TIME DELAY IN A SEMI-ACTIVE DAMPER

by
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Submitted in partial fulfilment of the requirements for the degree

M Eng (Mechanical Engineering)

in the
Department of Mechanical and Aeronautical Engineering,

University of Pretoria, South-Africa

March 2000

Ad Destinatum Persequor

UNIVERSITEIT VAN PRETORIA
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Abstract

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Key words Hydraulic valve, Simulation, Fluid power, Time delay, Semi-active suspension

In this study the feasibility of two mathematical models of the dynamics of a hydraulic bypass valve used on semi-active suspension systems for heavy vehicles is investigated. It is envisaged that similar models will eventually be incorporated into a full vehicle, three dimensional simulation study. The valve system contains an electro-hydraulic pilot valve circuit, a logic element, a damper and four check valves in a rectifier configuration.

Models were compiled from first principles in the MATLAB environment and with the commercial fluid power simulation software, AMESim. The numerical methods used in the MATLAB model were found to be incapable of solving the stiff, nonlinear and discontinuous governing equations efficiently, while AMESim is very capable of handling detailed and complex fluid power models.

Experimental work was conducted to determine certain steady state model parameters and to obtain dynamic performance data with which to validate model integrity.

Several external factors influenced the valve behaviour during experiments making data extraction challenging. Simple first order assumptions accounting for the external influences on the valve therefore had to be included in the models. If this is done the basic dynamic behaviour of the valve system is matched well by the models. In general, the number of unknown parameters associated with fluid power systems accounted for the largest portion of the error between the simulated and measured response.

The model as developed proved the possibility of creating highly accurate models but also indicated the amount of effort needed for their compilation.

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Opsomming

TYDVERTRAGING IN 'N SEMI-AKTIEWE DEMPER

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Sleutelwoorde Hidrouliese klep, Simulasie, Vloeierdrywing, Tydvertraging, Semi-aktiewe suspensie

In hierdie studie word die lewensvatbaarheid van twee wiskundige modelle van die dinamika van 'n hidrouliese verbyvloeiklep wat op semi-aktiewe suspensie gebruik word, ondersoek. Dit word voorsien dat soortgelyke modelle mettertyd in vol-voertuig, driedimensionele voertuigsimulasiestudies gebruik sal word. Die klepstelsel bestaan uit 'n elektro-hidrouliese beheerklep, 'n logiese element, 'n demper en vier eenrigtingkleppe in 'n gelykrigterkonfigurasie.

Modelle is uit eerste beginsels in die MATLAB omgewing opgestel en met die kommersiële vloeier-drywing simulasiepakket AMESim. Daar is gevind dat die numeriese metodes wat in MATLAB gebruik is, nie geskik is om die stywe, nie-lineêre, diskontinue stelsel vergelykings op te los nie. Daarenteen is AMESim by uitstek geskik om gedetaileerde en komplekse hidrouliese stelsels te modelleer.

Eksperimentele werk is uitgevoer om sekere gestadige toestand modelparameters te vind. Dinamiese metings is ook uitgevoer om die model se dinamiese gedrag teen te korreleer.

Verskeie eksterne faktore het die klepstelsel se dinamiese gedrag tydens eksperimentele werk beïnvloed, wat sodoende die verwerking van data bemoeilik het. Eenvoudige eerste-orde aannames moes daarvoor in die modelle gemaak word. As dit gedoen word, word die basiese dinamiese gedrag van die klepstelsel goed gemodelleer. In die algemeen kan daar gesê word dat die hoeveelheid onbekende model parameters die grootste deel van die foutterm uitmaak.

Die model soos ontwikkel, bewys die moontlikheid vir die ontwikkeling van hoogs akkurate modelle, maar dui ook die hoeveelheid arbeid nodig vir die osptel daarvan aan.

"Humanity's deepest desire for knowledge is justification enough for our continuing quest. And our goal is nothing less than a complete description of the universe we live in."

Stephen W. Hawking
A brief history of time

Fluid power has come a long way. Archimedes started this revolution on earth in the third century BC by observing how forces are transmitted through a fluid. Thousands of years later, Pascal stated the fundamental law of hydrostatics in 1648. He worked on the design of a machine used for force amplification, but only in 1795 did Bramah patent a hydraulic press. Many regard Bramah as the founder of fluid power technology, although a key component of his press was a self-sealing gland devised by Maudsley. In 1851, a weight loaded accumulator was devised by W Armstrong. Later mineral oil replaced water as hydraulic power transmission fluid and the fluid power industry was born. [Burrows 1994] Today, Fluid power technology boasts with some of the highest energy density forms of power transmission. Active accumulators can be used to reduce high frequency pulsations (0.5-1kHz) causing noise and vibration [Yokota 1996]. Actuators can be positioned within 1 μm with forces difficult to control with any other technology. Active suspension systems are implemented on a number of machines including our first supersonic car and in the foundations of the Eiffel Tower to compensate for subsidence [Burrows 1996].

Baie dankie

Aan professor Jasper Steyn, vir die voorreg om onder sy leiding te kon studeer. Sy volgehoue insette het veel meer as die akademiese vlak van my lewe positief beïnvloed.

Aan Ermetek vir die geleentheid om hierdie projek te kon aanpak, vir die toerusting wat tot my beskikking gestel is en vir die deurlopende advies.

To Imagine SA (France) for the extended copy of AMESim to the University of Pretoria. Your software proved to be a key element in the success and completion of this project.

Aan die Laboratorium vir Gevorderde Ingenieurswese (LGI) vir die finansiële ondersteuning, asook die beskikbaarstelling van die laboratoriumgeriewe.

Aan mnr Schalk Els vir tegniese advies en emosionele ondersteuning. Dit het baie berge klein gemaak.

Hierdie studie word opgedra aan Tan

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Abbreviations and variables

Abbreviations

AME, MAT, EXP	Used mainly in figures to indicate AMESim, MATLAB and Experimental trends
BDF	Backward Difference Fitting
CFD	Computational Fluid Dynamics
DADS	Dynamic Analysis and Design System
DAE	Differential Algebraic Equation
DEQ	Differential EQuation
FEM	Finite Element Method
LGI	Laboratory of Advanced Engineering
LPM	Litre Per Minute
LVDT	Linearly Variable Differential Transformer
ODE	Ordinary Differential Equation, also the name of a MATLAB procedure
PDE	Partial Differential Equation
PID	Proportional, Integration and Differentiation control algorithm
PWM	Pulse Width Modulation
SS	Steady State
LC or LC 25	Name of the Logic element used in this study
WSE or WSE 3d	Name of the Electrohydraulic valve used in this study
CP 108 (1or2)	Name of the check Valve used in this study
CSS	Name of a Displacement Transducer used in this study

Selected variables

P	Pressure, deltaP or ΔP refers to pressure drop
Q	Flow
QC	Excess Flow into a control volume
x	Displacement
$\dot{x}$	Velocity
$\ddot{x}$	Acceleration
A	Area
V	Volume
Dia or Diam	Diameter
Cd	Coefficient of Discharge
ρ	Density
β	Bulk Modulus
Re	Reynolds Number
ν	Kinematic Viscosity
F	Force