Machine Design Project Report

Group 7: Stair Climber

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Group 7

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1. ABSTRACT

As we have seen, engineering has made significant strides in the contemporary era. It is still challenging to carry heavy goods up and down stairs. Although the invention of elevators has made it easier to transport large items up and down stairs, not all locations—such as schools and college construction zones—allow the use of lifts. The creation of a system that makes it simple to carry large items up and down stairs is the aim of this project. The daily needs of our society create the necessity for such. For instance, hand trolleys are used to reduce the strains associated with lifting while standing on level ground. However, when it comes to transporting a weight up and down a small flight of stairs, these technologies typically fail.

The goal of our project is to develop a stair-climbing trolley that will make it easier to move heavy goods upstairs than to carry them manually. We describe the market demand, its significance, and the design requirements. The next step is to describe the various machine parts, show the CAD drawings, and comprehend the specifications. After that, we examine the market's supply of materials and do a cost analysis. Finally, we wrap off by outlining the working model, the difficulties encountered, and our upcoming work.

2. INTRODUCTION

We encounter the necessity to raise a heavy load on a daily basis in one way or another. Since we now frequently use elevators, we are unaware of the effort needed to carry something up steps. This is a severe issue in rural areas. People with disabilities who had to be carried upstairs either carry the entire wheelchair or transfer to a stretcher and be carried, both of which demand a lot of manpower. By evaluating, designing, and creating a device that can be utilized to ascend stairs while carrying weight, we want to find a solution to this issue.

NEED:

- Reducing the strain placed on workers or people when moving a heavy load upstairs.

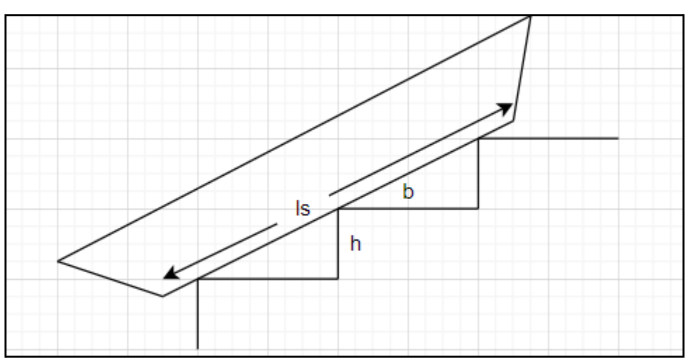
- To reduce the difficulty of disabled people using wheelchairs to climb stairs with little external assistance.
- It can be expanded as a domestic tool to transport heavy loads upstairs, saving money and preventing injuries from lifting heavy loads.
- Physically handicapped people who cannot walk find it difficult to travel through stairs when a lift is not available.

3. OBJECTIVE

- We aim to design a continuous tracks-based stair climber which can be further modified a bit to attach a wheelchair or a trolley to it and can ascend & descend stairs to aid differently-abled or aid movement of heavy goods where lifts are not available option.
- Making the total prototype as cost-effective and as less expensive as possible.

4. DESIGN

The design was modified multiple times to account for the load and budget constraints. Initially, we planned to use roller chains and sprockets with rugged rubber belts joined to the roller chain through adhesives as propulsion components. The aim of using roller chains was to provide enough strength by using them as reinforcements below the rubber belts. Still, the entire assembly was complicated which affected the reliability and the cost of the components was also very high. It was pointed out by sir and we realized that this was an overdesign for the required constraints as rubber belts are strong enough to take the specified loads. The design od propulsion was then modified to have pulleys and rubber belts driven by motor.



Generally, the staircase have b in range 25 - 30 cm while h is generally around 15 - 20 cm. We want the belt to be in contact with atleast two stairs at any point of time. Hence, l_s should be greater than 72 cm and we have designed for l_s to be 80 cm. Considering the typical dimensions of the staircase, the width of vehicle was designed to be 70 cm.

Material selection:

The majority of modern stair climbers are made primarily of steel, aluminum, and titanium. Steel is only available in standard stair climbers with folding-frame mechanisms. Aluminum is used extensively in the stair climber industry, primarily in ultralight and lightweight stair climbers. Axial tension and compression are two straightforward types of beam/channel deformation. Beams are the parts of machinery and equipment that primarily perform tensile and compressive functions. Bolts are always used to connect stair climber parts, and once tightened, they bear the tension. To analyze the beam which bears axial tensile or axial compression function, it will be turned out that the characteristics for the tension and compression of a beam is that two forces functioning at two ends of the beam are equal and opposite, and the action line is coincident with the beam axis. The characteristic of its deformation is that the beam will elongate or shorten along the axis and its cross-sectional will be thinner or coarsen.

The overall cost of the finished product which includes all expenses incurred during fabrication to produce the desired machine was ensured to be at the barest minimum by ensuring that the parts selected were not too excessive.

1. Cost: The materials used to make the component parts must be reasonably priced. They must meet the standards required for the plant's efficient operation and performance. This factor must be considered because it will affect the marketability of the stair climber as well as the production cost of running the stair climber.

2. Material Availability: The materials to be used in the fabrication of the component's parts must be readily available in order to reduce the overall cost of fabricating the process plant as well as the cost of maintaining the plant while it is in operation.

3. Rigidity and Strength: The machine frames used in the process plant must be rigid enough to withstand the load of the various components supported. This will help to reduce vibration effects during operation and improve its efficiency.

4. Overall Weight: The weight of the components used in the fabrication of each machine in the process plant should be as light as possible in order to reduce the stress involved in moving the components for maintenance.

5. Corrosion Resistance: Because the machine is a utility processing machine, the components of each machine, particularly those in direct contact with the utility material, must be made of materials that are less prone to oxidation in order to prevent rust breaks and corrosion.

5. DESIGN SPECIFICATIONS

MODEL

Mass of the System	40 Kg		
Design Payload	100 Kg		
Bounding Box Dimensions	Length: 147 cm	Width: 93 cm	Height: 48 cm

PROTOTYPE

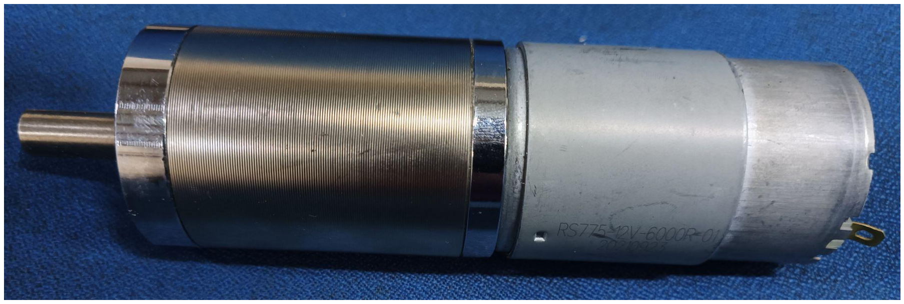
Mass of the System	9 Kg		
Design Payload	5 Kg		
Bounding Box Dimensions	Length: 70 cm	Width: 50 cm	Height: 38 cm

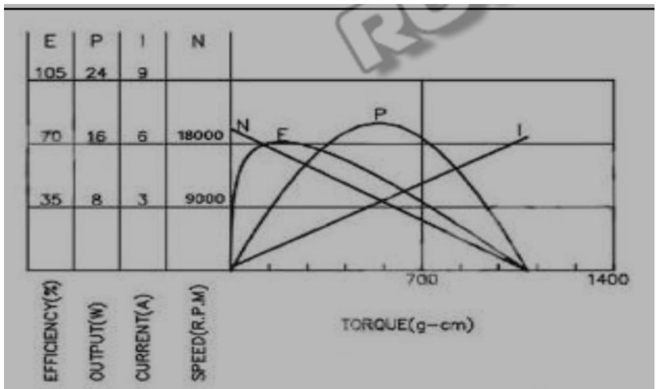
6. ANALYSIS OF MACHINE ELEMENTS

COMPONENTS

- **Wheels** - We are using six wheels, four with diameter 5 cm and two with the diameter of 10 cm. The purpose of the wheel is to keep the system and the rubber belt moving. According to the cost of components we found, we decided to get the wheels made out of nylon rods with grooves that fit right into the double-sided groove timing belt. But, getting the grooves were too costly. Then we modified the design to have a one-side groove belt and plane nylon wheels with washers on both sides to hold the belt. The surface on the wheel is knurled to increase friction between the wheel and the belt.

- **Rugged Rubber Belt -** These rubber belts have high strength, good flexibility, and elasticity in many types of machinery including power transmission machines. The initial design plan was to buy a DH timing belt (grooves on both sides). But, the DH belts cost more than 3k each. Hence, we modified the design to fit the budget. The length of the belt we are using is 65 inches to surround the chain perfectly. The width of the belt is taken to be 4.8cm to provide a tolerance of 2mm between the belt and washers of the pulleys. The new modified design is to mount the belt with the maximum possible tension so that slip does not occur. For the same reason, we chose a belt that has a rough surface on the side with no grooves (among the available and in-budget options).
- **Motors -** We are using two 70 kg-cm motors to drive the machine, which operates at 12 volts and the current can be modified using motor drivers to change the rpm of the motor to account for increased loads while driving the machine.





Base Motor Characteristic Graph

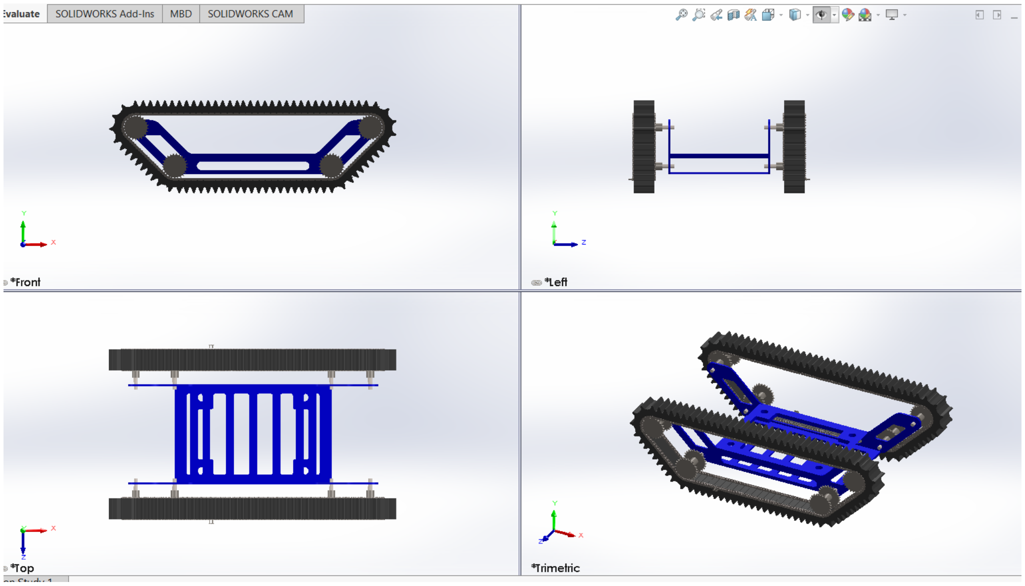
- **Battery** - We are using a rechargeable Lead - Acid battery of 12 V, with a capacity of 9 Ah, 20C.

Note: The C-rate is the unit battery experts use to measure the speed at which a battery is fully charged or discharged. For example, charging at a C-rate of 1C means that the battery is charged from 0-100% in one hour.

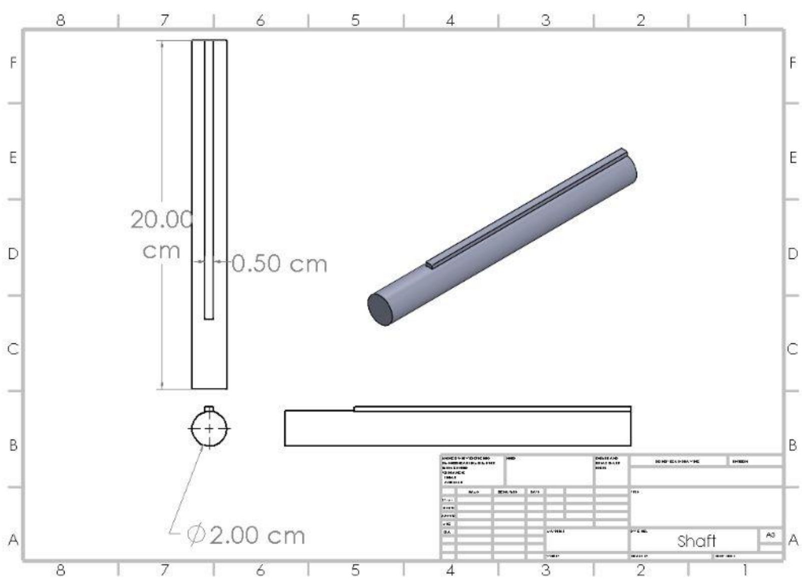
- **Base Frame** - We are using a frame of mild steel. We are using a frame which consists of 1 rectangle and 2 triangles . Also we have designed it such that we minimize the weight of the frame and maximize the stability. The welding was done externally. We couldn't get the design accuracy we needed. The frame made was unsymmetric. One of the four sides was not touching the ground.

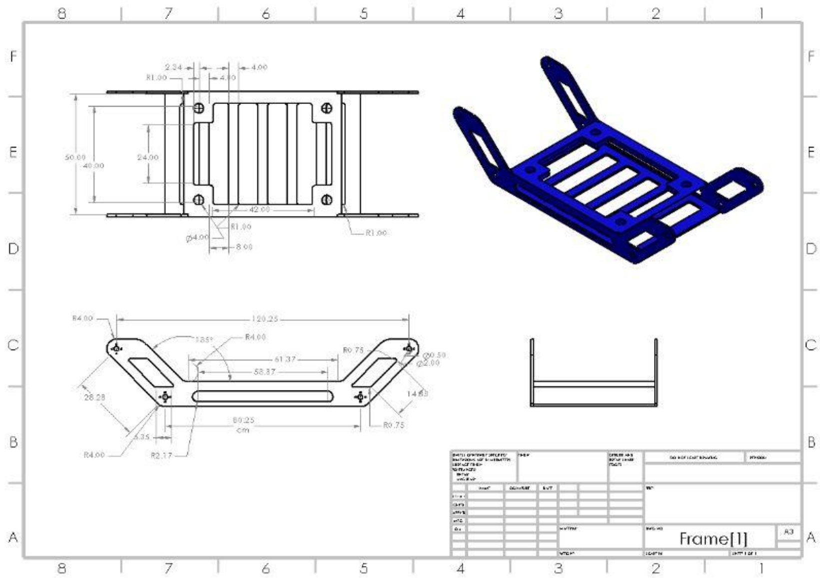
- **Shaft** - We are using 2 mild steel rods of length 57 cm each and diameter 1 cm to act as shaft for the front pulleys.

CAD MODEL



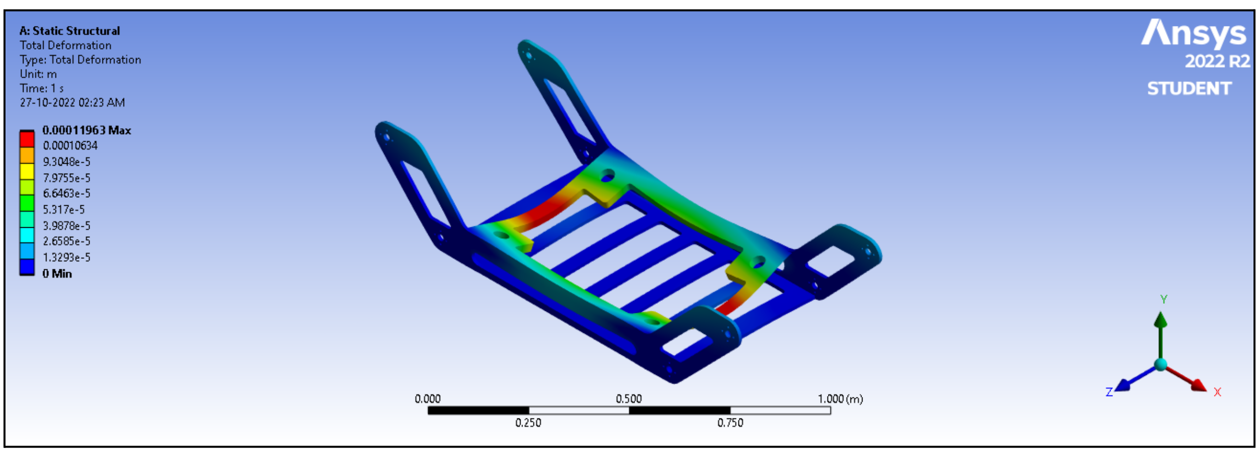
ENGINEERING DRAWINGS



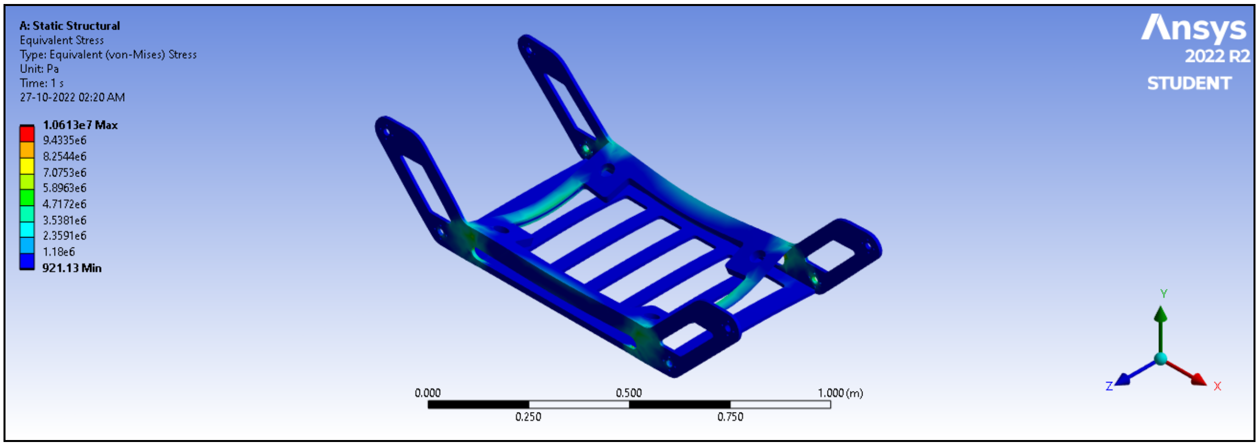


DESIGN VALIDATION USING ANSYS

The deformation and stress distribution in the frame were analyzed for the design load in ANSYS. The observed maximum deformation is 0.12 mm and the maximum von mises stress is 10.6 MPa giving us a factor of safety of 26 with respect to yielding.



Total Deformation Analysis



Total Stress Analysis

TORQUE & POWER REQUIREMENTS

$$F_{net} = mg\sin\theta + \mu mg\cos\theta = mg(\sin\theta + \mu\cos\theta)$$

Taking $\theta_{max} = 30°$ and $\mu_{max} = 0.5$

Power required to pull the system, $P = Fv = mg(\sin\theta + \mu\cos\theta)\,v$

Power generated by the motor, $P_{motor} = \tau\omega = \tau\frac{v}{R}$

R = radius of the wheel

Assuming only η fraction of power generated by motor converted into power to pull vehicle.

$$mg(\sin\theta + \mu\cos\theta)\,v = \tau\frac{v}{R\eta}$$

$$\tau_{total} = \frac{mg\,(sin\theta + \mu cos\theta)}{\eta} = n\,\tau_{motor}$$

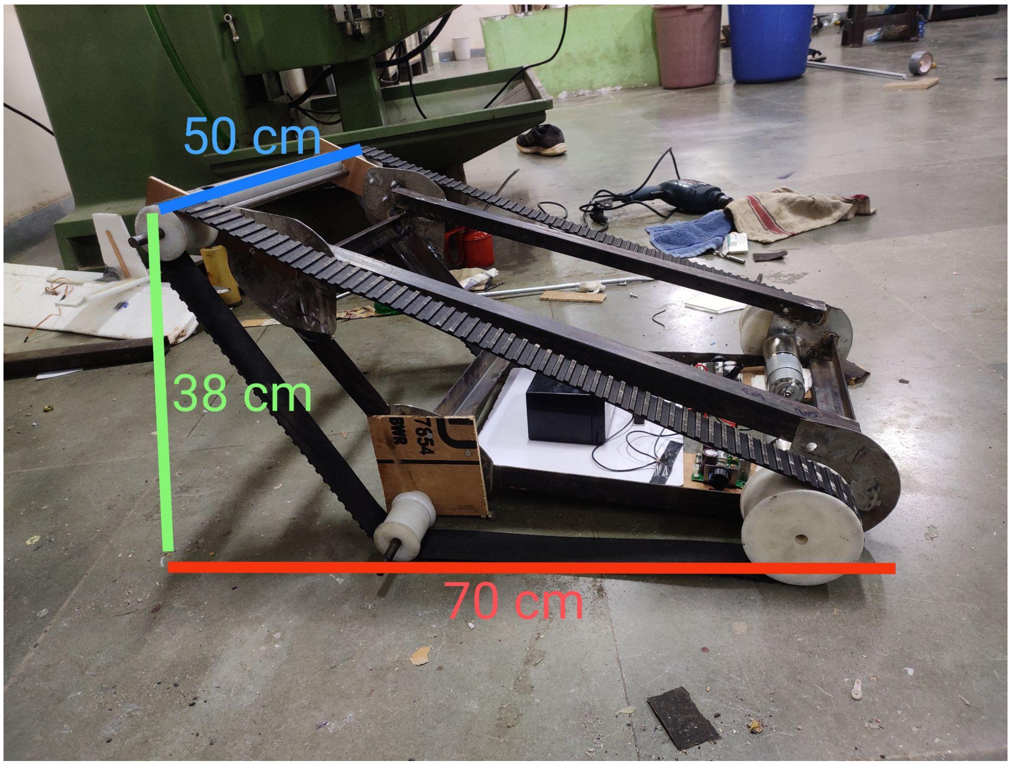
$$\tau_{motor} = \frac{mg\,(sin\theta + \mu cos\theta)}{n\eta}$$

Taking n = 2 (no of motor) and η = 80% efficiency, τ_{motor} = 0.583 mR kgcm

We can get the torque rate of the motor for selected mass and selected radius of the wheel.

FINAL MODEL

After multiple design alterations, we made the final design with all the constraints. Given, the final model with its box boundary



COST ANALYSIS & BOM

MECHANICAL:

PART	QUANTITY	PRICE (₹)
Chassis	1	4500
Wheels	4	2716
Conveyor belts	2	2124
Drill Bits	2	340
4 mm Screws & Bolts	20+	2/piece

ELECTRICAL:

PART	QUANTITY	PRICE (₹)
Jumper Wires	2	160
DC Motor	2	5664
Capacitor & Resistor	1	15
Battery	1	1534
Normal Wires		60
L298N Motor driver	1	60

7. CONCLUSION

Generally in small villages, towns, and cities, foot over bridges, multi-storeyed buildings, and other places with stairs, especially old structures do not have lifts. It becomes very difficult for physically disabled people to move through these places using conventional wheelchairs. It is also difficult to transport heavy goods through stairs and it requires considerable manpower it also has a risk of injury to laborers and/or damage to goods.

Hence, to solve this problem, we decided to design and build a caterpillar tracks-based stair climber machine. The design was modified multiple times to meet the cost and performance constraints. The parts were procured after extensively searching for parts that meet the design & cost requirement. The components were assembled and while assembling them, care was taken to have appropriate alignment of components wherever required.

The prototype made was able to manevour on level groun with considerable mass as payload and was able to manoevour on tilted surface. The prototype however, was not able to climb stairs due as th frame was not manufactured by the fabricator as per requirements and there were distortion in the frame. But the entire process was a great learning experience for the entire team and we learnt about and faced some of the challenges in manufacturing a simple machine.

8. FUTURE PERSPECTIVES AND CHALLENGES

Challenges faced:

- The exact design we made had a belt with teeth on both sides and pulley with grooves for maximum load transfer without slipping. But, these were way out of budget.
- The making of teeth into the wheels was costly and hence it was avoided,
- The frame was made by welding L section rods and there were distortions in the frame rendering it unsymmetric. The rod also hindered the place for mounting motors and the motors had to be mounted at alternate location.
- The drilling of holes into the frame was challenging due to the material and weld.
- The belt needed to be in maximum tension. But the plates on which the pulleys were mounted deformed when the belt was in complete tension. Reinforcements were installed to ensure not further deformation and the tension in the belt was also decreased.
- The asymmetricity in the frame is causing a difference in power on both sides. The speed of both the conveyor belts obtained is not equal.
- The asymmetry in the frame causes a slack in the belt and thus maximum tension is not obtained. Hence, it is difficult for the machine to climb stairs at this point.
- The quality of the belt could be improved for better grip if more budget is available.
- The frame is asymmetric which means that both the belts are not in contact with stairs when the vehicle heads straight towards the stairs. Hence, it is not able to climb stairs due to the asymmetry as only one of the beltn is in contact with stairs.
- It would be difficult to recharge the battery with the current circuit.

Future Scope/Improvements:

Due to the lack of funds and experience the final prototype deviated from the design proposed. We can mention the following changes that can be made to the vehicle to make it more efficient and overcome the difficulties faced.

- A better frame that suits our design specifications should be made. A Double Sided groove belt and perfectly fitting pulleys with washers on both sides should be used.
- By using a hydraulic mechanism to shift and maintain the CG, the center of gravity is easily maintained while ascending and descending from the stair-climber on the staircase. It affects the stability of the system and also it reduces the load on the motor.
- The power range produced to carry loads could be modified as per loading conditions by changing motor and battery.
- The material used for frame is Mild Steel as it is cheap and easy to weld. Instead of using Mild Steel Aluminium or composites can be used to reduce weight.
- The electric circuit can be modified to have better control, motor direction reversivbility and ease of recharging battery.

9. REFERENCES

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Roller Chain Drive Design

Material Sheet

Arduino Code

Analysis of Stairs-Climbing Ability for a Tracked Reconfigurable Modular Robot

Mechanical Design for Track Robot Climbing Stairs | Semantic Scholar

Design & Fabrication of Staircase Climbing Wheelchair using Conveyor Belt Mechanism

10. TEAM MEMBERS CONTRIBUTIONS

Team Member	Ideation Meets	Documentation (PPT, Reports)	Softwares for Analysis	Paper Research and Literature review	Manufacturing and Final Model Assembly
Anusha Mantha	Always comes	Prime contribution in PPT and report	Never	Often shown important results	Major contribution in purchasing material and mechanical assembly
Keyur Ashara	Always comes, always present revolutionary ideas	Prime contribution in PPT and Report	Prime contribution in SolidWorks and total contribution in ansys	Sometimes found important results	Prime contribution in purchasing and assembly of mechanical components
Shiv Modi	Always comes except 1-2 meets	Contribution in electric components description	Electrical Circuit architecture and modeling, initial fundamental calculation	Revised and pointed important results from paper suggested by teammates	Contribution in assembly and assembly of electrical architecture, preliminary testing of elec components
Tejaswi Pagadala	Always available for discussion and problem solving	Prime contribution in PPT and Report	Never	Prime contribution in research and analysis	Prime contribution in purchasing components and assembly
Ankit Bepari	Always available for	Major contribution	Never	Mostly prepared	Prime contribution

	discussion and problem solving	in analysis and calculation		formulas for analysis	in purchasing components and assembly
Anuradha Meena	Always available for discussion and problem solving, execute all allotted tasks	Prime contribution in PPT and Report	Major in contribution in SolidWorks	Contribution in research paper reading and presenting in teams	Prime contribution in final assembly
Ritu Raj	Always comes and execute given tasks	Never in report. Some contributions in PPT	Never	Major contribution in mass estimation	Prime contribution in assembly and purchasing components
Bhanu Meena	Always comes and focus in discussion	Rare contribution	Never	Noted out important results	Prime contribution in purchasing components , assisting in testing of electrical components and final assembly
Kuldeep Saini	Mostly present and helpful in analysis and deciding factors	Prime contribution in PPT and Report	Never	Calculating initial parameters	Assisting in assembly