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DESIGN AND MANUFACTURING OF STAIR-CLIMBING TROLLEY

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ABSTRACT

This project aims at 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. 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. In the light of this, the project attempts to design a stair climbing hand trolly which can carry heavy objects up the stairs with less effort compared to carrying them manually. It also endeavors to study the commercial viability and importance of such a product. Several designs were conceived that would allow a non-industrial hand trolley to travel over stairs, curbs, or uneven terrain while reducing the strain on the user.

In our project, the trolley is equipped with Tri-Star wheels which enable us to carry load up and down the stairs. It also eases the movement of trolley in Irregular surfaces like holes, bumps,

I.INTRODUCTION

A hand trolley is a small transport device used to move heavy loads from one place to another. It is a very common tool used by a large number of industries that transport physical products. Also called a hand truck or a dolly, the hand trolley is often used by stock persons who arrange and restock merchandise in retail stores. When used properly, trolleys can protect people from back injuries and other health problems that can result from lifting heavy loads.

A typical hand trolley consists of two small wheels located beneath a load-bearing platform; the hand trolley usually has two handles on its support frame. These handles are used to push, pull and maneuver the device. The handles may extend from the top rear of the frame, or one handle may curve from the back. An empty hand trolley usually stands upright in an L-shape, and products are usually stacked on top of the platform. When the goods are in place, it is tilted backward so that the load is balanced between the platform and the support frame. Especially if heavy or fragile materials are moved, the person operating the trolley should return it to an upright position carefully, to insure nothing falls off the platform. The front of the frame may be squared off for boxes or curved for drums and barrels. Sometimes, a hand truck also has straps for securing loose freight during transport. Professional material handlers prefer to use a hand truck when moving stackable items such as boxes,

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crates or packages. Heavier items are usually stacked on the bottom of the hand truck, with lighter objects saved for the top. Hand truck users must be careful not to stack it so high that their vision is blocked or the load becomes unstable. Generally, it is safe to load a hand truck to the level of its handles or the top of the frame. The load is then shifted onto the wheels with a backwards lifting motion. The user can maneuver the cargo by steering it left, right or forward.

II. OBJECTIVES OF STUDY

- The main objective of this project is to reduce the manual efforts.
- Combining various components to the simple trolley to create a multifunctional trolley which will help to climb on stairs automatically.

III.TRI-STAR WHEEL

3.1 TRI-STAR WHEEL DESIGN

The Tri-Star wheel was designed in 1967 by Robert and John Forsyth of the Lockheed Aircraft Corporation. They were first developed as a module of the Lockheed Terrasrae, a commercially unsuccessful amphibious military vehicle. A Tri-Star wheel functions as an ordinary wheel on flat ground, but has the ability to climb automatically when an impediment to rolling is encountered. This wheel design consists of three tires, each mounted to a separate shaft. These shafts are located at the vertices of an equilateral triangle. The three shafts are geared to a fourth, central shaft (to which a motor may be attached).When geared in this quasi-planetary fashion, these triangular sets of wheels can negotiate many types of terrain, including sand and mud; they can also allow a vehicle to climb over small obstructions such as rocks, holes, and stairs. The wheel assembly may be gear-driven, with two wheels in rolling contact with the ground. The third wheel idles at the top until the lower front wheel hits an obstruction. The obstruction prevents the lower front wheel from moving forward but does not affect the motion of the driving axle. This causes the top wheel to roll forward into position as the new front wheel. This wheel usually lands on top of the obstruction and allows the rest of the assembly to vault over the obstruction. Tri-Star wheel in motion is shown in figure 3.1.

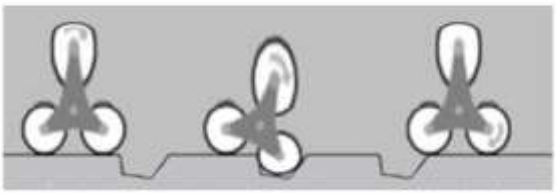

Fig3.1 Tri-Star wheel in motion

3.2 APPLICATION OF TRI-STAR WHEEL

- In our project, we are using this Tri-Star wheel arrangement in a hand trolley in the place of normal wheels setup to enable the trolley to climb up.
- Down the stair cases and also to up come small obstacles like holes and bumps on its path.

IV.SELECTION AND FABRICATION OF STAIR CLIMBER TROLLEY

4.1 MATERIAL SELECTION

- Material selection is a step in the process of designing any physical object. In the context of product design, the main goal of material selection is to minimize cost while meeting product performance goals.
- Systematic selection of the best material for a given application begins with properties and costs of candidate materials.

4.1.1 Trolley body

Material Used- Mild Steel

- **Mild Steel**

Mild steel, also called as plain-carbon steel, is the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications, more so than iron. Low-carbon steel contains approximately 0.05–0.3% 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. It is often used when large quantities of steel are needed, for example as structural steel. The density of mild steel is approximately 7850 kg/cm3 and the Young's modulus is 210 GPa (30,000,000 psi).

4.1.2 Tri-Star wheel web

Material Used- Stainless Steel Grade 304

- **Stainless Steel Grade 304:**

Steel Type 304 is a variation of the basic 18-8 grade, Type 302, with a higher chromium and lower carbon content. Lower carbon minimizes chromium carbide precipitation due to welding and its susceptibility to inter-granular corrosion. In many instances, it can be used in the "as-welded" condition, while Type 302 must be annealed in order to retain adequate corrosion resistance. Type 304L is an extra low-carbon variation of Type 304 with a 0.03%. Maximum carbon content that eliminates carbide precipitation due to welding. As a result, this alloy can be used in the "as-welded" condition, even in severe corrosive conditions. It often eliminates the necessity of annealing elements except for applications specifying stress relief. It has slightly lower mechanical properties than Type 304.

4.2 BEARING SELECTION

- **Ball bearing**

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 30mm, minimum load carrying capacity of 50kg radially and speed greater than 100rpm.

- **Bearing Selected - SKF 6006 Open Deep Groove Ball Bearing**

30x55x13mm

Inside Diameter: 30mm

Outside Diameter: 55mm

Width: 13mm

This 6006-2RS 30x55x13-millimeter sealed ball bearing has deep groove geometry for high speeds and supporting both radial and axial loads. This bearing has rubber seals on both sides of the bearing to keep lubricant in and contaminants out, and comes pre-lubricated from the manufacturer so that no additional lubrication is required. This deep groove sealed ball bearing is for use in applications that involve combined radial and axial loads, and a need for high running accuracy at high rotational speeds. Such applications include clutches, drives, gearboxes, compressors, pumps, turbines, and printing and textile machines, among others.

4.3 WHEEL SELECTION

Wheel material selected – Filled rubber

4.3.1 Types of Wheel Material

4.3.1.1 Filled rubbers

- In tires 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 tire that comes in contact with the road surface. The portion that is in contact with the road at a given instant in time is the contact.
- Treads are often designed to meet specific product marketing positions.

4.3.1.2 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.

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- The main ingredients to make polyurethane are isocyanides and polyols.
- Other materials are added to help processing the polymer or to change the properties of the polymer.

4.3.1.3 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.

4.3.2 Static friction

- The surface of the wheel and what it is rolling on are not perfectly smooth. They have irregularities shown in figure 4.1.

Fig4.1 **Close-up showing surface roughness**

- In sliding friction, this surface roughness is the reason for the static and kinetic resistance to motion. Although the wheel is not sliding, the surface roughness causes a "jiggle" when the wheel is rolling.

4.3.3 Various Wheel Materials and their Co-efficient of Frictions

Various Wheel materials and their co-efficient of frictions are tabulated in table 4.1 and shown graphically in figure 4.2.

Table4.1 **Various Wheel Materials and their Coefficient of friction**

Sr. No	Material	Coefficient of friction
1	Rubber/concrete	.85

2	Polyurethane/ concrete	.5
3	Steel/Concrete	.45

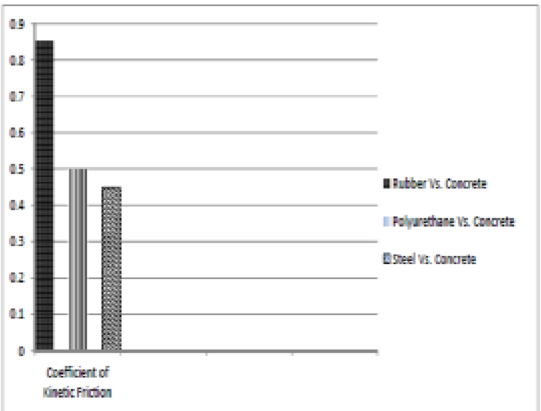


Fig 4.2 **Coefficient of kinetic friction of various tire materials and concrete Surface**

4.4 WHEEL FRAME

A specially designed wheel frame is required to hold the three wheels together on each side of the shaft. 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 reason, three wheel set on each side of vehicle attached with frame was introduced to provide smooth power transmission in order to climb stairs without much difficulty. 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.

4.4.1 Types of wheel frames

A few types of wheel frames are shown in the figure4.3, 4.4 and 4.5

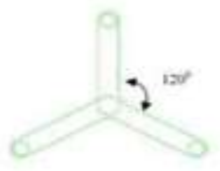


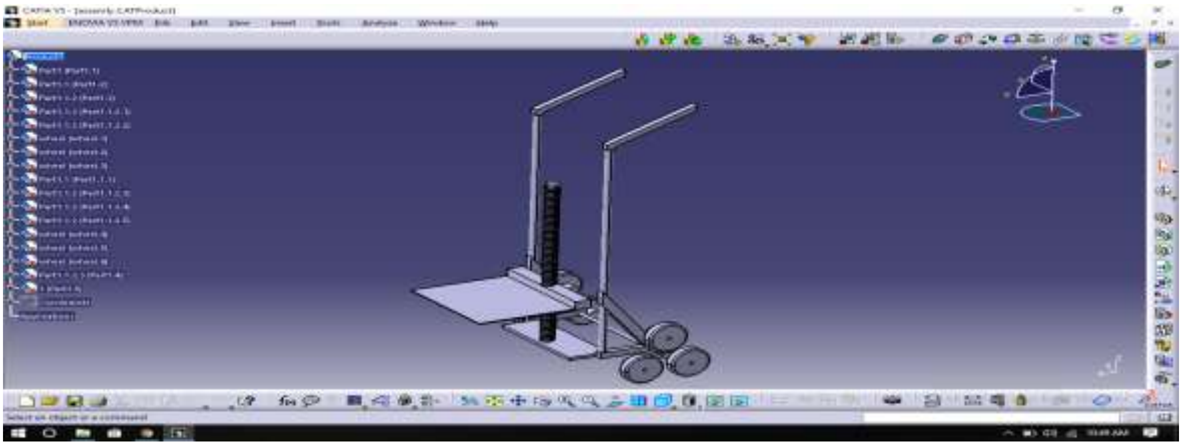
Fig 4.3 Straight Wheel Frame

Fig 4.4 Curved Wheel Frame

Fig 4.5 Quasi Planetary Wheel Frame

V. CAD MODEL OF TROLLEY

The cad diagram of trolley is shown in the figure 5.1 & 5.2.



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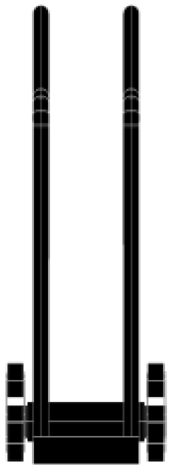

Fig 5.1 Front view

Fig 5.2 Isometric View

VI.PROCESSES INVOLVED IN FABRICATION

6.1 Gas cutting (Oxy-Fuel cutting)

Oxy-fuel cutting is a cost-effective method of plate edge preparation for bevel and groove welding. It can be used to easily cut rusty and scaled plates and only requires moderate skill to produce successful results. The oxy-fuel gas cutting process creates a chemical reaction of oxygen with the base metal at elevated temperatures to sever the metal. We have used this cutting to cut the measured lengths of hollow mild steel pipes and flat bottom plate as per our design.

6.2 Pipe bending

Tube bending as a process starts with loading a tube into a pipe bender and clamping it into place between two dies, the clamping block and the forming die. The tube is also loosely held by two other dies, the wiper die and the pressure die. The process of tube bending involves using mechanical force to push stock material pipe or tubing against a die, forcing the pipe or tube to conform to the shape of the die. Often, stock tubing is held firmly in place while the end is rotated and rolled around the die. For some tube bending processing, a mandrel is placed inside the tube to prevent collapsing. Much of the tooling is made of hardened steel or tooled steel to maintain and prolong the tools life. However wherever there is a concern of scratching or gouging the work piece, a softer material such as aluminum or bronze is utilized. Pipe bending machines are typically human powered, pneumatic powered, hydraulic assisted, hydraulic driven or electric servomotor. We have employed human powered-tube bending process to bend two mild steel hollow pipes to make 60_ bent handles.

6.3 Plasma arc cutting

Plasma cutting is a process that is used to cut steel and other metals of different thickness and sometimes other materials, using a plasma torch. In this process, an inert gas is blown at high speed out of a nozzle; at the same time an electrical arc is formed through that gas from the nozzle to the surface being cut, turning some of that gas to plasma. The plasma is sufficiently hot to melt the metal being cut and moves sufficiently fast to blow molten metal away from the cut. Through the application of CNC technology in industrial production, the technology cut a wide range of high accuracy, low-cost and high efficiency. It gradually achieves its purpose of high- tech computer numerical control cutting, with both computer- controlled and plasma arc characteristics We have used plasma arc cutting for cutting four stainless steel webs for the Tri-Star wheel arrangement which is shown in figure 4.9

Fig 4.9 Plasma Arc cut Tri-Star wheel web

6.4 WELDING

Welding is a fabrication process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower melting-point material between the work pieces to form a bond between them, without melting the work pieces. Many different energy sources can be used for welding, including a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound.

While often an industrial process, welding may be performed in many different environments, including open air, under water and in outer space. Welding is a potentially hazardous undertaking and precautions are required to avoid burns, electric shock, vision damage, inhalation of poisonous gases and fumes, and exposure to radiation. The main Types of welding used in industry and by home engineers are commonly referred to as MIG welding, Arc welding, Gas welding and TIG welding.

6.4.1 Arc welding

These processes use a welding power supply to create and maintain an electric arc between an electrode and the base material to melt metals at the welding point. They can use either direct (DC) or alternating (AC) current, and consumable or non-consumable electrodes. The welding region is sometimes protected by some type of inert or semi-inert gas, known as a shielding gas, and filler material is sometimes used as well. We have used Arc-Welding to join trolley parts together.

VII.DESIGN ANALYSIS OF TROLLEY

7.1 LOAD CALCULATION FOR AXLE

Length of the axle =0.44m

Distance between welds = 0.40m

Load applied/ carried = 30 kg (distributed equally by the welds to the axle)

=15 kg through each weld = 147.15N

Weight of the trolley = 20kg (uniformly distributed throughout the axle)

=196.2 N

Neglect the overhang beyond welded points since the wheel provides only

Negligible reaction

From equilibrium equationΣ_ = 0

And Σ_ = 0

Find reaction at the supports,

R1= 190.314N; R2= 190.314N

Calculate the maximum bending moment for the beam,

M (max) =6.7155 N-m

Considering FOS =1.5,

M (max) =10.07N –m

Bending equation,

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

Substituting M (max) =10.07 N-m

$$I = \frac{\pi r^4}{4}$$

$$Y = \frac{D}{2}$$

$$\sigma = 3.8 \frac{N}{mm^2}$$

Bending stress for the given material can be assumed to be 0.66×yeild strength

Thus, the allowable bending stress for the given material is 165 N/mm^2

The calculated bending stress for the material is within the allowable bending stress for the material, thus the design is safe.

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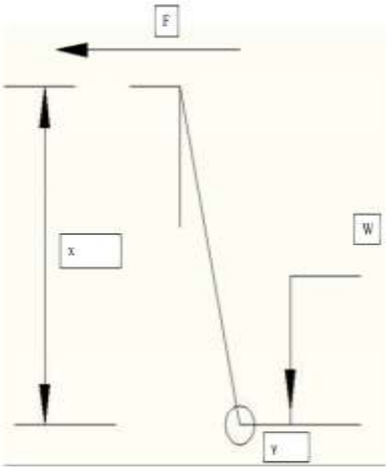
7.2 FORCE NECESSARY TO PULL THE TROLLEY

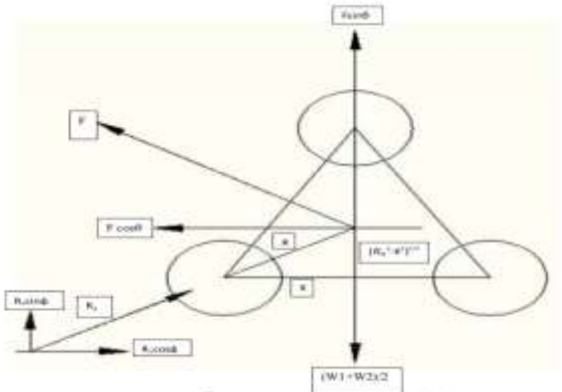


Maximum load determination

$$F.x = W.y$$

$$F = \frac{y}{x}.W$$

7.3 FORCE ANALYSIS ON WHEEL FRAME



Forces acting on the system

Where,

W1= weight of object to be carried

W2= weight of the trolley

Re = reaction force on one side

F = force applied (on one lever)

R_0 = distance of centroid from centre of wheel

K = distance between centre of wheel and line of action of weight

$$\left(\frac{W1+W2}{2} - Fsin\theta\right).k = Fcos\theta.\sqrt{R^2-k^2}$$

$$R_e cos\varphi = Fcos\theta$$

$$R_e sin\varphi + Fsin\theta = \frac{W1+W2}{2}$$

$$R_e = \sqrt{(Fcos\theta)^2 + (\frac{W1+W2}{2} - Fsin\theta)^2}$$

$$tan\varphi = \frac{W1+W2-2Fsin\theta}{2Fcos\theta}$$

VIII.INTERFERENCE

After its fabrication, we inferred few limitations like large noise production while moving the trolley up and down the stairs. In order to reduce the noise production the design of the wheel frame is to be modified such that line passing through the mid-point of the trolley wheel should pass through the mid-point of the step. The modified wheel CAD model is shown in figure 7.1.

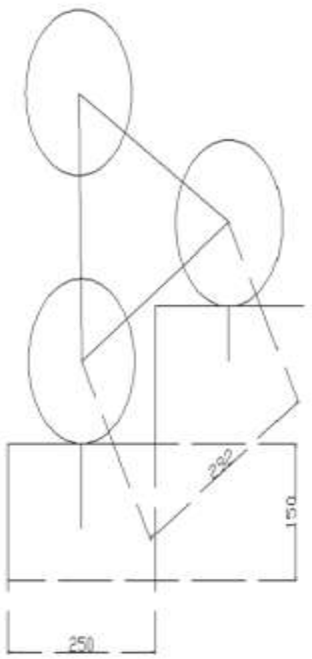


Fig 7.1 Modified Wheel Frame Setup

IX.CONCLUSION

Though this project had 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. During the test run of this project, it was realized that it wouldn't be a bad idea to consider this design for carrying heavy loads up the stairs. This product will be well acclaimed if it can be commercialized to suit the needs. Though the initial cost of the project seemed to be higher but more accurate manufacturing would shorten this. As far the commercial aspects of this product are concerned, if this product can be fully automated and produced at a lower cost the acceptance will be unimaginable. Presently, there are no competitors for such a kind of production our market.

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