Faculty of Mechanical Engineering

CONTROL OF PNEUMATICALLY ACTUATED ACTIVE SUSPENSION SYSTEM USING MULTIPLE PROPORTIONAL-INTEGRAL WITH KNOWLEDGE-BASED FUZZY

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CONTROL OF PNEUMATICALLY ACTUATED ACTIVE SUSPENSION SYSTEM USING MULTIPLE PROPORTIONAL-INTEGRAL WITH KNOWLEDGE-BASED FUZZY

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DECLARATION

I declare that this thesis entitle "Control of Pneumatically Actuated Active Suspension System using Multiple Proportional-Integral with Knowledge-based Fuzzy" is the result of my own research except as cited in the references. This thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
Name	:	FITRIAN IMADUDDIN
Date	:	1 October 2009

DEDICATION

To my beloved mother, father, and brothers

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ABSTRACT

This study investigates the use of pneumatically actuated active suspension system to improve ride performance of the vehicle. The main content of this study is the development and application of the Knowledge-Based Fuzzy (KBF) multiple Proportional-Integral (PI) control scheme and the investigation of the force tracking control system that can provide improvement in vehicle ride performance. These two controllers are arranged in a separated control loops called the inner loop controller for force tracking control of the pneumatic actuator and the outer loop controller using KBF multiple PI control to reject the effects of road-induced disturbances. The performance of the proposed controller is compared to the multiple PI controller without KBF scheme and the existing passive suspension system. Simulation studies are presented in time domain simulation while the experimental evaluation is conducted on a full-scale quarter car test rig. In general, it can be reported that the proposed control scheme is able to provide improvement in terms of body states compared to its counterparts. The proposed scheme is also easy to realize in practice due to its simple structure.

ABSTRAK

Penyelidikan ini mengkaji pengunaan sistem suspensi lasak menggunakan pneumatik untuk meningkatkan mutu pemanduan sesebuah kenderaan. Kandungan utama kajian ini adalah pembangunan skim dan aplikasi kawalan fuzzy proportional-integral berperingkat berpandukan pengetahuan (*KBF multiple PI control*) dan kajian mengenai sistem kawalan pengesan daya yang boleh menghasilkan peningkatan kepada mutu pemanduan kenderaan. Kedua-dua alat kawalan ini disusun dalam suatu gelung kawalan berasingan yang dinamakan pengawal gelung dalaman untuk kawalan daya pneumatik dan pengawal gelung luaran yang disebut *KBF multiple PI control* untuk menolak kesan daripada gangguan permukaan jalan. Mutu alat kawalan yang dicadangkan dibandingkan dengan alat pengawal *multiple PI* tanpa skim KBF serta dengan sistem suspensi pasif yang sedia ada. Kajian simulasi ditunjukkan dalam domain masa, manakala penilaian percubaan dijalankan pada *quarter-car-test-rig* skala penuh. Secara amnya, dapat disimpulkan bahawa skim alat kawalan yang dicadangkan berkemampuan untuk menghasilkan peningkatan yang berkesan dari segi kenyamanan apabila dibandingkan dengan sistem kawalan yang lain. Skim yang dicadangkan juga mudah untuk dijelaskan dalam bentuk latihan kerana bentuknya yang ringkas.

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LIST OF SYMBOLS

α_{in} - Heat transfer coefficient for compression

α_{in} - Heat transfer coefficient for expansion

μ_A - Functional mathematical form of a membership function

A - Piston effective areas

$A_{vi,in}$ - Valve areas for input path

$A_{vi,in}$ - Valve areas for exhaust path

β - Viscous friction coefficient of the pneumatic cylinder

c_j^i - Center (mean) of the membership function

σ_j^i - Spread (deviation) of the membership function

θ - Representation of fuzzy parameters (center and spread)

b_i - Output membership function for i-th rule

C_1 - Coefficient for unchoked flow

C_2 - Coefficient for choked flow

C_f - Non-dimensional discharge cefficient

C_s - Stiffness value of the passive damper

e - errors

e_z - body displacement errors

$e_{\dot{z}}$ - body velocity errors

$e_{\ddot{z}}$ - body acceleration errors

f - regulated scaling factor of knowledge-based fuzzy scheme

F - External force against pneumatic actuator

F_p - Augmented force from the actuator

F_f - Coulomb friction force of the pneumatic cylinder

K_I - Integral Constant

K_P - Proportional Constant

K_s - Stiffness value of the passive spring

L - Stroke length of the piston

M - Mass of the pneumatic piston

M_u - Mass of the wheel axle (unsprung mass)

M_s - Mass of the vehicle body (sprung mass)

$\dot{m}_r$ - Mass flow rate of air

P_1 - Pressures of the air in the first chamber of pneumatic cylinder

P_2 - Pressures of the air in the second chamber of pneumatic cylinder

P_{cr} - Critical pressure ratio

P_d - Downstream pressures

P_s - Supply pressure

P_u - Upstream pressures

R - Ideal gas constant

RMS - Root Mean Square

V_{01} - Inactive volume at the end of the stroke and admission ports of the pneumatic

V_c - Control Signal

x - Piston position relative to the middle of the stroke

Z_u - Vertical displacement of the wheel axle

Z_s - Vertical displacement of the vehicle body

Z_r - Vertical displacement of road profile

$\dot{Z}_u$ - Vertical velocity of the wheel axle

$\dot{Z}_s$ - Vertical velocity of the vehicle body

$\dot{Z}_r$ - Vertical velocity of road profile

$\ddot{Z}_u$ - Vertical acceleration of the wheel axle

$\ddot{Z}_s$ - Vertical acceleration of the vehicle body