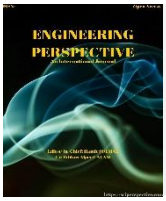

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Effect of Clutch Pedal Distances on Fuel Consumption Under Actual Operating Conditions

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ABSTRACT

Clutch systems are the auxiliary system for transmitting the power and torque obtained in the internal combustion engine to the gearbox, starting the vehicle, and providing gear changes. The different use of the clutch pedal directly affects the performance and fuel consumption of the vehicle. Research on fuel economy, performance, etc., in vehicles, is costly and time-consuming. In the studies conducted by researchers on braking and gearbox, experimental test equipment that allows the vehicle to operate in many different parameters and instantaneously control fuel consumption has been used. The studies have generally focused on braking and gearbox-related studies. This study investigates fuel consumption values at different pressing distances of the clutch pedal. In the experiments, with the engine at a constant speed of 3000 1/min and the gearbox in second gear, the fuel consumption at 0-20-40-60% depressions of the clutch pedal were measured. According to the data, fuel consumption values increased with increased clutch pedal depressing distance.

Keywords: Clutch; Fuel consumption; Pedal distance; Vehicle tester; Vehicle.

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1. Introduction

In vehicles, different systems such as clutch and gearbox are combined to transmit the power and torque obtained from the internal combustion engine to the wheels. Depending on the operating conditions, the movement obtained from the engine may not need to be continuously transmitted to the gearbox. The vehicle may need to stop and change speed to a lower or higher. The clutch systems between the engine and the gearbox transmit or interrupt the movement obtained from the engine. In clutch systems, which play an essential role in transmitting power and torque, when the clutch pedal is not pressed, the clutch disk engages with the flywheel surface, and the movement in the engine is transmitted to the gearbox. When the clutch pedal is pressed, the engagement is interrupted, and the movement from the engine is not transmitted to the gearbox. This working principle of the clutch system also gives the driver the flexibility to shift gears to reach the desired speed or torque values. Clutch systems are found in vehicles such as cars, vans, trucks, and tractors. Clutch systems used in automatic transmission systems, torque converters, and hydraulic controlled clutch systems are also essential systems that provide an environment for the efficient operation of vehicles and provide high performance and fuel economy with appropriate torque.

Whether in passenger cars or commercial vehicles, the torque from the internal combustion engine is transmitted to the gearbox by the clutch system [1]. The working principle of the mechanical clutch is based on the principle that a pad with a high coefficient of friction compresses and transmits motion to the disk that can make an axial movement with the flywheel. The engine's torque is transferred to the gearbox and from there to the wheels with the effect of the circumferential friction force on the pad. Mechanical clutches are preferred over hydraulic clutches due to their ease of manufacturing and maintenance [2]. Therefore, the clutch system acts as an interface between the engine and the vehicle. When the vehicle is in motion, the engine provides power and torque at a certain speed. In this process, slip time is critical for the clutch system. Engine and gearbox speeds are variable due to the driver effect.

During the vehicle's take-off, the driver influences all dynamics, such as the clutch and accelerator pedal [3]. This effect has made the clutch, in particular, an essential part of the proper functioning of the powertrain. The clutch system interrupts or engages the power flow during gear changes. Thanks to this system, a smoother gearshift is achieved, and wear on the gearbox is minimized [4]. The clutch is in a constant state of energy transfer when synchronizing between the engine and the gearbox. In slip, it absorbs the prime mover energy and inertial energy [5]. The primary function of the clutch system, which is located between the engine and the gearbox, is to allow gear changes. At the same time, the vehicle is in motion to transfer engine torque to the driveline and to reduce irregularities by minimizing torsional vibrations caused by the engine. They are responsible for equalizing gearbox output speeds by regulating torque flow [6,7].

Dry-type clutches are popular in the transmission systems of small and medium-sized vehicles and parallel hybrid vehicles' engine clutch systems [8]. In the automotive industry, single or double dry clutches are widely used for low fuel consumption, reduction of pollutant emissions, reliability, and efficiency [9]. Although these types of clutches have many vehicle perspectives, the most critical share is in automobiles. The expected task of a dry clutch is to transfer the torque from the engine to the vehicle wheels. The engine torque is transferred to the gearbox main shaft and then to the wheels through friction and contact between the pressure plate and flywheel. Like brake pads, a high coefficient of friction is an essential phenomenon in clutch pads. Under normal operating conditions, kinetic energy generates high temperatures with friction [10].

Figure 1 shows the components of the clutch system. Here A is the clutch lining, B is the flywheel, and C is the clutch disk. Figure 1 (a) shows a complete picture of the clutch system. Figure 1 (b) shows the clutch engagement when the clutch pedal is not depressed, while Figure 1 (c) shows the moment of separation of the clutch disc and the clutch lining when the clutch pedal is depressed.

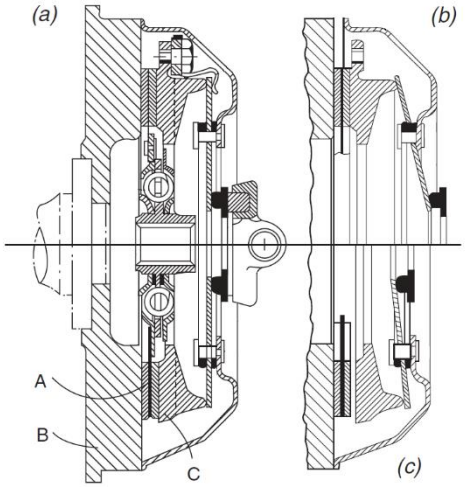

Figure 1. Schematic view of clutch system elements [11]

Improper torque distribution can lead to increased engine fuel consumption and emissions [12]. Research has been carried out in the automotive sector in recent years to improve driving and fuel efficiency. The power obtained in the engine is transmitted to the wheels by the drivetrain. The drivetrain is also very effective in the performance and fuel economy of the vehicle. Reducing fuel consumption and improving driving comfort is extremely important when developing new technologies. Trying every innovation and development in the industry without validation leads to high costs. In addition, this approach could be better for companies and researchers [13].

The braking phenomenon in vehicles can be continuous on a downhill descent or push-and-pull manner, depending on the traffic flow. Some drivers continue to press the accelerator pedal as traffic approaches an obstacle and then press the pedal hard [14]. Fuel savings of up to 27% can be achieved by the driver making gear changes under optimum conditions [15]. The clutch system is an essential system for vehicle control. Although the studies conducted by researchers have focused on braking or gearbox, they have not focused on the results related to clutch systems and fuel consumption. Fuel consumption, which directly impacts environmental problems and the economy, also exhibits a highly variable situation in clutch use. For optimum vehicle operation, the clutch pedal should be fully depressed, and the driver should take his/her foot off the clutch pedal. In this study, the fuel consumption of the clutch system in different pedal pressing distances other than optimum use in the vehicle test device in the laboratory environment was measured, and the results were compared.

2. Material Method

In the studies conducted by researchers, there are essential studies on tests related to vehicles. However, considering the high cost of road tests and the deviations that may occur in the test results, it is seen that precise measurements cannot be made. With the test device, different road conditions can be created in the laboratory environment, and tests can be performed in a standardized and precise manner [16]. Test platforms have advantages compared to on-road test drives in that they are cheaper to operate, easier to perform tests, repeatable, and can be fully automated [17]. The vehicle test device on which the experiments are carried out and the performance tests can create road conditions in the laboratory environment. Although there are many studies in this field in the literature, it is understood that studies have been carried out with simulation methods and road tests. However, not all conditions can be fulfilled in simulation tests. In addition, the cost of road tests is high, and the sensitivity of the experimental results is relatively low. The device in which the experiments were carried out was created by considering all these factors. The road conditions were created in the laboratory environment, and the standard tests were created to be more sensitive [16]. Technical specifications of the test device are given in Table 1.

Table 1. Test device technical specifications

Engine Volume	1.4 L
Number of Cylinders	4
Fuel Type	Gasoline
Maximum Power of the Engine	57 kW
Maximum Torque of the Engine	115 Nm
Gearbox Type	Manual 5 gears forward 1 reverse
Clutch Type	Dry type single clutch

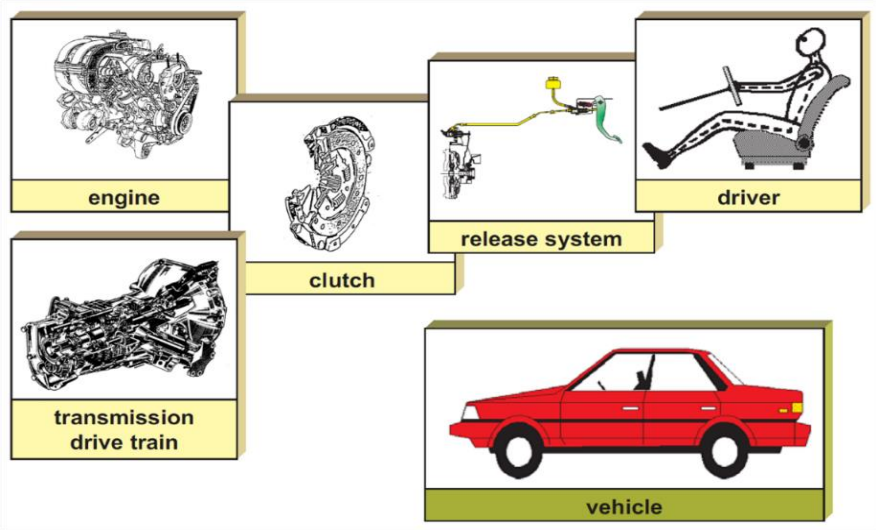

Figure 2. Clutch system representation in a vehicle [18]

Figure 2 represents the parameters related to the clutch during driving. The driver requires the use of the clutch system in situations such as gear changes or neutralization. The clutch pedal is pressed by the driver when such a need arises. When the clutch pedal is pressed, the mechanical or hydraulic system elements in between provide a pushing movement on the clutch ball. With this pushing movement, the clutch release plate removes the pressure on the clutch disk and allows the movement coming from the engine to leave the gearbox. With this motion transmission, gear neutralization or gear change operations can be performed.

Depending on the driver, different pedal pressing distances occur in using the clutch pedal during vehicle operation. Some drivers, such as drivers who are just learning to drive or tired drivers, for example, when waiting at a red light, apply continuous pressing force on the clutch pedal while the vehicle is in gear instead of shifting into neutral.

In addition, the clutch pedal is depressed at different distances to ensure that the vehicle takes off in the frictional effect that occurs when the flywheel and clutch lining is engaged during vehicle start-up. These different uses of the clutch pedal may cause differences in fuel consumption. This study aims to determine the changes in fuel consumption depending on the use of the clutch pedal. The schematic picture of the test rig is shown in Figure 3. Instantaneous fuel consumption can be measured precisely in the test device. The experiments were carried out by determining the fuel consumption at 0-20-40-60% clutch pedal distances where the engine can continue to run at 3000 1/min in second gear.

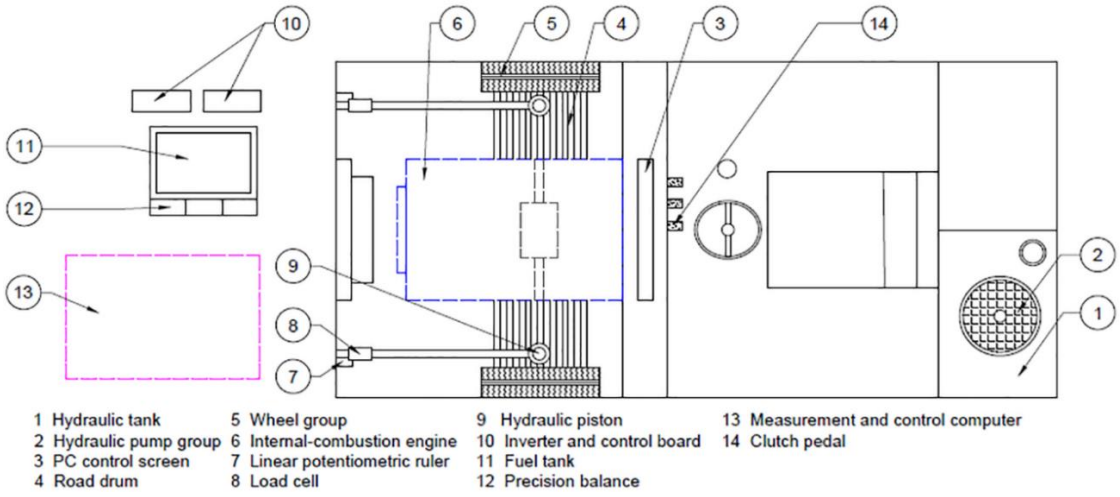

Figure 3. Schematic illustration of vehicle tester

3. Results and Discussion

Figure 4 shows the percentage values of pressing the clutch pedal for different situations of the experimental study. Drivers want a smooth and stable take-off by taking advantage of the sliding effect of the clutch lining between the clutch disk and the flywheel during the engagement. In order to ensure that the vehicle takes off under the desired conditions, it is essential that the engine is at a certain speed and the appropriate gear is selected.

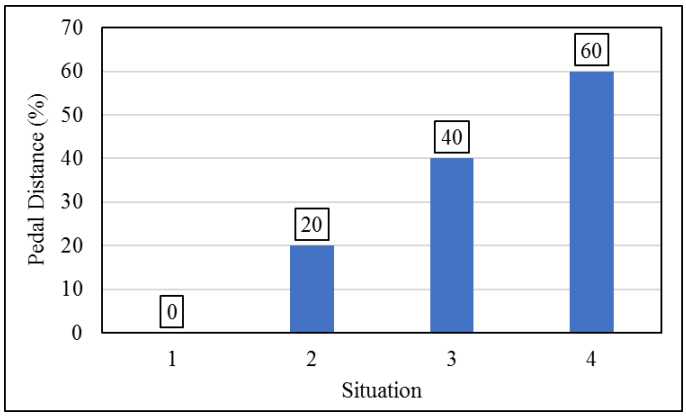

Figure 4. Percentages of pressing the clutch pedal

This study presents the fuel consumption at 3000 1/min in second gear when the clutch pedal was pressed at different distances. Figure 5 shows the fuel consumption values obtained when the clutch pedal is pressed at distances of 0-20-40-60%. The fuel consumption values increased as the pedal pressing distance increased. As the pedal distance increases, fuel consumption rates increase because the accelerator pedal is pressed more for operation at a constant speed of 3000 1/min.

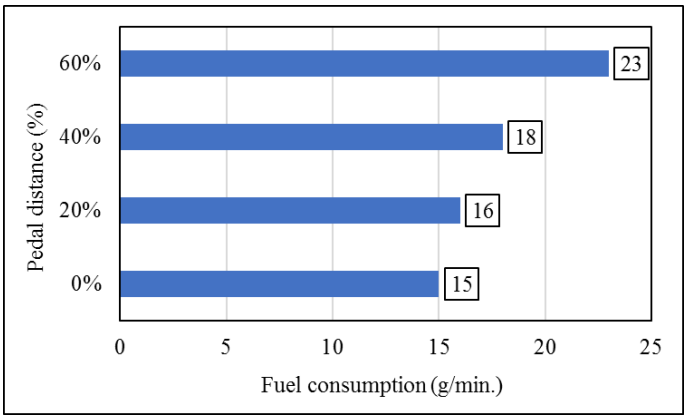

Figure 5. Fuel consumption depending on pedal distance

4. Conclusions

Clutch systems provide transmission, interruption, or partial transmission of the movement obtained from the engine between the engine and the gearbox. The clutch system plays a significant role in vehicle power and torque transmission. The primary purpose is to transmit the motion obtained in the engine to the gearbox differently. Environmental issues are becoming increasingly important, accelerating the studies on fuel consumption. The need for power and torque is high, especially when going uphill and at the first start. In such cases, pressing the clutch pedal may cause differences in vehicle fuel consumption. In this study, the fuel consumption values of a vehicle with a dry clutch lining in second gear at a constant speed of 3000 rpm and 0%, 20%, 40%, and 60% depressions of the clutch pedal were determined using a vehicle tester. Different usage scenarios were created in the experiment by varying the clutch pedal depressing distance. The results showed an increase in fuel consumption values as the clutch pedal travel distance increased. These findings reveal that effective and efficient use of the clutch system is important in controlling fuel consumption.

Conflict of Interest Statement

The authors declare that there is no conflict of interest in the study.

CRediT Author Statement

Hüseyin Bayrakçeken: Conceptualization, Supervision, **Hicri Yavuz:** Conceptualization, Writing-original draft, Validation, **Turan Alp Arslan:** Data curation, Formal analysis

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