Design Modification and Optimization of Trolley in an Off-Bearer Mechanism Present In Concrete Block Making Machines

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Abstract - *The trolley is a component of any Column mounted jib crane that supports the load of the fork and the hoisted weight and also the hoisting motors and gear drives. The trolley being suspended on the cantilever boom is subjected to various loads such as the static load of fork and hoisted components. The inertial load is also taken into consideration since the trolley is subjected to movement in the direction along the cantilever boom. Since the drives used for vertical traverse of the fork produced a lot of torque, the equivalent load is taken into account.*

Key Words: **Trolley, Jib, Boom, Cantilever, Fork.**

1. INTRODUCTION

The design and analysis of various components is discussed so as to compare and contrast the stresses in the older model and the modified design. The weight of the older component and new component is also compared. Lower the weight of the component, higher is the ease of operation and the material and cost of production. The various loads acting on the component are thoroughly analyzed and the final conclusion of design and reduction in horizontal span of the trolley is formulated. The static structural analytical solution obtained is validated by mesh convergence technique for grid independency.

1.1 Problem definition and solution

The older model being very heavier is not easily operable and unbalanced. The center of mass of the whole system is to the right of the point of suspension of the trolley when viewed from the front. This scenario can be eradicated by perfectly bringing the center of mass of the whole system in line with the point of suspension of the trolley as well as to the center of mass of the load such that the system remains balanced even in the unloaded condition.

A circular section is provided is used to mount the handles and control box. Taking into consideration, the fouling conditions the circular section is made off-set towards the square section resulting in the shift of center of mass of the system to a desirable position. The counterbalance is provided by the weight of the motor and trolley. Since the weight of the section is moved closer, the horizontal span of the trolley can be reduced.

2. DESIGN MODIFICATION

The complete design of the trolley is modified, making necessary changes in some parameters to make it both economically feasible and improve productivity. The calculations and line diagrams for both the older and the optimized design are shown below.

2.1 Cross Section Area of Trolley

Bending moment about the vertical section of the trolley
$M = Px600 + W_Tx253 = 1634090$ N-m(where P is the payload 2500N and W_T is the weight of the trolley which is equal to 530N).

For Older section

Cross section area of the trolley = 900mm²
$I = (50^4 – 40^4)/12 = 307500$ mm⁴ (Moment of Inertia about the centroidal axis).
y = 25mm (deflection from the outer fiber to the centroid of cross section)
Equivalent stress = Direct Stress + Bending stress
$=2500/900 + (1634090x25)/307500 = 135.63$ Megapascals.

For Optimized section

Cross section area of the trolley = 1100mm²
$I = (60^4 – 50^4)/12 = 559166.67$ mm⁴.
Equivalent stress = Direct stress + bending stress
$= 2500/1100 + 1634090/559166.67 = 89.943$ Megapascals.
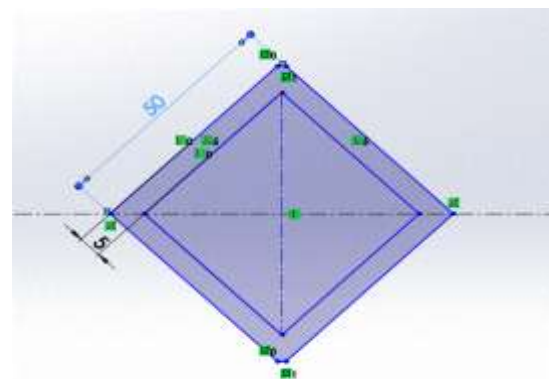y= 30mm (deflection from the outer fiber to the centroid of cross section).

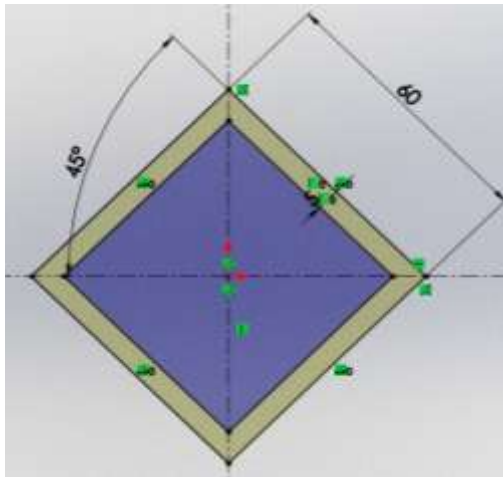Fig 1. Cross Section of the old trolley

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Fig 2. Cross Section of the new trolley

The Newer design has a comparatively lesser and better cross section area to minimize the material usage and save material cost to a good extent. The total bending moment and the thickness remains constant, whereas the Total Equivalent Stress accumulated is reduced from 135 Megapascals to 85 Megapascals.

2.2 Span Reduction

The new trolley design has a reduced span which in turn improves the machinability. Old trolley had a span length of 3032 mm which is not needed for the new design, as the total weight of the combined system (fork, trolley, motor and gearbox) is reduced. As the total weight is reduced, the counterweights can be placed at a very nearer distance thereby reducing the total span to 1815mm.
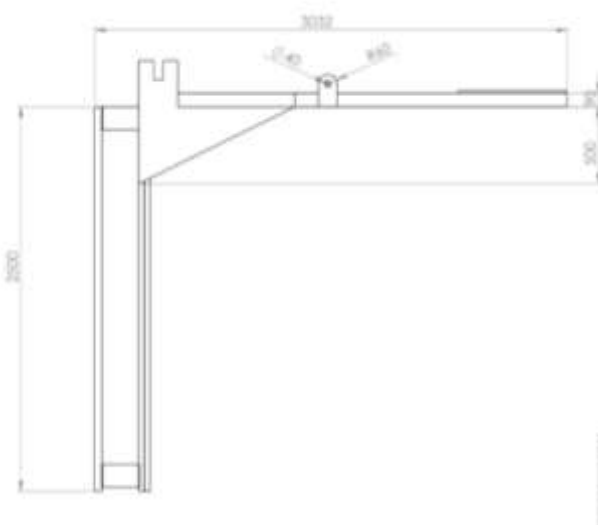
Fig 3. Front View of the older trolley
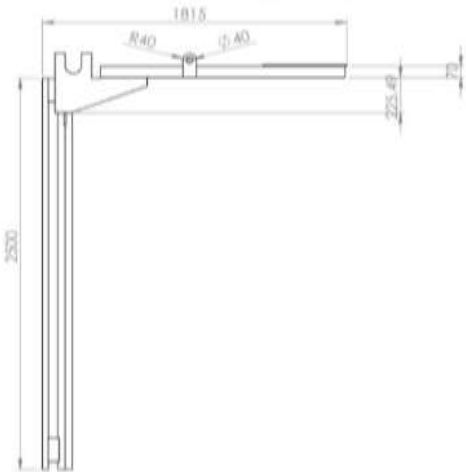
Fig 4. Front view of the optimized trolley

2.3 Center of Mass

It is mandatory for the combined system of trolley, fork and the drive system (motor and gear box) to be in a balanced condition so as to ease the operation of hoisting. This condition can be achieved only if the centroid of the system with payload and the centroid of the system without payload is same. If the centroid is in line with the center of the fork's extended portion. Since the geometric model is complex, solid modelling package is used to determine the center of mass of the system as follows.

The weight of the motor and Gear box = 47 Kg.,
Weight of the fork = 53 Kg.
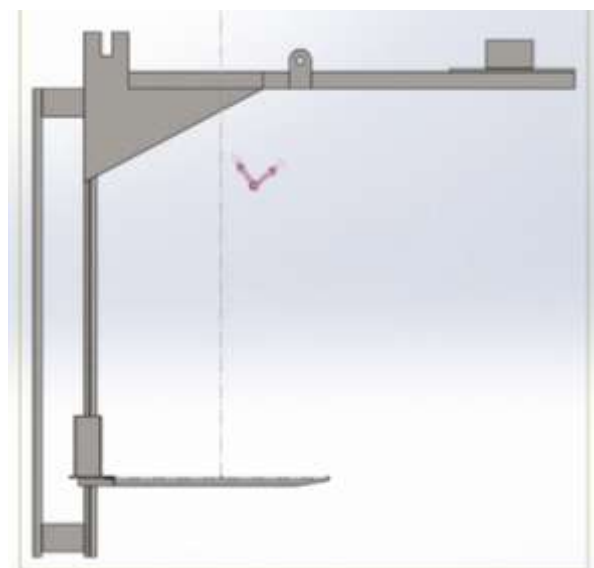Weight of the old trolley = 179 Kg.
Weight of the new trolley = 78 kg.

Fig 5. Center of Mass for the older trolley

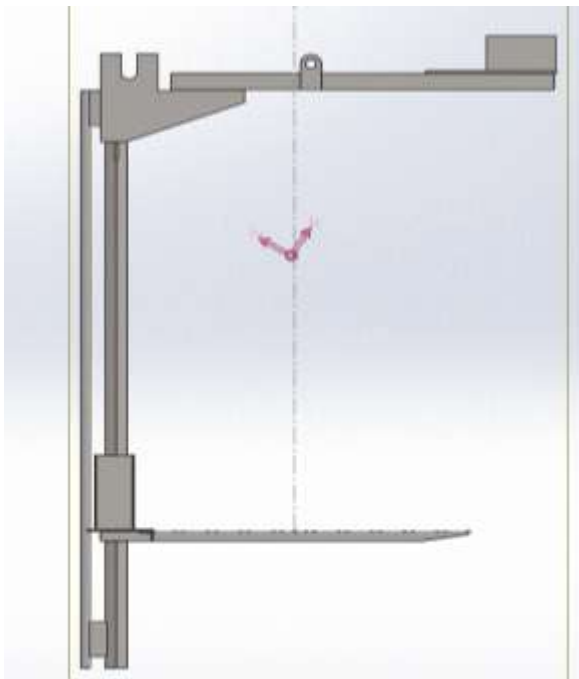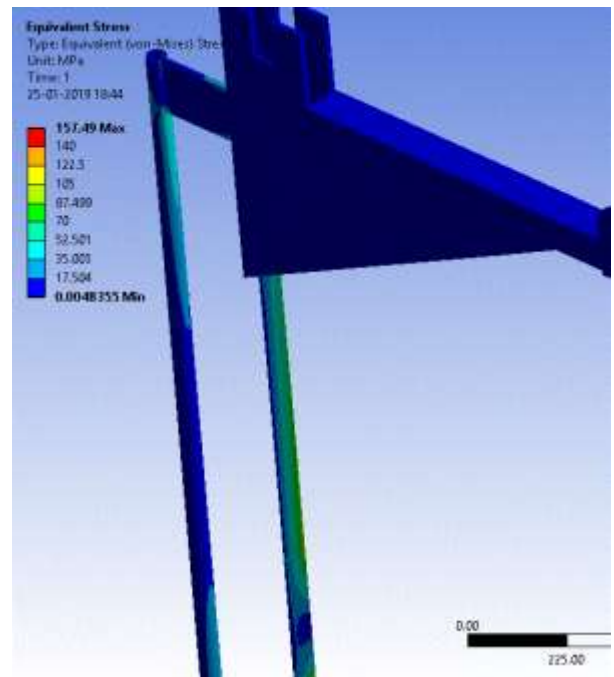Fig 6. Center of mass for the optimized trolley

3. STATIC STRUCTURAL ANALYSIS

- Analysis type: **STATIC STRUCTURAL**
- Mesh function: Default mesh function
- Mesh type: Automatic mesh (by default tetragonal dominant)
- Mesh size: Element size method(local surface refinement)Single load step of Force 2500 N(payload) and 470 N (motor and gear box)
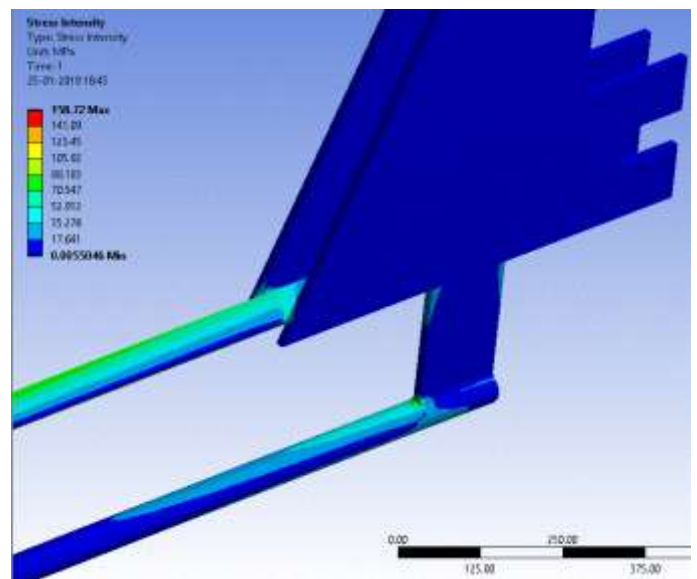- Boundary conditions: Fixed support at hoisting surface

Fig 7. Total Deformation of the older trolley when analyzed

Fig 8. Equivalent Stress on the older trolley when analyzed

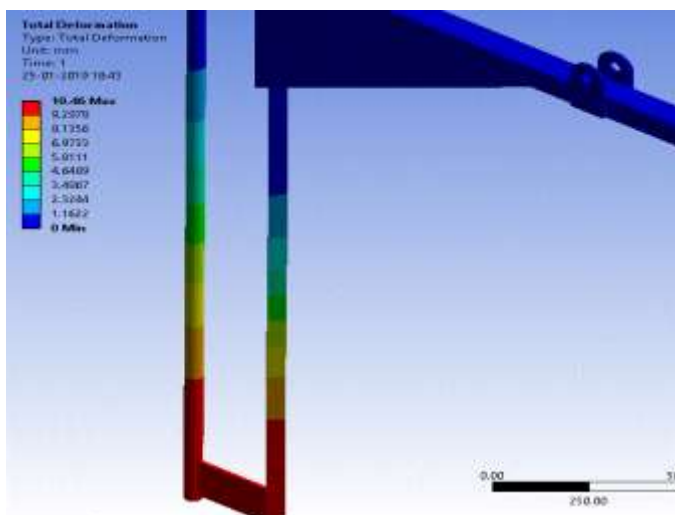Fig 9. Stress intensity on the older trolley when analyzed

The analysis of various stress parameters and deformation of the older trolley design and the optimized design was noted. There is a significant reduction in the stress values after the design modifications are done.
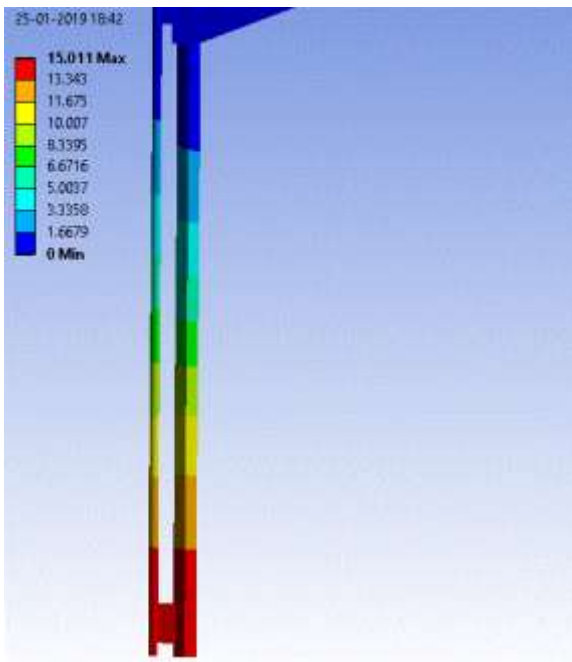
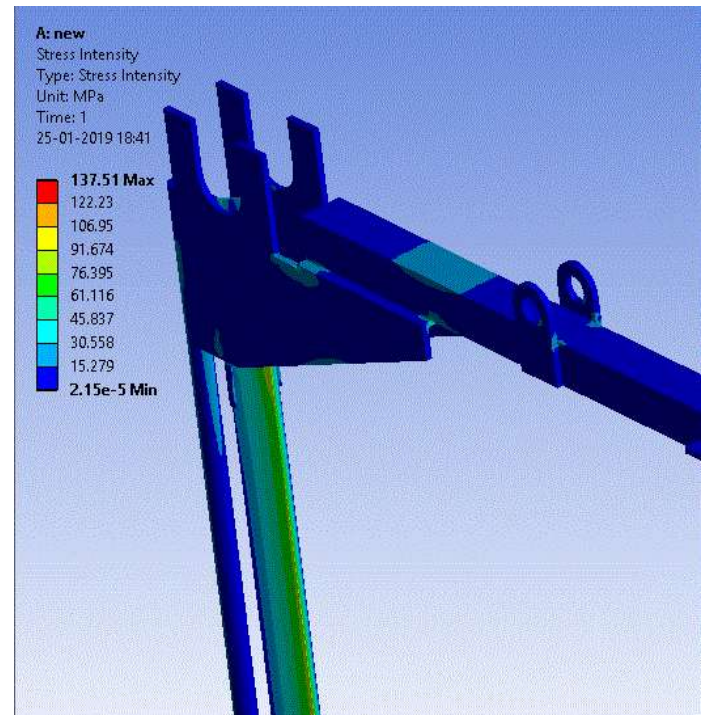Fig 10. Total Deformation of the optimized trolley

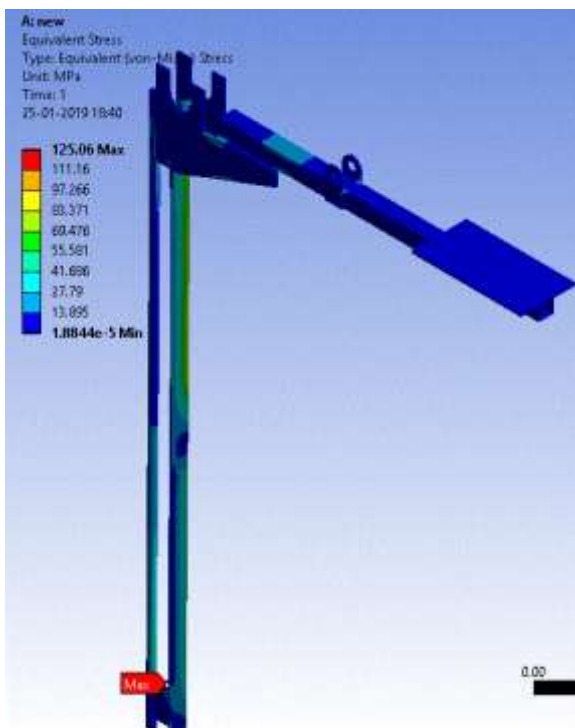Fig 12. Stress Intensity on the optimized trolley

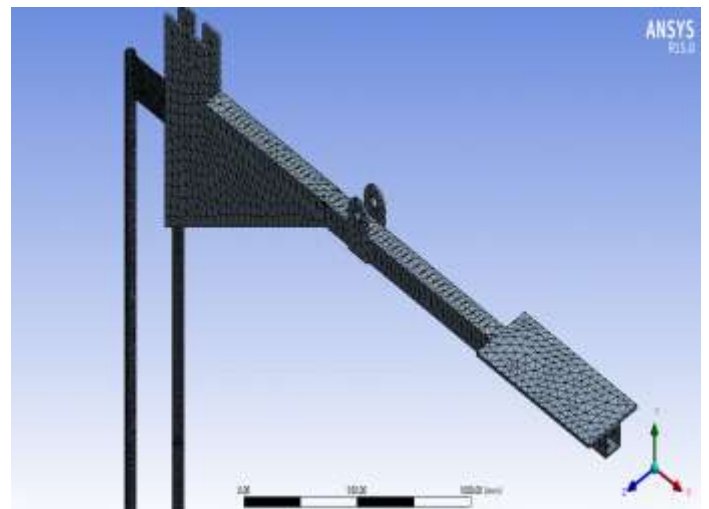Fig 11. Equivalent stress on the optimized trolley

Fig 13. Mesh Model for the older trolley

Selective mesh patterns are used in the above model for required area of interest which is located towards the left of the trolley. It is because the combined loads of fork, motor, gearbox are present at the other side and stress concentrations are analyzed to make it more balanced in the newer design. As a result, a more flexible and an optimized trolley design with much better weight distribution is obtained.

3.1 Grid Independence Test

Scaling test or Grid Independence test is a smaller cell calculation test for finer meshes, and it converges to a point as the mesh becomes finer. It is generally observed that the accuracy increases as the elements converge to one point after which there are no significant changes between the solutions of elements. Hence the solution becomes Grid independent or element independent in nature. A Convergence Curve is usually obtained when a series of stress values vs mesh density is plotted. The results are shown below.
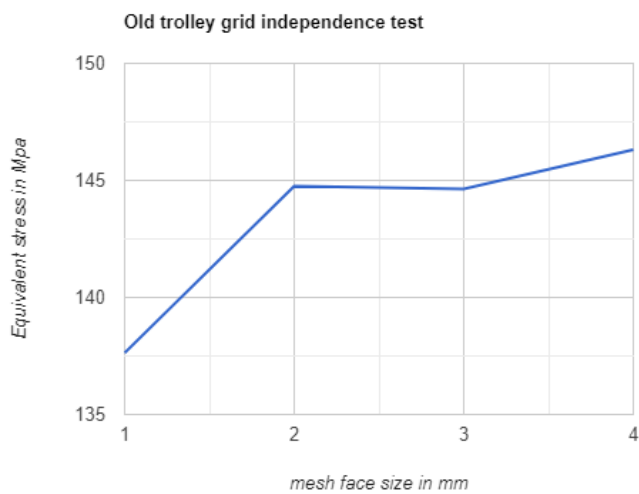

Fig 13. Convergence Curve for the older trolley
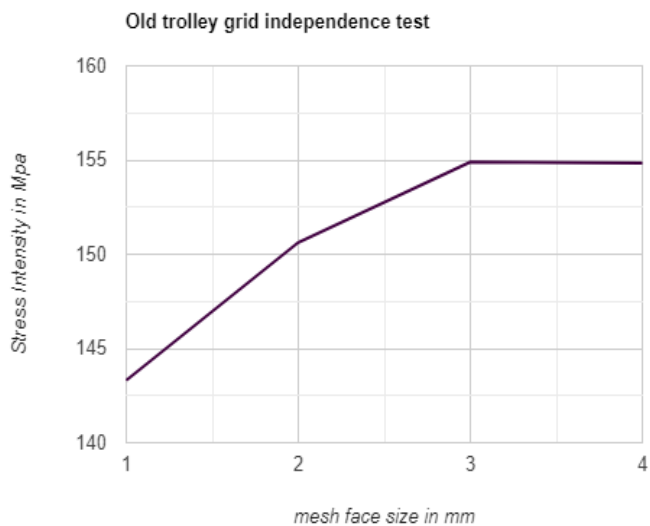(Equivalent stress Vs. Mesh Size)

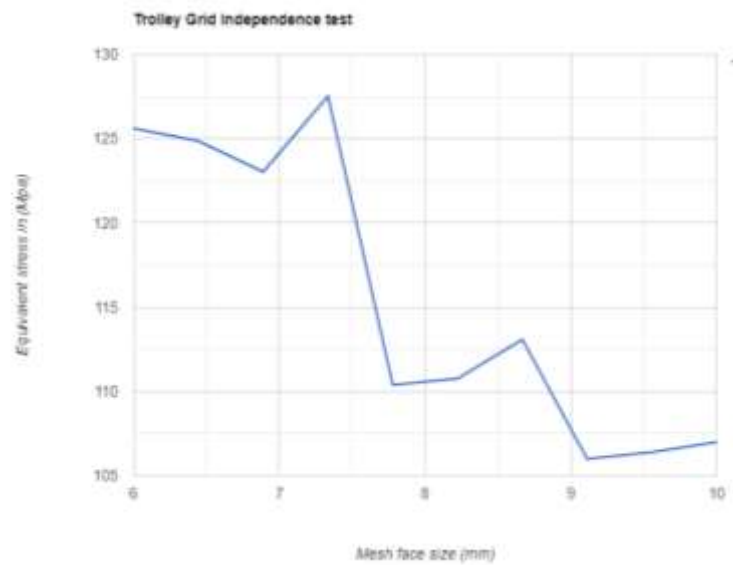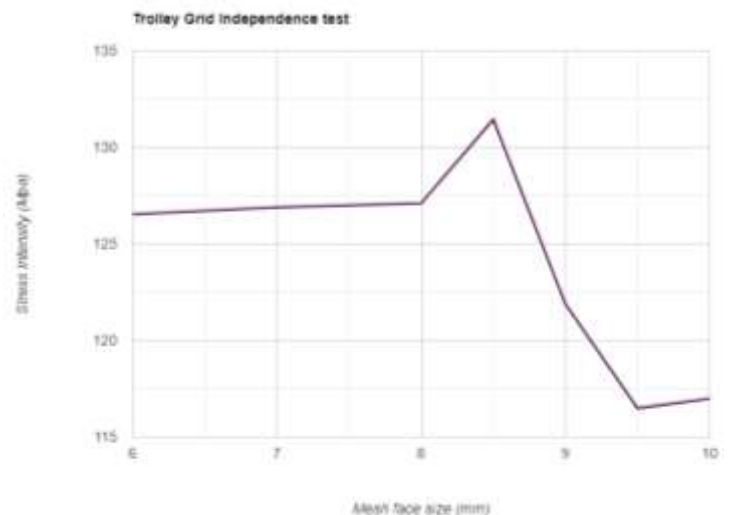Fig 14. Convergence Curve for the older trolley (Stress Intensity Vs. Mesh Size)

Fig 15. Convergence curve for the optimized trolley
(Equivalent stress Vs. Mesh Size)

Fig 16. Convergence Curve for the optimized trolley

(Stress Intensity Vs. Mesh Size)

Both the equivalent stress and the stress intensities vs mesh density plots have a fine convergence in the new design when compared to the older design and the maximum stress value is very much reduced (as much as 30Mpa). The total span length and weight is also optimized when compared to the older design making it more efficient and balanced with high commercial productivity.

It can be validated by the Jacobian ratio and element metric graphs supported by the convergence curves shown individually for both the old and new designs. The average Jacobian ratio for a surface mesh is always desired to be in the range of 1 to 1.4 in mesh statistics as ratios beyond that are said to be 'poor' elements according to ESA standards (Engineering Science and analysis). Generally, the ratio is obtained by the division of maximum determinant to the minimum determinant of the Jacobian. The new trolley design has the average very close to 1 (ie.1.06 to be precise)
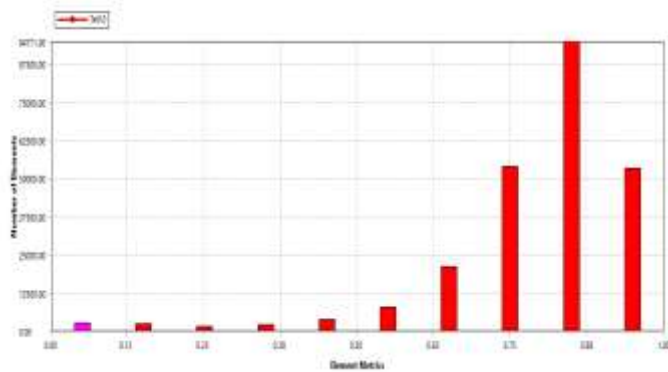

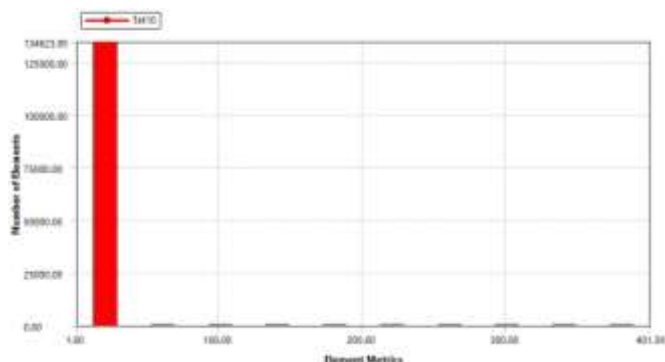Fig 17. Element Metrics of the old trolley

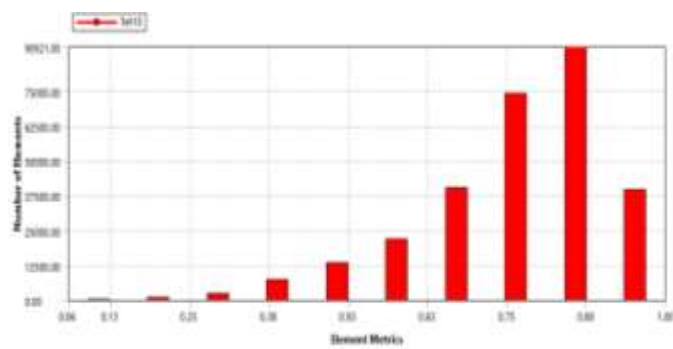Fig 18. Jacobian Ratio for the older trolley

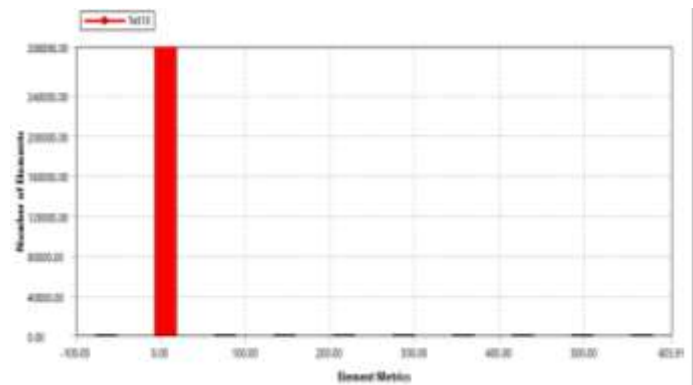Fig 19. Element metrics for the optimized trolley

Fig 20. Jacobian ratio for the Optimized trolley

One more important attribute to be noted is, refining the mesh repeatedly will not make it grid independent in any sense because there is a certain limit after which the properties or solutions do not change and the most finest details can be obtained at that stage itself. It is also observed that mesh convergence changes for different mesh face sizes. It is because every mesh configuration represents a new physical system and discretization which makes it unique every time.
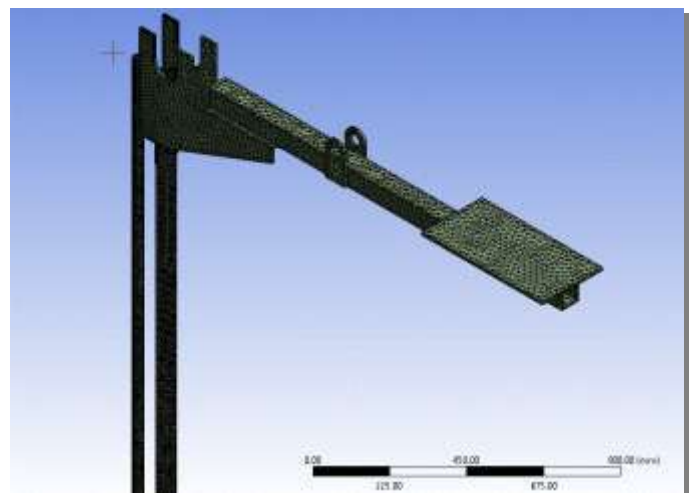

Fig 21 Mesh Model of the Optimized trolley

4. CONCLUSIONS

4.1 Result Evaluation

The results obtained from the theoretical and analytical solution makes it clear that the new proposed design is safer in all aspects when tested. The deflection and the equivalent stresses are compared for the old and new model of the trolley. The results comparison tabulated as follows

Parameters	Old trolley	New trolley
Equivalent stress (Megapascals)	146.49	124.86

Stress intensity (Megapascals)	154.01	126.90
Total Deformation (mm.)	10.46	15.11
Weight (Kg.)	179	77.64

The reduced stress values in the stress indicates the new design of the trolley produced is safe in operating conditions and the reduction in weight indicates the ease of operation and simplifies the manufacturing and erection of the system.

5. REFERENCES

1.) V.B Bhandari's "Textbook for Design of machine elements" – Third Edition

2.) K Suresh Bollimpelli, V Ravi Kumar's "Design and Analysis of Column Mounted JIB Crane"- INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING ISSN (ONLINE): 2321-3051 Vol.3 Issue.1, January 2015. Pages: 32-52

6. BIOGRAPHIES

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