Design of Stair Climbing Trolley
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Abstract—Stair Climbing Trolley is generally used for the carrying heavy weights with the help of less human effort. The manufacturing of the Stair Climbing trolley deals with proper design, accurate fabrication. 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 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 to climb stair. Using of this vehicle, the labour cost can be reduced as well as huge amount of loads can be transferred uniformly with less power consumption. In our project, the trolley is equipped with Tri-Star wheels which enable us to carry load up and down the stairs. This type of trolley can be used in both purposes i.e. carrying load on same floor as well as carrying load from stairs.

Keywords: Human Effort, Heavy Load, Stair Climbing

I. INTRODUCTION
This stair climbing trolley is one of the simplest operating vehicles which require less human effort without any external electrical power input to operate the trolley and move on the ground even though the path is uneven. The wheel mechanism adjusts itself to stair to climb different floors by vehicle and also on rough ground. Even though main researchers investigated on fabrication and design of stair climbing trolley less effort where implemented to perform analysis on cabin structure and wheel alignment. In this trolley the efforts are insisted to carry analysis on entire trolley structure is including wheels and fabricated with optimal measurements with suitable materials. 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 are 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. 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. Stair Climbing Trolley consist of 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. More expensive trolleys are battery powered. In this regard traditional wheelchairs and powered wheelchairs continue to play a vital role. However, wheelchairs to date provide a high level of movement only in artificial or “barrier free” environments. Lifting heavy loads like cupboard, refrigerator, washing machine etc. up to 100 kg is not easy job, especially where there are no lifting facilities (elevator). Moreover, in most of the buildings in the rural areas does not have elevators or escalators. In this case human labors are considered to be the only solution. Labor is becoming costly day by day, where growth rate is reducing. This problem can be solved if a trolley can lift loads while traveling through stairs.

II. OBJECTIVES OF RESEARCH
- To design all parts of trolley i.e. frames, wheels, bearing, and assembling them with modeling software AUTOCAD software according to specific dimensions.
- Fabrication of trolley based on above analysis with accurate measurements to withstand maximum load.
- To reduce the man power and efforts for heavy domestic load shifting through stairs.
- Trolley that can be used for stair climbing as well as hand trolley on the same floor.

III. WORKING PRINCIPLE
The climbing motion is made possible by the Tri-Star wheels alone. In the proposed model, the Tri-Star wheels are made of a set of three individually rotating wheels, with each individual wheel’s center equidistant from the center of the web. It is basically a three-socked wheel, with individual wheels attached at each end. While moving along a flat surface, two of the three wheels will be in contact with the ground surface and will roll along the ground, just as a normal wheel would. The mechanism comes into action when a stair case is encountered. One of the two wheels on the ground will come in contact with the riser of the first stair. At this point of time, this wheel will not be able to rotate along its own axis. Since, continuous force is being applied by the user as it is being pulled up the stairs, the trolley tends to move along the direction of application of force. Here, the Tri-Star setup rotates, along the axis of the main hollow shaft and allows the second individual wheel, to touch the tread of the first stair.
At this moment, the orientation of the Tri-Star with respect to the observer would have changed. Thus, the Tri-Star wheel swivels about the main shaft. Since there is continuous force application, the riser will exert and equal and opposite force on the first individual wheel. This enables the Tri-Star wheel to rotate and the entire trolley moves up the first step. This process will keep repeating for the entirety of the staircase and will enable the trolley to climb it. A similar process occurs when the trolley moves down the stairs as well but in this scenario, the Tri-Star wheels need not rotate completely along its axis while moving down the stairs.

IV. DESIGN CALCULATIONS

Stair climbing trolley is design to lift a load of 100kg. The hollow shaft connecting the two Tri-Star wheels is made of Mild Steel and the diameter is designed in such a way that the shaft overcomes the bending stresses acting on it. So it will act as a simply supported beam

Total Weight \( F = 100kg = 981 \text{ N} \)
Design of Axle,
Under equilibrium condition sum of all vertical forces is zero,
Calculation of end reaction at support.

\[
RA - 490.5 - RB = 0
\]
\[
RA + RB = 981 \text{ N}
\]

(490.5 * 100) + (490.5 * 550) – (RB * 650) = 0
RA = 490.5 N
RB = 490.5 N

Where, Shear Force Calculation

\[
\begin{align*}
\text{Shear Force at A} &= 1962 \text{ N} \\
\text{Shear Force at C} &= 0 \text{ N} \\
\text{Shear Force at D} &= -1962 \text{ N} \\
\text{Shear Force at B} &= 0 \text{ N}
\end{align*}
\]

Shear Force at A= 1962 N
Shear Force at C=0 N
Shear Force at D= -1962 N
Shear Force at B= 0 N

Bending moment Calculation –
Bending moment at A =0 Nmm
Bending moment at B =0 Nmm
Bending moment at C = 490.5 * 100 = 49050 Nmm
Bending moment at D = 490.5 * 100 = 49050 Nmm
Considering the maximum bending moment ,
\[
M = \frac{\pi}{32} * d^3 * \sigma_b \text{ (considering F.S. =2)}
\]

\[\begin{align*}
\text{Where,} \quad \sigma_b &= \frac{\sigma_{yt}}{\text{factor of safety}} \\
\sigma_{yt} &= 350 \text{ N/mm}^2 \text{ (from data book)}
\end{align*}\]

\[
\sigma_b = \frac{350}{2} = 175 \text{ N/m}^2
\]

\[
49050 = \frac{\pi}{32} \times d^3 \times 175
\]

\[
d = 14.18 \text{ mm}
\]

\[
d = 15 \text{ mm}
\]

Design of stair wheel

\[
R = \frac{\sqrt{a^2+b^2}}{2} = \frac{\sqrt{16^2+31^2}}{2}
\]

\[
R = 20.14 \text{ cm}
\]

\[
R = 201.4 \text{ mm}
\]
Minimum radius of regular wheel

\[ R_{\text{min}} = \frac{6Rt + a(3b - \sqrt{3}a)}{(3\sqrt{3} - 20 + 160(3\sqrt{3} - \sqrt{7} + 160)} \]

\[ = \frac{202.87 + 346.93}{202.87 + 346.93} \]

\[ R_{\text{min}} = 77.03 \text{ mm} \]

Maximum radius of regular wheel

\[ R = \sqrt{\frac{a^2 + b^2}{2}} \]

\[ = \sqrt{\frac{160^2 + 310^2}{2}} \]

\[ R = 174.42 \text{ mm} \]

Mean Radius = \[ R_{\text{mean}} + R_{\text{min}} \]

\[ = \frac{251.45}{2} \]

\[ R_{\text{mean}} = 125.28 \text{ mm} \]

\[ R = 125 \text{ mm} \]

\[ D = 250 \text{ mm} \]

Diameter of the wheel = 25 cm

V. MATERIALS

The following material is required for the fabrication of stair climbing trolley.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Components</th>
<th>Material Used</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Shaft</td>
<td>Mild steel</td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td>Bearing</td>
<td>Mild steel</td>
<td>6</td>
</tr>
<tr>
<td>3.</td>
<td>Plywood Plate</td>
<td>Wood</td>
<td>1</td>
</tr>
<tr>
<td>4.</td>
<td>Square pipes</td>
<td>Mild steel</td>
<td>5</td>
</tr>
<tr>
<td>5.</td>
<td>Nut And Bolt</td>
<td>Cast Iron</td>
<td>8</td>
</tr>
<tr>
<td>6.</td>
<td>Wheels (Tyre)</td>
<td>Thermosetting Plastic</td>
<td>6</td>
</tr>
<tr>
<td>7.</td>
<td>Stud And Axle</td>
<td>Mild Steel</td>
<td>6</td>
</tr>
<tr>
<td>8.</td>
<td>Sheet Metal Plate</td>
<td>Aluminium</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1: list of components

Knowledge of Welding, turning, grinding, Sheet metal working was used to assemble the various components.

VI. CONCLUSION

This trolley runs over the stairs very smoothly and in future it can be made fully automated and can be used commercial purpose. 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.

New trolley with star wheel and simple driving mechanism will help to prepare a trolley that will be able to climb without anyone’s assistance or with assistance.

REFERENCES


