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Design and Fabrication of Stair Climbing Trolley

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Abstract- This research presents the design and performance test of stair climbing trolley. The aim of this project is developing a mechanism for easy transportation of heavy loads over stairs. The need for such a system arises from day-to-day requirements in our society. In this research, shaft diameter is calculated by using bending strength of the beam. Mild steel shaft is selected for design to obtain high strength. The length of shaft is 21 in and the calculated diameter of shaft is 0.75 in. Bearing No: 204 of single row angular contact ball bearing is selected. The design is based on the bearing that can be only efficient for 60 kg load with the speed of the normal human.

Indexed Terms- Shaft Diameter; Bending Moment; Bearing Selection; Stresses

I. INTRODUCTION

A trolley is a small vehicle with wheels that can be pushed or pulled along and is used for carrying things. A stair climbing trolley is a type of trolley fitted with rotating wheels or tracks so that it can be pushed, pulled up or down and stepped on a stairway. Stair climbing trolley can be manual or battery-powered and, are commonly found in wheel, track, and push arm. When used properly, trolleys can protect people from back injuries and other health problems that can result from lifting heavy loads. In the existing design, 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 reasons, three wheels, which were set on each side of vehicle, attached with frame were introduced to provide smooth power transmission in order to climb stairs without difficulties.

This research can introduce a new option for the transportation of loads over the stairs. Trolley is equipment which used to move heavy loads from one place to another. It can reduce the human burden in their daily lives. This device is commonly used by a large numbers of industries to transport physical products and heavy loads. Trolleys are often used by those who organized and stock merchandise in retail stores and restock.

II. CONSTRUCTION PROCESS

A. Main Frame

Main frame in figure 1 is used to carry the total set up of arrangement. It has to be able to sustain the total weight of the arrangement. It is joined by arc welding to get permanent joint.

(a)

(b)

Figure 1. (a) The design of main frame and (b) the fabrication of frame by welding process

The assembly of wheels and wheel frames is welded to the main shaft. The upper tip of the angle beam is cut into 1x1 inches square shape for the handle. The metal plate having 1.5x2 inches rectangular shape is cut into 1x1 inches square shape. It is welded to cover the above angle beam after the handle is placed. Then the trolley is being done with the hand grinder to smooth surface.

B. Design of Ball Bearings

(a)

(b)

Figure 2. (a) The desired ball bearing and (b) fitting the shaft

A ball bearing is a type of rolling-element bearings which uses balls to maintain the separation between the bearing races. The shaft is placed into the bearing and the purpose 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 loads through the balls. As one of the bearing races rotates, it causes the balls to rotate as well. Since the balls are rolling, they have lower coefficient of friction than that of two flat surfaces which were sliding against each other. Figure 2 shows a ball bearing with minimum inner diameter of 30 mm, outer diameter of 47 mm, width 14mm, minimum load carrying of 60 kg radially and speed greater than 100 rpm.

C. Design of Trolley Wheel

(a)

(b)

Figure3. (a) The desired trolley wheels and (b) their arrangement

Wheels are designed to fit into the frame and fork via dropouts and hold tires. The wheel material selected for this project is filled rubber. Figure 3 shows the design of trolley wheels and their fabrication with plate.

D. Wheel Plate

(a)

(b)

Figure 4. (a) Sheet metal plate for wheel frame; (b) tri-star metal plate

Firstly, the plate is marked with triangular scale to cut into equilateral shape and for drilling. Figure 4 (a) shows 9 inch square metal plate having 0.5 cm thickness which is used for the wheel frame. In the second step, it is cut with hand grinder after the plate is marked as shown in figure 4 (b). A specially designed wheel frame is required to hold the three wheels together on each side of the shaft. The shaft is cut into 3 inch pieces to set up the wheels on wheel frames as shown in figure 5. Frame arrangement is suitable to transmit exact velocity ratio. It also provided higher efficiency and compact layout with reliable service. Easier maintenance was possible in case of replacing any defective parts such as nut, bolt and washer.

Figure 5. Fitting the tri-star plate with shafts

E. The Design of Shaft

The shaft is designed to rotate the member and which has a circular cross section and it is used to transmit power. Mild steel material is selected for this design and the diameter of shaft is estimated 0.75-in and length is 21-in.

Figure 6. The design of shaft

Figure 6. The design of complement trolley

III. METHODOLOGY

A. Maximum Force Required to Pull the Trolley

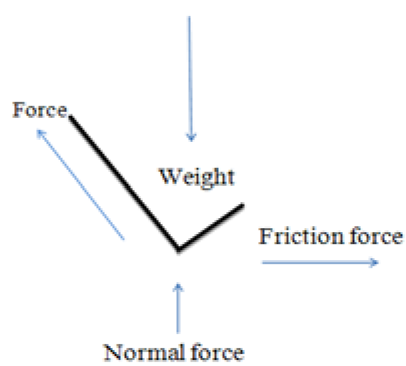

Figure 7. Force acting on the trolley

The forces acting on trolley in x and y directions are shown in figure 7. When the trolley climbed up the stairs, it is needed to incline at about alpha degree.

From the x-direction,

$$\sum F_x = ma_x \tag{1}$$

$$F \cos \alpha - F_f = ma_x \tag{2}$$

$$F \cos \alpha - f \times F_n = ma_x \tag{3}$$

From the y-direction,

$$\sum F_y = ma_y \tag{4}$$

$$F \sin\alpha - W + F_n = m a_y \tag{5}$$

Where,

F = Maximum force required to pull the trolley
m = Mass of trolley plus carried load
a = Acceleration of the trolley when load carrying on stairs
f = Friction coefficient between trolley wheel and concrete
W = Weight of trolley plus load carrying on stairs
F_n = Normal force to the trolley

B. Selection of Bearing

Static and dynamic load can be found the following equations;

$$C_0 = f_0 \times i \times z \times D^2 \times (\cos \beta)^2 \tag{6}$$

$$C = f_c (i \times \cos \beta)^{0.7} \times z^{2/3} \times D^{1.8} \tag{7}$$

C_o = Basic Static Radial Load for Bearing Acting from the Shaft
C = Basic dynamic load for bearing acting from the shaft
i = Number of rows of ball in bearing
z = Number of balls per row
D = Diameter of the steel ball
B = Nominal angle of contact between the line of action of the ball load and a plane perpendicular to the axis of bearing
f_o = Static Radial Load Constant
f_c = Dynamic Radial Load Constant

C. Design of Shaft

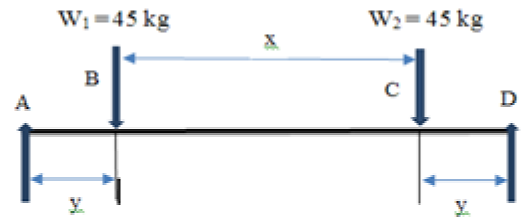

Figure 8. Load acting on the shaft of the trolley

When the shaft is subjected to an axial load (F) in addition to bending loads, then the stress due to axial load must be added to the bending stress.

$$\sigma_b = \frac{32 \times M}{\pi \times d^3} \tag{8}$$

For solid shaft,

$$\sigma_1 = \frac{32M_1}{\pi d^3} \tag{9}$$

In case of a hollow shaft, the resultant stress is as follows,

$$\sigma_1 = \frac{32M_1}{\left\{\pi (d_o)^3 \left(1\text{-}k^4\right)\right\}} \tag{10}$$

D. Specification Data

The specification data for this research are included in table 1.

Item	Marking	Value	Unit
Number of rows of balls	i	1	-
Diameter of ball	D	10	mm
Nominal angle of contact	β	42	deg
Friction coefficient between	f_c	50	-

trolley wheel and concrete			
Number of balls per roll	z	8	-
Distance between wheel and one edge of shaft	X	7	mm
Distance between two wheels	Y	65	mm
Weight mounted on one wheel	W1 =W2	45	kg

IV. RESULTS AND DISCUSSIONS

The estimated design data are shown in table 2 for this study.

Table 2. Theoretical result data for shaft design

Item	Marking	Value	Unit
Velocity at x direction	v_x	18.32	mm/s
Velocity at y direction	v_y	13.05	mm/s
Acceleration at x direction	a_x	0.964	mm/s^2
Acceleration at y direction	A_y	0.687	mm/s^2
Weight of trolley and load	W	882.9	N
Mass of trolley and load	m	90	Kg
Maximum force	F	644.3	N
Normal force	F_n	287.02	N
Static load	C_0	6.6	kN
Dynamic load	C	10.3	kN
Bending stress	σ_b	164.67	N/m^2
Diameter of shaft	d	1.8	cm

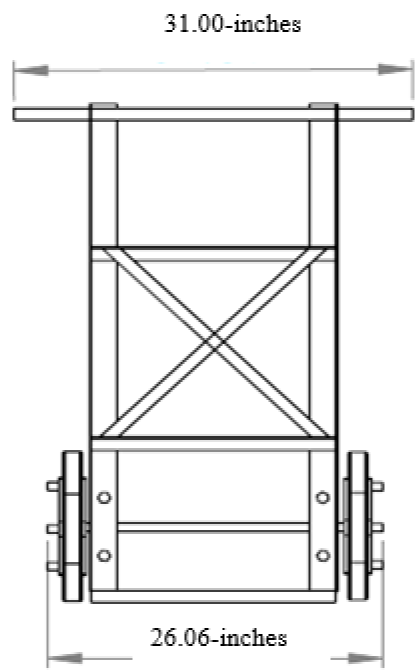

Figure 9. Modelling for back view of trolley

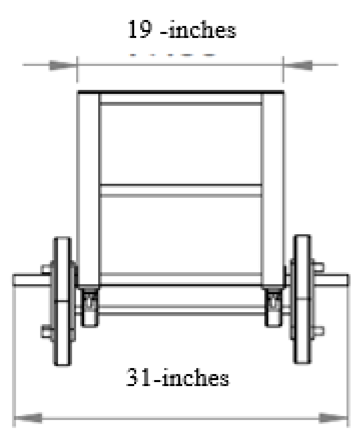

Figure 10. Modelling for top view of trolley

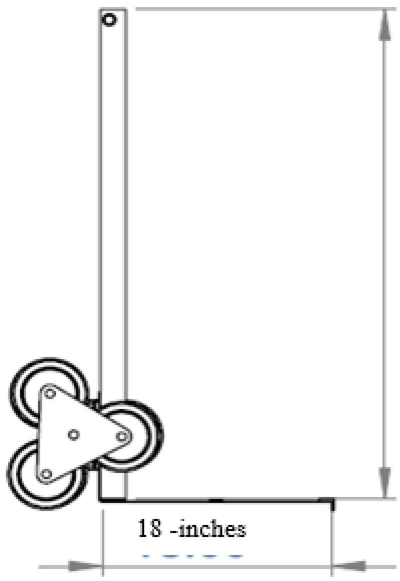

Figure 11. Modelling of side view of trolley

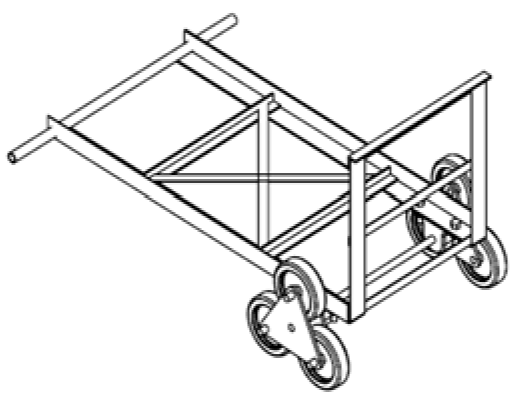

Figure 12. Isometric view of stair climbing trolley

In the basic models, some problems were identified. A lot of effort is required to adjust the inclination of the hand trolley for provide stable transportation of the loads. As a result of operator gets out of control when climbing the stair, the accident can occur due to the load roll back. This trolley has a pair of ground engaging wheels which wear quickly because of the heavy load bearings downwardly directly on the wheels. Another problem is used only for small stairs because of the size of their wheels which is limited to a maximum diameter due to the Tri-Star shaped plate. Need more space to be keep away when not use. Only luggage type good can be transported but small items cannot be filled. This project is made for maximum load of 60kg. Thus, loads greater than 60 kg cannot be carried by the stair climbing trolley.

V. CONCLUSION

Doing better work with lesser effort has been the main objective of human beings in any field. Stair climbing trolley can be used to lift objects, books, food grains and boxes above the ground level, or even patients to move upper level from ground where there is not lifting facilities. It can also move upper level through stairs, or run in very rough and rocky surfaces and, the man effort is reduced and time to lift the load is also reduced. The main effectiveness of the project is stair climbing mechanism for load carrier with decreasing effort. Although this project has some limitations regarding the strength and built of the structure, it can be considered to be a small step forward, as far as stair climbing vehicles are concerned. The initial cost of the project seemed to be higher but more accurate manufacturing will be shorten this. If this product can be fully automated and produced at a lower cost the acceptance will be unimaginable.

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