Design and Analysis of Brick Transporter

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Abstract - *Bricks are being widely used as construction materials for home, industrial, and commercial projects. A Trolley is a mechanical device used for carrying load or to transport the material to various locations. The convectional trolley has a major drawback that, it cannot carry heavy loads, requires more time to transport and requires more manual effort. It also requires more manual power and hence increases in wages. This project contains the design and development of trolley on the basis of creativity skills to perform multi functions. A trolley designed can overcome the problem of loading & unloading of bricks from trolley and transporting them from one place to other. It also contains analysis of trolley for various loads. The major areas of focus while designing the trolley are size, weight, load carrying capacity, cost etc.*

***Key Words*: Bricks, Convectional, Trolley, Transport, Loading & unloading, Capacity etc…**

1. INTRODUCTION

Manual handling refers to the use of a worker's hands to move individual containers by lifting, lowering, and filling, emptying, or carrying them. It can expose workers to physical conditions that can lead to injuries, strains and sprains to the lower back, shoulders, and upper limbs. Ergonomic improvements can be used to modify manual handling. A trolley is small transport device used to move significant load from one place to another. In most of the industries hand trolleys are normally used to transport finished product or raw materials.

Convectional trolleys cannot use to move on rough surfaces and carry heavy loads. So, in such place there are going to be a requirement of a trolley that reduce human efforts. In our project the trolley is provided to hold the bricks and carry them from one place to another with less human efforts. It additionally eases the movement of trolley in irregular surface like holes, bumps, etc.

Fig-1: Manual Brick Transportation

The problems of carrying heavy loads in a wheel cart or similar vehicles provide a vision to develop a trolley which can solve these problems. The new era of world demands an interactive and ergonomically suitable product like product which are affordable but should reduce human efforts, best suited to environment, easy to carry, and do not require maintenance.

2. OBJECTIVE

The objectives of the project are listed below:

- To carry large volume of bricks.
- To reduce the time required to transfer bricks from the trolley.
- To make use of trolley without any difficulties.
- To design a model which is durable & worker friendly.
- Modelling of trolley design for transportation mechanism.
- Analysis of load carrying ability and overall stability of the trolley structure.
- To verify the load carrying capacity of trolley using calculations.

3. PROBLEM ANALYSIS

As a part of our Project, we visited the construction sites and observed the present transportation of bricks in working area and discussed the various problems which are faced by the workers during transportation of bricks. The different problems observed & the suitable solutions proposed from this project are listed below:

• The existing method of manual Brick transporter is not effective in area utilization, so the equipment is built for improving area utilization.
• The convectional trolley requires more effort even for less area but, this model takes less effort.
• The time taken by existing trolley to transport bricks from one position to another is more but, it is less in case of designed model.
• The volume of bricks transported is more in designed model compared to conventional trolleys.
• The designed model is made of simple structures and designs which is easy to understand during maintenance.
• The current method of loading and unloading bricks requires more workers to transport them. By designing this model this can be achieved by a less number of workers.

4. DESIGN

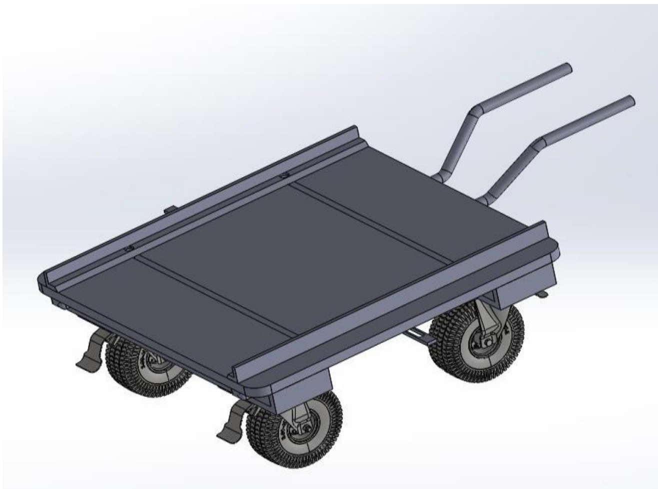


Fig-2: Isometric view of model

Bricks are unloaded in the construction site. Usually these bricks are unloaded manually into stocks and placed on the ground. These bricks are manually carried by workers using brick hod and placed wherever needed. The designed model consists of a latching mechanism. It consists of two jaws, one is fixed and another is movable, attached at the base end of trolley. The trolley is taken manually at the stocks and base is placed parallel to stocks. The movable jaw is operated in order to hold the ricks and the trolley is slightly inclined so, that the bricks rest on the trolley. Then the trolley is transported to the required place and the bricks are unloaded in the same manner in which it is loaded.

4.1 WORKING

The design of model works on Slider crank double lock Mechanism. It consists of a four bar chain having two turning and two sliding pairs. The double slider-crank linkage has four links joined in a kinematic chain consisting of two revolute joints and two sliding joints. One sliding constraint is perpendicular to the other which is used to convert a circular motion of the crank into an exact sinusoidal motion of the link moving in the fixed linear constraint. When lever ***a*** is turned counter clockwise, the axes of links 1, 2 and 3 will be located on a single straight line, i.e. points A, B, C, D and E will lie on a single straight line. At this, links 4 and 5 (the bolts) enter the corresponding recesses ***d*** up to the stops.

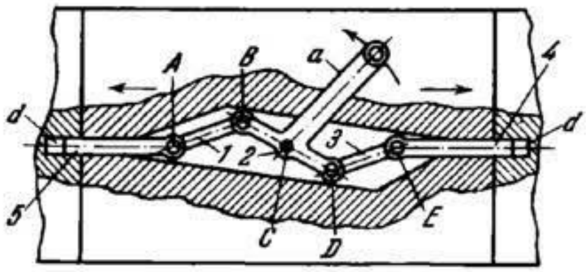


Fig-3: Working mechanism

Table 1: Parts list:

Sl No	Part	Quantity
1	Back plate	2
2	Linkage	2
3	Base	1
4	Main handle	2
5	Slots	2
6	Back cover plate	2
7	Front plate (jaws)	2
8	Locking handle	1
9	Lock plate	1
10	Wheel	4

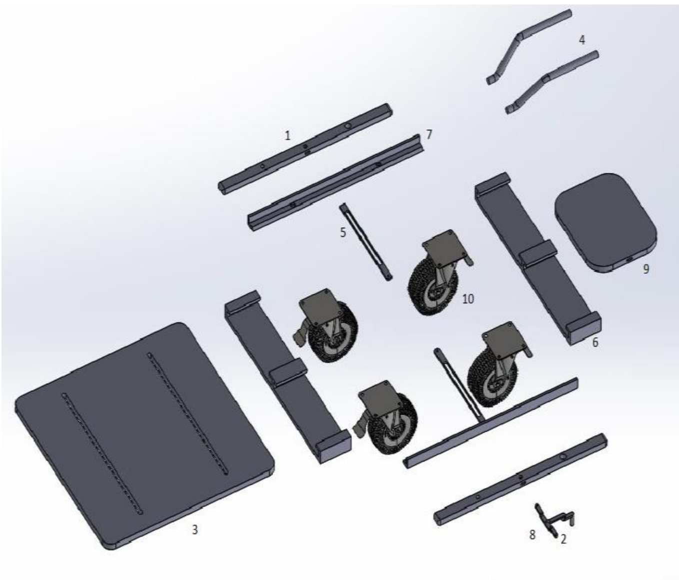


Fig-4: Exploded View of model

5. CALCULATIONS

5.1 Shear force & bending moment Calculations:

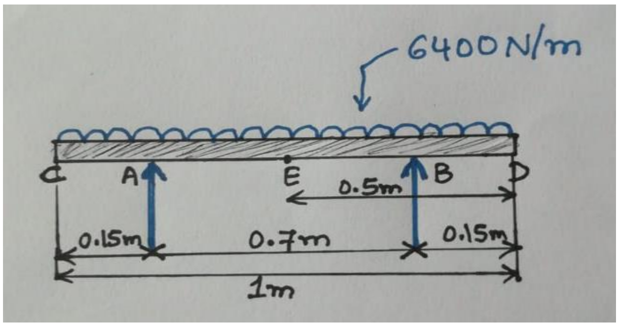


Fig-5: Load Diagram

Maximum weight of Bricks on trolley = 500 Kg.

Gross vehicle weight = 150 Kg.

Total weight of Bricks = 500 + 150 = 650 Kg.

Total Distributed load = 650*9.81 = 6376.5 = 6400 N/m.

$R_A + R_B$ = 6400*1 = 6400 N.

To find reactions at supports:

$R_A = R_B$ = (W*L)/2 = (6400*1)/2

$R_A = R_B$ = 3200 N.

(OR)

Taking moment about point A,

(-6400*0.15*0.15/2) = (-6400*0.85*0.85/2) + (R_B*0.7)

(-72) = (-2312) + (R_B*0.7)

R_B = 2240/0.7 **R_B = 3200 N.**

R_A = (1*6400) - R_B = 6400 – 3200 **= 3200 N.**

SHEAR FORCE:

Shear Force at C & D = 0.

Shear Force at B,

RHS(B) = 6400*0.15 = 960 N.

LHS(B) = (6400*0.15) -3200 = -2240 N.

Shear Force at A,

RHS(A) = -2240 + (6400*0.7) = 2240 N.

LHS(A) = 2240 -3200 = -960 N.

Shear Force at E = 3200 – (6400*0.5) = 0.

BENDING MOMENT:

BM_A = (-6400*0.15*0.15/2) = -72 Nm.

BM_B = ($-WL^2/2$) = ($-6400*0.15^2/2$) = -72 Nm.

BM at C & D = 0.

BM_X = -($W*x^2/2$) + R_B*(0.7 - 0.15)

BM_X= -($6400*0.5^2/2$) + (3200*0.55)

= -800 + 1120 = 320 Nm.

Therefore, the Maximum Bending moment occurs at 'x' distance from point D respectively. (x=0.5m)

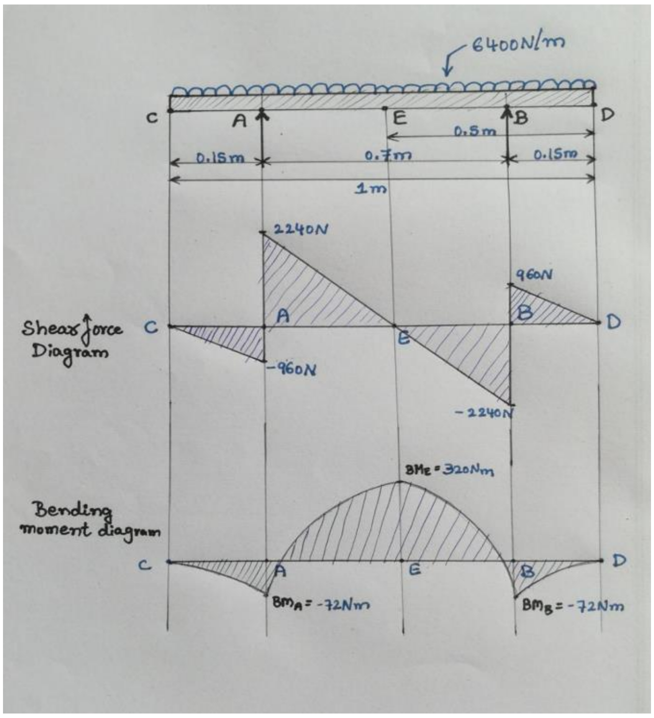


Fig-6: Shear force & Bending moment diagram

5.2 Specifications for the trolley:

Gross Vehicle Weight (GVW) = 150 kg

Radius of wheel/tire, R_w = .22m

Required approx. top speed, V_{max} = 0.5m/s

When trolley or vehicle is running on ground, the maximum inclination angle at worst case can be considered as 2^0

Time to attain top speed can be taken as 10 sec So time required to attain top speed, t_a = 10sec

Consider the surface for normal condition as concrete of good or fair type to calculate total tractive effort (TTE), required by the trolley in moving condition.

TTE (in kg) = RR (in kg) +GR (in kg) + FA (in kg).

Where, TTE = Total Tractive Effort (kg).

RR = force required to overcome Rolling Resistance (kg).

GR = Grade Resistance (kg), i.e. force required to overcome inclination.

FA = Force required to accelerate trolley to top speed (kg).

1) Rolling Resistance: It is force required in kg to overcome friction from ground and to move on any surface. Rolling Resistance.

RR (kg) = GVW (kg)*C_{rr}

Where, GVW = Gross vehicle weight in kg

C_{rr} = Surface friction. For concrete surface C_{rr} can be approximated as 0.0125.

2) Grade Resistance: Grade resistance is the force required to move the trolley up the slope or inclination.

GR (kg) = GVW (kg)*sinα

Where, GVW = Gross vehicle weight in kg

α = Inclination angle

3) Force of Acceleration or Acceleration Force: This is the force required to accelerate the trolley to the top speed in certain time interval.

FA (kg) = (GVW (kg)*V_{max}) / (9.81(ms^{-2})*t_a(sec))

Where, V_{max} = Top speed in m/s.

t_a = time required to attain top speed in seconds.

For verifying that the drive wheel will move or not, it is required to calculate drive wheel torque,

T_w = TTE (kg)*R_w*RF(-)

Where, T_w = Drive wheel torque in kg-m.

R_w = Radius of wheel /tire in m.

RF = Resistance Factor (Resistance factor is the frictional losses between the axle and wheel) (It is generally 1.1 to 1.5).

For verifying that the trolley can transmit the required torque from the drive wheel to ground. It is necessary to calculate the Maximum Tractive Torque (MTT).

MTT (kg-m) = W_w*μ*R_w.

Where, W_w = Normal load on drive.

R_w = Radius of wheel/tyre.

μ = Coefficient of friction between rubber and concrete (μ ~ 0.3 approx).

From above calculations, results can be carried out. Check T_w< MTT. So, required torque will transmitted and trolley will move as accordingly by selecting required and sufficient motors for drive wheels.

Hence the Design is safe.

5.3 MATLAB Calculations:

The above calculation is simplified by using MATLAB program. The program & output are as follows:

```
clc;
clear;

weights = [100 200 300 400 500 510 520 550 600];
VehicleWeight = 150;
Rw= 0.22;
RF=1.3;

GVW=weights+VehicleWeight;
RR=GVW*0.0125;
GR=GVW*sind(2);
FA=(GVW*0.5)/(9.81*10);

TTE=RR+GR+FA;

Tw=TTE*Rw*RF;

MTT=VehicleWeight * Rw * 0.3;

fprintf('The value of MTT = %f\n\n',MTT);
for i=1:size(Tw,2)
    if(Tw(i)<MTT)
        fprintf('For M = %d, Tw = %f; Tw<MTT\nThe required torque will be transmitted
    else fprintf('For M = %d, Tw = %f; Tw>MTT\nThe required torque is not transmitted
    end
end
```

Fig-7: MATLAB program

```
The value of MTT = 9.900000

For M = 100, Tw = 3.753488; Tw<MTT
The required torque will be transmitted to the ground and there will be no occurence of slipping.

For M = 200, Tw = 5.254883; Tw<MTT
The required torque will be transmitted to the ground and there will be no occurence of slipping.

For M = 300, Tw = 6.756279; Tw<MTT
The required torque will be transmitted to the ground and there will be no occurence of slipping.

For M = 400, Tw = 8.257674; Tw<MTT
The required torque will be transmitted to the ground and there will be no occurence of slipping.

For M = 500, Tw = 9.759069; Tw<MTT
The required torque will be transmitted to the ground and there will be no occurence of slipping.

For M = 510, Tw = 9.909209; Tw>MTT
The required torque is not transmitted and slipping occurs.

For M = 520, Tw = 10.059348; Tw>MTT
The required torque is not transmitted and slipping occurs.
```

Fig-8: Output

Maximum loading capacity, when torque is transmitted to ground will be between 650 to 660 Kg. Let us consider the maximum the GVW as 650 Kg. So, maximum capacity will be (GVW - 150) i.e. around **500 kg**.

6. ANALYSIS

The application of FEM for the modeling and simulation of different physical model in interconnect structures by using COMSOL Multiphysics software. The steps involved for analysis includes: Importing geometry, material selection, Physics (applying load), meshing & results.

Table 2: Material properties:

Parameters	Parameter value
Material of trolley	Mild Steel
Young's Modulus	205 Gpa
Poisson's ratio	0.303
Ultimate tensile strength	440 Mpa
Yield Tensile strength	370 Mpa
Density	7850 kg/m^3

6.1 Assumptions:

The load is applied on the top of trolley surface. The bottom surfaces of trolley are 'fixed' since they are connected to the wheels and hence they are carrying the load from top to the wheels.

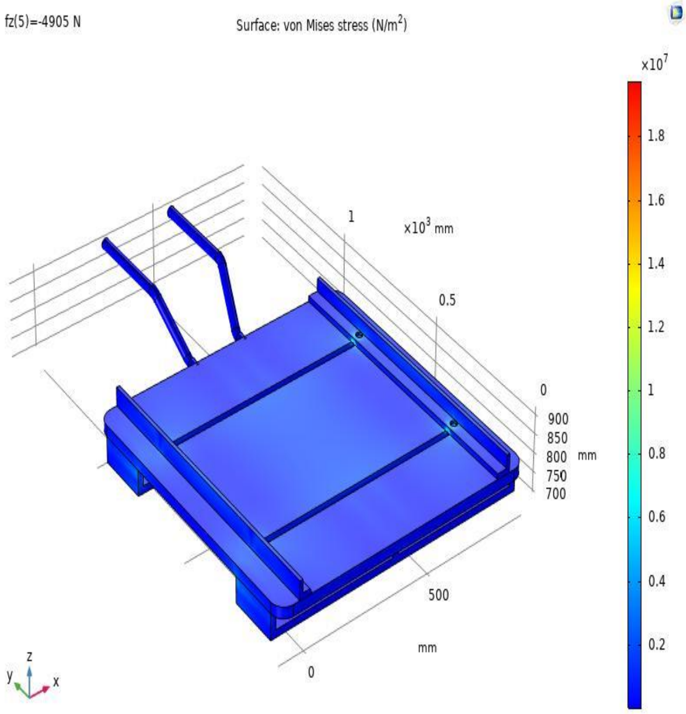


Fig-9: Stress diagram

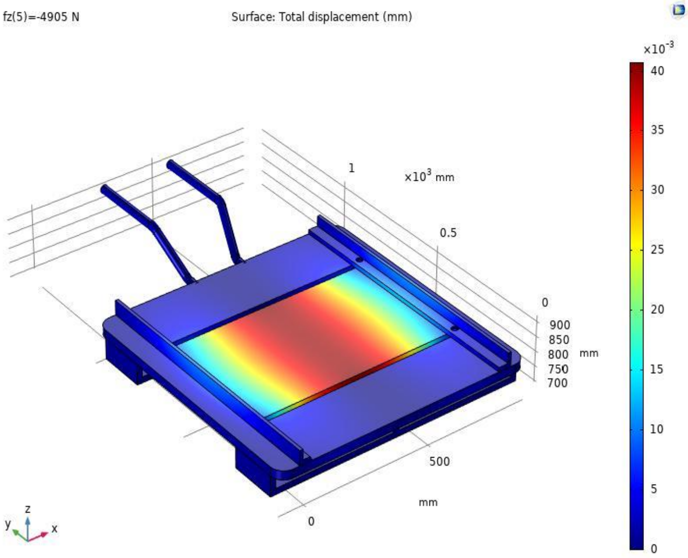


Fig-10: Displacement diagram

Static analysis is carried out for the geometry of trolley. The maximum displacement and maximum stress values for different loads are tabulated below:

Table 3: Stress & displacement table:

Sl No	Load (N)	Maximum Stress (N/mm^2)	Maximum Displacement (m)
1	630	$2.14 * 10^6$	$5.21 * 10^{-6}$
2	1260	$4.29 * 10^6$	$10 * 10^{-6}$
3	2520	$8.57 * 10^6$	$20 * 10^{-6}$
4	3780	$12.9 * 10^6$	$30 * 10^{-6}$
5	4905	$19 * 10^6$	$40 * 10^{-6}$

6.2 ANALYTICAL RESULTS

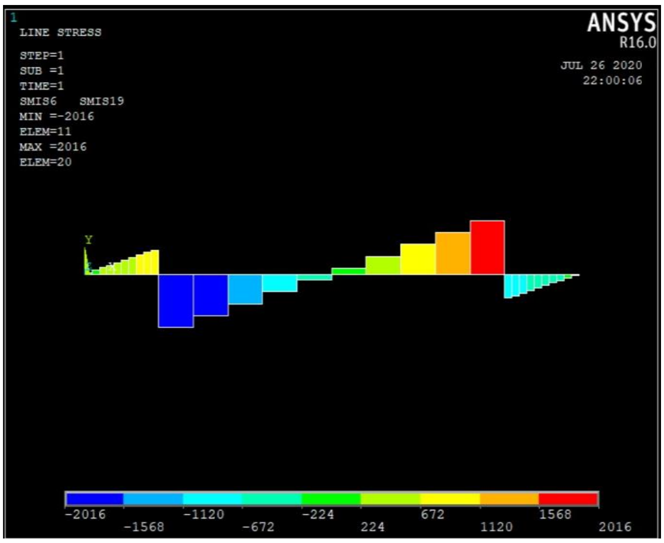


Fig-11: Shear force diagram

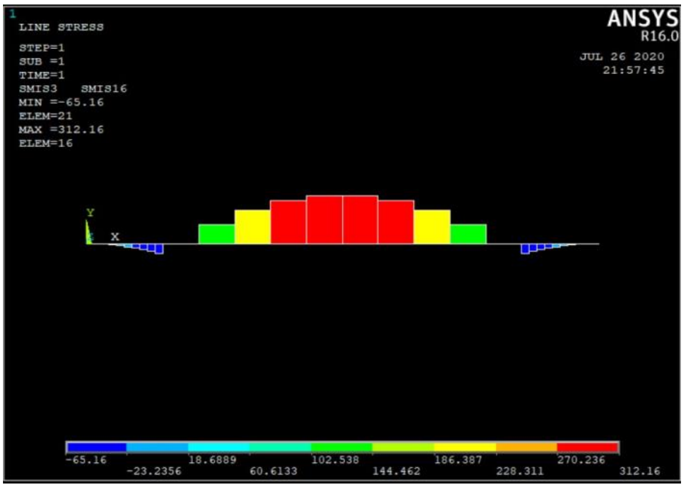
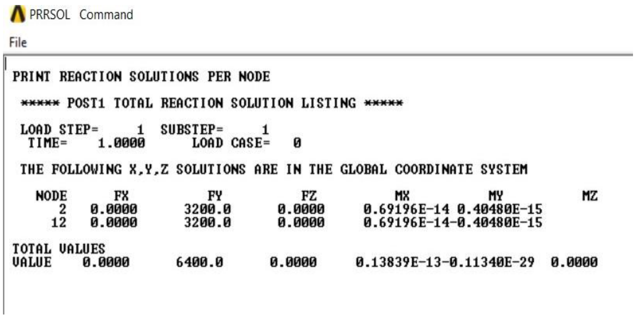


Fig-12: Bending moment diagram



PRRSOL Command

File

PRINT REACTION SOLUTIONS PER NODE

***** POST1 TOTAL REACTION SOLUTION LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN THE GLOBAL COORDINATE SYSTEM

NODE	FX	FY	FZ	MX	MY	MZ
2	0.0000	3200.0	0.0000	0.69196E-14	0.40480E-15	
12	0.0000	3200.0	0.0000	0.69196E-14	-0.40480E-15	

TOTAL VALUES

VALUE	0.0000	6400.0	0.0000	0.13839E-13	-0.11340E-29	0.0000

Fig-13: Reaction solution table

6.3 Percentage error:

1. Shear Force:

Calculated value = 2240N. Analytic value = 2016N. Percentage error = (2240 – 2016)/2240 = 0.1 = 10%.

2. Maximum Bending moment at point E:

Calculated value = 320Nm. Analytic value = 312.16Nm. Percentage error = (320 – 312.16)/320 = 0.0245 = 2.45%.

3. Maximum Bending moment at points A & B:

Calculated value = -72 Nm. Analytic value = -65.16 Nm. Percentage error = (72 – 65.16)/72 = 0.095 = 9.5%.

7. CONCLUSIONS

- The overall design ensures the ability of the trolley to carry multiple bricks by single worker at one instance of time.
- The model of trolley makes transportation of bricks easier than existing trolley therefore, reduces delays & damage and promotes safety.
- The load analysis ensures that the structure can withstand the weight of the bricks distributed along the entire structure of the base of the trolley.
- The maximum shear stress obtained 19 * 10^6 N/mm2, maximum displacement value is 40 * 10^{-6} m for the maximum load of 4905 N & Maximum Tractive torque for the existing model is found to be 9.928kg-m.

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REFERENCES

[1] Optimization of Material Handling Trolley using Finite Element Analysis" by Ramkumar R, Krishnaraju, A., IOSR Journal of Mechanical and Civil Engineering *(*IOSR-JMCE*).* Volume 13, Issue 6 Version (Nov. - Dec. 2016).

[2] "Design and Fabrication of Material Handling Transporter" by Sandeep Jadhav, Abhijit Dhanga, Vinayak Patil, Shubham Pawar, Akash Waware - International Research Journal of Engineering and Technology Volume: 05 Issue: 05 | May-2018.

[3] "Design and Fabrication of Efficient Material Transport Equipment" by Venkatesh Deshpande, Akshay A Karekar, Tejas Patil, Shashikant Shahapurkar, Praveenkumar Hubalikar - International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 06 | June-2017.

[4] "Design And Development Of Vertical Material Handling Lift For Reduce Cycle Time And Cost Optimization" by Shrinivas.B.Patil, Shenavi Sourabh R, Shaikh Rahim B, Khan Mhamudhusen N, Shinde Prafull S - International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 06 | May-2017.

[5] "Stress analysis of mechanisms for trolly-cum-wheelchair" by Praful R Randive and A V Karmankar. Vol. 2, No. 4, October 2013 - International Journal of Mechanical Engineering and Robotic Research.

[6] "Design and Analysis of Transfer Trolley for Material Handling" by Kaustubh V. Wankhade and N. A. Wankhade. Volume 2, Special Issue 1 MEPCON 2015 - International Research Journal of Engineering and Technology (IRJET).

[7] "Design of continuous loading vertical chain conveyor" by Aditya J. Kulkarni, Tanmay M. Kulkarni, Omkar J. Mahadik, Parshuram V. Mahindrakar - International Journal of Advance Research, Ideas and Innovations in Technology, Volume 4, Issue 6.