iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** VII **Month of publication:** July 2020

DOI: https://doi.org/10.22214/ijraset.2020.30487

Design and Manufacturing of Staircase Climbing Trolley

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Abstract: Trolley is usually used for carrying heavy weights to reduce human efforts. The fabrication of the trolley deals with detailed design, suitable manufacturing with low cost and testing of design using any FEA software which gives appropriate results for the motion of the trolley with design load. This paper deals with the manufacturing of such stair climbing trolley with a simple mechanism (Tri-Star wheel arrangement) at first the model is created with Catia. Then its analysis is done with ANSYS software to find out the generated stresses and deformation due to load under the various condition and design load.
Keywords: staircase climbing, Tri-Star wheel.

I. INTRODUCTION

In everyday life, we see the transportation of load is very hectic work for laborers. There are no proper arrangements on the working areas like uneven surfaces for transporting a load. It is very hard to pull or push the load on an uneven surface especially on stairs. Due to such type of work the efficiency of workers decreases. So, we have to find out a solution for this problem.

The solution for such type of problem is the trolley with modification in wheel arrangement so that the trolley will easily climb up on stairs and also easily works on an uneven surface. Basically, this type of trolley is the extension of the general trolley that we use. Wheels are arranged in a triangular pattern on both ends so that the pulling force required for trolley becomes less.

This is the simple mechanism of the trolley which we can use in any working area like construction sites, hospitals, schools, colleges, workplaces and many more. This is trolley is purely mechanical no electric power is required to drive the trolley so it is easy to use. This trolley helps us to reduce the force.

II. DESIGN

A. Construction

1) Frame
2) Shaft
3) Wheels
4) Bearing
5) Tri-Star Arrangement

B. Working

This project consists of Tri-Star wheel arrangement which is mounted on the both end of shaft with the help of bearing. Bearing is used for hold shaft stationary and moving Tri-Star arrangement. M.S. body frame is mounted on shaft. Wheels are mounted in triangular pattern on the Tri-Star arrangement. This type of triangular arrangement of wheels are easily clime on staircase with less human effort. As we pull or push the trolley first wheel is stuck to stair and due to the triangular arrangement other wheels are rotate and climb on stair. This trolley is useful on not only stairs but also uneven surface and stairs.

C. Mechanical Design

In project the components are listed down and stored on the basis of their procurement in two categories.

1) Design parts
2) Parts to be purchased.

For designed parts detailed design is done and dimensions as per the requirement. This simplifies the assembly as well as the post production and maintenance work. The various tolerances on work are specified. Process charts are prepared and sent to manufacturing stage. The parts that are to be purchased are selected directly from various catalogues and are specified to have case of procurement. In mechanical design at first stage of selection of appropriate material for the parts to be designed for application of specific purpose. This selection is based on standard catalogues or data books;
e.g.: - (PSG's DESIGN DATA BOOK) (SKF's BEARING CATALOGUE) etc.

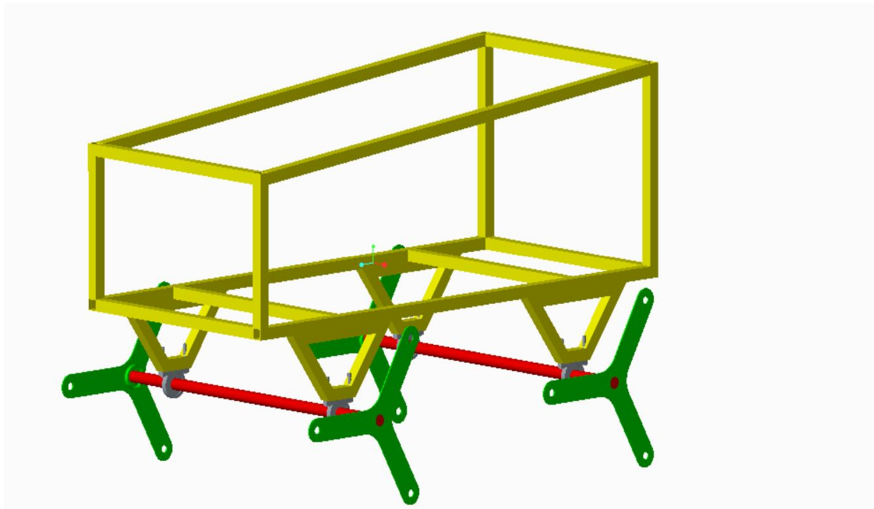

Fig.1 Cad model

Fig.2 Manufactured model

D. Part Design

Load = 200kg

Dimension of stairs

Rise = 150 mm

Run = 290 mm

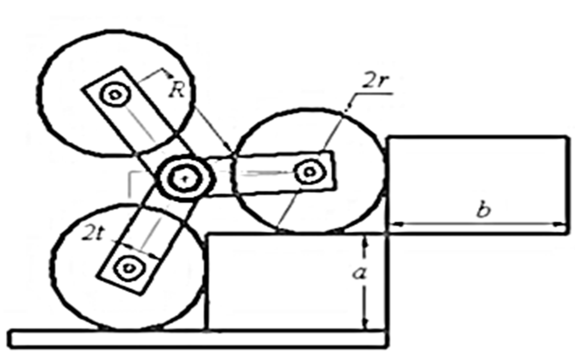

Fig 3 Dimension of stair

Design calculation for tri-wheel arrangement
Height of stair = a= 150 mm
Width of stair = b = 290 mm
Width of arm = t =25 mm

Distance between frame and center and wheel center

$R = \sqrt{\frac{a^2+b^2}{3}}$

$R=\sqrt{\frac{150^2+290^2}{3}}$

R= 188.50 mm

Minimum radius of wheel

$r_{min} = \frac{6Rt+a[3b-\sqrt{3}a]}{(3-\sqrt{3})a+(3+\sqrt{3})b}$

$r_{min} = \frac{6*188.5*25t+150[3(290)-\sqrt{3}(150)]}{(3-\sqrt{3})*150+(3+\sqrt{3})*290}$

r_{min} = 76.68 mm

Maximum radius of wheel

$r_{max} = \sqrt{\frac{a^2+b^2}{2}}$

$r_{max} = \sqrt{\frac{150^2+290^2}{2}}$

r_{max} = 163.24 mm

Mean radius

$r_m = (r_{max} + r_{min}) / 2$

r_m = (163.24 + 76.68) / 2

r_m = 119.96 mm ≅ 120 mm

Maximum height of stairs that can climb by wheels

$a_{max} = \sqrt{a^2 + b^2 - r^2}$

$a_{max} = \sqrt{150^2 + 290^2 - 120^2}$

a_{max} = 303.64 mm

Design of shaft
Load = 200kg
= 200*9.81
= 1962 N

Vertical forces

$R_A + R_B = 3924$

Summation of moment at point A

$(1962*120) + (1962*670) = 790*R_B$

R_B = 1962 N

R_A = 1962 N

Bending moment
At the end bending moment is 0
At point C

BM_C = 1962*120
= 235440 N/mm

BM_C = 1962*120

= 235440 N/mm

Maximum Bending Moment

BM_{max} = 235440 N/mm

Yield Tensile Strength = σ_{yt}= 350 N/mm^2

Factor of safety = 2

$\sigma_b\ permissible = \frac{\sigma_{yt}}{fos}$

$= \frac{350}{2}$

= 175 N/mm^2

$BM_{max} = \frac{\Pi}{32} * d^3 * \sigma_b$

$d^3 = (BM_{max} * 32) / (\pi * \sigma_b)$

$d^3 = (235440 * 32) / (\pi * 175)$

d = 23.93 mm ≅ 25 mm

Diameter of shaft is 25 mm

Bearing Selection

Radial Load (P) = 1962 N

Bearing Life

L_{10h} = 4000 hrs.

Speed = 25 rpm

$L_{10} = (60*n*L_{10h})/10^6$

$= (60*25*4000)/10^6$

= 6 million revolution

$C = P (L_{10})^{1/3}$

$= 1962 (6)^{1/3}$

C = 3565.19 N

From SKF's catalogue

Selected Bearing is follows:

Inner diameter = d =25 mm

Outer diameter = D =47 mm

Width = B = 8 mm

Basic Load rating

C = 7610 N

C_0 = 4000 N

Designation = 16005

E. Metallurgical specification

The machine is made up of mild steel.

Reasons

1) Mild steel is readily available in market.
2) It is inexpensive to use.
3) It is available in standard dimension.
4) It has good mechanical properties.
5) It has high tensile strength.
6) Low co-efficient of thermal expansion.
7) It has suitable factor of safety which is functional for both heavy and medium duty application.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VII July 2020- Available at www.ijraset.com

F. Properties of Mild Steel

Mild steel has a high resistance to breakage. Mild steel, as opposed to higher carbon steels, is quite malleable, even when cold. This means it has high tensile and impact strength. Higher carbon steels usually shatter or crack under stress, while mild steel bends or deforms.

G. Approach to mechanical design of system

In design the of parts we shall take up the following approach;
Selection of suitable material.

1) Assuming suitable dimension according to requirements.
2) Checking of design for failure of component under any possible force system.

III. RESULT

Design of staircase climbing trolley is designed with factor of safety 2. So theoretically this design is Safe. Material which is under more stress will be Tri-Star arrangement and shaft since they are rotating parts and carry different types of loads. To check whether design is safe or not maximum stress is found out with the help of Ansys software. Stress on helical rod is calculated with these conditions:

1) Maximum weight on rod is 1962N i.e. 200Kg
2) Boundary condition are applied.

After applying these results came as 145.63MPa. Material used for this part is Mild steel which have yield strength 370MPa. So, Shaft design is Safe.

A. Shaft Results

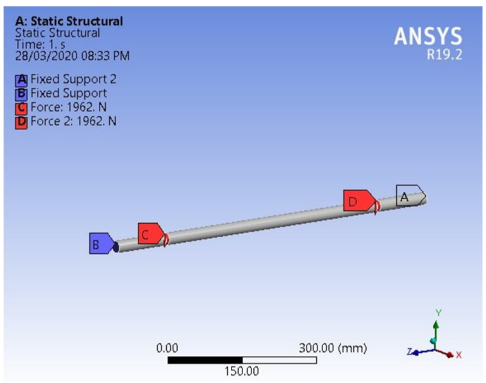

Fig.4 Boundary condition

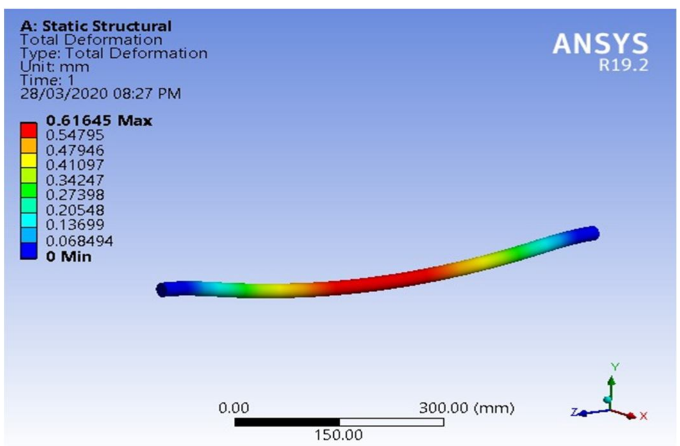

Fig.5 Total deformation

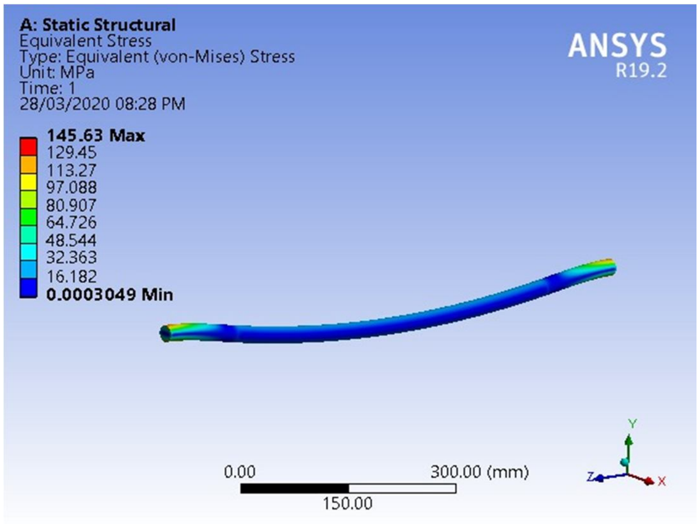

Fig.6 Equivalent Stress

From the diagram that maximum deformation due to 200 kg load is 0.61645 mm.
And von mises stresses whose values are maximum 145.63 MPa at middle and decreases to minimum value 0.0003049 MPa at the end of shaft.

B. *Tristar Results*

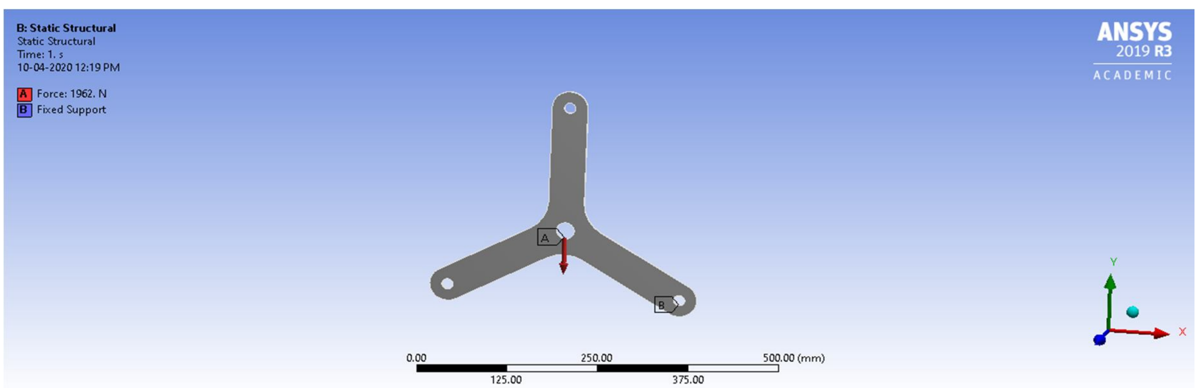

Fig.7 Boundary condition

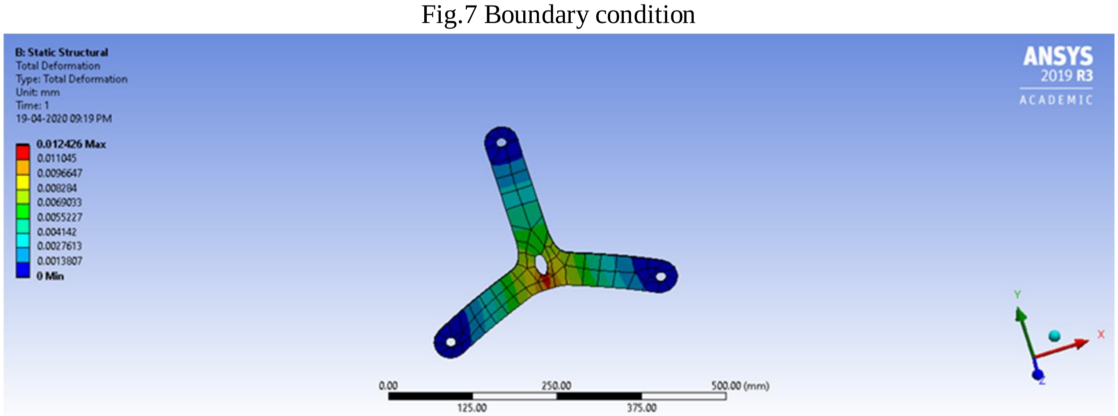

Fig.8 Total deformation

From the diagram that maximum deformation due to 200 kg load is 0.012426 mm.

Hence thickness of the plate is safe. Therefore, thickness of plate is 3 mm

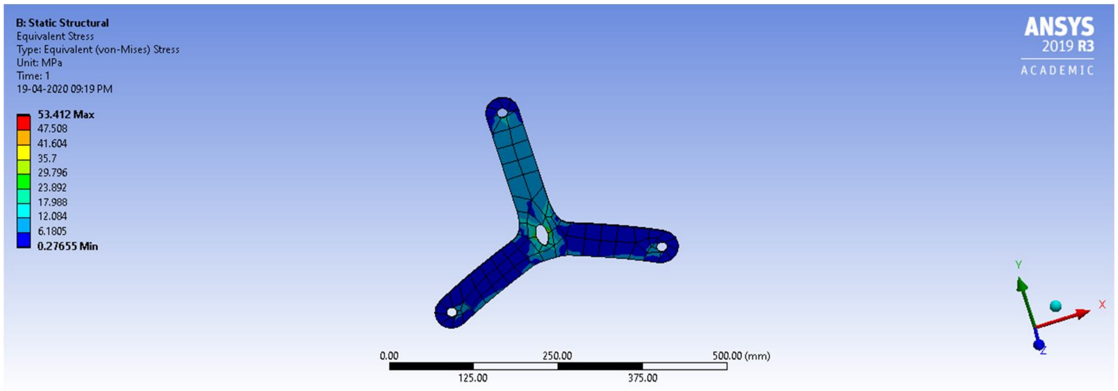

Fig.9 Equivalent Stress

From the diagram von mises stresses whose values are maximum 53.412 MPa at inner circle and decreases to minimum value 0.276655 MPa at the end.

IV. CONCLUSION

The Design of trolley is showed out to be safe and successful theoretically. Power required to move a trolley is very less. Machine requires less components so it's easy to manufacture with low cost. Due to its easy operating mechanism the machine is very convenient for use.

V. ACKNOWLEDGEMENT

I would like to place on record my deep sense of gratitude to Prof M. R. Bahiram. - Dept. of Mechanical engineering, K. K. WAGH INSTITUE OF ENGINEERING EDUCATION & RESEARCH for providing me infrastructural facilities to work in, without which this work would not have been possible.
Thank you, sir, for continuous encouragement and supervision throughout the course of present work.

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