Design of Rail Guided Vehicle utilized in scrap charging process in the Steel industry

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Abstract : In today's industries, the material handling system is unitary of the significant system. The primary application of material handling equipment for storage and shipping of the products. Goradia Special Steels Ltd. Khopoli, Raigad MH has encountered accidents while charging the scrap. Hence there is a need to Implement a system which will reduce the involvement of manpower. Robotic vehicles could also be the solution but the need is to Design a cost-effective system. Basically, the function of the material handling section is to choose the most appropriate material handling equipment which is safe and can fulfill material handling requirements. Design of Automated charging trolley is of great interest for efficient and safe sustainability. An Automated Charging trolley will be utilized in the foundry for charging the scrap inside an already installed Induction Furnace. Rail-Guides having inclination will be constructed to travel the charging trolley up to the Induction furnace. Trolley model is designed with various design parameters for the steel industries and the CAD Design is modelled using Solidworks- software. Results from FEA Analysis suggested that the proposed system is able to transport the scrap with better efficiency than the current method of charging the scrap. Foundry has a scrap area and the trolley has to travel from there to the induction furnace. For Start/Stop operation we have used Limit switches, PLC, Remote control. The Charging trolley will be mounted with dead weight, a gearbox, Two Hydraulic cylinders and a motor. Materials of construction used were of common heavy-duty engineering practice.

***IndexTerms* - Material Handling Equipments, Automation, Rail Guided Vehicle, 3D Modelling, FEA Analysis, Material Handling Selection, Hydraulics, Simulation.**

I. INTRODUCTION

The Goradia Special Steels Ltd.(GSSL) has a scrap melting Electric Induction furnace which is charged manually by their workers. So, we have to automate the charging operation for the sake of safety of workers and the need is to optimize these processes.The existing method of Scrap charging in Goradia Special Steels Ltd.(GSSL) was carried out by an overhead crane which is an old method and has risks associated with it. A lot of heat energy is released from the opening of the furnace. The scrap which is having the weight of about tonnes causes the inside molten metal to be thrown outwards and upwards. This can cause scrap dust to be ignited and cause fireball eruption.

The company has experienced two accidents while charging. Charging of the scrap is required to be carried out throughout the day to meet demands. This restriction is needed to be resolved.

Scrap is lifted from the scrap area with the help of electromagnet. The Electromagnet is operated from Overhead crane. This Scrap is suspended from Electromagnet into the furnace. Since the diameter of the electromagnet doesn't match the opening diameter of the furnace. Hence some scrap is thrown on the platform. This remaining scrap is manually pushed inside the furnace.

II. METHODOLOGY

2.1. Procedure

1. To solve the problem of charging the scrap into the furnace, a charging trolley (Rail Guided Vehicle) is designed using Solidworks CAD software.
2. To get an idea on designing and selection of Material Handling System of heavy duty, a Literature Survey was performed.
3. To complete the objective of charging scrap, the frame of trolley needs to be tilted upon the furnace opening, so that scrap would be dropped inside the furnace, Hence Hydraulic cylinder calculation was performed.
4. Selection of Bearing, Material of construction of trolley & Rails was carried out considering General Heavy Duty practices.
5. Finally the model was Simulated in Ansys workbench, It was found that induced von-mises stress was less than yield stress of selected material of construction.

2.2. Literature Survey

Kaustubh V. Wankhade and Dr. N. A. Wankhede [1] Designed a material handling system for molten metal. Handling & pouring of molten metal was carried out manually for small scale industry while it was carried out with the help of hook attached to the overhead crane in medium and large scale industry. Authors designed a feeder trolley mechanism for handling and pouring molten metal. This reduced the labour requirement and also risk factor.The authors reviewed various previous research for designing and modelling the material handling system. The mechanism included Hydraulic system hence human efforts were neglected while lifting the molten metal. Authors took help of literature in the field of ergonomics, gearbox design.

S.Z. Mafokwane, D.V.V. Kallon, M. Nkosi & F. Chiromo [2] had modelled, analysed a heavy duty material handling system to replace a Forklift in the manufacturing industry. They used Computer aided drawings (CAD) for modelling purposes and CAE for analysis of Static and dynamic stress of the proposed model. Industry 4.0 was considered important in the development of material handling systems. Authors concluded that it gave rise to innovation to meet the standardization of the MH system with good efficiency. This design incorporated the use of hydraulic cylinders to lift the material to be transported and usage of electrical components like motor, battery etc. to move the model. Authors used push button tandem for control of hydraulic system and wheel of designed frame.

Hu Wuhua [3] Suggests optimal routing rail-guided vehicle system path. Rail-guided vehicle systems are used as a material handling system in automated freight stations. The energy requirement is reduced by optimization techniques. Basically, energy consumption depends upon dynamic routing and routing dependent gross weight of rail guided vehicle systems. Simulation is performed in order to suggest the proposed new system is optimized for minimum energy consumption. Eventually the cost required for transportation of the air cargo is reduced. Reasons behind Selecting Rail Guided Vehicle instead of other Material Handling Systems:

1. Conveyor systems need more space, for given problems we have concised space hence we cannot use conveyor systems.
2. Crane is already used in GSSL and our objective is to increase its efficiency.
3. Programmable AGVs will need rigorous work and huge cost. Objective is to give a cost-effective solution.

hence it is concluded that Rail Guided System will fetch the objectives in much lower cost and its cost to benefit ratio is also very high than any other system.

2.3. Trolley Design

- The whole structure will transfer its load into 4 wheels. Out of 4 wheels, 2 wheels will be idle wheels and other two wheels will be motorised wheels which will be driven from the motor provided.
- The Motor, Hydraulic system will be mounted in a box. This box will be kept in the space provided on the trolley.
- The vehicle hopper tilting is driven by 2 double hydraulic cylinders, which have a large driving force and stable operation.
- Hydraulic components are concentrated in the design of the rear part of the device,keeping away from heat source and increasing the reliability of equipment operation.
- Using remote electrical control which can achieve shut down and emergency power off freely.
- The weight balancing Deadweight, improves the efficiency of hopper tipping (helps to make full use of the lever principle, increases tipping force).

2.4. Design Calculations

1. Design of Wheel

Diameter of wheel = 200 mm
Circumference of wheel = π D
= π * 200
= 628 ≈ 630 mm
Revolutions required to complete distance 4000 mm
= 4000630 = 6.369 ≈ 6.4

2. Motor Selection

4 Pole (N)
Ns = 120fP =120*504= 1500 – Nslip =1500 – 60 = 1440 rpm

6 Pole (N)
Ns = 120fP = 120*506 = 1000 – Nslip =1000 – 60 = 940 rpm
We will select 6 Pole Motor.

3. Reduction of rpm using Gearbox

Consider 2 min for travelling distance.
Now we Select 1: 250 gearbox ratio for heavy duty
RPM we will get = 940250 = 3.76 rpm
From wheel peripheral, for complete travelling distance of 4000 mm,
the number of revolutions made by wheel is 6.4
= 6.43.76 = 1.70 min = 102 seconds

4. Total weight to be displaced = 2000 KG + 1500 KG = 3500 KG

As 4 wheels are in use, we will divide the load equally on each wheel,

Load on wheel = 35004 = 875 kg/wheel

Now,
875 kg/wheel to Newton = 875 * 9.81 = 8583.75 N

Torque, T = F * r
= 8583.75 * 100
= 858375 N-mm
= 858.375 N-m …. For 1 wheel
But gearbox is attached with two wheel so overall Torque is
= 2 * 858.375
= 1716.75 Nm

5. Turning Radius of Rail

R = 2 * Distance between two wheels
= 2 * 1000mm
= 2000 mm

6. Bearing Design

For Idle wheels we will use UCFC Bearing. This four-bolt flange cartridge unit has a round cartridge on the backside of the flange which allows for precise mounting and alignment.

Figure 2.1. Bearing

Applications are Rotating drum, rotating roller and areas where precise mounting accuracy is required.

Sr.No.	Specification	Detail
1.	Bolt Size	M10
2.	Bearing No	UC206

Table 2.1 Bearing Specification

7. Hydraulic Cylinder Calculations

1) Cylinder Blind Area,

Diameter = 6" = 152.4 mm

Radius = ½ (Diameter) = 3" = 76.2 mm

Cylinder Blind Area = π × (Cylinder Radius)2

= π × (76.2)2

= 18241.46 mm2

2) Cylinder Rod End Area,

Cylinder Blind End Area = 18241.46 mm2

Rod Diameter = 76.2 mm

Rod Radius = ½ (76.2) = 38.1 mm

Radius2 = (38.1)2 = 1451.61 mm

π × (Radius)2 = π × (38.1)2 = 4560.36 mm2

Cylinder Rod End Area = Blind End Area - Rod Area

= 18241.46 – 4560.36

= 13681.1 mm2

3) Cylinder Output Force,

i) Push Force of a 6" (152.4mm) Diameter Cylinder operating at 2500 PSI (17.2368 MPa)

Cylinder Blind End Area = 18241.46 mm2

Pressure =17.23 MPa

Pressure × Cylinder Area = 17.23 × 18241.46

= 314300.35 N

ii) Pull Force of a 6" (152.4mm) Diameter Cylinder operating at 2500 PSI (17.2368 MPa)

Cylinder Rod End Area = 13681.1 mm2

Pressure × Cylinder Area = 17.23 × 13681.1

= 235725.35 N

4) Fluid Pressure (in MPa) required to lift the load

i) Pressure needed to develop 34.33KN ≈ 35 KN of push force ….. 3500KG = 34.33 KN

Newton of force = 35 KN

Cylinder Blind End Area = 18241.46 mm2

Newton of Force needed / Cylinder Area = 3500018241.46=1.918 MPa

ii) Pressure needed to develop 34.33KN ≈ 35 KN of pull force

Newton of force = 35 KN

Cylinder Rod End Area = 13681.1 mm2

Newton of Force needed / Cylinder Area = 3500013681.1 = 2.55 MPa

Factor of Safety = 20 %

5) LPM of Flow needed for Cylinder speed

LPM needed to extend a 6" (152.4mm) Diameter cylinder 8" (203.2mm) in 10 seconds

Cylinder Blind End Area = 18241.46 mm2

Stroke Length = 203.2 mm

Time for 1 Stroke = 10 Seconds

(Area × length) / (231× 60) / Time = (18241.46 × 203.2) / (231× 60) / 10
= 3790.43 LPM

6) LPM needed to retract a 6” (152.4mm) Diameter cylinder 8” (203.2mm) in 10 seconds
Cylinder Rod End Area = 13681.1 mm2
Stroke Length = 203.2 mm
Time for 1 Stroke = 10 Seconds
(Area × length) / (231× 60) / Time = (13681.1 × 203.2) / (231× 60) / 10
= 2842.82 LPM

7) Cylinder Blind End Area Output (LPM)
LPM come out of the Blind End Area when there is 60 LPM put in the Rod End Area
Cylinder Blind End Area = 18241.46 mm2
Cylinder Rod End Area = 13681.1 mm2
LPM input = 60 LPM
Blind End Area Rod End Area × LPM = 18241.4613681.1 × 60
= 79.99 LPM

Sr.No.	Specification	Detail
1.	Size	3” × 8”
2.	Type	Double Acting Cylinder

Table 2.2 Hydraulic Cylinder Specification

III. Description of System

A charging trolley was suggested as the solution after a literature survey which will meet the client's demand.

Sr.No.	Parameters	Detail
1.	Travelling Distance of Trolley from scrap area to furnace	50 m
2.	Cost Estimation	7 Lakhs
3.	Motor used	3 HP - 4 HP
4.	Loading Condition	Operation Mode
5.	Tilting Angle of Hopper	0°- 30°
6.	Limit switches	Honeywell Micro SWITCH

Table 3.1 Description of Trolley

3.1. Dimensions of Trolley

Sr.No.	Dimension	In mm
1.	Width of Frame	1000
2.	Length of Frame	2080
3.	Diameter of Wheel	208
4.	Height of Trolley	800

Table 3.2 Dimensions of Trolley

3.2. Materials of Construction

Sr.No.	Part	Material Selected
1.	Shaft	AISI 1070/N9
2.	Body and frame	IS 2062 Gr. B
3.	Rail	Gr.880 Rail

Table 3.3 Materials of Construction

Sr.No.	Material Selected	Properties
1.	AISI 1070/N9	UTS=640 to 760 MPa, Y.S.= 420 to 560 MPa
2.	IS 2062 Gr. B	UTS = 410 MPa, Y.S. = 250 MPa
3.	Gr.880 Rail	UTS = 880 MPa Y.S.= 460 MPa

Table 3.3 Mechanical Properties of Materials selected

IV. MODELLING

Model is designed using SolidWorks below is the layout of the designed RGV

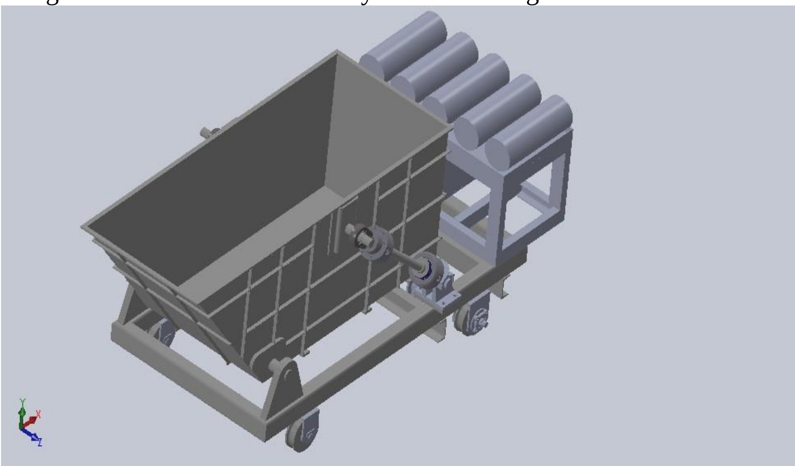

Figure 4.1. Isometric View of Model

V. FOUNDRY LAYOUT

The Layout of Foundry with Charging Area is highlighted in the given figure.

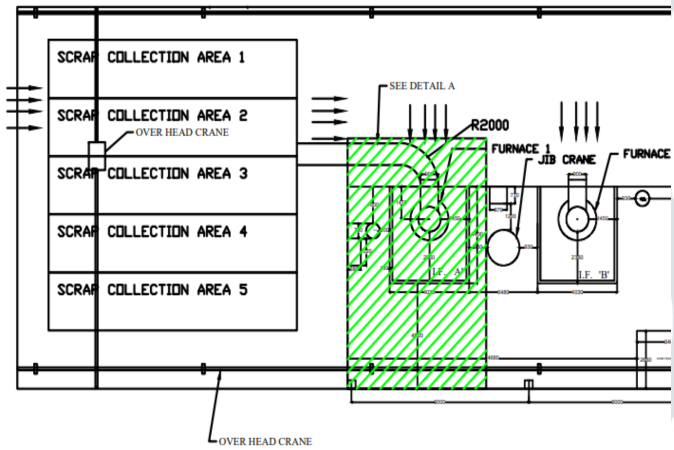

Figure 5.1 .Layout of Foundry

The trolley will travel from the Scrap area to the opening of Furnace. A Slope platform will be created to travel the trolley up to the furnace opening. Detail A- drawing of highlighted area is shown below:

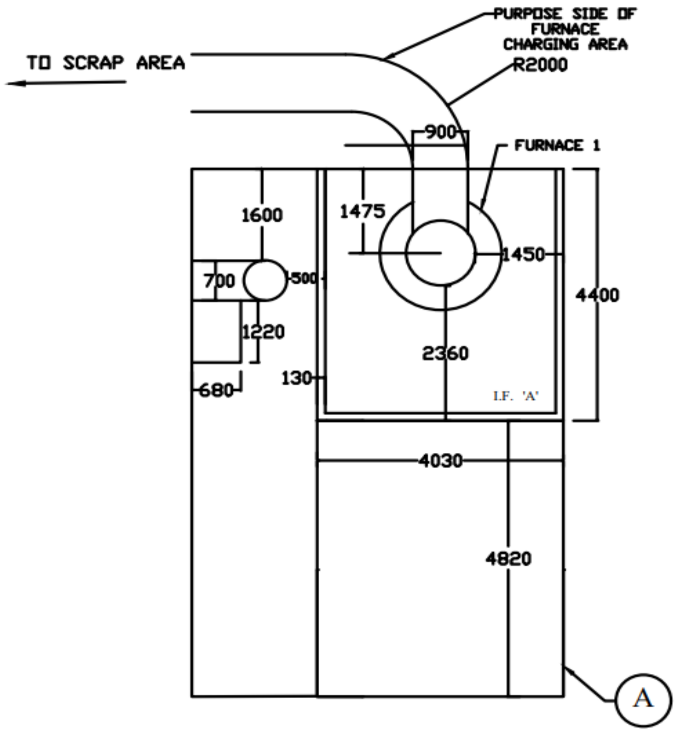

Figure 5.2 Detail A of Foundry Layout

VI. Analysis

The designed frame was analyzed with the Finite Element Method. The final structure was meshed and analyzed using

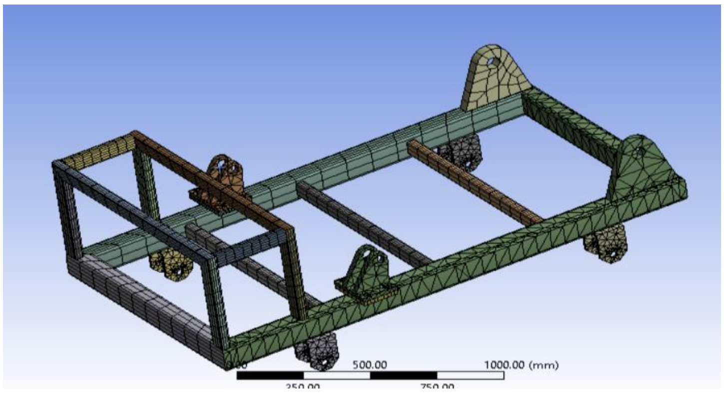

Figure 5.3 Meshing of Frame

ANSYS Workbench for stresses and displacements during various loading conditions.

We will apply a load of 6 kN and check whether the proposed design works or not. This Analysis will be performed in Ansys Workbench software.

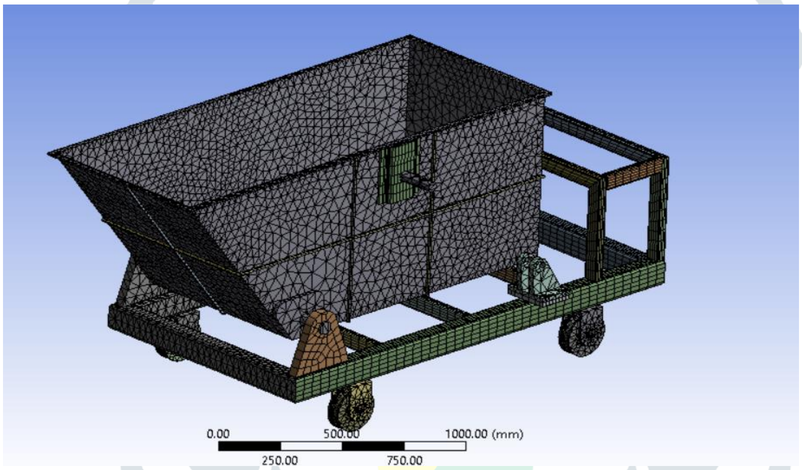

Figure 5.4 Meshing of Trolley

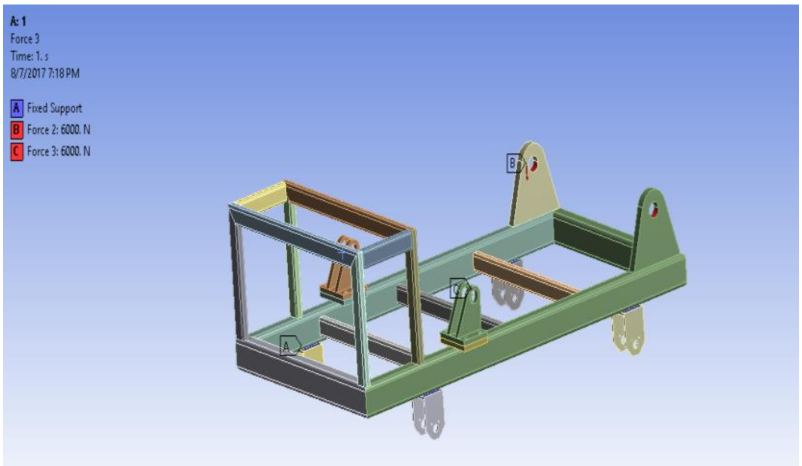

Figure 5.5 Loading on Trolley

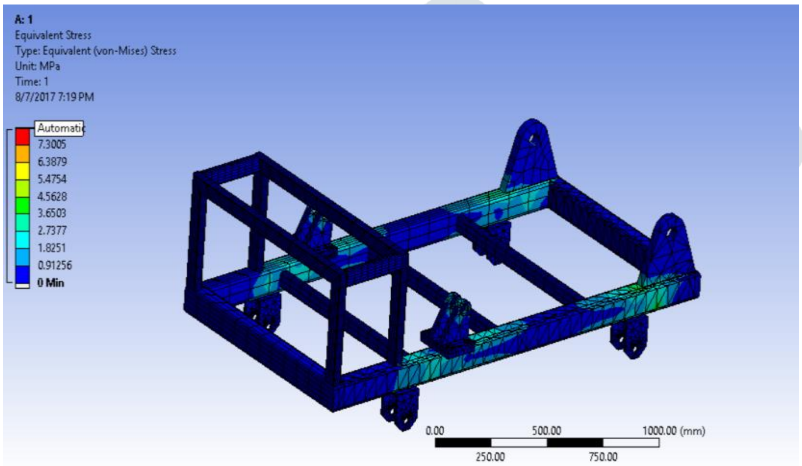

Figure 5.6 Von mises stress on Frame

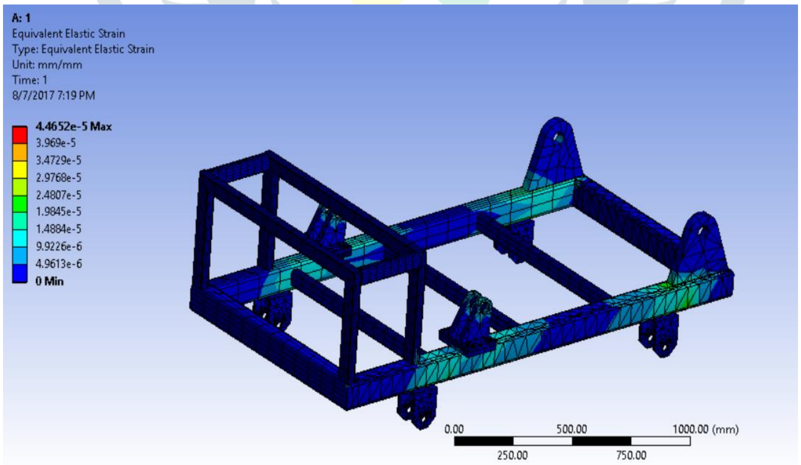

Figure 5.7 Strain on Frame

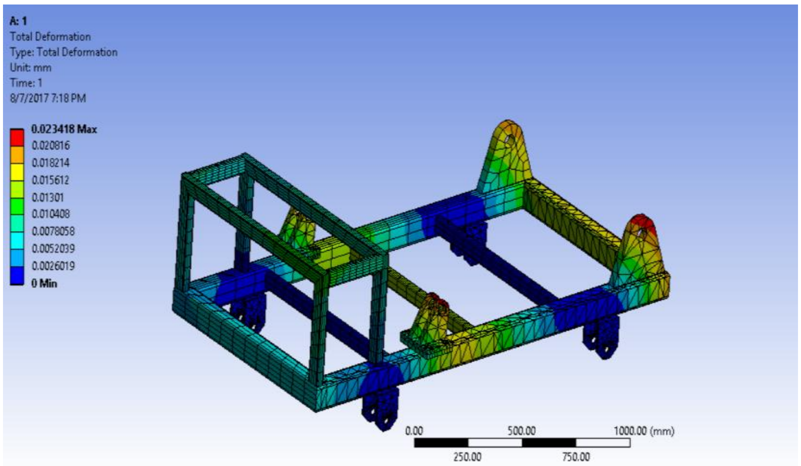

Figure 5.8 Deformation of Frame

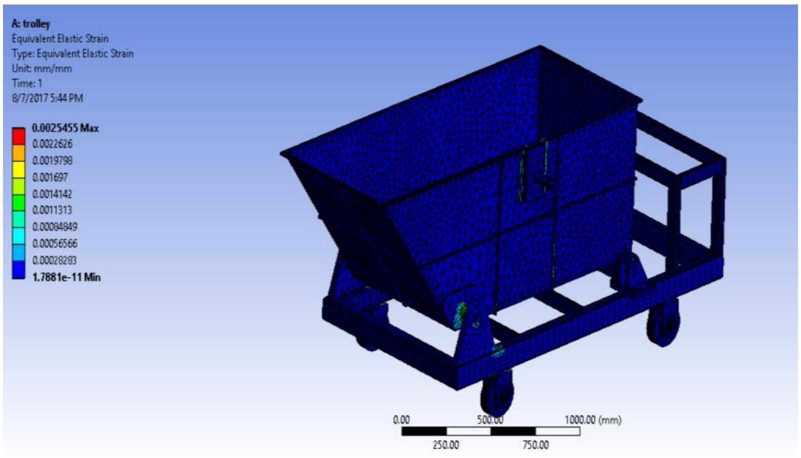

Figure 5.9 Strain on Trolley

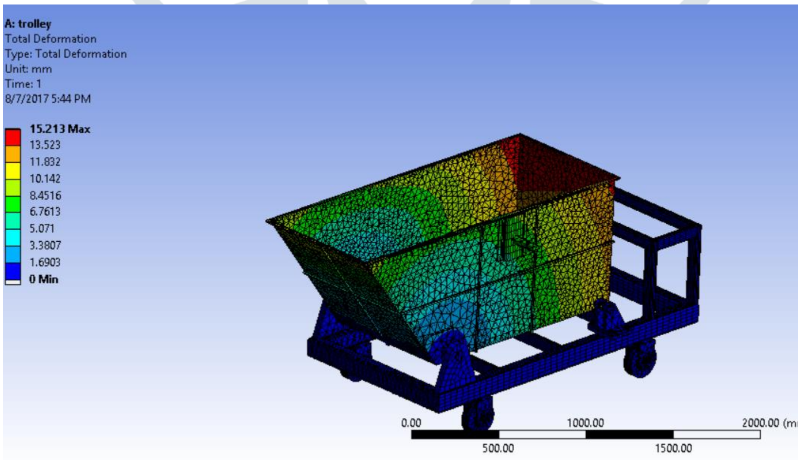

Figure 5.10 Deformation of Trolley

VII. Conclusion

To design a trolley, a design procedure is proposed. In this Project work , the design is carried out using Solidworks software and analysis of the trolley is performed using finite element ANSYS Workbench.

The material used in the trolley's frame has yield stress 250 MPa and maximum stress is about 8.8 MPa which is less than yield stress so it implies that the design of Trolley is safe. Total deformation is maximum at 0.023418 mm which is negligible.

Since the expected life of Rail Guided Vehicle is about 20-25 years & the thermal stresses would also incur during the operation. Also the trolley is going to travel on an inclined platform made by Rail Guides. Hence there is a much higher gap between Maximum stress induced and yield stress of material. The proposed Material Handling trolley Design is safe. As the ANSYS results show the Stress is under allowed stress for the used Shaft Material AISI 1070 and Frame IS 2062 Gr. B.

The trolley's speed can be increased by increasing the gearbox speed and reducing the failures in the gearbox and loading trolley.

After the calculation and design was done successfully according to the customer requirement and their approval for the same, the production drawings were released accordingly. production drawings of each and every part was made in detail and according to which the fabrication and manufacturing of those parts took place.

REFERENCES

[1] Kaustubh V. Wankhade and Dr. N. A. Wankhade **(2015)**"Design and analysis of transfer trolley for material handling – A review" , International Journal of Application or Innovation in Engineering & Management (IJAIEM), Volume 4, Issue 2, February 2015 ISSN 2319 - 4847.

[2] S.Z. Mafokwane, D.V.V. Kallon, M. Nkosi & F. Chiromo **(2019)**"Design Of Automated Heavy-duty Handling System Based On Industry 4.0 Principles" , International Conference on Sustainable Materials Processing and Manufacturing, SMPM 2019, Sun City Resort, South Africa, 08 – 10 March 2019.

[3] Hu, W. et al. "Energy-efficient rail guided vehicle routing for two-sided loading/unloading automated freight handling system." Eur. J. Oper. Res. 258 **(2017)**: 943-957.

[4] http://www.nottco.com/fluid-power/about/resources/hydraulic-cylinder-calculation.html.

[5] https://www.skf.com/in.

[6] S. R. Ingole, N. K. Chhapkhane, Mr. M. S. Kulkarni**(2015)**"Design and Static Stress Analysis of Material Handling Tool Pallet/Skid"International Journal for Research in Applied Science & Engineering Technology (IJRASET)Volume 3 Issue VI, June 2015 ISSN: 2321-9653.