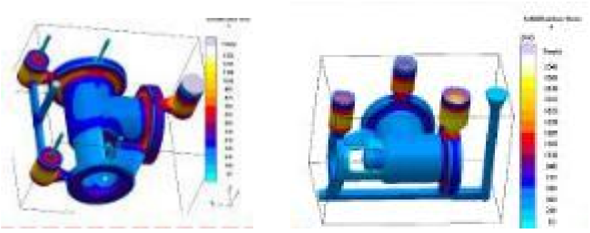
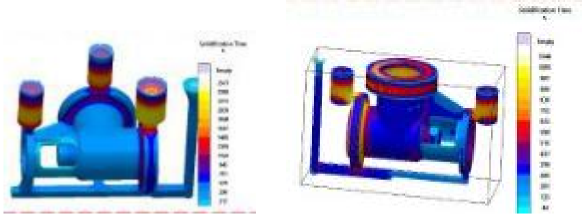


Fig.7: Total Solidification Time

So the design of the gating system and the time of pouring become critical parameters. Figure 8 shows the behavior of the solidification process of the four designs performed.



(a) Solidification #1 (b) Solidification #2



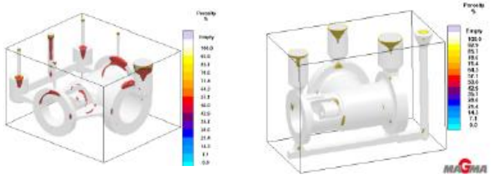
(b) Solidification #3 (d) Solidification #4

Fig.8: Solidification Design #1 to #4

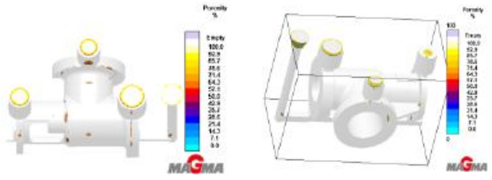
Design #2 and #3 show more directed solidification, and better than design #1. The improvement analysis is done in design #4.

3.3. Porosity

Porosity may be the most often accur and common complaint of casting users, becouse porosity in castings contributes directly to about reliability and quality. Porosity in castings is due to bubbles being trapped during solidification [10]. Porosity sources include entrapped air during filling, centerline shrinkage that occurs during the final solidification, blowholes from unvented cores, reactions at the mold wall, dissolved gases from melting and dross or slag containing gas porosity.



(a) Design #1 (b) Design #2



(c) Design #3 (d) Design #4

Fig.9: The Result of Design Simulation vs Porosity

The results of Design Simulation vs Porosity, the four designs of ESV housing have the same potential trend of area location flaw that is in the flange and middle body valve connection area. In the quality of the simulation results, the maximum potential defects are shown in Design # 1 and at least in Design # 4. The quality of castings on design # 4 is better, this can be seen based on the color gradations seen in the range of 80-90%. However, there is still a potential defect in the critical area, because it is difficult to get a free from defect (sound casting) simulation result due to the casting profile which has low castability with some wall thickness variations and right angles (90°), as shown in Figure 10.

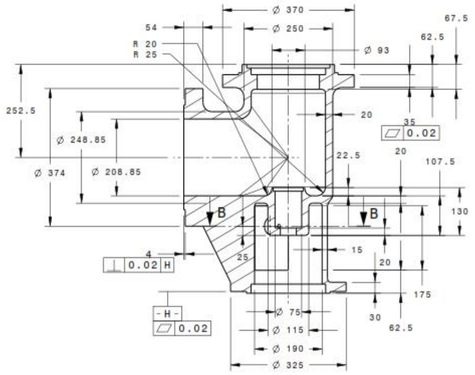


Fig.10: Cross Section Drawing

By using magmasoft software various designs of system castings computationally can be simulated, to get the most optimum design in terms of quality and efficiency. The simulated casting software Magmasoft can also predict critical areas of potential defects that may arise during casting. So it can be used as input for the effort of preventing the impact of defect risk during the casting process, for example by the use of chill and sand chromite on the walls of the critical casing to assist the foundry production process.

IV. CASTING PROCESS AND TESTING

The ESV middle casting process, from making wooden pattern to foundry, is shown in Figure 11 to Figure 13. Figure 11 shows the wooden pattern results from the middle ESV section. Figure 12 shows the ESV middle table mold and Figure 13 shows the results of ESV middle part casting

Fig.11: Wooden pattern middle part ESV

Fig.12: Mould box middle part ESV

Fig.13: Casting result middle part ESV

The test of the mid-cast results by using dye penetrant and ultrasonography test can be seen in Figure 14 and Figure 15.

Fig.14: NDT - UT Inspection

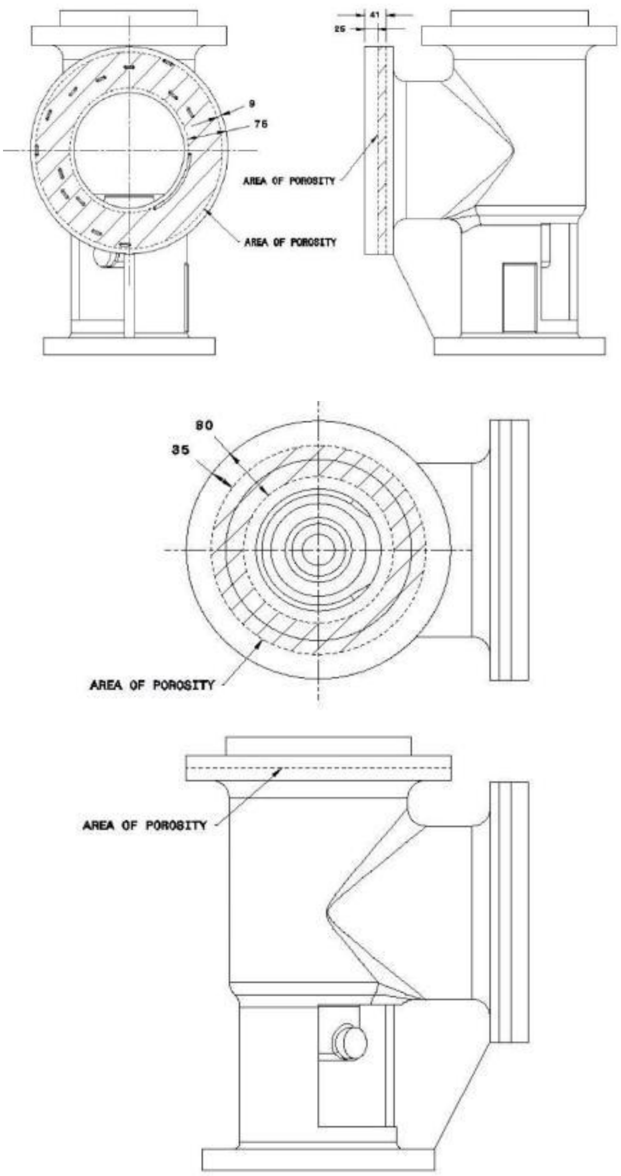


Fig.15: Area of Porosity

Final casting middle part ESV are shown in Figure. 14. Ultrasonografi test and dye penetrant test were performed on the final casting. The test confirmed that there is still a defects (crack) in flange area the casting result that better than initial design result. The results of this experiment indicate the suitability of the location of defects between the simulation results and the test results. Therefore it can be used as casting improvement input and NDT inspector guidance for the critical area of further casting process.

V. CONCLUSION

Optimization and design selection using the computational casting simulation method (Magmasoft) can produce design castings that can improve the quality of castings. The simulation results can also be used as inputs in conducting preventive actions to prevent potential defects occurring during the casting process execution.

Design # 4 is the preferred design that can reduce the potential for defects, but from ultrasound and dye penetrant test results, flange defects are still present, therefore other efforts are needed to improve the quality of casting, for example by the use of chill and sand chromite on the walls of the critical casing to assist the foundry process

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