International Journal of Fluid Power

Volume 10
Number 3
November 2009

AIMS AND SCOPE

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- analysis, modelling and control,
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International Journal of Fluid Power is abstracted and indexed in: Cambridge Scientific Abstracts, European Environmental Information Database, CEDEFOP-Training Village, Fachinformation Technik, Elsevier Compendex Engineering Information.

International Journal of Fluid Power

ISSN 1439-9776

Volume 10
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The International Journal of Fluid Power homepage can be found at:
http://journal.fluid-power.net

The Fluid Power Net homepage can be found at:
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Publication information
International Journal of Fluid Power (ISSN 1439-9776) is moving towards quarterly publication. Currently, three issues are planned for 2009. Annual 2009 subscription 98 € (print or digital version). Subscriptions are automatically extended every year. Cancellation is possible by fax or mail. For an additional version (digital or print) the subscription rate is 49 €. (All prices are with postage and packaging, not including VAT). All subscriptions are payable in advance. Payment may be made by credit card with VISA or Mastercard. Payments with Euro cheque, Dollar cheque or by international bank transfer (all bank fees to customers account) with 13 € handling charge. Issues are sent by standard mail. Further information is available on journal's website http://journal.fluid-power.net.

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Publishing and production
TuTech Innovation GmbH, Harburger Schloßstraße 6-12, 21079 Hamburg, Germany.

This journal is printed by Schüthedruck GmbH, Hamburg on acid-free paper, which meets the requirement of the ANSI Standard Z39.48-1984 specification for performance of paper and library materials.

ISSN 1439 9776

ACTIVE VIBRATION DAMPING FOR AN OFF-ROAD VEHICLE WITH DISPLACEMENT CONTROLLED ACTUATORS

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Abstract

Mobile earthmoving machines typically do not have wheel suspension. Consequently, vehicle dynamics are under-damped, and operators experience vibrations of low frequency and high amplitude which are detrimental to health, comfort and productivity. For most vehicles, the state of the art for improving ride quality is passive energy dissipation via seat dampers and hydraulic accumulators connected in parallel to the actuators. Alternatively, ride quality may be enhanced by active control of the seat or working actuators. In the present work, active vibration damping is considered for a skid-steer loader based on control of the flow rate to the boom lift cylinders with a variable displacement pump. A four degrees of freedom vehicle dynamic model is derived for linear motion in the vertical and horizontal directions, pitching angle, and boom motion with respect to the chassis. Dynamics of the hydraulic pump and actuator are also modelled. Considering the requirements of the intended application, the feedback control design emphasizes simplicity of implementation. The control law is a multi-DOF version of the well-known "skyhook damper" principle, where the control force is proportional to the vehicle velocity. Cascaded feedback loops of pump displacement and pressure produce the required force. An experimental evaluation was conducted according to ISO 2631-1 (1997) to measure the effect of the active controller on whole-body vibration as perceived by the operator. The active damping system reduced total vibration by as much as 34% and was consistently superior to a commercially available passive damping solution. Another controller with only pressure and position feedback was also tested; its performance was similar to the passive accumulators.

Keywords: active vibration damping, active suspension, displacement control, pump control, pressure control, loader

MODEL DEVELOPMENT AND EXPERIMENTAL ANALYSIS OF A VIRTUALLY VARIABLE DISPLACEMENT PUMP SYSTEM

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Abstract

This work presents the modelling and testing of a Virtually Variable Displacement Pump (VVDP). The system used a high speed on/off valve to modulate flow from a fixed displacement pump, directing the flow either to the tank or high pressure supply line of the hydraulic system. A lumped parameter model of the system was developed using sub-models to describe the dynamics of each component in the system. A test setup using currently available components was built to validate the overall system model and study the effects of switching frequency on system efficiency. Once verified, the model was used to simulate and further study the effects of changing the compressible fluid volume and line lengths. Simulation results show that reducing the line lengths and compressible volume improves the average VVDP system efficiency by 14 % over a range of switching frequencies and duty cycles while holding other system parameters constant.

Keywords: Virtual Variable Displacement Pump, Lumped Parameter Model, Verification, Optimization

CONTROL OF AN ADJUSTABLE HELMHOLTZ RESONATOR IN A LOW-PRESSURE HYDRAULIC SYSTEM

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Abstract

The theory of controlling adjustable tuned vibration absorbers (incl. the adjustable Helmholtz resonator) is reviewed. The theory review is completed with analytical models containing a two-degrees-of-freedom spring-mass model in which the spring constant between the primary system and the vibration absorber is controlled. The main focus of this paper is on the Helmholtz resonator in a hydraulic system, so all parameters are adapted to hydraulics. Two control methods are presented, open loop and closed loop. Both methods are modelled analytically and the models are experimentally verified by means of hydraulic test equipment consisting of a main pipe and an adjustable Helmholtz resonator. The open-loop control identifies the disturbance frequency and then adjusts the volume of the adjustable resonator accordingly by using a previously produced control list that contains information on frequency and corresponding cavity volume (piston position). The closed-loop control adjusts in order of different volumes of the resonator while continuously measuring the response of the system, and after this identifying phase the resonator is adjusted to the volume that produced the most favourable response. The peak-to-peak values in the main pipe were measured and the 20 dB attenuation level was measured when the resonator was used.

Keywords: control, helmholtzresonator, hydraulics

INCREASING HYDRAULIC ENERGY STORAGE CAPACITY: FLYWHEEL-ACCUMULATOR

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Abstract

The energy storage density of hydraulic accumulators is significantly lower than energy storage devices in other energy domains. As a novel solution to improve the energy density of hydraulic systems, a flywheel-accumulator is presented. Energy is stored in the flywheel-accumulator by compressing a gas, increasing the moment of inertia of the flywheel by adding hydraulic fluid, and by increasing the angular velocity of the flywheel. Through a numerical model of the energy flows in the system, the energy storage of the flywheel-accumulator was demonstrated to be approximately 10 times greater than a conventional accumulator. Furthermore, the flywheel-accumulator allows the hydraulic system pressure to be independent of the quantity of energy stored. The integral flywheel-accumulator presents numerous future research challenges, yet offers the potential to transform and enable numerous applications including plug-in hydraulic hybrid vehicles.

Keywords: hydraulicenergystorage, flywheel, accumulator, hydraulichybridvehicle

NUMERICAL AND EXPERIMENTAL INVESTIGATION ON O-RING-SEALS IN DYNAMIC APPLICATIONS

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Abstract

This paper presents a physically-based simulation approach to predict the friction force at oil lubricated contacts for rubber o-ring seals in dynamic applications. In the boundary lubrication regime the friction coefficient is calculated using a recently developed contact mechanics theory. The stress and strain fields in the rubber are calculated using the finite element analysis (FEA). In the FEA the temperature-dependent nonlinear rubber behaviour is considered. Loads due to the assembly process, thermal expansion, system pressure and tangential friction forces are included in the analysis. In the mixed and hydrodynamic lubrication regimes, the asperity-asperity and fluid-asperity interactions are determined from the Persson's dry-contact mechanics theory, the Reynolds-equation (gap flow) and the deformation model of the seal. To test the theory a test rig has been developed. Simulation results, carried out for an unpressurized o-ring seal system, are compared to the experimental data and, especially for small velocities where mixed lubrication prevails, the results are in good agreement.

Keywords: hydraulics, pneumatics, o-ring seal, finite element analysis FEA, gap flow, rubber friction, contact mechanics, fluid structure interaction