DESIGN OF MECHATRONIC COMPONENTS FOR AUTOMOTIVE INDUSTRY BY DISTRIBUTED PARAMETER SYSTEMS BLOCKSET FOR MATLAB & SIMULINK

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Abstract

In paper the basic constructional parts as beam and plate with piezoelements are considered. Dynamical models in the form of lumped-input/distributed-output systems are introduced. Distributed dynamical characteristics are analysed and distributed parameter control loops are arranged for considered smart structures, where time parts of control synthesis are solved by controllers of PPF (positive position feedback) and PVF (positive velocity feedback) type. At distributed parameter control systems analysis and design Distributed Parameter Systems Blockset for MATLAB & Simulink – third-party MathWorks product is exploited, www.dpscontrol.sk.

1 Introduction

In automotive industry diverse software products for sofisticated dynamical analysis of constructional components of complex forms are exploited as: MATLAB, FEMLAB, ANSYS, FLUENT, PAM-SYSTEMS, STAR-CD, etc. These machine parts as dynamical systems are distributed parameter systems given on complex definition domains. Distributed dynamical characteristics obtained in these software environments offer wide possibilities to design these components as mechatronic systems – distributed parameter smart structures.

2 Beam and plate with piezoelements

As basic mechatronic components of automotive constructions clamped beam and plate with piezoelements can be considered.

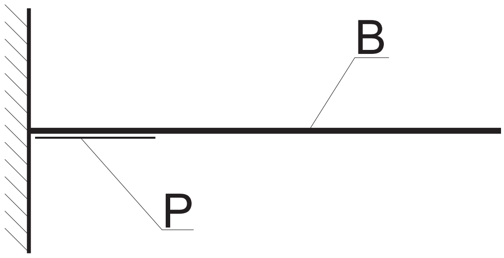

Figure 1: Clamped beam – B with piezoelement – P

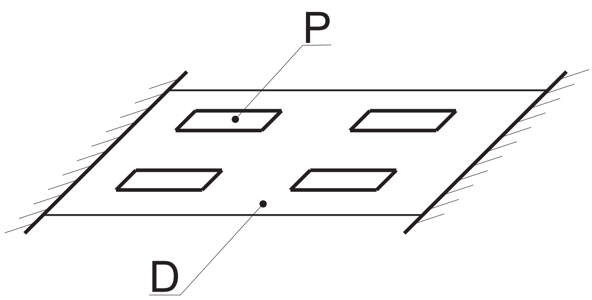

Figure 2: Clamped plate – D with piezoelements – P

For dynamical analysis a beam as aluminium-base alloy shell with dimensions 450x40x4 mm is considered. Piezoelement qp40w Quickpack is product of MIDE. It is a strain actuator only bonded on the surface of beam with full strain extension ±280 με at ±200 V. Dimensions of piezoelements are 101x25x1 mm. Dynamical analysis of beam with piezoelement is done in ANSYS environment, Fig. 3

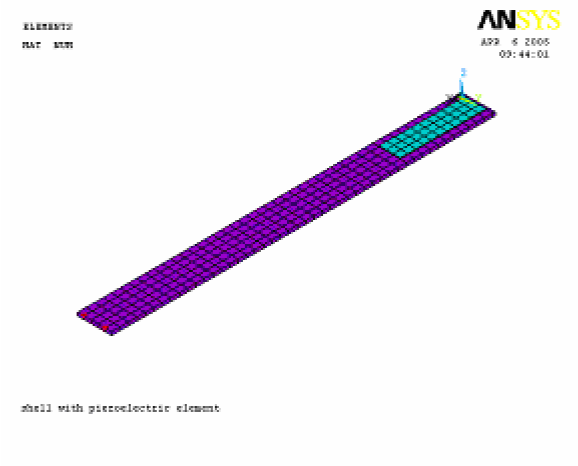

Figure 3: Beam with piezoelement as distributed parameter system in ANSYS environment

3 Distributed Parameter Systems Blockset for MATLAB & Simulink

The Distributed Parameter Systems Blockset is a blockset for use with MATLAB & Simulink for distributed parameter systems and their applications in modeling, control and design of dynamical systems given on complex 3D domains of definition, see Fig. 4. – www.dpscontrol.sk .

The blockset features:

- Engineering methods for DPS modeling, control and design
- DPS models based on lumped-input/distributed-output systems, time/space analysis, synthesis and design tools
- Distributed parameter PID, algebraic, state space and robust control schemes
- DPS Wizard demonstrates in step-by-step operation distributed parameter control loops arrangement and setting procedures
- Suite of blocks and schemes for DPS control practically in any field of technical practice
- Interactive Control Service for support DPS control solutions via the internet

The block **HLDS** models controlled distributed parameter systems as lumped-input/distributed-output systems with zero-order hold units. The **DPS Control Synthesis** provides feedback to distributed parameter controlled systems in control loops with blocks for **PID, algebraic, state space and robust** control. The block **DPS Input** generates distributed quantities which can be used as distributed control variables or distributed disturbances, etc. **DPS Display** presents distributed quantities with many options including export to AVI files. The block **DPS Space Synthesis** performs space synthesis as an approximation problem. The block **Tutorial** presents methodological framework for formulation and solution of distributed parameter systems of control. The block **Show** contains motivation examples: Control of temperature field of 3D metal body, Control of 3D beam of „smart“ structure, Adaptive control of glass furnace and Groundwater remediation control. The block **Demos** contains examples oriented to methodology of modeling and control synthesis. The **DPS Wizard** in step-by-step operation, by means of five model examples on 1D-3D with default parameters, gives a guide for arrangement and setting distributed parameter control loops.

4 Analysis of Distributed Parameter characteristics

At piezoelement step input in ANSYS environment field of displacements of the beam is computed in 624 points as distributed parameter transient response. This results along with sampling period and amplitude of step change are given in HLDS block.

At periodic disturbance on free end of the beam the distributed parameter output is appeared on DISPLAY of DPS Blockset, Fig. 5, 6, where matrix of computational nods and serial numbers of vertexes of basic geometry elements in counterclockwise direction are specified in this block.

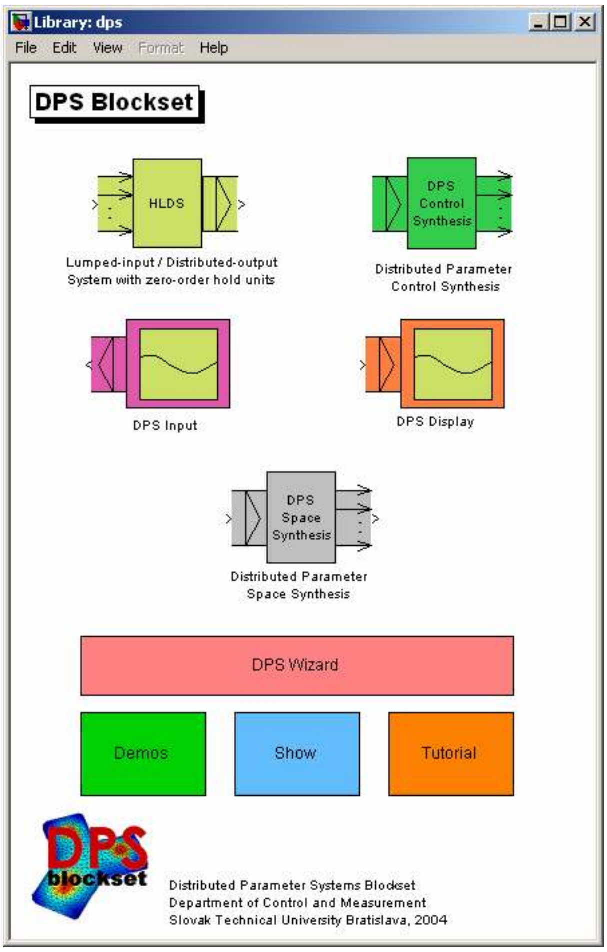

Figure 4: DPS Blockset for MATLAB & Simulink

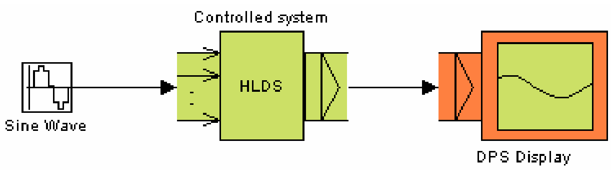

Figure 5: Model of beam with piezoelement as distributed parameter system

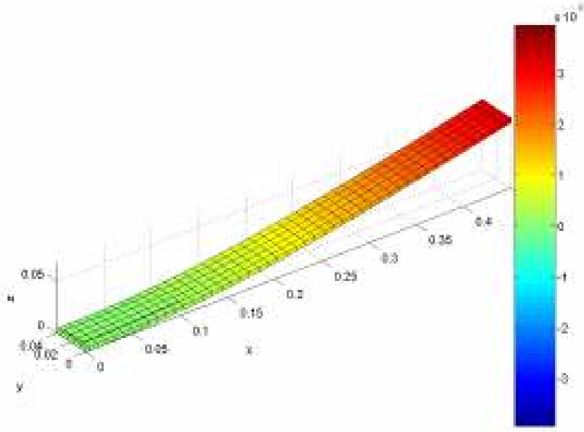

Figure 6: Periodic lumped disturbance action on free end of beam with piezoelement

5 Distributed Parameter Systems of control

In the MATLAB & Simulink environment by means of the DPS Blockset distributed parameter system of control is arranged - Fig. 7.

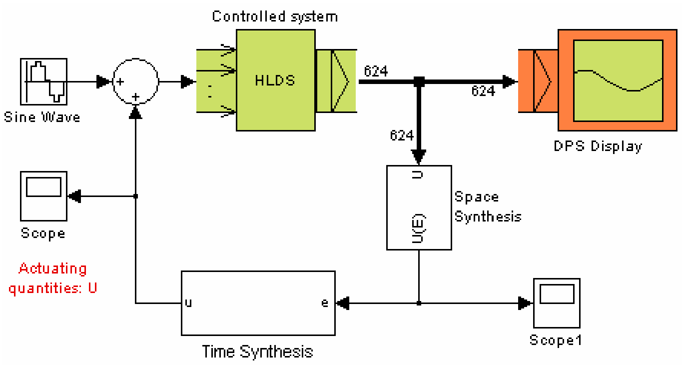

Figure 7: Distributed parameter system of control

For the synthesis in time direction PPF (positive position feedback) and PVF (positive velocity feedback) type controllers are used.

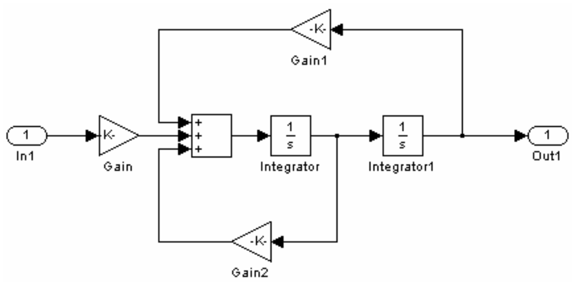

Figure 8: Model of PPF type controller

6 Simulation of control process

First the control of beam with piezoelement at PPF controller application was simulated. PPF type controller in time direction was realised in state-space. The actuation quantities depend on values of damping and gain of controller. In relation to the values of damping and gain various courses of output quantities are obtained. It means various reductions of controlled signal amplitudes. Because controlled system is excitated by periodic signals with eigenfrequencies the control process looses stability, what is seen at disconnected controller – unstable oscillation on free end of the beam, Fig. 9.

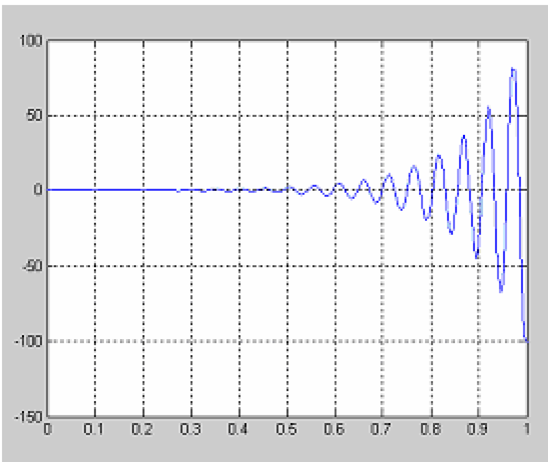

Figure 9: Unstable controlled quantity oscillation on free end of the beam at disconnected controller

Controlled system output quantity course at PPF for damping ξ= 0,02 and gain K=15 values is in Fig. 10. For this tuning of controller 78,9 % reduction of controlled quantity amplitude is obtained.

Controlled quantity course on free end of the beam at PVF type controller is in Fig. 11.

For damping ξ = 0,01 and gain K=1575 values of PVF controller 83,3 % reduction of controlled quantity amplitude is obtained.

Controlled system output quantity course at PVF for damping ξ = 0,001 and gain K=1475 values is in Fig. 12. For this tuning of controller 82,9 % reduction of controlled quantity amplitude is obtained and the given desired position of the beam is followed. Fig. 13.

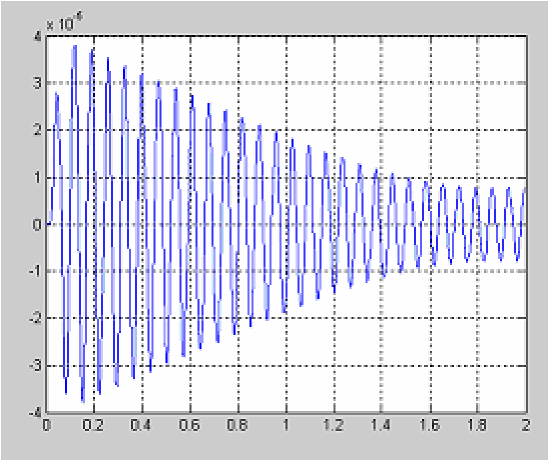

Figure 10: Controlled quantity course on free end of the beam at PPF type controller

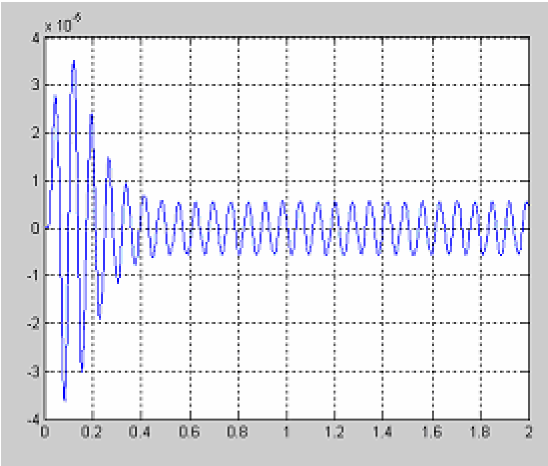

Figure 11: Controlled quantity course on free end of the beam at PVF type controller

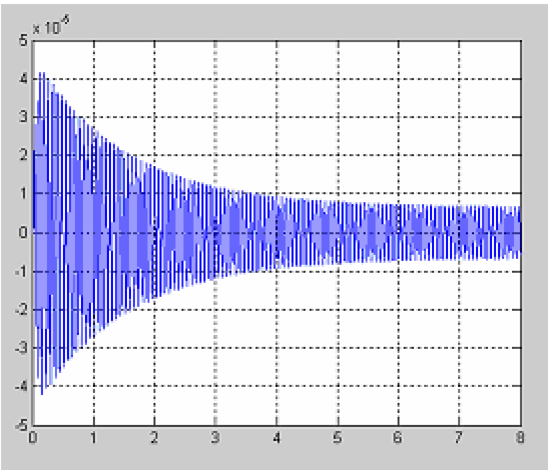

Figure 12: Controlled quantity course on free end of the beam at PVF type controller

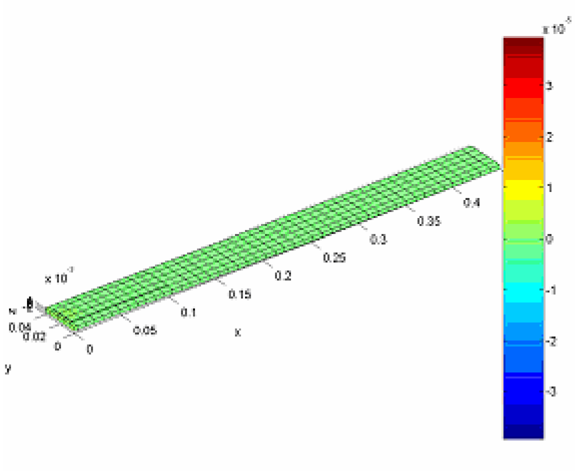

Figure 13: Final position of the beam with piezoelement at PVF type controller

Acknowledgement

This work has been carried out under the financial support of the Slovak Scientific Grant Agency VEGA for project „Control of Systems Given by Numerical Structures on Complex Definition Domains with Demonstrations via Internet“ (grant 1/9278/02), Slovak State Agency for Science and Technology for project „Modeling, Control and Simulation of Distributed Production Systems" (grant APVT-51-011602) and ESF project of EU - JPD 3 2004/1-032, project code 13120200024.

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