Qeios

Design and analysis of hand-break release system with the help of accelerator of automobile vehicle

Karan Choudhary[1], Emarti Kumari[1]*, Himanshu Bairwa[1], Rehaan[1], Divyanshu Parihar[1]

[1]Mechanical Engineering Department, MBM University Jodhpur-342011, Rajasthan, India.

*Email ID: Emarti.me@mbm.ac.in

Abstract

The handbrake (parking brake) is a crucial safety system in automobiles, which helps to lock the vehicle's motion and facilitate parking. Traditionally the operation of hand brake is done manually by a lever, and during the releasing of hand brake it can be mistakenly remains in applied condition (engaged position) by the driver. This accidental engagement can cause significant damage due to heat generation on the brake drum and shoes, potentially leading to further accidents when the brake is applied, potential locking up of wheels while driving. To address this concern, we propose the design and fabrication of handbrake release system by accelerator. This system will eliminate the risk of human error associated with manual operation and ensure the safe and reliable engagement and disengagement of the parking brake.

Keywords: handbrake; engaged position; automobile; bell crank lever

1. Introduction

The handbrake plays a pivotal role in ensuring both safety and functionality. Its primary function is to maintain the vehicle's stationary position when parked. Engaging the handbrake ensures that your car remains in place, especially on uneven or inclined surfaces, thereby preventing unintended movements. Due to inappropriate working of handbrake sensors, human errors, malfunctioning of Hand Brake, it can be lead to major accidents. In light of these challenges, it becomes evident that the handbrake's operation and safety can benefit from innovation and improvement. The handbrake has two functions: slowing down a moving vehicle and keeping it stationary on a slope [1]. Veeramanikandan *et al*. [2] used a ratchet mechanism with Solenoid valve to engage and disengage hand brake. Shedge *et al*. [3] developed a seat belt activated hand brake system, in which the seat belt of the car activates the parking brake through a pneumatic cylinder and deactivates hand brake when seat belt attached. Dalvi *et al*. [4] fabricated the electro mechanical parking brake system. It engages the handbrake when the ignition is off and the seat belt is removed. It disengages the

https://doi.org/10.32388/7HXRHH

handbrake when the ignition is on, the seat belt is fastened, and the foot brake pedal is pressed [5]. A systematic approach was given [7] for the design and development of parking brake systems for cars. Ishak *et al*. [7] developed a one dimensional model of leading-trailing drum-type brake system and conducted experiments on a test bench also verified it with the hand brake system in the vehicle. The mechanical efficiency of various types of cable constructions from different industries has been studied by Stoloff [8] for parking brake systems. A seat belt assisted automatic hand brake system was developed [9-10] for four wheeler vehicle.

Day *et al*. [11] performed finite element analysis of commercial vehicle drum brake system in the presence of mechanical and thermal load and studied the effect of lining wear due to heat transfer at the friction interface. Wolf [12] introduced the mathematical model to analyses heat transfer in brakes and calculated temperature distribution in disc and drum brake of a light truck through finite element method. Tirovic *et al*. [13] analyzed the stresses and deflection of a commercial vehicle disc brake calipers though finite element techniques and digital image correlations. Hwang *et al*. [14] investigated the effect of temperature in a solid disc by 3D modelling for repeated braking in a vehicle and also studied the thermal distortion and thermal stresses. Xiaoyan *et al*. [15] modelled a model of full automobile using ADAMS software and optimized the braking performance. McKinlay [16] demonstrated the influence of rollway on the parking brake system. Author used the finite element method based simulation software to analyze the change in contact pressure at the frictional interface during rollway event.

Limpert [17] analyzed various types of brake systems such as mechanical, hydraulic, air, and anti-lock brake systems. Author also investigated the brake failure considering partial and full brake failure. Koylu and Cinar [18] studied the effect of change in pressure in anti-lock brake system considering three different dampers. In this article authors will design and analyze hand brake release system to make cars safer with an Automatic Handbrake system. Instead of using a manual lever, that works automatically based on the car's ignition key.

2. Feasible Study

2.1 Force calculation

Here, force calculations are done as followed by Ishak *et al*. [7]. Schematic representation of force on hand brake lever, drum brake cable is shown in Figure 1. For attaching pawl at 9^{th} teeth there is a requirement of 350N force at hand brake is expressed as follows:

F_{hb} = 350 N , L_1 = 10 inch, L_2 = 2 inch

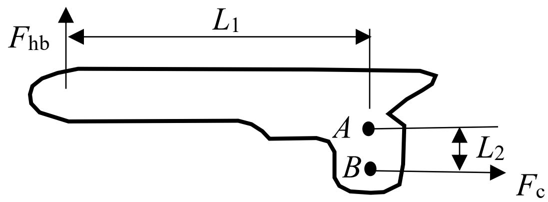


Figure 1. Schematic representation of force on hand brake lever, drum brake cable

$$F_c = \frac{F_{hb} \times L_1}{L_2} = 1750N \quad (1)$$

Where, F_{hb} – applied Force on handbrake lever, F_c – force on drum brake cable

Cable Efficiency is 80% (standard).

Thus, F_c = 1750×0.8 = 1400 N (at the drum brake Actuator lever)

2.1.1 Force in Drum Wall by brake shoe as shown in Figure 2.

Lever length, L_3 = 4 inch

Shoes Extension, L_4 = 1 inch

Force at shoes, $$F_d = \frac{F_c \times L_3}{L_4} = 5600N \quad (2)$$

Force at the pawl of hand brake $F_c = F_p$ = 1750 N (3)

Where, F_p = force on pawl link

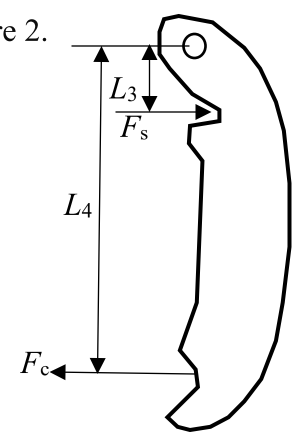


Figure 2. Forces at parking brake lever

Length of the link on the pawl is 3.5 inch – 1 inch so that mechanical advantage on the pawl will be achieved. So that force required to release pawl from teeth will be expressed as follows:

$$F_p' = \frac{F_p \times L_4}{3.5} = 500N \quad (4)$$

2.1.2 Now the same force will be required at bell crank lever output. $Fb_{out} = F_p'$= 500 N

Now effort required the input of bell crank will be given by:

$$Fb_{in} = \frac{Fb_{out} \times 3.5}{7} = 250N \quad (5)$$

Thus, less force will required at bell crank input of bell crank due to mechanical advantage of bell crank lever.

2.2 Motor requirement

Weight = 28 kg (wheel + drum brake + shaft)

Radius of wheel = 0.19 m

Angular velocity at starting $\omega_1 = 0$

Maximum angular velocity $\omega_2 = 2\pi\times120/60 = 12.56$ radian/sec (6)

Inertia of the wheel, $I = \frac{1}{2} \times m\times r^2 = 0.5054$ kg×m^2 (7)

Angular acceleration of wheel at time $t = 1$ second, $\alpha = (\omega_2 - \omega_1)/t = (12.56-0)/1 = 12.56$ rad/sec^2

Torque required, $T = I\times\alpha = 0.5054\times12.56 = 6.347$ N-m (8)

Power Required, $P = T\times\omega_2 = 6.347 \times 12.56 = 79.72$ Watt (9)

$P = 0.106$ HP

Power of Motor available $P = 0.17$ HP or $0.17\times746 = 126.82$ watt

Speed of available Motor $N = 1440$ rpm or $\omega = 150.79$ rad/sec

The difference in the power required and power available of motor created an issue regarding the speed. Hence, here authors used a gearbox for reduction of speed and increasing the torque.

Gear ratio = 1:4

Torque of motor = Power/angular velocity = P/ω

$T_1 = 0.841$ N-m

2.3 To Calculate RPM and Torque of gearbox both at input and output

From Gear train ratio: $N_2/N_1 = T_1/T_2 = D_1/D_2$ (10)

RPM at input of gear box is $N_1 = 1440$ rpm, $D_1 = 2$ inch, $D_2 = 6$ inch

$N_2 = (N_1\times D_1)/D_2 = 480$ rpm (11)

Torque at input of gear box is $T_1 = 0.841$ N-m

$T_2 = (T_1\times N_1)/N_2 = 2.52$ N-m (12)

Output rpm of gear box

$N_3 = N_2/4 = 120$ rpm (gear ratio) (13)

Torque at output of gear box is: $T_3 = T_2 \times 4 = 10.08$ N-m, diameter are $D_3 = 2.28$ inch, $D_4 = 3.07$ inch.

Speed of output shaft: $N_4 = (N_3\times D_3)/D_4 = 89.120$ rpm (14)

Final Torque on shaft: $T_4 = (T_3\times N_3)/N_4 = 13.57$ N-m (15)

The final value of toque at shaft for rotating wheel is 13.57 N-m; which is greater than required value of torque 6.347 N-m.

3. **CAD model of modified hand brake system:** schematic representation of CAD model is presented in Figure 3.

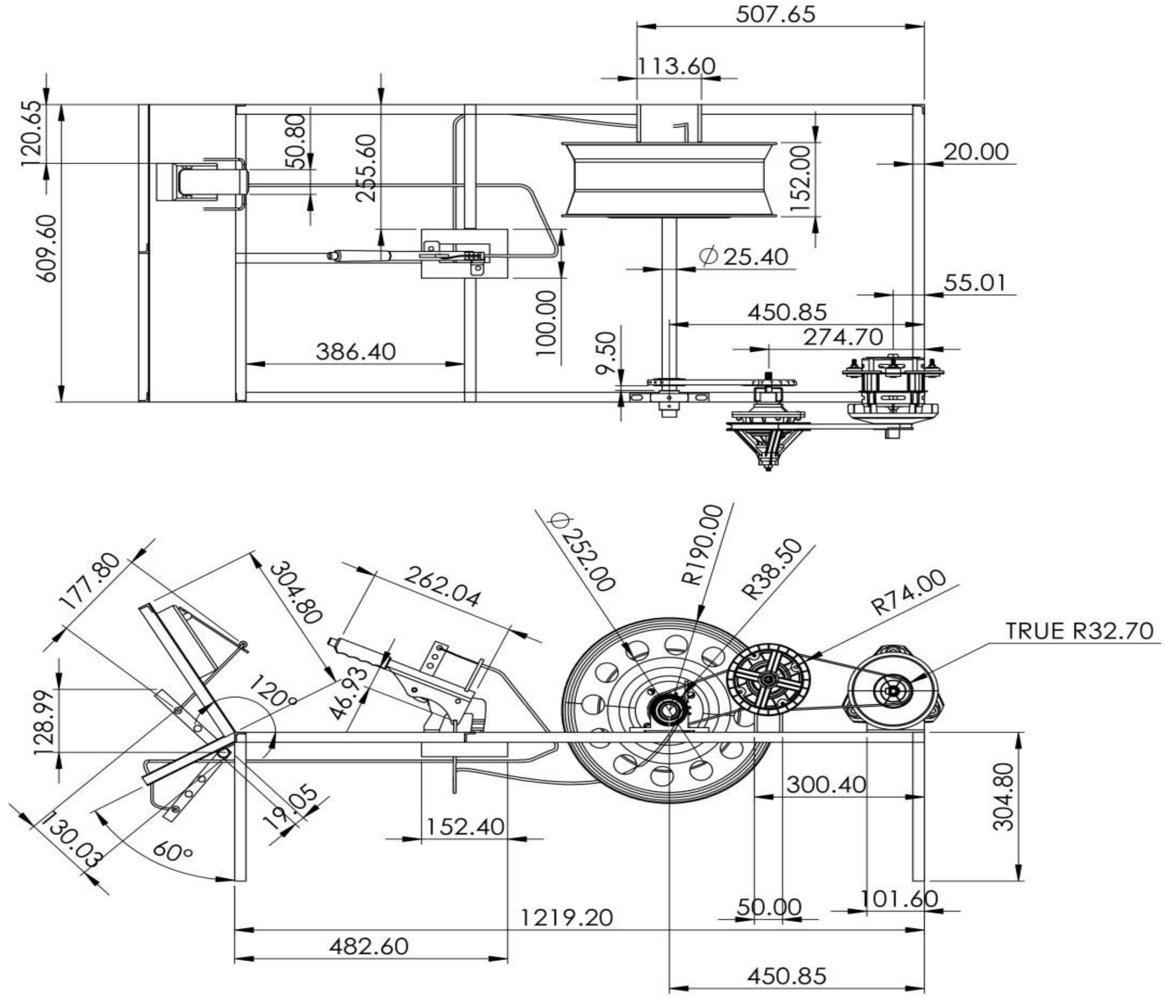


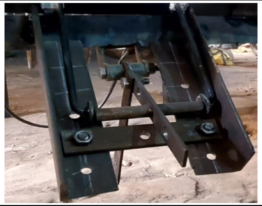
Figure 3. Line Diagram of Project Model (All dimensions in mm)

In Table 1 presented the various component (i. e. frame, shaft, pedestal, drum brake, wheel, L-shaped channel, gear box, motor, accelerator, hand brake, modified hand brake, link, bell crank lever, bicycle sprocket, bike sprocket, and brake cable) of physical model with its specifications, images and functions of these components.

Table 1. Schematic representation of parts, dimension, functions of developed model.

Component Name	**Specifications**	**Component image**	**Function**
Frame	Mild steel Length - 48-inch Breadth - 24-inch Height - 15 inch		The metallic frame act as a skeleton for the entire model and provide rigidity and stability.
Shaft **Pedestal**	Diameter - 1 inch Length - 12 inch Material - Mild Steel Diameter - 1 inch Material - Carbon Steel Company - UCP	  (a) Shaft (b) Pedestal	Support and rotate the wheel. To provide support for a rotating shaft
Drum brake **Wheel** **Channel (L shaped)**	Width - 3-inch Diameter - 8-inch Material - Cast iron Company Name - Ford Figo (Car) 1.2 L Width - 6-inch Diameter- 14-inch Material - Steel Company Name - Ford Figo (Car) 1.2 L Length - 5-inch Width – 4.75-inch Depth – 4 inch Thickness - 0.23inch Material – Mild steel	 (a) drum brake   (b) Wheel (c) Channel *Note - Wheel Drum Brake assembly is fixed on the channel	To provide support for a rotating shaft. Rotation with respect to shaft. To support Drum Brake assembly.

Gear Box **Motor**	Make - Godrej Pulley input Dia. - 6 inch Gear ratio- ¼ Material- PVC Make - Godrej Capacity - 0.17 HP pulley Dia. - 2 inch Material - copper		Speed reduction and increase torque. It is connected to shaft and rotate it. To provide power to gearbox.
Accelerator Mechanism	Length - 6.5 inch Breadth – 3 inch Height - 1.5 inch Weight - 300 gram Material - Mild Steel Brand - Samrat		Release of the Hand Brake and regulate the motor rpm.
Handbrake **Modified Handbrake**	Material - Mild steel Length - 11-inch Breadth - 2.5-inch Thickness- 1 inch Company Name - Mahindra Bolero car Diameter of Hole - 0.23 inch Material - Mild Steel Slot Length - 1.5 inch Slot Breadth - 0.5 inch Length of Link - 2.5 inch Thickness of Link - 0.19 inch	 	To ensure the vehicle does not roll away when parked.
Link	Length – 7 inch Breadth – 4 inch Diameter – 6 mm		Transmits the force between accelerator pedal and bell crank lever.

Bell Crank lever	Angle – 120° Length – 7×7 inch Breadth – 0.6 inch Thickness – 0.11 inch		Direction changing mechanism. Changes the direction of effort applied.
Bicycle Sprocket	Inner Diameter - 35 mm Teeth - 18T		To transmit power from gearbox to shaft with help of chain.
Bike Sprocket	Tooth Diameter – 61 mm Teeth – 14T		Rotates only in one direction.
Brake Cable	Diameter = 1.5 mm		Transmits the force from the accelerator pedal to the hand brake pawl. Also, it helps to transmit braking force from hand brake to rear brakes.
Spring	Spring constant = 5.56 No of coils = 28		To store and absorb pulling energy. It pulls down the hand brake lever.

3.1 Solid works model: schematic diagram of solid works model is given in Figure 4.

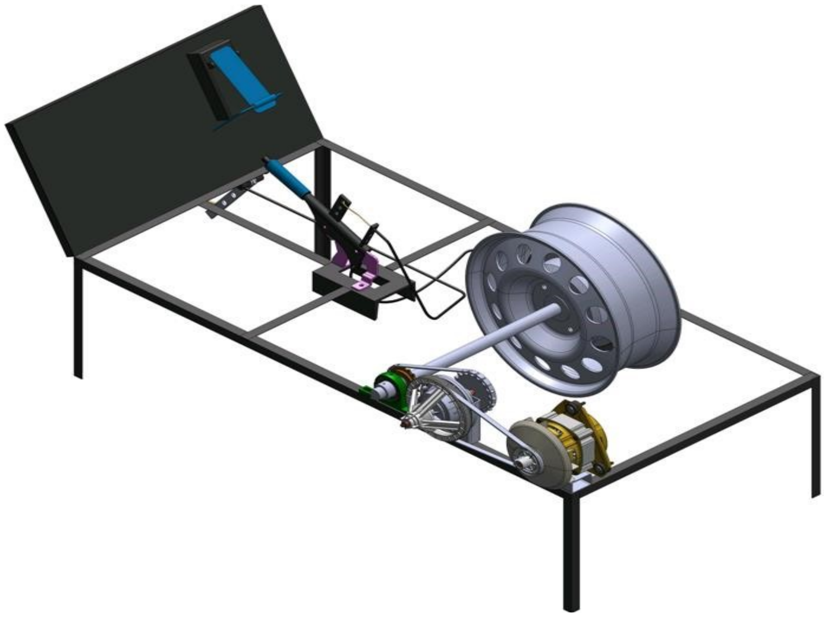


Figure 4. Schematic representation of Solid works model of developed product

3.2 Fabrication of hand brake system: schematic representation of developed product or physical model is presented in Figure 5.

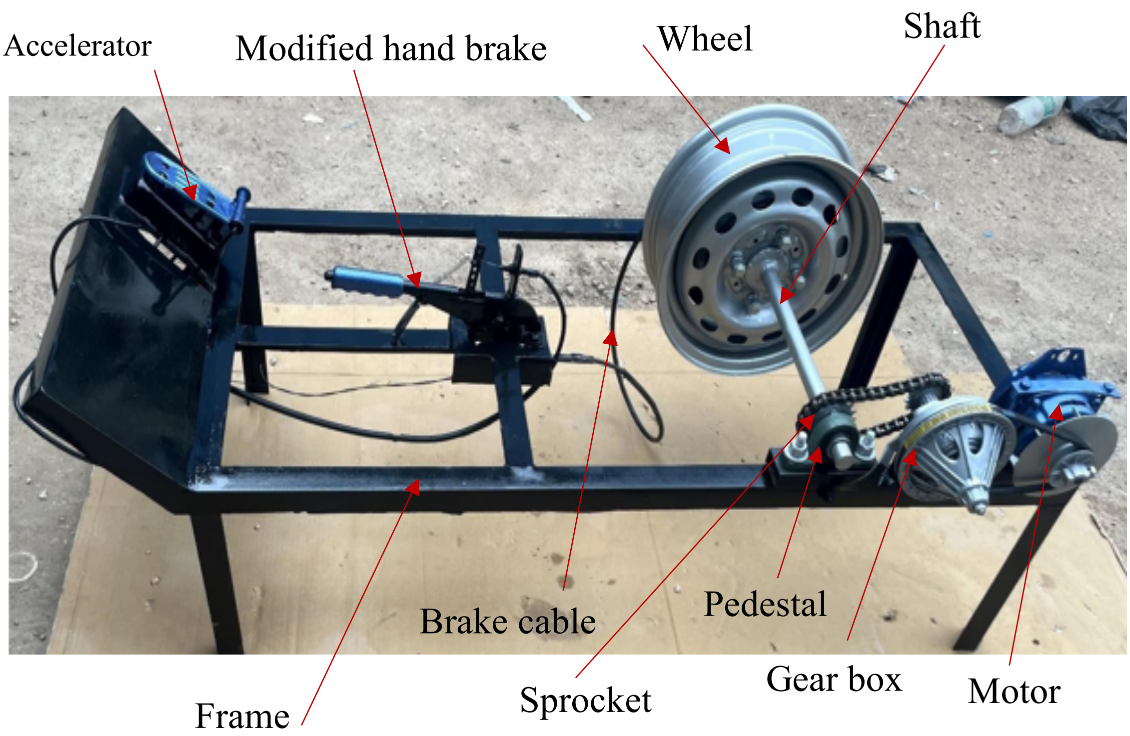


Figure 5. Physical model of developed parking brake system

4. Conclusion

In conclusion, a strong and dependable solution for vehicle safety is demonstrated by the design of the hand brake system with the help of accelerator, which makes use of an extensive mechanical mechanism. The system is engineered with great care to provide exact control, durability, and responsiveness. Incorporating mechanical components improves simplicity while also being more affordable and easier to maintain. The efficacy of the hand brake system's design is highlighted in this research, along with its potential to improve overall vehicle safety and operational efficiency.

References

1. Maske, A., Tuljapure, S. B., & Satav, P. K. (2016). Design & analysis of parking brake system of car. *International Journal of Innovative Research in Science, Engineering and Technology, 5 (7)*, 12578-12590.
2. Veeramanikandan, K., Sowsic, M., Selvaganapathi, S., Sujikumar, S., & Vishwa, T. (2021). Design and Fabrication of Automatic Hand Brake System. *Annals of the Romanian Society for Cell Biology*, *25*(6), 565-580.
3. Shedge, M. T., Sanap, S. C., Borde, A. B., Salbande, P. K., & Kabudke, P. D. (2021). Design And Fabrication Of Seat Belt Activated Hand Break. *International Journal of Innovations in Engineering Research and Technology*, *8*(07), 261-266.
4. Dalvi, R. E., Sutar, R. G., Karke, P. H., & Satpute, J. B. (2017). Design and development of hand brake release system. *Global Res Dev J Eng*, *2*(6), 280-284.
5. Gopan, G., Gopikrishnan, E. J., Cherian, G. J., Samuel, J. S., & Sreejith, R. (2017). Development of automatic hand brake system. *Int J Innov Res Sci Technol*, *3*(11), 328-332.
6. Lunia, P., Prajapati, M., Jayashankar, V., Parakh, V., & Rawte, S. (2015). *Systematic Approach to Design Hand Controlled Parking Brake System for Passenger Car* (No. 2015-26-0078). SAE Technical Paper.
7. Ishak, M. R., Belhocine, A., Taib, J. M., & Omar, W. Z. W. (2016). Brake torque analysis of fully mechanical parking brake system: Theoretical and experimental approach. *Measurement*, *94*, 487-497.
8. Stoloff, P. (2011). A Study of Parking Brake Cable Efficiency as Affected by Construction Type. *SAE International Journal of Passenger Cars-Mechanical Systems*, *4*(2011-01-2380), 1437-1444.
9. Muskan, N., Bharat, K., Sonali, P., & Anurag, C. (2021). Seat Belt Assisted Automatic Hand Brake. 8(2), 595-598.
10. Chouksey, J., Jawade, P., Shaikh, S., & Jadhav, P. (2020). Design and Development of Automatic Handbrake System for Four Wheeler. 11(7), 214-217.
11. Day, A. J., Harding, P. R. J., & Newcomb, T. P. (1984). Combined thermal and mechanical analysis of drum brakes. *Proceedings of the Institution of Mechanical Engineers, Part D: Transport Engineering*, *198*(4), 287-294.

12. Wolff, A. (2010). A method to achieve comparable thermal states of car brakes during braking on the road and on a high-speed roll-stand. *Archives of Transport*, *22*(2), 259-273.
13. Tirovic, M., Sergent, N., Campbell, J., Roberts, P., & Vignjevic, R. (2012). Structural analysis of a commercial vehicle disc brake caliper. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, *226*(5), 613-622.
14. Hwang, P., Wu, X., & Jeon, Y. B. (2009). Thermal—mechanical coupled simulation of a solid brake disc in repeated braking cycles. *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, *223*(7), 1041-1048.
15. Xiaoyan, Z., Peixin, Q., & Xiaojing, L. (2012). Braking performance study for automobile with numerical simulation. *Applied mechanics and materials*, *155*, 1159-1163.
16. McKinlay, A. J. (2007). *The phenomenon of vehicle park brake rollaway* (Doctoral dissertation, University of Leeds).
17. Limpert, R. (2011). *Brake design and safety*. SAE international.
18. Koylu, H., & Cinar, A. (2012). Experimental design of control strategy based on brake pressure changes on wet and slippery surfaces of rough road for variable damper setting during braking with activated anti-lock brake system. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of automobile engineering*, *226*(10), 1303-1324.