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Design & Analysis of the Side Arm of the Two Drive Side Arm Charger for Heavy Load

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Abstract: ***Power plants, steel plants, cement plants, other metal processing plants require raw materials in bulk quantity. Rail infrastructure in India, due to its low cost & energy efficiency allows these materials to be handled much cheaper than road. It is obvious to have efficient unloading facilities in plants to unload the material received by railway wagons. Track hoppers & wagon tipplers are the options available for mechanized unloading, of which wagon tipplers proved to be economical & have high demands. At wagon tippler unloading stations, wagon need to be placed on tippler table one by one where it is hold by hydraulic clamping arrangement. Tippler further rotates the wagon to discharge the contents of wagon into hopper. Side arm charger machine plays a key role in placement of wagon on tippler table. It is working on a parallel track, has got eccentric arm which couples with wagon from front & pulls the wagons to place them one after another on tippler table. It can handle entire stock of the wagons coming in one rake, approximately 60 nos. Sometimes there are requirements to handle less number of wagons at a time due to customer specific requirements or it depends on the space availability. The present work includes an effort to design and analyze the side arm of side arm charger machine for moderate pulling load equivalent to 30-35 nos. of wagon pulling. It includes design, 3D modelling of side arm & its analysis by Finite Element Analysis (FEA).***

Keywords: Side arm charger, wagon tippler, wagons, Finite element analysis**.**

1. Introduction

In order to accelerate the pace of development, the infrastructure industries of the economy, consisting mainly of steel plants, ports, mining, power generating units etc., large sums of investment are required. The power sector, especially the thermal power sector needs to add capacity and increase efficiency to meet the development need to economy.

Coal, iron ore, lime stone, dolomite, clinker, gypsum, slag, metal ores etc. are the prime materials required for power sector, steel plants, cement plants or any other metal processing plants. These material are preferably handled by railway wagons in bulk quantity in India. Low costs, energy efficacy, less infrastructure etc. make the rail transport much cheaper than that of road. Bulk material handling wagons include top open wagons, hopper wagons and tank Wagons. The trend is to go for large capacity units, located close to the coal deposit and construct split located Power plant units nearer to the source of mines (Coal mines).

The material transported in railway wagons needs efficient unloading facilities at the respective plants. Track hoppers & wagon tipplers are the options available for mechanized unloading, of which wagon tipplers proved to be economical & have high demands due to its less initial investment & ability to unload wide variety of open BOX wagons of Indian railway infrastructure. At wagon unloading stations, wagons need to be handled after rake is placed at tippler station & locomotive departs. Side arm charger machine takes over the control of entire rake left by the locomotive. It is further used to place the wagons one by one centrally on tippler table. Wagon on tippler then hold by hydraulic clamping arrangement & rotated to discharge the material contained in wagon. Side arm charger is a rail mounted machine works on parallel track to that of main rail track on which loaded wagons are standing. It is used to pull the loaded wagons along with the rake, places the single loaded wagon on tippler table & push out the empty wagons out of the tippler table after tippling.

The wagon handling capacity i.e. number of wagons being handled, weight of wagons, track curvature, track gradient etc. decides the pulling requirement of side arm charger. Side arm and main frame of the side arm charger need to be designed accordingly to take care of desired pulling requirement. In many plants side arm charger is designed for handling complete 60 nos. wagons of the rake. However it is further customer specific where customer may handle the rake at two unloading stations by splitting single rake into two half rakes in order to reduce the time to fully empty the rake. The requirement of handling half rake may arise due to space constraint where only half rake can stand at the tippler inhaul side.

Looking at the requirement of half rake handling, side arm charger machine pull requirement worked out to be 35 Ton considering other parameters like track curvature, wagon weight etc. which is moderate in comparison with high pull requirements where 60 wagons need to be handled. Design of side arm suitable for this moderate pull (35 Ton) is the scope of present work.

Schematic of unloading operation at wagon tippler unloading station is explained in below figures 1 & 2 in elevation & plan respectively.

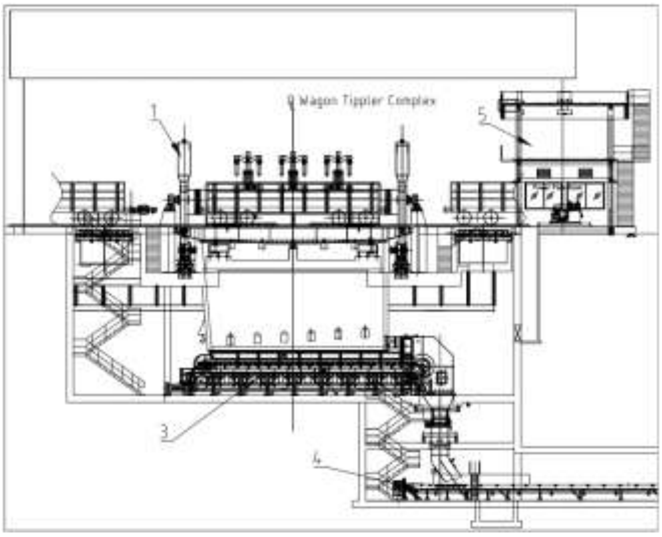

Figure 1: Wagon tippler complex Elevation

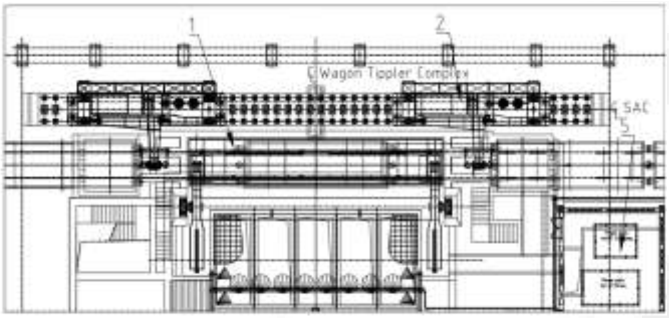

Figure 2: Wagon tippler complex Plan

Table 1: Item descriptions for Fig. 1, 2 & 3

Item No.	Item description
1	Wagon Tippler
2	Side Arm Charger
3	Apron Feeder
4	Conveyor
5	Control & Hydraulic Power Pack Room

1.1 Wagon tippler with Side arm charger Operation

Wagon tippler system is provided with arrangement to hold wagon in position by clamping wagon wheels at inhaul and outhaul side. Side arm charger is provided with front & rear coupler on side arm to couple wagons on both sides side arm. A rake of loaded wagons is pushed by locomotive on tippler track on inhaul side such that leading wagon of rake is placed at inhaul and clamps are applied on leading wagon wheels so it remains within reach of side arm charger inhaul travel stroke. Now locomotive is un-coupled from rake. The side arm charger, arm is lowered in front of leading wagon by hydraulic cylinder about 0.5 meters away from the leading wagon. Charger moves towards leading wagon, till charger front coupler engages with coupler of leading wagon automatically and stops in position.

Inhaul gripper clamps gets opened automatically with the help of hydraulic cylinder. The whole rake is pulled by Side Arm Charger up to predefined forward speed. During pulling of loaded rake in forward direction, Side arm rear coupler gets coupled with empty wagon standing on tippler platform previously emptied by tippler's last unloading cycle. Complete loaded wagon rake in coupled position with front coupler and single empty wagon travelled along with Side arm charger in forward direction. The whole rake is stopped by side arm charger after it travelled by one wagon length and second leading wagon gets positioned at Inhaul wheel gripper where it gets clamped.

The first leading wagon is decoupled manually from loaded wagon rake so it gets free from complete rake. After decoupling of loaded wagon from rake, the Side Arm Charger starts pulling one loaded wagon and moves further on tippler platform up to predefined forward speed. Side arm charger stops such that the loaded wagon is placed centrally on tippler table. After placement of loaded wagon at the center of the tippler platform, the side arm charger arm front coupler gets uncoupled automatically by hydraulic cylinder and loaded wagon is disconnected from Side arm. The side arm charger moves further pushing empty wagon and rake of previously emptied wagons, up to outhaul position to clear tippler platform. Holding arrangement provided at outhaul position does not allow wagons to roll back towards tippler platform. At this position side arm gets uncoupled from empty wagon & lifts the arm. Side arm charger in arm lifted condition travels backward towards inhaul side.

Loaded wagon placed on tippler platform will be gripped by wheel gripper on platform & then the cylinders for side wall movement are extended till the side wall lightly touches the loaded wagon so that the wagon will be supported by side wall throughout the tippling operation. The hydraulic clamps start lowering to clamp wagon from top and holds it firmly on tippler table. Loaded wagon is tipped up to 155 degree, where material gets unloaded and the same is brought back to normal 0 degree position.

During this period of tipping, side arm charger has travelled back towards inhaul position and stops about 0.5 meters distance away from next leading wagon coupler. Here arm gets lowered to horizontal and travel further towards next leading wagon to engage and pull further for next cycle of operation. All sequence of operation of Wagon Tippler & Side arm charger except decoupling of loaded wagon from rest of the rake shall be automatic and controlled from wagon tippler control room in addition to local control station. Thus cycles are repeated and rake of wagons are unloaded.

2. Literature Review

[1] Yanjun Xiao et al. [1] (2013) Studied in order to design and optimize the trolly frame of stacker-reclaimer running mechanism, it is very convenient and efficient to take advantage of ANSYS, which can not only ensure security but also reduce time and cost. The stacker-reclaimer is a common continuous and efficient bulk materials stevedoring and transporting device in the world, running mechanism is located in bottom of the whole machine, which plays an important role of supporting the machine and the running

function of the machine. Therefore, the security and reliability of the running mechanism is very significant and critical in the safe operation of the whole machine. To guarantee stiffness and hardness of the steel structure, it is carried out that the static analysis of the key components the trolly frames by using finite element analysis software. Through careful analysis and research, it proves that the design of the components meets completely requirements of real conditions.

[2] Pandhare A. P et al. [1] (2014) Studied skid base frame which is a structural assembly consisting of beams of various cross sections and dimensions. The base frame is subjected to gravitational loading of all the components mounted viz. Compressor, Air Receiver vessel etc. The frame discussed in this report was designed with conventional CAD design practices and then analyzed statically with FEA software. The acceleration loads considered during analysis phase resembled the actual loading cases. The analysis was carried out to determine the induced stresses and the deflections at various locations on proposed frame. The structure was optimized to reduce weight. The static analysis is applied when the value of any load acting on frame does not change with time. Generally linear behaving materials are used for manufacturing of frames.

[3] Somanath Ojha et al [3] (2016), studied about methodology for monitoring the coal handling equipment by which failure rate can be minimized. Every organization need productivity and it is possible for several equipment working in good condition with man power itself for care and maintain. So, as to require various types of technology or sensors of automated testing rather than manual testing which has been summed up. This paper emphasizes the different types of technology and sensors are used for measuring the coal handling equipment in coal handling plant which increases their production rate and also Helpful for management people for smooth operation.

3. Problem Formulation

Side arm charger is used to position the wagon of 140T on the wagon tippler platform from inhaul position to get unloaded on wagon tippler. After unloading wagon, pushing single empty wagon and pulling 30-35 wagons of 140T towards wagon tippler platform.

Side arm chargers will be of suitable capacity to resist rolling resistance, frictional resistance, slope resistance and curvature resistance of the rail track. For above requirement, side arm to be designed for pulling force of 35 Ton.

4. Objective

The salient objectives of the present study have been identified as follows:

1) Design of the side arm of the two drive side arm charger equipment for 35 T pulling capacity with consideration of travel, live & dead loads.
2) Linear static analysis of the side arm of Side arm charger device by FEA.
3) Validation of the Analytical & FEA Results with actual site Results.

5. Scope

In the present study, an attempt is made to design & analyze side arm of the two hydraulic drive side arm chargers for the 35 T pulling capacity which is equivalent to handle 30-35 Wagons of the 140T.

6. Research Methodology

The methodology to be worked out to achieve the above-mentioned objectives is as follows:

1) Design

Calculations of the various loads on side arm of the two Hydraulic drive Side arm charger. Calculation of the Travel load and drive of the Two drive side arm charger.

2) Modelling

To prepare the side arm charger mainframe & side arm model the modelling software will be used.

3) FEA analysis

Modelling is continued with the Structural analysis using Analysis software's. In that the pre-processing is done using the material property, Load and Boundary condition. Using this software we get the **stress** and displacement results.

4) Comparative Results

We are validating the Analytical & FEM software based results with Analytical and actual site results

7. Data for side arm of side arm charger

Table 2: Specifications of Side arm charger equipment

S.No	Details	Quantity / Value
1	Capacity	To Pull 30-35 wagons of the 140T and To push 25-30 Empty wagons on straight and leveled track.
2	Objective	To index Wagons on the Wagon Tippler platform.
3	Side arm lever	3800 mm
4	Drive Arrangement	Rack & Pinion
5	Type of Drive	Hydraulic
6	Total Pull	35 T

8. Analytical method

8.1 IS Code 800 Approach

Side arm charger is plate structure which experiences various loading conditions. Side arm charger is similar as Crane structure which is travelling To & Fro for placing wagon on WT platform. Side arm charger is travelling along the rails by means of the Runner wheels. A pulling load is acting at the tip of arm which is equivalent to load acting on cantilever beam. A criterion for the allowable deflection of the cantilever beam for the manual loading as per the IS 800 Part-1 is SPAN/120.

Distance between point of force application & point where arm is fixed to structure i.e. mainframe = 3025 mm.

Allowable Deflection for the SAC arm = SPAN / 120 mm.
Allowable Deflection of the SAC arm as per IS 800 Part -1 = 3025 / 120
L = 25.20 mm.

Deflection of the Side arm shall not exceed 25.20 mm.
Allowable Stresses = 166.66 N/mm^2
(With factor of safety of 1.5 on Yield Strength of $250N/mm^2$)

8.2 Analytical Calculations:

Stress & Deflection of the SAC arm will be calculated by considering side arm as cantilever beam fixed to SAC mainframe structure.

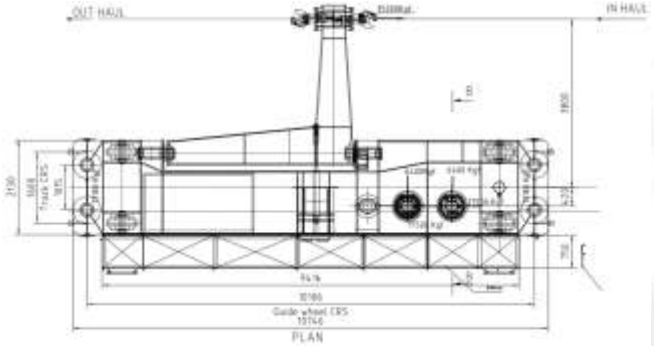

Figure 3: Load diagram of the Side arm charger

The above diagram illustrates the force acting at the tip of side arm, i.e. approx. F=350 kN

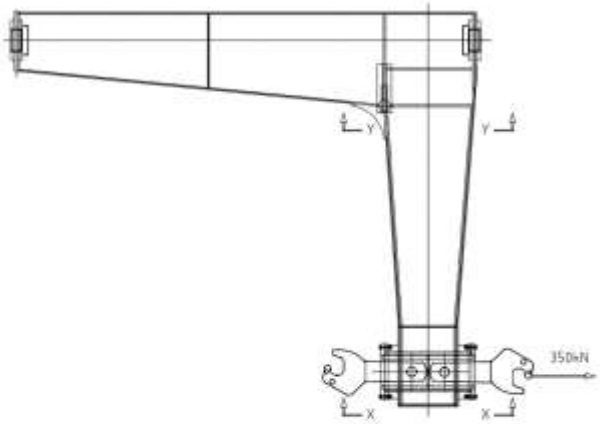

Figure 4: SAC Arm with forces & sections marked

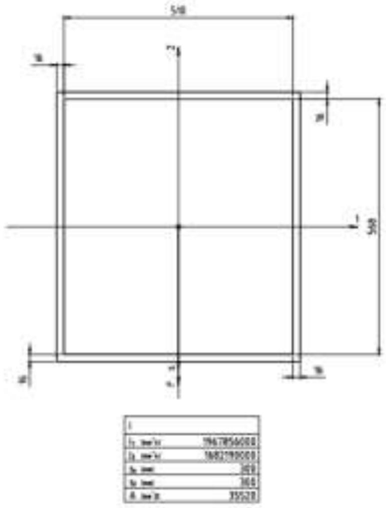

Figure 5: Moment of Inertia at Section X-X

Maximum deflection will be at Section X-X tip of arm.
Moment of Inertia $I_1 = 1682190000\ mm^4$

Deflection formula for cantilever beam = (W*L^3)/(3*E*I)
Maximum deflection at tip of arm = **12.67 mm**

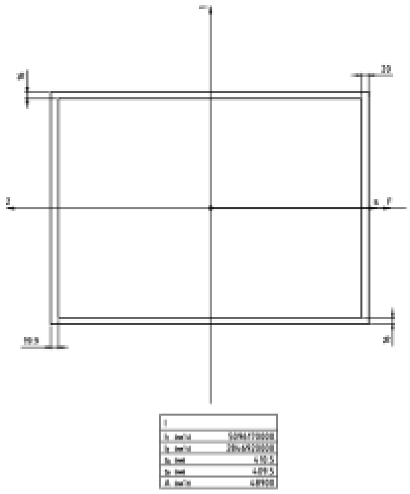

Figure 6: Moment of Inertia at Section Y-Y

Maximum stress will be at section Y-Y.
Stress formula as $\sigma_m = My / I_1$
Moment of Inertia $I_1 = 2846920000mm^4$
Maximum bending moment My = 11.725 x 10^8 N.mm
Maximum stress = **123.55 N/mm^2**

9. FEA modelling of side arm charger

A general-purpose commercial finite element code, Nastran is applied to conduct the static simulations and analysis. The FEA model of Side arm charger in this study is constructed based on the geometry. A 3-D solid model is constructed for the static analysis. The schematic of an FEA model used in static analysis is shown in figure.

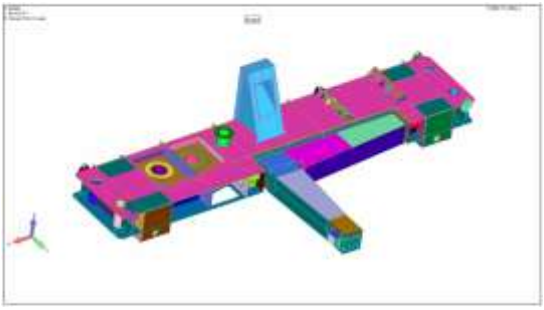

Figure 7: 3D Model of the Side arm charger Equipment

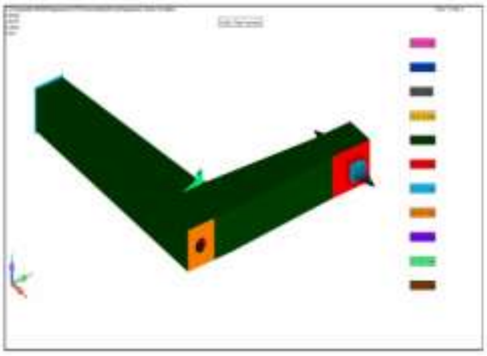

Figure 8: 3D Model of the Side arm

10. Meshing of the side arm of SAC

The 3D cad model in IGES file format is imported in FEMAP for the preparation of FE model. Cleanup and defeature to modify the geometry data and prepare it for meshing operation. This process involves deletion of curvature of very small radius. Mixed type of elements which contains quadrilateral as well as triangular elements, have been used in analysis. SHELL63 has both bending and membrane capabilities. Both in-plane and normal loads are permitted. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes.
The sensitive regions have been re-meshed by manually considering the shape and size of the parts. Quality check of all the elements has been performed and mesh is accordingly optimized.

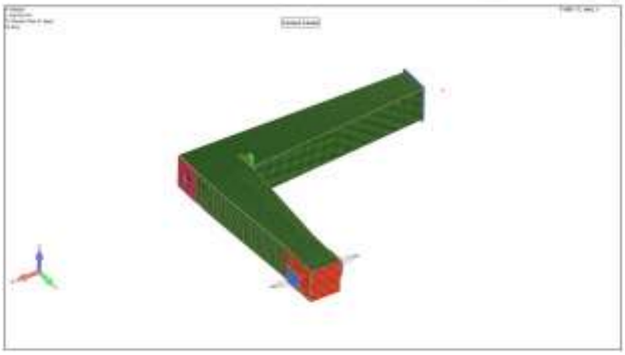

Figure 9: Meshed Model of the Side arm

11. Loading & Boundary conditions

1) Force due to pulling at side arm = 350 KN
2) Side arm coupling distance form Side arm bearing = 3350 mm
3) Self-weight = 3500 kg = 35 kN

A. Displacement Plot
Maximum deflection for the side arm charger arm resulted by the FEA analysis is 17.59 mm which occurs at the tip of arm when pulling load is in Negative X direction & the same is 13.36 mm when pulling load is in Positive X direction.

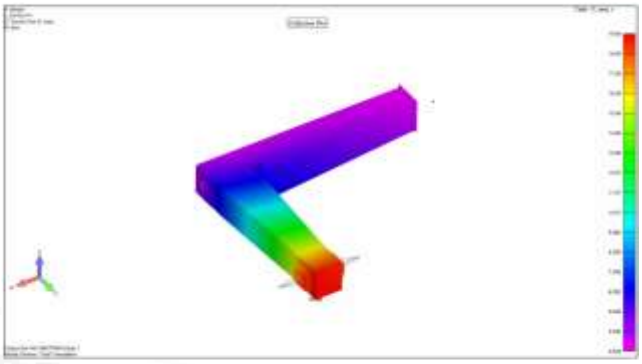

Figure 10: Displacement plot of side arm

B. Stress Plots
Nastran solver solves the FEA problem after the meshing completion. Stress values for the SAC arm & mainframe considering Side arm pull load of 35 Ton were up to 131.4 N/mm^2 for both directions of pulling load in positive & negative X direction.

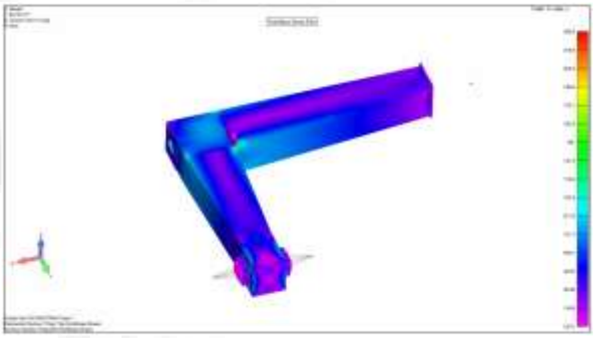

Figure 11: Stress plot of side arm

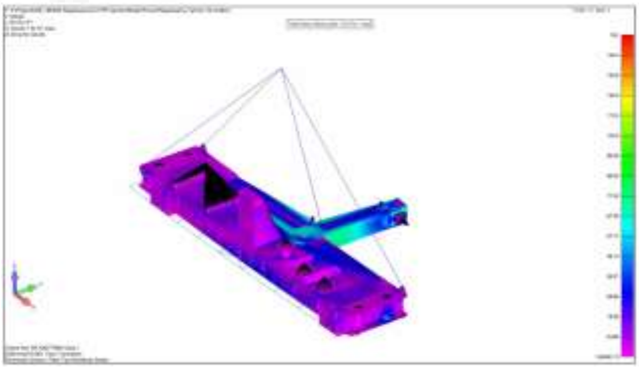

Figure 12: Stress plot of side arm along with mainframe

12. Experimentation

Actual site erection of the side arm along with other equipments of side arm charger equipment is done at site.

The deflection at arm tip is measured at site by fixing channel on main frame & extending it up to arm tip. Marker was attached at tip of channel to trace deflection plot on paper fixed to arm.

Following Photos of the Erection & experimentation of the Side arm charger equipment.

Figure 13: Erection of the Side arm charger

Figure 14: Side arm charger with drive & Hydraulic power pack Assembly

Figure 15: Side arm charger in operation at site

13. The Results & Discussion

1. Deflection & stresses in the side arm of the side arm charger are less than the allowable limits.

Deflection:
Allowable deflection as per IS800 (span / 120) = 25.20 mm.
Analytical

Stress:
Allowable Stresses = 166.66 N/mm^2
(With factor of safety of 1.5 on Yield Strength of 250N/mm^2)

Sr.No.	Details	IS 800 /2062	Analytical Approach	FEA	Expt.
1	Deflection (mm)	25.20	12.67	17.59/13.36	~ 15
2.	Stress (N/mm^2)	166.6	123.55	131.4	NA

2. FEA successfully operated for given loading condition.

14. Conclusion

As per Bureau of Indian Standard yield point for IS-2062 is250MPa, hence as the maximum stress range is 131.4 MPa was observed considering self-weight and external loads. Thus the complete structure is within the safe limit

15. Future Scope

The side arm chargers can be designed for 60 Ton pull or even more. Additionally side arm chargers with various pulling requirement & having more eccentricity can be part of future scope.

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