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Reduction of Breakdowns in Hot Metal Transfer Car by Modifying Existing Design

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Abstract: Failure of machines under load is frequent problem faced by industries in day to day work. Design failures contribute more to an extent for such cases. Proper identification of problems and rectification with experience without scientific analysis is the basic procedure undergone in most of the industries. This is mainly because of the time factor of the production. This proposed work deals with the problems of the existing design and how the analysis process is being used
Key words: Hot metal ladle, Stress field, Finite element computation, Simulation analysis.

I. INTRODUCTION

Failure of machines under load is frequent problem faced by industries in day to day work. Design failures contribute more to an extent for such cases. Proper identification of problems and rectification with experience without scientific analysis is the basic procedure undergone in most of the industries. This is mainly because of the time factor of the production. This thesis work is a study of failure of Break downs in Hot Metal Transfer Car is a study of Break down of Hot Metal Transfer Car during the production phase in Visakhapatnam Steel Plant RINL. Under the expansion of stage – II in VSP RINL, SMS – II department has been evolved. In this Hot Metal from Blast Furnace is collected in Torpedo Ladle. Now the Hot Metal is transferred to an empty Hot metal ladle placed on Hot metal transfer car. This car is in the pit. Desulphurization check is done here. If desulphurization is required, Hot Metal will be sent to Desulfurization Unit and then to convertor. During this process we observed a frequent break down of Hot Metal Transfer Car, which impacts in the loss of production. This is happening when the empty ladle is placed on the car. After a detailed study we found that, the reason for break down is the design of weak pedestal beams. In this project, We compared old design pedestal with an new design pedestal by designing a parametrical model for pedestal beams in hot metal transfer car by collecting data from existing model. Design is evaluated by analyzing the model by taking the stress and the displacement distribution in car pedestals subjected to conjoint influence of impact load this project work generalizes the application of Finite Element Analysis Techniques. The analysis is carried out by using “ANSYS workbench” and finite element package, and the model is done by using “Creo”. Constraints as ultimate stresses and variables of structural steel material and goals as maximum width of the pedestals and fitting load cells. Car model is “Hot metal transfer car”.

Various researchers have been evolved on the hot metal ladles in hot metal transfer car, Chenggang (1) focused on simulation analysis for stress field on hot metal ladle. Dr. Gongfa Li (2) Ladle is an important container in metallurgy industry, and its lifetime is very important for the natural production of enterprise. The stand or fall of refractory lining of ladle decides its lifetime, yet thermal stress is the direct reason of causing refractory lining breakage. In this paper the structure of ladle mainly by changing the structure of bottom with finite element method is designed, and three scheme models are put forward. By analyzing and comparing stress field of the three ladle models, finally an optimization scheme is put forward. The experiment results indicate that the lifetime of ladle gains obvious increment, and the rationality and practicability of the scheme have been proved. The method is feasible improve ladle’s lifetime Wei liu(3) Steelmaking–continuous casting is a complex process. The method of selecting a ladle, which also functions as a storage device, follows a specific process of the production plan. In ladle matching, several ladle attributes are considered. However, matching objectives are difficult to achieve simultaneously. Different molten steel properties have contributed to the complexity of matching constraints, and, thus, matching optimization is regarded a multiconflict goal problem. In the process of optimization, the first-order rule learning method is first used to extract key ladle attributes (performance indicators), including highest temperature, usage frequency, lowest-level material, and outlet. On the basis of a number of indicators, such as ladle temperature, quantity, material, and usage frequency, as well as skateboard quantity, the ladle matching model is established. Second, the rule of ladle selection is determined by the method of least-generalization rule learning. AndréZimmer (4) the heat transfer in a steelmaking ladle was studied. The evaluation of heat transfer of the steel was performed by measuring steel temperature in points including all refining steel process. In the ladle, the temperatures in the re-factories and the shell were also measured. To evaluate the thermal profile between the hot and cold faces of the ladle in the slag line position, an experiment which shows the importance of thermal contact resistance was carried out. Higher heat losses in the tapping and the vacuum were verified. The temperature measurements of the ladle indicate distinct thermal profiles in each stage of steel refining. Moreover, as each stage of the process depends on the previous one, the complexity of the ladle thermal control is incremental. So a complete model of heat losses in the ladle is complex. Bang-fuHuang (5) The models and influencing factors of steel ladles exchange during the steelmaking and continuous casting process of H steel plant were investigated. Based on analysis of the operation process and turnover time of steel ladles, relationship models for the turnover number, turnover rate, continuous casting number, number of ladles with additional turnover, and number of ladles without additional turnover were built. The turnover rules of steel ladles for one basic oxygen furnace (BOF) matching one continuous caster (CC) and two BOFs matching two CCs modes were simulated by using a Gantt chart. The models of steel ladle exchange were proposed for casting of a single CC and overlapping casting of two CCs. By analyzing the influencing factors, the following conclusions were drawn. The exchange ladle should not have the task of transporting liquid steel in the CC that stops casting earlier. The end time of the empty ladle in the CC that stops casting earlier should be earlier than the start time of the full ladle in the CC that stops casting later. After evaluating the factors influencing the start casting time, turnover cycle, casting time, continuous casting number, and overlapping time, a prioritization scheme of steel ladle exchange was proposed based on the steel grade. First, the turnover cycle and single heat casting time were determined; based on these, a reasonable ladle turnover number was calculated. Second, the turnover number and continuous casting number were optimized for maximizing the number of ladles without additional turnover. Lastly, to reduce the casting number during the overlapping time to be lower than the turnover number, the overlapping time was shortened.

II. STRUCTURAL STEEL MATERIALS

Structural steel is a category of steel used for making construction materials in a variety of shapes. Many structural steel shapes take the form of an elongated beam having a profile of a specific cross section. Structural steel shapes, sizes, chemical composition, mechanical properties such as strengths, storage practices, etc., are regulated by standards in most industrialized countries.

Most structural steel shapes, such as I-beams, have high second moments of area, which means they are very stiff in respect to their cross-sectional area and thus can support a high load without excessive sagging.

A. *Mechanical Properties*

1) Modulus of elasticity, $E = 210{,}000\ N/mm^2$
2) Shear modulus, $G = E/[2(1 + \nu)]\ N/mm^2$, often taken as $81{,}000\ N/mm^2$
3) Poisson's ratio, $\nu = 0.3$.
4) Coefficient of thermal expansion, $\alpha = 12 \times 10^{-6}/°C$ (in the ambient temperature range).

III. CREO MODEL

The three dimensional CAD modeling was done in Creo 2.0 Parametric which is user friendly software. For structural analysis, the geometry of existing design and proposed design was taken. The dimensions of the design are taken as per the standards obtained from Visakhapatnam Steel Plant (AP, INDIA).

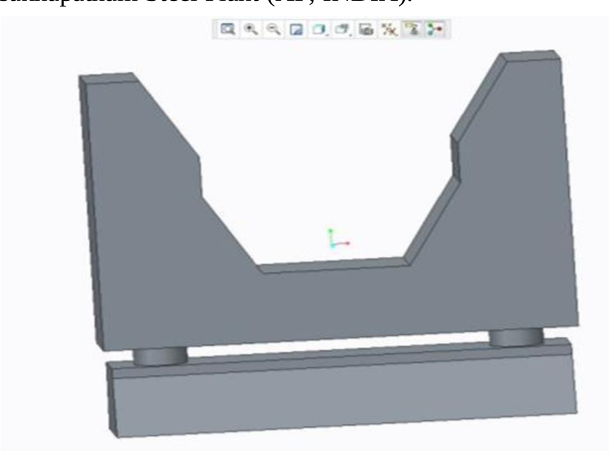

Figure 1: Existing Model

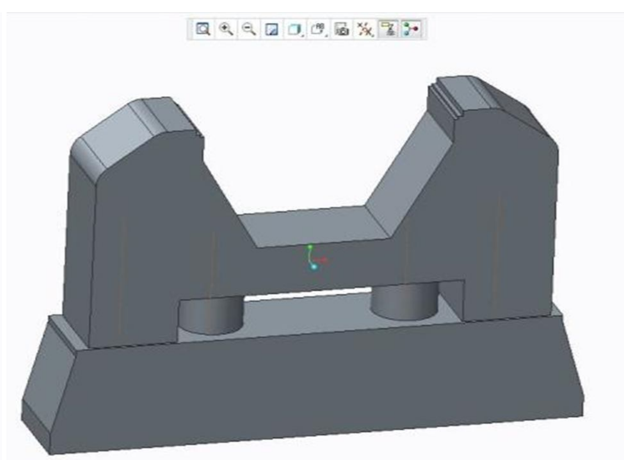

Figure 2: Proposed Model

IV. FEM MODELLING

A finite element mesh is created to the ladle beams as shown in figure 3&4. With element size of 10mm which creates 18513 elements and 34274 nodes. Each node will have 6-degree of freedom. On the other hand, complete Creo is shown in figure1 & 2.

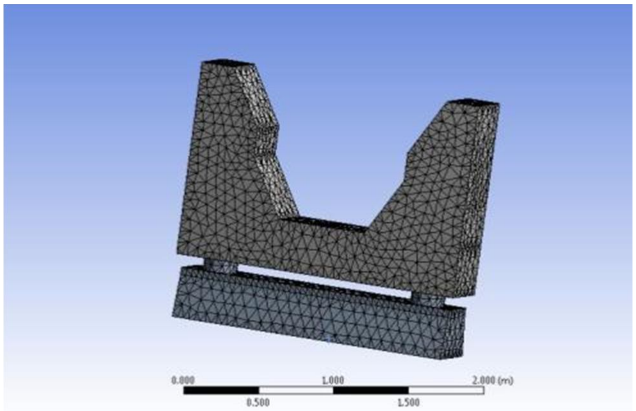

Figure 3: Old Mesh Model

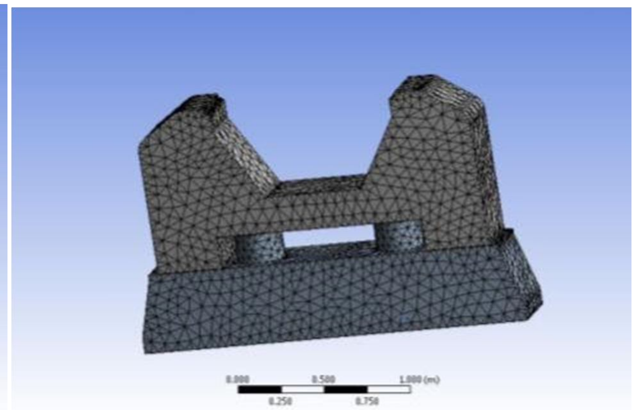

Figure 4: New Mesh Model

V. STATIC STRUCTURAL ANALYSIS

Structural analysis (Non-Linear static analysis) is used to determine the stress and strain distribution of the design. In this analysis pedestal beams (Figure 5) boundary condition and fixed support are analyzed. By using Creo, model has been made, and by the use of ANSYS workbench (finite element package) the stated analysis are carried out to find the induced displacements and stresses by the static loads , shear stress, Von - Mises stress values of the components.

A. Structural analysis for Existing old Model

1) *Applying loads on Pedestal beams at 80 tonnes:* The applied loads acting on the pedestal beams through the Torpedo Ladle are mainly composed of the 80 tonnes load which applies to the one side of the pedestal beams and the base bed is completely fixed at the bottom. The load is distributed from the side wise of the beams to the entire beam.

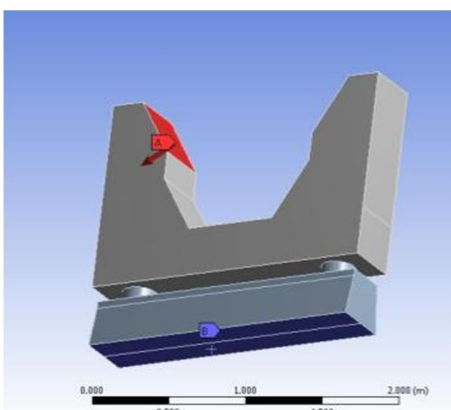

Figure 5: Loads on beam at A

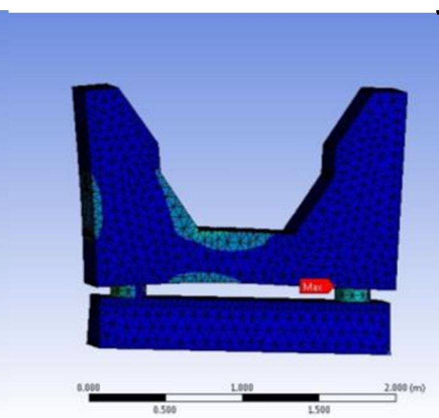

Figure 6: Total deformation on beam

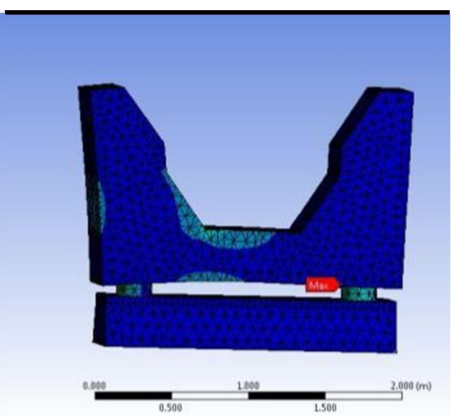

Figure 7: Safety Factor of beam

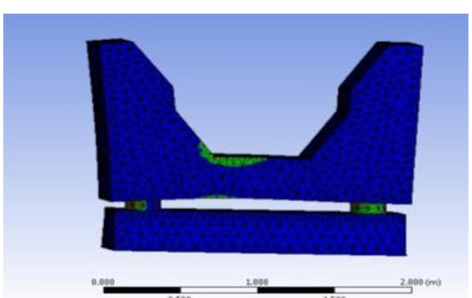

Figure 8: Maximum Shear Stress

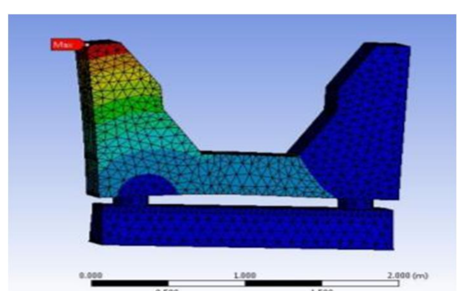

Figure 9: Maximum equivalent Von-Mises stress in beam

2) *Applying loads on Pedestal beams at 160tonnes:* The applied loads acting on the pedestal beams through the Torpedo Ladle are mainly composed of the 160 tonnes load which applies to the one side of the pedestal beams and the base bed is completely fixed at the bottom. The load is distributed from the side wise of the beams to the entire beam.

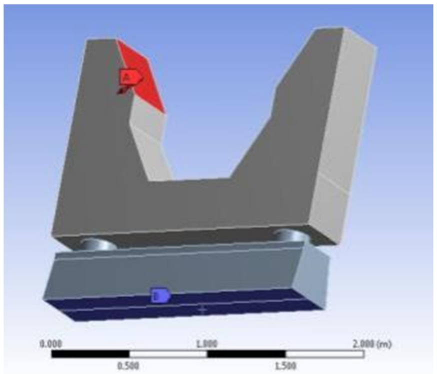

Figure 10: Loads on beam at A

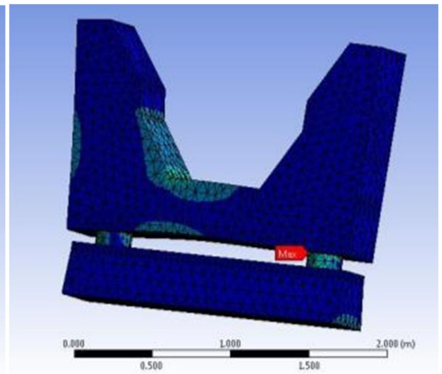

Figure 11: Total deformation on beam

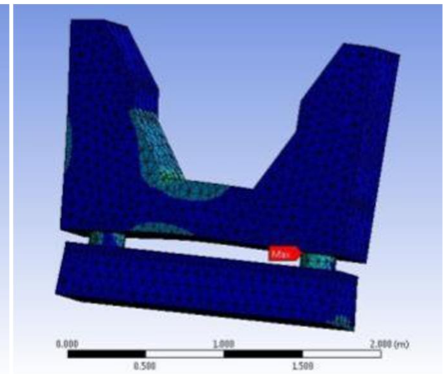

Figure 12: Safety Factor of beam

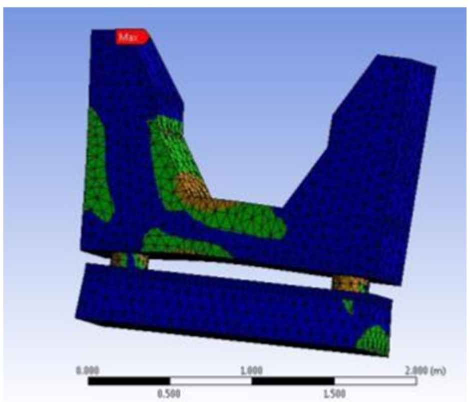

Figure 13: Maximum Shear Stress

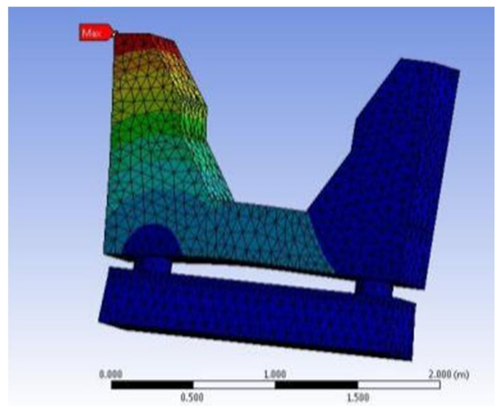

Figure 14: Maximum equivalent Von-Mises stress in beam

B. Structural analysis for Proposed Model

1) *Applying loads on Pedestal beams at 80tonnes:* The applied loads acting on the pedestal beams through the Torpedo Ladle are mainly composed of the 80 tonnes load which applies to the one side of the pedestal beams and the base bed is completely fixed at the bottom. The load is distributed from the side wise of the beams to the entire beam.

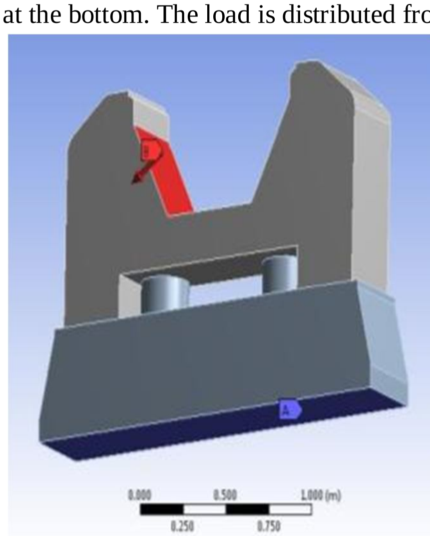

Figure 15: Loads on beams at A

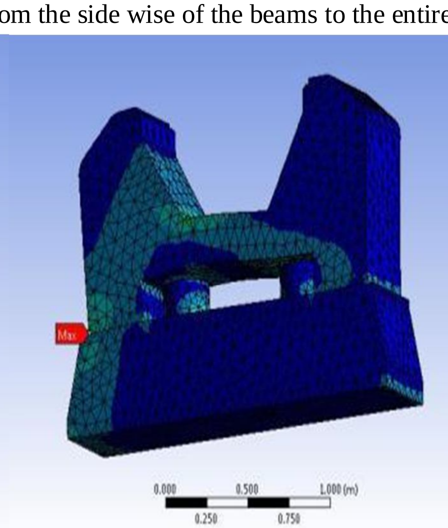

Figure 16: Total deformation on beams

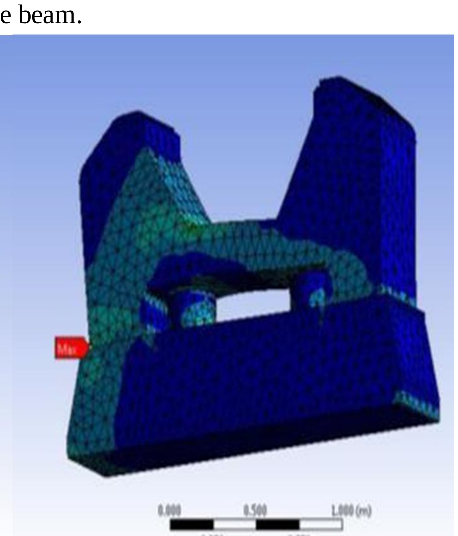

Figure 17: Safety Factor of beams

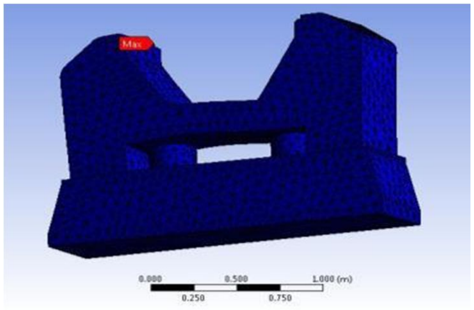

Figure 18: Maximum Shear Stress

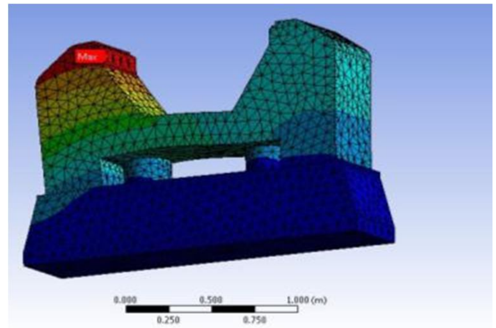

Figure 19: Maximum equivalent Von-Mises stress in beams

2) *Applying loads on Pedestal beams at 160tonnes:* The applied loads acting on the pedestal beams through the Torpedo Ladle are mainly composed of the 160 tonnes load which applies to the one side of the pedestal beams and the base bed is completely fixed at the bottom. The load is distributed from the side wise of the beams to the entire beam.

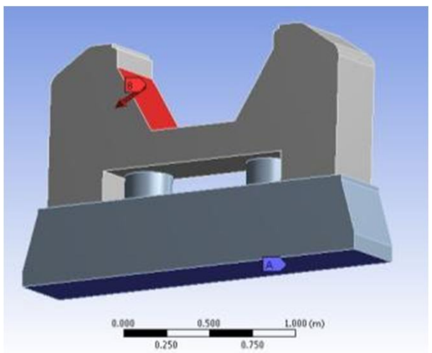

Figure 20: Loads on beams at A

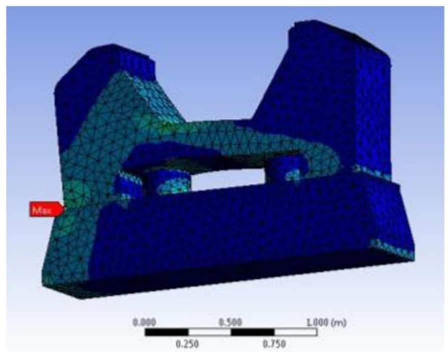

Figure 21: Total deformation on beams

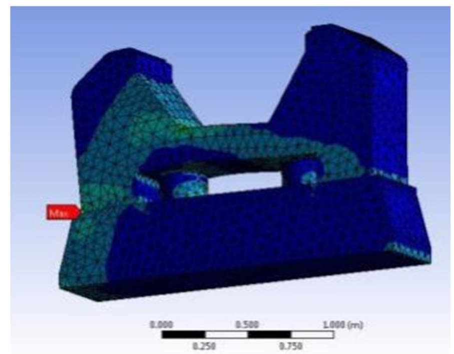

Figure 22: Safety Factor of beams

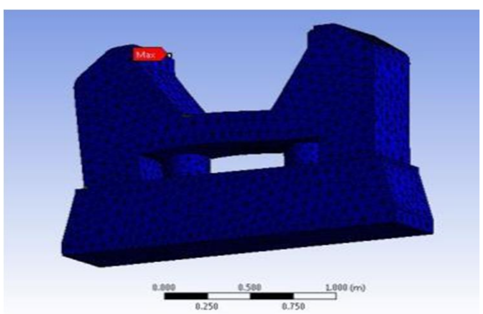

Figure 23: Maximum Shear Stress

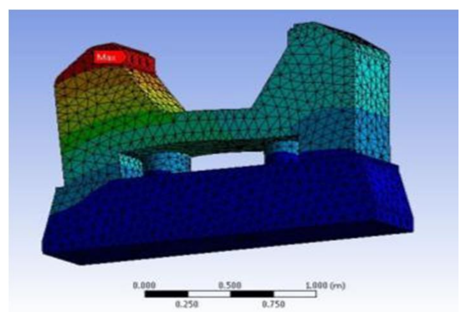

Figure 24: Maximum equivalent Von-Mises stress in beams

VI. RESULTS & DISCUSSIONS

TABLE I

Difference between Existing model and proposed model

Load		Existing Model	New Proposed Model
At 80 Tones	Total Deformation(M)	0.00086265	9.0292×10^{-5}
	Safety Factor	15	15
	Shear Stress(Pascal)	8.2142×10^{7}	1.3559×10^{7}
	Von – Mises Stress(Pascal)	1.5096×10^{7}	2.648×10^{7}
At 160 Tones	Total Deformation	0.0017253	0.00018058
	Safety Factor	15	15
	Shear Stress(Pascal)	1.6428×10^{7}	2.7117×10^{6}
	Von – Mises Stress(Pascal)	8.0191×10^{8}	5.2969×10^{7}

The analysis values of the existing and proposed models are extracted using ANSYS 17 solver. The simulation was done by fixed condition of design its root by restricting the base component.

From Table-1 it clearly says that the analysis values are merely decreasing showing that better performance can be achieved with help of the new modified design than the existing design.

Therefore project work of analysis was helped in finding out failures exisisted in existing model and showed how the proposed model will work effectively than the original old model. It dealt with finding out stress-strain values of pedestals using static analysis and stresses induced in the structure due to impact load conditions using static analysis.

Static or dynamic analysis can tell us about stress, displacement, acceleration etc. but not how long the component will survive. Many a times static or dynamic analysis predicts location of failure not matching with lab test or field failure and then analyst keep on thinking whether something is wrong with boundary conditions or material properties or geometry of the component. But when fatigue analysis is carried out using same static or dynamic results, it reveals correct location of failure.

Failures or crack usually initiates at surface. Life of the component depends on surface condition (like grinding, induction hardening, and shot preening). Dynamic analysis cannot take in to account.

VII. CONCLUSIONS

In this study the numerical analysis of equivalent Von-Mises stresses, maximum shear stress and total deformation are carried out successfully. FE-Loading and boundary conditions have played a importance role in getting accurate results. By using ANSYS 17 simulation software, the stress analysis is being done on the pre-model and the post-model. Under external loading conditions, fixed body Static Analysis is done on the ladle beams of both old and new proposed designs. The three dimensional Creo model was generated by using Creo modeling software and the model was imported to ANSYS. The effectiveness strength of the beams are observed. Finally, comparison is done between the existing model and new model. Hence from the results, it is predicted that with a simple modifications in the design, by changing the structure with additional support on the either side for the existing design, failure criteria can be minimized up to greater extent.

VIII. ACKNOWLEDGEMENTS

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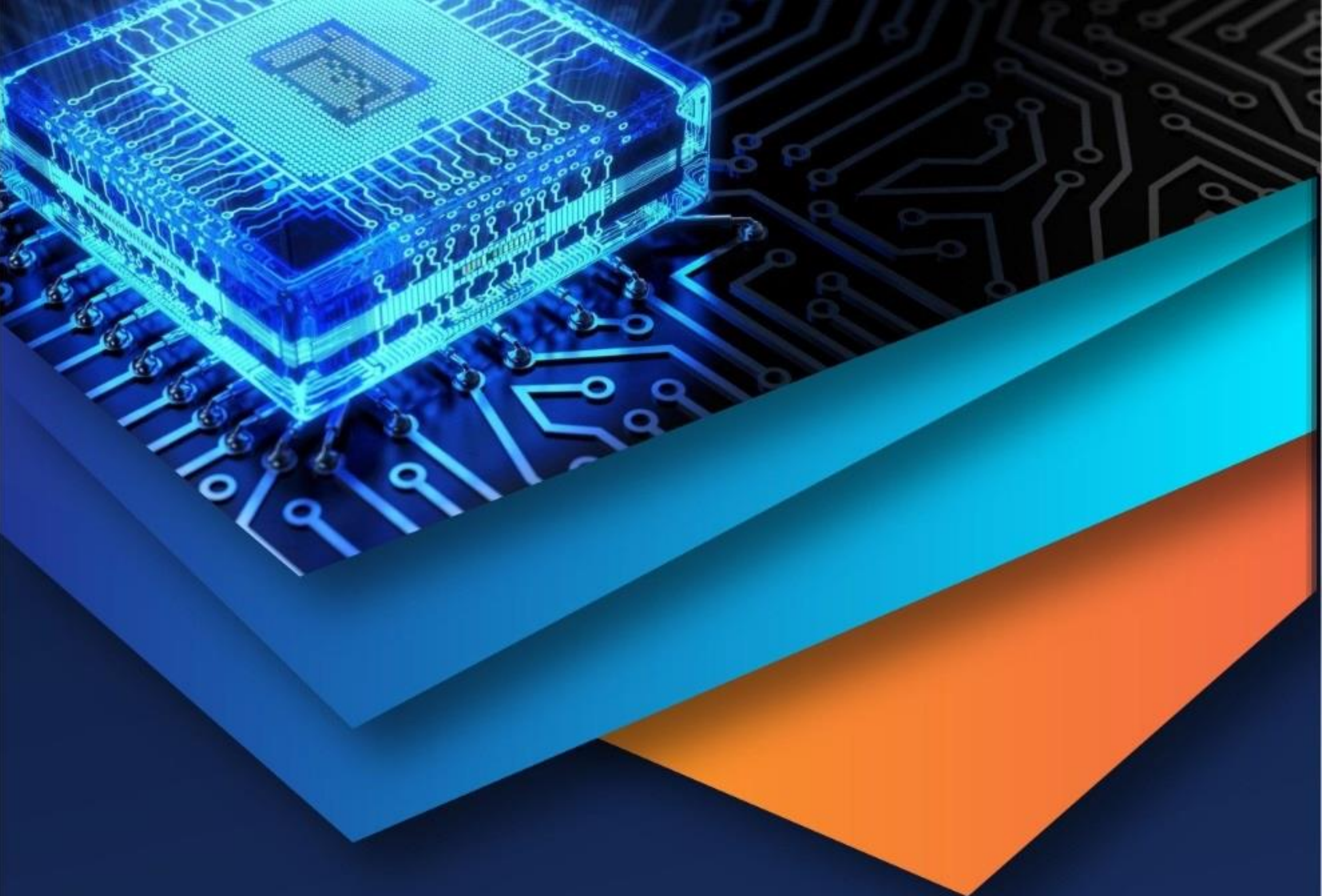

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