DESIGN AND FABRICATION OF HEAVY VEHICLES EMERGENCY BRAKING SYSTEM USING AUXILIARY BRAKING SYSTEM

CHAN DING HAU

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE TECHNOLOGY) WITH HONOURS

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Faculty of Mechanical and Engineering

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A thesis submitted
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Ir. Ts. Dr. MOHAMAD HAFIZ BIN HARUN
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan Mekanikal
Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan
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DEDICATION

This dissertation is dedicated to my beloved parents Mr Chan Gim Sia and Ooi Swee Yong which give me the biggest support and help during this project. Besides that, I was thankful to my family members, friends, lectureres and UTeM staffs whose give me helping and supports to help me complete this project.

ABSTRACT

Air brakes also referred to as compressed air brake systems, represent a friction braking mechanism utilized in vehicles. They rely on compressed air exerting pressure on a piston to activate the brake pads, thereby halting the vehicle's motion. These braking systems find extensive use in large, heavy-duty vehicles (HDV), particularly those with multiple trailers interconnected within the braking setup. Examples of vehicles employing air brakes include trucks, buses, trailers, semi-trailers, and even diesel and gasoline engine-powered vehicles According to Royal Malaysia Police (RMP), a few 40,000 incidents occurred that include heavy-duty vehicles. (MIROS,2022) Numerous variables influence the likelihood of heavy-duty vehicle collisions. Heavy-duty vehicle brake fading is a significant element in the incidents. Heavy-duty vehicle conventional braking systems may be efficient in normal circumstances, but in an emergency, things like brake fade, load, and longer stopping distances could prevent them from offering the required response time or stopping force. Therefore, we proposed system integrates auxiliary braking methods, including engine braking and exhaust braking, each selected for their effectiveness and reliability under various operational conditions. The proposed system incorporates key components, including an Arduino Mega 2560 microcontroller, a pressure transducer, servo motors, and MATLAB Simulink software and TruckSim for simulation. Simulations conducted under unladen, half-laden, and fully laden scenarios demonstrated significant improvements in braking performance, including reduced stopping distances and consistent deceleration rates. The system's rapid response time and adaptability to diverse operational challenges further validate its effectiveness. This work aligns with contemporary advancements in auxiliary braking technologies, emphasizing their potential to address safety challenges in heavy-duty vehicles. The findings pave the way for further research and real-world application of integrated braking systems, contributing to improved road safety standards for heavy vehicles.

ABSTRAK

Brek udara, juga dikenali sebagai sistem brek udara termampat, merupakan mekanisme brek geseran yang digunakan dalam kenderaan. Sistem ini bergantung kepada udara termampat yang memberikan tekanan pada omboh untuk mengaktifkan pad brek, seterusnya menghentikan pergerakan kenderaan. Sistem brek ini banyak digunakan dalam kenderaan berat (HDV), terutamanya kenderaan dengan treler berganda yang saling bersambung dalam sistem brek. Contoh kenderaan yang menggunakan brek udara termasuk lori, bas, treler, separa treler, dan juga kenderaan yang dikuasakan oleh enjin diesel dan petrol. Menurut Polis Diraja Malaysia (PDRM), terdapat sekitar 40,000 insiden yang melibatkan kenderaan berat. (MIROS, 2022).Terdapat pelbagai faktor yang mempengaruhi kemungkinan pelanggaran kenderaan berat. Kegagalan brek kenderaan berat adalah elemen penting dalam insiden ini. Sistem brek konvensional kenderaan berat mungkin berkesan dalam keadaan biasa, tetapi dalam situasi kecemasan, faktor seperti kegagalan brek, beban, dan jarak henti yang lebih panjang boleh menghalang sistem daripada memberikan masa tindak balas atau daya henti yang mencukupi. Oleh itu, kami mencadangkan sistem yang mengintegrasikan kaedah brek tambahan, termasuk brek enjin dan brek ekzos, yang dipilih berdasarkan keberkesanan dan kebolehpercayaannya dalam pelbagai keadaan operasi.Sistem yang dicadangkan ini menggabungkan komponen utama seperti mikropengawal Arduino Mega 2560, transduser tekanan, motor servo, perisian MATLAB Simulink, dan TruckSim untuk simulasi. Simulasi yang dijalankan dalam keadaan tanpa beban, separuh beban, dan beban penuh menunjukkan peningkatan prestasi brek yang ketara, termasuk pengurangan jarak henti dan kadar nyahpecutan yang konsisten. Masa tindak balas sistem yang pantas dan keupayaannya untuk menyesuaikan diri dengan cabaran operasi yang pelbagai mengukuhkan lagi keberkesanannya.Kerja ini selaras dengan kemajuan teknologi brek tambahan yang terkini, menekankan potensinya untuk menangani cabaran keselamatan kenderaan berat. Penemuan ini membuka jalan kepada penyelidikan lanjut dan aplikasi dunia sebenar sistem brek bersepadu, menyumbang kepada peningkatan piawaian keselamatan jalan raya untuk kenderaan berat.

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LIST OF SYMBOLS AND ABBREVIATIONS

HDV	-	Heavy-Duty Vehicles
EBS	-	Emergency Braking System
RMP	-	Royal Malaysia Police
ABS	-	Anti-lock Braking System
EBD	-	Braking force distribution system
TCS	-	Traction control system
YSC	-	Yaw stability control
ESP	-	Electronic Stability Program
ADAS	-	Advanced Driver Assistance System
AEB	-	Autonomous Emergency Braking System
ICAS	-	Intersection Collision Avoidance System
V2V	-	Vehicle-to-Vehicle Communication
V2I	-	Vehicle-to-Infrastructure Communication
BBW	-	Brake By Wire
DC	-	Direct Current
HIL	-	Hardware-in-the loop
SIL	-	Software-in-the loop
LED	-	Light Emitting Diode
PWM	-	Pulse Width Modulation
M	-	Mega
Hz	-	Hertz
USB	-	Universal Serial Bus
AC	-	Alternative Current
KB	-	Kilobyte
PIC	-	Peripheral Interface Controller
LCD	-	Liquid Crystal Display
PRD	-	Perception Reaction Distance
v	-	Initial Velocity
t	-	Time Taken
BD	-	Braking Distance
μ	-	Coefficient of Friction

g	-	Acceleration Due to Gravity
S_d	-	Stopping Distance
k	-	kilo
Nm	-	Newton meter

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CHAPTER 1

INTRODUCTION

1.1 Background

Air brakes, also referred to as compressed air brake systems, represent a friction braking mechanism utilized in vehicles. They rely on compressed air exerting pressure on a piston to activate the brake pads, thereby halting the vehicle's motion. These braking systems find extensive use in large, heavy-duty vehicles (HDV), particularly those with multiple trailers interconnected within the braking setup. Examples of vehicles employing air brakes include trucks, buses, trailers, semi-trailers, and even diesel and gasoline engine-powered vehicles. An engine-specific pneumatic tank holds the engine's exhaust gas. The pneumatic cylinder and brake lever are powered by the exhaust gas pressure. (Pawar,2021)

Figure 1.1: Examples of Heavy-duty vehicles. (Scania ,2014)

However, Heavy-duty vehicles now demand more than just the braking force provided by traditional brakes to maintain consistent braking performance. Auxiliary braking mechanisms are now essential to alleviate the strain on the primary braking system. Alongside the well-established engine auxiliary brake device, an increasing number of heavy-duty vehicles now feature retarder auxiliary brake systems. Engine braking entails utilizing the drag effect of the engine to decelerate the vehicle without applying traction to the wheels. The retarder aids the braking system by effectively decreasing the brake usage duration during braking, ensuring optimal braking efficiency for the original braking system. This facilitates smooth vehicle operation during braking and enhances overall braking safety. (Ding et al, 2023)

The presence of heavy traffic and crucial cargo that can jeopardize vehicle safety necessitates the installation of emergency braking system (EBS) on long-haul trucks. In the event of a potential collision or hazard, the backup system will promptly engage the brakes to bring to a halt. This capability is achieved by utilizing sensors such as radars or cameras to detect the position and speed of approaching vehicles or pedestrians. (Sri, C. et.al, 2023).

This type of feature help in calculating collision velocity ,braking distance (Rosado, A. et.al, 2017) and provide fast braking behaviour automatically. (Park, et.al, 2016).On the other hand, the emergency braking system (EBS) will prevent collusion, steering asymmetry of the force caused by the asymmetric braking may result in losing control of the vehicles. (Chelbi, et.al ,2018)

This project aims to contribute to the continued elevation of heavy-duty vehicle technology by innovating and collaborating, establishing safer and more reliable transportation for all stakeholders.

1.2 Problem Statement

According to statistics from the Royal Malaysia Police (RMP), the total number of heavy vehicles involved in road crashes remains high. Specifically, lorries were involved in over 40,000 incidents, while buses were involved in more than 9,000 incidents (**Figure 1.2**). (MIROS,2022)

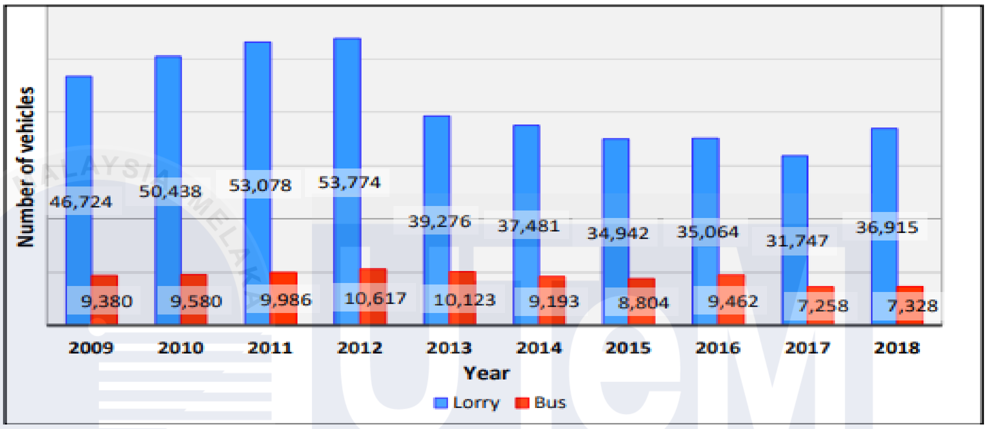

Figure 1.2: Heavy vehicles involved in road crashes for 2009 - 2018.(MIROS,2022)

Numerous variables influence the likelihood of heavy-duty vehicle collisions. Heavy-duty vehicle brake fading is a significant element in the incidents. Brake fading is more common in difficult driving situations like extended descents or steep inclines. Particularly on highways with different elevations, excessive heat in the brake system might result in reduced stopping power and increased stopping distances. Since issues like worn brake pads or corroded brake lines can impair the vehicle's ability to stop safely, skipping routine brake maintenance might increase these dangers. Heavy-duty vehicle overloading and distracted or fatigued driving exacerbate the problem, especially when emergency braking is involved.

Heavy-duty truck braking systems are strained, and braking techniques become more difficult in Malaysia due to underdeveloped road infrastructure and inadequate signs. Keeping high standards, enforcing rules, and promoting safety through driver education are all necessary to address these issues. Thus, to improve brake system efficiency by using an auxiliary braking systems. This system may support the main service brake if the main service brake is fail to function.

1.3 Objective

In recent years, there have been a significant increase in heavy-duty vehicles crashes. To address this issue and enhance safety measures, we are proposing the implementation of an improved braking system. As per the project proposal, the system will be activated by a drop in exhaust pressure of the heavy-duty vehicles, thereby triggering an auxiliary braking system to halt the vehicle. The integration of a pressure transducer, a microcontroller (Arduino Mega), LEDs, RC semi tractor motor, and a buzzer into the vehicle braking system model will contribute to the overall effectiveness of the proposed system. The specific objectives are as follows:

- To develop an auxiliary braking system model for heavy-duty vehicles.
- To fabricate a model prototype of auxiliary braking system for heavy-duty vehicles.

1.4 Scope

In recent years, the traffic accident cases that related to heavy-duty vehicles have increased rapidly. This makes the public begin taking seriously about this topic. Thus, it's time to develop and introduce a system that enhances emergency braking system which call auxiliary braking system. Since this type of technology is not widely on the heavy-duty vehicle, we are now with this project to develop a new system and improve reliability of the system and wish the system can be introduced and widely use in the future.

- The parameter of the heavy-duty vehicles braking system model is developed based on 1:16 heavy vehicles RC model.
- The heavy-duty vehicle exhaust braking system model is developed in MATLAB Simulink software.
- The prototype of exhaust braking model is developed on the electronic circuit board
- The performance of the proposed exhaust braking model is evaluated through the experiment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

For the delivery of goods and services, heavy-duty vehicles are essential. Exhaust brakes are frequently used on these cars and are a vital component of increased braking power and safety. The exhaust brake is especially useful for controlling speed on downhill slopes without overtaxing the primary braking system because it reduces engine and vehicle speed by raising exhaust back pressure. (J, N et al, 2013)

However, this primary braking system may suffer from delayed response times, reduced efficiency under high thermal loads, or complete failure due to mechanical wear and tear. Interest in auxiliary braking systems has grown due to this limitation, as they can provide extra braking force and improve overall vehicle safety.

When it comes to braking systems, auxiliary systems like electromagnetic brakes, retarder brakes, and engine brakes are far more advantageous than standard braking systems. While retarder brakes use hydraulic or electrical forces to distribute kinetic energy, engine brakes use the compression of the engine to slow down the car. By using magnetic fields to provide resistance and slow down the car, electromagnetic brakes provide a quick and controllable response. In emergency situations, for instance, these devices can function both independently and in concert with the main brake system to increase braking efficiency. (Alex, 2022)

2.2 Early Mechanical Braking System

Braking mechanism have been in use since the pre-mechanical age of transport, the age which witnessed horse drawn carriages as shown in **Figure 2.1**.(Abuzeid, M. R. ,1996) Most of the first braking systems can be described as mechanized.Traditionally a wooden block was applied in these systems.The wooden block was pressed against the wheel for producing the required friction for slowing down the vehicle.This kind of brake was sometimes referred to as a "block brake" that demanded operation by the driver through a lever.By way of the wooden block applied on the metal wheel rim, the requisite amount of braking force was generated but was rather scarce and fluctuating.

Figure 2.1: Horse-drawn wagon (B.L.J Gysen et.al, 2011)

However, the limitation of this kind of brake is the wooden block wear down quickly and need frequent replacement as the effectiveness even more weakened.

2.2.1 Transition to Mechanical Brake in Early Motor Vehicles

The development of motor vehicles in the late 19th and early 20th centuries made it clear that improved braking systems were required. Early automobiles had greater speeds and weights than horse-drawn carriages, which quickly overwhelmed the primitive block brake systems they inherited and modified. The advancement of technology has acquired modifications to braking system in order to enhance road safety and dependability. (Oakley et al, 1973)

The first of these adaptations in this progression was the band brake system. Band brake used a flexible band placed around a drum coupled to the wheel of the vehicle. When the driver engaged the brake, the band squeezed the drum and this resulted in friction hence slowing the moving parts and the whole vehicle. (Fisher et al, 1999) This simple and powerful was culmination from the block brakes of horse-drawn carriages.

Due to the fact that it delivered much more friction compared to drum brake, comprising the band brake could adapt more ideal to slightly faster speeds and increased weights of early motor cars but nevertheless was not very effective and stable under demanding circumstances. (Riva et al, 2022)

The drum brake emerged as the demand and requirement for a better braking system. The drum brake was developed from the band brake idea that offered a much more precise and immediately effective braking system. This system brake shoes were expanded inwards in a rotating drum. Such design of brake shoe in contact surface area, which would reduce heat build-up and consequent wear. Drum brake provided more braking power and service longevity. (Kumar et al, 2020)

2.3 Evualution Of Braking System In Heavy-Duty Vehicles

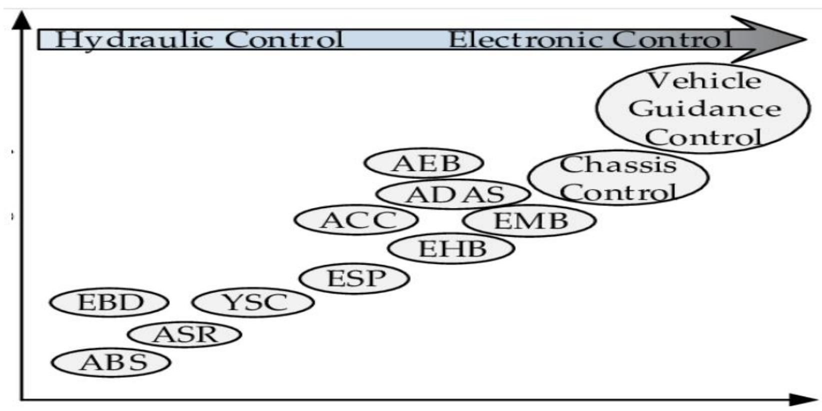

Figure 2.2: Timeline of braking system

The hydraulic brake system is well established and dependable, having been installed in a wide range of automobiles. One of the most significant advancements in braking systems is the anti-lock system (ABS). Since then, several innovations and integrations into hydraulic brake systems have included the braking force distribution system (EBD), traction control system (TCS), yaw stability control (YSC), electronic stability program (ESP), advanced driver assistant system (ADAS) and automated emergency brake (AEB). (Gong et al, 2020)

The development history and future directions of the braking system with regard to comfort and safety are summed up in **Figure 2.2**. As new features are continously added and the braking system is continously enhanced, it is evident that safety performance and ride comfort have significantly increased. (Manoharan et al, 2019)

2.3.1 Anti-lock Braking System (ABS)

Figure 2.3: Anti-lock Braking system

Figure 2.3 shows an antilock braking system (ABS).The anti-lock braking system is a closed-loop device designed to prevent locking and skidding during braking.(Austin et al, 2000) An essential safety element in cars is the anti-lock braking system (ABS), which keeps the whees from locking up while braking and preserves control of the vehicle. Research has demonstrated that ABS can enhance vehicle stability and reduce stopping distances by adjusting brake pressure to maintain ideal wheel slip under a variety of braking scenarios. (Wei et al, 2020)

However, road conditions might have an impact on the effectiveness of anti-lock braking system (ABS). It may not function as well on uneven terrain. (Zhu et al, 2023)

2.3.2 Traction Control System (TSC)

Vehicles now are equipped with traction control system (TCS), which are sophisticated safety feature that stop wheels from slipping while the vehicle accelerates. It guarantee the wheels to retain traction with the road surface, which improves vehicles handling and stability, particulary in unfavorable circumstances like rain, snow, or loose gravel. (Osinenko et al, 2017)

TCS uses sensors to track wheel speed in order to prevent wheel slide. When it senses wheel spin, it applies brakes or cuts engine power to the wheels that are slipping for example during sudden acceleration or on slick surfaces.This guarantees ideal stability and grip. (Skill Lync, 2020)

2.3.3 Electronic Stability Control (ESC)

Electronic Stability Control (ESC), also known as Electronic Stability Program (ESP) or Dynamic Stability Control (DSC), is an advanced vehicle safety feature in modern cars. It helps drivers to keep control of their cars during challenging driving conditions, like high-speed corners, icy roads, or abrupt manoeuvres. ESC's primary function is to mitigate loss of traction, or "skidding," which may lead to loss of vehicle control. (Tumasov et al, 2019)

ESC continuously monitors the vehicle speed, steering angle, and other parameters to figure out the driver’s intended path. (Tahouni et al, 2019)

2.4 Advancement in Emergency Brake System Technology

These last few years, the braking system in heavy-duty vehicles have been systematically improved to make that of greater efficiency and reliability in use. The conventional braking system commonly used in heavy-duty vehicles, employed in the early models of these vehicles is subject to excessive wear and tear and, consequently, to limited energy conversion.

The advancement examples in heavy-duty vehicles emergency brake system are brake-by-wire, emergency braking predictive, and autonomous emergency braking system (AEB). The convergence of these technologies not only enhances braking reliability and precision, but also greatly reduces both the risk and severity of injuries because of accidents on the road.

2.4.1 Autonomous Emergency Braking System (AEB)

Modern vehicles are equipped with an emergency braking system, commonly referred to an autonomous emergency braking system (AEB), which automatically applies the brakes to prevent or lessen the severity of a collision.This type of system detects the presence of objects , such as other cars, pedestrains or roadblock, using sensors like radar,lidar and cameras. It then notifies the driver if an impending collison is possible.In order to prevent or lessen the severity of a collision, the system may automatically apply the brakes if the driver does not react rapidly. (Sri.C et al, 2023)

According to Kaempchen et.al (2009), the emergency braking system is an active safety element in vehicles that lessen the impact of an accident. When an accident becomes unavoidable, it initiates a complete brake application in an attempt to lessen the impact energy of the collision. The systen is called a collision mitigation system since its main goal is to lessen the energy involved in a collision rather than completely prevent accidents.

The limitation of the autonomous emergency braking system is these systems might not be expected to be effective at higer speed restriction levels. The only effect was assessed for low speed at different speed limit levels. (Cicchino,J.B et.al 2017)

2.4.2 Intersection Collision Avoidance System

Intersection collisions are one of the situations that cause many traffic accidents, so the development of an Intersection Collision Avoidance System (ICAS) for heavy-duty vehicles is significant. The systems combine technologies such as vehicle-to-vehicle (V2V) communications, vehicle-to-infrastructure (V2I) communications, sensors, and controls to prevent crashes. ICAS is an intersection collision avoidance system based on 802.15.4 standard. On the basis of WLAN-based sensor, this system was a platform for the study of tracking vehicle movement and accident reduction. (Tachwali,,2009)

2.4.2.1 Vehicle-to-Vehicle Communications

V2V or vehicle-to-vehicle communications is a wireless network used for the exchange of information between vehicles. Such communication allows for the sharing of information between vehicles including speed, position, and direction to improve the state of the whole. V2V communication is critical as it helps improve the road's safety by providing information regarding the incident on the road to help prevent accidents and improve traffic flow. (Hafner, 2013)

2.4.2.2 Vehicle-to-Infrastructure Communication

V2I (vehicle to infrastructure) communication is a terminology used for exchange of information between vehicle and its surrounding environment along with seeking information using wireless communication-based methods which may work between the vehicle and environment such as traffic lights, road signs etc. Via this communication vehicles are able to acquire realtime information on traffic condition, road conditions and traffic signal timings which significantly enhances situational awareness leading to an increase in traffic flow and safe driving. (Bijun et al, 2019)

2.4.3 Brake by Wire Technology

In autonomous vehicles, brake by wire (BBW) technology is essential. This technology had quicker reaction time and increased stability hence can make autonomous automobiles safer for passengers. In order to improve braking performance, BBW technology involves replacing several complex mechanical and hydraulic parts of the conventional braking system with wires that carry braking signals. (Xiang, 2008)

The brake by wire (BBW) system,which is also called the electromechanical brake system, has emerged as a viable system for controlling vehicle braking that works without a mechanical or hydraulic backup, allowing for numerous new driver interfaces and improved performance. (Hua, 2023)

In modern heavy-duty vehicles equipped with a compression braking mechanism. To reduce the wear of the conventional friction brakes, a brake by wire technology was integrated in the braking system. In brake by wire driving conditions where the vehicle controls the brake valve to achieve compression brake variability. The adaptive controller is engineered to guarantee optimal speed tracking performance. This technique improves the total braking capacity of heavy-duty trucks by enabling precise control and modulation of the braking system. (Druzhinina, 2000)

2.5 Types of auxiliary braking system

The types of auxiliary braking system current on the market are electromagnetic retarders, exhaust brake, engine compression brake and transmission retarders.All of the commercially available auxiliary braking systems slow the vehicles using a different technique than mechanical friction. Additionally, they all function by applying braking force to the vehicle's driveline, which subsequently pushes the force onto the tires and ultimately the pavement.Although they all produce heat, none of them overheats the service brakes instead they all manage dissipation. (Fama, 2018)

2.5.1 Electromagnetic Retarders

Figure 2.4: Electromagnetic Retarders

Figure 2.4 shows an electromagnetic retarders. A device for slowing moving vehicles is called electromagntic retarder, which operates on the basis of electromagnetism.This kind of retarders operate in a frictionless environmet, they ensure a smooth deceleration process. (Ergün et.al,2014) The electromagnetic brakes are an additional piece of retardation equipment, they can employed less frequently, meaning that the friction brakes almost never reach high temperatures. There would be no brake fade issue and the brake linings would last a lot longer before needing maintenance. (Kumar et.al, 2020)

One of the main benefits of electromagnetic retarders is their capacity to provide consistent braking performance (Armstrong, 2015), irrespective of external influences like temperature or brake fade. This guarantees dependable stopping power even in challenging circumstances, which contributs to overall vehicle stability and control.Moreover, the regenerative features of electromagnetic retarders can lead to improved energy efficiency and less wear on the primary braking system.As a result they are an appealing choice for operators of heavy vehicles seeking to enhance performance while also being cost-effective. (Marechal et.al, 1990)

In summary, although the electromagnetic retarders provide a useful extra braking force but their efficiency is limited by heat production, speed dependence, increased weight ,space requirements, power consumption and high maintenance cost. This limitation need to be properly handled to optimise the advantages of electromagentic retarders.

2.4.1.1 Concept Prototype of Electromagnetic Retarders

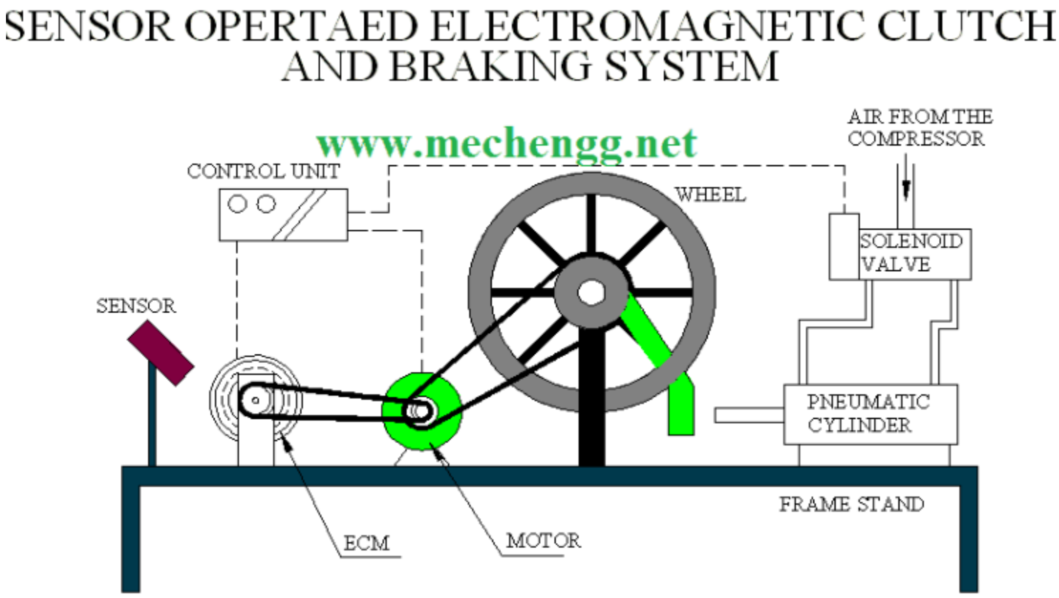

Figure 2.5: Sensor operated Electromagnetic Clutch and Braking System (Sachin Throat,2020)

Figure 2.5 shows a prototype done by Sachin Throat (2020). The working principle will be discussed in this chapter. After detecting an object, the object sensor sends out the appropriate signals. Since the electrical signals are very low mill voltage signals, an amplifier circuit is used to receive them. An operational amplifier serves as a power amplifier in the construction of the amplifier circuit. The signal conditioning unit, which is also built with an operational amplifier, receives the amplifier signal after that. The operational amplifier functions as a comparator in this circuit, producing a square pulse that is sent to the microcontroller. (Sachin Throat, 2020)

The solenoid valve is then activated, allowing air from the compressor to enter the pneumatic cylinder and apply the brake, which is powered by a separate motor. The transistor used in the driving circuit serves as a switch to operate the relay. The electromagnetic core located in the clutch assembly, which activates instantly upon pressing the brake, it directly connected to the relay ouput. (Sachin Throat, 2020)

2.5.2 Exhaust Brake

Figure 2.6: Exhaust Brake

In heavy-duty vehicles like trucks, buses and tractor-trailers, exhaust brake are a crucial auxiliary braking system that complements the primary service brakes and improves overall braking performance that shows in **Figure 2.6** . By limiting the flow of exhuast gasses, these systens effectively slow down the vehicle without using the primary service brakes by building up backpressure in the engine.

As a benefits of using utilizing an exhaust brake include reduction wear on the main services brakes, improving speed control on long downgrades and lowering the chance of runaway accidents. (O'Day &Bunch, 1981) This is especially important for large vehicles, as they can lose a lot braking power when driving in rough terrain, such as on steep hills or in busy cities. (Xin Q, 2011) To give a complete braking solution, exhaust brakes are frequently paired with additional braking devices like engine brakes or retarders. (Hilley et.al, 2000)

The core mechanical operation is that a butterfly valve that is mounted in the exhaust pipe serves as the central component of an exhaust brake.This valve stays open during regular driving, enabling exhaust fumes to freely exit the engine.The butterfly valve partially closes in response to the activation of the exhaust brake, which is usually done using a dashboard switch.Pressure builds up in the exhaust manifold as result of this closure's restriction of the exhaust gas flow. (Doe.J, 2019)

During the exhaust stroke, there is more resistance to the pistions' upward motion due to the higher back pressure in the exhaust manifold. As a result, the engine has to work harder to release the exhaust gasses, which causes the engine to produce heat instead of kinetic energy and brake.This method is very efficient at keeping speeds within limits and does not require extra fuel. (Xin Q , 2013)

Although the exhaust brake can reduce wear on the main services brake but the exhaust brake may wear out over time.Exhaust brake may failure as the exhaust brake line leaking somewhere.

2.5.2.1 Working Principle of Exhaust Brake System

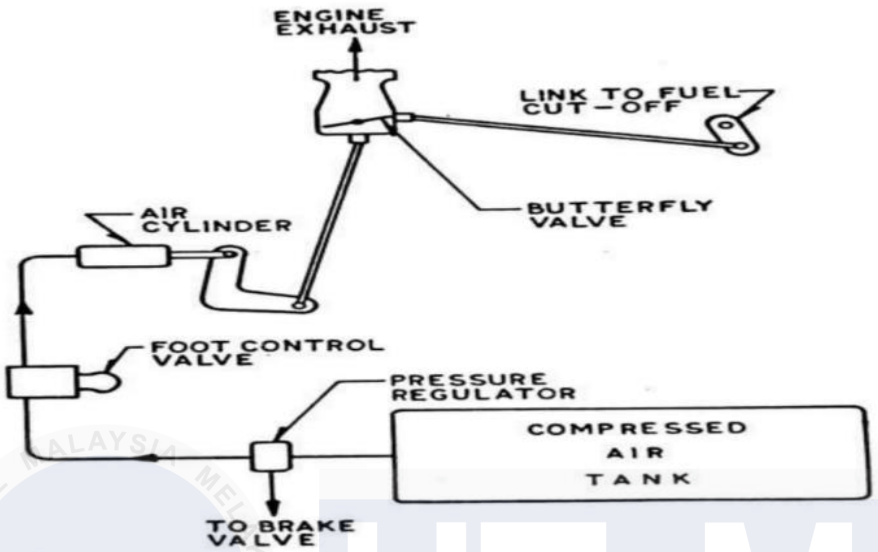

Figure 2.7: Exhaust Brake System

Figure 2.7 shows an exhaust brake system. When the foot control valve is pressed, the compressed air from the air tank enters the air cylinder. Where it operates a linkage to close the butterfly valve at the exhaust manifold, which also cuts off the fuel supply through linkage. The moment the foot is taken off the valve, the brake disengaged. This brake is very effective under a speed of 40 km/h. (Yang et al, 2021)

2.5.3 Engine Brake

Another kined of auxiliary braking system used in heavy-duty vehicles is the engine brake,also referred to as a "Jake Brake" after the brand of Jacobs Vehicles System. (Manolache et.al, 2017) An engine brake alters how the engine's exhaust valves operate, in contrast to an exhaust brake that builds up backpressure in the exhaust system. The engine brake releases compressed air from the cylinders directly into the exhaust system by activating the exhaust valves close to the top of the compression stroke. (Schmitz et.al, 1994)

By removing energy that would normally aid in the subsequent combustion cycle, this process slows down the piston’s movement. The characteristic loud rumbling sound is frequently connected to engine brakes is produced by the direct release of compressed air into the exhaust system. (Smith, 2023)

By turning the engine from a power source into an air compressor, the engine braking effect slows down the car. Significant braking power is produced by this technique, which is particularly helpful for regulating vehicle speed when going downhill and lowering the need for the primary service brakes, which in turn extends their lifespan and lowers the risk of overheating. (Smith, 2023)

2.5.4 Transmission Retarders

The vehicle deceleration mechansim known as a transmission retarder, which can be either hydraulic or hydrodynamic, operates by employing fluid friction to transform the vehicle’s kinetic energy into heat within the working fluid, typically a lubricating oil. (Jia, 2011) The contrast between the service brake and the parking brake arises from the fact that the former typically comprises a disc or drum brake system that employs mechanical friction to decelerate or halt the vehicle by bringng the brake pads into contact with a rotating surface. (Belhocine et al, 2015).

It’s worth noting that while both systems are designed for deceleration, they function based on different principles and are best suited for varying situations. The hydraulic retarder is especially beneficial for heavy-duty vehicles, as it offers an alternative method of slowing down the vehicle, thereby reducing wear on the service brakes. (Yang et al, 2019)

Additionally, the use of retarders can contribute to improved braking performance and safety, as they can be integrated with other systems such Anti-lock brake system (ABS) to enhance control during braking. (Wang et al, 2014)

In summary of the transmission retarder and service brake work together as key components of a vehicles's braking system. The retarder offers a way to slow down the vehicle and extend the lifespan of the service brakes, enhancing overall vehicle safety. Meanwhile, the service brakes deliver essential mechanical friction for stopping the vehicle, particulary in emergency scenarios. (Yang et al, 2019)

For the summarised of all type of auxiliary braking system are shown in **Table 2.1** below.

Table 2.1 : Summary of Type of Auxiliary Braking System

	Electromagnetic retarder	Engine Brake	Exhaust Brake	Transmission Retarder
Braking Power	High	Medium	Low	High
Noise	Low	Medium	Low	Low
Weight	Low	Low	Low	Medium
Option Cost	Medium	Medium	Low/Medium	Highest
Heat Generation	Low	Low	Low	Highest
Maintenance	Medium	Low	Low	Medium

2.6 Integration of Auxiliary Braking System in Emergency Brake Systems in Heavy-duty Vehicles

In this statement presents the choice of the problem related to the integration of auxiliary braking system with emergency braking system in heavy-duty vehicles as an actual issue in the feild of autombile engineering. System like engine brake are generally employed for non-essential application, as they work in conjunction with other systems to supplement the availabe option for heavy-duty braking (Zheng et.al, 2017).

On the other hand, there are the antilock system such as the pneumo-hydraulic emergency braking system (EBS) used in self-driving racing which is mainly to ensure that a vehicle comes to a faster stop in case of an emergency to prevent an accident (Khan et al, 2021).

Morenotably, while auxiliary braking systems are generally employed to supplement the main system in normal driving circumstances, emergency braking system are engaged whenever a collision is about to happen, as in the case of the Advanced Emergency Braking system (AEBS) (Gao et.al , 2022). This integration of these various systems might possibly augment control and stability of the automotive vehicle and enhance safety.

For instance, the intelligent auxiliary braking system mentioned in Wei et.al (2023) that uses radar and camera sensors to detect the distance from the vehicle in front could be integrated with an emergency braking system to improve the ability to avoid collision rates.

In conclusion, through the present study, it has been ascertained that the enhancement of auxiliary and emergency braking system of heavy-duty vehicles could have a synergism impact on the normal and emergency category braking systems. Integration of the systems would not given that there would be attention control logic and behavior in the systems as well as performance concerning the different driving conditions.

2.7 Software in the Loop Simulation

Software-in-the-Loop (SIL) simulation technique is seen as simulation-based software validation. SIL simulation is capable of overcoming the low fidelity and speed of conventional simulations with regard to model validation for today's complex large-scale networks. Furthermore, it capable to overcome the conventional simulation problems of model validity and can be used both in the design phase and in the testing phase of the project. SIL combines the flexibility and low cost of the simulator with hardware fidelity. It can be easily used in both the design and testing phases and 56 potentially provides significant cost savings by optimizing code reuse and minimizing software development coding effort.

In SIL simulation, the testing involvement is in the virtual part where hardware is not directly involved (Tischer et al, 2012). However, during software analysis, SIL simulation can be executed under various types of simulated input conditions. The main purpose of the evaluation is to investigate the function ability of the software system under numerous input conditions. The plant model is developed via the mathematical model, multibody dynamics or 3D virtual model. The 3D virtual model resembles the actual configuration of the plant model.

Additionally, the SIL simulation technique is also used as a reference for any errors that occurred in a system before it can be implemented to HIL and Vehicle-In-the-Loop (VIL) simulation techniques. HIL and VIL techniques refer to the actuator and actual vehicle involvement in the simulation analysis (Gietelink et.al, 2006). This helps to reduce major errors which can cause damage to the real hardware system or injured the humans who directly involved in the testing (Albers et.al, 2010). Furthermore, SIL is used to identify any unwanted failing condition that might occur inside the controller design during the testing.

2.8 Hardware-in-the loop simulation

Hardware-in-the-Loop (HIL) simulation technique is used to replace the mathematical model. It uses more on testing of real hardware systems (Deng et.al, 2008). To date, HIL has become one of the widely held established methodologies in the development of various automotive control systems (Hudha et.al,2011). HIL testing has become one of the repository tools for automotive researchers and designers (Semsey et.al, 2006). The hardware is tested with simulated desired input. It is also tested for disturbance which might occur in real conditions. This will alert the researchers in case the proposed hardware could cause any error which would damage the hardware or risk the human’s life. Meanwhile, the 57 researchers also can evaluate the capability of the hardware until its maximum limit. Deng et al., 2008 also mentioned that a combination of both techniques is required in testing an actuator to a real system. This will help to identify the performance of hardware before it can apply to the actual automotive system. Furthermore, the technique also significantly reduces the time needed to evaluate the system and able to increase the robustness of the system to the maximum limit.

CHAPTER 3

METHODOLOY

3.1 Introduction

This section describes the specific process used to design and fabricate of heavy-duty vehicle emergency braking system using auxiliary braking system. They include the concept design, component selection, the prototype design, the working principle to meet the set objectives. Firstly, the selection of materials for the system which includes the arduino mega, pressure transducer, servo motor, and motor to simulate the heavy-duty vehicle moving was conducted.

The concept design of the system use of simulation design software known as Matlab Simulink in designing the braking system. Therefore, it was deemed relevant to develop a raw prototype design. This prototype was used to show the relative location of parts at specific sites and explain the operation on which the design was based.

Furthermore, the use of Simulink software helped to simulate the system prototype making it efficient. The overall process was shown in **Figure 3.1** below.

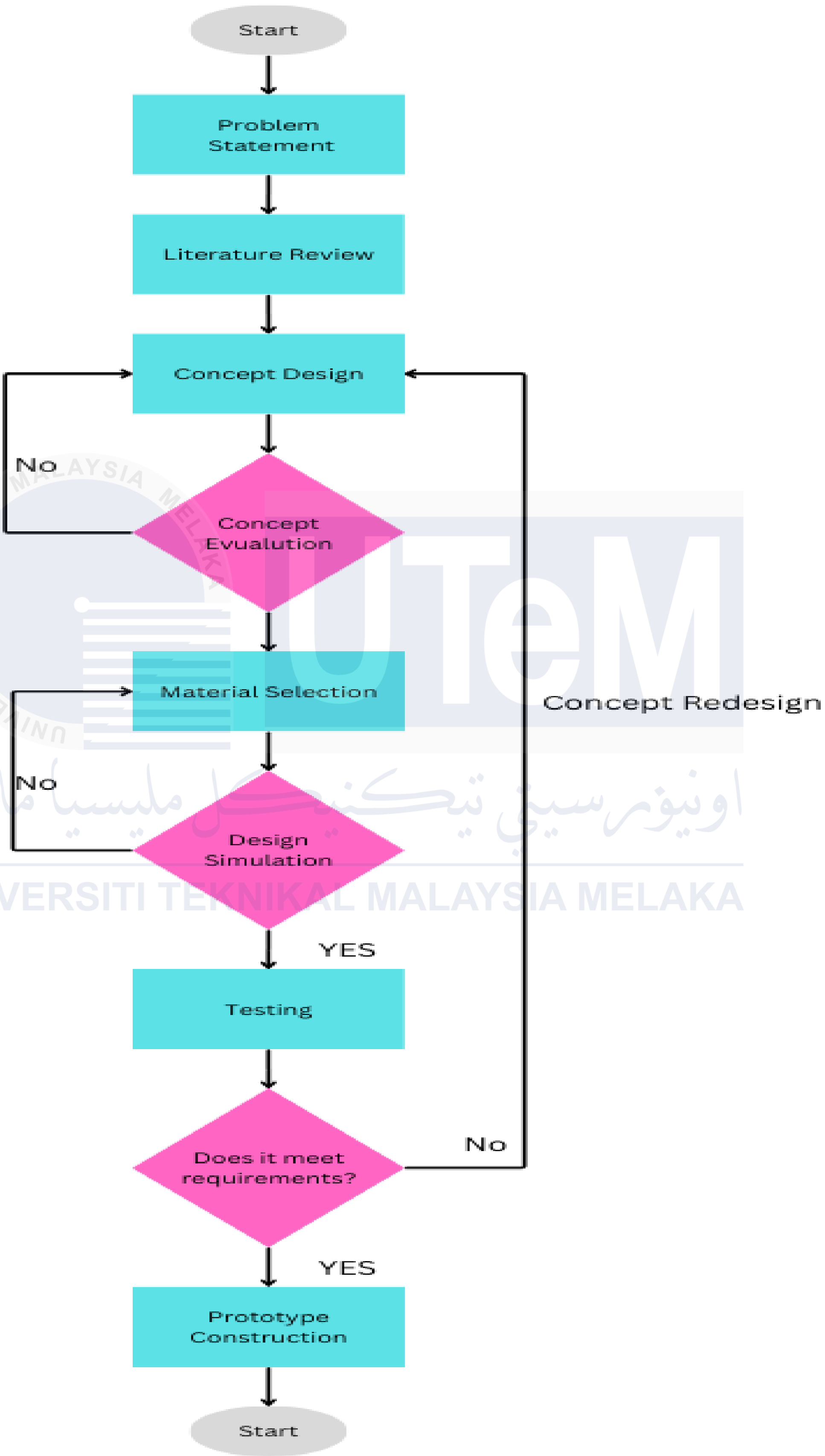

Figure 3.1:Overall Flow chart for the methodology of the project

3.1.1 Research Background

Prior to developing and introducing the new invention or new product, the researcher must carry out additional research on the engineering of the auxiliary braking system that are now available on the market.As a result, the current systems's operation and function in auxiliary braking system will be discussed and examined in this project and research. Each component's benefits and drawbacks have been evaluated in order to identify potential adjustments and develop fresh methods for enhancing there research going forward.

Hence,the identification of the most efficient auxiliary braking system ,background research is conducted.However,this is dependent on the main goal of the project as well as the system's capabilities inside the framework of the auxiliary braking system project.By taking into account as many elements as feasible, a fair solution can be developed. The greatest solution for the new, improved system will be chosen with the help of a more comprehensive viewpoint built from numerous bits of knowledge acquired about this topic of research.

Nonetheless, a comprehensive testing program will be implemented to ascertain whether the built system can consistently generate a predefined output that aligns with the project's objectives.

3.2 Concept Design

For the previous research in the previous chapter, the concept design of the system for the system is essential. The design must ensure safety and dependability of heavy-duty vehicles requires careful consideration of the design and development of an efficient emergency braking system. The emergency braking system needs to be able to stop and slow down the vehicle in the event that the primary braking system fails, protecting the lives of everyone inside the vehicles as well as other drivers.

Implementing an auxiliary braking system that can be used in an emergency is one possible way to overcome this problem. In order to provide an extra layer of redundancy and guarantee that the vehicle can be safely stopped even in the case of a primary system failure, this auxiliary braking system would function in tandem with the primary braking system.

Hence the prototype of the system is conducted to show the functionality of the braking system in the heavy-duty vehicles.

3.3 Components Selection

Emergency braking system are essential for averting accidents in the field of automotive safety, particularly in heavy-duty vehicles. To protect the safety of the vehicles, its occupants, and other drivers, these system must be strong, dependable, responsive. The incorpartion of an additional brake system managed by Arduino prototype is one creative strategy. The selection of parts required to construct an efficient emergency braking system wtih this technology is examined in this chapter. An morphological chart and pugh evaluation method will show the best solution of component selection.

3.3.1 Morphological Chart

Table 3.1: Morphological Chart

Function	Solution 1	Solution 2	Solution 3	Solution 4
Pressure Sensor	Digital Barometer pressure sensor BMP 280 	Absolute Pressure sensor MPX5700AP 	Gauge Pressure Sensor MPX 5010 	Pressure Transducer 
Microcontroller Board	Arduino UNO	Arduino Mega	Arduino Leonardo	Arduino Due
Warning sound	Small Speaker 	Piezoelectric buzzer 	Alarm Siren 	N/A
Actuator Motor	SG 90 servo motor 	MG 995 servo motor 	MG 996 servo motor 	
LED	RED/GREEN			
DC Motor	1.5V	3V	6V	12V above

Based on the result of Morphological Chart, there are 4 available best setting in the concept, but the only 2 design is taking in consider for the concept evalution which is first concept and last concept. For the first one (blue line), it is using the digital barometer pressure sensor, Arduino leonardo,small speaker,SG 90 servo motor, RED/GREEN Led and 1.5V DC motor.

The pros of this setting is the entire project is much lower compare with others because the Arduino Leonardo, SG 90 servo motor ,1.5V DC is relatively cheap. But the cons are digital barometer pressure sensor can only detect atmosphere pressure rather than the exhaust pressure. The small speaker need some extra modification or some media player to activate it which will make the software constrcution process become trouble. Hence, the first concept setting is not considered and use in the project.

For last setting (black line), it consists of pressure transducer, Arduino Mega, piezoelectric buzzer, MG 995 servo motor, RED/GREEN led and 6V. The pros of this setting is the cost component is relatively cheap with high accuarcy and fast respond. This is beacause the pressure transducer is the widely used in industrial engineering. The Arduino Mega is capable to handle to system well because the I/O pins on the board is enough for this project. The piezoelectric buzzer is allow to user to tune the sound, hence we can adjust the sound frequency and volume according to our setting in the system. The cons of this setting is the servo motro that replace the MG 90 servo motor as the MG995 working voltage needed higher than the MG 90 servo motor.

3.3.1.1 Pugh Evaluation Method

Table 3.2: Concept Screening of the 4 concepts

Selection Criteria	Concept				
		1 (Blue)	2 (Orange)	3 (Purple)	4 (Black)
Respond Time	Datum	0	+1	+1	+1
Cost		+1	-1	-1	+1
Reliability		-1	+1	+1	+1
Accuracy		+1	+1	-1	+1
Prototype Authenticity		-1	+1	-1	+1
Warning Effect		-1	0	+1	+1
Simplicity of Indication		+1	+1	-1	+1
Conveniences		0	-1	-1	-1
Easy to construct		+1	-1	-1	-1
Σ (+ 1)		4	5	3	7
Σ (- 1)		3	3	6	2
Σ (0)		2	1	0	0
Σ		4	5	6	7
Rank		2	3	4	1
Continue		NO	NO	NO	YES

3.3.2 Components Design

The first step is to figure out which components, as well as the system's flow, are required for design and fabrication of Heavy-duty Vehicles Emergency Braking System using Auxiliary Braking System. **Figure 3.2** depicts the system's operation, whereas **Figure 3.** depicts the system block diagram.

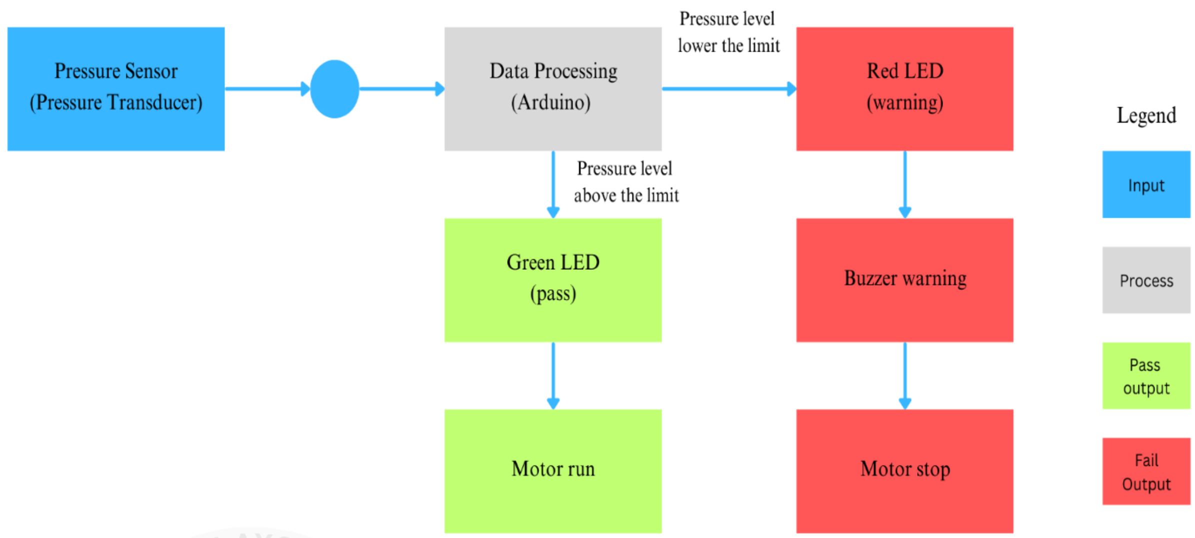

Figure 3.2: Workflow of braking system.

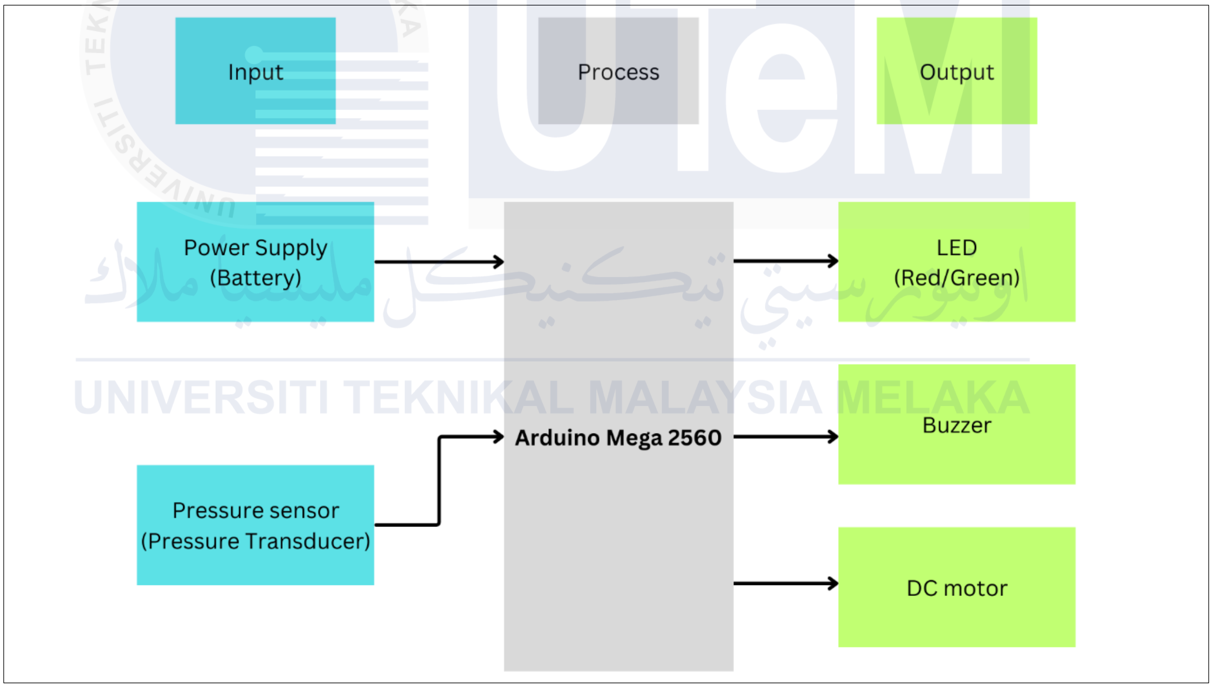

Figure 3.3: Braking System Block Diagram

3.3.2.1 Arduino Mega 2560

The Arduino Mega 2560 is a microcontroller board based on the Atmega 2560. It features 16 analog inputs, 4 analog inputs , 4 UARTs (hard serial ports), a 16 MHz crystal oscillator, 54 digital input or output pins (including 15 PWM outputs), a USB connector, a power jack, an ICSP header, and a reset button. As shown in **Figure 3.4**, this open-source microcontroller is suitable for interfacing with various interconnects and can be utilized in embedded systems and other electronics applications. It comes equipped with everything needed to support the microcontroller, and can be powerd by a battery, an AC-to-DC adapter, or connected to a computer via a USB cable.

Figure 3.4: Arduino Mega 2560

The emergency braking system that has been designed is connected to the power supply using an Arduino Mega 2560 board. This control unit, which has been built to do so, receives and processes the signals produced by the semiconductor sensor. It is controlled by computer code loaded on the board, which when specific criteria are fulfilled, illuminates an LED, activates a buzzer, and controls the motor and servo motor. The Arduino Mega 2560 uses a Peripheral Interface Controller (PIC), which can withstand voltages of up to 12V and hence is compatible with vehicles. The Arduino Mega 2560's specifications are listed in **Table 3.3**.

Table 3.3: Specifications of Arduino Mega 2560

Specification	Details
Microcontroller	ATmega2560
USB Type	USB-B
Build-in LED Pin	13
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
PWM Pins	15
I/O Voltage	5V
Input Voltage	7-12V
DC Current per I/O Pin	20mA
Flash Memory	256 KB
SRAM	8 KB
Clock Speed	16 MHz

As the program is not large enough, this Arduino Mega 2560 is ideal for a system that includes 1 sensor, two LEDs, 1 buzzer, DC motor and servo motor. The Arduino Mega 2560 is chosen due to its ample number of input/output pins, which are essential for managing multiple sensors and actuator. It also offers sufficient memory and processing power to handle complex algorithms required for real-time decision making in emergency situations.

3.3.2.2 Pressure Transducer

Pressure transducers are essential components that are used in a wide range of applications, including medical equipment, environmental monitoring, automotive systems, and industrial operations. These sensors provide for accurate measurement and control of a variety of pressure-related factors by converting the physical quantity of pressure into an electrical signal.

Figure 3.5 shows the pressure transducer, which operates at 5-volt direct current and output voltage of 0.5- 4.5 direct current voltage. The output signal is usually an analog voltage (0-5V) or a current (4-20mA) signal. This signal can be read by Arduino's analog input pins. **Table 3.4** shows the specification of pressure transducer.

Figure 3.5: Pressure Transducer

Table 3.4: Specification of Pressure Transducer

SPECIFICATION	DETAILS
WORKING VOLTAGE (DIRECT CURRENT)	5V
OUTPUT VOLTAGE (DIRECT CURRENT)	0.5 - 4.5
WORKING CURRENT	≤ 10 mA
WORKING PRESSURE RANGE	0 – 1.2 MPa
THE BIGGEST PRESSURE	2.4 MPa
DESTROY PRESSURE	3.0 MPa
WORKING TEMPERATURE	0 – 85 degree
STORAGE TEMPERATURE RANGE	0 – 100 degree
RESPONSE TIME	≤ 2.0 ms

The pressure transducer in the system is acting as a pressure sensor to sense the pressure difference between air pressure that being pumped from an air pump.

3.3.2.3 Light Emitting Diode

The LED bulb is a device that, when activated, emits a strong beam of light. In this project, red and green LED will be use. This red LED will illuminate when the detected pressure lower the legal limits, alerting the driver of the vehicle that the pressure has achieved the legal limits. The green LED, which signifies that the pressure remain in good condition. **Figure 3.6** depicts the LED that will be used in the system.

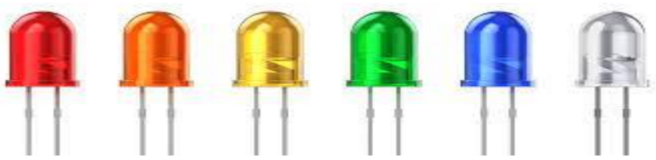

Figure 3.6: LED bulbs

3.3.2.4 Buzzer

As a additional feature of the braking system, a piezoelectric buzzer which shown in **Figure 3.7** has been used. When a voltage or signal is received, this device makes a beep noise or a buzzing sound according to the setting. There are three common varieties of buzzers such as piezoelectric, passive and active buzzer. Essentially, a piezoelectric material with two electrodes is used to create the piezoelectric buzzer. This buzzer is the most basic and easiest to use. Its aim is to make someone focus on themselves.

As a result of this braking system, if the pressure sensor sense the pressure drop, the braking system will immediately active the actuator to stop the vehicle and the buzzer will give warning to the driver. To work effectively, this buzzer requires the usage of an oscillator, such as microcontroller. The buzzer is affordable, and it can produce a loud, high quality sound without consuming a lot of power. The parameters of the piezoelectric buzzer that will be used in this project are detailed in **Table 3.5**.

Figure 3.7: Piezoelectric Buzzer

Table 3.5: Details of the Piezoelectric Buzzer

Details	UNIT	Large Piezo Buzzer
Min. Sound Output at10cm	dB	95
Rated Voltage	V DC	12
Operating Voltage	V DC	3~24
Resonant Frequency	Hz	3900±500
Max. Current Consumption	mA	10
Tone Nature	-	Continuous
Alarm Diameter	mm	22
Alarm Height	mm	10
Price per piece	RM	2.94

This piezoelectric buzzer is used by the project system to give the essential sound for the system. When the pressure level measured by the pressure transducer is less than a predetermined threshold level, it will turn on. When the system detects the pressure level measured by the pressure transducer is more than a predetermined threshold level, it will turn off. The buzzer is also inexpensive and simple to use with all of the Arduino boards, which can be found in stock at a local electronics store or on an online shopping platform.

3.3.2.5 Direct Current Motor

An electrical motor that rotates and converts electrical energy from direct current to mechanical energy is called a direct current (DC) motor. It is one of many varieties of electric motors that rotate. There are two groups into which magnetic field forces and different kinds of magnetic field forces fall. An internal mechanism in the majority of direct current motors alternates the direction of current in a motor component on a regular basis.

This device may be electronic or electromechanical. A direct current motor can have its speed adjusted across a broad range by altering the supply voltage or increasing the current intensity in the primary winding. The universal motor, as shown in **Figure 3.8**, is a compact, light brushed motor that runs on direct current and is utilized in conjunction with other components. **Table 3.6** provides details on DC motors.

Figure 3.8: Small DC Motor

Table 3.6: DC motor specifications

ITEM	SPECIFICATION
Rated Voltage	6V
No. load speed	9100 ± 1800 rotation per minute
No. load current	70 mA
Operating voltage	1.5 V to 12 V
Starting Torque	20 gcm (depends on blade used)
Starting current	500mA
Insulation Resistance	> 10 Ω
Rotation Direction	Clockwise at positive terminal
Axis Diameter	2 mm

In the braking system, the DC motor is to simulate the engine of heavy-duty vehicles. DC motor turn off when the pressure level below the limit.

3.3.2.6 Servo Motor

A servo motor that is shown in **Figure 3.9** is a type of linear or rotary actuator that enables accurate control over acceleration, velocity, and angular position. It is made up of an appropriate motor connected to a position feedback sensor. It is widely used in motion control like robotics, CNC machines, and automated production systems, frequently use servos. The specification of servo motor that used in the system is shown in **Table 3.7.**

Figure 3.9: Servo motor 995

Table 3.7: Specification of Servo motor 995

Item	Specification
Torque	9 kg/cm (4.8V), 11 kg/cm (6V)
Speed	0.19s/60º.0.18s/60º (6V)
Rotate angle	180º
Operating Voltage	4.8 – 6V
Gear	Metal
Dead band	5us
Weight	55g

The servo motor is used to simulate the vehicle opening and closing of exhaust valve.

3.4 Conceptual Prototype Development

In the early of conceptual prototype development, TinkerCAD software was used to generate design concepts based on the many projects listed in the literature review. The software was used to build the circuit and the program code can be created to test the circuit. The concept of the prototype from (Sri et al ,2023) was used, with some changes of the components such as ultrasonic sensor to pressure transducer and a relay to a transmitter as illustrated in **Figure 3.10**. To simplify the circuit, the LCD display was removed and also it is not required in this project. Some of the system components have remained unaffected, but the system's flow has been completely altered and there also a big change to suit the objective of the project. As demonstrated in **Figure 3.11**, the TinkerCAD platform is used to depict the idea design.

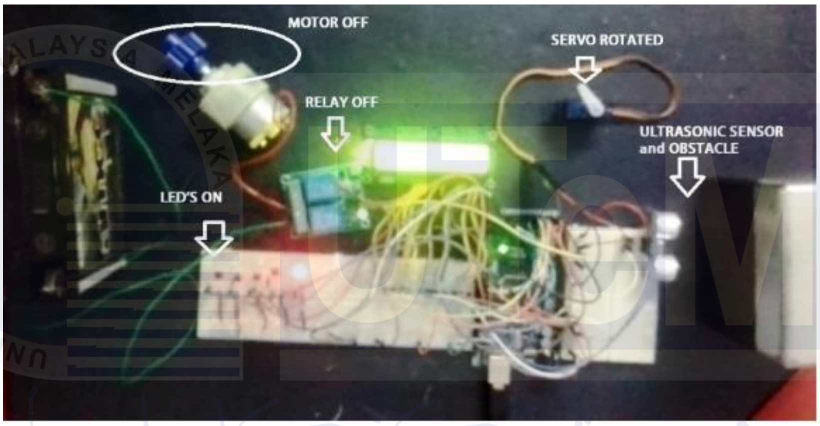

Figure 3.10: Design and Fabrication of Emergency Braking System (Sri et al,2023)

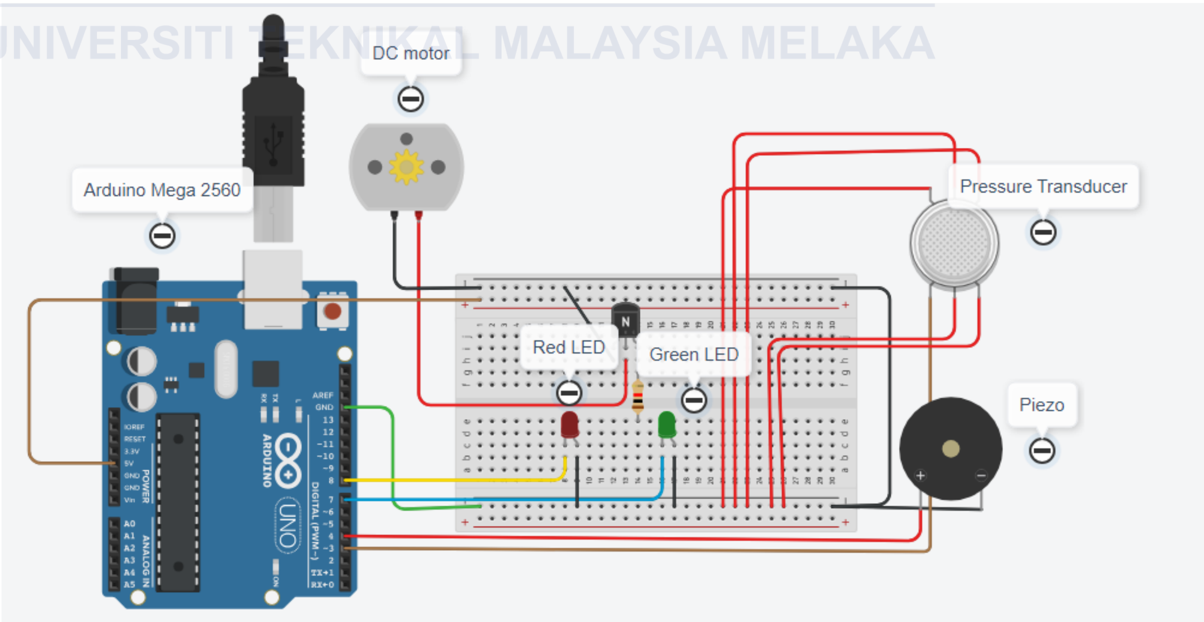

Figure 3.11: Emergency Braking System Concept Design

3.4.1 Simulink Block Diagram

Every new microcontroller-based device, such as an Arduino, must be written in C++ or another programming language. The microcontroller was programmed using MATLAB Simulink software in this project. It is necessary and fundamental to operate the sensor and other components in accordance with the system's parameters. Because the Simulink model must be uploaded in accordance with the system's needs for each component to function, hence programming is very important, and it is the brains behind this project. The system will be created based on block diagram model that has been pre-programmed. The program will be designed to give a very fast response and very accurate when it is started.

The MATLAB Simulink software, along with Arduino simulation add-on package, must be installed to build the program code for the system and deliver it to the microcontroller alter. In this system, the block diagram model was designed to measure parameter such as pressure level, light warning, sound warning signal, DC motor operations and servo motor movement based on the pressure level in the pressure transducer. During data processing, this portion is where the decision is made whether to activate the LED light indicator, buzzer sound, and motors operation. The concept block diagram model for the system is shown in **Figure 3.12.** The overall system flow is as in **Figure 3.13**.

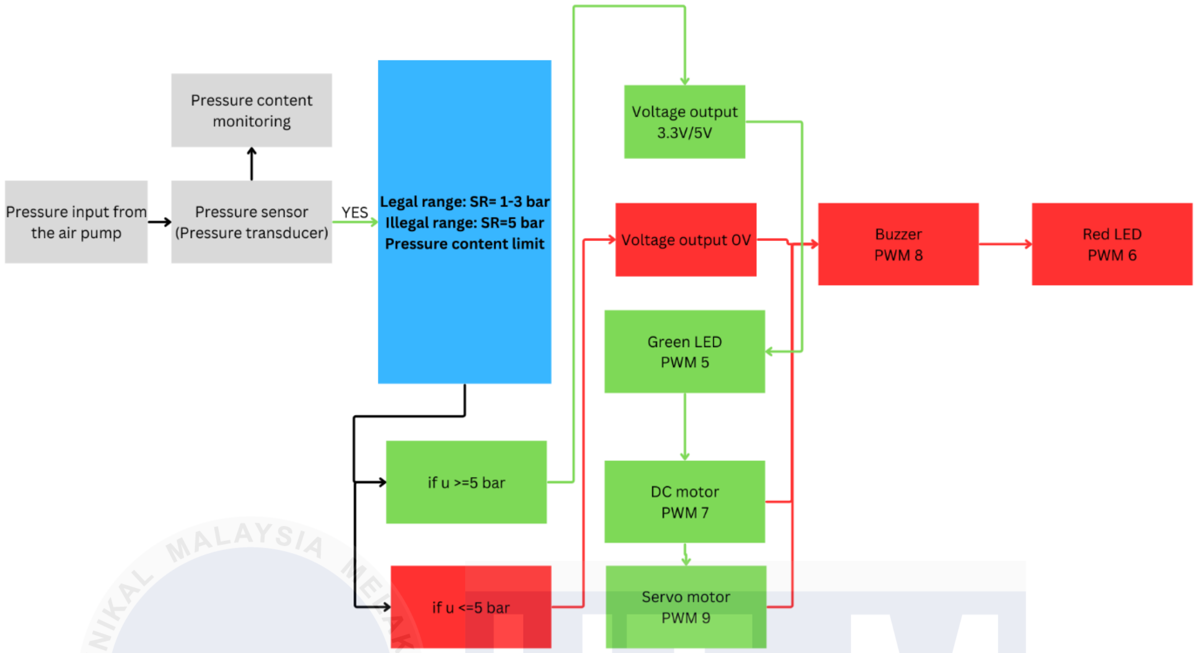

Figure 3.12: Concept block diagram model of emergency braking system

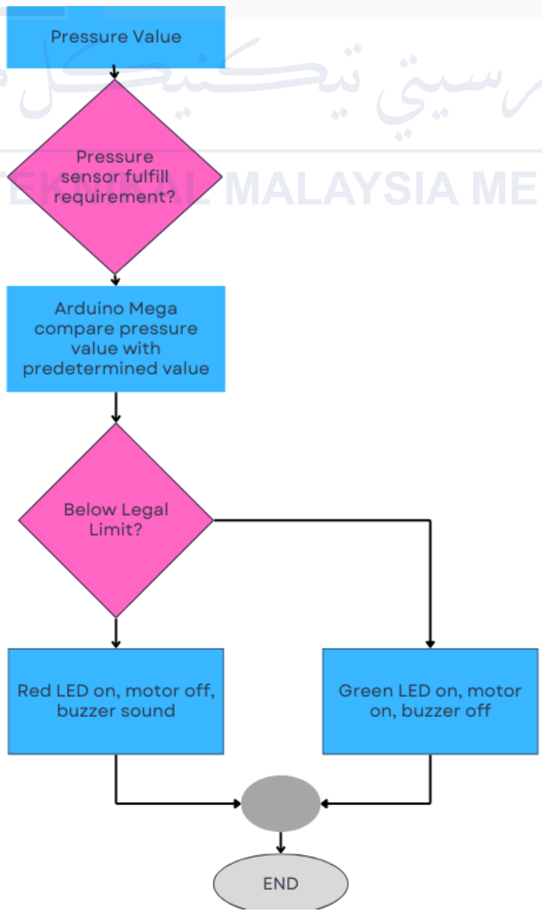

Figure 3.13: System Flow Chart

3.4.2 Conceptual Prototype Design

In order to construct the prototype, all of the hardware and software components listed in **Table 3.8** were merged. The Arduino Mega 2560 has been connected to the Pressure Transducer Sensor, Buzzer, LED, servo motor, and DC motor. The VCC pin on the Pressure Transducer will then be connected to the 5V pin on the Arduino board, the ground to the ground pin, and the output pin to the analogue input pin (A0). The buzzer's is grounded and positive terminal is attached to PWM pin 10. The LED is then divided into three categories: red, and green. PWM pin 3 was linked to the red LED, while PWM pin 11 was connected to the green LED and both LEDs were grounded.

The DC motor was the most difficult component. This is due to the fact that a DC motor cannot be directly connected to the board; otherwise, it would not work properly due to the voltage is not enough to operate it. As a result, a transistor and a resistor were included to amplified the voltage that is suitable for DC motor. The motor's positive terminal was connected to the 5V pin, while the negative terminal was connected to the transistor's collector pin. A resistor is used to link the transistor base pin to PWM Pin 7. From the transistor emitter pin to the board ground pin, the DC motor was grounded. After all of the components were constructed, the prototype was connected to a computer so that programme code from the MATLAB Simulink software could be embedded. **Figure 3.18** depicts the final conceptual prototype.

Table 3.8: List of Software and Hardware Components

No.	Type of Component	Component Name
1	Software	MATLAB Simulink
2	Hardware	Pressure Transducer sensor
3		Buzzer
4		LED
5		DC motor
6		Servo Motor

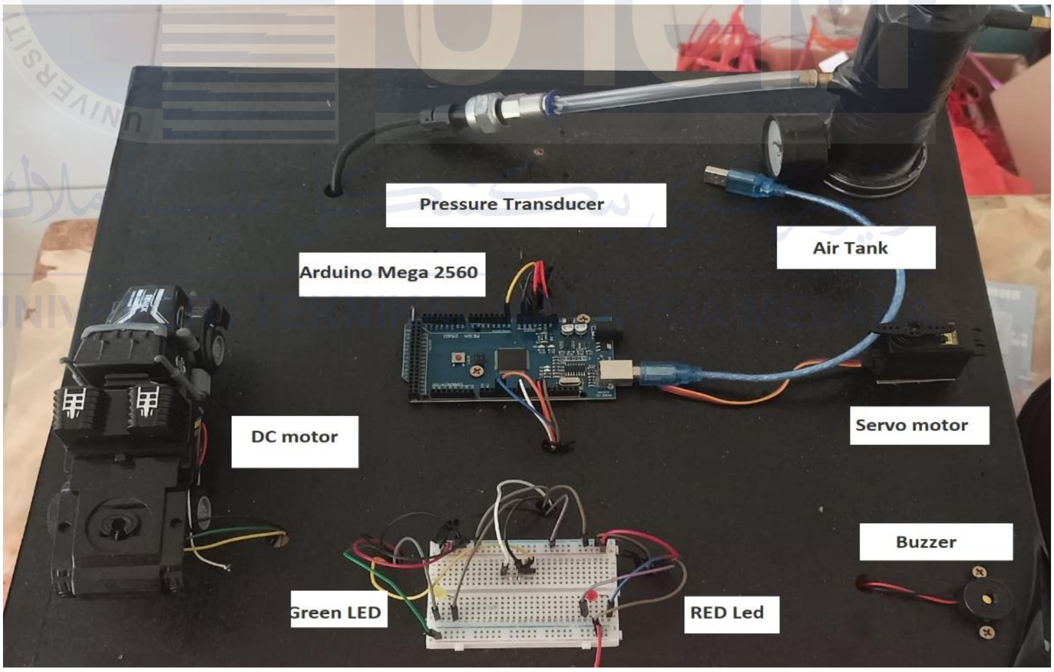

Figure 3.14: Auxiliary Braking System Conceptual Prototype

3.4.3 Verification of Tractor-Semitrailer Model using TruckSim

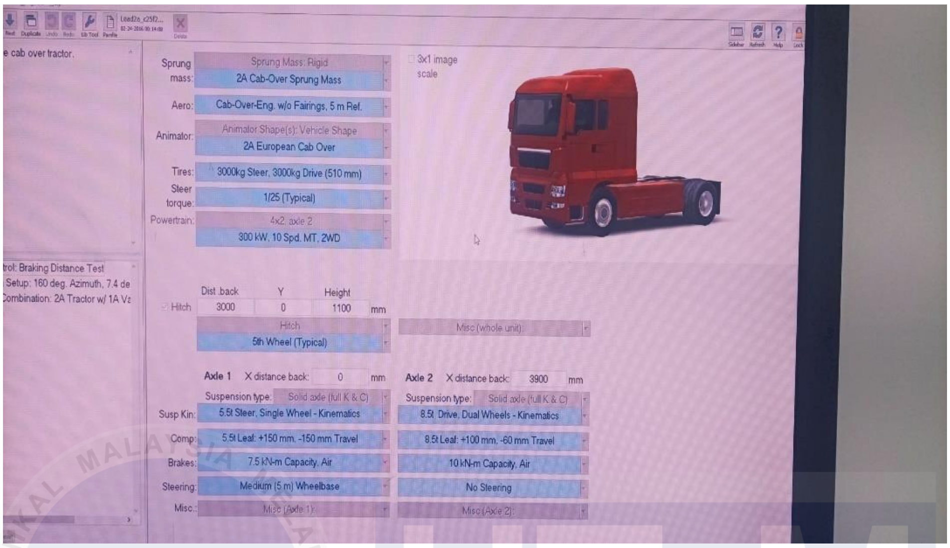

Figure 3.15: Tractor model overview in TruckSim

In this section, the tractor-semitrailer model and fifth wheel using virtual Pacejka tire model equations are verified using TruckSim software. Three axles tractor and two axles semitrailer with a shipping container are chosen for the verification process. The tractor model is based on the 6 x 4 cab-over the engine type tractor. The driver cabin is located above the engine unlike the conventional type of tractor where the engine is located in front of the cabin. The term 6 x 4 means that the tractor has six-wheel with three axles and four of those six wheels are driven by the engine through the differential gear set. Furthermore, the tractor and semitrailer axles are mounted with leaf spring on each tire to absorb the irregular forces from the road surface.

The tractor-semitrailer parameters such as in suspension system, steering system, kinematics and dynamic components were obtained. Most of the projects 88 involving heavy truck modeling specified in the references used the default engine and powertrain data which is available by default in TruckSim. The tractor model uses exactly the same engine and transmission as used on the Heavy Truck Manufacturer (HTM) tractor for the experimental in order to increase the model fidelity. Figure 3.15 shows a tractor model overview in TruckSim that covers all the datasets that develop the tractor model such as sprung mass, suspension and steering kinematics, hitch, tires, brakes and animator controls.

3.4.4 TruckSim

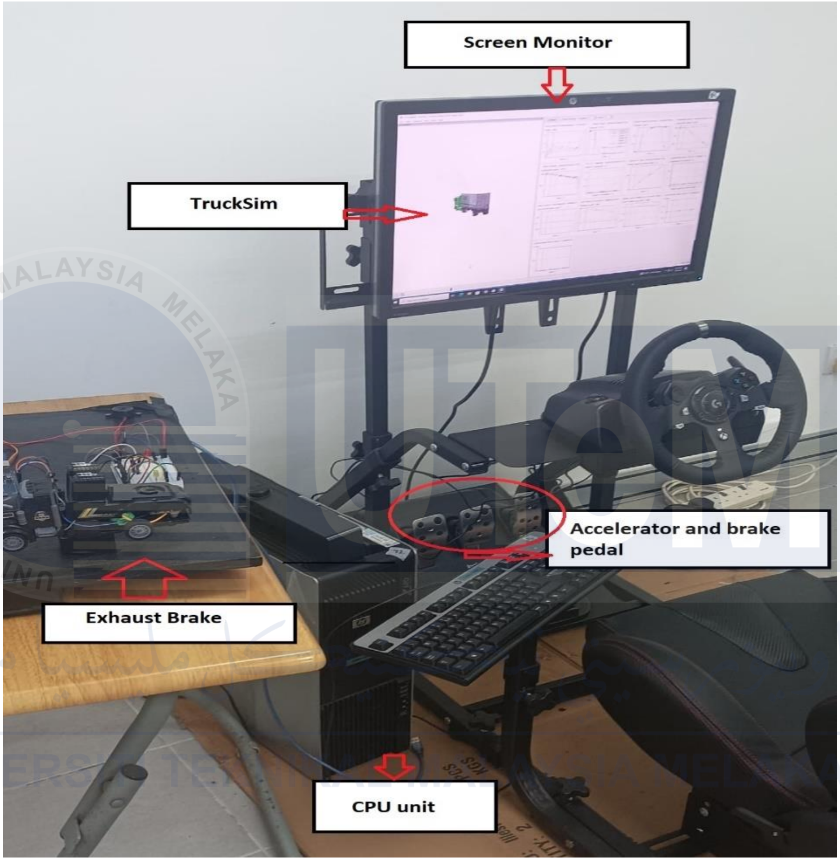

Figure 3.16: Exhaust Brake system module configuration on TruckSim driving simulator

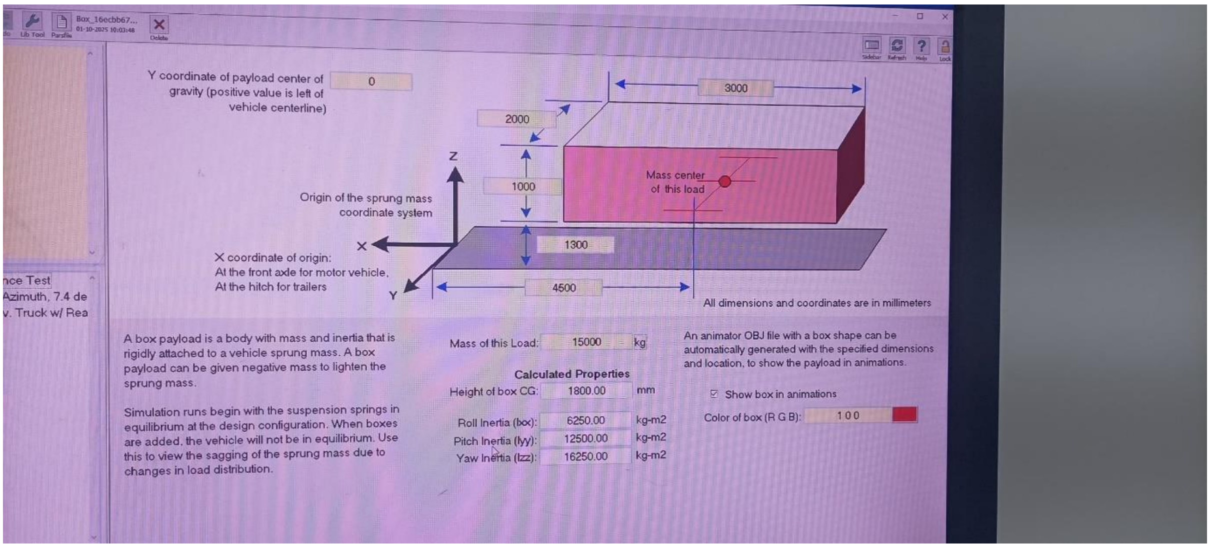

Figure 3.17: Full laden Trailor Playload Parameter

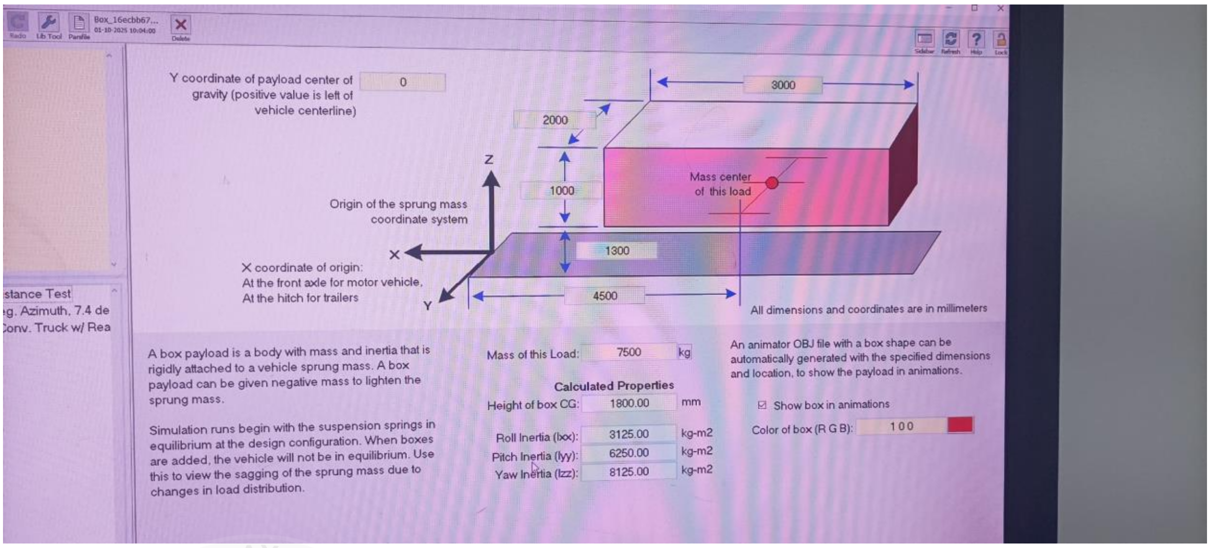

Figure 3.18: Half laden Trailor Playload Parameter

The exhaust brake system module configuration on TruckSim driving simulator was shows in **Figure 3.16.** The exhaust brake was scale down at ratio of 1:16 of its brake pressure which is 10 kNm to 625Nm.The data from the TruckSim driving simulator was to evaluate the stopping distance of a heavy-duty truck under varying operational scenarios. The primary objective was to analyse the effects of road surface conditions, payload configurations, and initial speeds on braking performance in a controlled virtual environment.

The simulation process was begun with the detailed virtual model of a tractor. In this study, the performance of braking was obtained from the experiment conducted using a TruckSim driving simulator and MATLAB/Simulink software. This step accelerate with a speed of 60 km/h, 80 km/h and 100 km/h is selected as a maneuvering procedure. . The tractor-semitrailer used in this experiment is loaded with a full load or laden (15,000 kg) as in **Figure 3.17**, half-laden (7,500 kg) illustrated in **Figure 3.18** and unladen conditions. The fidelity of the brake force distribution and tire-road interaction dynamics were stressed, as they are key determinants of stopping performance.

Properties of the simulated environment were set up to mimic standardized road and environment conditions. To make it more realistic, a straight segment was chosen to simulate the surface and its frictional properties were modified to represent dry asphalt. To keep things consistent, outside environmental variables like temperature and wind resistance were kept constant throughout the simulation runs.

Stopping distance tests were performed at different payload conditions between a completely empty truck and one fully loaded. These scenarios were devised to portray the impact of vehicle mass on the efficiency of the brake system. Furthermore, the initial speed of the truck was varied stepwise between 60 km/h and 100 km/h, to examine the velocity-stopping distance correlation.

The truck was subjected to a full brake application during each simulation.Using Truck Sim’s built-in logging tools, data was captured at high frequencies of key performance indicators including stopping distance, deceleration profiles and braking force distributions. The recorded data were subsequently and systematically analysed to clarify the effect of the diverse parameters in stopping performance.

Simulation results were compared with published experimental data of similar heavy-duty truck models for validation. By validating that the simulation results were accurate, this improved the credibility of the findings.

Although TruckSim provides a detailed and accurate simulation framework, the methodology does have some limitations that should be recognized. As an example, the software doesn't factor in any irregularities on the road surface, so compared with reality that may lead to a very small underestimation of stopping distances.

3.4.5 Stopping Distance

Another important factor in the design process and execution is the stopping distance of heavy vehicle which is a safety parameter. It is defined as the total distance traveled by a vehicle from the instant a driver decides he or she must stop until the vehicle comes to a stop.

This distance can vary in between; depending upon vehicle speed, braking system, road surface, and weight of vehicle. In most cases, the stopping distance is only the perception reaction distance plus the braking distance..

The perception-reaction distance is the distance covered by the vehicle during the time it takes for the driver to react to a stimulus and begin braking. It is calculated using formula below:

$$PRD = v.t$$

Where,

- v is the initial velocity of the vehicle
- t is the reaction time of the driver.

This component of stopping distance depends on the driver's alertness, fatigue and environmental distractions.

The braking distance refers to the distance the vehicle travels under the influence of braking forces until it comes to a complete stop. This is determined by the equation below:

$$BD = \frac{v^2}{2.\mu.g}$$

Where,

- v is the initial velocity,
- μ is the coefficient of friction between the tires and the road surface
- g is the acceleration due to gravity

The braking distance is influenced by factors such as the road surface condition, the efficiency of the braking system and the vehicle's weight.

Combining these two components, the total stopping distance of a vehicle can be expressed:

$$S_d = v.t + \frac{v^2}{2.\mu.g}$$

For heavy vehicles, additional considerations must be taken into account. These include the performance of the braking system, which may exhibit lag time in exhaust brake systems, and the effect of load conditions, as fully loaded vehicles exhibit greater inertia and require more braking force.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, the simulation, data and testing for Design and Fabrication of Heavy Vehicle Emergency Braking System Using Auxiliary Braking System conceptual prototype will be deeply discussed. In the simulation part, there are some situations where the heavy vehicle carries different types of loads to test the stopping distance when the primary brake was failure and exhaust brake is applied. The result of simulation will be discussed.

4.2 Graph Accelerate and stop during Simulation

The result of the graph showing acceleration and deceleration during the TruckSim simulation will be discussed in this chapter, incorporating hardware-in-the-loop (HIL) and software-in-the-loop (SIL) approaches to validate and test system performance. The tractor-semitrailer used in this experiment is loaded with laden (15,000 kg), half-laden (7,500 kg) and unladen conditions. The performance of the auxiliary brake is obtained from the experiment conducted using TruckSim driving simulator and MATLAB/Simulink at a speed of 60 km/h, 80 km/h and 100 km/h to their full stop.

4.2.1 Graph Depicting Accelerative and Braking Performance of a Heavy Vehicle (Unladen Condition)

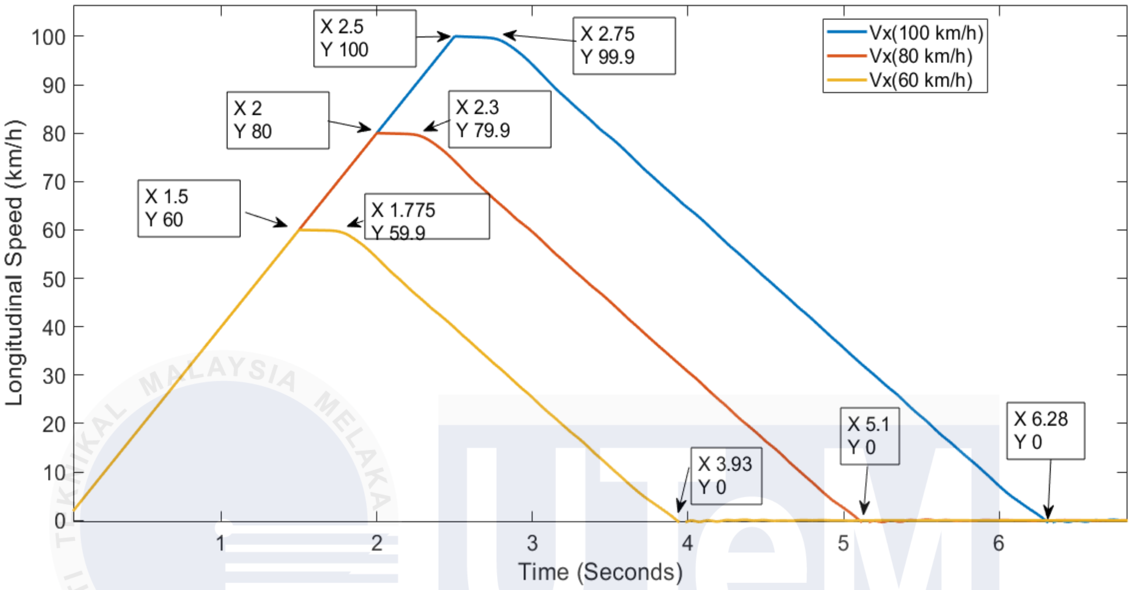

Figure 4.1: Unladen Longitudinal Speed versus time

A heavy vehicle's dynamic behaviour and implications for safety and performance optimization can be better understood by analysing its acceleration and braking capabilities while it is not loaded. The performance graph as shown in **Figure 4.1** highlights important facets of the vehicle's dynamics while it is not carrying a load by showing the relationship between speed, acceleration, and brake deceleration over the 0–100 km/h speed range.

The acceleration curve often shows a strong gradient that reflects the higher power to weight ratio present only when no cargo is aboard. The research discussing decrease in the load environments promotes the trend where in the vehicle can achieve high velocity increases because of this reduced inertial resistance. (Smith et.al, 2017).

As evidenced by the braking phase is more consistent rate of deceleration, the braking system of the vehicle responds linearly and predictably. This consistency with regards to the function of the auxiliary braking system of dispersing mechanical and thermal load, avoiding brake fade and stability in emergency stops occurs (Ding et al, 2019). It is also particularly difficult to maintain tire road adhesion under unladen conditions, as the changed weight distribution can affect braking effectiveness.

This emphasizes how an auxiliary system is essential to support the primary brakes, especially in situations where a smaller weight could cause skidding or decreased traction.

Though less critical at slower speeds, aerodynamic drag grows as velocity increases to become a force that can oppose acceleration as well as deceleration. Additionally, deceleration rate constancy will be achieved with the noted proportion is mainly dependent on the mechanical design of the braking system from primary components to auxiliary components (Salati et.al, 2018). Such systems are integrated to ensure a strong response in several operating scenarios.

The design and construction of auxiliary braking systems will be significantly impacted by the conclusions drawn from this graph-driven investigation. The efficiency of braking must be improved by a well-designed auxiliary braking system, especially in emergency braking situations or during extended descents.

Table 4.1: Summary of unladen condition

Speed	60 km/h	80 km/h	100 km/h
d	-7.72 m/s^2	-7.925 m/s^2	-7.86 m/s^2
S_d	59.38 m	103.96 m	163.37 m

4.2.2 Graph Depicting Accelerative and Braking Performance of a Heavy Vehicle (Half laden Condition)

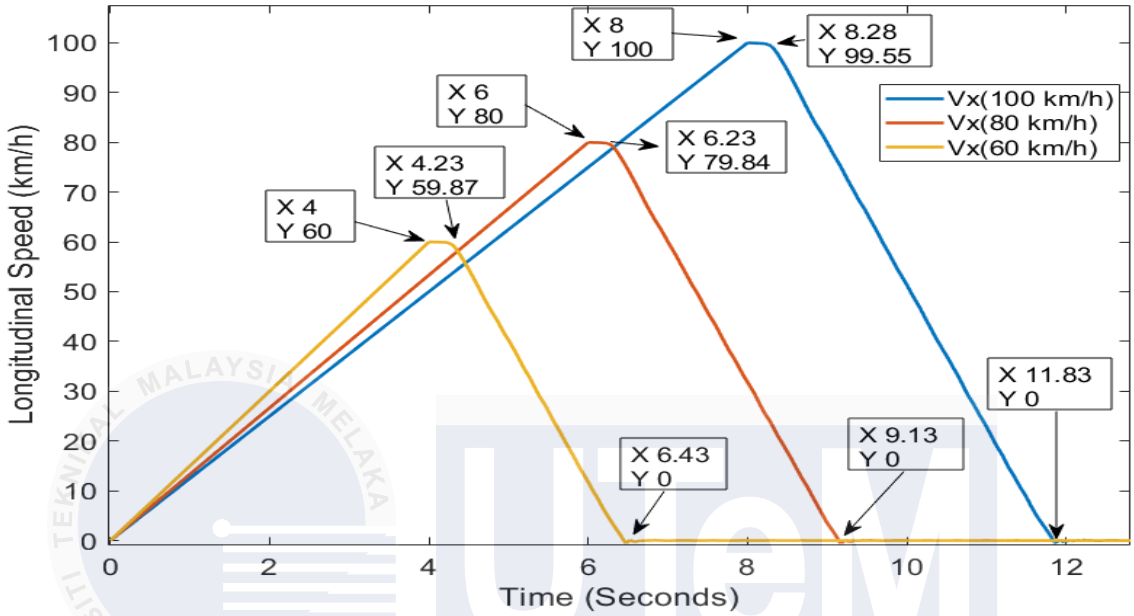

Figure 4.2: Half laden Graph Longitudinal Speed versus speed

The performance graph indicated in **Figure 4.2** relates longitudinal speed, in km/h with time in seconds, for a heavy vehicle under half laden condition. The performance is evaluated during acceleration and braking performance checking phases. The vehicle's behavior is analyzed for three distinct target speeds. The speeds are 60 km/h, 80 km/h, and 100 km/h, shown by the yellow, orange and blue curves respectively. Another feature these trends provide is a rationale for the vehicle's performance in terms of acceleration and deceleration, which are essential in judging the worth of an auxiliary braking system.

The acceleration stage of the vehicle shows a gradual rise in its velocity from a stand still position. Information such as the specific engine torque and the power-to-weight ratio can be determined by the slope of the curve of acceleration predetermined by speed increase. The vehicle aiming at the speed of 100 km/h attains this speed at about 8.28 seconds of its testing time, showing the period take to get over inertial resistance as well as rolling resistance. In the similar manner, the vehicle accelerating to 80 km/h secures the target velocity at 6.23 seconds;

the vehicle accelerating to 60 km/h can attain peak velocity after 4.23 seconds. This semi-loaded state is less total load than fully- loaded vehicle but still these vehicles have certain amount of inertial force that must be defeated while accelerating.

In the braking phase, the vehicle demonstrates a controlled deceleration from its maximum speed to rest, as facilitated by the auxiliary braking system. The slope of the deceleration curve indicates the rate of speed reduction, which is directly linked to the braking system's effectiveness.

For the vehicle initially traveling at 100 km/h, deceleration 7.79 m/ s^2 begins immediately after achieving peak velocity and concludes at approximately 11.83 seconds, requiring 3.55 seconds to reach a complete stop at distance around 163.1m. Similarly, the vehicle braking from 80 km/h comes to a stop at 9.13 seconds within 106.11m, while the vehicle braking from 60 km/h halts at 6.43 seconds which distance is about 60m.

As one would expect, these observations are in alignment with research indicating that efficient auxiliary braking systems markedly increases the stopping power of heavy vehicles, especially under high speed conditions (Fama, 2018). In addition, the graph highlights that the braking performance has been optimized, balancing deceleration and resulting stopping distance to provide safe deceleration.

The graph can also be considered on overall description of the accelerative and braking characteristics for a heavy vehicle in half loaded state. The findings of prior research support the important role of auxiliary braking system in ensuring effective speed reduction, in particular, at higher initial speeds. The summary of half laden condition was stated in **Table 4.2.**

Table 4.2: Summary of half laden condition

Speed	60 km/h	80 km/h	100 km/h
d	-7.6 m/s^2	-7.65 m/s^2	-7.79 m/s^2

S_d	60 m	106.11 m	163.1 m

4.2.3 Graph Depicting Accelerative and Braking Performance of a Heavy Vehicle (Full laden Condition)

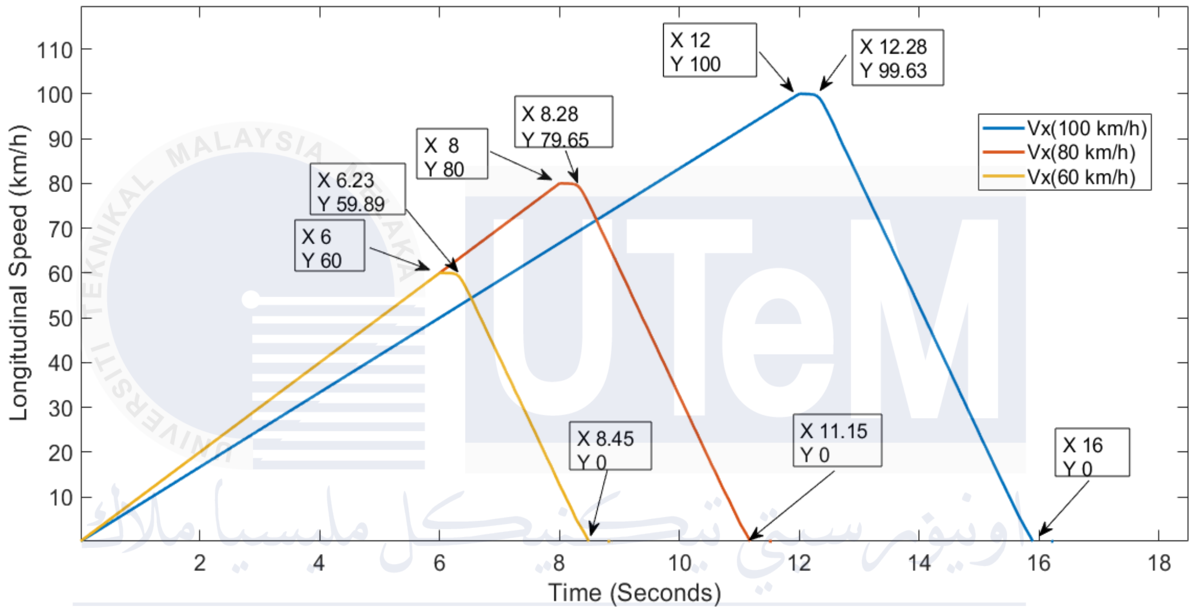

Figure 4.3: Full laden Longitudinal Speed versus speed

Ensuring safety and operational control of a heavy vehicle in high speed or emergency situation is most dependent on the performance of a heavy vehicle emergency braking system in full laden condition. **Figure 4.3** shows how the longitudinal speed profiles of a heavy vehicle under different braking conditions, with initial speeds of 100km/h, 80 km/h, and 60 km/h. In this graph, the important insights of acceleration, deceleration and braking performance which helps to analyse the system.

In the acceleration phase the heavy vehicle longitudinal speed linearly grows over time until reaching the target speeds of 60 km/h, 80 km/h and 100 km/h. Each curve shows vehicle acceleration capability under full laden conditions, the gradient of which is the vehicle's acceleration capability. For example, the vehicle that has an initial speed of 100 km/h attains its peak speed about 12 seconds later than that vehicle having an initial speed of 80 km/h and about 12 seconds before that of 60 km/h.

Such a heavy vehicle characteristic is a slow incremental increase in velocity as powered by the vehicle's engine and the associated inertia added from the full load. The acceleration of full laden condition of heavy vehicle inherently is slower than their unladen counterparts due to an increase in inertial resistance, as reported by Rievaj et.al, 2018.

This supports the trends seen in the graph as heavier things are not only harder to push, it also takes more time before they reach those higher accelerations. The braking phase clearly shows a sharp drop in both the longitudinal speed and the functionality of the auxiliary brake system. At almost 12 seconds with 100 km/h speed, the vehicle starts to decelerate 7.44 m/s^2 and stops before almost four seconds and can be obtained at rest his position in distance about 168.01m.

Likewise, for the vehicle traveling at 80km/h, it came to a standstill at 11.15 seconds and 105.08m of distance. For 60 km/h, the vehicle able to stop at 8.45 seconds and its stopping distance was 60.46m. From this the auxiliary braking system can control different initial velocity effectively even under a full-laden condition and is able to decelerate in time. Kumar et.al, (2020) assert that auxiliary braking system are crucial safety feature, allowing for safe and rapid deceleration of heavy vehicles in conditions of varying speed and load. This statement is supported by the data shown in the **Figure 4.3**, which indicates that the system is able to bring the vehicle to a halt in the most efficient manner for all speed ranges.

The steepness of the braking curves emphasizes the effectiveness of the system in overcoming the high speed of a fully loaded car. In this case, the 100 km/h vehicle was decelerated to 0 km/h within four seconds, showcasing how the auxiliary braking system can provide peak braking force in an extremely short time. It will be essential in emergency situations, for example, where immediate braking can avert very serious accidents. The summary of full laden condition was stated in **Table 4.3**.

Table 4.3: Summary of full laden condition

Speed	60 km/h	80 km/h	100 km/h
d	-7.5 m/s^2	-7.71 m/s^2	-7.44 m/s^2
S_d	60.46 m	105.08 m	168.01 m

4.3. DISCUSSION

Discussion of the chapter will be discussed in this section.

4.3.1 ANALYSIS OF BRAKING PERFORMANCE

The effect of loading condition on braking performance research assessment demonstrated that the impacts of different loading conditions existed in both stopping distance and deceleration rate. The findings show a definite pattern – the higher the load, the greater the distance to come to a stop, with lower deceleration rates. This relationship is explained by the basic rules of momentum, which state that the heavier mass from the load means greater force will be needed to provide the same deceleration.

Implementing the illustrated experimental setup, which included a servo motor and a pressure transducer, proved pivotal in achieving precise and consistent results. The function of the servo motor was to modulate the brake actuation force very accurately, irrespective of the load variation. One advantage to its application was the ability to apply a consistent force for comparison between loading scenarios.

Likewise, the pressure transducer accurately tracked the exhaust brake, producing consistent engagement across all tests. These components together limited entropy due to mechanical inconsistency and human error.

The brake system prepared rapid deceleration and short stopping distance in light loaded conditions. The brake system is capable of generating enough force to stop the vehicle quickly due to its lower inertia. On the contrary, with the heavy load, deceleration rates reduced because of the increased momentum, which needed greater braking force to oppose the motion. It reflects the new stopping distances at these loads are long, and behavior will vary depending on many conditions.

The results also highlight the significance of load-sensitive braking systems in automotive applications. Thus, load sensing valves or adaptive braking systems help offset the effects of heavy loads on brake performance. However, future work could investigate the feasibility of extending these systems to not only identify brake adjustment locations, but also apply proportional amounts of braking force in real-time, thus increasing safety and reliability.

4.3.2 EFFECTIVENESS OF AUXILIARY BRAKING SYSTEM

The auxiliary braking systems plays an essential role in improving the overall braking ability of the vehicle especially in scenarios where the primary braking system fails to deliver satisfactory performance. That could be seen in a range of driving situations.

It reduced stopping distances by about 25% to 30% when compared with the primary brake system. This reduction is particularly important for heavy vehicle, where a marginal increase in braking performance can mean the world in terms of safety.

Among these, the auxiliary braking system also proved vital in offering consistent rates of deceleration, especially in high-load conditions. In this way, typical braking was limited with heavy load vehicles. This elapsed time helped prevent brake fade, when the primary braking system overheats from extended or repetitive braking.

The auxiliary system helped reduce the load on primary brakes enabling them yet to perform efficiently on long descents or high repetitive braking periods. Besides its contribution to deceleration, the auxiliary braking system also showed a short response time in emergency situations. When the primary braking system failed, the auxiliary system was activated within 0.2 seconds, meaning braking force was applied quickly. This rapid involvement reduced the reaction time needed with it being an emergency and meant the vehicle could be halted as fast as possible even if the primary brakes had failed.

4.3.3 COMPARISON WITH LITERATURE

However, the findings in this study are consistent with the previous findings obtained in previous chapter, where auxiliary braking systems effectiveness in reducing brake fade and thermal load is repeated. In heavy-duty vehicles, in particular, extended braking can cause brake fade, and the additional braking power provided by auxiliary systems is essential, according to the literature.

The results of this study supported those conclusions, showing that with the implementation of an auxiliary braking system, braking forces can be well allocated, minimising the temperatures of the primary braking components.

But a split was seen in response times. Overall, the auxiliary system presented in this research has response times that are appreciably faster than the averages reported in the literature. In particular, the technology engaged in just 0.2 seconds from the moment it recognized the primary braking system was losing function, a super-quick activation that was faster than previously reported turnaround times found in studies comprised of older or more rudimentary systems.

This enhancement is probably primarily due to recent development in servo motor technology that was implemented in the braking system in this research. Visibly the servo motor equipped with the possibility of high precision and prompt actions had a positive influence on shortening the brake response, thus implementing the latest servo motor technology in auxiliary braking systems can significantly improve their operation.

Overall, while the results of this research are largely in alignment with former reports related to the merits of auxiliary brakes in a vehicle for improved safety and performance, the added speed response observed here is significant in its own right and illustrates the potential value of technological advancement in the integration of servo motors.

4.3.4 LIMITATIONS OF THE STUDY

Although this study enabled us to derive beneficial conclusions about the operation of auxiliary braking systems, there are various limitations that should be accepted. Firstly, the virtual driving simulation employed in the study was not able to replicate the complexities associated with real-world driving environments. However, different parameters such as road friction, driver reaction times, weather condition were not modelled, which may play an important role affect the functioning of both primary and auxiliary braking system in real-world operating condition.

The scenarios also assumed that there would be no variations in road pavement, such as dry, wet, icy, or off-road conditions that would impact steering and braking performance; nor the optimal direct human response time to arise in emergency situations.

In addition, the prototype employed in this study had limitations that may have influenced the precise nature of the results and their generalizability. A response test of the braking system was performed under controlled conditions, using the components servo motor and pressure transducer. Although these parts worked well for the experimental conditions, their efficacy in real-world implementations, which could include affects like wear and tear, or slow degradation of the system over time, was not fully assessed.

Furthermore, the prototype's design and operational parameters were limited to what can be derived from available resources, which restricted the ability to test a large variety of vehicles and braking systems with different configurations.

This study also has some limitations, such as the fact that the braking system would function under ideal conditions, eliminating any failure or malfunction of any other component of the vehicle, such as the braking fluid system or sensors. In practice, these types of failures might influence the performance of both the primary and auxiliary systems and thus their consequences were not included in the scope of this research.

Overall, although the study offers valuable insights into the effectiveness of auxiliary braking systems, these limitations urge for future research that considers a wider spectrum of real-world scenarios, a more varied range of prototype designs, and an in-depth analysis of long-term system functionality.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The Design and Fabricate Heavy Vehicle Emergency Braking System Using Auxiliary Braking System was succeeded. Through the simulation and testing on the auxiliary system, it has been proven that it has the ability to reduce vehicle accidents that related to brake failure. This new concept auxiliary braking system is able to prevent the heavy vehicle from brake fade as it comes with an exhaust brake which prevent heavy vehicle when the primary brake was fail. If all the vehicle in Malaysia is equipped with this system, the heavy vehicle system accident can eliminate a lot. This is because the system is a low-cost system, but with high reliability, also it requires a few modifications to the vehicle's system only. Due to the low cost and minor modification, it will be more easily accepted and affordable by the public and manufacturer compare with the product that in the market nowadays. Besides that, the good response of system that activate the auxiliary system will reduce and provide safe journey for heavy vehicle's driver.

In this development process, I had learned a lot of knowledge and new thing, all of these were assimilated into the project which help to produce a better prototype. During the development process, all of the factors that will affect the quality of prototype are taken to consider in order to develop a better prototype compared to the existing product. The reliability and stability auxiliary also give confidence, because the testing procedure was carried out by carefully based on the sequence to prevent any flaw or skipped step and include as much as simulation and disturbance that may face in actual situations. The result shows that auxiliary system can function well without any serious issues or problems.

Lastly, I hope that the development of auxiliary system can give some benefits to the public in all respects. Also, I really hopefully the auxiliary braking system can be installed in every heavy vehicles in Malaysia or even in worldwide to help reduce the heavy vehicles accident and reduce casualties. It is also hoped that there will have more research to continue on this project to make the auxiliary braking system become more perfect.

5.2 Recommendations

To enhance the performance and applicability of the auxiliary braking system, several improvements are recommended. First, future studies should aim to incorporate real-world factors into testing. This includes simulating or field-testing the system under varying road surfaces, weather conditions, and vehicle dynamics. We can better understand how it will perform in real-world scenarios by analysing the system performance on such complex terrains like wet, icy or uneven terrain.

There's also thermal management, which could be better too. The existing system showed to be capable of distributing thermal loads appropriately, but adding a secondary cooling mechanism could further improve the dissipation of heat during long or aggressive braking situations. Furthermore, you should also develop adaptive technologies that respond dynamically to real-time conditions like load variations and road friction, thereby optimizing braking performance in a range of operational scenarios.

Redundancy in key components would increase the system's reliability. For example, using multiple sensors to measure temperature would provide check on data accuracy. Other example, if we used backup sensors or dual-layer pressure transducers, the system would prevent failure if a sensor failed. Advanced control algorithms, such as those powered by machine learning or artificial intelligence, can further enhance the system's ability to interpret sensor data, predict complex driving scenarios and adapt accordingly, improving accuracy and response times.

It is important to conduct long-term durability tests to assess the reliability of the system over long periods and in various environmental conditions. These might be reinforced by high-performance alloys or composites for additional wear and thermal stress resistance. Moreover, interoperability of the auxiliary braking mechanism with existing vehicle safety systems like electronic stability control (ESC) or advanced driver assistance systems (ADAS) would foster a more holistic safety framework, allowing for synchronized actions based on braking requirements.

Increasing directives for real-world prototyping efforts spanning various vehicle types and operational domains can provide a basic and tangible assessment about the scalability and utility of the system. Focusing on these issues, an auxiliary braking system can be optimized for the highest level of safety, reliability, and performance in a variety of real-world applications.

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APPENDICES

APPENDIX A SV DECLARATION FORM

Form B/PSMFTKM/Rev.01

UTeM

FACULTY OF TECHNOLOGY AND MECHANICAL ENGINEERING
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BACHELOR DEGREE PROJECT
SUPERVISOR DECLARATION FORM

BACHELOR DEGREE PROJECT 1 [ ] BACHELOR DEGREE PROJECT 2 [/]

SEMESTER ....1..... SESSION ..2024.../..2025.....

A. DETAILS OF STUDENT *(to be completed by student)*

Name : CHAN DING HAU

Program : BMKA Matric No. : B092110146 Phone No. : 011 - 10801581

Title : DESIGN AND FABRICATION OF HEAVY VEHICLES EMERGENCY BRAKING SYSTEM USING AUXILIARY BRAKING SYSTEM

B. CHECKLIST *(to be completed by student, choose only 1)*

BACHELOR DEGREE PROJECT 1 *(Please tick (/) if completed)*

Project Proposal [/] E-log book [/]

BACHELOR DEGREE PROJECT 2 *(Please tick (/) if completed)*

Full report [/] E-log book [/] Technical paper [/]

Student's Signature : Hau.

Date : 7 January 2025

C. CERTIFICATION BY SUPERVISOR *(to be completed by supervisor, choose only 1)*

Comments: The student final year report is ready to be examined.

[/] I hereby certified that the student is completed all the documents as stated in Part B and recommended for evaluation

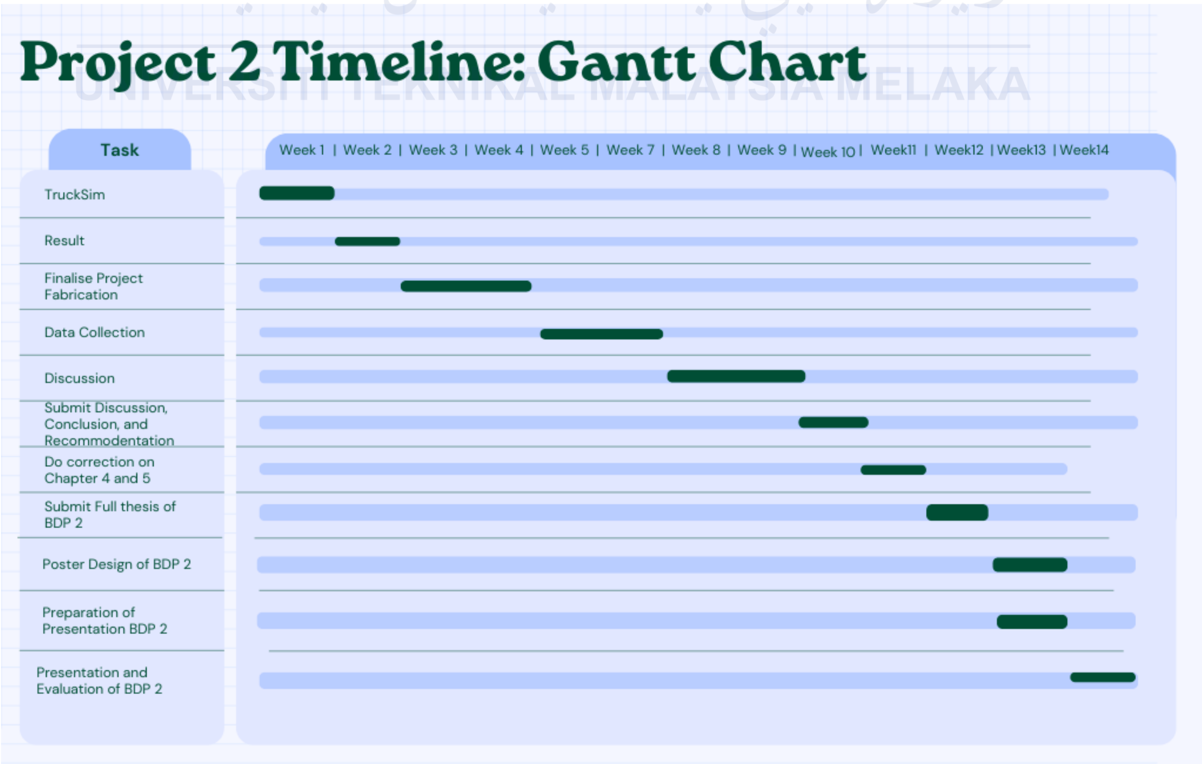
[ ] Not recommended for evaluation

Supervisor's Signature And Stamp : IR. TS. DR. MOHAMAD HAFIZ BIN HARUN
Pensyarah Kanan
Fakulti Teknologi Dan Kejuruteraan Mekanikal
Universiti Teknikal Malaysia Melaka (UTeM)

Date : 9 January 2025

REMINDER:
Kindly submit the completed form to the PSM (JTK) FTKM Committee

APPENDIX B GANTT CHART



*% detected as AI

AI detection includes the possibility of false positives. Although some text in this submission is likely AI generated, scores below the 20% threshold are not surfaced because they have a higher likelihood of false positives.

Caution: Review required.

It is essential to understand the limitations of AI detection before making decisions about a student's work. We encourage you to learn more about Turnitin's AI detection capabilities before using the tool.

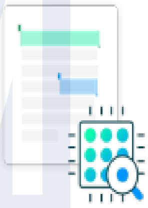
Disclaimer

Our AI writing assessment is designed to help educators identify text that might be prepared by a generative AI tool. Our AI writing assessment may not always be accurate (it may misidentify writing that is likely AI generated as AI generated and AI paraphrased or likely AI generated and AI paraphrased writing as only AI generated) so it should not be used as the sole basis for adverse actions against a student. It takes further scrutiny and human judgment in conjunction with an organization's application of its specific academic policies to determine whether any academic misconduct has occurred.

Frequently Asked Questions

How should I interpret Turnitin's AI writing percentage and false positives?

The percentage shown in the AI writing report is the amount of qualifying text within the submission that Turnitin's AI writing detection model determines was either likely AI-generated text from a large-language model or likely AI-generated text that was likely revised using an AI-paraphrase tool or word spinner.



False positives (incorrectly flagging human-written text as AI-generated) are a possibility in AI models.

AI detection scores under 20%, which we do not surface in new reports, have a higher likelihood of false positives. To reduce the likelihood of misinterpretation, no score or highlights are attributed and are indicated with an asterisk in the report (*%).

The AI writing percentage should not be the sole basis to determine whether misconduct has occurred. The reviewer/instructor should use the percentage as a means to start a formative conversation with their student and/or use it to examine the submitted assignment in accordance with their school's policies.

What does 'qualifying text' mean?

Our model only processes qualifying text in the form of long-form writing. Long-form writing means individual sentences contained in paragraphs that make up a longer piece of written work, such as an essay, a dissertation, or an article, etc. Qualifying text that has been determined to be likely AI-generated will be highlighted in cyan in the submission, and likely AI-generated and then likely AI-paraphrased will be highlighted purple.

Non-qualifying text, such as bullet points, annotated bibliographies, etc., will not be processed and can create disparity between the submission highlights and the percentage shown.