

Experimental dynamic analysis of a manipulator crane and analytical prediction of results

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1 INTRODUCTION

The governing loads taken into consideration in the design of the manipulator crane (i.e. the fuel loading machine) of a pressurized water reactor are seismic loads. Such loads are derived from a response spectrum analysis using a finite element model of the manipulator crane in a fuel loading position above the reactor vessel. In order to qualify the mathematical model of the manipulator crane used in this analysis, FRAMATOME and REEL have performed an experimental modal analysis of the crane for a four loop reactor. Experimental results are compared to calculated frequencies and mode shapes.

2 EXPERIMENTAL MODAL ANALYSIS

Major components of a manipulator crane are the following :

- a crane travelling above the reactor vessel pit
- a trolley
- a drum and mast assembly located on the trolley.

The drum is fixed to a rotating crown wheel installed on the trolley deck. The mast assembly is connected to the crown wheel through three 120° apart pretensioned spring systems which ensure a firm clamping of the mast assembly for normal operating loads and provide a restoring stiffness for large earthquake-induced horizontal inertial loads. The mast assembly has a Y shaped cross-section and contains a retractable fuel gripper mast, a control rod cluster gripper mast and a T.V. camera mast. Winches located in the drum are used to control travel of these retractable masts. The trolley travels on tracks supported by the crane and the crane travels on tracks above the reactor vessel pit, thus allowing positioning of the mast assembly in both horizontal direction above the reactor vessel. For both moving assemblies (crane and trolley) guide wheels restrain sliding motion perpendicular to the track, on one side of the moving assembly.

For the experimental modal analysis, free movement of both crane and trolley on their respective track were precluded by ensuring a rigid clamping between rail and moving assembly (crane or trolley) on the guide wheel side.

The test was performed with the fuel gripper mast fully extended, holding a mock-up fuel assembly. This configuration is the one which is considered to lead to the larger loads in the crane structure when the

seismic analysis is performed. The modal analysis was done using to types of excitation :

- sine sweep excitation between 0,5 Hz and 50 Hz with an hydraulic actuator in several locations of the structure.

These locations are selected such as to obtain participation of the structure major components : mast assembly at one quarter of its length under the trolley deck in the x and y direction, trolley deck in the z direction, crane beam in the x and z direction. x, y and z direction are respectively the crane travelling direction, the trolley travelling direction, the vertical direction,

- drop test with a 40 Kg mass, dropped on the drum, successively in x and y direction.

Accelerometers located in 32 points of the structure record the response of the structure in x, y, z directions and therefore constitute a meshing which enable us to obtain mode shapes. The overall view of the structure with indication of the excitation locations is shown on figure 1.

Transfer functions are derived between the structure response recorded by the accelerometers and the input signal (sine function or impact acceleration generated by the dropped mass). A typical transfer function is shown on figure 3, providing the response of an accelerometer located on the assembly mast in the x direction for a drop test impact on the drum in the x direction. Modal parameters for each modes (damping, frequency) are computed from these curves using a curve fitting technique.

3 ANALYTICAL PREDICTION OF FREQUENCIES AND MODE SHAPES

The analytical prediction of frequencies and mode shapes in the test configuration is performed using a 130 modes (600 degrees of freedom) finite element model composed of plates and beam elements. This model is shown on figure 4. Comparison between analytical and experimental mode shapes is based on the visualisation of the mode shapes and the evaluation of participating masses in both horizontal direction. Major mode shapes are the following :

	Calculated frequency (Hz)	Experimental frequency (Hz)
Rocking of drum and mast assembly in x0z plane	1,87	1,75
Rocking of drum and mast assembly in y0z plane	2,18	2,52
Trolley and mast assembly bending	3,08	3,49
Trolley and mast assembly bending in y0z plane	5,70	5,97
Crane support beam bending	7,06	6,78
Trolley floor deflection	10,24	9,27
Crane guide beam bending	12,27	11,12

A fairly good agreement can be seen between calculated and experimental results. A sensitivity study of the major modeling parameters shows that the connecting stiffness between trolley, drum and mast assembly is a key variable of the model.

Also the interface condition between moving assemblies, crane or trolley, and their respective track can considerably affect results : i.e. assuming that either both driving wheel brakes are blocking the assembly displacement or one side of the assembly can move freely.

4 CONCLUSION

Due the complex structure of the manipulator crane, a large number of modes are found below the cut-off frequency of a typical seismic response spectrum (33 Hz). Major contributing modes can be correctly predicted by calculation, provided special care is taken in properly modeling connecting stiffness between the crane various components and selecting representative boundary conditions as regard the crane and trolley displacement on their respective track.

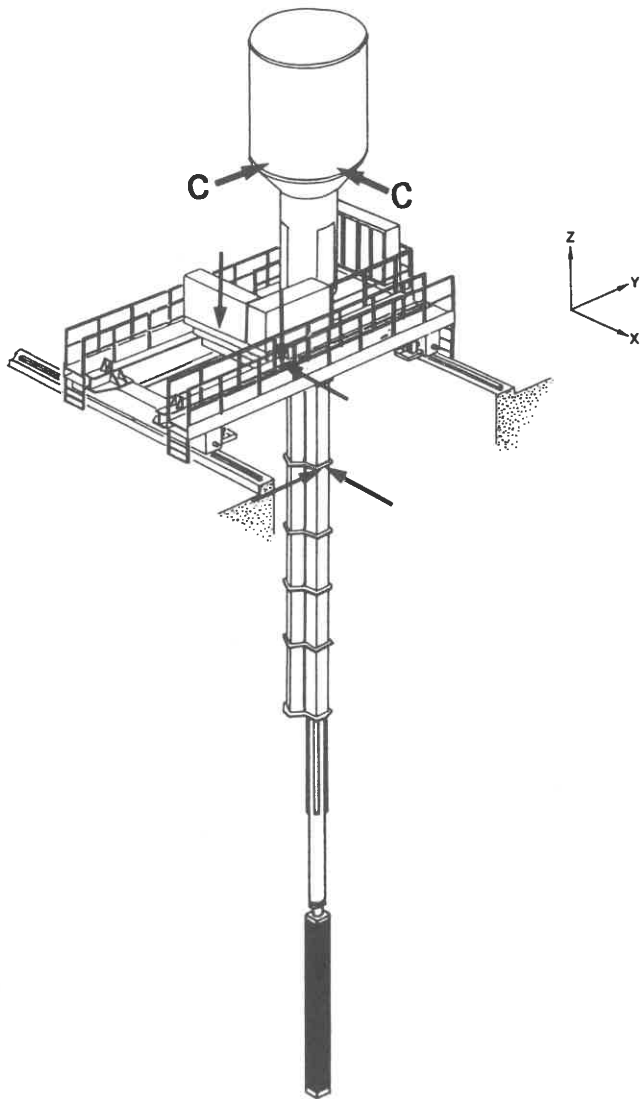


Figure 1. View of manipulator crane showing locations of excitation with hydraulic actuator or dropped mass (C)

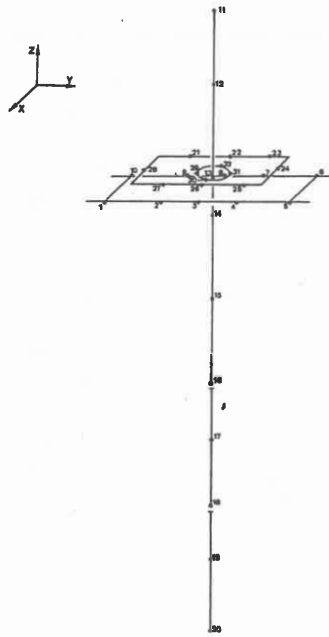


Figure 2. Distribution of accelerometers on manipulator crane

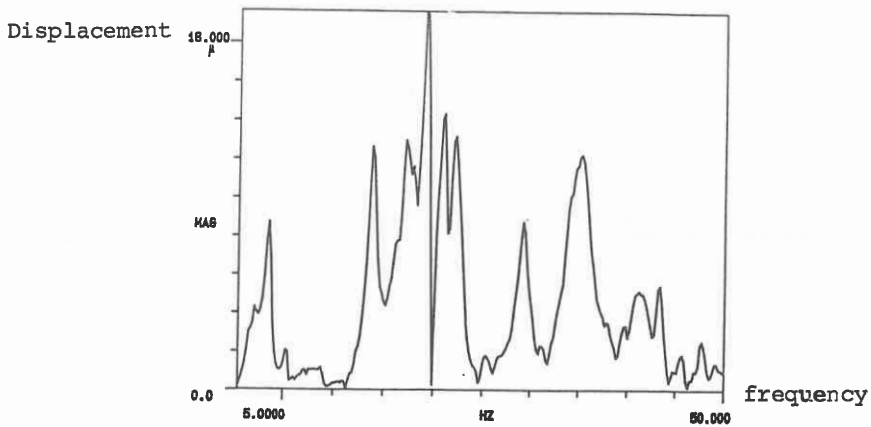


Figure 3. Typical transfer function, providing the response of an accelerometer located on the assembly mast in the x direction for a drop test impact on the drum in the x direction

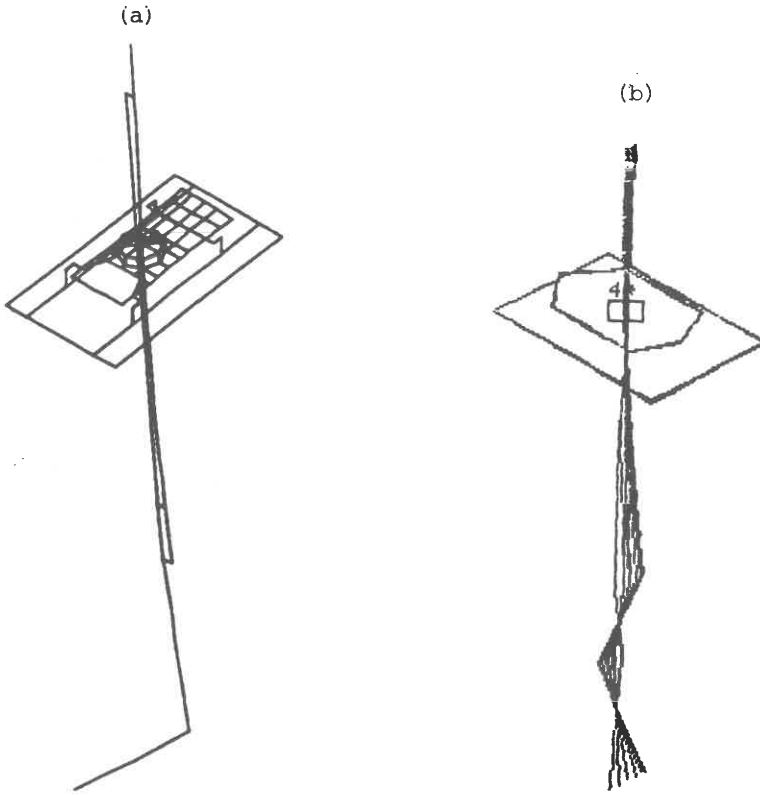


Figure 4.

Figure 4(a) shows a visualization of the first major mode (rocking of drum and mast assembly at 1,87 Hz) obtained with the finite element model

Figure 4(b) shows a visualization of the same mode obtained experimentally at 1,75 Hz