Design and Analysis on Feeder System for Hydro Leak in the 10"Class 300 Gate Valve Butt Weld End Body Casting

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Abstract— The shell leak is one of the severe defects which may result in failure of the plant process if it occurs at the installed plant. The shell leak may even cause a fire hazard if the same occurs in the oil and gas plant. There could be a chance of fatal accidents due to shell leak. Hence to avoid these problems the valve bodies are tested with the pressure which is 1.5 times more than the working pressure with a specified time as per the internal guiding standards. These shell leak could be the result of various issues including gas porosity; crack; shrinkage; less wall thickness etc. In order to overcome the above discussed factors, this paper aims with identification of root cause for shrinkage issue, deciding accurate operation to perform by adapting MAGMA software, application of selected/adapted process, and verifying the significances of the selected operation/process. The paper is limited to castings produced by a sand process purely from the inputs received from the past development data of this casting at Foundry(MACPL), analyzing various causes and respective solutions to shrinkage cavity formation, analyzing the effectiveness of proper solution by using MAGMA simulation. With this analysis, a permanent solution is obtained without any further wastage of production time and money.

Key words: Shell leak defects, Plant failure, Steel Casting, Shrinkage, MAGMA software

I. INTRODUCTION

The shell leak is considered as major issue in the plant process. The shell leak may also leads to the fire hazards, fatal accidents in the plant. In order to overcome these circumstances value bodies are required to be tested at higher pressure of 1.5x time of working pressure at desired time by referring standards [1]. The shell leak may also leads to gas porosity, shrinkage, wall thickness, crack etc. To overcome this, the castings can be used which offers defect free solution but foundry must have a strong feeders methoding and gating, desired venting in moulds, effective core hollowness and effective deoxidation of molten metal. The shrinkage is mainly observed in the zone of shell leak at level IV which is taken into consideration as major defect and it has to be verified and corrected to get a sound casting. The feeder methoding and gating of this product can be performed with manual calculations and it may result into ineffective feeding thus there may be chances of undesired directional solidification with enhanced complexity valve body shape. Different kinds of software are presented in recent past in which 3D models of the castings production is used in this software to check the soundness by moulds filling simulation, solidification analysis, gating and feeder design etc [2]. The metal filling visualization of mould about metal solidification in which gas entrapment, metal turbulence, time for metal filling and time for solidification by which defects can be predicted and which may include shrinkage cavities, gas entrapment, cold metal; gas entrapment. Using this concept, development time for sound casting, cost-effective reducing the rejections of trial and error method, to ensure that manual error of modulus calculation during feeder design is avoided. Considering all these advantages this is an effort to analyze the corrective action with the help of MAGMA simulation software to avoid the shell leak of the 10inch class 300 valve body casting [3].

In order to overcome the above discussed factors, this paper aims with identification of root cause for shrinkage issue, deciding accurate operation to perform by adapting MAGMA software, application of selected/adapted process, and verifying the significances of the selected operation/process. The proposed work can be incorporated with scope and approach area of this study is limited to castings produced by a sand process purely from the inputs received from the past development data's of this casting at Foundry(MACPL) [3-4], analyzing various causes and respective solutions to shrinkage cavity formation, analyzing the effectiveness of proper solution by using MAGMA simulation, adapting proper process in the pattern & core box casting production and verifying the soundness through NDT

In this case, the customer has given the input that at the leakage spot there is a shrinkage of level IV in order to analyze the root of it, MAGMA simulation is considered of the current feeder and gating design on the casting model to see whether the root cause is improper feeding and directional solidification. In case the results of the current method seem to be satisfactory the rest of the root cause to be analyzed. The paper is organized with sections like review of existing researches in identifying and solving shell leak defects, still casting etc in section II. The implementation concepts of MAGMA simulation, feeder methoding, solidification casting etc is discussed in section III. The analysis of outcomes obtained from execution of simulation is discussed in Section IV. The Conclusive points of the paper are discussed in Section V.

II. EXISTING RESEARCH SURVEY

This section gives analysis of different types of researches involved in shell leak involving defects like gas porosity, shrinkage, wall thickness and crack.

The work of Dussud et al. [7] discusses the minimization of casting defects by performing the analysis on some casting defects in Akaki Basic Metals Industry (ABMI) industries. The author has performed a statistical analysis to minimize major steel casting defects. In this, steel casting defects like gas defects and shrinkage defects are analyzed.

A feeder design research for casting is done in Mohamed et al. [8] were a feature-based solid modeling integrated with a fuzzy logic system is given. This feature-based to provide manufacturing information to the fuzzy system application. The fuzzy system is based on heuristic rules of the feeder which helps in classifying the castings and design feeders. The outcome of [8] builds an interface among fuzzification and defuzzification which helps in balancing of inputs and outputs.

The work towards continuous casting mechanism is presented in Kalandyk et al. [9] in which the internally cracked product was considered and utilized the fuzzy controller to minimize the defects. During the continuous casting process, the melted steel is passed to water-cooled crystallizer tank. The work [9] mentions a control method with fuzzy logic having a set of rules and reasoning implications. The work addressing the molten metal level issue and controlling it is found on Omura et al. [10]. The author has considered issues of PID controller which cannot perform well in an abnormal condition and hence considered a fuzzy controller that controls during distribution phases.

The study towards casting defects and resolving them was discussed in Rajkote and khan [11]. The current industries were focused on productivity, not on quality. Hence, [11] has attempted to identify the root cause of casting defects and provided better guidelines for controlling the casting defects.

Similarly, to analyze the root cause of casting defects Wilson et al. [12] introduced an analytical tool which can be a corrective and comprehensive in analyzing critical defects. The tool involves identification of defects, knowing strategies for defection reduction.

Reducing the defects like gas holes and sand inclusions were studied in Perzyk [13]. The study includes Pareto chart which can reduce the 3/4th of the defects. The work of Chandana and Chandra [14] includes the forging operations which generate 6 cylinder crankshaft utilized in heavy vehicles. This [14] also includes Pareto diagrams to identify the forging defects and applied Cause and Effect Diagram (CED) to determine the causes and reduce the rejection rate. Another case of casting wastage reduction was presented in Khekalei et al. [15] in which automotive rubber belt manufacturing was considered. Also, the cord and fabric materials were considered as raw materials. Through performance analysis, it is found that cord wastage was reduced.

The contributory work of Ahmed and Ahmad [16] focused on defects reduction in the process of lamp production by using Pareto diagram. The outcomes of [16] indicate that diagrams were significant in identifying the abnormalities in lamp production.

A combined work of Dabade and Bhedsgaonkar [17] were mentioned on analysis of casting defects through experimentation and simulation. The author has implemented the Taguchi based algorithm and outcomes with a 15% reduction in shrinkage porosity causing a significant reduction in manual casting operations. The works towards steel casting were discussed below. In the work of Jayet-Gendrot et al. [18] design and experimentation on steel casting of fatigue porosity. Similarly in Heuler et al. [19] discussed a comparative analysis on fatigue life of test specimens having casting inclusions and porosity defects by using crack initiation and propagation mechanisms. The benchmarked work of Stephens et al. [20] discussed fatigue property data in sound cast steels. Through performance analysis suggest that [20] comparative analysis of sound and unsound steels was performed.Most of the existing researches were involved with casting simulation performed with different simulation software of casting.

III. SYSTEM MODEL

In order to overcome the shrinkage issues, the following design process (shown in Figure.1) is implemented which involves 3D model, Unigraphics, exporting STL format, geometry, meshing etc.

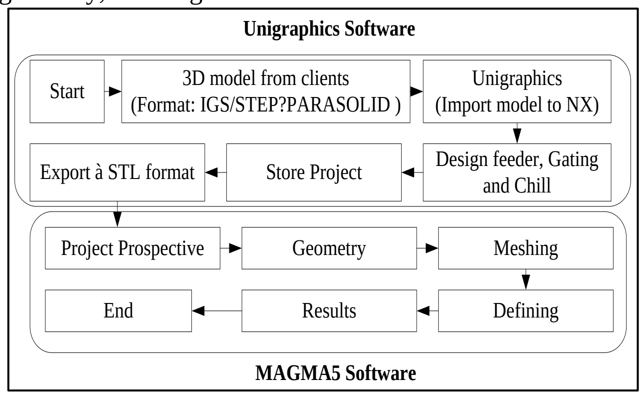

Fig. 1: Block representation of design process

The designer of casting design includes 3D model of the same it would be time-saving and the results could be accurate if can get the 3-D models from the customers or from the pattern makers based on which the pattern is made. Usually the foundries get these 3D models from their customer who is responsible for the design of these valve bodies in Standard for the Exchange of Product model data shortly called as STEP format which is one of the CAD formats that is used widely for exchanging the models in few cases the models could be received in IGS or PARASOLID formats also based on the availability. For this shell leak valve body, the STEP format 3 D model was received from the customer and the same was verified against the 2 D drawings to ensure the correctness. The 3 D model received in STEP format will be imported to NX Unigraphics software to design the cope –drag of mould; core; feeders; feeder neck; Chill; Gating system on the casting model. During extruding in this software one has to give the Boolean option to ensure the effective results in MAGMA simulation. Upon completion of the designing one has to export the same to STL format. In case it is not exported to STL format all the designs will be merged and form as a part of the casting. This design of feeder location; feeder neck; gating system chill could be based on the manual calculations of modulus or by ones experience in methoding or trial and error method. In this already calculated methoding of feeder location , feeder neck with gating system including chill locations for the shell leak castings the same was incorporated to analyse the specific root cause for the shrinkage in the valve body. Stereo-lithography tessellation language is shortly known as STL which is also known as de facto data exchange standard in CAD/CAM applications. In STL the object is represented as a collection of triangular facets, each facet has 3 vertices and a normal outwards from the facet. This format represents the 3D forms as boundary representation of solid model which are constructed entirely of triangular facets. Project prospective is the initial stage where the project is created in the MAGMA software. Here one has to define which folder or which location this project has to be saved. Project prospective are represented with black encircled location in the software that has been used for our shell leak valve body analysis project. The geometry or CAD model which has been designed and saved in STL format is imported from NX Unigraphics to MAGMA simulation software. The geometry can be assigned after importing CAD model of STL format, the MAGMA software considers the whole model as a casting hence to overcome this issue one has to assign the elements their respective names. In this case, mould is need to be assigned first and then chill by feeders and its neck then the castings. It has to ensure that the assigning is followed in the same hierarchy. It has to be verified to cross check has all the elements and parameters be assigned by clicking on the elements. Once the elements are assigned overlaid principle has to be used as provided in the software to ensure the continuity in the boundary of elements and to obtain a good accurate result. It has to be ensured that upon the completion of assigning and after the application of overlaid principle Boolean should be updated to ensure that the elements are arranged in the required order. The elements which result is needed to be assigned at the last. The number of elements to mesh will be 20, 00,000by default. During the meshing, the elements are divided into finite elements and are also divided layer-wise. During meshing the elements lawyer at the thinner surface of the castings are usually divided into 2 lawyers. The disadvantage of 2 layer meshing is that MAGMA software during simulation considers 2 layered part as a hollow surface. In our project, upon considering 50,000,000 cells there were two layer mesh elements in the thin layer of the model that had selected. Hence to overcome the issue of 2 layer elements Multiple Parameter set options. There are further 2 options available under this named as Standard Parameter Set and Advanced Parameter Set. As default upon selection of multiple parameters set during meshing all the geometry will be considered under Standard Parameter set. But in the geometry there will be casting, chill, and feeder, gating system here among these only casting shall have a thin wall or section and other geometries will not be necessarily checked for the thin surface. Hence the casting alone from the Standard Multiple Parameter sets is imported into Advance Multiple parameters set in order to generate the meshing as per one's own requirement as shown above. It has to be ensured that equidistance meshing should be selected for accurate results.

The definition stage of simulation consists most important inputs that are taken from the production team in order to analyze the realistic results of the simulation. It can also be said that the results of MAGMA simulation are most likely to be depended on this parameters. This definition consists of the following 3 important parameters.

1) Material Definition
2) Heat Transfer Definition
3) Result Definition.

IV. RESULTS & ANALYSIS

The production of casting was taken up to check the results of the simulation on the production of casting. The simulation method was implemented in the pattern and taken up for production.

A. Feeder and chill design as per MAGMA in the pattern

The feeder location was made by cutting plywood sheet with respective diameter and painted green in colour, two type of feeder or sleeve to be used in this product manufacturing they are an open sleeve which is open from the mould cavity to the atmosphere and other one blind sleeve which will be open up to certain height. Hence to distinguish the both are given the colourcode for open sleeve the green paint is marked for blind sleeve green paint with yellow line is marked which will help to understand the need of feeder in the shop floor. In order to avoid the manual error in the making of mould and during placing the feeder the pattern is mounted on plywood sheet and a box is made up to the required height of open sleeve. Locations on the pattern where the chill is required as per the MAGMA simulation report are marked on the pattern with the chill number written for a better understanding of shop floor personnel. The bottom half of the core box is fixed with the blind sleeve holders. All the necessary parameters like draft angle; undercut; surface finish; chill markings are checked and the pattern – core box is released to moulding.

The pattern is received at mould and core making shop. The scrap and rod are arranged in the pattern for providing the strength and for easy handling. The sleeves of the necessary dimensions are arranged on the pattern. The chill of necessary numbers is kept at the marked locations. The bottom half of the core is taken and the blind sleeve is placed as per the requirement and 3part sand is used where 3 types of oil with iron oxide powder is mixed in the batch mixer with the required proportion. The two halves of core boxes are closed and the 3 parts and is filled inside the core box and rammed to ensure that the core sand will get the necessary compactness and strength. After about 25minitues of curing the core is stripped from the core box.

The mould and core tilted from pattern and core box are moved to coating yard where the alcoholic based Zircon coating is done on the mould cavity to ensure that the required strength to withstand the molten metal temperature is provided to moulds cores and also to ensure that the thin film is formed which will avoid the mould and core sand from getting eroded from the mould during molten metal flow. The feeders (Sleeves) are cleaned and opened the chill placement is checked the core diameter is measured then the mould and core are assembled for pouring the molten metal.

The casting is to be poured in ASTM A216 grade WCB hence grade WCB is mild steel grade. The melting was carried out in 1500Kg induction furnace PTA. The melt started with charging PK51 powder at the bottom of the furnace which helps to remove the metal impurities called slag formed during the melting process. This is followed by charging the furnace with 600Kgs of Mild steel scrap bundles and 900Kg of WCB returns. The alloys like 6Kg of High Carbon Ferro Magnesium is added and 1.2Kg of Ferro Silicon is added to the furnace upon the melting of Mild steel scrap and WCB return. The metal sample is taken and checked for the correctness of the composition in Optical Emission Spectrometer. Upon the clearance from the chief chemist, the metal was taken for pouring in the ladle which was preheated up to 900°C. The temperature of the molten metal is checked in the pyrometer the tapping temperature for this WCB grade is fixed as 1610°C to 1650°C. Hence for this melt, the molten metal was tapped at 1620°C to the ladle, the de-oxidants like calcium silicide; aluminium was added to ladle to ensure that the dissolved nitrogen and hydrogen is removed from the molten metal before pouring the same to the mould core assembly.

Once the molten metal is cooled in the mould cavity the casting is removed out by breaking the mould and core which is called a knock out process for this casting based on the weight of the casting and wall thickness of the casting, the cooling time is fixed in foundries. For this casting, the knock out was carried out after 12hours from the pouring.

Shot Blasting is a process where the steel shots are used to clean the knocked out castings. The castings once removed from the mould will have sand layers covered on it. In order to remove the sand layers hitting manually would cause dent and damage mark on the casting surface hence to avoid the same the steel shots are fed into the shot blasting machine and the casting is placed in the enclosed chamber wherein the shot hot the casting and remove the sand layers on the casting making it clean.

As per the results received from the Radiography test there were no major defects identified and the leakage spot was also checked and the shrinkage observed in the defect casting was now been cleared after the corrective action.

V. CONCLUSION

In Foundry MAGMA simulation software was procured in 2015. Since then the new developments of casting method are validated in this software prior to production. This 10inch class 300valve body was developed by foundry in 2010 with the manual method. The 10 no's of castings were supplied with manual method and one among them was found to be shell leak. Upon the receipt of this issue from the customer the manual method was taken up for analysis in MAGMA simulation wherein it was evident that the leakage was due to shrinkage in the particular area. This shrinkage causes the discontinuity in the metal surface causing the leakage. With this analysis, a permanent solution is obtained without any further wastage of production time and money. The trial and error method was also not necessary. The new method was done and validated in MAGMA simulation to address the shrinkage issue leading to shell leakage.

REFERENCES

[1] Mills, Kenneth C. "Structure and properties of slags used in the continuous casting of steel: part 1 conventional mould powders." ISIJ International 56.1 (2016): 1-13.
[2] Vdovin, K. N., O. A. Marochkin, and V. V. Tochilkin. "Creating a stream simulator to improve the wear resistance of refractories during the casting of steel on continuous section casters." Refractories and industrial ceramics 54.6 (2014): 435-437.
[3] Bonollo, F., et al. "StaCast project: From a survey of European aluminium alloys foundries to new standards on defect classification and on mechanical potential of casting alloys." 71st World Foundry Congress, Bilbao, Spain. 2014.
[4] http://www.malnadalloycastings.com/
[5] https://www.magmasoft.com.sg/en/company/press/press-releases-and-news/magmasoft-5.4-autonomous-engineering/
[6] Patel, Saurabh, Asso Prof SP Joshi, and Assi Prof RR Patel. "INVESTIGATIONS OF FEEDING BEHAVIOUR FOR ALUMINIUM ALLOYS SAND CASTING-A Review."
[7] M. Dussud, S. Galichet, L. Foulloy, and P. Simonnin, "Fuzzy logic control of continuous casting installations," in Proc. 13th IFAC World Congr., San Fransisco, CA, 1996, vol. M, pp. 469–474.
[8] Adil Mohamed Elbasheer Ahmed, Mohamed Ibrahim Shukri, WaielFathiAbd El-Wahed, "A Fuzzy Expert System for Rigging System Design"Journal of Science and Technology 12 (02) December 2011 ISSN 1605 – 427X.
[9] B. Kalandyk, R. Zapała, A. Rakowska, Characteristics of defects present inindustrial steel castings due to metal-mould reactions, Archives of Metallurgy and Materials 54, 2 (2009).
[10] K. Omura, Y. Otsuka, and M. Konishi, "Diagnostic expert system for mold level control equipment in continuous caster," in Proc. 6th Int. Iron and Steel Congr., Nagoya, Japan, 1990, pp. 62–68.
[11] Rajesh Rajkolhe, J. G. Khan, "casting defects and its remedies" published in "International Journal of Research in Advent Technology", Vol.2, No.3, March 2014 E-ISSN: 2321-9637
[12] Wilson, P.E., Dell, L. D., & Anderson, G. F., (1993), "Root Cause Analysis: A Tool for Total Quality Management", Milwaukee: ASQC Quality Press, pp-111-120
[13] Perzyk, M., (2007), "Statically and Visualization Data Mining Tools for Foundry Production", Foundry Commission of the Polish Academy of Science, 7(3), pp-111- 116.
[14] Chandna, P. & Chandra, A., (2009), "Quality Tools To Reduce Crankshaft Forging Defects: An Industrial Case Study ", Journal of Industrial and System Engineering.
[15] Khekalei, S.N., Chatpalliwar A.S. &Thaku, N., (2010), "Minimization of Cord Wastage in Belt Industry Using DMAIC", International Journal of Engineering Sciences and Technology, 5(4), pp-178-195.
[16] Mohiuddin Ahmed &Nafis Ahmad, (2011), "An Application of Pareto Analysis and Cause and Effect Diagram for Minimization of Raw Material in Lamp Production Process", Management Science and Engineering, 5(3), 87-95.
[17] Uday a. Dabade&rahul c. Bhedasgaonkar, (2013), "Casting Defect Analysis Using Design of Experiments and Computer Aided Casting Simulation Technique", Published in Forty sixth CIRP Conference on Manufacturing System.
[18] Jayet-Gendrot, S., Gilles, P. and Migne, C., "Behavior of Duplex Stainless Steel Casting Defects under

Mechanical Loadings," Fatigue and Fracture: 1997 PVP-Vol. 350, vol. 1, ASME, pp. 107-116, 1997.

[19] Heuler P., Berger C., Motz J., "Fatigue Behaviour of Steel Castings Containing Near-Surface Defects," Fatigue Fracture Engng. Mater. Struct. Vol. 16(1), pp. 115-136, 1992.

[20] Stephens, R.I., Fatigue and Fracture Toughness of Five Carbon or Low Alloy Cast Steels at Room or Low Climatic Temperatures, SFSA Research Report Nos. 94A and 94B, 1982.