Flywheel: Jurnal Teknik Mesin Untirta Volume 8, Issue 1, April 2022, page 7-13

FLYWHEEL: JURNAL TEKNIK MESIN UNTIRTA

Homepagejurnal: http://jurnal.untirta.ac.id/index.php/jwl

Automatic Footstep Design and The use of LDR Sensors in Vehicles

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ARTICLE INFO

Received 08/03/2022
revision 14/04/2022
accepted 15/05/2022
Available online 04/06/2022

ABSTRACT

Vehicle modification has become a necessity for its users; this is done to get a practical and modern impression and consider the functionality side. One of the modified parts of the vehicle is the footstep feature. This component is beneficial as a support point when getting in and out of the car. Initially, the presence of this component was found in many SUVs, and this is because these types of vehicles generally have high ground clearance, making it difficult for vehicle owners to get into the car. The step function finally changed to make the car look more elegant from the left and right sides. Footstep designs that are common in the market are permanent. When installed in the vehicle, its position protrudes from the car body. Footstep will add to the dimension of the car and is quite annoying when the car crosses a narrow road. Therefore, a footstep mechanism was designed to enter the car body when the door is closed and go down and protrude when the car door is opened. The LDR sensor, which adjusted the LED lights, is applied to ensure adequate lighting for the passengers to see the footsteps in the dark conditions. So, the lighting leads to the footstep board and the side of the car when the door is opened. From the tests carried out, the longest time to open the footstep is 0,84 seconds, and the longest time to close the footstep is 1,09 seconds. These results indicate that the target time has been met, which does not exceed 1,5 seconds with or without load on the experiment.

Keywords: *Bottle modification, footstep, ground clearance, sensor, lights*

1. INTRODUCTION

Automotive innovation has developed significantly and has been widely applied by vehicle manufacturers for various products [1,2]. Apart from supporting the vehicle, the footstep also provides comfort for the vehicle. Footsteps are located on the bottom of the car (on one or both sides), usually at the foot of the car door. The installation of the footstep itself is not too difficult; the important thing is to know which part of the chassis will be used as a footstep when installed.

The automatic footstep feature is a side step or step that can lower itself when the door is opened or closed. It works by using a motor mounted on the side of the stairs. They fulfill two main functions. The most obvious function is to function as a step. Without the extra effort to get into some taller cars, getting into them will be like climbing a mountain.

Car passengers, especially the elderly and children, have difficulty getting in and out of the vehicle; besides, this car's ground clearance is relatively high compared to the sedan-type vehicle [3]. Protecting the car from various forms of road debris is the second function of the footstep. As the vehicle moves, its wheels kick up all kinds of waste, from rocks and dirt to other, more destructive things. A running board can prevent some debris from being thrown high enough to scratch and damage doors and side panels. In addition, footsteps can help keep the interior of the vehicle clean. In this way, the running board or footsteps can act like a doormat, where passengers can wipe dirt off their feet before entering the vehicle.

Figure 1. Footstep and sidebar.

Footstep and sidebar are two different things that are sometimes used interchangeably by some manufacturers, as shown in Figure 1. Like a sidebar, a footstep provides a stepping surface into the vehicle. Sidebars usually have individual step pads to correspond to each door on the vehicle, and they are generally narrower than footsteps. The sidebar is more suitable to be applied to cars that have lower ground clearance. The footstep is also usually more comprehensive than the side rails and has an even better profile. Instead of individually placed stair treads pads, flat stair treads usually have treads that run the length of the plank.

Sensor technology is an essential part of the mechanical and electronic engineering industry. Sensory development brings positive changes to the advancement of innovation, especially in the automotive field. It can significantly improve the overall operational efficiency and have low cost and high efficiency [4]. However, the existing automotive features have also prepared sensor implementations to anticipate problems, one of which is the application of the LDR sensor on the footstep, which helps passengers not to fall when entering and exiting the vehicle in dark conditions.

In addition, some cars use an LDR sensor so that the lights can automatically turn on when driving at night. This tool utilizes the LDR sensor, which will detect light intensity through the light it receives [5].

Light Sensor LDR (Light Dependent Resistor) is one type of resistor that can experience changes in resistance when experiencing changes in light reception [6]. LDR has excellent opposition in the dark or low light. In the dark, the resistance of the LDR is about 10 MΩ, and in the morning, it is 1 KΩ or less.

The LDR can be coupled with other components into an automatic relay that turns the lights on and off based on changes in light intensity. Controlling the lights using the LDR sensor is assisted by a microcontroller, so we can get convenience in the design and implementation of lamp control, namely determining complete darkness and light brightness that the LDR can accept so that the lamp can be ON or OFF simultaneously automatic. LDR sensor sensitivity level can be adjusted by adjusting the size of the resistor or VR resistor [7].

2. METHODOLOGY

The design and manufacture of automatic footsteps have been carried out, but the results obtained have not been maximized. Several factors considered in this study become the focus of the target mechanism stages to maximize it.

The research stage is to design the concept of the mechanism first; namely, if the car is in a closed-door condition, the footsteps will be stored next to the car chassis. When the door is open, the steps will automatically descend and protrude so that passengers can easily use the stairs as a base to get into the car.

The requirements set out in the design of mechanisms and devices must ease the movement of the footstep itself so that the action in and out can be faster. The stairs' dimensions are wider with an electric motor as the driving force. In addition, this device can also support DC motors with ample torque and heavy loads. When a passenger opens the car door, the steps must be able to get out as quickly as possible. When the door is closed, the steps must be able to enter as soon as possible, so the driver does not have to wait long, and the vehicle can be started immediately.

Another consideration that is the focus is that the design of the footsteps is made so that it does not reduce the car's ground clearance and does not exceed the width of the car body when the efforts are not in use. So, in this case, this footstep can add aesthetic value to the car to make it look luxurious and elegant.

Figure 2. A base plate bracket.

Installation on the car chassis is done by making a base plate bracket using a cast iron plate, as shown in Figure 2. Next, C-type bolts are used to mount on the chassis. A C-Bolt joint allows a gradual removal process without damaging the frame—this amount between the chassis and the car body, as shown in Figure 3. When closed, the swivel stand folds inward, and the walk-in frame is kept in the space between the chassis and bodywork.

Figure 3. Installation of a footstep on the chassis.

After attaching the footstep to the chassis, tests are carried out to open and close the ladder. The footstep does not seem to reduce the car's ground clearance in closed conditions, so it meets the criteria.

Figure 4. Footstep drive module.

There are three main control components in the electrical system: a regulator of the step mechanism, a safety measure, and a regulator of LED lights that can turn on automatically when the side of the car is dark and the door or footstep is open. Electrical components are installed as safely as possible, and the location for storing electrical components is safe. It does not interfere with the performance of other car components. The footstep module is located at the bottom of the dashboard on the front passenger side, as shown in Figure 4. The module location is under the passenger side dashboard as it is relatively easy to fix if there are other issues besides the rather ample location space.

Fuses are designed as a safety system for electrical components in a short circuit, as shown in Figure 5 [8]. The fuse is placed close to the battery head to maximize the function of the fuse. Thus, the car will remain safe because the fuse will immediately blow, and the electric current will stop flowing. It is hazardous if the "+" poles cable is damaged and sticks to the body.

Figure 5. Fuse installation.

Due to the potential of digitally controllable LED lighting, many intelligent lighting systems have been proposed [9]. The light sensor module functions as a switch that can automatically operate based on the sensor's light intensity input. Therefore, the LED light that shines on the running board will turn on automatically when used only in dark environmental conditions. This light sensor module has pretty tiny dimensions, so it can be placed in a narrow place, as shown in Figure 6.

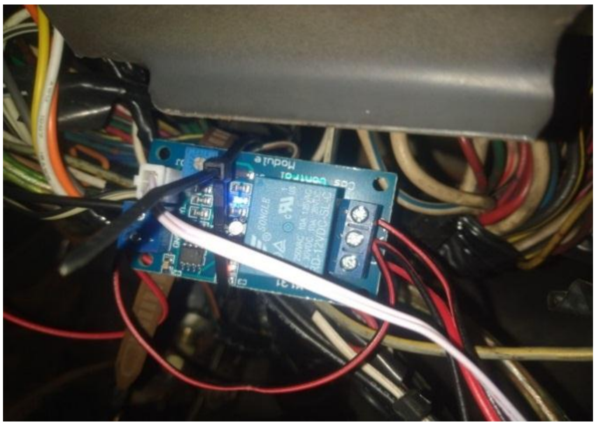

Figure 6. Light sensor module.

In the drive system, the drive module becomes a regulator equipped with a safety system to prevent the DC motor from burning due to jams when operating the footstep. The working control system of this drive is that when reading, the door is open, and the parking brake is active; the module can command the DC motor to rotate so that the footstep can be opened. The implementation of the electrical circuit wiring diagram and supporting components as a complete working mechanism is shown in the schematic, as shown in Figure 7 [10].

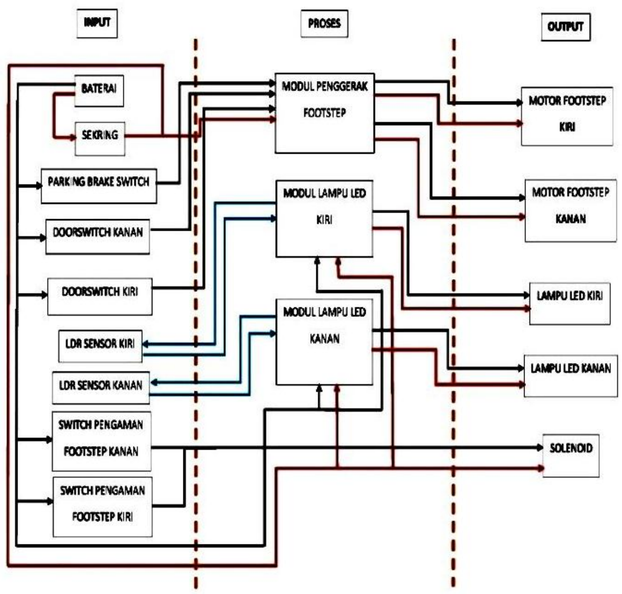

Figure 7. Schematic wiring diagram.

The purpose of the fuse is to protect the car's electrical system in the event of a short circuit. The "+" battery cable through the fuse with a constant current feeds some electrical components. In this design, one fuse is used for all footstep electrical components.

3. RESULTS AND DISCUSSION

The footstep mechanism is designed using a folding mechanism that starts by measuring the distance between the floor of the car and the ground when the vehicle is flat, as shown in Figure 8.

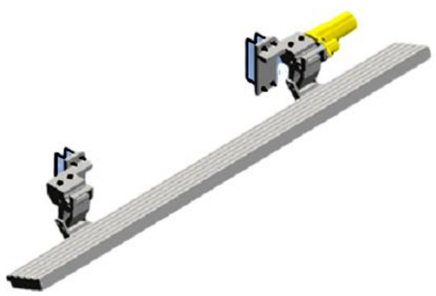

Figure 8. Footstep design used.

The distance between the car's base and the bottom is 430 mm. Thus, it is determined that the tread reduction measured from the car's floor is 200 mm. The design choice with this folding mechanism is more durable, efficient, and has more outstanding durability. The design selection is taken from the value of the most significant profit. The folding mechanism design can use a DC motor as the driving mechanism of the stop mechanism [11].

3.1 DC motor specification selection

Determination of the specifications used is based on design data, as follows:

Table 1. Data design.

Parameter	Unit
Drive rod folding angle (α)	90°
Footstep open/close time (t)	1,50 s

The step angle must be converted to radians to calculate the angular speed of a DC motor using the equation [12]:

$$\text{A full rotation} = \frac{\text{the length of circumference}}{\text{radius}} \quad (1)$$

$$360° = \frac{2\pi r}{r}$$

$$360° = 2\pi \text{ radian} \quad (2)$$

$$\theta = \frac{\alpha^o}{360^o} \cdot 2\pi \quad (3)$$

If α (drive rod folding angle) = 90°,

$$\theta = \frac{90^o}{360^o} \cdot 2\pi = 0{,}50\pi \; rad$$

If the bend angle of the pedal drive rod has been obtained in radians, then the required angular velocity can be calculated by the equation [13,14].

$$\omega = \frac{\theta}{t} \quad (4)$$

$$= \frac{0{,}5\pi}{1{,}50}$$

$$= 1{,}047 \text{ rad/s}$$

To converse between angular velocity and speed rotation [15].

$$n = \frac{30}{\pi} \cdot \omega \quad (5)$$

$$= \frac{30}{\pi} \cdot 1{,}04$$

$$= 10 \text{ rpm}$$

The need for a DC motor beyond rpm is the ability to withstand the load of the stairs when closing the footstep. To get the minimum capacity of a DC motor to complete the footstep without limitation.

Table 2. Specifications of the footstep.

Parameter	Unit
L_1	525 mm
L_2	525 mm
L_3	410 mm
L_4	250 mm
Footstep mass (m)	17 kg

An FBD is a diagrammatic representation that focuses only on an object of interest and on the forces exerted on it by other objects, as shown in Figure 9 [16].

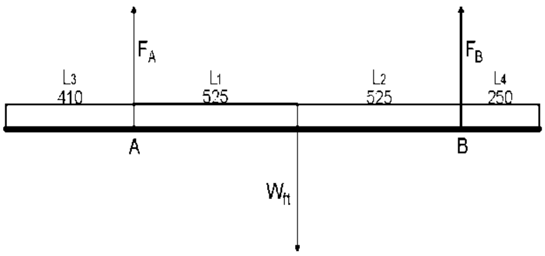

Figure 9. FBD of the footstep.

Footstep weight can be obtained as follows [17],

$$W_{ft} = m \cdot g \quad (6)$$

$$= 17 \cdot 9{,}81$$

$$= 166{,}77\ N$$

After knowing the footstep weight, the torque required for the DC motor to drive the components can be determined using the equation [18]. The radius of the drive shaft used is 0,008 m.

$$T = W_{ft} \cdot r \quad (7)$$

$$= 166{,}77 \cdot 0{,}008$$

$$= 1{,}334\ Nm$$

With the calculation data obtained, the selected DC motor is a DC motor which is classified as a side gearbox range rover DC motor with the following technical specifications as shown in Table 3.

Table 3. DC motor technical specifications.

Parameter	Unit
Voltage	12 V
Power	20 Watt
Electric current	1,6 A
Rpm output	20 rpm
Output torque	60 Nm

3.2 Analysis of support force on footstep

Load analysis is calculated when the passenger sets foot to determine the support forces when loaded by the passenger, as shown in Figure 10.

Figure 10. The footstep condition is opened.

The calculation is done using 150 kg of stair load, where a person with a weight near 75 kg stands at the front of the stair and another stand at the back of the stair. The details pack is placed in the middle and the behind stairs as in static calculation. The free-body diagram is shown in Figure 11 below.

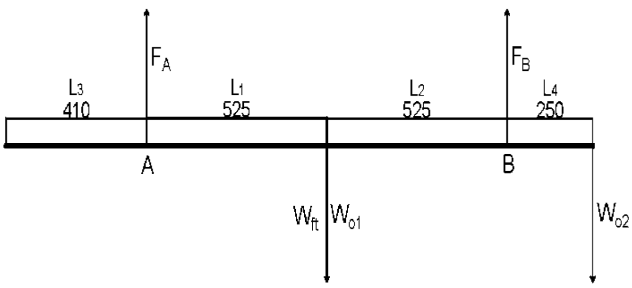

Figure 11. Free body diagram.

$$W_{t1} = W_{o1} + W_{ft} \tag{8}$$
$$= 735 + 166{,}77$$
$$= 901{,}77\ N$$

$$W_{t2} = W_{o2} \tag{9}$$
$$= 735\ N$$

Using Newton's third law, the equilibrium of the forces is as follows [19,20].

$$\sum F_y = 0 \tag{10}$$

$$\sum (F_A - W_{t1} + F_B - W_{t2}) = 0 \tag{11}$$

$$\sum (F_A - 901{,}77 + F_B - 735) = 0$$
$$\sum (F_A + F_B) = 1636{,}77\ N$$

$$\sum M_A = 0 \tag{12}$$

$$(W_{t1} \cdot L_1) - F_B(L_1 + L_2) + W_{t2} \cdot 1{,}3 = 0 \tag{13}$$

$$FB = 1356{,}60\ N \ ;\ FA = 280{,}17 N$$

The load on the front and rear supports when the footstep is subjected to the passenger load, which the bracket must support.

3.3 Performance tests

The test was conducted To measure the performance of the designed and built rungs by opening and closing the rungs on both left and right sides five times, then the average time required to open and close the rungs was taken.

Figure 12. The footstep condition when it is closed.

A sampling of the opening and closing times of the footstep is done with a stopwatch, starting with the tread starting to open until it is fully open and the impression starting to close until it is fully closed (Figure 12).

Table 4. Left side footstep test results.

Test	Opening time (s)	Closing time (s)
1	0,88	1,22
2	0,98	0,88
3	0,85	1,18
4	0,83	1,15
5	0,75	1,01
Related	0,84	1,09

Table 5. Right side footstep test results.

Test	Opening time (s)	Closing time (s)
1	0,73	1,08
2	0,65	0,93
3	0,55	0,78
4	0,55	0,80
5	0,45	0,75
Related	0,59	0,87

According to the test results, a footstep can be opened and closed in less than 1,50 seconds. The results obtained were much better than the target, with the longest closing time of 1,22 seconds and the longest opening time of 0,84 seconds.

4. CONCLUSIONS

From the test results, it can be seen that the automatic footstep operation works without problems. Footsteps can move close and open well. A sampling of the opening and closing times of the footstep is done with a stopwatch, starting with the tread starting to spread until it is fully open and the footprint starting to close until it is fully closed. The results show that the longest time to open the footstep is 0,84 seconds, and the longest time to complete it is 1,09 seconds. The target time test looks better than the time set in the design goal.

The load on the footstep is realized by providing a passenger load of 150 kg, and the footstep is not damaged when tested. This automatic footstep is designed with a DC motor because the electricity in the car is DC. Observations on each electrical device are also checked. All electrical components' performance is also functioning correctly to monitor the environmental information such as rpm output, torque, and sensor combined with a microcontroller.

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