DESIGN AND FABRICATE ROLLOVER WARNING DEVICE FOR BUS

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE TECHNOLOGY) WITH HONOURS

2022

Faculty of Mechanical and Manufacturing Engineering Technology

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

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this thesis entitled "Design and Fabricate Rollover Warning Device for Bus" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : *Muhammad Zulfadhli Bin Mansi*

Date : 18th January 2022

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 Engineering Technology (Automotive Technology) with Honours.

Signature :

Supervisor Name : *Ir.Ts.Dr. Mohamad Hafiz Bin Harun*

Date : 18th January 2022

DEDICATION

First of all, I would like to express my gratitude to Allah for providing me with the strength necessary to complete this research and see my thesis become reality. This study and research are dedicated to my beloved parents, Mansi bin Md Arif as well as Hayati binti Muda @ Hamid, who have always supported and encouraged me in completing my study. Not forget to mention my siblings, supervisor Ir.Ts.Dr. Mohamad Hafiz bin Harun, and my friends who have supported me throughout my education journey. Thank you for all your assistance, which I will always appreciate and will never forget.

ABSTRACT

Accidents involving bus rollover can be classified as one of the most fatal types compared to other types of vehicle accidents. There are various aspects that lead to occupant injury and fatality. This thesis discusses the design and fabricate of a Rollover Warning Device (RWD) for road vehicles, particularly those with a higher center of gravity height to track width ratio. The RWD use rollover index algorithm to basically learn dynamics of a road vehicle as well as estimate its immediate roll stability of dynamic states of the vehicle. The condition of dynamic roll stability, especially load transfer ratio (LTR), is applied as an input to an RWD based on the rollover index algorithm for the purpose of determining the value of rollover index. The project was developed using computer simulations and proved using testal data. Due to the device's passive nature, which requires the driver to take corrective action, its effectiveness is restricted to assisting with risky moves that build gradually, such as those encountered during on-ramp maneuvers. MatLab software is used to modify and optimize the parameter of the block model of the rollover index algorithm. Meanwhile, TruckSim software is used to analyze the presented rollover trend warning system. This rollover index algorithm is developed based on the fastest time response proposed by previous researchers. The simulation of step steering maneuvers at different velocitys uses the MATLAB/Simulink software to determine the rollover index. As a consequence of the results, it can be concluded that Odenthal's rollover index algorithm gives the fastest rollover index based on the early warning indicator on the vehicle unit. The efficiency of the rollover index needs to be improved by using the Odenthal rollover index algorithm, which was modified and optimized using Particle Swarm Optimization (PSO). Finally, instead of lateral acceleration, a rollover index algorithm is proposed that integrates the modified Odenthal rollover index algorithm with driver steering and vehicle velocity inputs. The modified Odenthal rollover index algorithm's capability is tested by simulating step steering maneuvers at different velocitys and loads using the Hardware-in-the-Loop (HIL) simulation in the TruckSim driving simulator and the MATLAB/Simulink software. The test results show that the modified Odenthal rollover index algorithm provides a driver with a 12.36% faster Time-To-Warn (TTW) than the Odenthal rollover index and an enough Time-To-Respond (TTR) to take corrective measures. Thus, the modified Odenthal rollover index algorithm provided a more effective early warning system that significantly reduces rollover accidents.

ABSTRAK

Kemalangan yang melibatkan bas bergolek boleh dikategorikan sebagai kemalangan paling bahaya jika dibandingkan dengan jenis kemalangan yang lain. Terdapat pelbagai aspek yang menyebabkan kecederaan dan kematian kepada penumpang. Tesis ini membincangkan reka bentuk dan rekaan peranti golekan amaran (RWD) untuk kenderaan jalan raya, terutama yang mempunyai nisbah pusat graviti yang tinggi hingga nisbah lebar yang lebih tinggi. RWD menggunakan algoritma indeks golekan untuk asasnya mempelajari kenderaan jalan raya yang dinamik dan juga menganggarkan kestabilan golekan segera terhadap keadaan dinamik kenderaan. Keadaan kestabilan golekan dinamik, terutamanya nisbah pemindahan beban (LTR), diaplikasikan sebagai input ke RWD berdasarkan algoritma indeks golekan untuk tujuan menentukan tahap kepekaan output. Projek ini dibangunkan menggunakan simulasi komputer dan dibuktikan dengan menggunakan data eksperimen. Oleh kerana sifat pasif peranti ini, yang memerlukan pemandu untuk melakukan tindakan pembetulan, keberkesanannya adalah terhad untuk membantu pergerakan berisiko yang berkembang secara beransur-ansur seperti yang dihadapi semasa pemanduan di jalan. Perisian Matlab digunakan untuk mengubah dan mengoptimumkan parameter blok model algoritma indeks golekan manakala perisian TruckSim digunakan untuk menganalisis sistem ramalan yang cenderung untuk bergolek. Algoritma indeks golekan ini dikembangkan berdasarkan tindak balas daripada masa terpantas yang dicadangkan oleh penyelidik sebelumnya. Simulasi pemanduan stering berperingkat dengan pelbagai kelajuan telah dijalankan menggunakan perisian MATLAB/Simulink bagi mendapatkan indeks golekan. Berdasarkan permerhatian daripada keputusan simulasi, ianya boleh disimpulkan bahawa algoritma indeks golekan yang telah dicadangkan oleh Odenthal menghasilkan indeks golekan yang paling pantas berdasarkan kepada pengesanan amaran awal pada unit kenderaan. Kecekapan prestasi indeks golekan ditambah baik dengan menggunakan algoritma indeks golekan Odenthal yang telah diubahsuai dan dioptimumkan menggunakan Pengoptimuman Kawanan Zarah (PSO). Akhirnya, selain dari pecutan sisi, algoritma indeks golekan telah dicadangkan dengan mengintegrasikan algoritma indeks golekan Odenthal yang diubahsuai dengan masukkan stering pemandu dan halaju kenderaan. Prestasi algoritma indeks golekan Odenthal yang diubahsuai diuji secara simulasi yang melibatkan pemanduan stering berperingkat, dengan pelbagai kelajuan dan beban melalui penyelakuan Hardware-in-the Loop (HIL) dalam simulator pemanduan TruckSim dan perisian MATLAB/Simulink. Hasil keputusan eksperimen menunjukkan bahawa algoritma indeks golekan Odenthal yang diubahsuai menghasilkan masa-untuk-amaran 12.36% lebih pantas berbanding indeks golekan Odenthal kepada pemandu dan menawarkan masa-untuk-bertindak yang mencukupi untuk memulakan pergerakan pembetulan. Oleh itu, algoritma indeks golekan Odenthal yang diubahsuai mencadangkan sistem amaran awal yang lebih baik dan boleh mengurangkan kemalangan golekan dengan lebih berkesan.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. I would like to extend my appreciation to the Universiti Teknikal Malaysia,Melaka (UTeM) for providing the research platform. Thank you also to the Malaysian Ministry of Higher Education (MOHE) for the financial assistance.

My greatest appreciation goes to my main supervisor, Ir.Ts.Dr. Mohamad Hafiz Bin Harun, Universiti Teknikal Malaysia, Melaka (UteM) for all his support, advice and inspiration. His patience for guiding and providing priceless insights will always be remembered.

Last but not least, from the bottom of my heart a gratitude to my beloved father, Mansi bin Md Arif, for his encouragements and who have been the pillar of strength in all my endeavors. My eternal love also to my mother, Hayati binti Muda @ Hamid for her patience and understanding. I would also like to thank my beloved friends for their endless support, love and prayers. Finally, thank you to all the individuals who had provided me the assistance, support and inspiration to embark on my study.

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LIST OF SYMBOLS AND ABBREVIATIONS

ABC	-	Artificial Bee Colony
ABS	-	Anti-lock Braking System
ACO	-	Ant Colony Optimization
ADKEY	-	Ad Port
AS	-	Ant System
COPs	-	Combination Optimization Problems
CPU	-	Central Processing Unit
DHIL	-	Driver-Hardware-in-the-Loop
ESC	-	Electronic Stability Control
GA	-	Genetic Algorithm
GND	-	Ground
GSA	-	Gravitational Search Algorithm
HIL	-	Hardware-in-the-Loop
LTR	-	Load Transfer Ratio
MIROS	-	Malaysian Institute of Road Safety Research
MORI	-	Modified Odenthal Rollover Index
NHTSA	-	National Highway Traffic Safety Administration
No.	-	Number
NRP	-	Network Routing Problem
PSO	-	Particle Swarm Optimization
RI	-	Rollover Index
RSC	-	Roll Stability Control
RSF	-	Roll Safety Factor
RWD	-	Rollover Warning Device
SIL	-	Software-in-the-Loop
SOP	-	Sequential Ordering Problem
SPK	-	Speaker
SSF	-	Static Stability Factor
SUV	-	Sport Utility Vehicle

TSP	-	Traveling Salesman Problem
TTW	-	Time-To-Warn
TTR	-	Time-To-Respond
VCC	-	Voltage Common Collector
WHO	-	World Health Organization
YSC	-	Yaw Stability Control

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

In this current situation around the world, the statistics of road accidents are increasing day by day even though the latest technology related to vehicle safety is still growing well. Accidents on the highway are things that won't go down because they always happen every day. Statistics from the World Health Organization (WHO) have reported more than 1.17 million deaths every year worldwide and 20 to 50 million are injured by road accidents. In addition, what's more balanced is that the majority involved in the accident are adolescents between the ages of 5 and 29. Every year, 1.17 million deaths are caused in traffic crashes which contribute for 70% of the total. Pedestrians are involved in 65% of deaths with children contributing for 35% of those killed and around 23 to 34 million people are involved in traffic accidents around the world as per estimates. That is almost twice as many as was currently estimated. It is estimated that more than 200 United State people die each year as a result of road fatalities abroad. Besides that, in Europe, more than 50,000 people are killed in traffic crashes, and then another 150,000 are injured. Meanwhile, the overall number of road injuries in Malaysia exceeded 223,000 in 1999 who 16 peoples were killed in traffic accidents according to (Kareem, 2003).

In Malaysia, road accident involves buses was one of the most accident happened at road too. Around 2007 and 2010, 47% of MIROS-investigated incidents resulted in deaths, with fatalities of 1 until 3 people being the most popular, and accidents involving minor injuries contributing for at least 22%. From this statistic, express buses have the greatest traffic accidents and deaths and as compared to other types of routes, highways have a higher accident rate. From the journal have stated that the main cause of mechanical failure among all types of vehicle buses was reported as brake breakdown, for around 56% of overall mechanical failure, and about 52% of all commercial buses were involved in traffic accidents with an average annual of 3.8 accidents per commercial bus according to (Kareem, 2003).

There are several reasons that caused accident that happened on road such as plays gadget while driving, drunkenness, change routes without signaling, driving at high velocity, violate the red light, rollover during cornering and many more. Among all of these factors, there is one factor contributes to road accident which is rollover.

According to (Matolcsy, 2007), the most serious bus crash is rollover incident. According to injury figures collected by the author from over 300 incidents, the total casualty rate is 25 accidents. In a rollover, four main injury mechanisms can endanger the occupants which are penetration, projection, absolute and partial ejection. To prevent these types of accidents, various methods of safety can be used. The seriousness of a rollover crash can be specified in two ways which are dependent on the number of victims, and the other evaluates the circumstances of the rollover.

1.2 Problem Statement

A rollover involves of any vehicle rolling over a true longitudinal or lateral axis of 90˚ or more referring to Figure 1-1 below. A rollover occurs as a vehicle loses control on two wheels and moves to one side. Any vehicle may be affected, but those with a high vertical profile, such as heavy trucks, SUVs, and buses, are at a much higher risk. A few factors such as sudden steering, drastic path changes, or rapid curves at high velocitys may cause a vehicle's Center of Gravity to shift it to the side and turn while for a bus with too much weight will becomes an even greater possibility to rollover.

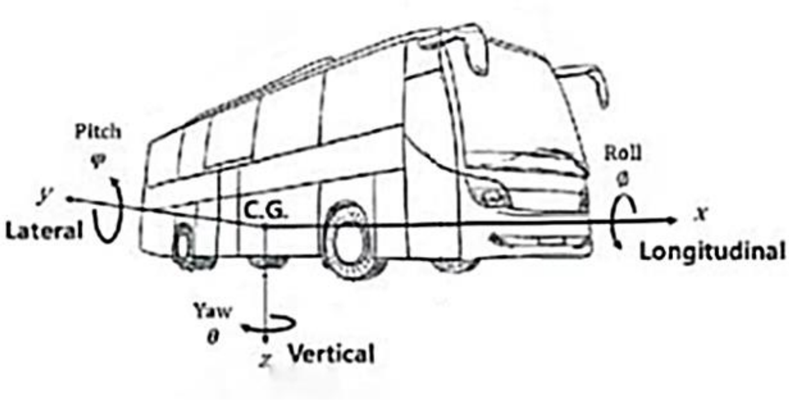

Figure 1-1 Axis of Motion and Movement (Bae et al., 2019)

According to (Oluwole et al., 2015), statistics obtained from the Malaysian Institute of Road Safety (MIROS) for the period 2003 until 2012 regarding bus accidents, 47 % of cases investigated by MIROS during 2007 and 2010 lead to death, with death rates of one until three victims being the most frequent, and cases with minor injuries having at least 22 %. Meanwhile, express and single deck buses have the highest crash and death rates at highway.

Besides that, the National Highway Traffic Safety Administration (NHTSA) reports around 280,000 rollover accidents (NHTSA Rollover Ratings) every year. In 2004, 31,693 occupants of passenger vehicles were killed in car accidents, with 10,553 of those killed due to rollovers (Strashny & NHTSA, 2007). Indirectly, these patterns highlight the importance of researching rollover prevention and safety in today's society.

Rollover can happen only if some factors lead it to roll. One of the factors that contributed to rollover is human error or human behavior. Referring to Figure 1-2, human error is responsible for more than 80% of traffic accidents (Fai, 2015).

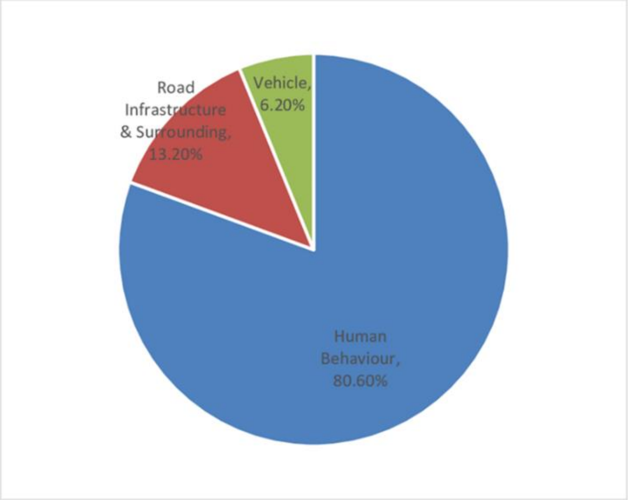

Figure 1-2 Malaysia Road Accident Factor from Malaysian Institute of Road Safety (MIROS) (Fai, 2015)

As a result, from the statistic above, to reduce the human error factor which contributes to rollover, vehicle assistance device is proposed by introducing the rollover warning device. This rollover warning device is to generate an early warning to the driver which helps the driver able to have an appropriate time to correct the maneuvering. Therefore, it will help to prevent the road accident. According to (Yu et al., 2013), it is expected that approximately 42 % of accidents may be prevented if the vehicles had been installed with a warning system that could assist drivers to drive buses in an appropriate manner before to a rollover. Current rollover warning device are used the output response, which the rollover algorithm and index can be identified. By using the output response as an input to the rollover algorithm, it is too late for the driver to perform the corrective action because the vehicle is tending to rollover. Once the vehicle tends to rollover, it will continuously to roll. The probability of a bus or coach rolling over is assessed using a real-time rollover prediction algorithm. Thus, this study will propose a new approach by using steering input and vehicle velocity response.

1.3 Research Objective

The main aim of this research is to design and fabricate rollover warning device for bus. Specifically, the objectives are as follows:

a) To modify the rollover index algorithm for bus.

b) To optimize the parameters of the modified rollover index algorithm for bus.

c) To design and fabricate rollover warning device for bus.

1.4 Scope of Research

The scopes of this research are as follows:

- The rollover index algorithm is developed based on the fastest time response propose by previous researches.
- The selected rollover index algorithm is modified in order to improve the capability of the rollover warning system.
- The rollover index algorithm for bus is proposed by employing a modified rollover index algorithm with vehicle velocity and driver steering input and optimize using particle swarm optimization (PSO).
- The rollover warning device is design and fabricate using a microcontroller.

CHAPTER 2

LITERATURE REVIEW

2.1 Early Warning Indication

Safety is very important either on vehicle or occupant. However, they still need to be careful of human error factor such as driving recklessly, fatigue while driving, and unconcerned about environment. These errors may lead the vehicle tend to rollover. According to (Tian et al., 2018), bus rollover is a major source of concern for bus manufacturing companies as well as traffic authorities when it comes to traffic accidents. In order to address this issue, researchers and engineers have designed a variety of rollover avoidance devices. In contrast, once the phase of an oncoming rollover has begun, there is lack of time for the actuators to react appropriately, specifically in severely harmful cases. In order to avoid bus rollover issues, it is necessary to be able to estimate the rollover probability in advanced and to calculate an appropriate time. So that, rollover early warning indicator are important to alert the driver before either one of the vehicle tire start to lift up and then rollover occurs.

2.2 Rollover Index

Rollover is an incident of vehicle collision in which a vehicle turns over onto its left or right side or roof. It is involves of any vehicle rolling over a true longitudinal or lateral axis of 90˚ or more. Rollovers are more likely to result in death than other forms of vehicle incidents. The characteristics of large vehicles itself contributed to their poor roll stability and tendency to rollover accidents. Vehicle rollover accidents are serious traffic accidents that result in loss of life and property, and they have become a major concern impacting transportation security.

2.2.1 Types of Vehicle Rollover

The National Highway and Traffic Safety Administration (NHTSA) classifies rollovers based on their origin There are some factors are included in the classifications such as turn-over, flips-over, climb-over, end-over-end, and bounce-over (Amirul Affiz, 2014).

Turn-over factor occurred when a vehicle performs quick turns as well as the centrifugal forces created by the turning is countered by normal surface friction, then vehicle roll in the manner seen in Figure 2-1.

Figure 2-1 Centrifugal Force Countered by Normal Surface Friction Causes the Vehicle to Turn Over (Amirul Affiz, 2014)

Flip over factor is when a vehicle comes into contact with an incline like object, such as the rear slope of a river or a downed guardrail, the vehicle rotates about its longitudinal axis. Figure 2-2 illustrates car flip-overs.