Design & Fabrication of Tri-Wheel Stair Case Climbing Hand Trolley

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Abstract - *Now-a-days simple mechanical devices like hand trolleys with single and dual wheel are finding their use in large number of industries as well as for household purposes. But their usage is limited to carry goods along the floors from one location to the other. Out of the formulated designs that are available in the market, no design fulfils the need of support in shifting the load over stairs. To eliminate this difficulty, stair wheels (combination of three wheels) are used as a substitute which will reduce the effort of lifting. The present paper focuses on the design and manufacturing of a tri-wheel stair climbing hand trolley to move along rough surfaces and to transport considerable loads over stairs with the improved wheel arrangement, with comparatively less human effort & manufacturing cost. The design concerns including steepness of the stairs, steadiness and speed of the trolley while climbing the stairs are discussed. Hybrid trolleys such as tri wheeled ones can be adopted to carry several items at various locations where mechanical elevators cannot be installed.*

Keywords — *climbing hand trolley, stairs, lifting, transportation, stair wheel frame, bearings, axel, shaft, Low Cost.*

I. INTRODUCTION

In the early 2000s, a research group has come up with a rover type of vehicle [1] with rhombus configuration with one wheel mounted on a fork in the front, one wheel in the rear and two bogies attached on either side of it. Chang Hsueh-Er came up/suggested/proposed with a five wheeler trolley [2], which can be operated manually. Anastasios et al. and D. Helmick et al. has designed a robotic carrier with no wheel attached and was driven by belt. Serious research has been done to redesign such mechanisms to make them efficient, economical and affordable.

Urbanization results in structurally congested buildings in the rural areas in many countries where availing elevator facility is difficult. Even in the small industries and construction sites the load is transferred by means of cranes which can lead to accidents/slips in some cases. Stair climbing trolleys acts as a replacement in locations where human labour seems to be the only alternative, thereby reducing human effort. They are designed to safely manoeuvre heavy items which may exceed 150 kg for instance refrigerators, washing machines, cupboards, water cans, books, small containers, food grains, toxic items etc., from ground floor to top floor and vice versa.

The objective here is to design and manufacture a multi functioned trolley that serves different purposes which includes moving on the floor and climbing the stairs. In the early designs, a single wheel or a set of wheels set on each side is merely capable of moving the vehicle on flat surfaces. Here the modelling is done in such a way that it has tri wheels on every facet that enables shifting the load over stairs. It comprises of two sets of three wheels attached to a frame at $120^{0,}$ positioned at the bottom of the trolley which works as a single unit. Handles are provided to give support to the frame and apply the human effort either to push or pull the trolley. The size, shape, selection of the frame, position of the trolley changes as per the working load and requirement. With bearing support, the wheels are mounted on the shaft. Material selection is also a main consideration. In general, Stainless steel is used to carry heavy loads and mild steel is preferred [3] for moderate loads. The movement of stair wheel trolley on steps is shown in fig1.

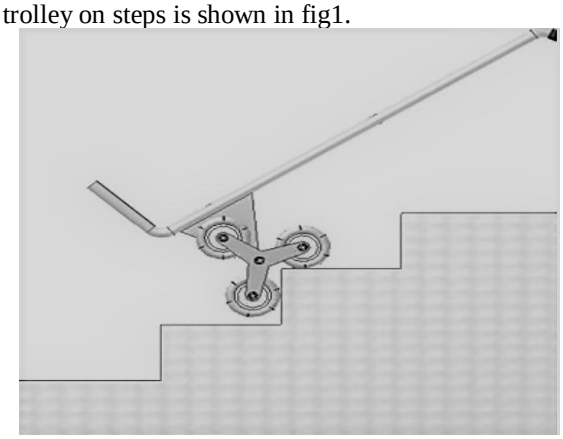

Fig1:movement on stairs

II. DESIGN

A. Determination of Basic Dimensions

The basic external dimensions were considered based on literature survey only [4]. But the designed model has the dimensions which are calculated based on the step size (height and width) where the fabricated model is going to be tested. The design of the vehicle is so modest allowing others to use stairs at once.

- The external diameter of the solid shaft is taken as 25 mm.
- The length of the shaft is 825 mm.
- Two pairs of Quasi-static frames and a total of six rubber wheels are used [5].
- The diameter of wheel is taken as 120 mm for suitable dimensions of the stairs which is about 140-150 mm in height and 300-350 mm in depth.
- The inter-lobe angle of Tri-Star clamp is assumed as 120˚.
- The distance between the centres of two wheel was taken as 190 mm.
- The distance between two wheel frames is taken as 635 mm.

B. Design Calculation for Tri- Star Wheel:

Stair-wheels have been designed for traversing stairs with height 14 cm and width 30 cm.

To calculate the length of the tri star plates and minimum and max radius of wheels the following formulas are used [6].

Where

a= height of stair = 140mm

b=width of stair = 300mm

t = 25mm

Height and width of the stairs is shown in Fig2

Distance between frame center and wheel center

$$R = \sqrt{\left(\left(a^2 + b^2\right)/3\right)} = 191\text{mm}$$

Minimum radius of wheel,

$$r_{min} = \frac{6Rt + a\left(3b - \sqrt{3a}\right)}{\left(3 - \sqrt{3}\right)a + \left(3 + \sqrt{3}\right)b} = 75.5\text{mm}$$

Maximum radius of wheel

$$r_{max} = \sqrt{\left(\left(a^2 + b^2\right)/3\right)} = 165\text{mm}$$

Mean radius r = 120.25 mm

Maximum allowable height of stair

$$a_{max} = \sqrt{3R^2 - r^2} = 308\text{mm}$$

Designed height is much lower than the allowable height.

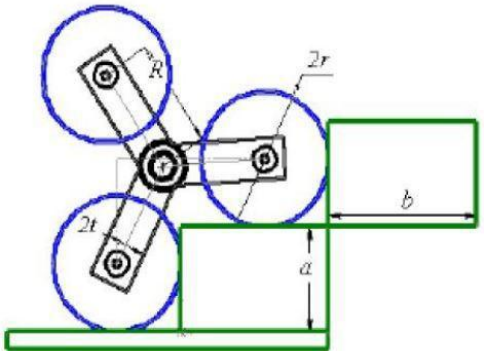

Fig2: Tri-wheel on stairs

C. Design Methodology

The tri star wheel trolley presented here is designed using the version CATIA P3 V5 R11. CATIA is a multi-platform mechanical design suite. It is a characteristic aided supported, parametric solid modelling design tool. Conceptualization, design, engineering, manufacturing and PLM are multiple phases supported by CATIA.

It is easy to transform 2D sketches into 3D parts in CATIA as it has user-friendly graphical interface. By means of using automatic or user described relations to confine design objective complete 3-D replica are generated with or without constraints. To perform operations like add, remove, rotate, sweep and cut the material while modelling, the different features used are Pad, Pocket, Revolve, Rib, Slot, Loft etc. for this design [7].

D. Designed Parts

After calculating the basic design dimensions of the Stair climber, each part is designed with the help of CATIA. All the designed parts are described below in detail.

a). Body

The body is designed for a height of about 650mm and is later fabricated with Mild Steel. The handle is attached to the extreme rails of the trolley body on either sides at an angle of 20^0 (with vertical). The base of the trolley is welded and it is made up of Mild Steel material. The design of trolley body side view and front view are shown in Fig3 and Fig4 respectively.

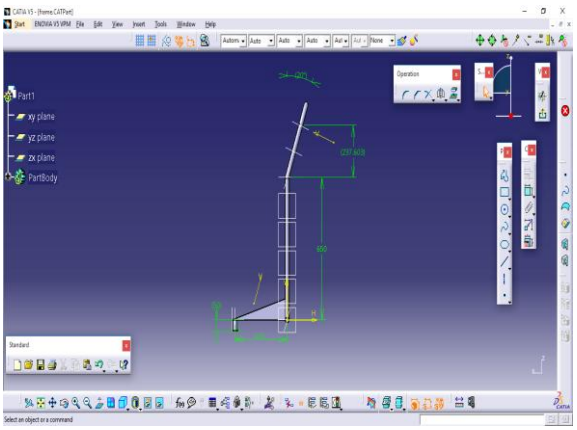

Fig3: Design of trolley body (side view)

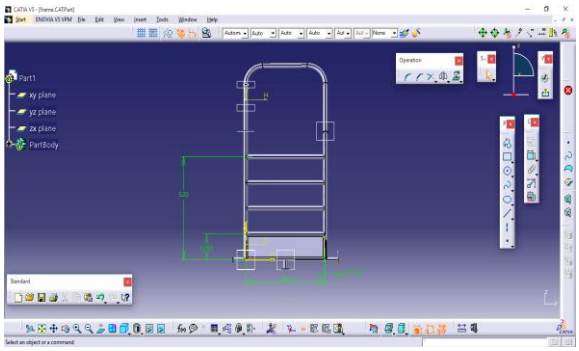

Fig4: Design of trolley body (front view)

b). Tri-Star Wheel Frame

The following figure shows the design of Tri-Star wheel frame as per the dimensions, which holds the three wheels together. The modification of the wheel frame is the main task in the project [8]. To climb stairs with a single wheel is tedious. As per the wheel alignment to the frame Tri-wheel setup rotates when it hits the edge of the stairs in the climbing process. The design of frame is shown in Fig5

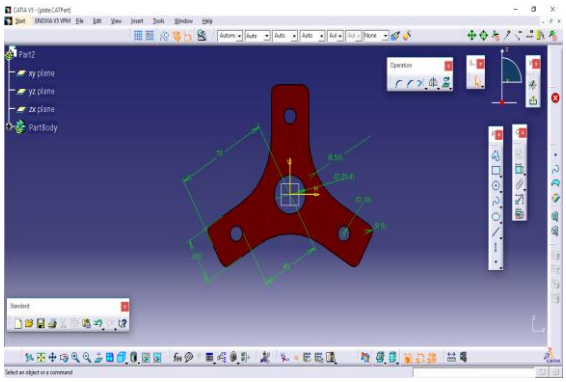

Fig 5: Design of Quasi-static frame

c). *Wheels*

Stair-wheels are designed for traversing stairs with 140mm in height and 300mm in width. As per the stair dimensions, each wheel should be having the external and internal diameters as 60mm and 40mm respectively. The same is designed in CATIA as shown in Fig6.

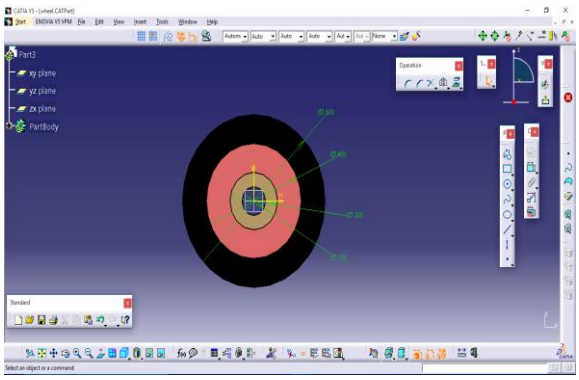

Fig6: Design of wheel

d). Assembly Of Wheel, Frame And Body

The wheel which is fixed to the frames on either side is then assembled to the solid shaft. External thread is cut at both ends of the shaft. Nut and bolt are used to lock the wheel assembly with the shaft.

III.MATERIAL SELECTION & FABRICATION

The fabrication of the trolley begins with the fabrication of quasi Tri-Star frame setup. Various links are joined together using welded and bolted joints.

A. Tri Star Wheel Frames

It is used to hold the wheels together. The wheels are joined to each of the arms of the frame and while climbing the stairs Tri-Star setup rotates as it hits the edge of the stairs. The sequence of operations involved in the fabrication of Tri-Star frame setup are oxy-fuel gas cutting, grinding, drilling, and boring. Though straight wheel frame is easy to manufacture quasi static wheel frame (shown in Fig7) is selected with a 50mm radius curve in between two arms in order to provide strength and stability to the wheels and the angle between two wheel axes is 120^0 for smooth functioning. The maximum thickness is maintained as 5mm. Stainless steel is selected with high chromium and low carbon content in order to minimize corrosion & carbide precipitation due to welding.

Fig7: Cutting of Tri-Star wheel frame

B. Wheel

The coefficient of friction between floor surface and wheels should be taken into account while selecting the material for wheel. The possible materials available are rubber, steel, polyurethane etc. out of which rubber has more coefficient of friction with respect to concrete floors. Therefore rubber is chosen as the wheel material. Deep groove ball bearings are selected according to the wheel requirements and are fitted as shown in the Fig8. Wheels and quasi frame assembly is shown in Fig9.Wheels, frame and shaft assembly is shown in Fig10.

Fig8: Wheels used

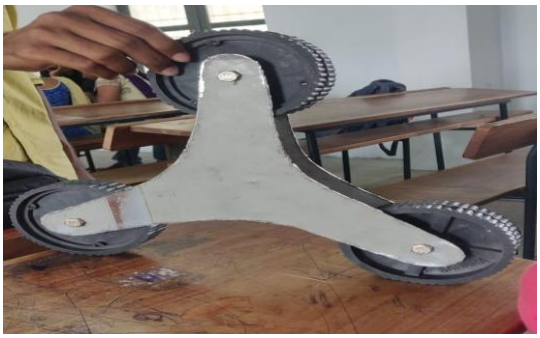

Fig9: Wheels and Tri-Star frame assembly

Fig10: Wheel and Shaft Assembly

C. Trolley body

Mild steel is selected for the trolley body as mild steel offers material properties that are suitable for many applications than iron. The density of mild steel is approximately 7850 kg/cm^3 the Young's modulus is 210GPa. Mild steel has comparatively low tensile strength, but it is cheap and malleable. Therefore mild steel metal pipe of circular cross section with one inch diameter is used to make the handle & body. Final assembly is shown in Fig11.

Fig11: Fabricated trolley

IV. CONCLUSIONS

The primary objective of bearing heavy load like 120-150 kg is achieved during testing. The performance is slightly complicated when the straight frame was tested for varying step sizes. But when tested with Quasi-static frame, the vehicle exhibited greater performance even for stairs with different dimensions. Static structural analysis demonstrates that it is capable of moving heavy loads with less deformation and without any fracture.

To operate with ease a motor can be arranged to the vehicle. Usually, its minor shortcoming is its noise. But it is very ergonomic to operate on stairs, inclines and uneven surfaces. It is efficient, economical and easy to assemble. It is proposed for material handling. Several advantages with this machine are effortless transportation of Heavy luggage, furniture from one floor to other. Bricks of different models and sizes can be easily carried in construction sites. The overall performance of the vehicle is observed as high with uniform steps.

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