Jerzy POKOJSKI, Jerzy WRÓBEL

Institute of Machine Design Fundamentals
Warsaw University of Technology, Warsaw, Poland

THE COMPUTER AIDED DECISION MAKING IN THE DESIGN OF THE MECHANICAL ACTIVE SYSTEMS

Summary. In the paper the problem of the computer aided decision making in the design of the mechanical active systems is presented. The polyoptimization methodology approach is applied in the optimization of nonlinear characteristics for active, dynamic models. The rule based expert system is used for solving the problem of the optimal structure selection. As an example the class of simple 2 DOF active vehicle suspension models is considered. The results are compared with a passive model.

1. INTRODUCTION

The following article presents the problem of the optimal synthesis of mechanical active systems. The methodology is based on the multi-criteria programming methods and methods of the expert systems technology.

The active elements are becoming more popular in mechanical systems and specially in the vehicle suspensions. The plurality of applied solutions is in the opposition to the almost complete lack of theoretical frames for the efficient structures selection. In the literature we can observe many different models, with a different kind of active elements and different control systems.

The problem of optimal dynamic system synthesis, in this case, consists of two problems: how to select the structure of the dynamic, active system and what parameters should have a particular dynamic system. The first one is difficult for the detailed formalization. The expert system technology can be applied as a tool for its solving. The second problem can be solved with the help of polyoptimization methodology.

Most of considered, in the literature, models have two-degrees-of-freedom. As an example the class of simple two-degree-of -freedom active vehicle suspension models is considered too. The results are compared with a passive model, without active elements.

The polyoptimization methodology approach is applied in the optimization of nonlinear characteristics for active, dynamic models. The rule based expert system is used for solving the problem of the optimal structure selection.

The basic goal of this work is to create an efficient algorithm supporting a process of the structure and the characteristics of the dynamic system selection which give the most preferred dynamic behavior of the dynamic system.

2. THE STRUCTURE OF THE DECISION PROBLEM

Let's assume that there is considered the class of two-degree-of-freedom active dynamic models. Let's assume that this class consists of N structures. If we want to formulate the multi-criteria optimization problem for all these N structures, treated as one global problem, we should solve a sequence of single decision problems (for every structure) and compare final results [9,10] (fig.1). Such an approach costs a lot of calculations and it is not applied by human experts.

Human experts select some sequence of analyzed structures. Results which they got while optimization influence the next stage - next structures selection which are analyzed later (fig.2). This cycle is repeated.

In the paper there is considered some number of problems dealing with some particular structures. Authors - experts tried to acquire knowledge dealing with the problems:

- if there is some particular user, knowing his goal, expert system should suggest him which structure (or structures) and with what parameters should be considered by him first.

- after getting some results expert system should help the user in next structure (or structures) selection for the next step of examination. This stage can be repeated.

As a rule based expert system is used system JP from [11]. As a method of multi-criteria decision making is used approach with linear scalarization function [6,7].

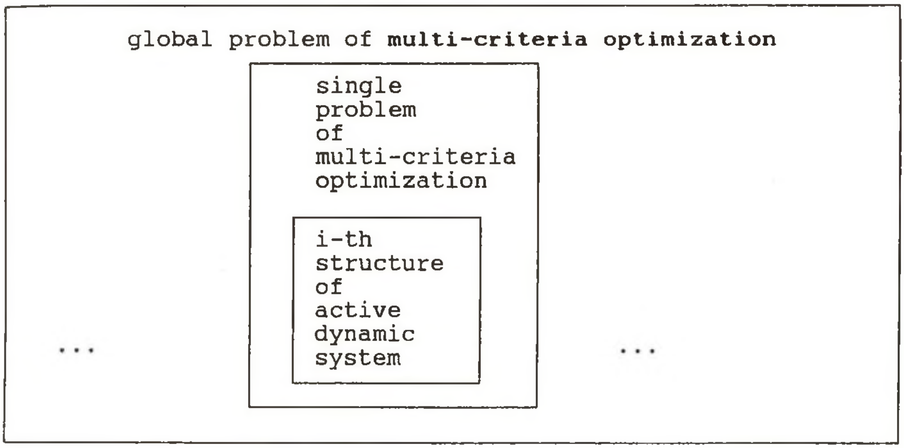

Fig.1. Approach with global multi-criteria optimization.

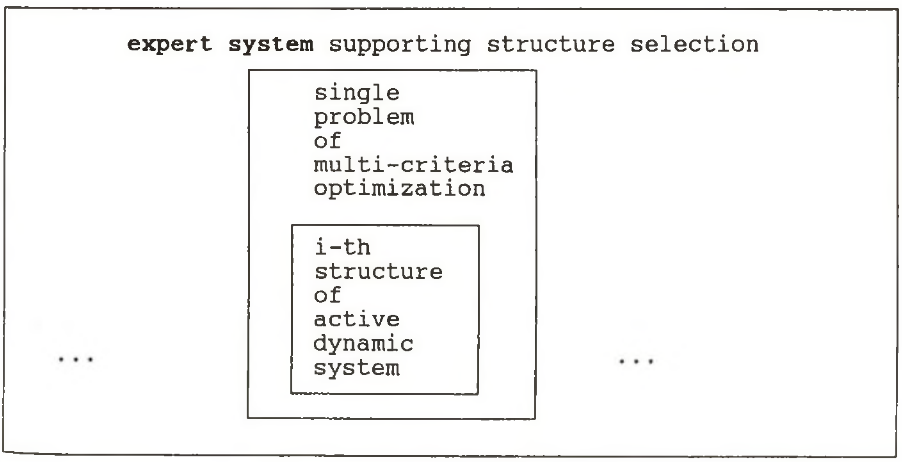

Fig.2. Approach with expert system supporting global problem solving.

3. MATHEMATICAL MODELS OF THE MACHINE DYNAMICS PROBLEMS

As an exemplary problem there is considered class of active dynamic models of vehicle suspension. The first exemplary problem is the following:

$$m_1\ddot{y}_1 + k_1(y_1 - y_2) + c_1(\dot{y}_1 - \dot{y}_2) + k_{pp}(y_2-q)=0$$
$$m_2\ddot{y}_2 + k_1(y_2 - y_1) + c_1(\dot{y}_2 - \dot{y}_1) + k_2(y_2 - q) + c_2(\dot{y}_2 - \dot{q}) - k_{pp}(y_2-q)=0 \tag{1}$$

where: m_1, m_2 - sprung mass, unsprung mass, y_1, y_2 - displacements of sprung and unsprung masses, k_1 - suspension stiffness coefficient, c_1 - suspension damping coefficient, k_2 - tire stiffness coefficient, c_2 - tire damping coefficient, k_{pp} - active element coefficient, q - kinematic excitation (gaussian stationary stochastic process with a given power spectral density).

The multi-criteria optimization problem has the following form:

Criteria:

$$Q_1 = \delta^2_{y_1-q}, \qquad Q_2 = \delta^2_{y_1-y_2}, \qquad Q_3 = \delta^2_{y_2}, \qquad Q_4 = \delta^2_{\ddot{y}_1} \tag{2}$$

Decision variables:

$$x = (k_1, c_1, k_{pp}) \tag{3}$$

Feasible domain:

$$\Phi = \{(k_1, c_1, k_{pp}) : k_{1min} \le k_1 \le k_{1max}, c_{1min} \le c_1 \le c_{1max}, k_{ppmin} \le k_{pp} \le k_{ppmax}\} \tag{4}$$

The second exemplary problems is the following:

$$m_1\ddot{y}_1 + F + c_1(\dot{y}_1 - \dot{y}_2) + k_{aa}\ddot{y}_2 = 0,$$
$$m_2\ddot{y}_2 - F + c_1(\dot{y}_2 - \dot{y}_1) + k_2(y_2 - q) + c_2(\dot{y}_2 - \dot{q}) - k_{aa}\ddot{y}_2 = 0 \tag{5}$$

where: k_{aa}- active element coefficient, q - kinematic excitation (only one harmonic wave), F - nonlinear force equal:

$$F = \begin{cases} k_o(y_1-y_2) + (k_o-k_1)a & \text{for} \quad (y_1-y_2) \le -a, \\ k_1(y_1-y_2) & \text{for} \quad |y_1-y_2| < a, \\ k_o(y_1-y_2) + (k_1-k_o)a & \text{for} \quad (y_1-y_2) \ge a. \end{cases} \tag{6}$$

The multi-criteria optimization problem has now the following form:

Decision variables:

$$x = (k_1, c_1, k_{aa}) \tag{8}$$

Feasible domain:

$$\Phi = \{(k_1, c_1, k_{aa}) : k_{1min} \le k_1 \le k_{1max}, c_{1min} \le c_1 \le c_{1max}, k_{aamin} \le k_{aa} \le k_{aamax}\} \tag{9}$$

Criteria:

$$
\begin{aligned}
Q_1 &= \max_{t\in[0,T]} |y_1(t) - q|, \\
Q_2 &= \max_{t\in[0,T]} |y_1(t) - y_2(t)|, \\
Q_3 &= \max_{t\in[0,T]} |y_2(t)|, \\
Q_4 &= \max_{t\in[0,T)} |\ddot{y}_1(t)|
\end{aligned}
\tag{7}
$$

For comparing there was considered passive system with random and deterministic excitation.

4. RESULTS OF THE EXEMPLARY PROBLEM SOLVING

Results of solving of some multi-criteria single decision problems are shown in the figures 3 and 4.

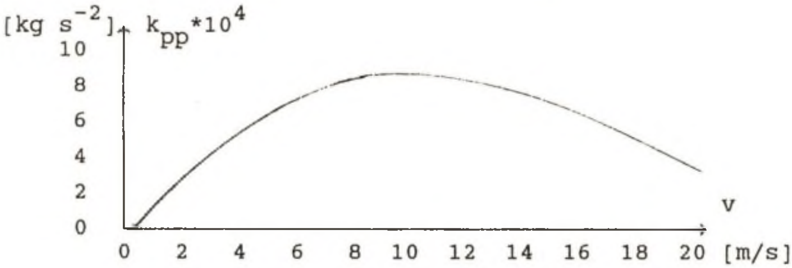

Fig. 3. The polyoptimal values of k_{pp} coefficient as a velocity function

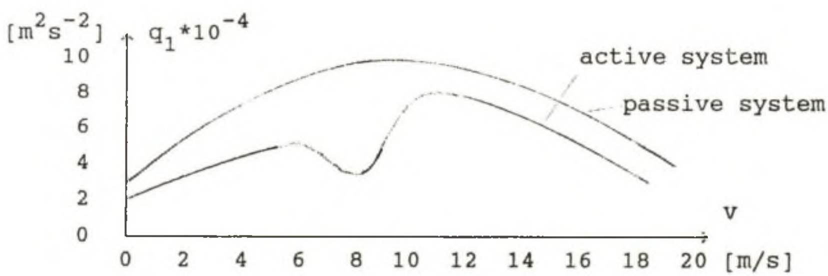

Fig. 4. The comparison between an active and passive system

The process of knowledge acquisition is in introductory stage. Authors- experts try to learn problem and articulate their knowledge in the form of rules and build own knowledge base.

5. FINAL CONCLUSIONS

The systematic hybrid (symbolic, numeric) approach shown in the paper allows to exploit human knowledge and intuition for faster large optimization problem solving in machine dynamics.

REFERENCES

[1] Bestle D., Eberhard P.: Analyzing and Optimizing Multibody Systems. Mech. Struct. & Mach.20(1), pp 67-92 (1992).

[2] Brown D., Leifer L.: The Role of Meta-Level Inference in Problem Solving Strategy for a Knowledge - Based Dynamics Analysis Aid. Jour. of Mech. Design. Dec. 1991, Vol. 113, pp.438-445.

[3] Haug E. J.: Computer Aided Analysis and Optimization of Mechanical System Dynamics. Springer-Verlag, Berlin, 1983.

[4] Haug E. J., Deyo R.C.: Real-Time Integration Methods for Mechanical System Simulation. Springer-Verlag, 1990.

[5] Hoeltzel D., Chieng W.: Hybrid (Symbolic- Numerical) Optimization in Mechanism Design for the Elimination of Redundant Constraints. Jour. of Mech. Design. 1991, Vol.113, pp. 110-123.

[6] Hwang Ch., Masud A.: Multiple Objectives Decision Making - Methods and Applications. Springer-Verlag, 1979.

[7] Hwang Ch., Yoon K.: Multiattribute Decision Making. Springer - Verlag, 1981.

[8] Keeney R.,Raiffa H.: Decision with Multiple Objectives, Preference and Trade-offs. Wiley, 1976.

[9] Pokojski J.: Computer Aided Decision Making in Vehicle Dynamics. Modelling, Simulation and Control, B, Vol.17, pp. 1-11, 1988.

[10] Pokojski J.: Computer Aided Decision Making in Machine Dynamics. Works of Warsaw University of Technology, s. Mechanics, No 134 ,pp. 1-108, (in Polish), 1990.

[11] Pokojski J.: Rule based expert system JP. Report, 1992 (unpublished).

[12] Yang B. (and others): An Integrated System for Design of Mechanisms by an Expert System - Domes: Applications. Jour. of Mech. Design, March 1991, vol. 113, pp.25-31.

Revised by: Stanisław Wojciech