INVESTIGATION ON MANEUVERABILITY IMPROVEMENT OF A FOUR-WHEEL DRIVE AND REAR-WHEEL STEERING SYSTEM: NUMERICAL SIMULATION ANALYSIS

LI MAO QI

MASTER OF SCIENCE

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

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 degree of Master of Science.

_____

(Supervisor's Signature)

Full Name : DR. MOHAMMAD IZHAR BIN ISHAK

Position : JUNIOR LECTURER

Date : 7TH JULY 2023

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

_____

(Student's Signature)

Full Name : LI MAOQI

ID Number : MMA18005

Date : 7TH JULY 2023

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LI MAOQI

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ABSTRAK

Dalam beberapa tahun kebelakangan ini, Teknologi X-by-wire ialah kemajuan dalam industri automotif dan diiktiraf oleh banyak negara sejak beberapa tahun kebelakangan ini. Ia termasuk memandu-dengan-wayar (DBW) dan steer-by-wire (SBW). DBW boleh didapati dalam bentuk pacuan dua roda (2WD) dan pacuan empat roda (4WD). 4WD mempunyai dua bentuk: pemacu motor berpusat dan pemacu motor teragih. Pemacu motor berpusat adalah menggunakan motor untuk menggantikan enjin untuk menyediakan kuasa untuk kenderaan. Pemacu motor yang diedarkan terutamanya berdasarkan motor dalam roda, dan roda digerakkan oleh motor dalam roda untuk menyediakan kuasa untuk kenderaan. SBW mempunyai dua bentuk: stereng dua roda (2WS) dan stereng empat roda (4WS). Ia bukan sahaja secara mendadak mengurangkan beban operasi pemandu tetapi juga menyelesaikan masalah yang kenderaan biasa tidak dapat melaksanakan 4WS. Biasanya, kebolehgerakan yang lebih rendah mudah ditunjukkan pada kenderaan 2WS semasa kenderaan membelok. Tidak kira semasa memandu kenderaan di jalan raya bandar yang sempit atau tempat letak kereta, ia dikehendaki memusingkan stereng beberapa kali apabila kenderaan itu perlu dipandu. Selain itu, kenderaan itu boleh terdedah kepada fenomena understeer (US) atau oversteer (OS) yang berlaku semasa stereng. Tujuan utama penyelidikan ini adalah untuk mensimulasikan prestasi stereng kenderaan dengan membina model kenderaan konvensional moden dan untuk menyelesaikan masalah yang mungkin berlaku semasa selekoh kenderaan dengan menggunakan sistem kawalan 4WS aktif untuk mengawal kadar yaw. Dalam penyelidikan ini, eksperimen 2WS selekoh pada beberapa kelajuan tetap dan sudut kemudi telah dijalankan menggunakan kereta ujian sebenar. Model simulasi kereta ujian telah dibina dalam MATLAB Simulink menggunakan persamaan dinamik kenderaan tak linear dengan spesifikasi kenderaan untuk parameter. Sistem kawalan PID telah digunakan dalam simulasi ini untuk mengawal sudut stereng roda belakang untuk mencapai 4WS. Dengan membandingkan simulasi dan keputusan eksperimen, dapat disimpulkan bahawa persamaan dinamik kenderaan tak linear boleh digunakan untuk melakukan simulasi gerakan kenderaan. Selepas mengesahkan persamaan dinamik kenderaan, bagi mengesahkan sama ada masa putaran stereng akan mempengaruhi pergerakan kenderaan, kajian ini mensimulasikan dua masa berbeza untuk melengkapkan putaran roda iaitu 2 saat dan 25 saat dengan bahagian hadapan. sudut stereng ialah 10 darjah. Keputusan menunjukkan bahawa tidak kira sama ada masa putaran stereng adalah pantas atau perlahan, ia tidak menjejaskan kelajuan fenomena US dan OS kenderaan. Dengan mensimulasikan situasi selekoh kelajuan kenderaan dari 10km/j hingga 80 km/j dalam kenaikan 10km/j. Disimpulkan bahawa kenderaan itu akan berlaku fenomena AS apabila kelajuan pusingan kenderaan lebih rendah sekitar 20km/j; apabila kenderaan membelok dengan kelajuan lebih tinggi daripada 50km/j, kenderaan akan mengalami fenomena OS berlaku. Selepas menggunakan sistem 4WS, masalah OS dan AS diselesaikan dengan cekap. Walaupun kenderaan itu membelok pada kelajuan 80km/j, selekoh keadaan mantap (SSC) masih boleh dicapai. Selepas menggunakan sistem kawalan PID, kebanyakan selekoh boleh dikawal. kecuali apabila roda berputar kepada 10° dalam masa dua saat sahaja dan kelajuan kenderaan melebihi 60km/j iaitu kenderaan tidak terkawal dalam masa yang singkat, sistem kawalan PID tidak dapat menjadikan roda belakang mempunyai sudut stereng yang sesuai. untuk menjadikan kenderaan itu mempunyai SSC. Ringkasnya, kajian ini menyelesaikan hampir semua fenomena AS dan OS yang boleh berlaku dalam kenderaan 2WS dengan menggunakan sistem 4WS.

ABSTRACT

X-by-wire technology is an advancement in the automotive industry and is recognized by many countries in recent years. It includes drive-by-wire (DBW) and steer-by-wire (SBW). DBW is available in two-wheel drive (2WD) and four-wheel drive (4WD) forms. 4WD has two forms: centralized motor drive and distributed motor drive. A centralized motor drive is to use the motor to replace the engine to provide power for the vehicle. The distributed motor drive is mainly based on the in-wheel motor, and the wheel is driven by the in-wheel motor to provide power for the vehicle. SBW has two forms: two-wheel steering (2WS) and four-wheel steering (4WS). It not only dramatically reduces the operating burden of the driver but also solves the problem that ordinary vehicles cannot perform 4WS. Usually, the lower maneuverability is easy to show on 2WS vehicles during vehicle turning. No matter when driving a vehicle on a narrow city road or parking, it is required to turn the steering wheel several times when the vehicle needs to steer. Moreover, the vehicle can be prone to understeer (US) or oversteer (OS) phenomena that occur when steering. The main purpose of this research is to simulate the steering performance of the vehicle by constructing a model of modern conventional vehicles and to solve the problems that may occur during vehicle cornering by applying an active 4WS control system to control the yaw rate. In this research, experiments of 2WS cornering at several constant speeds and steer angles were conducted using an actual experimental vehicle. A simulation model of the test car was constructed in MATLAB Simulink using nonlinear vehicle dynamics equations with the specification of the vehicle as the parameters. A PID control system was used in this simulation to control the rear-wheel steering angle in order to achieve 4WS. By comparing the simulation and the experimental result, it can be concluded that the nonlinear vehicle dynamics equation can be used to do the simulation of the vehicle motion. After verifying the vehicle dynamics equation, in order to verify whether the time of rotating the steering wheel will affect the motion of the vehicle, this study simulated two different times to complete the rotation of the wheel which is 2 seconds and 25 seconds with the front steering angle is 10 degrees. The results show that no matter whether the time of steering wheel rotation is fast or slow, it does not affect the speed of the vehicle's US and OS phenomenon. By simulating the cornering situation of the vehicle speeds from 10km/h to 80 km/h in the 10km/h increment. It is concluded that the vehicle will occur US phenomenon when the vehicle turning speed is lower around 20km/h; when the vehicle corners with a speed higher than 50km/h, the vehicle will have an OS phenomenon happen. After applying the 4WS system, the OS and US problems are solved efficiently. Although the vehicle is turning at a speed of 80km/h, steady-state cornering (SSC) can still be achieved. After applying the PID control system, most of the cornering can be controlled. except when the wheels rotate to 10° in only two seconds and the vehicle speed is greater than 60km/h which is the vehicle is out of control in a very short time, the PID control system cannot make the rear wheels have an appropriate steering angle to make the vehicle have an SSC. In short, this study solved almost all US and OS phenomena that can occur in 2WS vehicles by applying the 4WS system.

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