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Consideration Regarding the Dynamic Mechanical System Identification

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Summary:

In the continuous effort to improve knowledge on the dynamic behavior of a building, the trend is towards the study of a building's behavior having as starting point the tests carried out on site. Tests on site are the current trend in studying buildings behavior. This approach provides the means to:
- Verify structure's quality;
- Verify its security level in real operational conditions;
- Validate existing analytical models of behavior;
- Verify assumptions made on a priori to predict structures response;
- Gain knowledge to improve sizing methods;
- Developing new models of behavior.

The accuracy of modal parameters - frequency and eigenform of vibration own - depend on the precision, which can be measured by the frequency response function (FRF), hence the critical importance of how the excitement of the structure to vibration amplitudes maintain as close to the operating level in all areas of interest have.

Developed techniques for identifying the frequencies and forms its own specific structures using a ***single excitation, excitation concurrent multi-point excitation in several consecutive points***. These methods involve performing iterative process leading to the possibility of automation.

KEYWORDS: *modal parameters, single excitation, frequency response function, parameters identification.*

1. INTRODUCTION

In the continuous effort to improve knowledge on the dynamic behavior of a building, the trend is towards the study of a building's behavior having as starting point the tests carried out on site. This approach method provides means to:

- ***Assess (verify) quality of structure and its level of security in real operational conditions (real-life situation), the validation of analytical models*** of existing behavior and a priori assumptions made for the structure prediction of response;
- ***Accumulate knowledge necessary to improve methods of sizing*** and justified development of new models of behavior.

Studies on identification of dynamic structures are particularly present at international level and relatively little addressed in our country.

Identifying dynamic involves a combination of basic concepts of systems theory, structural theory models, mathematical statistics, and estimation theory with practical elements of experimental tests, measurement techniques, capture and automatic processing of experimental data.

Special emphasis is currently on deployment and development of techniques for identifying systems for studying the dynamic-seismic behavior of buildings, to optimize the design of new structures and/or safety of the structures damaged by earthquakes, by strengthening and redesign.

A traditional definition of system identification is given by *L.A Zadeh (1962) as* ***"the determination, on the basis of input and output, of a system within a specified class of systems, to which the system under test is equivalent".***

Thus, identifying a system raises several issues:
- Identifying the system type;
- Nature of the characteristics, which needs to be identified;
- A source of data on the system response;
- Source of data regarding actions upon which the operation of identification is carried out.

Problem identification can have two main aspects:
A. Parameters identification – when analytical expression of the mathematical model is known and the coefficient involved unknown (unknown coefficient values).
B. Total or global identification – no information or a priori information is insufficient to allow a mathematical representation.

Identification of dynamic structures can be defined as: a set of techniques that allow determination of physical parameters that occur in the equations describing the behavior of structures subjected to dynamic – seismic actions. These techniques have been developed due to difficulties encountered in accurately assessing the rigidity, damping and mass of real-size structure.

For experimental determination of dynamic characteristics one of the following methods may be applied:
i.) Methods of identification using known excitability factors (active method;)

ii.) Methods of identification using size excitation of the normal functioning of the system (passive methods).

The accuracy of modal parameters – frequency and own types of vibration - depend on the precision which can be measured by the frequency response function hence, the critical importance of structure's excitement in order to maintain the vibration amplitudes close to the operating level in all areas of interest.

Generally a process of identification includes:
1) ***Choosing the model and its structure***
Generally, the construction of a model goes through the following steps:
- Choosing a model structure based on physical knowledge;
- Determining parameters from the available data (estimation of parameters);
- Checking and testing the model (diagnostic test).
2) ***Choosing the comparation criteria*** - approximation to model the properties consistent with the actual real structure is expressed by minimizing a ***criterion function;***
3) ***Estimation and correction parameters.***

Determination of parameters can be performed either by ***estimation theory*** or by ***optimizing parameter.*** In general, choosing an algorithm to adjust unknown parameters, which are used to evaluate them so that the identification criterion should be minimized.

Modifying the structure of the model using the criterion function to be minimized does handling identification systems as a problem of optimization. Identification using parametric estimation can be obtained by applying statistical theory to verify the operating parameters of the structure.

The parameters that define the response of a structure can be:
- *Measurable parameters (observed)* can be determined by direct measurements on actual structure (the coefficients of flexibility matrix, eigenform, functions in response frequency)
- *Abstract parameters (intuitively)* that can be obtain by the properties of materials (the stiffness, damping and inertia matrix elements).

Troubleshooting estimate parameters can be done in two ways:
- **Using explicit mathematical equations** resulting directly with a set of numerical quantities, such as coefficients of differential equations, their eigenfrequencies, damping factors;
- ***Using a method of correcting (adjustment) model***, which assumes implementation of a model whose parameters are ordered in such way so that the model's characteristic is similar to the system in a sense established beforehand.

Application procedure for correction of the model calculation by estimation theory experimental data is the following assumptions and general considerations:

- *The corresponding dynamic structure is linear-elastic or linearization in a given field, invariant with respect to time;*
- *Dynamic model structure is determined in the sense that is known initially through physical parameters - mechanical structure of (*the inertia, stiffness and damping matrix*);*
- *Experimental model is excited by deterministic signals, the recording and processing are considered and disturbance quantities entry.*

Correction procedures can be distinguished by two phases:
i.) The location/detection errors;
ii.) Error correction.

Stage localization/detection of errors is the most difficult. The difficulties arising due to the following reasons:
- there is a lack of experimental data
- perceived incompatibility, usually between the experimental and analytical model studies on the sizes and dimensions
- the different distribution of systematic errors in the analytical and experimental model.

The main objective of the methodology for correction of dynamic models used to study the structure can be defined as a process for "*refining*" an existing analytical model.

Corrected model should reproduce the following:
- the modal proprieties in points which the experimental measurements were done;
- frequency response function, obtained experimentally;
- In the modal properties that have not made measurements;
- frequency response function, obtained analytically only;
- correct representation of model's connection.

2. PROCESSES IDENTIFICATION OF SYSTEMS WITH 1DOF

The simplest method of identification is based on analysis dynamic response of the system with 1 DOF.

A dynamic test is based on the measurement of several quantities of excitation forces applied to the structure. Measurement of excitation force and response in a number of points in the whole area of frequencies is sufficient to describe the behavior of the structure.

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The result can be measured in travel, speed or acceleration and the different terms used for the ratio of response and action. Frequency response function is the complex spectrum of the output (response) and excitation spectrum:

$$H(j\omega)=\frac{U(j\omega)}{F(j\omega)} \qquad (1)$$

where: U(jω) is the response spectrum, F(jω) is the excitation spectrum, H(jω) is the transfer function (FRF).

Have been developed various methods of identification systems based on 1DOF response functions used (accelerated, mobility, inertance). So, using accelerated have developed:

- method of peak amplitude;
- method of lagging (phase difference, trail behind) diagram;
- actual component diagram method of admittance;
- polar diagram method of admittance.

3. METHODS OF IDENTIFICATION DYNAMICS OF SYSTEMS WITH NDOF

These techniques used to identify NDOF systems have been developed due to the difficulties encountered in assessing the exact rigidities, damping and mass. The main challenge is to determine the characteristics represented by the mass (M), damping (C) and stiffness (K) matrices which are not directly measurable in measurable quantities such as frequency, modal shapes, and dampings.

Testing large structures complex takes place in two phases:
Phase I – determining the number of coarse eigenmodes vibration and their resonance frequencies using a single jigger;
Phase II – of the isolated modes by a proper distribution of a number of jiggers along the structure. a match structure and excitation forces from vibrations, thus only interested in how to be dominant excited.

For large structures, with numerous links and disproportional damping and non-linear effects, disproportional near modes are frequent and not only prevents localization frequencies for the identified modes and modal shapes for a fixed jigger position may not coincide with those established in other positions of the jigger.

3.1 Identification of modal frequencies and shapes using a single harmonic excitation

A linear and elastic structure excited by a sinusoidal force will respond directly proportional to the force excitation and has the same frequency.

Measurement of excitation force and response in a number of points on the range frequency is sufficient to describe the behavior of structure.

Were developed following methods of identification using a single excitation:
- method of peak amplitude;
- Kennedy and Pancu method;
- modal connections method (Raney and Hawlett).

3.2 Identification of linear systems excited harmonic simultaneously in several points

A complex structure vibrating simultaneously in several ways. For a correct analysis of the unwanted modes must be eliminated.

To excite a structure in one of the main vibration distribution of forces should be shaped:

$$\{F\} = (\omega_i^2 - \theta^2)[M]\{Y_i\} + \theta[C]\{Y_i\} \tag{2}$$

Since the purpose of excitation with more jiggers is not only a way to excite interest but also to eliminate the contribution of modes outside the resonance should be noted that outside the resonance can not be undone if all jiggers are placed in unexpected mode nodes.

Methods developed for matching excitation forces from jiggers are:
- method’s DECK;
- method’s CLERC;
- method’s L.M.A.;
- method’s ASHER;
- modal adjustment method.

3.3 Identification methods using harmonic excitation in several consecutive points

These methods are considered as "methods of excitation at a point" because it used only one spark drawer which is moved successively to different points of the structure. Current methods using consecutive excitation are:
- independent force methods (Trail – Nash);
- independent overcharge methods.

4. CONCLUSIONS

Tests on site are the current trend in studying buildings behavior. This approach provides the means to:
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Depending on the identifying system, the results can be used for:
- verification and validation of analytical models and their correction;
- creation of dynamic models to represent the real structure;
- determination of sizes that are not directly measurable (the inertia matrix M, damping matrix C, the stiffness matrix K) to measurable quantities (frequencies, modal shapes, damping);
- to provide the structural changes;
- predict behavior by calculating the complex structure by using hybrid method consisting in the decomposition structure in sub structures which may determinate the experimental actual characteristics;
- determination by calculating the response to other excitations or more simultaneous excitations based to the measured response for a particular type of excitation.

Some applications in other areas of identifying and estimating the parameters are listed below:

1. In air and automotive industries to determine:
- aerodynamic coefficients;
- the speed of vibration of the surface of an aircraft or missile;
- vibration modes damping depending on the frequency;
- characteristics of dynamic tire – train;
- the dynamic characteristics of landing gear and car suspension;
- dynamic characteristics of turboreactors, turboprops, pistons moving alternative, etc.

2. In process industries (chemistry, fuels, materials) to determine:
- rheological and dynamic characteristics of the material undergoes deformation or leakage;
- the characteristics of combustion processes;
- dynamic parameters of the instruments, transducers, and components of the adjustment processes etc.

Miscellaneous:
- determining the dynamic parameters of biological populations;
- determining the characteristics of systems for which you made predictions that the economic dynamic;
- determining the dynamic characteristics of the human operator on various devices;
- determining the dynamic characteristics of the human or animal body function.

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