DESIGN AND FABRICATION OF STRING-DRIVE WHEELCHAIR

A PROJECT REPORT

Submitted by

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BONA FIDE CERTIFICATE

Certified that this project titled "**DESIGN AND FABRICATION OF STRING-DRIVE WHEELCHAIR**" is the bona fide work of

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who carried out the work under my supervision. Certified further that to the best of my knowledge the work reported here in does not form part of any other thesis or dissertation on the basis of which a degree or an award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

Wheelchairs are one of the most used mobility enabling devices used by the physically disabled. The importance of the liberation and freedom that a wheelchair provides to its user cannot be understated. Typically, the drive system of a manually operated wheelchair is often achieved by using a hand-rim on the wheels , through which the user can push the wheels manually, or by using a chain-based pedal system, which enables the user to use the pedals to move the wheelchair. The major drawback of both these systems is that these are not very ergonomic or comfortable for the user. Therefore, improvement in comfort and ease of use of the wheelchair is a very important facet of this design .Moreover the chain-based system also introduces several losses and friction in the system that reduces the efficiency of the drive and therefore as a result increases the physical effort required by the user.

The proposed String-drive wheelchair aims to improve the ergonomics of the wheelchair , while also reducing the force required to propel the wheelchair. The string-drive mechanism uses a lever-based system to revise the input from the user, the levers are positioned to the side of the seat in such a way that the user's hand can naturally rest on it, this increases the comfort of the wheelchair. Further, a RULA analysis of this lever mechanism revealed reduced levels of muscle fatigue in the back and lumbar region of the user.

The levers actuate a string which is then coupled with a ratchetted freewheel hub mechanism connected to both sides of the wheel hub. This mechanism is tensioned with an industrial grade elastic band, that recoils the string winding without rotating the wheels. Therefore, both strokes provide power to the wheel. Calculations and analysis also show that the string-wheel mechanism requires less force from the user when compared to the typical wheelchair drives.

ACKNOWLEDGEMENT

We wish to express our deep sense of gratitude to my guide **Dr. K. Shanmuga Sundaram,** Professor, College of Engineering Guindy, Anna University, Chennai, for unflagging zeal with which he guided us in carrying out the project work. We are deeply in debt for his invaluable guidance and inspiring suggestions throughout our project.

Finally, we express our heart-felt gratitude to **Dr. S. Balasivanandha Prabu,** Professor and Head, Department of Mechanical Engineering, College of Engineering Guindy Campus, Anna University, Chennai, for providing the facilities for successful completion of the project

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1. INTRODUCTION

Wheelchairs are one of the most common devices used by the differently abled persons for mobility. There are many types of wheelchairs classified on the basis of actuation such as the rim-operated, lever-operated, pedalled wheelchairs. There are many types of wheelchairs classified on the basis of transmission such as direct, chain and motorized. Our project focuses on a new type of string-drive transmission.

1.1NEED FOR THE PROJECT

Our project focuses on the group of people with paraplegia who cannot move their lower body. Even though motorized wheelchairs are available, they are not affordable by everyone and hence manually operated wheelchairs are preferred. Currently they utilise the hand-pedalled wheelchair and the rim-operated wheelchair.

These wheelchairs lead to musculoskeletal problems over prolonged use and requires great effort for operation. Our design requires minimal effort to operate the wheelchair and hence is a superior design compared to the existing methods of operation.

2. LITERATURE REVIEW

1	Exploratory investigation of the outcomes of wheelchair provision through two service models in Indonesia	Megan E. D’Innocenzo ,Jonathan L. Pearlman ,Yasmin Garcia-Mendez ,Stephanie Vasquez-Gabela ,Christina Zigler ,Perth Rosen ,Eviana Hapsari Dewi ,Ignatius Praptoraharjo ,Anand Mhatre	The usage of wheelchairs by different groups of people and the outcomes and the improvement in mobility given by wheelchairs. No significant differences were found when comparing device satisfaction across wheelchairs types. Results emphasize the need for routine maintenance to address frequent wheelchair breakdowns. They also demonstrate a large disparity in several outcome variables across groups
2	Wheelchair Design and Its Influence on Physical Activity and Quality of Life Among Disabled Individuals	Ali Ebrahimi, Alireza Kazemi, Azin Ebrahimi	This papers was studied to were referred in order to assess the usage patterns and the quality of life improvements that wheelchairs give the patients that use them. Results of this journal corroborate that designing the wheelchairs in a way that increases physical activity can increase the quality of life of patients
3	Design and Performance Evaluation of 4 Wheeled Omni Wheelchair with Reduced Slip and Vibration	S.Ganapathy, J.Charles, D.Magesh, M.Mohammed Ashik, D.Monishraam	This Paper focussed on the design and improvement of the current design of wheelchairs used now. It gives the design and the methodology behind developing a wheelchair for indoor applications.
4	Effect of wheelchair design on wheeled mobility and propulsion efficiency in less-resourced settings	Christopher J. Stanfill, Jody L. Jensen	This study used accelerometers in the wheelchairs to record and analyse mobility data in rural areas and determine how patients responded to different types of wheelchairs
5	Ergonomics of Wheelchair Design: A Prerequisite for Optimum Wheeling Conditions	Lucas H V van der Woude, Dirkjan (h.e.j.) Veeger	This study used trial and error type testing of different variation of the wheelchair to determine the best ergonomic dimensions and usability and accessibility of the wheelchair for the patient. These insights were used in the initial design of the wheelchair
6	Design and Development of Lever Operated Wheelchair	Aniket Vidyagar, Prof. Ganesh D. Korwar, Sumedh Kulkarni, Nikhil Gund Sreeraj Karpe, Somnath Hirole	By using Ratchet and pawl mechanism which is used in normal bicycles help to reduce efforts applied by patient wheels of bicycle are used instead of push edges. The wheels will be rotated with the help of a lever which will be attached to the wheels by means of lever operated mechanism.

1	Exploratory investigation of the outcomes of wheelchair provision through two service models in Indonesia	Megan E. D'Innocenzo ,Jonathan L. Pearlman ,Yasmin Garcia-Mendez ,Stephanie Vasquez-Gabela ,Christina Zigler ,Perth Rosen ,Eviana Hapsari Dewi ,Ignatius Praptoraharjo ,Anand Mhatre	The usage of wheelchairs by different groups of people and the outcomes and the improvement in mobility given by wheelchairs. No significant differences were found when comparing device satisfaction across wheelchairs types. Results emphasize the need for routine maintenance to address frequent wheelchair breakdowns. They also demonstrate a large disparity in several outcome variables across groups
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7	Ethnographic and Ergonomics considerations in design of Wheelchair	Chandrakant Kulkarni, Abhijit Dandavate, Maheshwar Chamnalli	In ethnographic study, the attitudes of people or groups of people regarding disability problems are studied. Such method of research can be very useful in analysing the reliability of a design of an engineering product.
8	A Study on Smart Wheelchair Systems	Mohammed Hayyan Alsibai, Al Sibai, Sulastri Abdul Manap	This paper reviews the recent studies in smart wheelchairs for patients who are unable to use the wheelchair by themselves. String drive can be used to provide autonomy to people with only one hand as well.

9	Design and Fabrication of Lever Propelled Wheelchair	Prof. Nikhil V. Bhende, Mithun G. Kolhe, Dinesh S.	A revised mechanism that uses lever actuation to drive a chain sprocket was proposed and a prototype was build and

		Ahuja, M. Waseem Saleem Ansari	analysed and compared with an existing design.
10	Design and Fabrication of Lever Operated Wheelchair for Disabled Person with No Legs	Jagdish P. Choudhary, Poonam G. Choudhary, dar Madhusudan Kulkarn	This paper provides a modified design of a wheelchair by replacing the chair drive with a slider crank mechanism, but no model was fabricated.

2.1 LITERATURE SUMMARY

The literature surveyed was mainly chosen to gain a more rounded and deeply technical knowledge of wheelchairs and the implications that they bring with them. Several papers and journals were referred in order to assess the usage patterns and the quality-of-life improvements that wheelchairs give the patients that use them. Megan E. D'Innocenzo could not come to a satisfactory conclusion about the device satisfaction across wheelchair types. Ali Ebrahimi states that designing the wheelchairs in a way that increases physical activity can increase the quality of life of patients.

Then we moved on to journals that focussed on the design and improvement of the current design of wheelchairs used now, these papers gave a proper understanding of the design and fabrication of wheelchairs, this will be necessary for the fabrication of a prototype. Lucas H V van der Woude Discusses the best ergonomic dimensions and usability and accessibility of the wheelchair for the patient. Prof. Ganesh D. Korwar studied the ratchet and pawl mechanism which the centrepiece of the string-drive system.

The Next category of focus was Ergonomics the addition of the new type of drive train would pose a great challenge in maintaining the existing comfort and ease of use and accessibility of a wheelchair , these journals were studied with great care so that the added functionality does not compromise the ease and comfort , which are two important factors in the design of a wheelchair. Chandrakant Kulkarni, Abhijit Dandavate, Maheshwar Chamnalli studied the attitudes of people or groups of people regarding disability problems. These were very important inputs to the design considerations.

Different types of drivetrain systems used in wheelchairs were also probed for potential use cases and additional features. Mohammed Hayyan Alsibai presents a review of multiple papers aimed at designing new improved drive systems for wheelchairs.

The cost and affordability also played a major role in the decision to go for this type of drive train. Several papers relating to the design of lever action-based wheelchairs were referred, since the string drive-based drive train is also a lever action-based actuation system. Prof. Nikhil V. Bhende and his team have also built a lever based acting wheelchair; this system was taken into consideration while designing. Jagdish P. Choudhary provides the design of a slider crank based drive system which is also lever actuated. But it must be noted that all these papers were based on the redesign of the existing chain and sprocket-based drivetrain into a lever-based system, and there were no research papers, journals or articles published based on the usage of flexible element-based drivetrains such as the proposed string drive system. This provides a gap in the research areas to be explored.

3. WHEELCHAIR MECHANISMS

The existing wheelchair mechanisms can be classified based on their actuation systems and transmission systems:

3.1BASED ON ACTUATION SYSTEM:

3.1.1 Lever Actuated:

The lever actuated system uses a lever on either side of the chair or only on one based on the configuration. Lever has a bearing or similar mechanism allowing it to rotate about the actuation point where it is attached to the body of the wheelchair. The lever produces a back and forth, reciprocating motion which is then used to propel the wheelchair forward. Our string wheel drive uses a similar level actuated mechanism.

3.1.2 Pedal Actuated:

The pedal actuated system is one of the most commonly used actuation systems. This system uses a pedal mechanism like the one found in cycles. The drawback in this type is that this pedal assembly is bulky compared to the lever system and it also requires a third front wheel to be added in order to function. Due to this , the pedal-based system also introduced ergonomic challenges to the user as it blocks the path to easy embarking and disembarking of the wheelchair

3.1.2 Hand-rim Actuated:

The handrail actuated system is the simplest form of actuation system. This functions as both an actuation and transmission system at the same time. It consists of a railing that is attached directly to the outer rim of the wheels of the wheelchair. The user can grab on the railing and propel the chair forwards by just pushing and pulling on the rails. This can also be driven differentially to steer the wheelchair to the left and right.

3.2BASED ON TRANSMISSION SYSTEM:

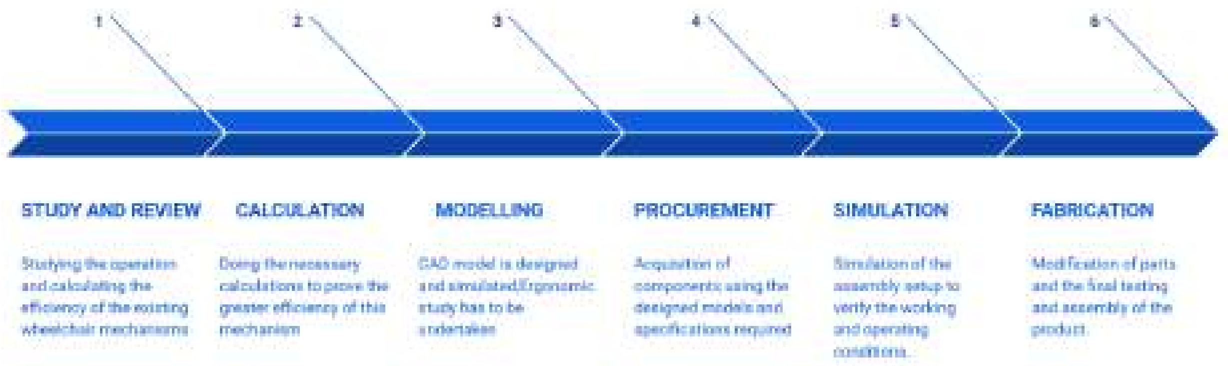
3.2.1 Chain Based Transmission:

This is the commonly used transmission system used till date in the level and pedal based actuation wheelchairs. The chain mechanism is similar to the powertrain found in bicycles. A larger driving sprocket is coupled to the pedal or level . A smaller driven sprocket is attached to the hub of the wheels and an interlocking chain is used to transfer the power from the driver to the driven sprocket. The main problem with these chain-based systems is the frictional losses that arise due to the hundreds of linkages found in the chains.

3.2.2 Hand-rim Transmission:

This is the same handrail actuated system. This system is simple and as it is directly attached to the wheels of the wheelchair using nuts and a screw , it does not require any out of transmission system. The ration of the handrail directly rotates the wheel and drives the wheelchair.

4. METHODOLOGY



- Studying the operation and calculating the efficiency of the existing wheelchair mechanisms along with their market availability.
- Going through the research papers related to the mechanisms for wheelchairs.
- Doing the necessary calculations to prove the greater efficiency of this mechanism compared to the existing other mechanisms.
- Incorporating these mechanisms, a CAD model is designed and simulated.
- Ergonomic study undertaken and the necessary alterations in the design done.
- With a fully furnished design, procurement, and fabrication of necessary components to make the mechanisms for the corresponding functions is done.
- Incorporation of these systems in a basic model wheelchair and alterations in accordance with the ergonomic study is done.
- Final assembly is tested for mechanism and under actual working conditions.

4.1 WORKING PRINCIPLE

The wheelchair utilizes a lever-based actuation where, by the principle of mechanical advantage of levers, the effort required will be less to operate the wheelchair.

A string attached to the lever will actuate the wheel hub of the wheelchair when it experiences a tensile force. When the lever is moved back to the initial position, the string slacks and a recoil mechanism in the wheel hub rewinds the string back onto it and the process is repeated.

A single wheel is operated with 2 string drives so that 2 power strokes can be obtained in 1 cycle of motion.

A bevel gear setup is used to reciprocate the motion of one lever onto the other, so that the levers can be actuated with a single hand.

5. STRING-DRIVE WHEELCHAIR

There are bicycles that operate on string-drive mechanism with cam-based operation. There are also primitive models of wheelchair with string-drive but with significant disadvantages such that they could not reach out in the market.

The key differences between the existing and our current model are:

1. Power Stroke: In the existing stringchair, one cycle of hand motion leads to one power stroke in one wheel independent of the other. In our design, one cycle of hand motion produces two power strokes due to the unique positioning of the pivot point and the attachment point of the string on the lever. Therefore, the power output is doubles.
2. Steering: The stringchair operates on differential steering which is unstable. Our design facilitates the use of Ackermann steering with minimal complexity and design.
3. Single hand operation: Stringchair wheels are independent, and they have to be actuated in sync with a rowing action for forward motion. Our design is incorporated with a bevel gear setup where the motion of one

lever is reciprocated on the other lever and hence can be operated with a single hand itself.

5.1 LOAD CALCULATIONS

To determine the effort required to actuate the wheelchair, load calculation was carried out. The following parameters were decided based on calculated conclusions:

Mass of the wheelchair = 15 kg

Mass of human = 75 kg

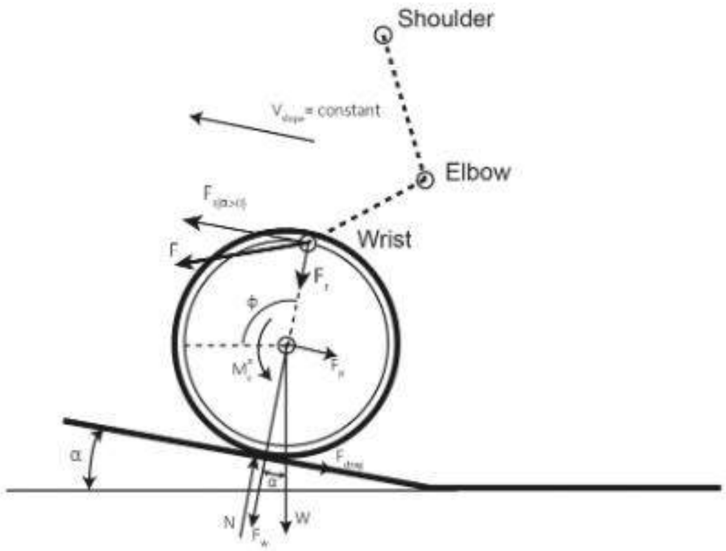
Mass of chair for hand-pedal wheelchair = 45 kg

Radius of the wheel = 0.3 m

Rolling Resistance = 0.02

Slope (for boundary conditions) = 5.00

5.1.1 HAND-RIM OPERATED



Normal wheelchair		
For 10% gradient, 5-degree slope	0.09	rad
Rolling Resistance loss	13.18	N
Gradient loss	76.83	N
Net Force Required	90.01	N
Force required by hand	**108.01**	**N**

5.1.2 HAND-PEDALLED WHEELCHAIR

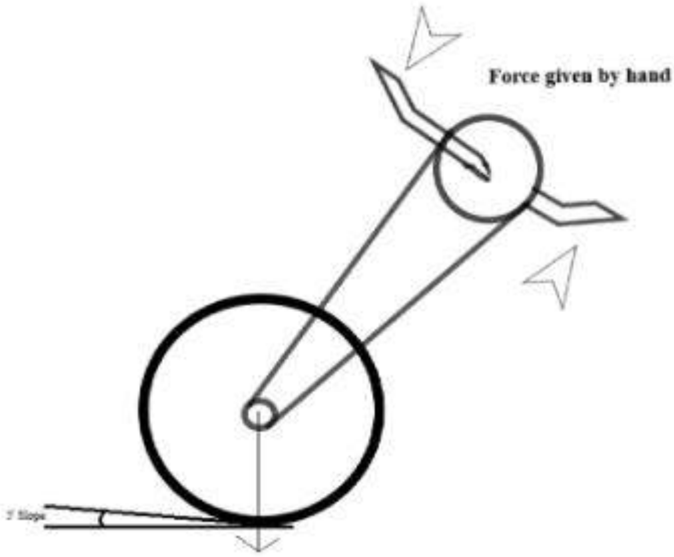
The following measurements were noted down for calculation:

Radius of rear wheel sprocket = 0.04 m

Radius of front wheel sprocket = 0.09 m

Distance of pedal from the centre = 0.18 m

Circular handlebar radius = 0.25m



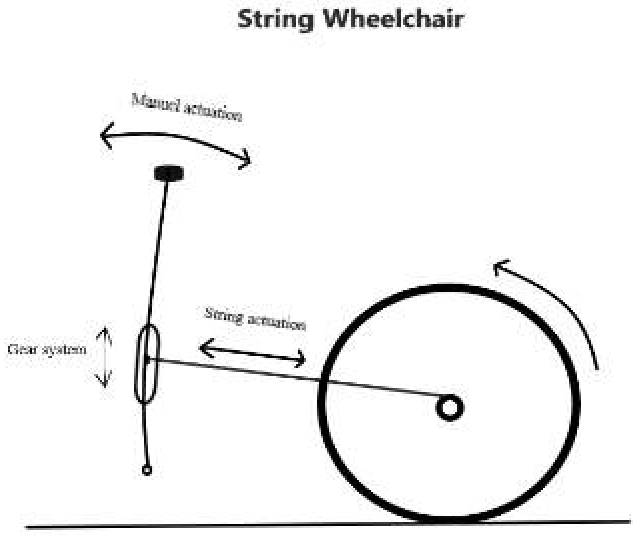
Pedal Wheelchair		
For 10% gradient, 5-degree slope	0.09	rad
Rolling Resistance	17.57	N
Gradient loss	102.44	N
Net Force Required	120.02	N
Net torque required	36.00	Nm
Tension on small sprocket rear	900.12	N
Moment on large sprocket	81.01	Nm
Force to be given on Pedal	**450.06**	**N**

5.1.3 STRING-DRIVE WHEELCHAIR

The following measurements were used for calculation:

Length of lever = 0.55 m

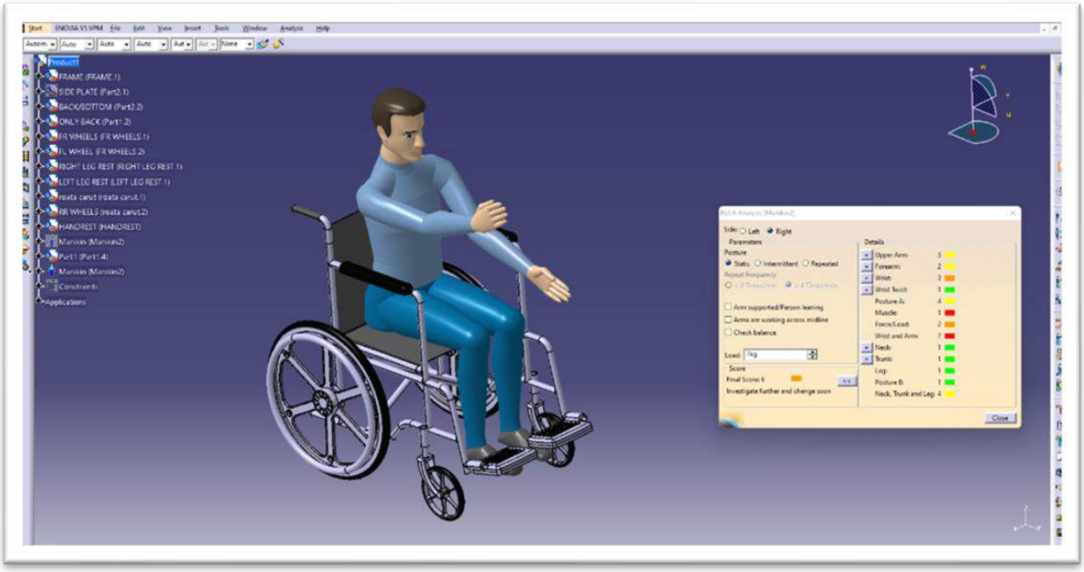
Lever attachment distance from pivot = 0.10 m

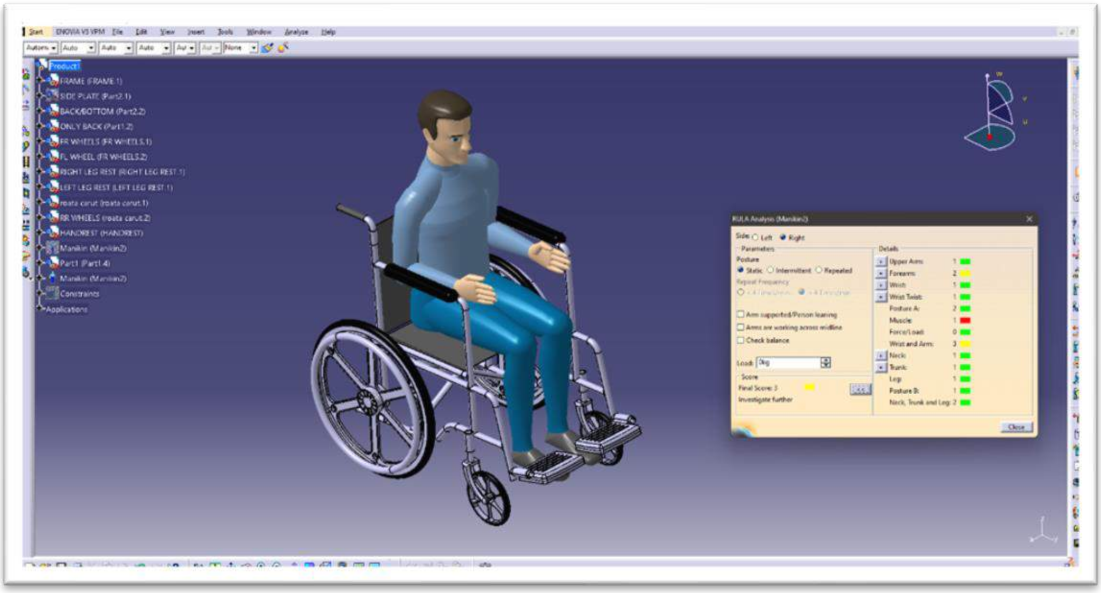


String wheelchair		
For 10% gradient, 5-degree slope	0.09	rad
Rolling Resistance	13.18	N
Gradient loss	76.83	N
Net Force Required	90.01	N
Net torque required	27.00	Nm
Tension on small Ratchet	675.09	N
Force on Lever pully	675.09	N
Force required by hand	**122.74**	**N**

5.2 RAPID UPPER LIMB ANALYSIS (RULA)

RULA was developed to evaluate the exposure of individual person to ergonomic risk factors associated with upper extremity MSD. The RULA ergonomic assessment tool considers biomechanical and postural load requirements of job tasks/demands on the neck, trunk, and upper extremities. With the help of Catia V5 Ergonomics Workbench we performed required RULA analysis. The score obtained in the RULA is shown below





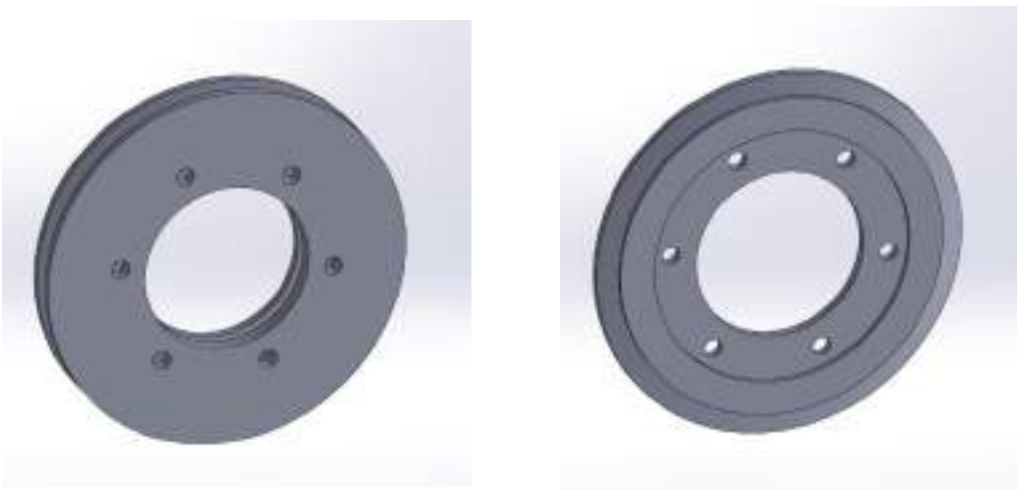
The obtained scores in our string-drive Wheelchair are less compare with Pedal Wheelchair and we have got overall RULA score of 3 which is within the acceptable limit and hence our sitter ergonomics is efficient.

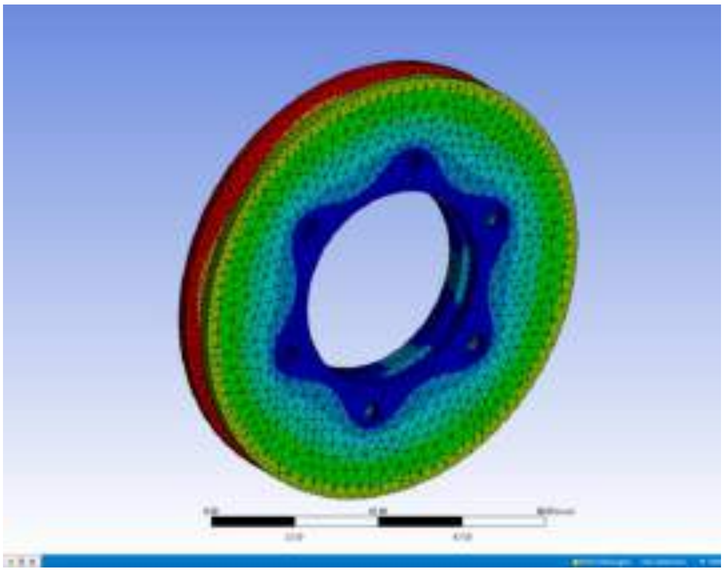
5.3 CAD Modelling

3D modelling was done in Solidworks to verify the mechanism and validate the design. Then the working mechanism was incorporated into the wheelchair for the finalised setup.

5.4 LOAD ANALYSIS

The setup to be attached on the wheel hub on which the string rests and rewinds was manufactured through 3D printing. Load analysis was performed on the part modelling and a suitable material PLA was chosen for 3D printing.





5.5 PROCUREMENT

The following components were procured:

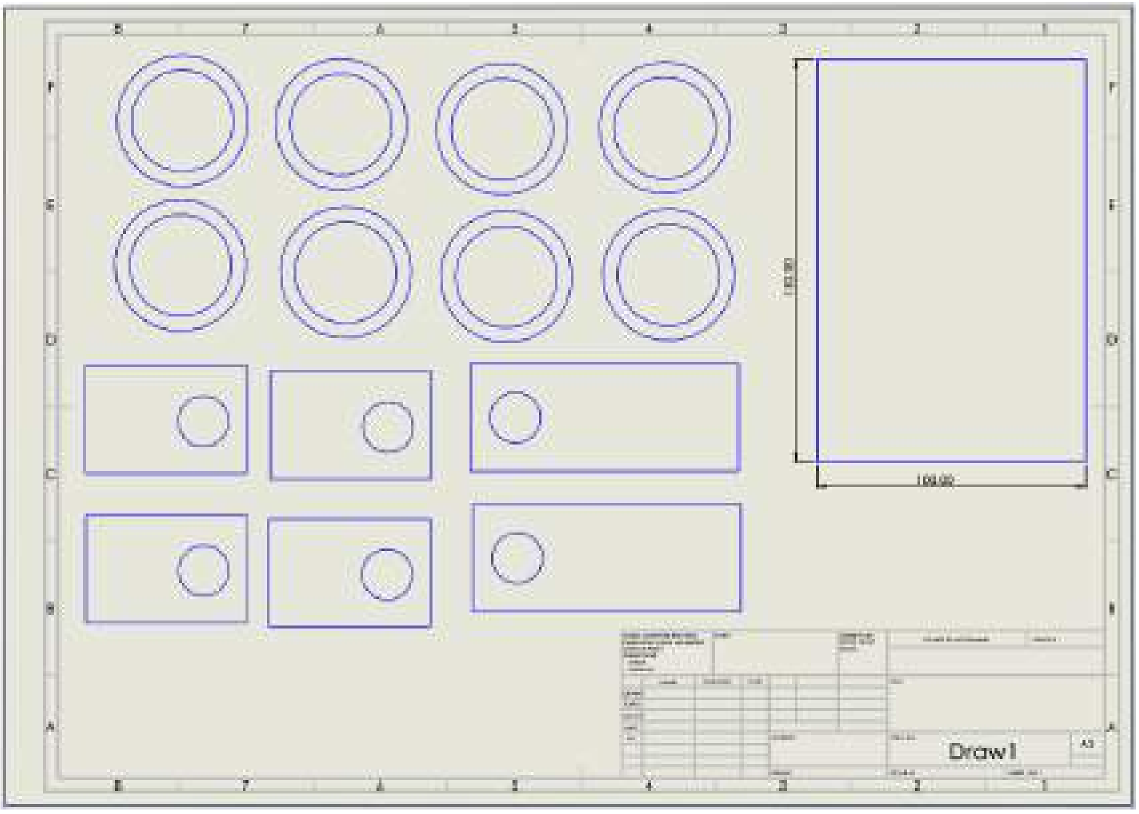
	
	
	

5.6 FABRICATION

Laser Cutting was done to get tabs , rings and support plate.



Tabs were welded onto the wheelchair to fix the lever on the wheelchair.
A support structure was welded onto the wheelchair to support the bevel gear setup. A bearing was used to rest the bevel onto the support.
A freewheel sprocket was attached into the 3D printed assembly and the sprocket was mounted on the wheel hub. The wheel hubs of the wheelchair were replaced with the custom-made wheel hub.
Strings were wound on the 3D printed assembly on the wheel hub and the other end of the string attached above and below the pivot points on the lever.

An elastic mechanism was incorporated into the wheel hub for recoiling and rewinding of the string.

5.7 TESTING

The final working assembly was tested with a load of around 70 kilograms and the wheelchair was operated using the mechanism with minimal effort.

6. FUTURE SCOPE

Ackermann steering can be incorporated with the help of the 2 support wheels located at the front of the wheelchair instead of going for a third wheel or differential mechanism to ensure stability while manoeuvring.

An electronic gear-shift system can be included in the lever to change the pivot point in accordance with the speed of the wheelchair and the torque required to operate it.

7. CONCLUSION

It is evident that the effort required to operate a string-drive wheelchair is the least compared to other transmission mechanisms and hence the motive of the project has been justified. Thus, by providing an ergonomic design, the user can operate it in a comfortable and effortless manner. Design and fabrication of the proposed idea was completed, and its working was verified.