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Functionality Parameters Testing of a Parking Brake Lever for Passenger Cars

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Abstract - *The Parking Brake is one of the essential components of vehicles. In order to make sure that a vehicle remains stationary, when it is parked at a certain place where road slope is there, the driver has to apply sufficient pulling force on the hand brake lever. Otherwise, the vehicle will start to rollaway towards the slope. The torque generated by the parking brake system is lower than the torque required by the vehicle to remain stationary. This causes a danger situation not only to the vehicle's occupants but also to the people surrounding it. Basically, the objective of the work is to check the functional parameters of the parking brake lever of passenger cars. The present work deals with the most important functional parameters of Parking Brake Lever (PBL) of four-wheeler car. The functional parameters tested are angular travel, lateral play, force required to lift the parking brake lever and button operating force. To check these functional parameters of the parking brake lever more efficiently, a special testing machine is designed and with the help of this machine functional parameters are verified experimentally. The testing machine designed and manufactured is of semiautomatic type. The results obtained are closer to the actual values.*

Key Words: Parking Brake Lever (PBL), Angular travel, Lateral play, Anti-Lock Braking System (ABS).

1.INTRODUCTION

In recent decades, there is very rapid technological advancement. Very faster growth in industries leads towards requirements of quick actions and immediate solution to any kind of problem. In today's fast-moving world every industry tries to attain perfection in at least one field. Thus, every industry is approaching towards the process of automation. Automation uses various automatic controls that can be achieved using PLC or by any other means. Many of the times a hydraulic, pneumatic, electrical or an electronic system or their combination is responsible for automating the system. When cost and resource availability are major constraints, semi-automatic system is referred rather than completely automated system. Some of the benefits of automated system includes increase in productivity, reduced human error, enhanced quality monitoring and increased speed of production. The vehicle will start to roll away where the torque generated by the parking brake system is lower that the torque required by the vehicle to remain stationary. This poses a danger situation not only to the vehicle's occupants but also to the people surrounding it (A H Rozainia, 2013). In automobiles, mechanical parking brake unit is a mechanism that used to hold the vehicle stationary either on the even or slope road. It consists of a cable (usually adjustable for length) directly connected to the brake mechanism on one end and to a mechanism that can be actuated by the driver on the other end. This actuating mechanism is often a hand-operated lever on either side of the driver, or a pull handle located below and near the steering wheel column or a (foot-operated) handle located far apart from the other pedals. Customer desires the lateral play in parking brake and should be in the specified limits (Prof. P. B. Wakchaure, 2013). In road vehicles, the parking brake, also called hand brake, or emergency brakes used to keep the vehicle stationary and, in many cases, also perform an emergency stop. Parking brakes on older vehicles often consist of a cable connected to two-wheel brakes at either ends to a pulling mechanism which is operated with the driver. As soon as the parking brake of the vehicle is actuated, it is indicated on the dashboard of the vehicle. In most automobiles the parking brake operates only on the rear wheels, which have reduced traction while braking. In automobiles, especially in cars, the parking brake is a latching brake which is usually used to keep the vehicle at a stationary position. The parking brake lever is generally pulled by the driver of the car when the vehicle has to be parked. Thus, it is also called as the parking brake or emergency brake as sometimes it is applied when the car must be stopped in emergency (M. V. Patel, 2017).

Brakes are one of the most important safety systems in a motor vehicle. The main functions are to de-accelerate, to maintain the speed during downhill operation, and finally to park the vehicle stationary either a flat or sloped road condition. The first two functions are related to the service brakes, while the last function is referred to the secondary or parking brake (Prof. P. B. Wakchaure, 2013) (Mohd Razmi Ishak, 2016). The most common use for a parking brake is to keep the vehicle motionless when it is parked. Parking brakes have a ratchet locking mechanism that will keep them engaged until a release button is pressed. They are recommended always to be left with the handbrake engaged, in concert with their lowest gear usually either first or reverse. It is operated by pushing the lever down with one's hand to apply the brake, and pulling it upwards to release it. However, this has been known to cause severe back problems in drivers who do this regularly and many choose to push it up with their feet. Some cars with automatic transmission are fitted with automatically releasing parking brakes. Research on control strategy is one of most important topics of regenerative braking and can be roughly categorized into two types according to the propose of research. One is to enhance the braking performance and driving comfort. The other is to improve the regenerative efficiency and to save resources (A H Rozainia, 2013). In a conventional vehicle featuring a mechanical braking system, the kinetic energy is dissipated as heat in the brake linings. On the other hand, in a hybrid vehicle, the electric motor can be used as an electric generator to impose a negative torque in order to charge the batteries. Hence, the regenerative braking feature of an electric vehicle is a key technology to improve the vehicle's energy efficiency (Jonathan Nadeau, 2017).

Large vehicles are usually fitted with power operated or power assisted handbrakes. Power assisted handbrakes are usually found on large vans as well as some older heavy vehicles. These operate in the same way as a conventional handbrake, but pulling the lever will operate a valve that allows air or hydraulic pressure or vacuum into a cylinder which applies force to the brake shoes and makes applying the handbrake easier. A recent introduction is the electric parking brake. It is expected that these systems will incorporate other features in the future. BMW, Renault, already have a system where the emergency brake initiates when the car stops and then goes off as soon as the gas pedal is pressed preventing the car from rolling. The vehicle operator can easily turn off the system. However, this method requires an additional electric circuit to drive a DC motor here to use an on–off control method for the force control logic to supply the maximum voltage until the clamping force reaches the desired final force. Using this method, the DC motor continues to rotate after the power is cut-off due to its momentum, resulting in an excessive clamping force. For functions that need fast or repeated apply-release operations such as anti-lock brake systems (ABS) and drive-away release, the excessive clamping force may cause a longer release time. Thus, the excessive force caused by the inertia effect should be compensated. The important parameters to be checked in industry while producing the parking brake lever systems are Lateral play, Angular travel, Button force and Total force to lift the parking brake lever. Checking of these parameters will ensure the proper design and functionality of the parking brake lever. Sometimes due to negligence or in emergency conditions, we humans often forget to apply parking brakes. This may lead to rolling of vehicle in case of slopes and collision with other vehicles in parking area. Constant enhancements in active safety and improvements with respect to the reliability and comfort of operation mean that mechanical handbrakes are increasingly being replaced by new other systems and this giving birth to new ideas of parking brake techniques (Amit B. Maske, 2016). Automotive safety has gained an increasing amount of interest from the general public, governments and the car industry (Reddy, 2015).

2.DESIGN OF THE TESTING MACHINE

Based on the functional parameters to be tested, the testing machine is divided into mainly five subassemblies. Fixture assembly for holding the parking brake during testing, lateral play testing subassembly, angular travel subassembly, button operating force testing subassembly and lifting assembly for determining the force to lift the arm. While designing care is taken about positioning locating, clamping and orientation of the specimen. Fool proof design is done. Breaks are continually being improved and supplemented with electronic systems that are helpful in controlling the vehicle under breaking. However irrespective of such electronic systems breaking is most frequently accomplished by acting the friction line brake shoes with pneumatic or hydraulic systems so first of all their proper operation should be ensured (Vytenis Surblys, 2016). The excellent braking characteristics are a key security measure for automobile operation. Braking system is used in modern automobiles for enhanced safety and reliability (Zhang Xiaoyan, 2012).

2.1 Design of the Shaft (Bhandari, 2010)

Dead shaft is used to providing hinge support to the lifting arm. We design the shaft, by considering axial load acted on the shaft, given by whole lifting arm. Mild steel is used for the manufacturing of shaft as a base material. We preferred mild steel due to its supporting properties as far as the application is concerned. Following are the mechanical properties of mild steel.

Table 1. Properties of Mild Steel Material [5]

PROPERTY	VALUE
Ultimate tensile strength	440Mpa
Yield strength	370Mpa
Hardness	131BHN

Overall load acting on the shaft is 1471.5 N, FOS considered is 3. The Final load by considering FOS is 1471.5×3 = 4414.5N. According to A.S.M.E code, the allowable shear stress for the shaft with keyway effect is,

$\tau s = 0.75\times(0.18\times Sut)$ (R.B. Patil, 2018)

$= 0.75\times(0.18\times440) = \mathbf{59.4\ N/mm^2}$

$\tau s = 0.75\times(0.3\times Syt)$ [7]

$= 0.75\times(0.3\times370) = \mathbf{83.25\ N/mm^2}$

Hence, $\tau s = \mathbf{59.4\ N/mm^2}$

The shaft is supported by two bearings. Let the support reaction forces at end points A and B are R_A and R_B as shown below

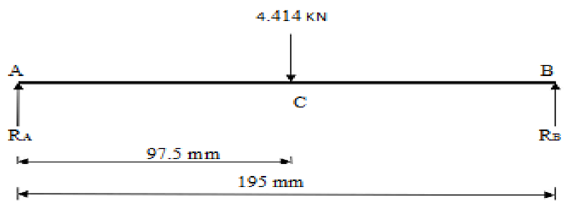

Figure (1). Loading diagram for shaft

RA = RB = 4414/2 = 2207 N

Moment at point C is given by,
MA = 2207× (195/2)
= 21518.25 N-mm
Being a dead shaft, the torque transmitted by the shaft is zero. Thus, Equivalent torque is nothing but the torque due to the bending moment and it is given by

$$Te = [(KbM)^2+(KtT)^{2}]^{(1/2)} \text{ (Patil, 2018)}$$

$$= [(1.5\times21518.25)^2 +(0)]^{(1/2)}$$

$$=322773.75 \text{ N-mm}$$

Let, 'D' be the shaft diameter. We have, Torsion Equation,

$$T_{max} = [(16\, Te) / (\pi D^3)] \quad \text{(Patil, 2018)}$$

$$59.4 = [(16\times322773.75) / (3.14\times D^3)]$$

$$D = 31.36 \text{ mm}$$

Hence, by calculation diameter of shaft can be taken as 35 mm.

2.2.Design of the Key (Bhandari, 2010)

For a key, cast iron is chosen as a material for key σc = Compressive Stress of Cast Iron
= 230 N/mm2
Te = Equivalent Torque = 322773.75 N-mm
h = Height of the key b = width of key
σc= { [Te/(b/2)] / [(hl/2)] } (Patil, 2018)
230 = (322773.75/(10/2))/(h×60/2) h = 9.3557mm
Hence, Dimensions of key are h = 10mm, b = 10 mm

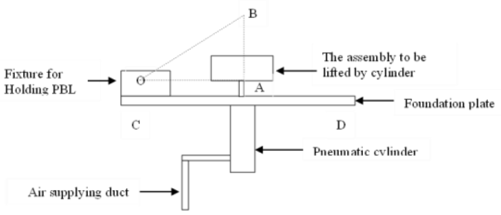

Figure (2). Block Diagram for Finding Stroke of Cylinder

The PBL is held at point 'O' in the fixture resting on the foundation plate 'CD'. The other end of the PBL will rest on the fixture provided in the assembly at point 'A' which the cylinder has to lift. The cylinder will lift the assembly until value of angle BOA becomes 60^0

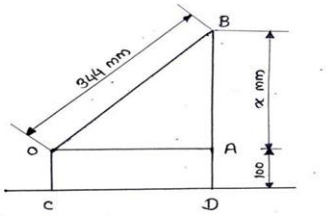

Figure (3). Stroke of Pneumatic Cylinder

From the above Figure (3),

Let, *l*(AB) = X mm
Total stroke of cylinder = BD
l(OB) = Length of PBL in fully actuated condition
= 344 mm Hence, From Figure (3),
BD = AD+AB
BD = 100 + X
To find X, we have
Sin 600 = X/344
X = 344× Sin 600
X= 297.5mm
Total stroke BD = 100+297.5 = 397.5mm
Thus, the suitable stroke length for cylinder is 400 mm
A pneumatic cylinder with bore diameter of 40 mm & Stroke length of 400 mm is chosen.

3. CAD MODEL OF THE TESTING MACHINE

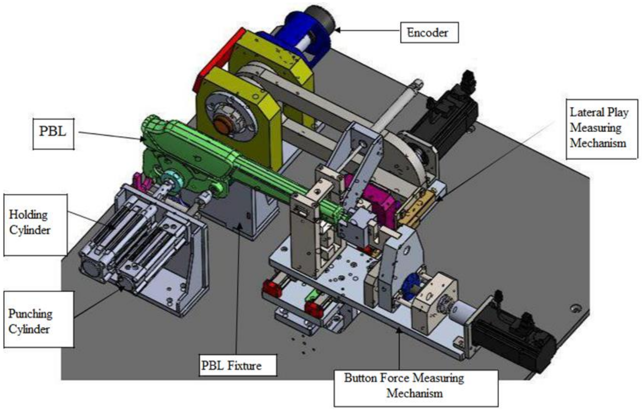

Figure (4). PBL Testing Machine

4. EXPERIMENTATATION

4.1. Starting of the Cycle

The parking brake lever (PBL) is loaded in the fixture. The pneumatic circuit is provided such that the cycle will start if and only if operator presses both the knobs and when operator's both hands are busy. Otherwise, the cycle won't get started. This ensures the safety of the operator. Once both the knobs are pressed, the cylinder locks the parking brake and held it firmly inside the fixture for further tests. A locking pin is then inserted at uppermost side of the parking brake lever. A sequential pneumatic circuit is used for doing these operations in sequence. After the completion of these processes, actual test cycle starts.

4.2. Switch Continuity Test at First Notch Engagement

After holding the parking brake lever in the fixture firmly, the cylinder placed at the bottom side lifts the assembly. As soon as the cylinder starts lifting the parking brake lever, the switch at the end part of the parking brake lever comes into contact with the notch provided. The notch has an electrical contact and hence it checks the continuity of switch in the same manner as the mustimeter does. If the switch is functionally correct then corresponding signals are sent using PLC and it is preceded for further operation otherwise a signal of discontinuity indicates the fault and cycle get stopped.

4.3. Measurement of Angular Displacement

The switch continuity test and the angular displacement measurement tests are carried out simultaneously. As soon as the lifting of the assembly starts, measurement of the angular displacement initiated. The device used to measure the angular displacement called 'Encoder', plays a vital role. The setup has an incremental type of encoder which produces pulses corresponding to change in the angle. These pulses are then counted using the PLC and thus angular displacement is measured. The limiting value for angular displacement lies in the range 450 ± 3.50. If the measured angle after complete stroke of the bottom cylinder lies in the set limit, then a green signal is generated otherwise component have to go to rejection bin.

4.4. Measurement of the Force Required to Lift the PBL

The force required to lift the PBL should be within the limiting range so that PBL can be lifted by the driver without more efforts. The range for lifting the PBL is 50N to 60N. This test also carried simultaneously with the previously mentioned two tests. A 'S' type load cell placed exactly below the locking pin plays the role of measuring this force. When the bottom cylinder lifts the assembly, load cell comes into contact with PBL. The applied force causes strain induction in the material and this is measured by the load cell having Wheatstone bridge circuit. Corresponding voltage pulses are thus generated and signals are sent to PLC which further gives the value of the force. The value of the force achieved while testing is within the specified range. The component will only be accepted if the force value lies in the limit specified. As far as the cycle time is concerned, all the above-mentioned tests carried out simultaneously which may be regarded as the advantage of the system.

4.5. Lateral Play Measurement

The test is carried basically to measure the displacement of the PBL in the lateral plane. When vehicle is in running condition, it suffers from the vibrations. If the parking brake lever is rigidly fixed, then there are chances that it makes cracks and hence undergo fracture. Thus, to avoid it, lateral play is kept in PBL. It mainly consists of sliding rail blocks, a LVDT, servomotor, 'S' type load cell and a lead screw as a functional unit. Once the previously mentioned tests are successfully completed, a signal is sent to servo drive and lateral play measurement is started. The servomotor rotates the lead screw and thus the plate mounted on it pushes the rail blocks in forward direction. The PBL rests on the rail blocks and thus they also receive push force in the same direction as that of the rail blocks. The rail blocks have assistance of LVDT. The 'S' type of the load cell is placed to measure the push force. Once the force is at the set value, the displacement reading is taken using LVDT at that time and is sent to PLC and hence compared with the standard set limit and component will proceeded for next test. The rage for lateral play is 4mm to 5mm. After test the readings recorded were within the limits

4.6. Measurement of the Button Operating Force

As soon as the previous test is completed, signals are set up to activate the servo drive of this unit and the test thus started. The button holding block is moved in the forward direction in the same manner as previous using the lead screw. The block is moved until the button pressing is ensured using reed switches placed. Thus, the load cell placed as shown measures the force required for pressing of the button and it is recorded. The button operating force recorded is 3N. In this way the button force measurement is carried out

4.7. Unloading and Cycle Completion

When all the tests are carried successfully, a cylinder actuates and gives a punch mark on parking brake as a remark indicating that the brake is functionally alright. Then the lock pin is removed and parking brake is unloaded. In this way, all the required parameters are checked and parking brake is transferred to packaging section.

5. CONCLUSIONS

The functionality parameters of Parking Brake Lever (PBL) are checked using the designed testing machine. The accuracy in the measurement is higher as compared to older methods. Disadvantage of previous systems (Amit B. Maske, 2016) such as damage due to sudden impacts is overcome during testing. As far as the loading and unloading aspects of the parking brake are concerned, it is presently loaded as well as unloaded manually, after testing So, the process may be regarded as a semi-automatic process. If the PBL is loaded and unloaded without human effort, then the process may immerge out as an 'Automatic Process'. Hence, there is scope to make the whole process automate. Along with the same, it may be possible to measure all the parameters of PBL simultaneously, so that the cycle time will get reduced and the productivity may increase. The functional parameters tested are angular travel, lateral play, force required to lift the PBL and button operating force. The limiting value for angular displacement lies in the range 450 ± 3.50. The result obtained is 460.The effort range for lifting the PBL is 50N to 60N. The result obtained is 55N. The rage for lateral play is 4mm to 5mm. The result obtained is 4mm.The button operating force recorded is 3N. The results obtained are closer to the actual values

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