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A Theoretical Design Analysis of A Mechanism Capable of Climbing Stairs For Wheelchairs

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Abstract
Ability to walk and run through different terrains is ability with which as humans we are blessed with but due to many unfortunate happenings or some deficiency many people lose this ability but with the advancement of technologies several mechanisms are devised for such people wheelchairs being the one. Some limitations with them is the mobility while moving through stairs thus this paper works on designing and studying a mechanism which is able to climb on the stairs . The proposed design is drawn on Solidworks and a 3D rendered view is obtained using keyshot. Considering the standard stair norms required force analysis has been done considering a no slip condition. Further calculation of the design parameters for the mechanism has been calculated at stable state.

Keywords: Stair climbing, Solidworks, No slip

1. Introduction

A wheelchair is an apparatus used by differently abled people to maintain their own transportability. Various options of wheelchairs are available in market nowadays people according to their comfort cost and requirement can choose out of numerous options. The Wheelchair has obstructions against structure impediments in its manner. Indian manufactures for wheelchairs hardly think about transparency and ergonomics of the people supposed to use them even after the acts like PWD 1995 monitors such practices. Various urban networks of India have kept an eye on the issue by giving different alternatives to the auxiliary limits like giving grades at as far as possible, cutting down Krebs, wheeler seat inclines lifts, etc. yet simultaneously a wheelchair customer needs to orchestrate several designing directions .The maker has attempted to plot a wheelchair capable to climb staircases and hence the issue faced by many wheelchair customers can be addressed. The amount of patients with inability is on the rising according to the primary power report "the worldwide incapacitated people report", there are 650 million people which are around 10% of the overall masses are incapacitated during the 1970s, and now the number has extended to 15%. Developing masses that has unending diseases is rising, which causes the degree of hindered individuals to expand. The going with picture is about the degree change of older people and progressively energetic people from 1950 to 2050, the percentage of the energetic youths is lessening from 13% to 6%, rather than the percentage of old masses.

Joshi [1] created a staircase climber that jumps on staircases with manual exertion. Characteristics related with the instrument incorporate lightweight plan, its size and utilization of worm gear for pivot of shaft. Lin Zhang and Xi Feihong [2] proposed a structure of stair climbing wheelchair in which the planetary wheel component was demonstrated and examined in Auto work area Inventor and Rhino. Highlight of lock framework will keep away from the wheelchair to descend while ascending and down stairs. R Rajeskaret.al [3] planned and created a staircase climbing wheelchair. Rather than utilizing typical wheels, 5 wheels were utilized and each steel pole, on which 5 wheels are fixed, is similarly disposed at 72° from one another. While climbing, the inactive wheel will be in contact with the ground and another wheel will be in contact

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with the stair. The wheelchair moves gradually when it is pulled in reverse towards the staircase.Design and fabrication of unidirectional dumper design of unidirectional instrument is done by Tupkaret. al [4] to assist emptying of loose material on 1800 of the tipper according to the accessibility of room. Paper aimed to expand the effortlessness in emptying trolley. Here joined target work is considered, which limits the weight and centre distance and expands power and proficiency. Demonstration and analysis of tractor trolley axle using ANSYS is performed by Manasaet. al [5]. The potential burdens acting and the spot of burdens are noted. As per the measurements tractor trolley hub is demonstrated utilizing CATIAV5 programming and their determination. Shindeet. al [6]developed a three way dropping dumper using direction control valves that actuate the ram of a pressure driven chamber for lifting the trailer lodge in require side. Further alterations and working confinements will place this work in the principle alliance of utilization. This idea spares time and vitality which prompts proficient working. Hamed [7] provided the design of robot capable of hiking stairs for the rescue operations in case of a war or other type of emergencies design comprises of a large motor driven wheel to climb the stair while rear wheel to provide movement over debris. Urvashiet. al [8] Worked on a project which was able to provide stable support to the person on a wheelchair while moving through a wheel chair, work has been conducted to maintain the centre of gravity lower, the mechanism was designed using Solidworks while the force and stress analysis was conducted on ANSYS.

2. Design

The CAD model of the Stair-o-bot is displayed in thefigures 1 and 2. CAD software used is “Solidworks”, for rendering software used is “Keyshot”.

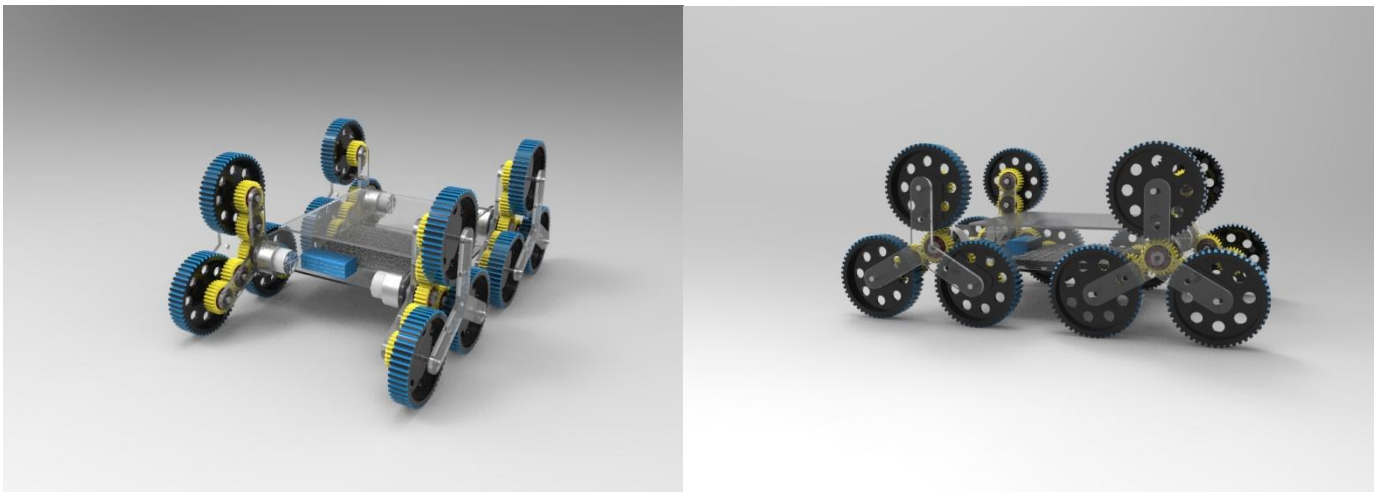

Figure 1 Rendered view as developed in 'Keyshot'

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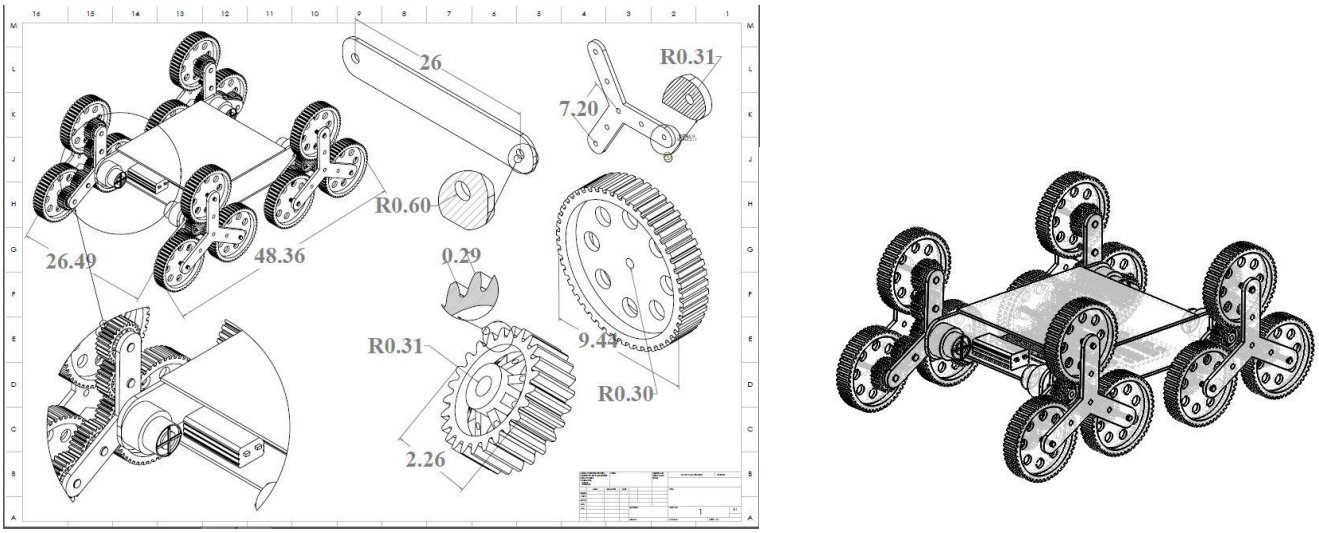

Figure 2 Draft sheet (dimensions in cm) and wire frame view

3. Calculations

3.1.Parameters

The deviation in the dimensions for the planetary wheels framework is limited by the stairs norms, the wheels of this design requires a steady help on the means all through the technique for rising stairs, if wheel diameters are outrageously enormous, the mechanism can't oversee itself on the steps, if the diameter is excessively minor, the mechanism can have a lower effectiveness once it proceeds onward on a levelled surface, and it's a poor capacity to adjust to the ground.

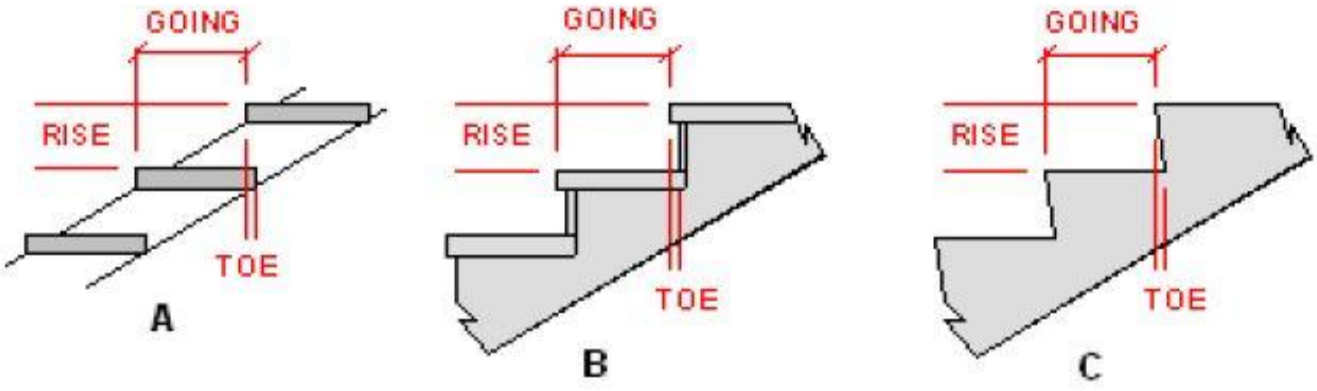

Figure 3 Different types of stairs and standard nomenclature [9]

Table 1 Stair parameters [9]

RISER(R)		GOING(G)		SLOPE RELATIONSHIP = 2R+G	
MAXIMUM	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
10cm	5cm	24cm	15cm	44cm	25cm

Thus from the table above it can be seen that the width of the staircases should be less than 24cm; the height shouldn't be more than 10cm. The structure should be stable help inside the base width of 24cm, and may

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conjointly seem an exact separation. Hence, here the component of the stairs chosen is width to be 24cm, and furthermore the height is 10cm is selected.

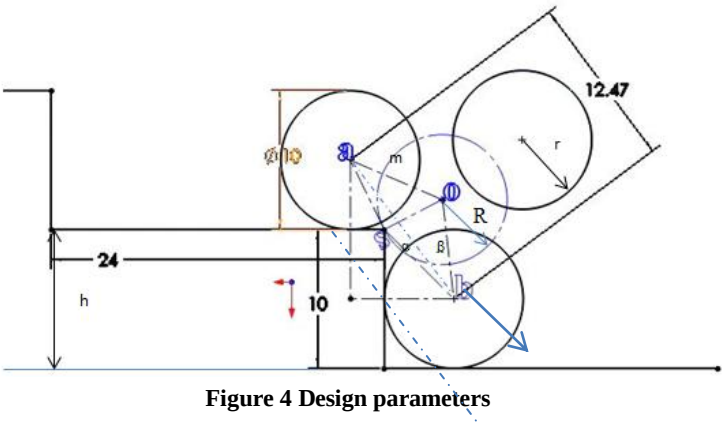

Figure 4 Design parameters

According to the figure of the design, calculation of few parameters are carried out in the next section

$$sb = \sqrt{r^2 + (h - r)^2} \quad \text{(i)}$$

$$sa = \sqrt{\left(\sqrt{3m^2 - h^2} - r\right)^2 + r^2} \text{ (ii)}$$

Therefore,

$$cos\alpha = \frac{Sb^2 + ab^2 - Sa^2}{2Sb \times ab} = \frac{h(h-r) + r\sqrt{3m^2 - h^2}}{m\sqrt{3r^2 + 3(h-r)^2}} \text{ (iii)}$$

For a system free of interference for the wheels and under the mechanical limits arm of wheel rotation i.e. length of 'ao' is calculated, for m = 7.92 cm. Based on this value the radius of wheel is calculated as 5 cm, taking these values to be worked together using equation (iii) α is calculated to be equal to 30.27°.

Since,

$$\beta = \alpha + 30^o$$

Thus β is 60.27°

$$R_{max} = \text{OS} = \sqrt{Ob^2 + Sb^2 - 2Ob \times Sbcos\beta}$$

$$= \sqrt{3.07^2 + 7.07^2 - 2 \times 3.07 \times 7.07cos52°}$$

$$= 4.68\text{cm} \quad \text{(iv)}$$

From equation (iv) maximum length for the centre of drive shaft should not be more than this value of Rmax for maintaining a movement free of interferences between edge of stairs and wheelchair while moving on these stairs designed for the aforementioned parameters.

3.2.No slip condition while climbing on stairs

The condition that is appeared in figure 5 is that the best position to slide down the staircase. The space between the front and furthermore the back wheel is intended to be 22.52cm, and likewise the separation

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between the focal point of gravity and front wheel(one that is contacting the stairs) is intended to be x. As per the force and moment standard for the accompanying conditions are acquired.

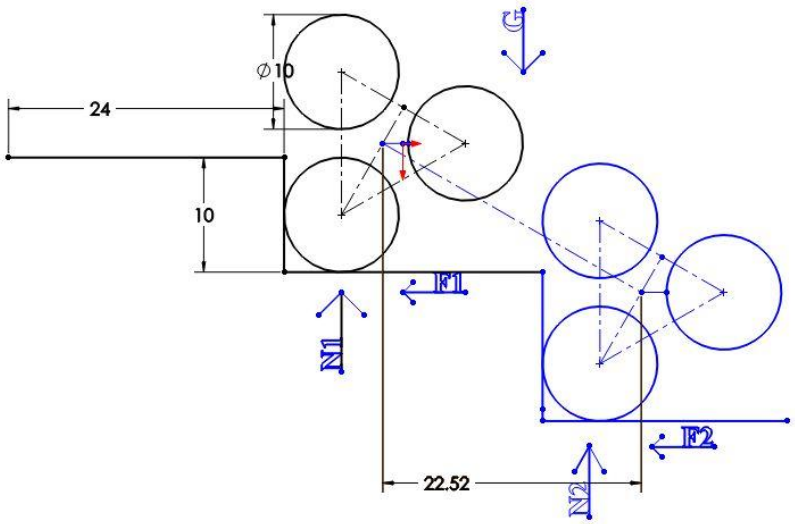

Figure 5 No slip condition

$$N_2 = xG \quad \text{(v)}$$

$$N_1 = (22.52 - x)G \text{(vi)}$$

$$N_x = N_2 tan30° \text{(Reverse direction of F2)(vii)}$$

Here, G is the total weight on wheel chair and x is the horizontal distance of weight from rear wheel.

For climbing the stairs up the minimum condition to meet for no slip following conditions should be maintained.

$$\mu N_1 \geq N_x \quad \text{(viii)}$$

$$\mu(22.52 - x)G \geq x \cdot G \cdot \tan 30^o$$

Friction coefficient $\mu = 0.3$ is chosen here,

$$0.3(22.52 - x) \geq 0.58x \quad \text{(ix)}$$

$$x \leq 7.67\text{cm}(x)$$

Since while climbing up on stair the wheelchair will tilt forward thus for steady movement the centre of gravity should be closer to the rear portion of the wheel chair. Thus for climbing up on the stairs without slipping, the centre of gravity is kept at 7cm from the rear wheels.

3.3. Force analysis

3.3.1. While moving on levelled ground

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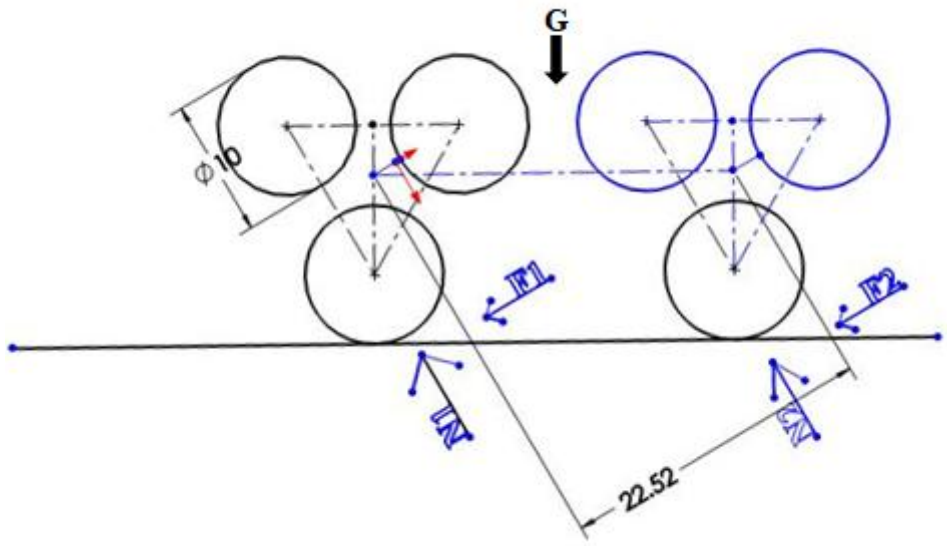

Figure 6On levelled surface

$$f_{Friction} = F_{Resistance} \quad \text{(xi)}$$

$$T = f \times R_{max} \quad \text{(xii)}$$

Since $F_{resistance}$ is is very small thus T which torque on the wheels will be negligibly small, thus the movement of wheelchair on flat surface is adequately stable.

3.3.2. While moving on a slope

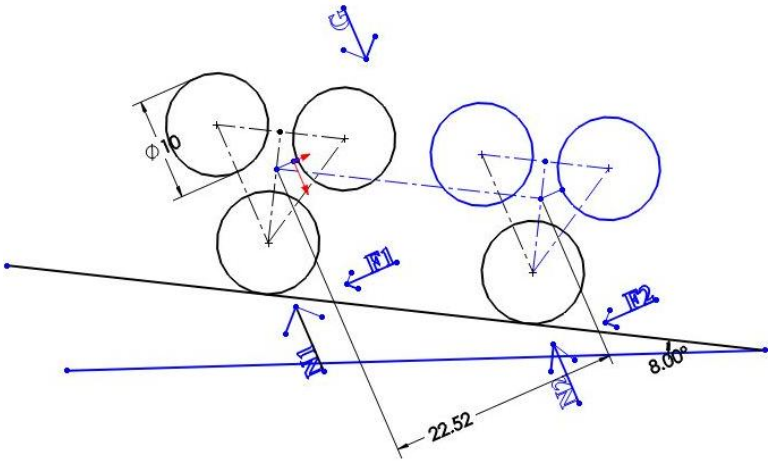

Figure 7On inclined surface

Calculation for the torque on wheels over a slope of 8^o is done using the following equations:

$$f = \mu N_1 \quad \text{(xiii)}$$

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$$4N_1 = ((22.52- x)/100)G \times \cos 8^o = ((22.52-7)/100)20 \times \cos 8^o \quad \text{(xiv)}$$

$$N_1 = 3.0737 \text{ N}$$

$$f = \mu N_1 = 0.3 \times 3.0737$$

$$T = f \times R_{max} = 0.0431 \text{ Nm}$$

3.3.3. While climbing on the stairs

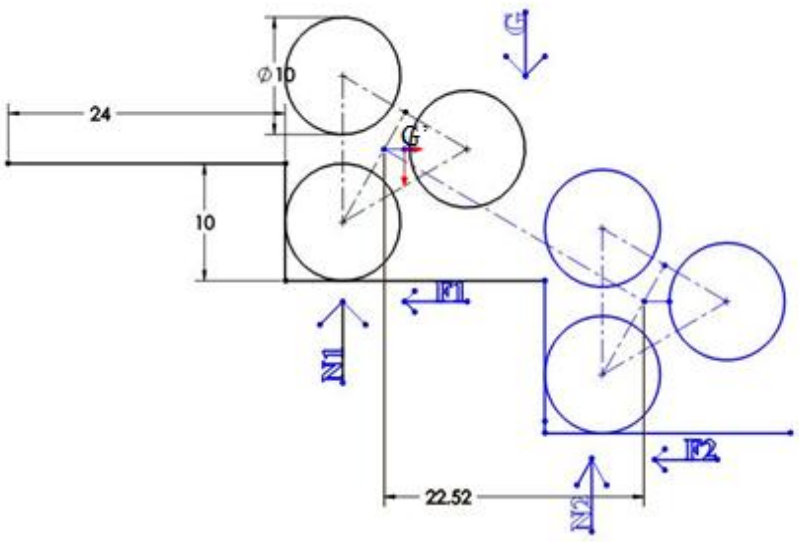

Figure 8On stairs

The total weight G if transferred to the wheel arrangement can be seen serving two important functions to wheelchair in climbing the stairs; firstly it will help in rotation the wheels while changing the steps and lastly are that it will hinder the rotation when moving through the same step.
Calculation for this case can be done using the following conditions

$$G' = ((22.52\text{-}x)/100)G = 1.552\text{x}10^{-1} \times 20 = 3.104 \text{ N}$$

The balance equation for centre of the triangle:

$$T = G' m \cos\theta = 2.24\text{x}10^{-1}\cos\theta \text{ Nm}$$

The designed weight for the present calculation is taken as 2 kg thus the value of G is 20 N applied along with a turning arm length of about 7.24 cm as calculated in section 3.1, if θ is considered to 0 i.e. in the horizontal state in this state it will need maximum torque to rotate the planetary wheel arrangement, the calculated torque amounted to 0.224 Nm using the above values for required parameters.

4. Conclusion

This paper advocates the designing of a wheelchair mechanism capable of climbing the staircase in stable manner, since a small model was considered for the design so for a load of 20 N analysis for the possible scenarios under which the movement of wheelchair maybe subjected, thus the outcome of this study is

realized by these values for a no slipping condition of the mechanism what could be the limiting values of the torques required in the planetary wheels for the cases mentioned before.

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