UNIVERSITI PUTRA MALAYSIA

FUZZY-PID CONTROLLER DESIGN FOR BRAKE-BY-WIRE SYSTEM OF ELECTRICAL VEHICLE

AMEER M. F. SIDER

FK 2014 27

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By

AMEER M. F. SIDER

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfillment of the requirements for the Degree of Master Science

June 2014

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DEDICATED

قال تعالى:

((وَوَصَّيْنَا الْإِنْسَانَ بِوَالِدَيْهِ حَمَلَتْهُ أُمُّهُ وَهْنًا عَلَىٰ وَهْنٍ وَفِصَالُهُ فِي عَامَيْنِ أَنِ اشْكُرْ لِي وَلِوَالِدَيْكَ إِلَيَّ الْمَصِيرُ))

لقمان 14

This thesis is dedicated to:

my beloved parents who encourage, side and patronize me

my darling brothers Islam and Ameen who support, stimulate and stand with me during my study,

my sweetheart sisters Tasneem, Ala' and Ayah

my all friends particularly Abbas, Arafat, Alala, Sameer, Fadil, Masri, Ferasa, Hassan and Bilal

and to my beloved holy land Palestine.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

FUZZY-PID CONTROLLER DESIGN FOR BRAKE-BY-WIRE SYSTEM OF ELECTRICAL VEHICLE

By

AMEER M. F. SIDER

June 2014

Chair: Mohd Khair Bin Hassan, PhD

Faculty: Engineering

This study presents Fuzzy-PID controller design for brake-by-wire of electric vehicle**.** BBW is a new brake technology in which mechanical and hydraulic components of traditional brake systems are replaced by electric circuits and devices to carry out the function of braking in a vehicle by wire-transmitted information. The advantages of electronic devices such as reducing vehicle weight and increasing brake performance are considered the main purposes trend of automotive industry towards this new brake technology.

The motivation of this study is to enhance the safety aspects for the vehicle while attaining any desired speed. To achieve that, an optimal brake force at different road types and conditions and for different brake commands must be obtained within a reasonable time and without vehicle sliding.

The aforementioned matters are accomplished essentially by obtaining mathematical modeling of the vehicle-wheel dynamics based on braking characteristics behavior. The derived model after that is utilized to construct two different BBW systems named as hard brake and normal brake system to handle and meet various brake situations and conditions which they are built according to the selected state dynamics of each system.

In view of that, the mechanism behavior and operating process of both brake systems are dominated by implementing distinct control algorithms based on PID and Fuzzy-PID controllers. Indeed, the fundamental objective of the applied control methods is to attain desired vehicle speed from one side and to maintain vehicle stability and controllability from other side. Above and beyond, BBW operating process is improved by developing new integrated control strategy that involves both designed brakes (hard and normal) in

one sole framework. Constructing such a system is primarily based on conventional IF-ELSE conditional control. Nonetheless, the braking operation of the proposed BBW systems is carried out by utilizing permanent magnetic DC motor according to the predetermined control signal.

The simulation analysis of the proposed BBW schemes and their controllers are conducted on MATLAB software using Simulink tool, where five road types and conditions (asphalt (dry, wet), cobblestone (dry, wet) and concrete) are engaged in the analysis and investigation of the output behavior of the plant and its operating process. Moreover, the study presents supplementary explanation about performance of the proposed actuator (PMDC) as well as about the process of braking mechanism.

The simulation results and outcomes demonstrate efficient operating brake systems that lead to obtain desired vehicle speed successfully within reasonable brake time. This is a clear evidence of obtaining safety aspects of the vehicle as well as passengers since control strategy could maintain optimal brake force that leads to shorter stopping distance, hence increasing safety aspects. Furthermore, the ability of proposed control strategies to operate during various situations (hard or normal brake request) at different road conditions is also achieved effectively. Consequently, the aim of the study which is designing electronically brake system for BBW of electric vehicle that can operate in different brake situations and at different road conditions is successfully accomplished and achieved.

Finally, after the analysis and discussion of BBW and controller design, suggestions for key future development and enhancement of the current study are presented such as implementing adopted BBW design practically.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai memenuhi keperluan untuk ijazah Master Sains

FUZZY-PID REKABENTUK BAGI SISTEM BREK-DENGAN-WAYAR UNTUK KENDERAAN ELEKTRIK

Oleh

AMEER M. F. SIDER

Jun 2014

Pengerusi: Mohd Khair Bin Hassan, PhD

Fakulti: Kejuruteraan

Kajian ini mengenai reka bentuk kawalan Fuzzy-PID untuk sistem brek-dengan-wayar (BBW) elektrik kenderaan. BBW adalah teknologi baru bagi brek di mana komponen-komponen mekanikal dan hidraulik sistem brek tradisional digantikan dengan sistem pintar, litar elektrik dan alat-alat untuk menjalankan fungsi brek di dalam kenderaan oleh penghantaran maklumat melalui wayar. Kelebihan elektronik dan sistem bantuan pintar ini dapat mengurangkan berat kenderaan, meningkatkan prestasi brek dan keupayaan untuk mereka bentuk sistem kawalan bersepadu dianggap trend utama industri automotif ke arah teknologi brek baru.

Motivasi kajian ini adalah untuk memperbaiki aspek keselamatan untuk kenderaan serta mencapai kelajuan kenderaan. Oleh itu, satu daya brek yang optimum pada jalan yang berlainan jenis dan keadaan dan bagi arahan brek yang berbeza mesti diperolehi dalam masa yang munasabah serta tanpa gelongsoran kenderaan.

Perkara tersebut dapat dicapai pada dasarnya dengan mencipta model matematik dinamik kenderaan roda berdasarkan ciri-ciri tingkah laku brek. Model yang diperolehi akan digunakan untuk membina dua sistem BBW berbeza dinamakan sebagai brek keras dan sistem brek biasa untuk mengendali dan memenuhi pelbagai situasi brek (kecemasan atau keadaan biasa) yang mereka dibina mengikut keadaan dinamik bagi setiap sistem.

Sehubungan itu, tingkah laku mekanisme dan proses operasi kedua-dua sistem brek dilakukan dengan menggunakan algoritma kawalan yang berbeza berdasarkan pengawal PID dan Fuzzy-PID. Oleh itu, matlamat asas kaedah kawalan yang digunakan adalah untuk mencapai kelajuan kenderaan yang diingini dan juga dalam masa yang sama untuk mengekalkan kestabilan kenderaan dan pengawalan. Seterusnya, proses operasi BBW bertambah baik dengan membangunkan strategi kawalan bersepadu yang

melibatkan kedua-dua brek direka (keras dan normal) dalam satu rangka kerja tunggal. Membina sistem seperti ini adalah berdasarkan kawalan bersyarat konvensional IF-ELSE. Walaubagaimanapun, operasi sistem brek BBW yang dicadangkan dijalankan adalah dengan menggunakan magnet kekal DC motor mengikut isyarat kawalan yang telah ditetapkan.

Analisis simulasi dan kajian skim BBW yang dicadangkan dan pengawalan dikendalikan pada perisian MATLAB menggunakan alat Simulink, di mana lima jenis jalan raya dan syarat (asfalt (kering, basah), batu bulat (kering, basah) dan konkrit) terlibat dalam analisis dan penyiasatan terhadap tindakan yang diberi oleh output sistem dan proses operasi. Selain itu, kajian ini memberi penerangan yang tambahan serta ilustrasi mengenai prestasi penggerak yang dicadangkan (PMDC) dan juga tentang proses mekanisme brek.

Keputusan simulasi dan hasil menunjukkan sistem brek operasi yang cekap membawa kepada kelajuan kenderaan diingini berjaya diperoleh dalam masa tindakbalas brek yang munasabah. Ini adalah bukti yang jelas bagi mendapatkan aspek keselamatan kenderaan dan juga penumpang memandangkan strategi kawalan boleh mengekalkan kuasa brek yang optimum yang membawa kepada jarak berhenti lebih singkat, seterusnya meningkatkan aspek keselamatan. Tambahan pula, keupayaan strategi kawalan yang dicadangkan untuk beroperasi dalam pelbagai situasi (permintaan brek keras atau biasa) pada keadaan jalan yang berbeza juga dicapai dengan berkesan. Oleh itu, tujuan kajian yang merekabentuk secara elektronik sistem brek untuk BBW elektrik kenderaan yang boleh beroperasi dalam keadaan brek yang berbeza dan pada keadaan jalan yang berbeza adalah berjaya dilaksana dan dicapai.

Akhir sekali, selepas analisis dan perbincangan mengenai BBW dan reka bentuk pengawal, cadangan untuk pembangunan utama pada masa hadapan dan peningkatan kajian semasa dapat dibentangkan seperti mengguna pakai reka bentuk BBW secara praktikal.

ACKNOWLEDGEMENTS

First of all, thanks is due to Allah, the Most Gracious, Most Merciful (S.W.T.) whom we attain our ability and strength. I would like to express my gratitude and appreciation to **Dr. Mohd Khair Hassan** for his wise supervision, advice, guidance, suggestion, and support during the research time. Thanks also to my co-supervisors (**Dr. Siti Fauziah Tohara and Dr. Mohd Amran Bin Mohd Radzi)** for their opinion and wonderful suggestion during the research time. My sincere gratitude is due to them.

I would like also to thank laboratory management of Control System Engineering Department for the support and assistance.

Thanks are also to my parents who deserve my deepest appreciation for their un-bordered help and patronize. I am grateful for the countless sacrifices they made to ensure that I can pursue and finish my study successfully particularly Dr. Arafat. May ALLAH bless and protect all of them and may they live long and healthy.

I certify that a Thesis Examination Committee has met on 30th of June 2014 (Monday) to conduct the final examination of Ameer M. F. Sider on his thesis entitled "Design Fuzzy-PID controller for Brake-By-Wire of Electric Vehicle" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Master of Science.

Members of the Thesis Examination Committee were as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master Of Science. The members of the Supervisory Committee were as follows:

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