DESIGN AND FABRICATE ROLLOVER WARNING DEVICE FOR TRACTOR-SEMITRAILER

MUHAMMAD SYUAIB BIN SAMSUDIN
B091810502

BACHELOR OF MECHANINCAL AND MANUFACTURING ENGINEERING TECHNOLOGY (AUTOMOTIVE) WITH HONOURS

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Muhammad Syuaib Bin Samsudin

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MUHAMMAD SYUAIB BIN SAMSUDIN

A thesis submitted in fulfillment of the requirements for the degree of Bachelor of Mechanical and Manufacturing Engineering Technology (Automotive) with Honours

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DECLARATION

I declare that this Choose an item. entitled " DESIGN AND FABRICATE ROLLOVER WARNING DEVICE FOR TRACTOR-SEMITRAILER "is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	
Name	:	MUHAMMAD SYUAIB BIN SAMSUDIN
Date	:	27 JUNE 2021

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical and Manufacturing Engineering Technology (Automotive) with Honours.

Signature	:	
Supervisor Name	:	Ir Ts Dr Mohamad Hafiz bin Harun
Date	:	27 JUNE 2021

DEDICATION

I dedicate my dissertation work to my family and many friends. A special feeling of gratitude to my loving parents, Samsudin and Faridah Hanim whose words of encouragement and push for tenacity ring in my ears. My brothers and sister Sharidah, Syafiq, Shuhail and Shahrani have never left my side and are very special. I also dedicate this dissertation to my peers who have supported me throughout the process. I will always appreciate all they have done, especially Daniel, Zulfadhli, Muzzammil and Aiman for helping me develop my thesis. I dedicate this work and give special thanks to my best friends Haiqal and Aiman for suporting me mentally and physically.

ABSTRACT

Tractor-semitrailer collisions with rollover are among the deadliest forms of vehicle collisions. Numerous factors may contribute to the harm or death of an occupant. The purpose of this thesis is to explore the design and fabrication of a rollover warning device (RWD) for tractor semi-trailers, specifically those with a greater centre of gravity height to track width ratio. The RWD algorithm uses the rollover index to essentially learn the dynamics of a road vehicle and to estimate the vehicle's immediate roll stability in various dynamic situations. The state of dynamic roll stability, specifically the load transfer ratio (LTR), is fed into a RWD based on the rollover index algorithm in order to determine the value of the rollover index. Computer simulations were used to create the idea, and experimental data were used to validate it. Due to the device's passive nature, which needs the driver to take corrective action, its efficacy is limited to assisting with gradually increasing dangerous manoeuvres, such as those encountered during on-ramp manoeuvres. The parameters of the rollover index algorithm's block model are modified and optimised using Matlab software. Meanwhile, the present rollover trend warning system is analysed using the TruckSim programme. This algorithm for calculating the rollover index is based on the quickest time response offered by earlier research.

ABSTRAK

Perlanggaran *tractor-semitrailer* dengan golekan adalah bentuk perlanggaran kenderaan yang paling berbahaya. Banyak faktor boleh berkontribusi kepada kerosakan atau kematian penghuni kenderaan.Tujuan tesis ini adalah untuk mengeksplorasi desain dan pembuatan peranti amaran golekan (RWD) untuk setengah trek traktor, khususnya yang mempunyai pusat tinggi graviti yang lebih besar kepada nisbah lebar trek.Algoritma RWD menggunakan indeks gulungan untuk pada dasarnya belajar dinamik kenderaan jalan dan untuk menghargai kestabilan gulungan segera kenderaan dalam berbagai situasi dinamik. Keadaan of kestabilan golekan dinamik. Khususnya the nisbah pemindahan beban (LTR), disuapkan ke RWD berdasarkan algoritma rollover index untuk menentukan nilai indeks golekan.Simulasi komputer digunakan untuk mencipta idea, dan data percubaan digunakan untuk sahkan ia. Kerana sifat pasif peranti, yang memerlukan pemandu untuk mengambil tindakan penyesuaian, kegunaannya terbatas untuk membantu dengan gerakan yang bertambah berbahaya secara perlahan-lahan, seperti yang ditemui semasa gerakan di atas rampa. Parameter bagi model blok indeks gulungan algoritma diubahsuai dan optimum menggunakan perisian Matlab. Sementara itu, sistem amaran perkembangan kini dianalisis menggunakan program TruckSim.Algoritma ini untuk menghitung indeks golekan berdasarkan balasan masa paling cepat yang ditawarkan oleh kajian sebelumnya.

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LIST OF SYMBOLS AND ABBREVIATIONS

ABC	-	Artificial Bee Colony
ACO	-	Ant Colony Optimization
CG	-	Centre of Gravity
DOF	-	Degree of Freedom
GA	-	Genetic Algorithm
GSA	-	Gravitational Search Algorithm
HIL	-	Hardware-in-the-Loop
HTM	-	Heavy Truck Manufacturer
LQR	-	Linear Quadratic Regulator
LTR	-	Load Transfer Ratio
MF	-	Magic Formula
MIL	-	Model-in-the-Loop
MIROS	-	Malaysia Institute of Road Safety Research
MORI	-	Modified Odenthal Rollover Index
MPC	-	Model Predictive Control
NHTSA	-	National Highway Traffic Safety Administration
ORI	-	Odenthal Rollover Index
PSO	-	Particle Swarm Optimisation
RAR	-	Rearward Amplification Ratio
RI	-	Rollover Index
RMS	-	Root Mean Square
RSF	-	Roll Safety Factor
SIL	-	Software-in-the-Loop
SRT	-	Static Rollover Threshold
SSC	-	Step Steer Cornering
TTR	-	Time-To-Respond
TTW	-	Time-To-Warn
DHIL	-	Driver-Hardware-in-the-Loop

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CHAPTER 1

INTRODUCTION

1.1 Background

On today's highways, roadside accidents, whether lethal or non-lethal, are a typical occurrence. According to the National Highway Traffic Safety Administration (NHTSA), which is based in the United States of America (USA), 36,096 individuals were killed in motor vehicle crashes in 2019, a decrease of 2.0 percent from 36,835 in 2018. The reduction in 2019 was the third consecutive yearly decline, despite an increase in vehicle miles travelled of 0.9 percent in comparison to 2018. Drivers, passengers, motorcyclists, pedestrians, and pedal cyclists all died in fatal collisions in 2019. SUV fatalities increased 3.4 percent over the previous year, while heavy truck fatalities increased somewhat. The overall fatality rate, as defined in terms of deaths per 100 million vehicle miles travelled, decreased to 1.10 in 2019 from 1.13 in 2018 (NHTSA,2019). According to the National Highway Highway Safety Administration, traffic fatalities increased by 4.6 percent in the first nine months of 2020, which includes approximately six months of data from the COVID-19 epidemic. Simultaneously, automobile miles travelled decreased by around 14.5%. This resulted in a 1.35 death rate per 100 million vehicle miles travelled, up from 1.10 in the same time last year. According to Triple-I Chief Actuary James Lynch, the increase in traffic deaths per 100 vehicle miles driven in the second quarter of 2020 was very certainly the result of faster driving. The third quarter of the year appears to be continuing the trend. In 2019, 2620 individuals died as a result of rollover (NHTSA, 2020).

According to the Malaysian Ministry of Transportation (MMoT), 548,598 accidents occurred in 2018, involving 837,695 vehicles. Among all of that, 6284 people died in roadside accidents. Although it is not as high as the data for the United States of America, it is still a significant issue since when comparing the number of Americans and Malaysians, the number of accidents per total person is nearly identical. Additionally, the Ministry of Transportation reports that the number of roadside signs increases year after year (MMoT, 2018).

Many factors are causing a roadside accident to happen, one of which is drunk driving. This is caused by irresponsible individuals who do not care about their surroundings and drive their vehicle even though they are incapable of doing that due to their intoxication. A sleepy driver is also one of the main factors of roadside accident. This happens mostly among tractor semi-trailer drivers as they want to get more trips in doing their job, and due to this, they cause a lot of roadside accident. They are driving over the speed limit also most likely to cause an accident. This is because the driver could not comprehend the appropriate distance between vehicles and adding to the over speed limit driving it is more likely to cause an accident. Other than that, while the driver was driving over the speed limit, they also might not stop at a red light. This would cause most likely a fatal collision due to their carelessness. Tractor semi-trailer has a high centre of gravity, and this likely to cause a tractor semi-trailer to rollover, which is a severe problem. Due to this, there are still irresponsible individual to add load below or above required to add to the semi-trailer to avoid the rollover. Other than that, sharp corners are most likely to cause the semi-trailer to rollover, and this is also a severe problem because it would cause a roadside accident.

The effect of all these roadside accidents would cause a lot of loss either in financial or individual life. This is because it would cause a lot to repair a crashed vehicle and improve broken road or collecting the debris on the road and it would involve a lot of individuals either to help the victims or clean the wreckage. Other than that, unwanted death toll would be a significant loss to anyone, either the person who cause it or suffers from it. By this, there must be an excellent solution to overcome this problem.

1.2 Problem Statement

When any vehicle crosses a true longitudinal or lateral axis at a 90-degree angle, this is referred to as a rollover. When a vehicle loses control on two wheels and begins to drift to one side, it rolls over. While any vehicle is susceptible, vehicles with a high vertical profile, such as heavy trucks, SUVs, and buses, are substantially more vulnerable. Numerous factors, such as abrupt steering, drastic course changes, or quick curves at high speeds, can cause a vehicle's Center of Gravity to shift to one side and cause it to turn, while an overloaded tracktor semitrailer enhances the likelihood of rolling over.

Statistically, accidents involved by a vehicle according to the National Highway Traffic Safety Administration (NHTSA), which from United State of America (USA), 36,096 people died in motor vehicle crashes in 2019 (NHTSA, 2019). According to transport statistics, Malaysia overall in the year 2018 were 548,598, and among that, 6284 death were caused by the accidents (MMoT, 2018).

Rollover can occur solely as a result of specific variables. Human error or bad behaviour is one of the factors that contribute to rollover. Human error is responsible for more than 80% of road accidents, according to the Malaysian Institute of Road Safety's (MIROS) Figure 1.1 Satistic (Fai, 2015).

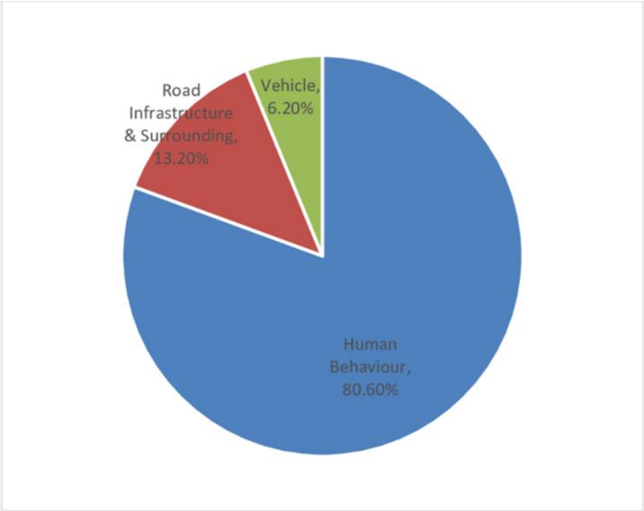

Figure 1 Statistic from Malaysian Institute of Road Safety (MIROS) (Fai, 2015)

Therefore, depending on output response time, it shows that any drivers would be late to perform any correction manoeuvre. This research will propose a new approach by using steering input and vehicle speed response.

1.3 Research Objective

The main aim of this is to design and fabricate a rollover warning device for the tractor-semitrailer. Specifically, the objectives are as follows:

a) To design and fabricate rollover warning device for tractor-semitrailer.

b) To modify the potential rollover index algorithm for tractor-semitrailer rollover warning algorithm.

c) To optimise the parameters of the modified rollover index algorithm for tractor-semitrailer to improve the rollover warning indication

1.4 Scope of Research

The scope of this research are as follows:

- The rollover warning device is designed and fabricates using a microcontroller.
- The rollover index algorithm is developed based on the fastest time response propose by previous researchers.
- The rollover index algorithm for the tractor-semitrailer is proposed by employing a modified rollover index algorithm with driver steering and vehicle speeds input using particle swarm optimisation.
- The selected rollover index algorithm is modified to improve the performance of the rollover warning system.

CHAPTER 2

LITERATURE REVIEW

2.1 Early Warning Indication

The first step in detecting a potential vehicle rollover is to receive an early warning signal. Instabilities can be categorised into three types: roll instability, yaw instability, and trailer yaw oscillation, which cause most heavy truck accidents. Due to their excessive weights and dimensions and their high centre of gravity (c.g.), huge freight vehicles' roll stability limitations are known to be significantly lower than those of conventional road vehicles. When the centrifugal forces placed on the vehicle during a move surpass the car's rollover threshold, the vehicle rolls over, resulting in a rollover. Vehicle jackknifing can be induced by yaw instability produced by braking or a combination of braking and steering actions coupled with axle wheel lock-up. Jackknife is defined by an uncontrollable and quick relative angular yaw motion between the tractor and the trailer. One of the most common causes of major accidents is jackknifing, which occurs when an articulated vehicle sweeps across the path of another vehicle (Liu,1999). Tractor jackknifing instability is characterised by rapid relative yaw motion produced by locked wheels at the tractor's rear axle, leaving the driver with inadequate time to fix the situation. In the case of trailer swing, the tractor is typically kept under control, but the semi-trailer may experience severe yaw oscillations (Dorian, 1989).

The Static Stability Factor (SSF), Tilt Table Ratio (TTR), Critical Sliding Velocity (CSV), and other indicators have been around for a long time. References (Schubert et al., 2004), (Hac, 2002), and (Aleksander Hac and Martens, 2004) published more advanced rollover sensing algorithms that combine suspension features and dynamics. Unfortunately, all these indicators are inherently stagnant. In essence, both static and dynamic elements play a role in rollover accidents. Because vehicle dynamics are ignored while detecting a rollover hazard, rollover detection systems relying solely on static rollover parameters are unlikely to provide good results.

2.2 Rollover index

The vehicle rollover index is a real-time variable used to determine when a wheel lifts off (Kazemian, 2017). Additionally, the rollover index has been referred to as the roll safety factor and load transfer ratio. The rollover index is a real-time variable that is used to determine whether a wheel lifts off. Numerous studies have attempted to construct a rollover index that reliably forecasts untripped wheel lift-off (Phanomchoeng, 2013). The fundamental definition of rollover R is as follows:

$$\boldsymbol{R = \frac{F_{zr} - F_{zl}}{F_{zr} + F_{zl}} \ , -1 \le R \le 1} \quad (2.1)$$

The right and left wheels vertical force are F_{zr} and F_{zl} Subsequently, when R is more than one or less than -1, a vehicle is probably would rollover. It is also to be noted that a vehicle is moving straight when F_{zr} = F_{zl} and R = 0. If $F_{zl} = 0$ then R = 1, it would come to an outcome that just the left wheel lifts off the ground. The relation of equation 1, because the forces aren't measurable so they can't be implemented. Researchers have made numerous attempts to retrieve the indices. The index based on lateral acceleration and untripped rollover was developed in several of the attempts. Base on ∅ and a_y .

$$\boldsymbol{R_1 = \frac{2m_s a_y h_R}{mgL_w} + \frac{2m_s h_R \tan(\emptyset)}{mL_w}} \quad (2.2)$$

$m = m_s + m_u$, h_R = the height of the centre of gravity, m_u = the unsprung mass, m_s = the sprung mass, a_y = the lateral acceleration, and $\emptyset$ = the rotation angle. This rollover index is used to detect untripped rollover. Due to the difficulty of determining roll angle, some research calculated the rollover index solely based on lateral acceleration (Odenthal, Bunte, & Ackermann, 1999; Solmaz, Corless, & Shorten, 2006). The vehicle's lateral acceleration capability may be arbitrarily reduced by the stability control with this rollover index. It also fails to detect rollovers caused by vertical road inputs or other external inputs, as we will explain (Phanomchoeng, 2013).

$$R_2 = \frac{2m_s a_y h_R}{mgL_w} \qquad (2.3)$$

The acceleration of the sprung mass is also considered independently in the commercial form of the index (Phanomchoeng, 2013).

$$\boldsymbol{R_3} = \frac{\boldsymbol{2m_s a_y h_R}}{\boldsymbol{mgL_w}} + \frac{\boldsymbol{2m_s h_R \tan(\emptyset)}}{\boldsymbol{mL_w}} + \frac{\mathbf{m_u}(\boldsymbol{\ddot{z}_{ur} - \ddot{z}_{ul}})}{\boldsymbol{mg}} \qquad (2.4)$$

$(\boldsymbol{\ddot{z}_{ur} - \ddot{z}_{ul}})$ = difference between acceleration of unsprung masses.