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

Automobile Reverse Wheel Locking System

Shrutish Gadakh[1], Niranjan Dhokarikar[2], Sanket Dhut[3], Shrushti Fuley[4]

[1,2,3,4]*S.Y. Student, Department of Mechanical Engineering, Vishwakarma Institute of Technology, Bibwewadi, Pune*

---***---

Abstract - *In a manual gear driven four-wheeled vehicle, it becomes difficult many a times for the driver to control the vehicle due to unexpected rollback of the wheels while climbing a positive gradient. This situation mainly occurs when the vehicle is parked on a slope and needs to be started from rest. At this instant, when the driver releases the hand brake and presses the clutch pedal while lifting the foot on the brake pedal, the vehicle has a tendency to regress. This may even lead to an accident with the vehicle parked behind. The following project aims at making an anti-rollback mechanism that prevents the reverse wheeling of a vehicle on an incline.*

Key Words: **manual gear driven, reverse wheeling, positive gradient, accident, anti-rollback mechanism**

1.INTRODUCTION

While travelling through heavy traffic on an inclined plane, the driver has to move the vehicle very slowly step by step to avoid crashing with the vehicle ahead. While starting up the car, the driver has to perform three tasks at the same time, i.e., releasing the brake, releasing the clutch and accelerating the vehicle. Not every driver is skilled enough to deal with this kind of situation and this may lead to an uncontrolled reverse motion of the car if it is not accelerated at the right time. As a result, the car may crash with the vehicle behind and accidents may occur.

The following project introduces a reverse wheel locking system using a ratchet and pawl mechanism. A ratchet is a mechanical component that allows rotary motion in only one direction and thus, when fixed to the rear axle of the car, can prevent the unexpected rollback of the wheels. A pawl is a mechanical component that remains engaged with the ratchet teeth such that when the ratchet rotates in one direction, the pawl slides over the ratchet tooth and enters into the notch before the next tooth. Thus, the pawl gets jammed in the depression between adjacent teeth and prevents any backward motion. This pawl can be disengaged from the ratchet when reverse motion needs to be allowed using a hydraulic or pneumatic actuator.

The project prototype is designed such that the pawl remains engaged with the ratchet teeth throughout the entire motion of the car but gets disengaged when the driver intentionally uses the reverse gear. This can be done by coupling the gear handle with a hydraulic actuator that controls the engagement and disengagement of the pawl. An IR sensor integrated with an Arduino UNO board detects whether the car is in reverse gear and initiates an actuator accordingly which acts as a backup to the mechanical system.

Using this type of mechanism, the car can be allowed to move in the reverse direction only when intended by the driver. Rest of the time, only the forward motion of the car is possible thus, preventing the unnecessary rollback while travelling on hilly terrains.

2. LITERATURE REVIEW

[1] Analysis of Pawl Ratchet Mechanism in Heavy Vehicles was done by the students of Mechanical Engineering Department of RMD Sinhgad School of Engineering, Pune, Maharashtra, India. In this research paper, the analysis of ratchet and pawl mechanism in heavy vehicles was performed. Here, plain carbon steel and structured steel were used as materials for ratchet and pawl respectively. This paper also mentions as to where the ratchet and pawl mechanism can be mounted in heavy vehicles to prevent backward motion on a hill or incline. The analysis of the mechanism design was carried out in Ansys workbench and the corresponding stresses were analysed. However, the paper does not demonstrate the exact working of the mechanism as well as the conditions according to which it will be activated.

[2] Research on designing of automatic reverse wheel locking mechanism was done by the students of

Department of Automobile Engineering, Oriental Institute of Science & Technology, Bhopal. In this paper, the ratchet and pawl mechanism to prevent the unexpected rollback of vehicle wheels on an incline was introduced wherein the working of these mechanical components was demonstrated. Here, an inclinometer was used to detect the inclination of the vehicle. However, there was no mention about how the engagement and disengagement of the mechanism will take place. But it is a matter of concern to decide whether the system will be controlled manually or electro-mechanically. Also, the use of sensors in such projects add a reliability issue as the failure of the sensors in detecting the inclination can prove to be life threatening.

[3] The work on Design and Fabrication of Self-Locking Wheel Mechanism for Manual Transmission 4 Wheeled Automobiles Subjected to Positive Gradients done by the students of Department of Mechanical Engineering from Saintgits College of Engineering, Kottayam, Kerala, India introduces a self-locking wheel mechanism considering the problems with the pre-existing manual transmission systems especially when the vehicle is moving up an incline or when it is to be parked on an incline. Here, along with the ratchet and pawl mechanism, an Arduino UNO board as well as a gyro sensor was used. The ratchet and pawl mechanism fitted to the idle shaft of the vehicle is the one which prevents the back roll of the vehicle on an incline int this work. The Arduino Uno board connected with the gyro sensor was used to measure the inclination of the road surface with the datum and the critical slope was programmed into the microcontroller. When the vehicle travels on a flat surface, as there is no chance of back roll, the microcontroller detects no change in the gradient and hence, the ratchet and pawl mechanism does not get engaged. When entering into a positive gradient, if the slope exceeds the set value (which is programmed), the microcontroller sends signal to the solenoid via regulator IC to engage the pawl with the ratchet wheel and thus, arresting the backward motion and allowing only forward motion. When entering into a negative gradient, since there is no chance of back roll, the sensor after detecting the negative slope sends no signal to the solenoid and hence, the ratchet and pawl will be in disengaged position.

Even though this work clearly explains the working of the mechanism in vehicles, it is highly dependent on sensors and other electronic components for the engagement and disengagement of the ratchet and pawl. However, in such cases, mechanical systems are more reliable than electronic ones as failure or poor calibration of the electronic components can lead to a failure of the entire system. Moreover, a delay in signal transmission can also affect the performance of the system thus, causing problems to the driver.

[4] Reverse Braking System, a work published by Mechanical Engineering students of Shri. Chhatrapati Shivajiraje College of Engineering, Pune explains the use of the ratchet and pawl mechanism that was collectively mounted on the rear axle to ensure that the vehicle does not move backwards while climbing an incline. Here, an electronic push button was provided on the steering wheels which can be used by the driver to engage or disengage the mechanism as per the requirement. However, there is a possibility that the driver forgets to disengage the mechanism while using the reverse gear. As a result, the wheels may get locked even when reverse motion is required and this can lead to damage of the components and in severe cases may lead to accidents. Also, adding a push button also add another task that needs to be focused on by the driver while driving the vehicle. This may become tedious at times as the driver has to repeatedly use the push button every time he switches between forward and reverse gears.

3. METHODOLOGY/EXPERIMENTAL

3.1 Materials/Components

The project makes use of the following components:

Ratchet and Pawl pair: These two components used together allow rotary motion of the car axle only in forward direction and thus, prevent the backward rolling of the wheels. Ratchets and Pawls are usually designed from steels, stainless steels, cast iron, brass, etc. They are often heat treated to impart surface hardness and wear strength as well as beam strength as the ratchet teeth are subjected to bending failure.

Fig -1: Freewheel used as ratchet

IR sensor and Arduino UNO board: The IR sensor integrated with the Arduino UNO board detects whether the vehicle is in a reverse gear by analyzing the position of the gear handle and controls the hydraulic actuator that engages or disengages the pawl from the ratchet according to the motion requirement.

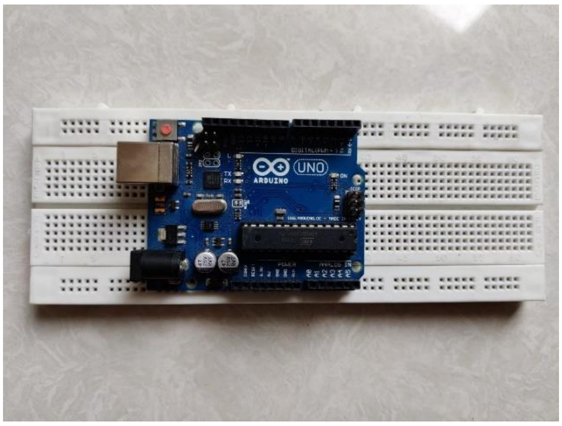

Fig -2: Arduino UNO board

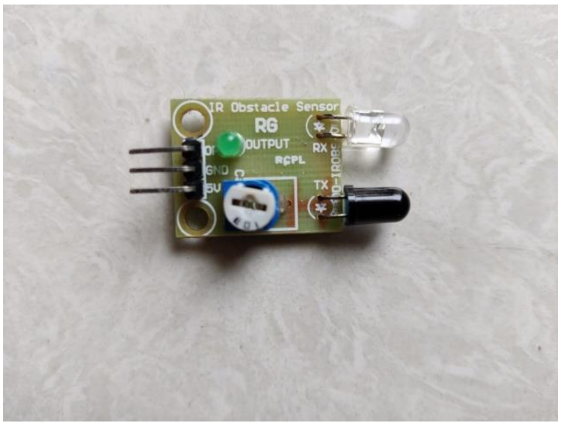

Fig -3: IR sensor

Hydraulic actuator: This actuator performs the task of engaging or disengaging the pawl from the ratchet teeth as per the input given by the IR sensor. Another such actuator is directly connected to the gear handle to carry out the same operation in case of failure of the sensor in detecting the reverse gear.

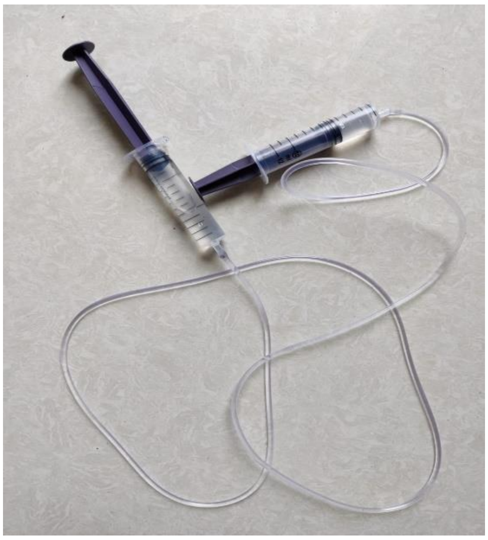

Fig -4: Hydraulic actuator (Syringes)

3.2 Synthesis/Design

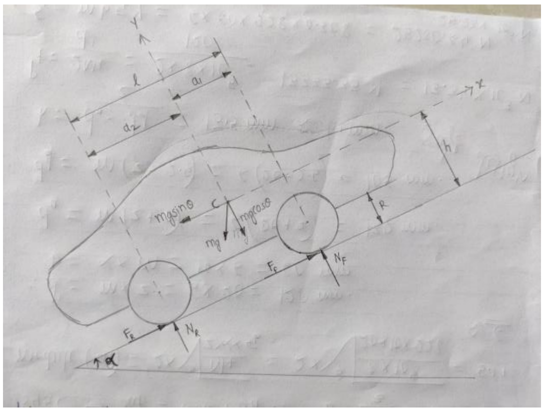

Fig -5: Free Body Diagram

Calculations for torque on the ratchet due to weight of the vehicle:

$2F_f + 2F_r - mg*\sin\alpha = 0$ .... (1)

$2N_r + 2N_f - mg*\cos\alpha = 0$ ...... (2)

$2N_r*a_2 - 2N_f*a_1 - 2*(F_r + F_f) * h = 0$ ... (3)

$L = a_1 + a_2$ .... (4)

Solving these equations, we get

$N_f = (mg/2L) * (a_2\cos\alpha - h\sin\alpha)$

$N_r = (mg/2L) * (a_1\cos\alpha + h\sin\alpha)$

$F_r + F_f = (mg*\sin\alpha)/2$

Let the coefficient of friction between the road and the tyre be μ.

$F_r = \mu*N_r = (\mu mg/2L) * (a_1\cos\alpha + h\sin\alpha)$

Assuming L = 3m, a_1 = 1m, a_2 = 2m, h = 1m,

Mass of car + passengers = M=2000kg,

g = 9.18 m/s^2, μ = 0.7,

Wheel radius = R = 0.25m,

At critical angle of inclination (α_{max}), the total force of friction is equal to the weight component along the incline.

Hence, $mg\sin\alpha_{max} = \mu mg\cos\alpha_{max}$

$\tan\alpha_{max} = \mu = 0.7$

$\alpha_{max} = 35$ degrees

Torque on the rear wheel = Torque on the axle = Torque on the ratchet = $T = F_r * R$

$= (\mu mgR/2L) * (a_1\cos\alpha_{max} + h\sin\alpha_{max})$

$= ((0.7*2000*9.81*0.25)/ (2*3)) *(\cos 35 + \sin 35)$

$= 796.98$ N-m = 800 N-m = $8*10^5$ N-mm

This is also the resistive torque acting on the ratchet tooth due to the pawl.

Calculations for ratchet dimensions:

Material: S45C, S_{ut} = 686 MPa

$\sigma_b = S_{ut}/3 = 686/3 = 228$ N/mm^2

$\psi = b/m = 10$

$z = 20$

Module $= m = 2*(M_t/ (z* \psi* \sigma_b))^{1/3} = 6$

$d' = m*z = 6*20 = 120$ mm

$b = \psi*m = 60$ mm

$d_a = m*(z+2) = 132$ mm

$d_d = m*(z-2.5) = 105$ mm

h = 14 mm

Lewis form factor = Y = 0.308

$S_b = mb\sigma_b Y = 25280.64$ N

$P_{eff} = P_t = 2M_t/d' = 13333.33$ N

$P_{eff} < S_b$. Hence the design is safe.

Calculations for Pawl design:

The pawl is subjected to bending moment due to eccentric loading, where e = h

$M_b = P_t*e=13333.33*14=186666.62$ N-mm

Width of pawl tip, x = 10 mm

$\sigma_{b1}= (6M_b/bx^2) + (P_t/bx)$

Substituting the values of M_t, P_t, x and b,

we get, $\sigma_{b1}= 208.88$ N/mm^2

$\sigma_{b1} < \sigma_b$. Hence, the design is safe.

Thickness of pawl hub = t_h = 10mm

Diameter of the pawl pin, d

$= 2.71*((P_t/2\ \sigma_{b1}) * (b/2 + t_h))^{1/3}$

= 29.39 = 30mm

3.3 Characterization/Testing

As a prototype of the project a wooden model of a typical four-wheeled vehicle was built. The hydraulic actuator was made using injection syringes and saline tubes filled with water. One end of this actuator remains connected to the gear handle and the other end controls the engagement and disengagement of the ratchet and pawl. A bicycle freewheel which also allows motion in only one direction was used to serve the purpose of a ratchet. A small metallic element was used to lock or unlock the teeth of the freewheel as and when required and thus, performs the task of the pawl. A breadboard circuit integrated with an Arduino UNO board was used to detect if the car is in a reverse gear. An LED was used to indicate that this condition has been satisfied and the electronic actuator which will be used as a backup to the hydraulic actuator needs to be activated. The model was placed on an inclined wooden plank that resembles a hilly terrain and was released to check the working of the system.

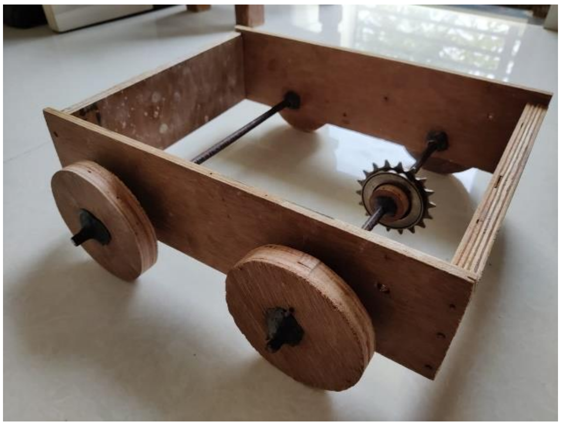

Fig -6: Basic design

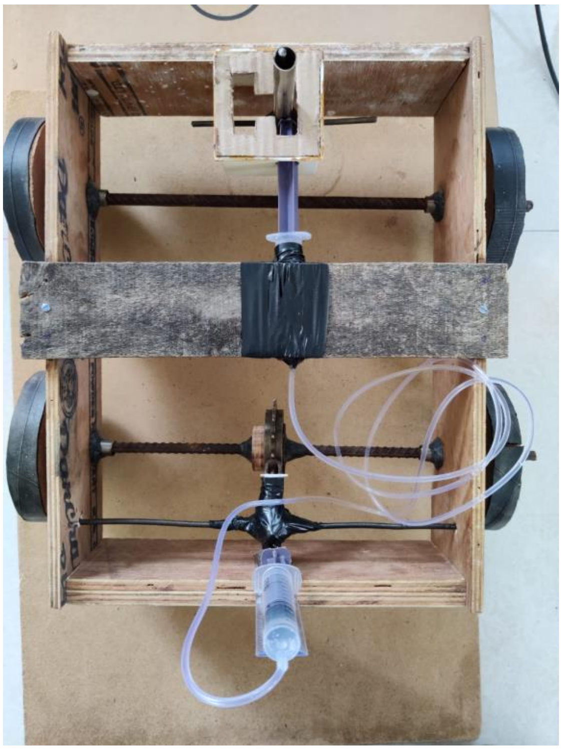

Fig -7: Top view of the system

4. RESULTS AND DISCUSSION

When the vehicle model is placed on an inclined plane, it has a tendency to move down the incline due to its weight. But, as the locking mechanism remains engaged throughout the motion, it does not allow the wheels to roll back. As a result, the vehicle can move only in one direction on the incline, i.e., forward. When the driver hits the reverse gear, the piston of the hydraulic actuator (here, the injection syringe) gets pressed and as a result the pawl gets disengaged from the ratchet teeth (here, freewheel teeth) and thus, motion in the reverse direction is permitted. Also, at the same time the distance between the IR sensor and the gear handle becomes less than a specific value and this is detected by the sensor and it sends a signal to another actuator which acts as a backup to the hydraulic actuator (here, demonstrated by glowing an LED. The glowing of Green LED indicates that the car is in a reverse gear and that of the Red LED indicates it is not). Again, after switching to some another gear, the piston of the hydraulic actuator is brought back to its initial position and the pawl gets engaged with the ratchet teeth once again thus, preventing any backward motion.

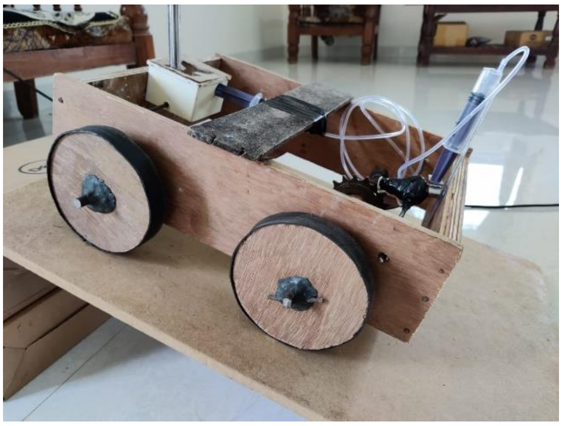

Fig -8: Vehicle on incline

Fig -9: Ratchet-Pawl engagement

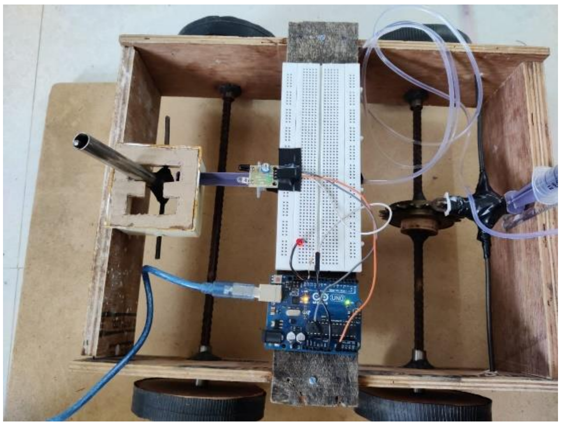

Fig -10: Vehicle not in reverse gear

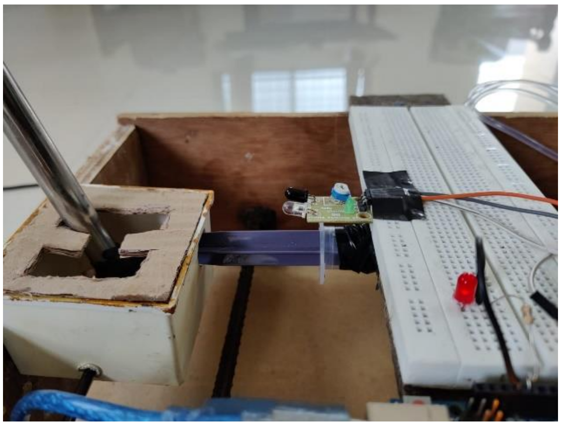

Fig -11: Red LED glowing

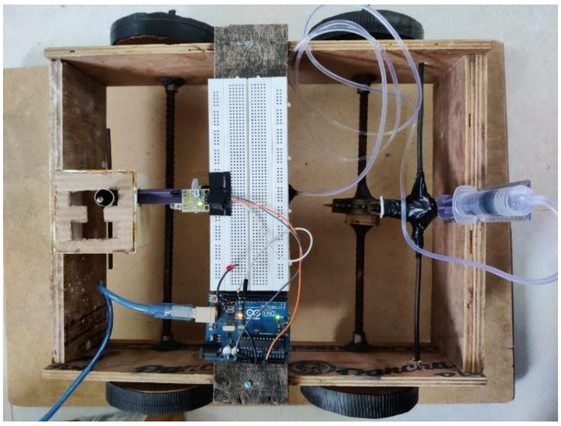

Fig -13: Vehicle in reverse gear

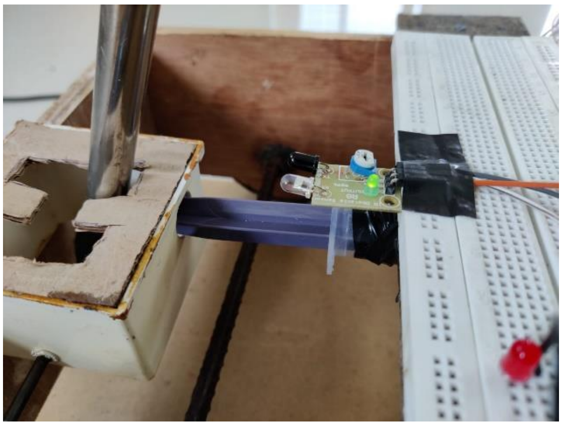

Fig -14: Green LED glowing

Fig -12: Disengagement of ratchet and pawl

5. LIMITATIONS

The mechanism introduced in this project does not prevent the skidding of vehicle wheels on slippery surface. Failure or poor calibration of the sensors can lead to a failure of the entire transmission system. Hence, a backup mechanism always needs to be maintained. The ratchet and pawl must have a high load carrying capacity. As a result, the design and manufacturing of these components can turn out to be expensive. In some cases, introduction of the ratchet on the car axle may require a change in the position of other neighboring components.

6. FUTURE SCOPE

Multiple sensors can be used to ensure accuracy in detecting whether the car is in a reverse gear or not. Multiple ratchet–pawl pairs can be mounted on both the axles to impart more strength to the locking mechanism. This also reduces the total load acting on an individual ratchet and thus, requires a relatively compact design. Certain design modifications can be done in the vehicle tyres to avoid skidding of the vehicle on an inclined plane during rainy season or when the friction between the tyres and the road is very low.

7. CONCLUSIONS

In this way, the prototype of automobile reverse wheel locking mechanism was built considering all the necessary design parameters and the CAD model for the same was built using Solidworks 2020. The introduction of electronics in the project makes it more reliable by providing a backup to the mechanical system. With certain modifications and design improvements, this mechanism can prove to be very helpful in preventing the discomfort as well as accidents that may occur due to rollback of vehicle wheels on an incline. Moreover, it does not cause any problems in moving the vehicle in reverse direction whenever required.

ACKNOWLEDGEMENT

The author would like to thank the authorities of Vishwakarma Institute of Technology, Pune for providing this opportunity to apply the concepts of machine design and theory of machines in solving real world problems. The author also expresses his sincere gratitude towards Prof. (Dr.) Mahesh Walame for his valuable guidance during the completion of this project. Finally, the author would like to thank all the resources available on the Internet as well as the authors of various books and research papers that provided the necessary information as and when required.

REFERENCES

[1] Mechanisms and Mechanical Devices Sourcebook by Neil Sclater, McGraw Hill Publication

[2] Design of Machine Elements, by V. B. Bhandari, McGraw Hill Publication.

[3] Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, fundamentals, theory and design, by

Mehrdad Ehsani, Yimin, Gao, Sebastien E. Gay, Ali Emadi, CRC Press

[4] Jazar R.N. (2014) Forward Vehicle Dynamics. In: Vehicle Dynamics. Springer, New York, NY.

[5] Design Databook of Engineers by PSG College Kaliakathir Achchagam

[6] Machine Design Databook, Digital Engineering Library, The McGraw Hill companies