Failure Analysis of Robo Operated Pouring Ladle

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Abstract— This experimental investigation is performed for determining Failure analysis of Robo operated pouring ladle which is undergoing failure at the crossection where handle and pouring cup joins. Here the analysis constitutes Hardness measurement, microstructural, composition and structural analysis by CAD software. Later in this study, a new proposed modified design is also incorporated which has low Von misis and Principal Stress.
Key words: Failure Analysis, Robo, Pouring Ladle

I. Introduction

Failure is a phenomenon where the desired objective is not fulfilled. Objective can vary from fracture of a product to inability to perform in a desired way. Hence, criteria of failure are heavily dependent on the context in which it is being used therefore, detection, analysis and rectification of failures is an important factor to be cared of.

Failure analysis is a branch of science in which data is analyzed to determine the cause of failure and also to determine corrective actions.

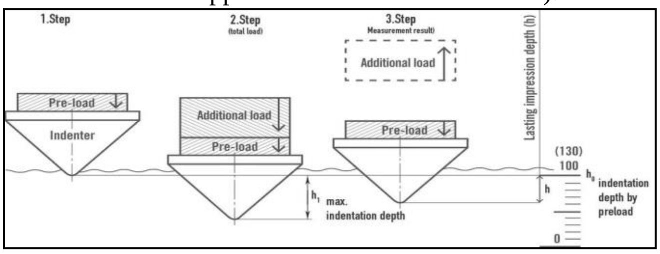
In this project work Failure analysis of High Chromium alloy Cast Iron pouring ladle is done which is used as a pouring cup in brass castings. These failure occur at a section where handle and cup joins, as shown in Figure 1.

Fig. 1: Actual High Chromium Alloy Cast Iron pouring Ladle (with and without fracture)

II. Experimental Procedure

In this section we discuss the various experimental techniques which are being followed:

1) Quantitative analysis of ladle (already available) by manufacturer.
2) Rockwell hardness testing:
   The sequence followed is Rockwell hardness test is as follows:
   1) First, the indenter is pressed with the test pre-force (also referred to as pre-force or preload) to a penetration depth of h_0 in the specimen to be tested. h_0 defines the reference level (basis) for subsequent measurement of the residual indentation depth (h). This minor load is applied for good contact between the indenter and the sample surface.
   2) Next, the additional test force is applied for a dwell period defined in accordance with the standard (several seconds), whereby the indenter penetrates into the specimen to a maximum indentation depth of h_1. The test pre-force plus the additional test force gives the total test force (also referred to as total force or main load).
   3) After the dwell period, the additional test force is removed, the indenter moves up by the elastic proportion of the penetration depth in the total test force and remains at the level of the residual indentation depth (h) expressed in units of 0.002 or 0.001 mm. This is also referred to as the depth differential (difference in indentation depth before and after application of the total test force).



3) Microstructure Testing: Microstructure Testing in this project is done by Optical Microscope under the magnifications of 10X, 40X and 60X to compare the variations in microstructure between failure and rest portion of ladle.
   CAD analysis: Here are the major steps for analysis includes:
   1) Show the supporting geometry
   2) Prepare the part for analysis
   3) Assign material
   4) Assign boundary conditions (Loads and Restraints)
   5) Solve the problem
   6) Visualize the results
   7) Analyze the results
   8) Change the design and resolve
   9) Reanalyze the results

III. RESULTS

A. Chemical Composition: The chemical composition of High Chromium alloy Cast iron is provided in TABLE1.(already available by the manufacturer)

B. Rockwell hardness testing:

Fig 2: Rockwell Hardness Sample

In order to find the hardness of the sample (taken from the portion where Failure takes place) firstly the flat surface is prepared which is then placed under the Digital Rockwell hardness testing machine and readings are taken on both faces of the sample. The results shows that there is approximate uniformity in hardness all over the sample.

Element	Percentage
CARBON	3.62%
MANGANESE	0.63%
SULPHUR	0.08%
PHOSPHORUS	0.023%
SILICON	1.82%
CROMIUM	34.08%
NICKEL	0.30%
MOLEBEDENUM	0.53%
COPPER	0.48%

Table 1: Quality standard of pouring ladle

Since the ladle is of High Chromium Alloy Cast Iron which is hard material hence the scale used is HRC where the maximum load is 150kgf

SIDE 1

LOAD(kgf)	HARDNESS (HRC)
150	52.2
150	53.6
150	55.6
150	55.8

SIDE 2

LOAD(kgf)	HARDNESS (HRC)
150	50.3
150	53.1
150	54.1
150	52.9

Table 2: Rockwell hardness of pouring ladle

C. Optical microscope results: Sample prepared for optical microscopy has been shown below:

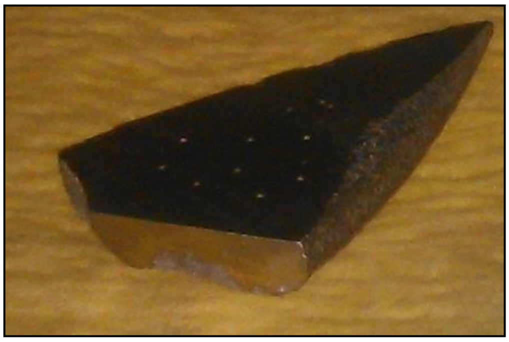


Fig. 3: Sample prepared for Optical Microscopy

These samples are prepared by sectioning the cross section of failure portion, so that the changes in microstructure can be easily compared and the most frequently used etchants for cast irons are 2% nital and 4% picral.

In microscopic examination of failure portion we majorly focus on the changes in microstructure

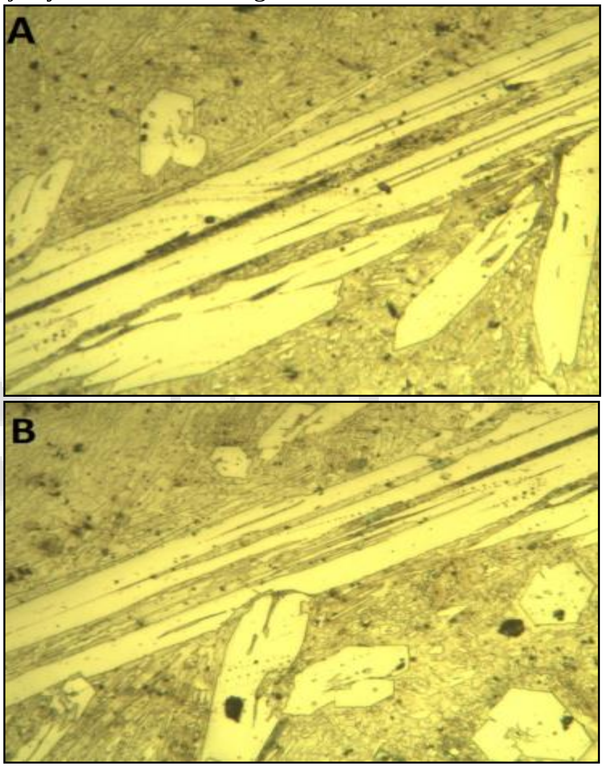
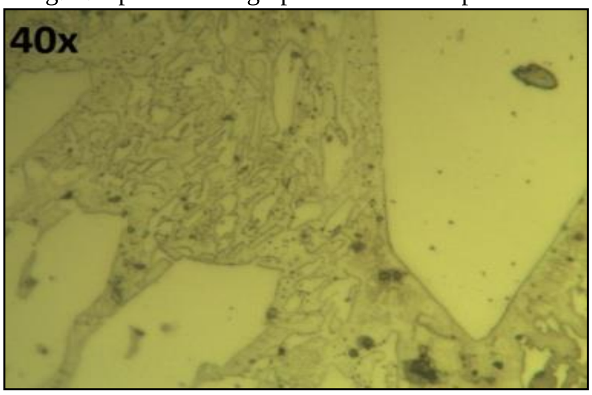


Fig. 4: Optical micrograph of etched sample at 10x



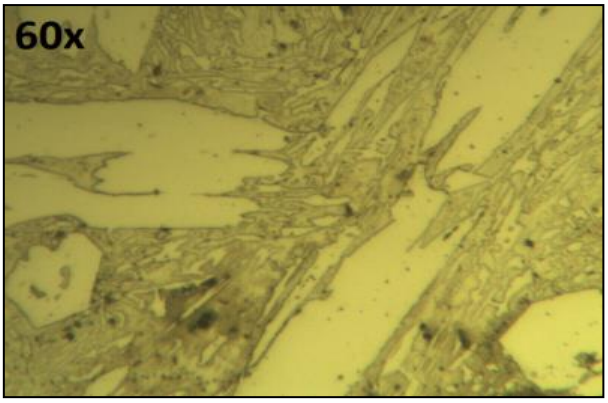


Fig. 5: Optical micrograph of etched sample at 40x and 60x

Here we observe that there is no variation in microstructure. Hence we can conclude that the Failure is due to inappropriate structure/design. Hence we, proceed to CAD design analysis.

D. CAD analysis:

Following is the CAD modeling and analysis procedure to in order to correct the structural Failure due to inappropriate design of High chromium alloy cast iron pouring ladle:
Under this analysis we will first prepare the original model of pouring cup, as shown below:

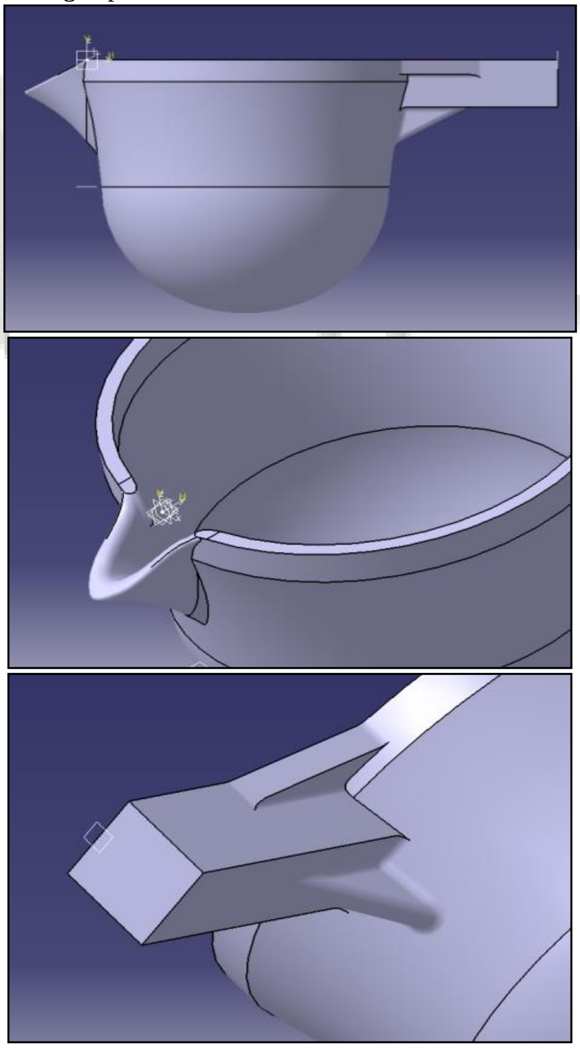


Fig. 7: Initial problem structure

After making original ladle, it is analyzed under generative structural analysis module (here the material taken is Iron which has closest mechanical properties i.e. Poisson ratio, young's modulus etc. with High chromium alloy cast iron).

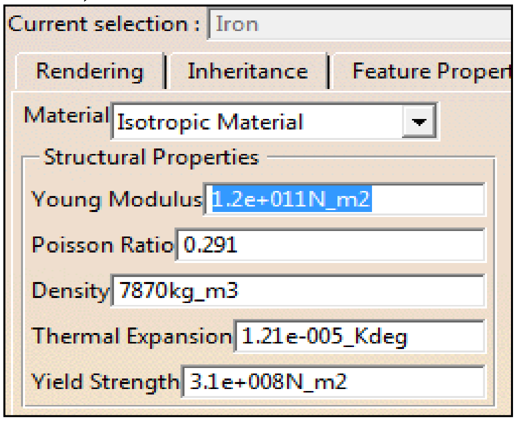


Fig. 8: Mechanical properties of iron

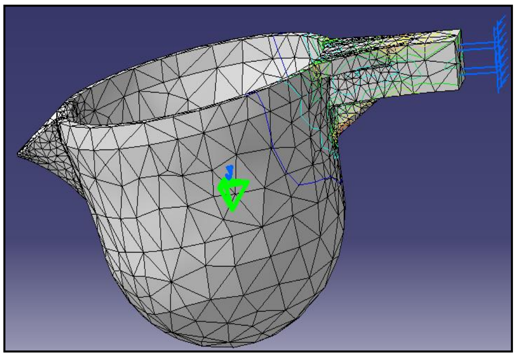
Here we also note that the maximum weight of molten brass poured from it is 8.09 kg which is measured by weighting the molten brass cooled inside pouring cup:

Fig. 9: Cooled molten brass liquid inside pouring cup

	Electronic Machine	Mechanical Machine
BRASS PRODUCT	8.090 KG	8.100 KG
LADLE	3.680 KG	3.750 KG

Table 9: Weight of pouring ladle and brass product

Hence, we can analyze by taking 100N force acting on inner surface of ladle in downward direction.



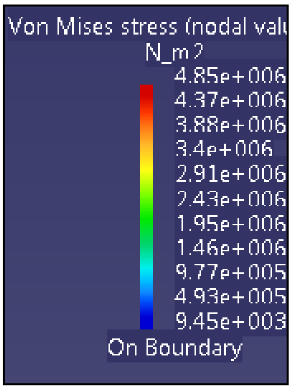


Fig. 10: Von Misis Analysis

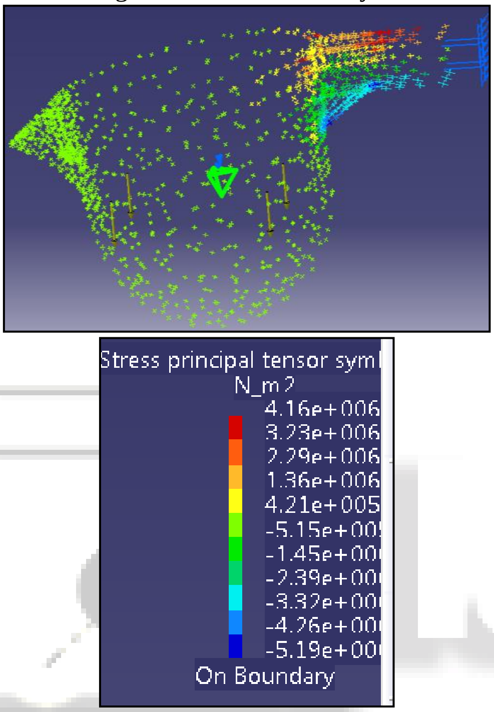


Fig. 11:Maximum stresss analysis

Here we note that Von misis and Maximum Principal stress are maximum at the crossection of handle joining with ladle which is depicted by red portion in figure 10 & 11.

- Here, Maximum Von Misis stress = 4.85 * 10^6 N-m^2
- and Maximum Principal stress = 4.16* 10^6 N-m^2

Now the First modification in design is done by increasing the area of support and then again the analysis was repeated.

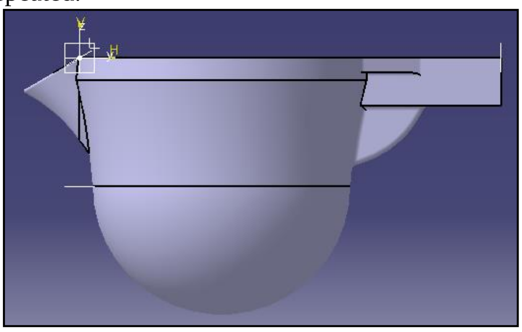


Fig. 12: First modification in design

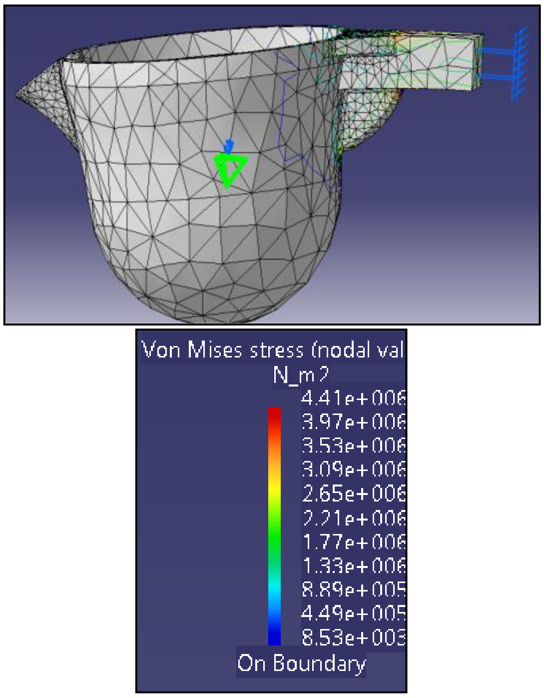


Fig13Von Misis Analysis

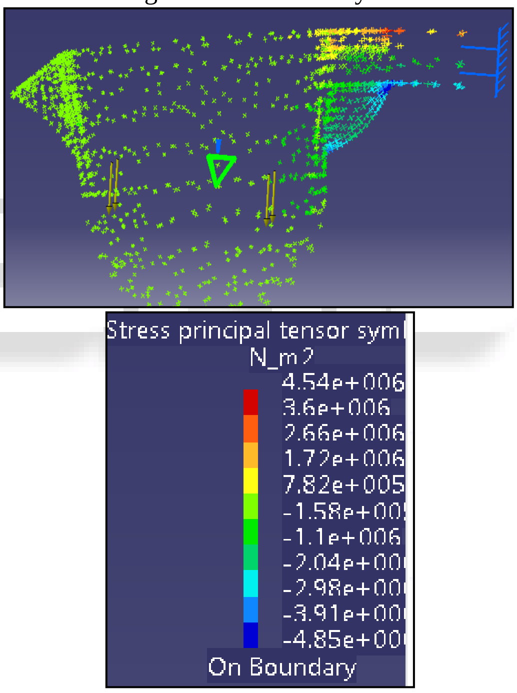


Fig. 14: Max. stress analysis

- Here, Maximum Von Misis stress = 4.41 * 10^6 N-m^2
- and Maximum Principal stress = 4.54* 10^6 N-m^2

So, here we can note that although von misis stress decreases drastically but maximum principal stress increases. Hence, a new modified design is proposed.

Now since our motive is to decrease both von misis and maximum principal stress at crossection of handle with ladle so, in new modification we will increase the area which will consequently reduce the stress at crossection as stress is inversely propotional to area. This can be achieved by increasing the contact area of handle and joint.

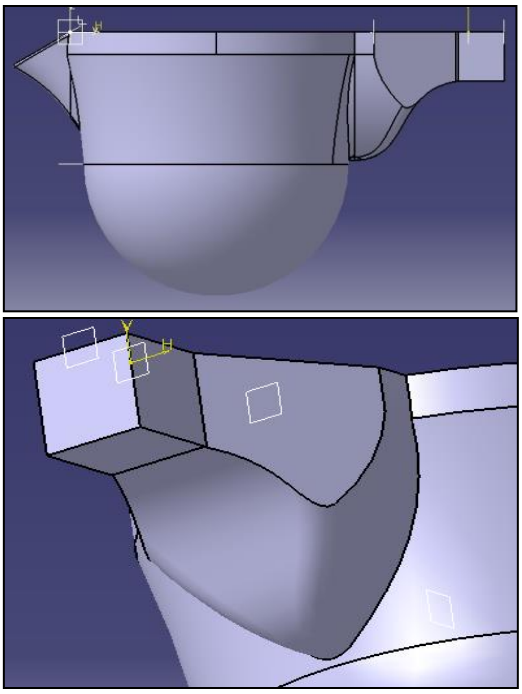


Fig. 15: Final Proposed design

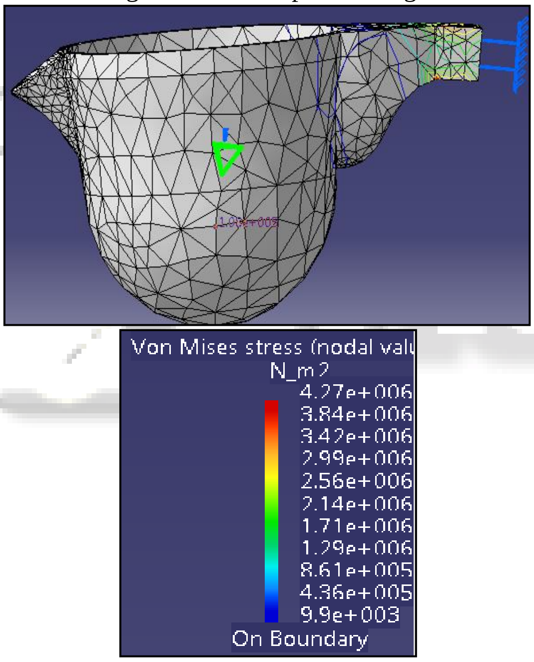
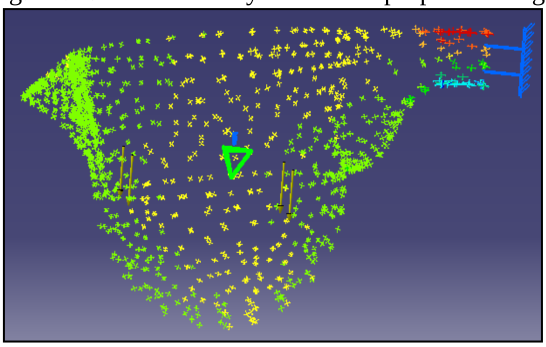


Fig. 16: Von Misis analysis of Final proposed design



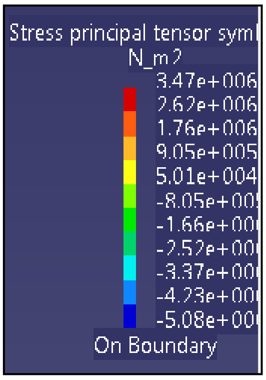


Fig. 17: Max. stress analysis

- Here, Maximum Von Misis stress = 4.27 * 10^6 N-m^2
- and Maximum Principal stress = 3.47* 10^6 N-m^2

From above result it can be seen that both Vom misis and Maximum principal stresses reduces to a greater extent after modifying the design.

IV. Conclusions

The following are conclusions are drawn from these results: Von misis stress of the final design drops down from 4.85 * 10^6 N-m^2 of failed sample to 4.27 * 10^6 N-m^2 .

Maximum principal stress also dropped from 4.16* 10^6 N-m^2 to 3.47* 10^6 N-m^2

Thus from comparing the results of Von misis and maximum principal stress it can be conclude that now the final proposed design is more structurally stable as it can now bear more stresses and resist failure.

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