Application of E-Bike Chain-Drive Transmission in Stair Climbing Trolley

Eeshan Nandkumar Chaudhari[1], Hrugved Bharat Pawar[2], Akshay Suhas Oak[3], Kimaya Pradeep Patil[4]

[1,2,3,4]B.E. (Mechanical), Sinhgad College of Engineering, Pune, Maharashtra, India

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Abstract - *This project aims at developing a mechanism for easy transportation of heavy loads over stairs. Devices such as hand trolleys are used to relieve the stress of lifting while on flat ground: however these devices usually fail when it comes to carrying the load over short fleet of stairs. Hence the need for using staircase climbing trolley has been greatly felt to ease the effort required to carry the heavy loads manually. The main objective of the project is to find an effective and user friendly method of carrying loads through stairs using minimum efforts from the user and to provide a smooth movement. A few issues of vibrations, speed control, and so forth greatly affect the working of the trolley. Hence this project involves the design of an ergonomic staircase climbing trolley for a variety of staircase types. The model is an application of the E-Bike Chain-Drive Transmission system. The frames and wheels are designed and developed according to the statistical data of dimensions of staircases in Indian buildings.*

Key Words: *Tri-star, E-Bike Transmission, Stair Climbing, Failure Analysis, Motor, Throttle*

1. INTRODUCTION

Customary hand trucks function well on level ground, yet their handiness decreases when it gets necessary to move a load over an unpredictable surface. Package deliverymen, for instance, frequently think that it is important to drag stacked hand trucks up short stairwells just to arrive at the front entryway of a building. The whole reason for utilizing an ordinary hand truck is to avoid from lifting and haul substantial objects around.

Lifting a hand truck up the stairs nullifies the purpose of the device, since the user must provide enough upward force to lift the entire weight of the trolley and its load. Moreover, the geometry of a hand truck makes it difficult to lift with one's legs as is the proper form. Much amount of strain is placed on the back muscles and the risk of operator injury is sharply increased. The pulling up of a standard hand truck up the stairs results in a uneven and vibrating motion. This movement may harm the items loaded on the hand truck or cause them to collapse entirely. A hand truck that could climb stairs without requiring the user to lift would improve the safety of moving heavy objects over irregular surfaces. The stair-climbing hand truck is designed to reduce burdens rather than increase them. A special type of wheel arrangement known as 'Tri-Star' arrangement is used in this project as shown in Fig. 1.

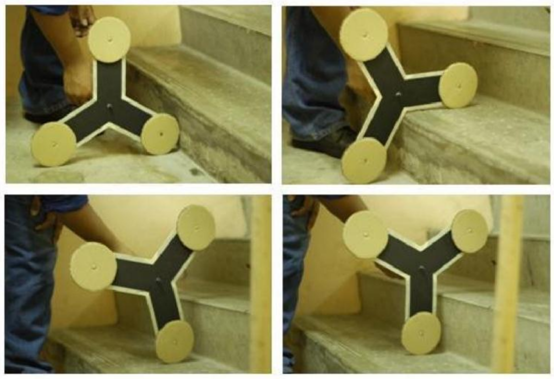


Fig. 1 Tri-Star Wheel Arrangement

2. LITERATURE REVIEW

A Stair Climbing Trolley is a device used to carry heavy loads over stairs in many industries and institutions. This device is fitted with rotating wheels or tracks so that it can be pushed or pulled up or down steps or a staircase. Stair climbers can be manual or battery-powered. Tracked versions offer the greatest Safe Working Limit (S.W.L) with regards to the load being moved. Different types of mechanisms used for Stair Climbing Trolley are as follow:

- Tank mechanism (Chain mechanism)
- Push-arm mechanism
- Rocker-Bogie mechanism
- Tri-Star mechanism

G. S. Modak et al[1] studied the evolution of stair climbing power wheelchair. They studied tank (chain) mechanism wherein the wheels of the trolley were arranged in continuous track, as that of tanks. It was basically battery powered mechanism. It was used to carry heavy loads up to 1000kg. This method of transportation was very robust and could climb steep stairs and other awkward terrain. The disadvantages of this mechanism were that the trolley was bulky due to battery provided for supplying power and due to heavy load carrying capacity, the speed of the machine was slower than compared to other mechanisms.

Pokal Rajan et al[2] worked on push-arm type stair climber having an arm fitted to the bottom of the trolley that unfolded outwards, pushing on the step above. It could lift the trolley up in an arc to rest on that step. Repetitions of this movement allowed the trolley to move up the stairs. The mechanical opposite of this motion allowed the unit to move downstairs. The disadvantages of this mechanism were that it had low load carrying capacity and speed of this machine was low, as more time was required by the push-arm to stabilize over the stairs and push the load above or below the stairs. Also the entire load of the trolley was concentrated on two arms alone.

Mayank Das Manik et al[3] designed a rocker bogie mechanism for climbing stairs with loads. The rocker bogie system reduced the motion by half compared to other systems because each of the bogie's six wheels carried independent mechanism for motion and in which the two front and two rear wheels had individual steering systems which allowed the vehicle to turn in place as 0 degree turning radius. The usage of links instead of wheels for the trolley was the modification. Though it was fastest, it had some limitations. It had very low load carrying capacity up to 10kg, as the links could not withstand heavy loads. Due to fast speed, whenever the mechanism used to encounter with a jerk (height greater than 10 per cent of wheel radius), there would be a large shock transmitted through the chassis which damaged the suspension system or toppled down the entire vehicle. Hence it had stability issues when it would run on higher speeds.

The tri-star stair climber trolley as proposed by Pravin Raj et al[4] relied on a wheel configuration of three wheels set into a triangular arrangement replacing the standard wheels on either side of the trolley. This arrangement of wheels is known as Tri-Star arrangement of wheels. This form of stair climber was most commonly found in the manual non-electric variety and was found very useful for courier drivers and for light weight deliveries. They manufactured a stair climber with the Tri-Star arrangement of wheels. The wheel assembly was rotated by a gear- motor mechanism where a DC gear motor was used to provide the necessary power for rotation and a pinion- gear mesh for reducing the rotating speed of the wheel. The motor was connected to a lead acid battery of similar ratings. The trolley could carry weight of about 100 kilograms through the stairs with very minimal effort applied by the user. This mechanism had some disadvantages like it had constant speed of rotation which would be unfavourable in case of any mishandling. Also the trolley was prone to jerks and vibrations.

Pratik H. Rathod et al[5]designed and fabricated the stair climbing hand truck which could climb stairs with less effort compared to carry it manually. The technical issues in designing of the vehicle were the stability and speed of the vehicle while climbing stairs. However, the steepness of the stairs was also the important concern of the study. The vehicle had four wheeled arrangement to support its weight when it moved over the surface. Each set of wheel frame consisted of three wheels attached with nut and bolt. Using the vehicle, the labour cost could be reduced as well as huge amount of loads could be transported uniformly with less power consumption. The hand truck had advantages like it was capable of carrying heavy load without suffering any deformation or local fractures if it were to go into real world production at an ideal scale.

Among all the mechanisms discussed above, Tri-Star was the more efficient and easy to use. It was cheaper than the other mechanisms and could handle loads of relatively greater magnitude of about 150 kg. Thus, Tri-Star wheel arrangement is used in the design of the Stair Climbing Trolley. The Tri-Star arrangement requires some human efforts to climb the stairs. Also there are possibilities of slipping of the trolley from the stairs. In order to reduce these defects, trolley is modified into automated battery operated model.

3. SELECTION OF MATERIAL AND DESIGN OF TROLLEY

In system design, we mainly concentrate on the following parameters:-

1. System selection based on physical constraints:
While selecting any machine it must be checked whether it is going to be used in large scale or small scale industry. In this case it is to be used in the institution building. So, space is a major constrain. Hence the system is to be very compact.

2. Arrangement of various components:
Keeping into view the space restriction, the components should be laid such that their easy maintenance or servicing is possible. Moreover, every component should be easily visible & none should be hidden.

3. Components of system:
As already stated, system should be compact enough so that it can be accommodated at a corner of a room. A compact system gives a better look & structure.

4. Chances of failure:
The losses incurred by owner in case of failure of a component are important criteria of design. Factor of safety is kept high so there are less chances of failure. Periodic maintenance is required to keep the product trouble free.

5. Servicing facility:
The layout of components should be such that easy servicing is possible especially those components which required frequent servicing can be easily dismantled.eg. In this case, the batteries need to be charged. Hence they must easily disassemble and reassemble.

6. Height of trolley from ground:
For ease and comfort of operator, the height of trolley should be properly decided so that he may not get tired during operation. Also, enough clearance should be provided.

7. Weight of trolley:
The total weight of trolley depends upon the selection of material components as well as dimension of components. A higher weighted trolley is difficult for transportation.

3.1. Trolley Body

Material Selection for Trolley Body:

Material Used: Mild Steel

Mild steel, also called as plain-carbon steel, is the most common form of steel because its price is relatively low. Low-carbon steel contains approximately 0.05 to 0.3 % Carbon making it malleable and ductile. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing. The density of mild steel is approximately 7850 kg/cubic cm and the Young's modulus is 210 GPa (30,000,000 psi).

Dimensions of Trolley Body:

Considering the application of trolley, the selected dimensions of trolley body are as follows:-
Trolley height = 1.22 m (4 feet)
Trolley base = 0.61 m (2 feet)
Trolley and base width = 0.76 m (2.5 feet)

3.2. Wheel Selection

The selection of wheel includes the load carrying capacity of wheels, its size and its weight. So for proper and smooth rotation of wheels over the staircase, suitable material must be chosen.

Types of Wheel Material:

Filled rubbers:
In wheels, rubbers are usually filled with particles like carbon black or silica. They consist of a tread and a body. The tread is the part of the wheel that comes in contact with the road surface. Treads are often designed to meet specific product marketing positions.

Polyurethane:
Polyurethane (PUR and PU) is a polymer composed of a chain of organic units joined by carbonate (urethane) links. While most polyurethanes are thermosetting polymers that do not melt when heated, thermoplastic polyurethanes are also available. The main ingredients to make polyurethane are isocyanates and polyols. Other materials are added to help processing the polymer or to change the properties of the polymer.

Steel:
Steel is an alloy of iron, with carbon being the primary alloying element, up to 2.1 % by weight. Carbon, other elements, and inclusions within iron act as hardening agents that prevent the movement of dislocations that naturally exist in the iron atom crystal lattices.

Various wheel materials and their co-efficient of frictions for a concrete surface are tabulated in Table 3.1.

Table 3.1 Materials and coefficients of friction

Sr. No.	Material	Coeff. of friction
1	Rubber	0.85
2	Polyurethane	0.50
3	Steel	0.45

Wheel Material Selected: Filled rubber

3.3. Wheel Frame

In Tri-Star arrangement, a specially designed wheel frame is required to hold the three wheels together on each side of the shaft. In the existing designs, the power transmission to the single or double wheel trolley is useless to climb the stairs due to height factor of stairs. The design of the straight wheel frame became more complicated and was needed to be modified with its curved- spherical shape to give proper drive, which creates more frictional force. For these reason, three wheels' set on each side of trolley attached with frame was introduced to provide smooth power transmission in order to climb stairs without much difficulty. Wheels arranged on the plate are equally spaced and placed at 120° from each other. Frame arrangement is suitable to transmit exact velocity ratio also. It provided higher efficiency and compact layout with reliable service. Easier maintenance was possible in case of replacing any defective parts such as nut, bolt, washer, etc.

Types of wheel frames:

A few types of wheel frames are shown below in Fig 3.1

(1) Straight (2) Curved (3) Quasi-Planetary

Fig. 3.1 Various Types of Wheel Frames

Wheel Frame Selected- Quasi Planetary Wheel

Design of Tri-Star Frame and Wheels

The design of Tri-Star frame and wheels as shown in Fig 3.2 is done by keeping into consideration the different sizes of rise and tread of staircases. Taking the average rise and tread of steps;

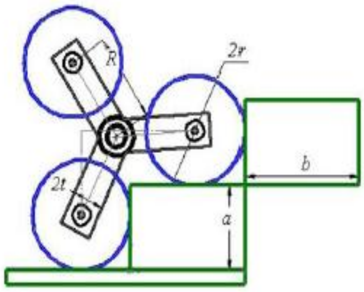


Fig. 3.2 Tri-Star Wheel Design [4]

Rise (a) = 0.15 m, Tread (b) = 0.28 m
Radius of Wheel (r) = 0.1016 m

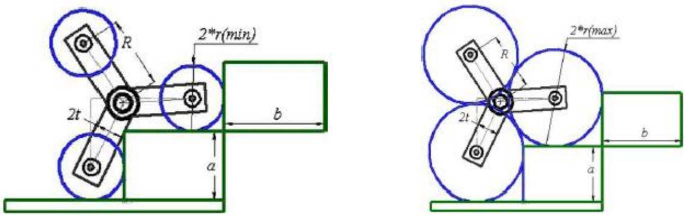
$$R = \sqrt{\frac{a^2+b^2}{3}} = 0.184 \text{ m}$$

The minimum value of the radius of regular wheel (r_{min}) to prevent the collision of the holders to the stairs is derived as follows [Refer Fig 3.3 (a)]

$$r_{min} = \frac{6Rt + a(3b-\sqrt{3}a)}{(3-\sqrt{3})a+(3+\sqrt{3})b} = 6.47 \text{ cm} \approx 0.07 \text{ m } (t = 1) \ldots (1)$$

The maximum value radius of the radius regular wheels (r_{max}) to prevent the collision of the wheels together is [Refer Fig 3.3 (b)]

$$r_{max} = \sqrt{\frac{a^2+b^2}{2}} = 22.46 \text{ cm} \approx 0.225 \text{ m} \ldots (2)$$



(a) (b)

Fig. 3.3 Tri-Star Wheel structure and dimensions [4]

The maximum value of the thickness of holders (t_{max}) to avoid the collision between the holders and stairs is derived by [Refer Fig 3.3 (a)]:

$$t_{max} = \frac{ar(3-\sqrt{3})+br(3+\sqrt{3})+a(\sqrt{3}a-\sqrt{3}b)}{6R} = 6.94 = 0.07 \text{ m} \ldots (3)$$

3.4. Design of Shaft

From 'Design of Machine Elements' by V. B. Bhandari

Assuming standard diameters of shaft;

Diameter (D) = 0.025 m
Length of the shaft =0. 95 m

Shaft subjected to torsional as well as bending moment:

Assume, load (P) = 50 kg
P = 490.5 N

Maximum Bending Moment (M) = 245.25 * 381
M = 93.44 Nm

Torque (T) = Pt * radius of sprocket
T = 180.31 Nm

Equivalent torque (T_e) = $\sqrt{(K_B * M)^2 + (K_T * T)^2}$

For K_B = 1.5 and K_T = 1.25
T_e = 265.42 Nm

Maximum Shear Stress $\tau = \frac{16 * T_e}{\pi D^3}$ … (4)
= 86.51MPa

Now $\tau_{all} = \frac{0.5\, S_{yt}}{FOS}$

Material used for shaft is mild steel.
Hence S_{yt} = 360 MPa

Assuming factor of safety = 1.5

τ_{all} = 120 MPa

Maximum shear stress < Allowable shear stress
86.51 MPa < 120 MPa

Thus, the design of shaft is safe and satisfactory.

3.5. Bearing Selection

A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races. The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads. It achieves this by using at least two races to contain the balls and transmit the loads through the balls. In most applications, one race is stationary and the other is attached to the rotating assembly. As one of the bearing races rotates it causes the balls to rotate as well. Because the balls are rolling they have a much lower coefficient of friction than if two flat surfaces were sliding against each other.

Selecting a ball bearing with minimum inner diameter of 25 mm, minimum load carrying capacity of 50 kg radially and speed greater than 40 rotations per minute (RPM).

Selection - SKF 6005-2Z Open Deep Groove Ball Bearing

Inside Diameter: 25mm
Outside Diameter: 47mm
Width: 12mm

Design of Bearings

Bearing selected is SKF 6005-2Z Open Deep Groove Ball Bearing

Equivalent Dynamic Load (P) = $XVF_r + YF_a$
As load in this case is purely radial, $F_a = 0$

Also inner race rotates while external is stationary,
V = 1 and P = F_r

Maximum radial load F_r= 490.5 N
P = 490.5 N

Calculations for dynamic loading capacity of bearing:

L_{10} (million revolutions) = $(C/P)^3$ for ball bearings

For trolley used intermittently;
L_H = 8000 hours

But,

$$L_{10} = \left(\frac{60*n*Lh}{10e6}\right) \quad \dots (5)$$

= 144 million revolutions

Now,

L_{10} (million revolutions) = $(C/P)^3$
C = 2570.94 N

As the required dynamic capacity of bearing is less than rated dynamic capacity of bearing (11.9 kN); selected bearing is safe for use.

3.6 Selection of Motor Kit

The selection of proper motor kit includes selection of motor, batteries, throttle and controller. The motor provides the necessary torque for climbing; batteries provide the voltage and current to the motor. The throttle is used to control the amount of current which flows in the motor. Hence the speed is controlled.

Selection of Motor

Rating = 24 Volts DC, 350 Watts
No. of teeth on sprocket = 9
Torque = 35 Nm
Motor RPM = 3000
Motor RPM after reduction = 300
Model = MY1016Z3 Zheijiang Brand make (Fig 3.4)

Fig 3.4 DC Geared Motor

Motor Controller Specifications

The Motor Controller 24V for MY1016Z3350W (Fig 3.5) includes attachments for the motor like accelerator, brake, battery, battery charging, brake light, power lock.
Dimensions = 83*70*38 mm
Cable length = 10 cm (approx.)
Weight = 196 gm
Rated voltage = 24 V DC
Current limit = 33 A
Rated power = 350 W

Fig 3.5 DC Geared Motor Controller

Throttle Specifications:

Throttle is used to control the rotational speed of the motor. It is similar to scooter accelerator available in the market. Refer (Fig 3.6).

Type = Twist Throttle
Inner diameter of handle = 23 mm
Inner total length = 120 mm
Weight = 210 gm

Fig 3.6 Twist Throttle

3.7 Design of Chain Drive

In this project, chain drive is used as transmission system. Advantages of using chain drive are:-

- Chances of slip occurrence are almost negligible
- Less space required since they are made of metal
- Transmit more load and power as compared to belts
- Comparatively higher efficiency than belt drive

Selection of transmission ratio

i = $(z_2/z_1) = (n_1/n_2)$
For n_1= 300 RPM and n_2= 60 RPM
i = 5

Selection of number of teeth on driver sprocket:
$z_1 = 9$

Determination of number of teeth on driven sprocket:
$z_2 = i * z_1 = 45$

Selection of standard pitch (P)
Optimum centre distance
a = (30 to 50) P
Selecting standard pitch (P) = 0.0127 m
Distance between centres (a) = 0.0127*40 = 0.508 m

Selection of chain
Considering simplex chain ISO 08B-1 R1278 is selected for pitch 0.0127 m.

Calculation of total load on driving side of chain

Power transmitted *(N)* = T * ω

$$\omega = \frac{2*\pi*n_1}{60} = 31.42 \text{ rad/s}$$

As T = 175 Nm
Therefore *N* = 5.497 kW

Total load $P_T=P_t+P_c+P_s$

$$v = \frac{z_2 P n_2}{60*1000} = 0.5715 \text{ m/s}$$

As pitch (P) = 0.0127 m,

Breaking load (Q) = 1820 kgf = 17854.2 N
Weight per meter (w) = 0.70 kgf = 6.86 N

$P_t = (\frac{1020*N}{v})$ (Tangential force of power transmission)
= 1981.46 N

$P_c = \frac{wv^2}{g}$ (Tension due to centrifugal force)
= 0.22 N

P_s= k*w*a (Tension due to sagging of chain)
= 3.50 N

Total load $P_T=P_t+P_c+P_s$
= 1985.18 N

Calculation of design load

Design load = $K_s * P_t$

For $K_S = K_1*K_2*K_3*K_4*K_5*K_6 = 1.9$
Design load = 3771.84 N

Calculation of factor of safety

$$FOS = \frac{Breaking\ load}{Design\ load}$$
= 4.73

Actual length of chain

$a_p = (a/p) = 40$

$$L_p = 2a_p + (\frac{z_1+z_2}{2}) + \frac{(\frac{z_2-z_1}{2\pi})^2}{a_p} \quad \dots (6)$$

= 107.82 links

Selecting 110 links
Hence total length of chain = 110 * P = 1397 mm

Exact center distance

$M = \frac{z_2-z_1}{2\pi^2}$
= 32.82

$e = L_p - \frac{z_1+z_2}{2} = 80.82$

$$a = \frac{(e+(e^2-8M)^{0.5})}{4} * P \quad \dots (7)$$

= 0.508 m

Pitch diameter of sprocket

PCD for small sprocket,

$$d_1 = \frac{P}{\sin\left(\frac{180}{z_1}\right)}$$

= 0.037 m

PCD for larger sprocket,

$$d_2 = \frac{P}{\sin\left(\frac{180}{z_2}\right)}$$

= 0.182 m

4. MODELLING AND ANALYSIS OF TROLLEY

4.1 CAD Model of the Components

The Tri-Star plate is shown in Fig 4.1, houses the 3 planetary wheels and the rotating shaft passes through the centre of the plate. There are 2 Tri-Star plates on either side of shaft. The two plates support the wheels from both sides with the help of nut and bolts. The shaft passing through the centre is welded to the plate.

Fig 4.1 CAD Model of Tri-Star

Shaft used in this trolley is a solid shaft. The shaft provides rotation to the Tri-Star wheels plate. The shaft rotates with the help of motor provided and coupled to the transmission system. Outer diameter of the shaft is 25 mm. Length of the shaft is 950 mm. CAD model of shaft is shown in Fig 4.2

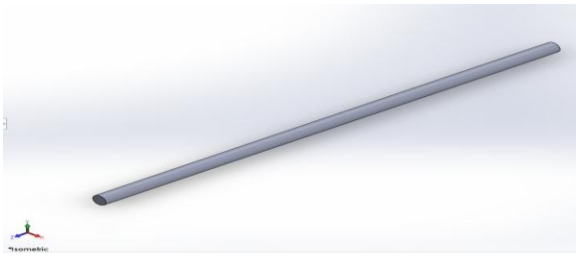


Fig 4.2 CAD Model of Shaft

The trolley frame is joined to the rotating shaft with the help of bearings. The shaft passes through the bearings and on the extremity; Tri-Star wheels are joined to it. The entire Tri-Star trolley frame along with the transmission system is shown below in Fig 4.3

Fig 4.3 CAD Model of Tri-Star trolley frame

4.2. Analysis of the Components

In ANSYS Workbench, the maximum total deformation is found out to be 0.01987 mm in the region where two wheels are rested on ground and they carry the entire weight on the trolley, refer Fig 4.4. The minimum deformation is 0.00220 mm in the region where no load acts i.e. the wheel is not in contact with ground.

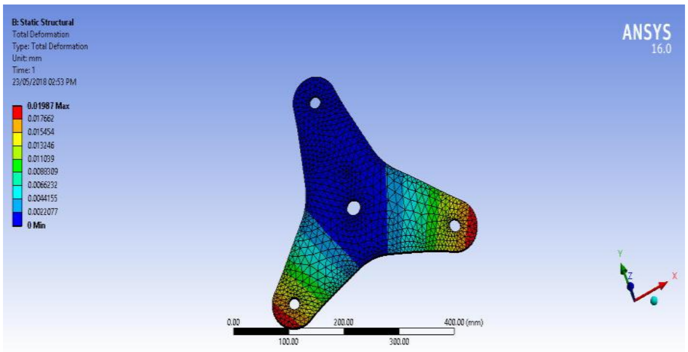


Fig 4.4 Analysis of the Tri-Star Frame (Total Deformation)

The maximum Von-Mises stress on the plate is 10.985 MPa while the minimum is 0.00014 MPa as shown in Fig 4.5.

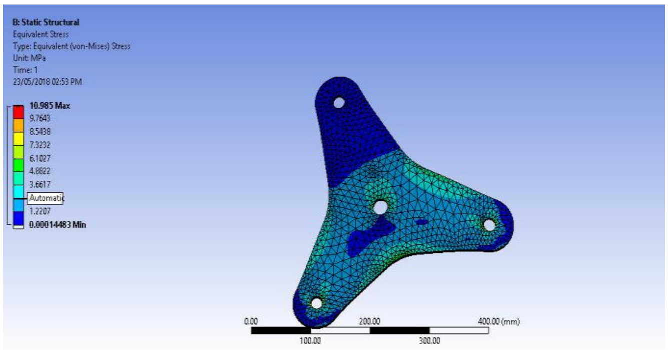


Fig 4.5 Analysis of the Tri-Star Frame (Von Mises Stress)

Analysis of the Shaft

The maximum deformation of shaft is equal to 0.88174 mm and is near the ends of the shaft while the minimum deformation of the shaft is equal to 0 mm at the region where the sprocket is attached as shown in Fig 4.6.

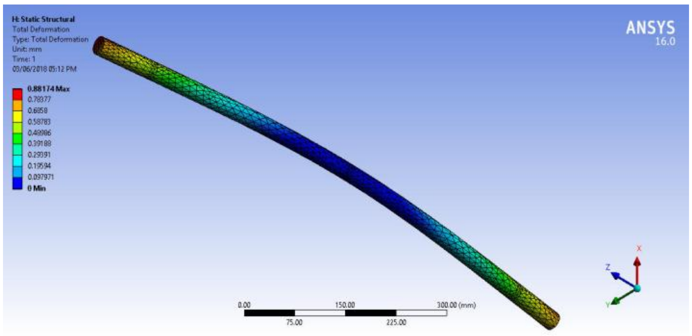


Fig 4.6 Analysis of the Shaft (Total Deformation)

Value of maximum shear stress obtained is 61.828 MPa which is quite less than the maximum allowable shear stress 120 MPa. As the value of maximum shear stress is below allowable shear stress, the design for the shaft is safe and satisfied, refer Fig 4.7.

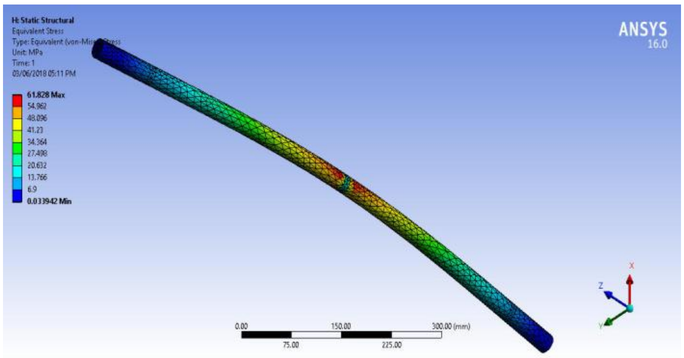


Fig 4.7 Analysis of the Shaft (Von Mises Stress)

4.3 Summary of Analysis

- For the Tri-Star Frame

1. Maximum total deformation is 0.01987 mm and minimum deflection is 0.00220 mm
2. Maximum Von-Mises stress on the plate is 10.985 MPa while the minimum stress is 0.00014 MPa
3. The tri-star frame is safely designed.

- For the Shaft

1. Maximum deformation of shaft is equal to 0.88174 mm and minimum deformation is 0 mm.
2. Maximum shear stress obtained is 61.828 MPa which is less than the maximum allowable shear stress 120 MPa.
3. The shaft is safely designed.

5. FABRICATION AND TESTING OF TROLLEY

This chapter includes detailed information about the fabrication and testing of the Stair Climbing Trolley.

5.1 Fabrication of Tri-Star Setup

The fabrication of stair climbing trolley has been done with the fabrication of Tri-Star setup. The Tri-Star plate is made up of mild steel of 3 mm thickness. The lobe shape is cut from metal sheet with the help of laser cutting, refer Fig 5.1. The wheels chosen are made up of rubber. One wheel is to be attached at each arm of the plate. They are attached by placing 2 plates on either side of the wheels. Then nuts and bolts are used to hold the parts together. While climbing the stairs, the tri star setup rotates because of the shaft and climbs the stairs when it hits the edge of the stairs.

Fig. 5.1 Tri-Star and wheel arrangement

5.2 Fabrication of Wheel and Shaft Assembly

The shaft has been fabricated from a circular cross section bar of mild steel. The diameter of the shaft is 0.025 m while the length of the shaft is 0.950m. After the required operations of shaft on lathe machine, the sprocket is fitted on it. The sprocket is fitted in the middle of the shaft. Following the process, bearings are fitted on shaft at distance equal to the width of trolley. After the bearings are fitted, the pair of tri-star wheel setups is fixed at the ends of the shaft by means of welding.

5.3 Assembling the components

The trolley frame, Tri-Star wheels arrangement, shaft and transmission system are assembled together. Motor and batteries are mounted on the trolley and are fitted by nut and bolts. Chain is passed over the motor sprocket and sprocket over the shaft. The throttle which is used to control the speed of the motor is attached to a handle behind the trolley.

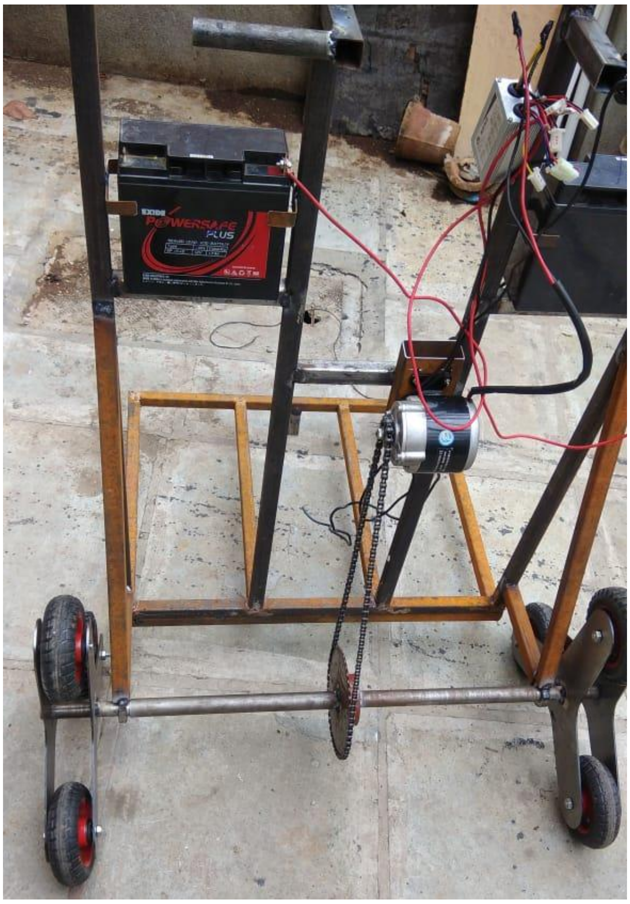


Fig 5.2 Assembly of components

6. RESULTS AND DISCUSSION

Based on Analysis of the Components:

The deflections are very less and stresses acting are under allowable stresses for the shaft and Tri-Star plate, Hence they are designed safely.

The maximum deformation is 0.01987 mm in the region where two wheels are rested on ground and they carry the entire weight on the trolley whereas the minimum deflection is 0.00220 mm in the region where no load acts i.e. the wheel is not in contact with ground. The maximum Von-Mises stress on the plate is 10.985 MPa while the minimum is 0.00014 MPa.

The maximum deformation of shaft of 0.88174 mm and minimum stress of 0.033 MPa is near the ends of the shaft while the minimum deformation of the shaft of 0 mm and maximum shear stress of 61.828 MPa is at the region where the sprocket is attached. The allowable stress is 120 MPa.

Based on Calculations of Components

For shaft, the net shear stress acting is 86.51 MPa and the allowable shear stress is 120 MPa when a factor of safety of 1.5 is considered. Hence the shaft is safe to use.

The bearings selected are single row deep groove ball bearings. They have net dynamic capacity of 2570.9 N which is far less than that of allowable dynamic capacity which is 11900 N. Hence the bearings selection is properly done.

The chain drive used for transmitting the required power has breaking load of 17854.28 N while the working load on chain is only 3771.84 N. Hence the value of factor of safety for chain is 4.73 which is according to the standards. Hence the chain is safe to use.

7. CONCLUSIONS

The conclusions of the project can be stated as:

- The stair climbing trolley has been designed in such way that it can carry the heavy loads as well as bulky loads over stairs and also used for carrying loads on flat surface from one place to other place without many efforts from the user.
- The use of battery powered trolley gives the necessary force required to climb up the trolley. This decreases the human effort to carry heavy loads. Considering this, analysis for safe working of components has been done in FEA software to keep the acting stresses within the permissible limit.
- The trolley including the Tri-Star plate and shaft are fabricated by mild steel as it gives a considerable factor of safety for working. The power transmitted is controlled at every step with the help of throttle provided at the handle of the trolley.
- Accordingly to the tests conducted, the stair climbing trolley has a capacity of carrying a load of 100 kg on flat surface. It has the ability to ascend a flight of stairs of 30 degree elevation carrying a load capacity of 40 kg.

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