NEW SOLUTIONS IN EXPERIMENTAL MODAL ANALYSIS OF MECHANICAL STRUCTURES

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Summary The paper presents new solution of problems which are essential for modal analysis test engineers. The problems are related to automated modal analysis which is under development in many laboratories worldwide. The problems can be classified into two groups: selection of model structures and real time modal analysis. The first problem is important during experimental modal analysis in order to increase the analysis objectivity. The solution of second one helps to apply modal analysis for damage detection in mechanical structure. The algorithms, software implementation and case studies are presented.

INTRODUCTION

One of the most intensive investigates problem in modal analysis is automation of identification procedure. In the area two main problems can be distinguish:

- identification of modal properties of the mechanical systems if structure of model is not known (model order, location of excitation, predicted mode shapes, etc.)
- tracking of modal parameters during structure operation (real time modal analysis)

Both problems are under investigation at the University of Science and Technology – AGH from many years.
In the paper recent developments of experimental modal analysis procedures are presented.

AUTOMATION OF EXPERIMENTAL MODAL ANALYSIS PROCEDURES

During experimental modal analysis testing engineers and analysts are often forced to make decision about model structures, what constitutes one of the most important problems in automation of this analysis [1]. The idea of the proposed methodology is to formulate a set of algorithms that aid decision-making during modal analysis in order to increase the analysis objectivity. In the result the autonomous modal analysis procedure is formulated.

The modal analysis results depend on the modal experiment plan and execution as well as parameter estimation.

First, there are considered the modal experiment test planning algorithms aiming at selection of excitation points and response signal measuring points. These algorithms might use the preliminary modal experiment results, as numerical structural dynamics models are not too often available in the industrial practice.
Next, the modal experiment database architecture and implementation is investigated. This database should allow both easy data quality assessment and parameter estimation planning.
Finally, the autonomous parameter estimation procedure is formulated. The formulated parameter estimation planning procedure results in a definition of properties of a set of the estimation procedures which should allow obtaining of repeatable estimation results with use of various: subsets of modal experiment database, estimation algorithms and parameter values of estimation procedures. The formulated stabilization diagram processing algorithm uses fuzzy reasoning to select the most representative system poles. Usually analysis of the experimental database leads to a large amount of results. The modal model consolidation procedure aim is to aid determination of the final modal model which is the most representative for all the available estimation results.
The authors' experience showed that introduction of tools aiding the decision-making during modal analysis might considerably shorten the modal analysis time especially in case of investigation of complex structures.
Other type of decision which should be made by analysts during modal analysis is selection of model order. The solution based on neural network supported procedure is presented in the paper.
In presented procedure [2] a model order is selected with the use of a self-organizing neural network that classifies data contained in a stabilization diagram. to the desired length by the zero values.

The steps of a model order determining process are as follows:

- Determining a transfer function for an object of interest,
- Building stabilization diagrams with the use of the *Vioma* toolbox which is formulated by authors,
- Determining a vector of weight coefficients,
- Grouping the data contained in the vector of weight coefficients with the use of neural network,
- Counting the number of determined groups and displaying a number that unequivocally specifies a model order

.
There is also shown a comparison between results of model order selection obtained with the use of proposed neural network based approach and results obtained with the use of the classical stabilization diagrams method. The method of

model order selection with the use of a neural network aims at eliminating errors made during a model order visual assessment on the basis of a stabilization diagram.

REAL_TIME MODAL ANALYSIS AND ITS APPLICATION FOR DAMAGE DETECTION

The second group of newest problems in experimental modal analysis is related to on-line modal parameters estimation of mechanical structures during their operation [3]. The problem is formulated as follows: the model structure is assumed but during investigation parameters of structure are subjected to change, changes of modal parameters during operation should be monitored. This approach is very useful for control and diagnostics purposes of complex mechanical structures like airplanes, satellites, bridges, masts, etc. The following methods are applied for on-line modal analysis in the paper:

- a method based on measured signal segmentation
- a method based on parameters updating.

The methods are based on real-time identification of autoregressive model of acceleration signal measured during operation and employing relation between autoregressive models and modal model parameters. The schemes of both methods are shown in figure 1.

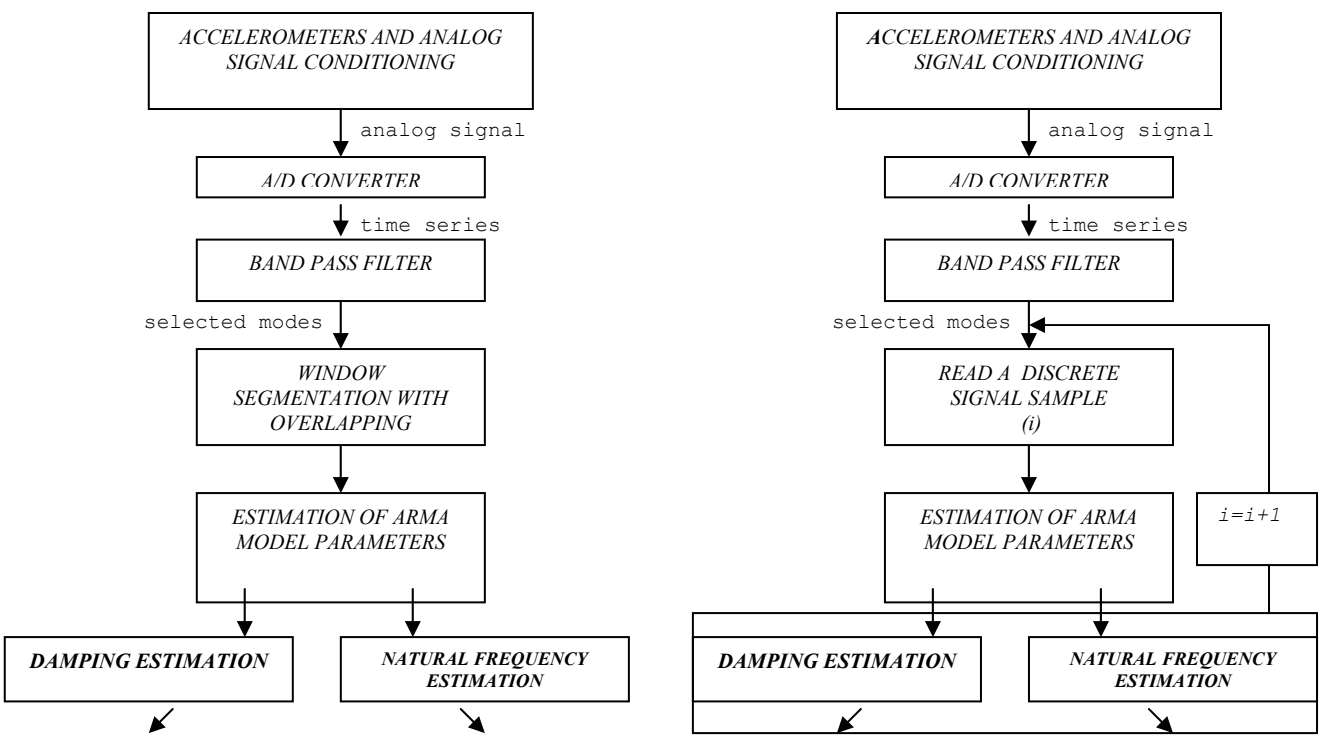

Figure 1. Schemes of formulated real time modal analysis a) signal segmentation based algorithm, b) model updating algorithm.

Simulation verification results of proposed procedure for two degrees of freedom system with varying damping parameters are discussed. The methods have been applied for identification of flutter region for trainer jet from in-flight vibration measurements. The electronic device based on DSP technology is designed and tested for on-line modal parameters monitoring during airplane flight. The results of this test are reported in the paper.

References

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