inter•noise 96
25th Anniversary Congress – Liverpool

INCE: 46.4

ACTIVE VIBRATION CONTROL OF OPERATOR SEAT FOR HEAVY MACHINERY

T Uhl, J Kowal, T Salamon & Z Korendo

University of Mining and Metallurgy, Faculty of Mechanical Engineering, Department of Robotics and machine Dynamics, Kraków, Poland

1. INTRODUCTION

The main goal of active suspension of a driver seat is to improve the comfort for the driver and safety for his operation. These two requirements are in conflict, because if we consider comfort the spring should be very weak (driver acceleration should be small as possible), but if we consider safety the relative deflection of seat and car should be small as possible, this requires very stiff spring in the seat suspension. Therefore the design of the seat suspension is relatively complex task. It can be said that the conventional passive systems have reached limits of their performance for seat suspension [7]. To further improve suspension properties, many studies dealt with semiactive [1,2,9] and active systems [3,8]. Also some practical solutions have been reported [7]. Because of the difficulties in the design and complexity of modern suspension systems a new computer based design technology is required [8]. One possibility of the design of such system is presented in this paper.

2. ACTIVE SUSPENSION - LABORATORY SYSTEM

Research works were done on special designed and constructed active suspension system of operators seat in our laboratory.

Scheme of the system is presented in figure 1. The experimental setup consists of pneumatic and mechanical part. The metal bellows used as actuators are very flexible and has very low inertia. The DOWTY PN211 proportional servovalve were used to control the pressure inside bellows.

The following signals were recorded during experiment: control signals of the valve, internal pressure of the bellows and seat displacement.

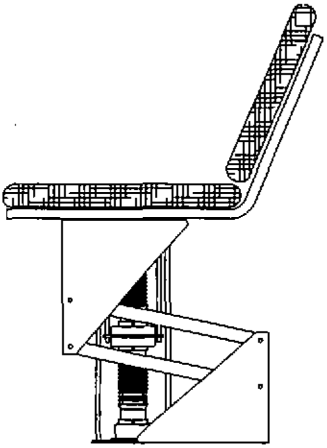

Fig. 1. The experimental setup

3. MODEL IDENTIFICATION

In order to investigate the basic performance of the antagonised bellows two parts of model were distinguish: H1 – electro-pneumatic and H2 – mechanical.

The system was excited with chirp sinus signal within frequency range of 0.5 Hz to 16 Hz. during identification and controller performance test.

The electro-pneumatic part of the system can be described with the following equation [16]:

$$\frac{dP_i}{dt} = \frac{dM(u,P)_i}{dt} + \gamma \frac{RT}{V_i} - \frac{dx}{dt} \gamma \frac{SP_i}{V_i}$$

where: P_i — internal pressure of the metal bellows, i=1,2, M_i — mass of the pressured air, S — effective cross-section area of the bellows, T — temperature, R — air gas constant, γ — specific heat ratio, V — specific heat ratio, x — displacement, u — control voltage of servovalve.

The equation was linearized around the equilibrium point and the following transfer function of electro-pneumatic part of the system has been assumed:

$$H_1(z^{-1}) = \frac{b_{1,0} + b_{1,1}z^{-1} + b_{1,2}z^{-2}}{1 + a_{1,1}z^{-1} + a_{1,2}z^{-2} + a_{1,3}z^{-3} + a_{1,4}z^{-4}}.$$

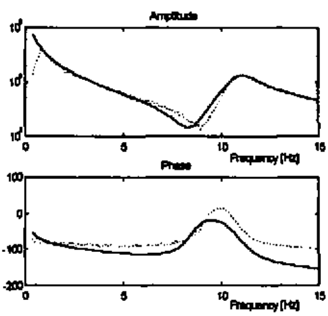

Fig. 2. H_1: Spectral transfer function (dotted line) — measured, analytical transfer function (solid line) — simulated.

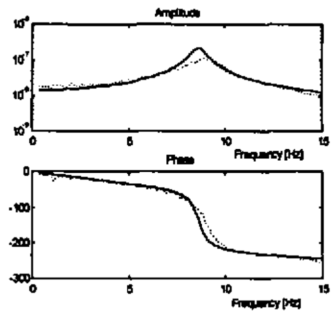

Fig. 3. H_2: The adjustment between the spectral transfer function (dotted line) — experimental and analytical model (solid line) — simulated

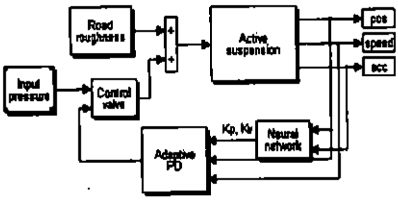

Fig. 4. Simulink block diagram with applied neural based controller.

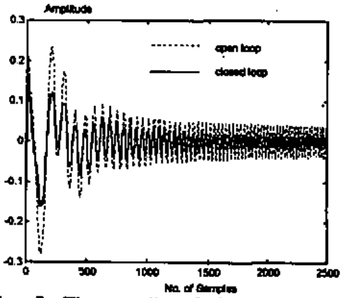

Fig. 5. The results of the controller performance testing.

The mechanical part of the system can be described by the following formula:

$$m\ddot{x} + b\dot{x} + kx = S(P_1 - P_2) - F$$

where: m — mass of the seat, b — viscous friction coefficient, k — stiffness (spring rate) of the bellows, S — effective cross-section area of the bellows, P — internal pressure, F — external force.

Based on the linear relations between displacement and pressure the following transfer function is assumed:

$$H_2(z^{-1}) = \frac{b_{2,1}z^{-1} + b_{2,2}z^{-2}}{1 + a_{2,1}z^{-1} + a_{2,2}z^{-2}}.$$

The least square method was used to estimate the parameters. The experimental (doted line) and simulated results are shown in figures 2 and 3.

Identified models are based for control system design.

4. CONTROL SYSTEM DESIGN AND HARDWARE IMPLEMENTATION

The control algorithm was implemented on dSPACE DS1102 floating-point controller board installed in PC. The board is based on Texas Instruments DSP TMS320C31 with a set of on-board I/O.

The Matlab Control Toolbox and Neural Networks Toolbox has been used for PD with variable gains controller design, for the system behaviour simulation the SIMULINK block diagram has been applied. The idea of applied controller consists in changing the system pools out of the input signal frequency range (Fig. 4).

The experimental results of controller performance testing are shown in figure 5. The chirp sine signal has been applied for performance testing of the designed controller.

5. CONCLUSIONS AND FINAL REMARKS

The integrated design methodologies for active suspension control systems has been presented. We found that the employed hardware and software tools are very effective for the design process. In particular we have investigated the new neural networks based controller for active suspension system. We also with a success implemented this neural network based controller in hardware for experimental setup.

6. LITERATURE

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