DESIGN AND FABRICATION OF STAIR CLIMBING HAND TRUCK

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Abstract

This topic deals with the designing and manufacturing of a hand truck, which can climb stair with less effort compare to carry it manually. The technical issues in designing of this vehicle are the stability and speed of the vehicle while climbing stairs. However, the steepness of the stairs is also the important concern of this study. The uses of this special vehicle are in the frequent lift of goods such as books for library, medicines for hospital, regular goods of any technical or non technical institutes, or transportation any toxic material for industries and give freedom to the retarded person or paralyzed patients to move anywhere over flat surface as well as stairs. The vehicle has four wheels arrangement to support its weight when it moves over the flat surface. Each set wheel frame consists of three wheels attached with nut and bolt. Using of this vehicle, the labor cost can be reduced as well as huge amount of loads can be transferred uniformly with less power consumption. Moreover, considering some drawbacks due to lack of implementation of all techniques during manufacturing phase the test and trial run showed considerably significant and encouraging results that might help the future researchers to incorporate a gear box and steering mechanism to make the vehicle more versatile.

Keywords: Stair climbing vehicle, wheel frame, bearings, axel, ratchet mechanism.

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1. INTRODUCTION

Lifting objects ,loads such as books, food grains etc. to store above the ground level, or even patients to move upper level from ground is not easy job, especially where there is no lifting facilities (elevator, conveyer, etc) Moreover, in most of the buildings in the world does not have elevators or escalators. In this case human labors are considered to be the only solution. Labor is becoming costly as well as time consuming in the developed countries, where growth rate is getting negative. This problem can be solved if a vehicle can lift loads while

traveling through stairs. The project introduces a new option for the transportation of the loads over the stair. Most of the buildings of the country are structurally congested and unavailing of elevator facility so it is difficult and laborious to lift up heavy loads. The stair climbing hand truck can play an important role in those areas to lift loads over a short height, like libraries, hospital, and in construction area. The vehicle, which can move upper level through stairs, or run in very rough and rocky surfaces, is called stair climbing hand truck or say stair climbing vehicle.

Stair climber trolleys have a total of six wheels, three on each side. They are set in a triangular pattern. The uppermost wheel rests on the upper step, with the other two wheels set on the lower step. This allows you to apply leverage as you pull the trolley up a set of stairs

Some stair climber trolleys have a locking mechanism on the wheels to lock them in place. Other trolleys feature a double handle for increased sturdiness. The width of the nose plate, the base of the trolley where the load sits, may vary from 7 inches to an extra-wide 14 inches. More expensive trolleys are battery powered.

As we enter the second millennium since the time of Christ there is an increasing mindfulness of the need to focus technology on helping people. This has been in part on account of many countries currently experiencing what is referred to as an “aging population,” that is the number of children born has continued to reduce over a long period of time. The result of this along with many other factors has caused the need for a reducing number of care workers to care for an increasing number of persons. One specific area of need is that of providing increased freedom in terms of mobility for the elderly or disabled.

The reasons being to provide an optimum quality of life for the disabled or elderly, and to reduce the load on care workers, the two aspects being closely linked by the conscious sense of being a “burden” . Autonomy in the area of mobility has always been highly valued, but is sometimes impaired by some form of disability. In many cases this results in reliance on some form of external transport mechanism. In this regard traditional wheelchairs and powered wheelchairs continue to play a vital role. However wheelchairs to date provide a high level of mobility only in artificial or “barrier free” environments. That is there remains a significant gap between the obstacle negotiating ability of a wheelchair and that of the average able bodied person. This aspect is perhaps most apparent when considering stair-climbing. While modern

architecture and new policies continue to make newly built areas as “accessible” as possible to persons with a wide variety of disabilities steps will always be a reality in the “real world”.

This thesis focuses on the study of stair-climbing capable mechanisms for the elderly or disabled. Common mobility assistive techniques and devices are outlined in this section and recent advances in curb and stair climbing devices are outlined.

2. Methodology of design modification

2.1. Modification of roller which only rolls over flat surface to the rollers which can climb the stairs

Figure 2.1.1: Initial design

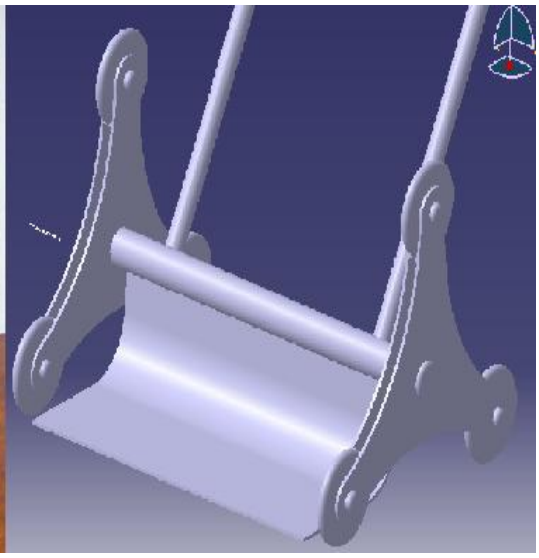


Figure 2.1.2: Final design

In the initial designs (shown in fig 2.1.1), each single or double wheel set on either side is only capable of moving any vehicle on flat surface, but further study on same topic helps us to carry any goods on vehicle on stairs (shown in fig 2.1.2). In this concept we attached set of three wheels on either side of vehicle rather than single or double wheel. These three wheels are attached to frame 120º apart with help of nut and bolt.

2.2 Modification of straight to curved wheel frame

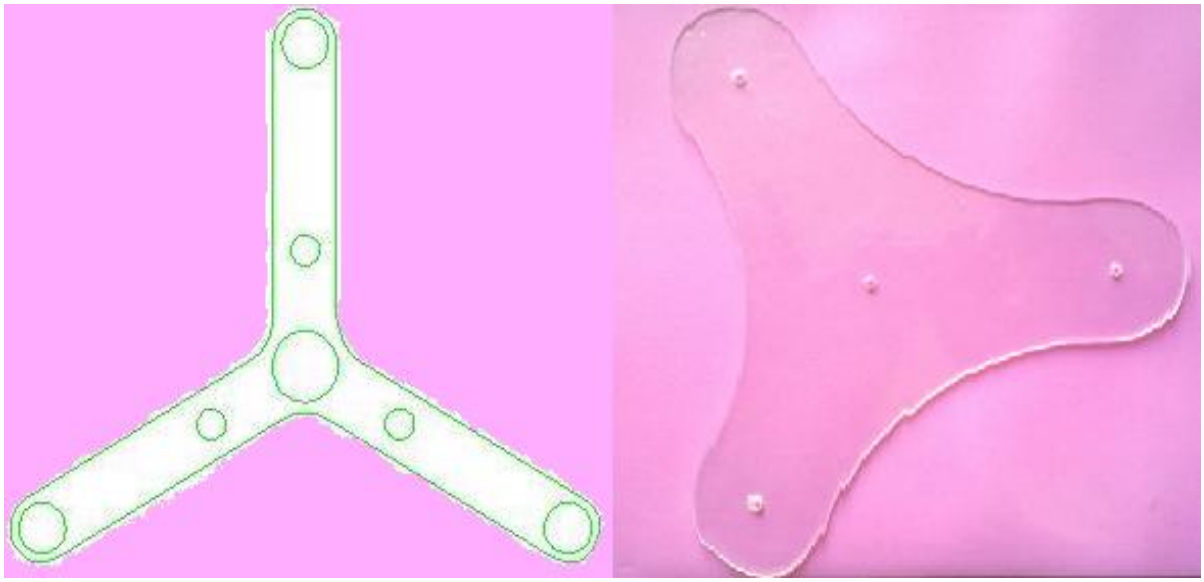


fig. 2.2.1: Initial wheel frame fig. 2.2.2: Modified wheel frame

The straight wheel frame shown in the figure 2a takes more thrust to tilt the wheel frame to engage next planetary wheel. The length of each arm is high and thus creates vibration and the vehicle would be unstable. In the present design, the wheel frame was made curve so that the front surface of the arm could not collide with the edge of the stair. The optimization of the curvature was done to eliminate above problem. The curve wheel frame (fig. 2.2.1) also requires less power to tilt compare to straight frame (fig. 2.2.2).

2.3 Ratchet Arrangement

A ratchet Mechanism is based on a wheel that has teeth cut out of it and pawl that follows as wheel turn. Studying the diagram you will see that as ratchet wheel turns and pawl falls into 'dip' Between the Teeth. The ratchet wheel can only turn in one direction. Ratchet mechanism very useful device for example they are used in Mechanical lock, Bicycle, Kick of a Bike. They are also very useful when using a system, such as the one seen opposite, to lift heavy weight. It allows positive motion of vehicle in either direction and locked in other

direction which serves the braking function of vehicle. A wheel provided with suitably shaped teeth, receiving an intermittent circular motion from an oscillating or reciprocating member, is called a **ratchet wheel**. A simple form of ratchet mechanism is shown in fig. 2.3.2 *A* is the **ratchet wheel**, and *B* is an oscillating lever carrying the **driving pawl**, *C*. A **supplementary pawl** at *D* prevents backward motion of the wheel. If you try this mechanism, you may turn the crank of the link mechanism. The rocker will drive the driving pawl to drive the ratchet wheel.

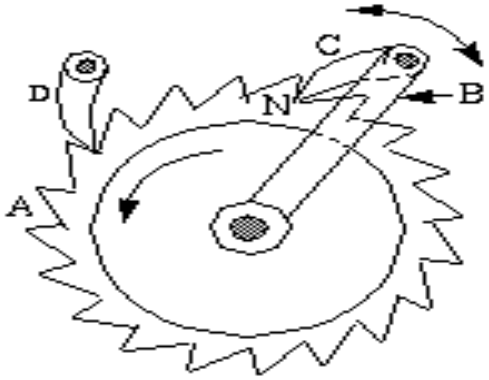


Fig. 2.3.1 Ratchet mechanism

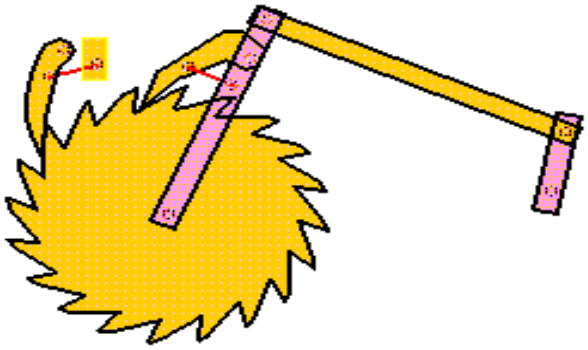


Fig. 2.3.2 Ratchet mechanism

2.4 Modified design.

In the first design, the power transmission to the single or double wheel trolley is useless to climb the stairs due to height factor of stairs creates huge obstacle on the way of vehicle. also The design of the straight wheel frame became more complicated and was needed modified with its curve- spherical shape to give proper drive, which create 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 obstacles. 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. In fig 2.4.1, the arrangement of vehicle parts such as wheel frame, wheels, washer, nuts and bolts are shown. The wheel is attached to the wheel frame at three corners of frame and shaft is attached at the centre and the. Planetary wheels are getting power from the human power via center shaft and bearing arrangement. Two

wheel frames are attached both side of the wheel arrangement.

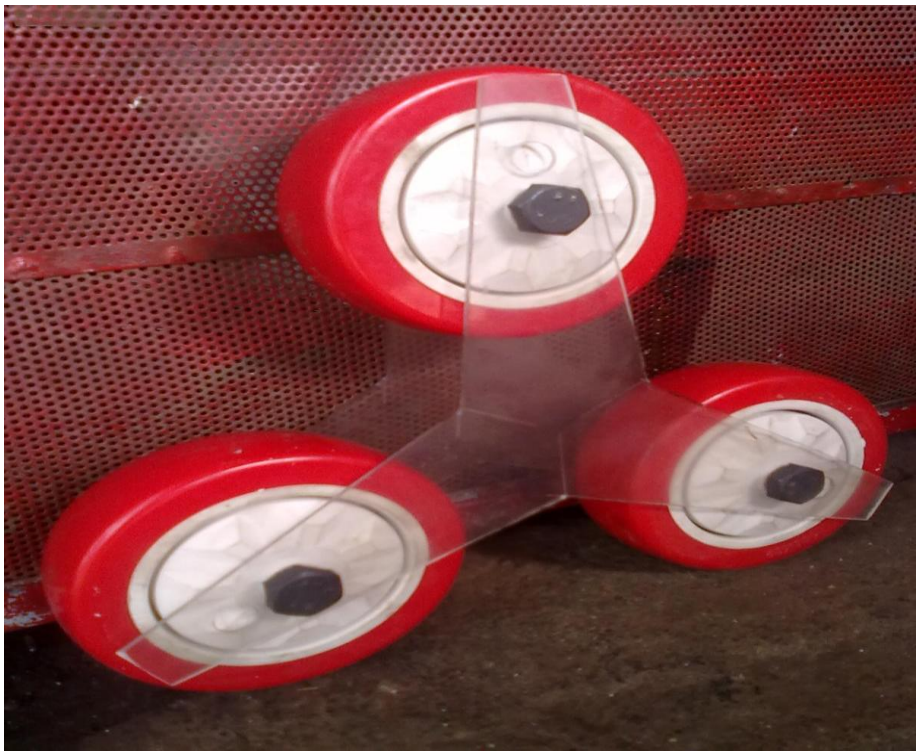


Fig. 2.4.1 3D view of wheel arrangement

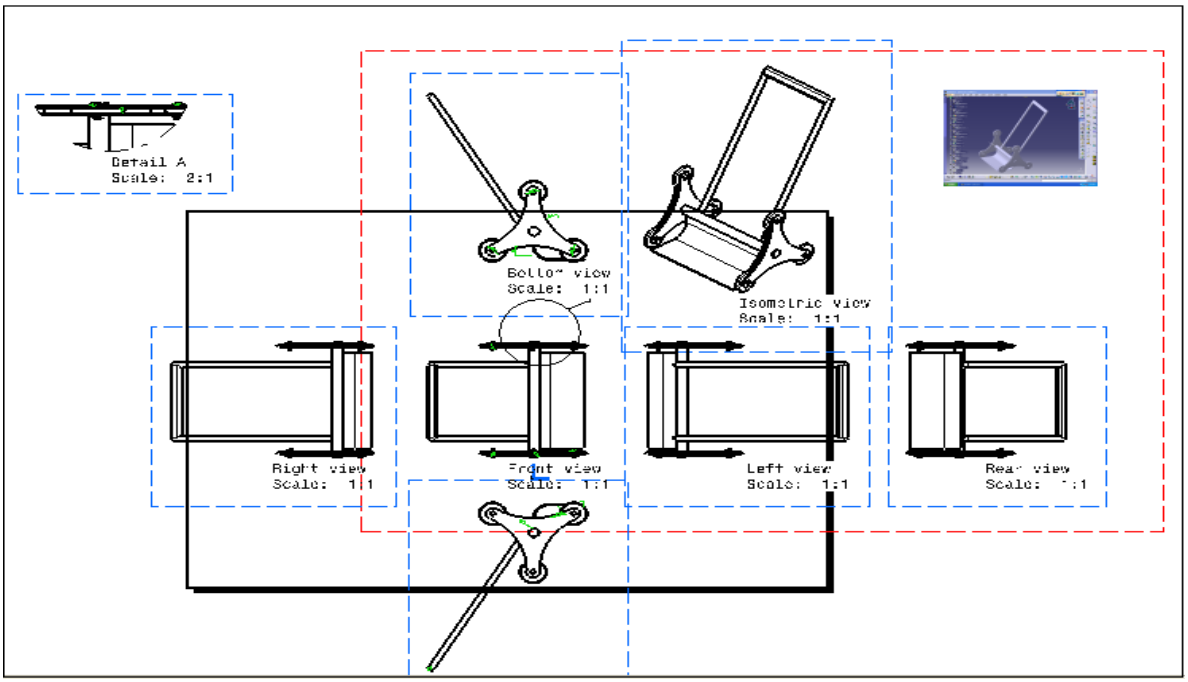
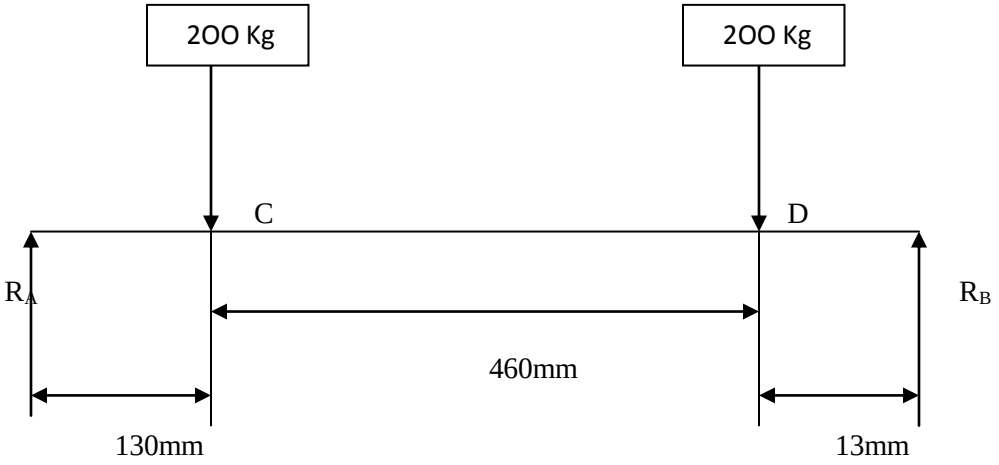


Fig. 2.4.2 Drafting Modified design

2.5 METHODOLOGY OF DESIGN OF AXLE



F = 200 kg = 1962 N

Under equilibrium condition sum of all vertical forces is zero,

Calculation of end reaction at support-

$R_A - 1962 - 1962 + R_B = 0$

$R_A + R_B = 3924$ N

Taking moment about A

$\sum \mathbf{m_A = 0}$

$(1962 * 130) + (1962 * 590) - (R_B * 720) = 0$

$R_B * 720 = 1412640$

$R_B = 1412640 / 720$

$R_B = 1962$ N

$R_A = 1962$ N

Where,

R_A - vertical reaction at A

R_B – vertical reaction at B

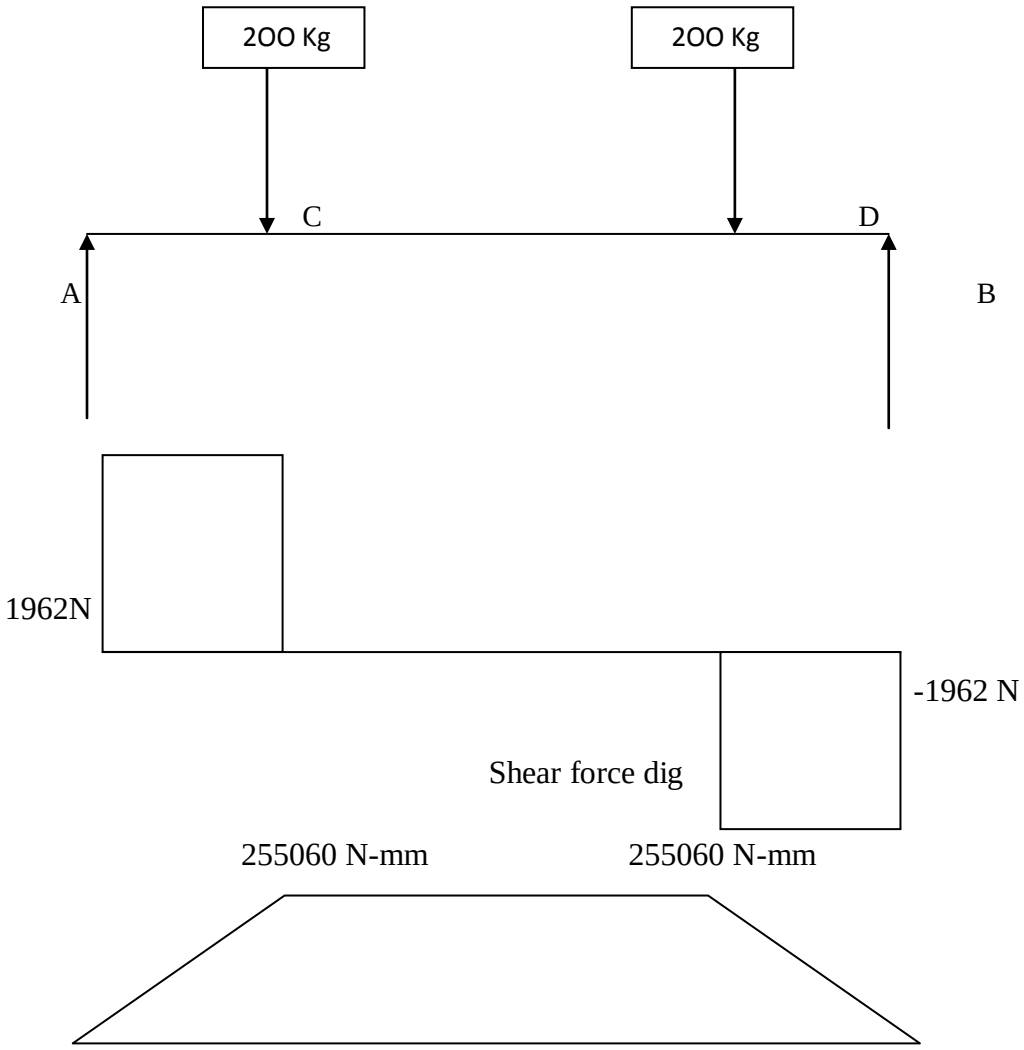
Shear Force calculation

S.F at A= 1962 N

S.F at C=0

S.F at D= -1962 N

S.F at B= 0



Bending moment dig

B.M. Calculation:

Bending moment at A =0

Bending moment at B =0

Bending moment at C

1962 * 130 = 25560 N mm

Bending moment at D

1962 * 130 = 25560 N mm

Considering the maximum bending moment

$\mathbf{M= \pi/32 * d^3 * \sigma_b}$ (considering F.S. =2)

$\sigma_b = \sigma_{yt}$ / factor of safety

For SAE 1040 Yield Stress σ_{yt} = 350 N/mm^2 (from data book)

Therefore, σ_b = 350 / 2 = 175 N/mm^2

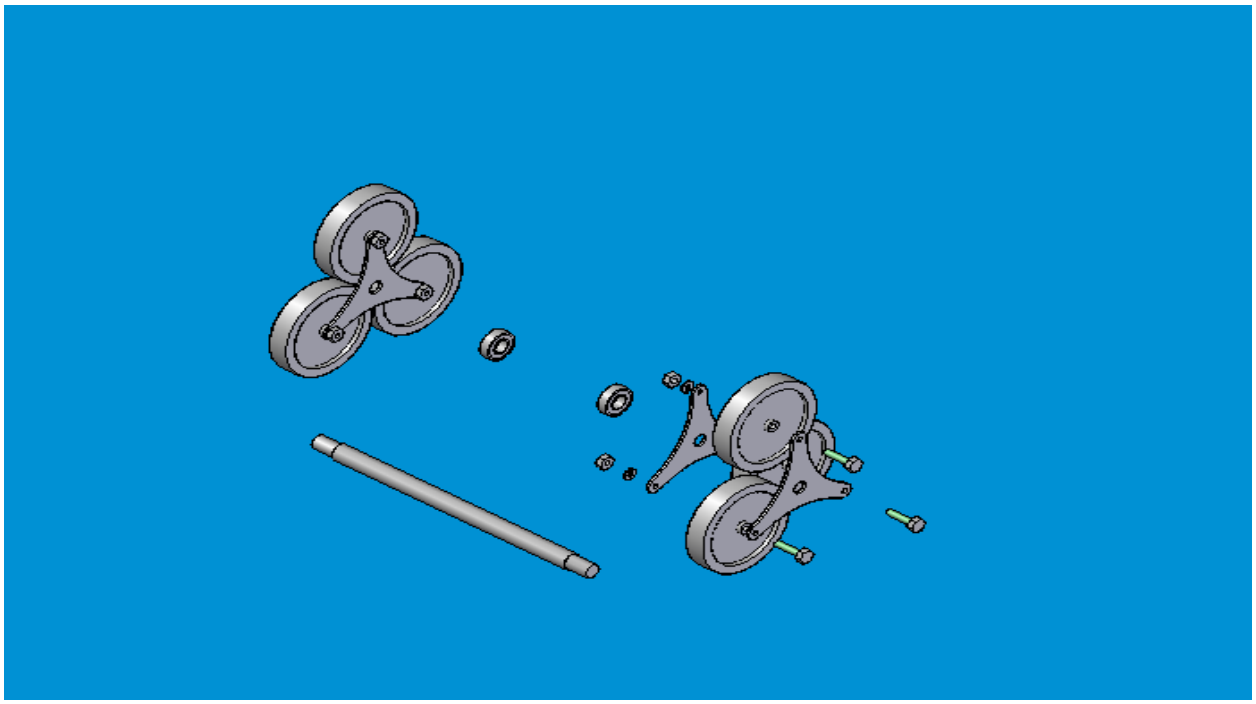
$255060 = \pi/32 * d^3 * 175$

$(255060*32) / (175 * \pi) = d^3$

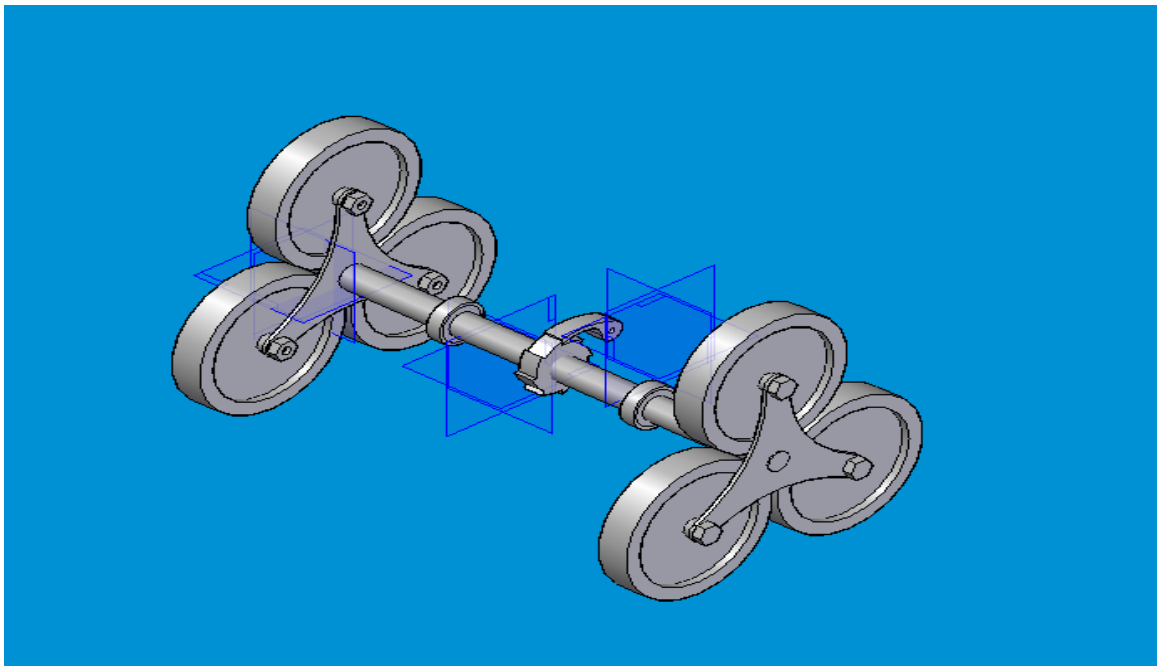
D = 24.57 mm say 25 mm

D= 25 mm

2.6 Assembly and Disassembly of stair climbing hand truck in CAD



2.6.1 Disassembly of Stair Climbing



2.6.2 Assembly of Stair Climbing

2.7 Methodology for manufacturing stair climbing hand truck

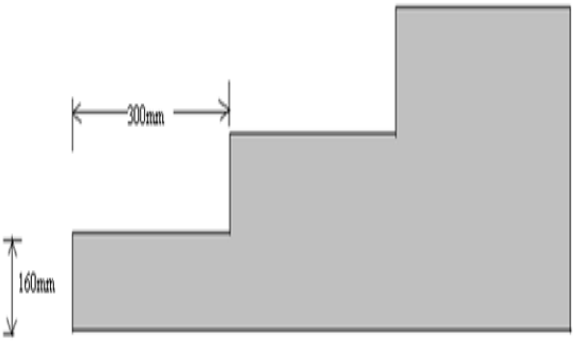


Fig. 2.7.1: stair dimensions

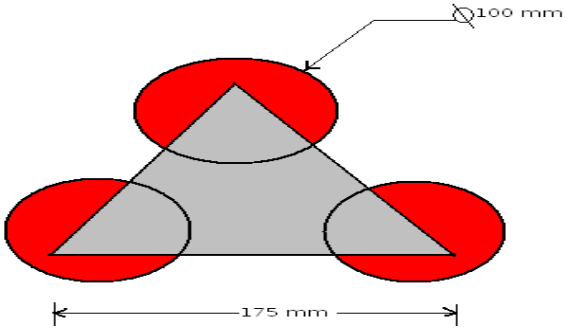


Fig.2.7.2: wheel arrangement with frame

1) First of all we collect the data of topic on which we are working

2) The important technical issue of the project is speed of vehicle and the size of stair.

3) We select appropriate wheels of greater strength and capacity to carry req load of material.

4) So, we measure the height, width and angle of inclination, and it is observed are as follows

   a. Width of stair 300 mm
   b. Height of stair 160 mm
   c. Angle of inclination of stair 36^0

5) Accordingly we decide, size of frame in which wheel has to be mounted.

6) Our next step is to clamp the wheels and frame with the help of nut, bolt and washer.

7) In this way two set of wheel is prepaid as shown in above figure.

8) Now another challenge is come in picture that is of the Design and selection of the shaft that connects both the set of wheel and also it's another function is to carry the load impulse by the goods place on carriage.

9) After designing the shaft the process of turning, facing, threading, drilling is carried out to serve the purpose of it

10) Then we select exact bearing which will fit on wheel frame (6205 ball bearing)

11) This bearing is support the shaft at both ends.
12) Now Shaft which is processed by different operation is inserted in wheel frame on which bearing is fitted.

13) Shaft and wheel frame is clamped by washer and nut, and also check nut is provided to have additional tightness

14) In this way, the mechanism which will climb the stair is ready.

15) Next to this, we have to construct the carriage to carry the goods.

16) For this purpose, we select the hollow pipe of 9 mm external dia.

17) Cut it and welded it, according to require shape and size.

18) Then the finishing operation is carried out.

19) Finally Project is ready after painting it.

3. Results and Analysis

When the trial was taken it was found that the vehicle was moving well over the stair. It can move on flat surface uniformly at 20 rpm without any fluctuation and there was no variation of speed over steps. It was observed that there was very low noise and vibration over flat surface or stair. It was observed that the vehicle was disturbed when it faced the stair of different step sizes. This was because of the shape and size of the wheel frame. Therefore for a range of stairs size can be considered for this vehicle. Although, different sizes step are not usually available in building design. It showed good performance when the step size was uniform. Here in this project separate frame can be used to move over the stair of different size and shape, which made its use over wide range of size of stairs. From the test run of the vehicle it was seen that the maximum height the vehicle could climb the stair whose inclined angle was 44° maximum. If the inclination is more than 44° it would fail to climb the stair. In building construction, very few stairs are generally available having inclination more than that i.e.44°. The smooth ramp angle (θ_s) was not listed for the vehicle. But it can be easily predicted that stair inclined angle (θ) is less than that of ramp (θ_s).

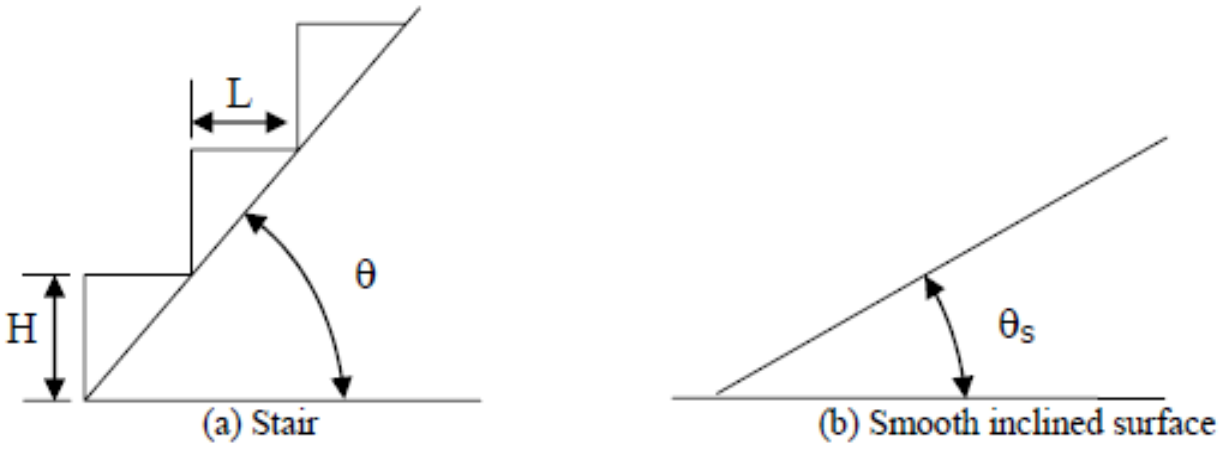


Fig.2.8.1: Maximum climbing angle, (θ, θ_s)

The velocity of the vehicle during climbing the stair was higher than that on the flat surface as the wheel frame (higher radius) was used to climb stair. The velocity of the vehicle on the stair was 55 in/hr. However; the speed of the vehicle running on a ramp was not measured. This speed should not be higher or equal to the speed on the horizontal surface. From the above discussion, it could be summarized that considering some of the limitations, the vehicle was an effective alternative to transport loads using stairs. Some limitations could not be avoided because of the lacking in technological availability. This pioneer project, with a little further improvement, was hoped to be succeed to meet up the demand of carrying loads over the stair.

3.2 Labor saving

The Power Mate Motorized Stair climbing Hand Truck reduces the effort required to move heavy loads by over 87%. This means that what is normally a two man job is easily moved by one. Loads requiring four men can be safely handled by two.

3.3 Safety

Power Mate Motorized Stair climbing Hand Trucks do 100% of the lifting virtually eliminating the risk of back injury. Using the push buttons on the hand grips, the operator has 100% safe control of the load at all times. Therefore, there is little likelihood of damage occurring to steps, carpet, walls, floors and product

3.4 What is the maximum inclination for normal use?

This is approved that the inclination of 44 degrees which covers more than 90% of all stairways. We recommend that you stay within this limit. There is an optional maximum inclination warning alarm (not included in standard models) that alerts the operator of an inclination of more than 44 degrees. You would still be able to operate the equipment but be aware that you are exceeding the limit and thus take the necessary safety precautions. We have decided to give you this choice knowing that should you be in a difficult position, for example if the motor stalls, major problems in removing the load from the Track would be eliminated.

3.5 What will happen if the stair inclination exceeds 44 degrees?

Please note that the stair has not been approved beyond 44 degrees. You should not try to use the stair inclination under these conditions. If you get into this precarious position involuntarily, this is what will happen: the stair climbing vehicle fails to climb the stairs. One thing to bear in mind is there are no brakes if you slip down to the bottom it goes. Also if someone does something stupid like try to take a big refrigerator down by themselves the outcome won't be pretty because you don't have the opportunity to decide it is too heavy, instead you will all arrive the bottom in short order if you manage to keep up. If there is a wall or window there will also be some renovating to do. Having moved lots of times before with a regular hand truck I would have to say this was far better experience. Nothing can make moving fun but this well worth the money.

4. Conclusion.

Though this project had some limitation as a first step of making any Stair Climbing hand truck, it was a pioneer project. During the test run of this project, it was realized that it would capable of carrying heavy load without suffering any deformation or local fractures if it would go into real world production at an ideal scale. Though the initial cost of the project seemed to be higher but more accurate manufacturing would shorten this.