Design and Development of Forklift Attachment to Improve Mechanical Advantage

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***Abstract*— This project deals with design and development of forklift attachment. Attachment is designed to increase the mechanical advantage of forklift. Task is to lift and transfer heavy sheet metal coils, which can be handled by cranes or high capacity forklifts. But cranes cannot go in the warehouses and existing forklift is of 8 ton capacity therefore buying a new forklift for this operation is costly. Therefore attachment is designed which works on the moment or lever principle, so that we can able to increase mechanical advantage by adjusting length of the arms. This whole structure will be tested for its workability by studying the forces acting on the linkages. The complete attachment will get attached to the forklift of 8 ton capacity. And due to the dead weight of 8 ton and moment principle it will be able to lift a sheet metal coil of around 16ton. Methodology adopted is to find the suitable cross section for the arm which is the most critical component of the attachment. After analyzing the attachment in FEA and Adams, a prototype will be manufactured and this will be tested for its capacity.**

Keywords: Mechanical Advantage, forklift, sheet metal coil, etc.

I. INTRODUCTION

The topic deals in two areas, Material Handling systems and Improvement in an existing product. The project is about design and development of an attachment which will be an extension to the existing forklift and due to this attachment forklift be able to lift the load which is of double the capacity of the same forklift. Arm of the attachment will work on lever principle. In this way we will be able to increase the mechanical advantage of the forklift. Some basic definitions and principles that we are going to use are given below. Class I type of lever will be used for concept design of the attachment. Attachment will consist of dead weight, arm, fulcrum, dead axle and wheels. Dead weight will be attached to left side end of the arm, at fulcrum point axle will be mounted and wheels will also be mounted. Sheet metal coil will be carried out at the right side end of the arm. In this way assembly of the attachment will get complete, now dead weight will fixed in the forks and fork will be at the higher position of the forklift reach. Then driver will take forks below and due to pivot at the fulcrum point sheet metal coil will get lifted above the ground and in this way coil can be transferred from one place to another place.

The attachment that is previously designed is a new product development and this is also an improvement in the same new product. Therefore there are no research papers and patents available for reference. This literature review is based on the papers and patents which are related to the same area and finding some information which will be helpful in this project.

Shilpa D. Chumbhale and Prasad Mahajan have discussed about the failure and optimization of excavator arm. Failures of the excavator boom are due to bending stresses due to lifting frequently due to play in the pin joints dislocations occurs. Methodology used for analysis is first completing numerical calculations and validation of performed work with existing work. Analysis is performed using Ansys and then validation.

Amol Bhosale and his colleagues have worked on the optimization of the hydraulic excavator boom using FEA approach. While designing they have considered factors such as better design, maximum reliability but also minimum weight and cost. And analyzing the model in the FEA, optimization is performed by changing the thickness of the material. Calculated von mises stresses and reactions are checked for the factor of safety taken during designing.

John B. Ulm has patent on the Detachable Boom for Industrial Trucks, relative to elevator type industrial trucks which are used in plant yards. Invention is used to increase the efficiency of the truck by providing an overhanging boom to hang the goods. And it is kept detachable if not in use.

Jeffrey L. Addleman has patent on Forklift Variable Reach Mechanism. Main objective is to provide self-leveling low profile essentially self-contained forklift carriage unit. It gives the wide rotational range to the boom machine.

Billy G. Chandler has patent on Adjustable Forklift Adapter and Method. It includes a tiny portion extending generally horizontally forwardly from a proximal end. The leg portion includes an upper leg member and lower leg member which are slidingly engaged to one another such that the leg portion is extensible. Also provided is a means for locking the upper leg member to the lower leg member into a selected position With respect to one another. A hydraulic implement may

therefore be adapted to lift paleted and other loads by hanging two such forklift adapters over the implement.

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II. ANALYTICAL DESIGN:

A. *Deciding variables and FBD*

There are some tangible and intangible which are important while calculating the forces and the stresses which are given below.

- Intangible Variables –
  1. Forklift Capacity = 8000 kg
  2. Load to be lifted = 16000 kg
  3. Distance between left side end of the arm to the pivot point = 5000 mm
  4. Distance between left side end of the arm to the pivot point = 2500 mm
  5. Configuration, shape, size and dimensions of the dead weight.
  6. Sheet metal coil dimensions
  7. Wheel specifications

- Tangible variables –
  1. Vertical movement of the dead weight when it is attached to the forklift:
     This distance will change between 0 to 300 mm ranges. Because when dead will be attached to the forklift and the arm and arm will move inside the sheet metal coil then driver will take forks below 300 mm to lift the coil above the ground.

According to these parameters free body diagram is prepared as shown in figure 1.

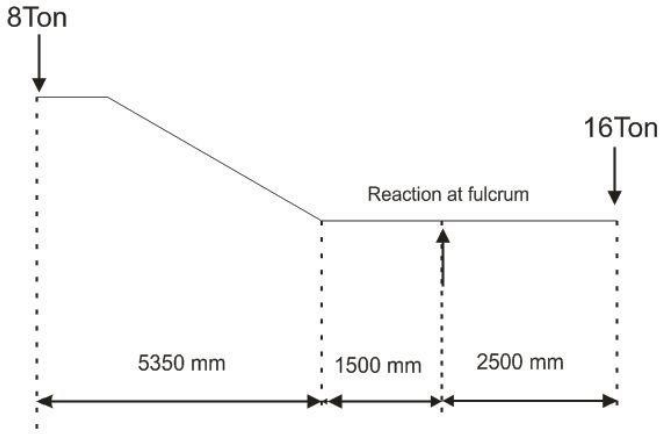

Figure 1: Free Body Diagram of arm

From this FBD, maximum bending moment which is coming at the fulcrum point is calculated. And bending stress for the arm is calculated considering standard cross sections of Square hollow, Rectangular hollow and I sections.

B. *Calculation bending stresses and factor of safety for different cross sections*

Stresses are calculated for no of cross sections from which some cross sections are selected which are given below in Table 1, 2 and 3. Material selected for the arm is a structural steel having yield tensile strength of 355 MPa. According to that factor of safety is calculated.

Length	Height	Thickness	FOS
300	300	16	1.42
350	350	12.5	1.59

Table 1: Selected square hollow cross sections

Length	Height	Thickness	FOS
400	300	12.5	1.45
400	300	16	1.79

Table 2: Selected rectangular hollow cross sections

Section Height	Flange width	Flange thickness	FOS
460	191	16	1.38
528	209	13.2	1.54
533	209	15.6	1.77

Table 3: Selected I sections

C. *Cad Modeling*

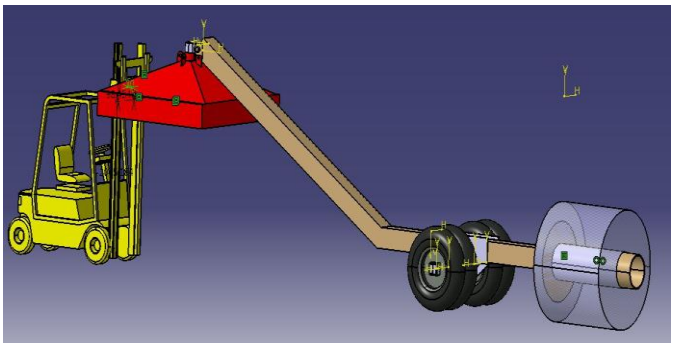

Figure 2: CAD Model of the complete system

As shown in figure 2, red part is the dead weight, silver part is the sheet-metal coil which to be lifted and peach color part is arm.

III. NUMERICAL ANALYSIS:

Arm is the most critical component of the complete attachment therefore numerical analysis is performed for the above selected cross sections in a following way. By taking the example of 1st selected square hollow section (300*300*16 mm) for the numerical analysis procedure is explained because same process is followed for other cross sections.

1. Firstly specifying all the material properties modeling of the arm is completed as shown in figure 3.

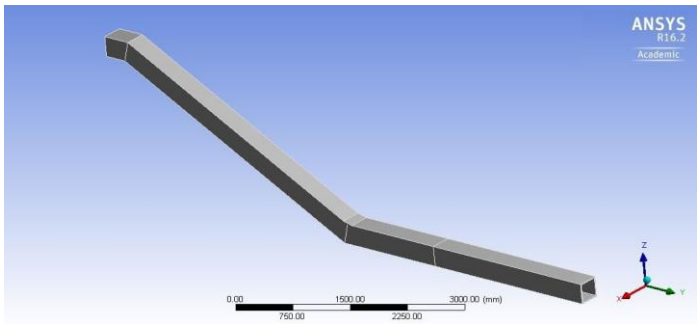

Figure 3. FEA modeling of the arm

2. Then the meshing is performed and boundary conditions are applied as we have given in FBD. Boundary conditions are shown in figure 4.

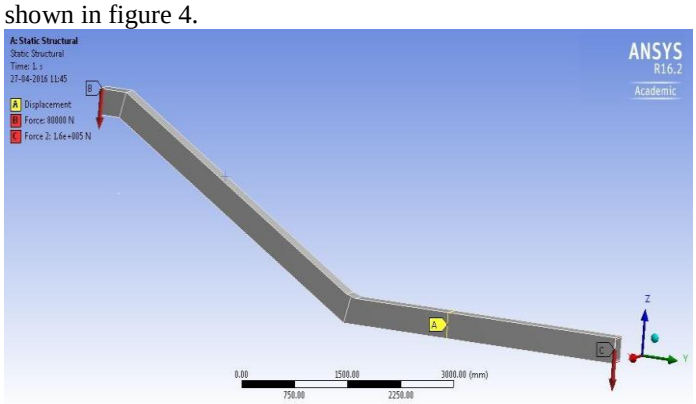

Figure 4: Boundary conditions applied to the arm

3. Maximum stress or the equivalent von mises stress is calculated for the arm by simple structural analysis. Maximum stress coming out is around 429 MPa as shown in figure 5.

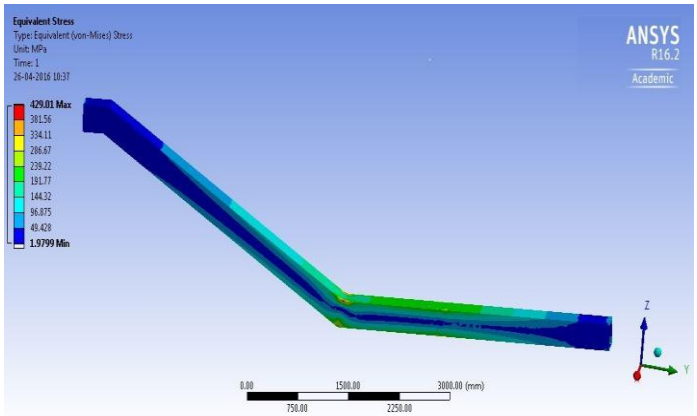

Figure 5: Maximum stress or the equivalent von mises stresses

As we can see maximum stress is coming at the angular area due to sharp edges therefore stress is concentrated at that area.

4. To reduce this stress concentration a triangular rib is provided at the angle given to the arm therefore stress is properly distributed over that surface and reduced maximum stress can be observed as shown in figure 6.

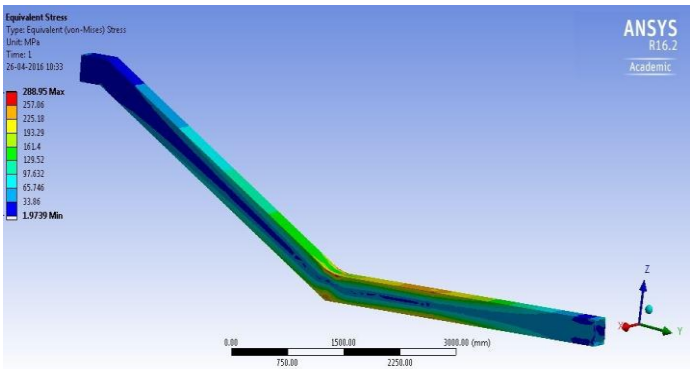

Figure 6: Max stress after adding a triangular rib

As we can see in figure, max stress is reduced to 288 MPa which well below the allowable stress limit.

5. We are interested in the stress coming at the fulcrum point because maximum bending moment is coming at that position. Therefore stresses at this point are calculated as shown in figure 7. Maximum stress coming at that point is 238 MPa

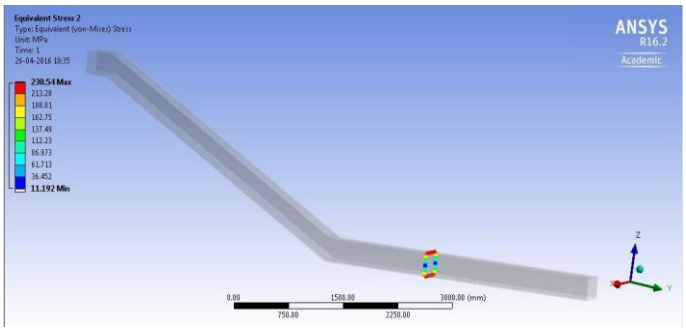

Figure 7: Stresses at the fulcrum point.

IV. MULTIBODY DYNAMIC ANALYSIS

Multibody dynamic analysis is performed in ADAMS/View Software. In this analysis all bodies including forklift are considerd for analysis as a one model. Actual weight, forces, movemets are given to respective bodies. And real time force and stress analysis is observed. From this analysis, variation of foreces and stresses can be observed during whole movement. Modelling of whole project in ADAMS/view is shown in figure 8.

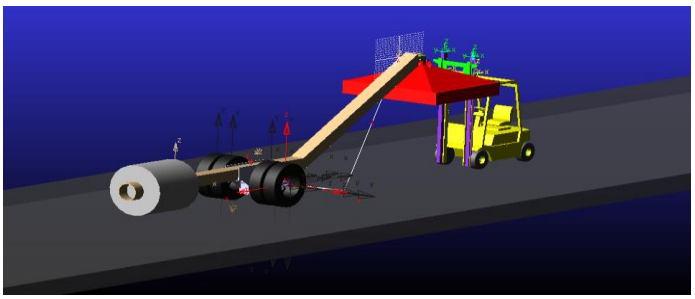

Figure 8: Modeling in ADAMS/view for dynamic analysis

As shown in figure, lower horizontal surface/box is considered as a ground and movement is given to the model so that it can travel on ground and while this movement, variation of forces can be observed. Silver color part is a sheet metal coil which is going to be lifted by forklift using designed attachment.

Forced generated at the fulcrum point and its variation with respect to time is shown in following figure 9. It shows force coming at the fulcrum point and on left side contact forces coming on the wheels can be observed. Dynamically force coming on the fulcrum point will vary between 250 to 256.5 MPa.

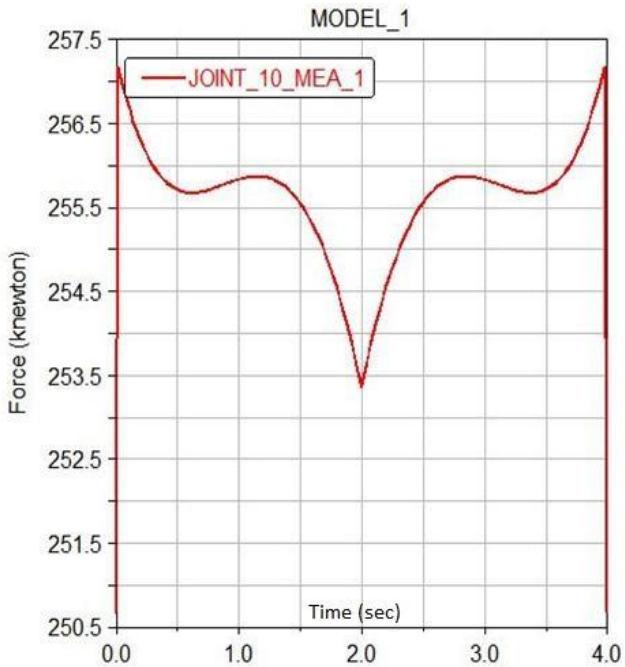

Figure 9: variation of the force generating at the fulcrum point

V. RESULTS:

Analytical and numerical analysis is performed for the most critical section that is Arm. Stresses are calculated at fulcrum point where the maximum bending moment is acting and the results from the analytical and numerical calculation are compared below.

1. For Square Hollow Cross sections

1.1 Comparison between stresses at fulcrum point

Length (in mm)	Height (in mm)	Thickness (in mm)	Analytical σ_b (Mpa)	FEA Results σ_b (Mpa)	FOS
300	300	16	249.7	238.5	1.49
350	350	12.5	222.62	222.07	1.59

1.2 Comparison between maximum stress on the arm without stress distribution and with stress distribution

Length (in mm)	Height (in mm)	Thickness (in mm)	Maximum stress on the arm	
			Without modification σ_{max} (MPa)	With addition of rib σ_{max} (MPa)
300	300	16	429.0	288.95
350	350	12.5	416.07	334.54

2 For Rectangular Hollow Cross sections

2.1 Comparison between stresses at fulcrum point

Length (in mm)	Height (in mm)	Thickness (in mm)	Analytical σ_b (Mpa)	FEA Results σ_b (Mpa)	FOS
400	300	12.5	244.7	253.1	1.45
400	300	16	197.77	200.71	1.79

2.2 Comparison between maximum stress on the arm without stress distribution and with stress distribution

Length (in mm)	Height (in mm)	Thickness (in mm)	Maximum stress on the arm	
			Without modification σ_{max} (MPa)	With addition of rib σ_{max} (MPa)
400	300	12.5	540.8	362.39
400	300	16	437.33	269.86

3 For I Cross sections

3.1 Comparison between stresses at fulcrum point

Section height (in mm)	Flange width (in mm)	Flange thickness (in mm)	Analytical σ_b (Mpa)	FEA Results σ_b (Mpa)	FOS
460	191	16	256.42	277	1.38
528	209	13.2	230.49	231.2	1.54
533	209	15.6	199.77	200.5	1.77

3.2 Comparison between maximum stress on the arm without stress distribution and with stress distribution

Section height (in mm)	Flange width (in mm)	Flange thickness (in mm)	Maximum stress on the arm	
			Without modification σ_{max} (MPa)	With addition of rib σ_{max} (MPa)
460	191	16	633.11	380.37
528	209	13.2	399.72	326.51
533	209	15.6	394.14	313.41

VI. CONCLUSION:

As the main objective is to increase the mechanical advantage of the system, the designed attachment can be used in conjunction with 8 ton capacity forklift to lift and transfer a load of 16 ton. Therefore mechanical advantage has increased to 2.

This attachment is a great advantage to the MSME companies because for the same operation industry requires to hire a 20-25 ton capacity crane for which they have to pay a rent of around 25000 rupees for a day. And the requirement of the crane will be twice a month approximately but by manufacturing this attachment in house, there is no requirement of hiring a crane and this cost can easily be saved.

The same attachment can be parameterized that means we can design the same attachment for the forklifts of different capacity by scaling the dimensions. For example in this problem I have designed for 8 ton capacity forklift and so this forklift can lift upto 16 tons. We can also design for 3 ton capacity forklift and it will lift upto 6 tons and so on.

As we can see from the result tables all the selected square and rectangular cross sections can be used for manufacturing according to safety factor, while the shape and dimensions of the I sections are quite difficult to use for the arm considering other attachments to be fitted on the arm and also from the manufacturing point of view. From square and rectangular cross sections according to availability of the material 300*300*16 square hollow cross section is selected.

ACKNOWLEDGMENT

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