ANALYSIS OF A FOUR STATE SWITCHABLE HYDRO-PNEUMATIC SPRING AND DAMPER SYSTEM

CHRISTIAAN LAMBERT GILIOMEE

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By

Christiaan Lambert Giliomee

Study leaders: Prof. JL van Niekerk, Mr. PS Els

Department of Mechanical and Aeronautical Engineering

University of Pretoria

Summary

Spring and damper characteristics determine to a large extent the ride quality and handling of a vehicle. Since the requirements for good ride and good handling are conflicting, adjustable suspension elements are developed. In this study a two-state semi-active hydro-pneumatic spring, in conjunction with a two-state semi-active hydraulic damper is investigated. A mathematical model of the spring/damper system is developed and verified with measured data.

Two types of tests were performed on a prototype spring/damper unit, namely characterisation tests and single degree of freedom tests. The characterisation tests included characterising the hydro-pneumatic spring, the hydraulic damper, as well as the hydraulic valves in terms of valve response times. For the single degree of freedom tests, the step response, random input response and sine sweep response were determined.

Simulation models of the characterisation setup, as well as the single degree of freedom setup were constructed in Matlab Simulink. A real gas, thermal time constant model was used for modelling the hydro-pneumatic spring, while a look-up table was used for the damper characteristics. A hydraulic flow model was developed from first principles and first order valve dynamics were also included in the models.

Good correlation was obtained between measured and simulated data for the characteristation tests, as well as the single degree of freedom tests. The spring/damper model can be incorporated into a full 3D vehicle model in order to predict the ride and handling of a vehicle fitted with such a system.

ANALISE VAN ‘N VIER-TOESTAND SKAKELBARE HIDROPNEUMATIESE VEER- EN DEMPERSTELSEL

Deur
Christiaan Lambert Giliomee

Studie leiers: Prof. JL van Niekerk, Mnr. PS Els

Departement Meganiese en Lugvaartkundige Ingenieurswese

Universiteit van Pretoria

Opsomming

Veer- en demperkarakteristieke bepaal tot ‘n groot mate die ritgemak en hantering van ‘n voertuig. Aangesien die vereistes vir goeie ritgemak en goeie hantering teenstrydig is, word verstelbare suspensie elemente ontwikkel en gebruik. In hierdie studie word ‘n twee-toestand semi-aktiewe hidropneumatiese veer, gekoppel met ’n twee-toestand semi-aktiewe hidrouliese demper ondersoek. ’n Wiskundige model van die veer- en demperstelsel is ontwikkel en geverifieer met gemete data.

Twee tipes toetse is uitgevoer op die veer- en demperstelsel, naamlik karakteriseringstoetse en enkelvryheidsgraad toetse. Die karakteriseringstoetse het behels die karakterisering van die hidropneumatiese veer, die hidrouliese demper, asook die bepaling van die kleprespons tye. Enkelvryheidsgraad toetse het ingesluit trap respons, willekeurige en sinusvormige opwekking toetse.

Simulasiemodelle van die karakteriseringsopstelling, asook die enkelvryheidsgraad opstelling is geprogrammeer in Matlab Simulink. ‘n Werklike gas, termiese tydskonstante model is gebruik vir die hidropneumatiese veer model, terwyl oplees tabelle gebruik is vir die demper model. Die hidrouliese vloei model is afgelei uit eerste beginsels en eerste orde klep dinamika is ook ingesluit in die modelle.

Goeie korrelasie tussen gemete en gesimuleerde data is verkry vir die karakteriseringstoetse, asook die enkelvryheidsgraad toetse. Die veer- demperstelsel kan nou in ‘n volledige drie-dimensionele voertuig model ingebou word om die ritgemak en hantering van ’n voertuig met so ’n suspensie te voorspel.

All models are wrong. Some are useful.

J. Box

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INDEX

ABBREVIATIONS

2D	-	Two dimensional
3D	-	Three dimensional
A/D	-	Analogue to Digital
ADAMS	-	Automatic Design and Analysis of Mechanical Systems
APC	-	Armoured Personnel Carrier
APG	-	Aberdeen Proving Grounds
ASC	-	Adaptive Suspension Control
AFV	-	Armoured Fighting Vehcile
ATV	-	All Terrain Vehicle
BWR	-	Benedict-Webb-Rubin
D/A	-	Digital to Analogue
DADS	-	Dynamic Analysis and Design System
EAS	-	Electronically Controlled Air Suspension
FRF	-	Frequency Response Function
GVM	-	Gross Vehicle Mass
HIL	-	Hardware in the Loop
HSS	-	Hydro-pneumatic Suspension System
MBT	-	Main Battle Tank
PRC	-	Programmed Ride Control
RAM	-	Random Access Memory
RMS	-	Root Mean Square
SDOF	-	Single Degree of Freedom
TEMS	-	Toyota Electronically Modulated Suspension
TACOM	-	Tank Automotive Command
USMC	-	United States Marine Core
VTF	-	Vehicle Test Facility

LIST OF FIGURES