International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 07 | July 2021 www.irjet.net p-ISSN: 2395-0072

Design, Fabrication and Testing of Inclined Car Parking Lift Mechanism

Pawan Subedi[1], Dinesh Rawal[2], Saroj Khadka[3], Dinesh KC[4], Ajay Kumar Jha[5]

[1-5]*Tribhuvan University, Institute of Engineering, Pulchowk Campus, Lalitpur, Nepal*

Abstract - *This technical article introduces a vehicle parking lift mechanism that can be relevant for inclined surface when inclination is higher and vehicles find it difficult to move up and down the ramp for basement parking. As an initial step the lift mechanism including a base plate, front shaft support, track wheel, rotating shaft, worm gear box, rope with pulley and driving parts as motor designed in CATIA V5. Using a commercial software ANSYS workbench, static structural analysis is performed to obtain the details regarding the total deformation, equivalent stress, safety factor and strength of the mechanism. A prototype of the mechanism for the ramp with inclination angle of 19° with motor gear assembly is built and an experimental study is carried out focusing on time duration and velocity of the base plate based on varying payloads. The payload ranges from 0 to 250kg and the respective velocity and time duration values are obtained. From the result of simulation, it was determined that the cantilever bar used for power transmission carries the minimum FOS of 1.2 and with maximum equivalent stress of 208.9 Mpa. The simulation was carried out with the payload of 200kg but during the test of the system, it was found that the machine could lift 251 kg with decrease in velocity of 0.015 m/s.*

Key Words: Lift-Mechanism, static Structural Analysis, deformation, equivalent Stress, Safety Factor

1. INTRODUCTION

Various forms and technology of the parking systems have been developed. They are generally powered by electric motors or hydraulic pumps that move vehicles into the parking location. Vehicle parking systems and the corresponding technologies have increased and diversified over the years. Car parking systems have been around almost since the time cars are invented. In the places like stars hotels, vehicle parking systems are vital as the flow of vehicle is high. Vehicle Parking systems are developed in the early 20th century in response to the need for storage space for vehicles (abudreea, 2016).

Vehicle parking problem is an important concern to be taken into account [1]. Though, if there is space for parking the vehicle but so much time is squandered in guiding the vehicle through the slope and also there is risk of sliding of vehicle. This can result and accidents for the vehicles with poor braking. It will I be great deal if in some way we find out that the proper mechanism to guide the vehicle down the high angled slope. Many innovations are being created to find solution for the same [2].This project deals with one of the methods to deal with such problems.

We have proposed a mechanism to provide mechanical support to vehicles and drivers who find difficulty in riding down the high angled slope especially when the parking is at the lowest basement of the building. The project is based on actual site condition in western city of Nepal (Pokhara) where the light and small vehicles find difficulty in moving down the slope while parking as the ramp of high inclination and re-structuring of the ramp is impossible for already built structure. The drivers without any issue can safely take the vehicle to the parking area with the support of proposed mechanism. It provides safety to both the vehicle and drivers.

2. METHODOLOGY

As the project basically focus on providing support to the vehicle for moving up and down the plane selection of material carries first priority based on design and analysis of the components.

2.1 Selection of Materials

Among the different parts of the lifting mechanism base-plate, shaft holder, shaft, wheel chock, nuts and bolts are the critical part of the machine. The selection of material for these component is very important as it directly influence the strength, weight, manufacture ability, form factor and expenditure of the project. The importance of material selection should be further emphasized when they are in operation. So the selection is done by the help of decision matrix for these parts.

In the decision matrix table for the higher cost lower value is given, for less weight higher value is given and higher the strength higher value is given and for better manufacturing ability higher value is given. As per the requirement strength is the highest requirement so it is given the highest value of 40% and other variables 20%

Variables	Cost	Wt.	Strength	Manufacturability	Total
Wt.--> **Options**	*0.2*	0.2	0.4	0.2	1
Mild Steel	10	09	09	08	09

Wood	09	10	06	10	8.75
Cast Iron	08	07	10	09	8.5

Table -1: Decision Matrix for material selection of baseplate.

Variables	Cost	Wt.	Strength	Manufacturability	Total
Wt.--> **Options**	*0.2*	0.2	0.4	0.2	1
Mild Steel	09	08	09	10	09
Wood	10	10	05	08	8.25
Cast Iron	07	07	10	08	08

Table -2: Decision Matrix for material selection of shaft.

From the above decision matrix **table 1** Mild steel holds the maximum value than wood and Cast iron so the decision is to choose Mild steel for fabricating base plate and from **table 2** mild steel holds the maximum value so mild steel for fabrication of shaft is selected. **Table 3** indicates all the major parts of the system.

Parts	Material	Make or Buy	Dimension(mm)
Base Plate	MS	Make	1000x500x16
Support Wheel	MS	Buy	Diameter- 65
Rope and Pulley	Carbon and Steel	Buy	Diameter4 and 40
Shaft Support	MS	Make	20 (thickness)
Wheel chock	MS	Make	800x100x8
Main Shaft	*MS*	Make	24
Nots, bolts, screw	MS	Buy	Varies
Bearings and sprocket	SS/Steel	Buy	20 (bearing)

Table -3: Other Machine Parts.

2.2. Working principle

The inclined car parking lift mechanism is a simple mechanism which is used to transport the vehicle to and from the parking area on the highly inclined surface where the vehicles face difficulty in climbing up and down.

While moving down the front wheel rests on the base plate and is supported by the wheel chock, whereas while the vehicle is moving up, the rear wheel rests on the base plate .In this way the vehicle is pulled up and lowered down by the help of the lifting mechanism. Its working principle is similar to that of vertical lift. Unlike vertical lift no any counter weights are kept to balance the weight. It is non-automated machine i.e. it has to be driven with manual switches, however it can be made automatic using various sensing devices. Motor provides the input rotary motion which is transmitted to the shaft via chain and sprocket system. A gearbox is coupled to the Motor to reduce the speed and increase the torque. The shaft is connected to the twisted rope which in turn connected to the base plate. While the shaft rotates the rope is winded around it as result the base-plate moves linearly along the plane at a specified velocity. The stopper or wheel chock is controlled via specially programmed 24V DC motor. Motor shaft rotates the worm gear which in turn rotates the shaft of chock. The self-locking property of the worm gear prevents the slipping of chock while the vehicle rests on it. This is the working mechanism of the inclined car parking lift

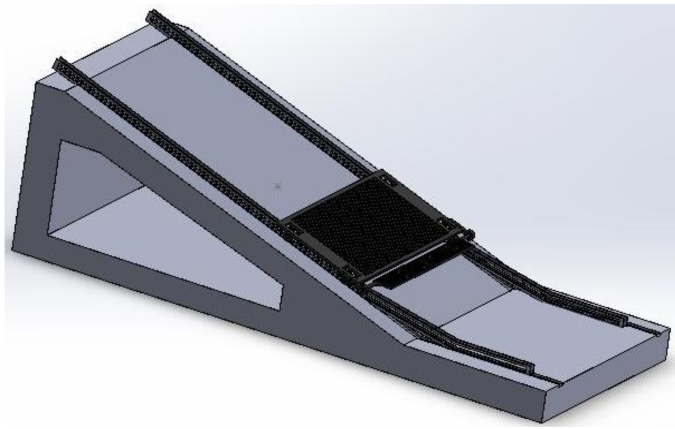

Fig -1: Model of ramp.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 07 | July 2021 www.irjet.net p-ISSN: 2395-0072

2.3. Design of machine components

2.3.1 Design of Worm and Worm Gear

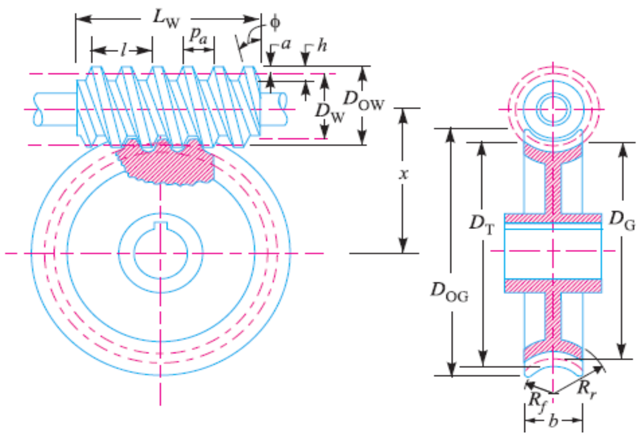

Fig -2: Worm gear properties

Fig-2 indicates the basic gear properties.

When the worm rotates at 1440 rpm, the speed of worm gear is 48rpm. This shows that the worm gear has to make 48 complete rotations per minute. At this reduction ratio the speed of the machine is 0.132m/s. The velocity ratio (VR) of the machine is found to be 30.

The lead of the worm is given by Dw*tanλ and standard module of the worm is calculated as P_a/π. Which is found to be 7.

Centre distance between the worm and gear and pitch circle diameter of the worm is calculated using

X = $\frac{L_N}{2\pi}\left(\frac{1}{sin\lambda}+\frac{VR}{cos\lambda}\right)$ and $D_w = \frac{l}{\pi * tan\lambda}$ respectively.

Similarly for the worm gear knowing the no. of teeth as 90 following values are obtained:

Outside diameter (D_0) = D_G + 0.8903P_a = 649.59 mm. Throat diameter (D_T) = D_G + 0.572P_a = 631.144 mm. Face width = 2.15P_a+5 = 52.3 mm

2.3.2 Dimensional Calculation of Main Shaft

The design parameters for the main transmission shaft are considered as Transmitted torque by shaft (T) =98.8 Nm, Shaft material:- Cast Iron, Maximum shear stress (τ_{max}) =5*10^{10} N/m^2, Maximum allowable bending (M) = 7000 Nm (Approx.)

Due to combine shock & failure factor applied to bending & Torsion are 1.5 and 1.2 respectively. And the required diameter of the shaft is calculated to be 15mm using the MSS theory equation $\boldsymbol{\tau}_{max} = \frac{16}{\pi d^3}\sqrt{(K_d M)^2 + (K_\tau T)^2}$

2.3.3 Power Requirement

As the prototype has been designed for the sin19^0 slope, we have calculated the tension on the rope for the 19 degree ramp and applied load of 200 kg, which is found to be 869.37N. For the desired speed of main shaft 48 rpm, we have calculated the power requirement to be 0.8HP which we approximated to 1 HP as we have the motor availability of 1Hp.

2.3.4 Selection of Ball Bearing for Main Shaft and Secondary Shaft

The design parameters are considered for the ball bearing of main shaft are considered as Torque = 98.8 Nm, Radius of Sprocket = 33.75 mm, Reliability = 95%, Rated life of bearing = 10^6 rev.

For the base part wheel chock shaft design parameters are considered as Speed of D.C. motor (N) = 12 rpm, Input voltage (V) = 24 V, Input current (I) = 3 A, Diameter of worm gear (d) = 10 cm, Reliability (R) = 95%, Rated life of bearing () = 10^6 rev

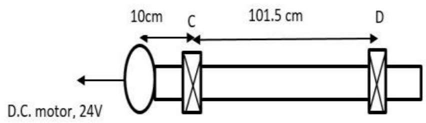

Fig -3: Main shaft bearing position.

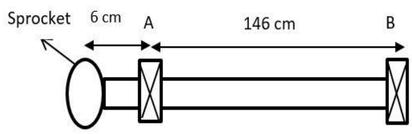

Fig -4: Secondary shaft bearing position.

Based on force and moment balance equations ∑ = 0 and ∑ = 0 we calculated the reactions at A and B.

For the position A, we calculated desired load (Ra) and considering reliability(R) of 95%, desired speed (() of 48 rpm (for main shaft) and 12rpm (for lower shaft), life () of 10000 hrs and rated life () of 10^6 rev we calculate the C10 value of bearing using = $C_{10} = F_D\left[\frac{X_D}{X_0+(\theta-X_0)(1-R)^{\frac{1}{b}}}\right]^{\frac{1}{a}}$

From design hand book we find:
Bore diameter of ball bearing = 20 mm and 15mm
Outer diameter of ball bearing = 47 mm and 35 mm

2.3.5 Design of Rope

Considering the design parameter for the rope as Desired load = 2 KN, Speed of rope (V) = 0.13 m/s, Time to coverage the distance (t) = 12.37 s. For the factor of safety of 4.2 and design load 12.6KN (1.5*4.2*2) and using the equation 750 $d^2 = F_D$ we select the 6 x 19 type metallic twisted rope of diameter 4mm.

2.4 Fabrication

Prototype of the inclined car parking lift mechanism is fabricated in the robotics club Institute of Engineering, Pulchowk campus, Nepal. The design process followed series of calculation and several iteration after analysis and fabrication for the assembly. The standard components are designed according to design procedure.

Base plate is the structural metallic platform where the vehicle's front or rear wheel rests while the mechanism is moving. Mild steel is selected as material for base plate. For fabrication of the base plate first the two 16mm square rod of 1m length and 16mm thick plate of dimension 500mm*100mm is joined accordingly. After that the 12mm square rod is joined in the remaining part by the arc welding process.

Fig -6a: Base plate assembly.

Wheel chock and shaft are the components which provide rigid support to the vehicle while moving up and down the plane. The flap of size 800mm x 100mm x 8mm of curved edge profile is fabricated. The wheel chock and shaft are welded together.

Fig -6b: Flap and base shaft assembly.

Pulley and Shaft assembly were fabricated as per the design calculation. The pulley is fixed to the main shaft and 4mm twisted metallic rope is used as a power transmission from shaft to the baseplate with the help of **cantilever bar**. Mild steel is used as the material for shaft. A sprocket is placed at its one end where chain is connected to transmit power from the motor. The material of shaft is Mild steel and is fabricated in lathe.

Fig -6c: Pulley and shaft assembly.

A **worm gear** assembly is placed on the shaft of the wheel chock. The worm is made from stainless steel and is connected to the 24 V motor shaft. Gear is made up of plastic and is connected to the shaft. The self-locking property of worm gear prevents the wheel chock from slipping. Worm and gear are fabricated in lathe and milling machine.

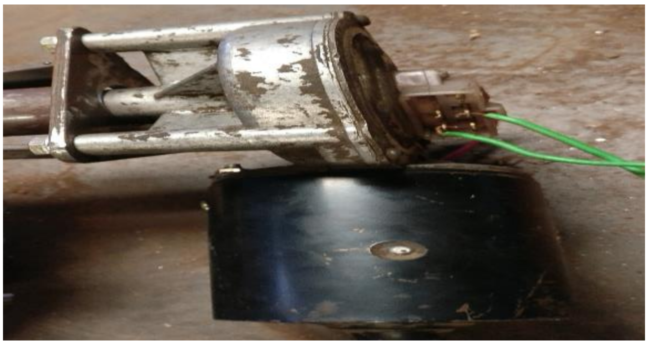

Fig -6d: Worm gear and shaft assembly.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 07 | July 2021 www.irjet.net p-ISSN: 2395-0072

Wheel chock in the machine can be controlled by smart phone. Different electronic component was integrated to a **circuit board** to control wheel chock by smart phone. The power input to the circuit is 220V AC supply. Whereas the transformer and converter in the circuit changes the supply to 20V DC. Arduino was used as the controller and programmed by C programming language.

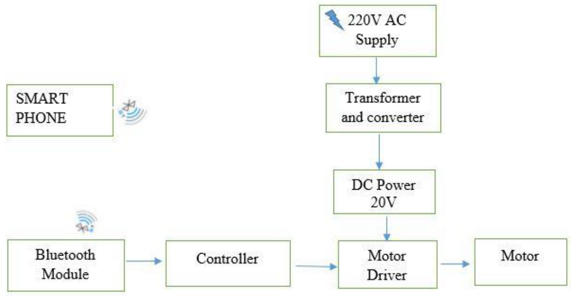

Fig -6e: Flap motor control flow diagram.

3. RESULTS AND DISCUSSON

3.1 Static Structural Analysis

Static structural analysis is vital part of our project. For the developed prototype we take the static load of 200kg and selected the mild steel material. ANSYS workbench is used to determine the total deformation, equivalent stress and factor of safety of each fabricated components. Fig 5a, 5b, 5c, 5d and 5e show the respective data of base plate, wheel chock, shaft support, cantilever bar and main shaft respectively.

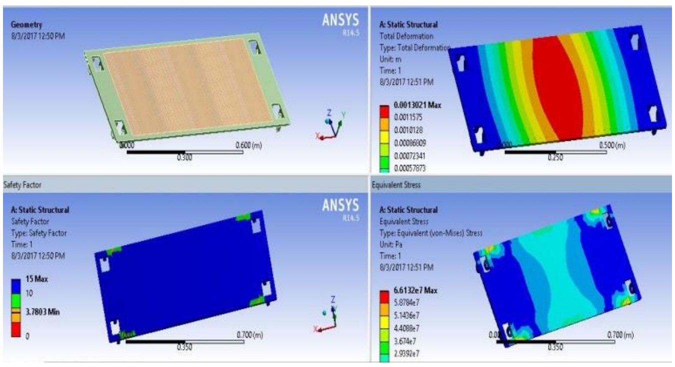

Fig -5a: Analysis of Base Plate.

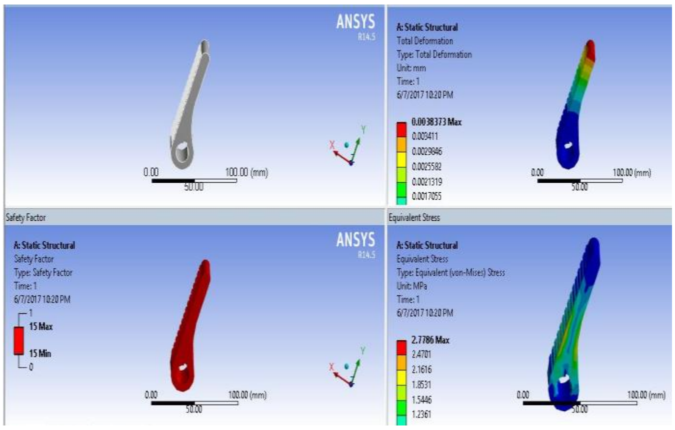

Fig -5b: Analysis of chock (flap).

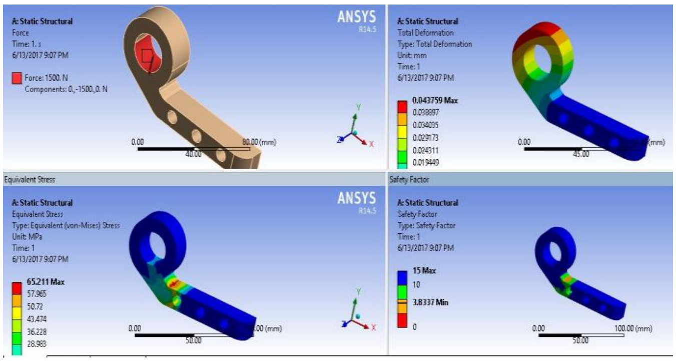

Fig -5c: Analysis of shaft holder.

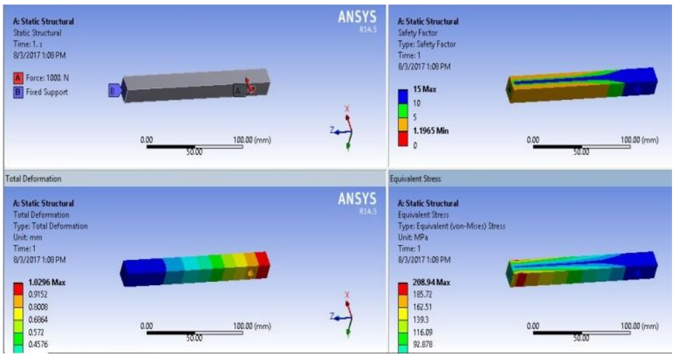

Fig -5d: Analysis of cantilever support.

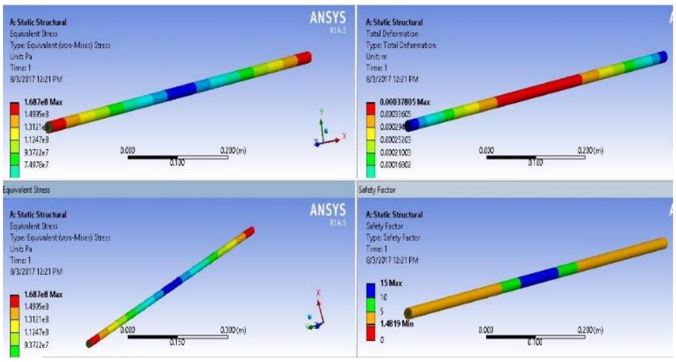

Fig -5b: Analysis of shaft.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 07 | July 2021 www.irjet.net p-ISSN: 2395-0072

The corresponding data is tabulated in the **table: 4**

Components	Total Deformation (mm)		Equivalent Stress(Mpa.)		Factor of Safety	
	Max.	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**
Shaft	0.039	0.17	168.7	74.9	15	1.48
Chock(Flap)	0.004	0.002	2.7	1.2	15	15
Shaft Holder	0.004	0.02	65.2	28.9	15	3.83
Base Plate	1.3	0.5	66.1	29.3	15	3.78
Extension Cantilever Bar	*0.91*	0.45	208.9	92.8	15	1.2

Table -4: Static structural analysis of components.

From the result of simulation, total deformation, equivalent stress and factor of safety are found. It is found that, extension cantilever bar have the least factory of safety of 1.2 and maximum equivalent stress of 208.9 MPa.

3.2 Testing of Mechanism

The test was carried out for the mechanism giving different known weight to calculate the time duration and velocity. Mobile stopwatch was used to calculate the time taken for the machine to travel from initial to final point. The distance between initial and final point is 1.6m. The data are taken for the system climbing up and climbing down. The observed data are plotted against the payloads as in figures:

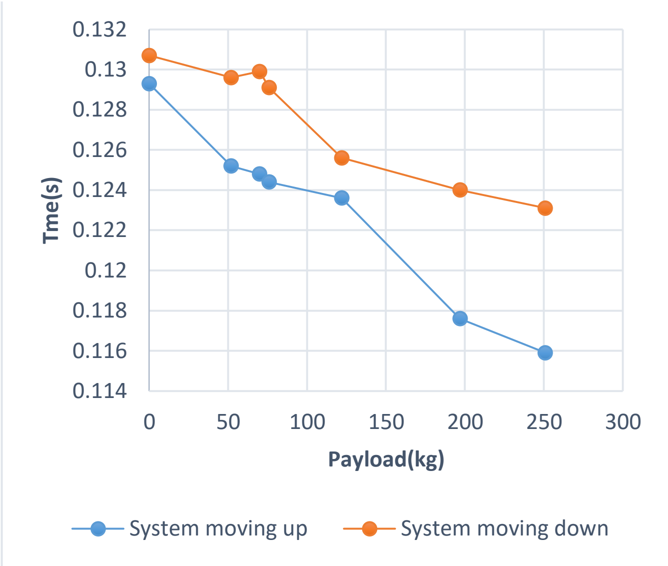

Fig -7a: Effect of payload on average time.

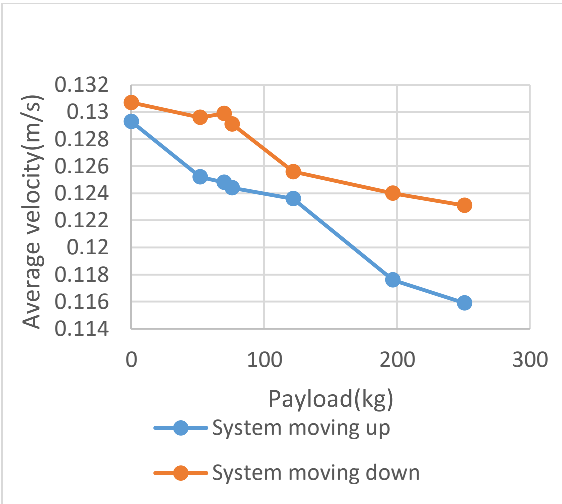

Fig -7b: Effect of payload on average velocity.

Fig-7a and 7b indicate the effect of payload on average time and velocity respectively while moving up and down the inclined plane.

The data from the static structural analysis and test results are close to the objective of the project. So the validity of the project has been justified based on the results obtained.

4.0 CONCLUSION AND RECOMMENDATIONS

The project defines a simple and easy mechanism operated manually which is obviously safer option to use than using vehicle itself. This system can be implemented in those sites where the ramp inclination is high due to limited space. This mechanism can help to increase the usable volume reducing the space for parking. This mechanism can reduce the emission of different pollutants in the parking basement as while suing it the vehicle does not use its engine power. The main benefit would be smart and safer transport of vehicle from top to bottom and bottom to top of the ramp.

There are further works left to be done on this project to make it more reliable. The mechanism can be automated by using sensor to replace man power which further boosts the commercialization of the lift mechanism. The whole mechanism can be made automatic using IOT sensors. This mechanism can be better project in sector of basement parking lift system since this can be used in different slopes and it can be modified to carry the goods as well as the wheel chaired person.

5. ACKNOWLEDGEMENT

We are very grateful to **Prof. Dr. Bharat Raj Pahari** for providing us a valuable project, helping in proper design concept and making us aware of possible availability of manufacturing material related to this project.

6. REFERENCES

[1] Beer, F.P. (2007). Mechanics of Material. Mc Graw Hill.
[2] Dr Y Raghavender Rao. (2017) Automatic Smart Parking System using Internet of Things (IOT), International Journal of Engineering Technology Science and Research.
[3] K. Mahadevan, K. B. (2011). Design Data Hand Book. CBS Publishers and Distributors.
[4] Khurmi, R. S. (2011). A text book of Machine Design. S. Chand & Company Ltd.
[5] Khurmi, R. S. (2011). Theory of Machine. S. Chand & Company Ltd.
[6] Mitrinovic', D. S. (1975). Introduction to the special functions, Civil Engineering Book, Belgrade.
[7] Abramowitz, M., stegun, I. (1979). Handbook of Special Mathematical Functions, Applied Mathematical Series -55, Mir Publishers, Moscow.
[8] Hlebanja, J., Duhovnik, J. (1981). Power Transmission between Teeth at Small Loads, Proceedings of the International Symposium on Gearing and Power Transmissions.
[9] Vladic, J., Zlokolica, M. (1998). On the Dyanamic Analysis of the Load Lifting Machines, Proceedings of ICVE'98, Dalian, China.
[10] Slavic, J., Nastran, M., Boltezar M. (2006). Modeling and Analyzing the Dynamics of an Electric-motor Brush, Jthenal of Mechanical Engineering.
[11] M. Ahmed, W.G.Wei, (2014). Study on Automated Car Parking System Based on Microcontroller, IJERT, and Vol. 3 Issue 1.
[12] R. Mithari, S.Vaze , and S. Sanamdikar. (2014). Automatic Multistoried Car Parking System, IJITAM, Volume-1, Issue-6.
[13] Serway, Raymond A. and Jewett Jr, John W. (2004). Physics for Scientists and Engineers. 6th Ed. Thomson Brooks/Cole. Belmont, CA.
[14] Dowling, Norman E. (1999). Mechanical Behavior of Materials. 2nd Ed. Prentice-Hall Inc.
[15] Hibbeler, R. C. (2004). Statics and Mechanics of Materials. Pearson Prentice Hall.
[16] Ulrich, Karl.T., Eppinger, Steven. D. (2008). Product design and development. Fourth edition.
[17] Hult, J. and Travnicek, L. (1983). Carrying capacity of fibre bundles with varying strength and stiffness. J Mech Theor. Applic 14, 141-158.
[18] Siemens AG 2002-2008. Car Park Management. Available from: http://www.industry.siemens.de/traffic/EN/products/urban/parkloesungen.htm; accessed 10 March 2017.
[19] Katanga Executive Parking. How to use Katanga Valet Parking. Available from: http://www.valet.co.za/template.pHP?page=home (n.d.); accessed 14 April 2017.