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MODAL TEST AND ANALYSIS OF THE 2^{ND} STAGE OF SMALL LAUNCH VEHICLE

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Abstract
The structure of small launch vehicle can be divided into engine section and payload section. This paper introduces modal test of the payload section of small launch vehicle. From this test, dynamic properties of the 2^{nd} stage structure of small launch vehicle can be obtained. In this test, to simulate free-free boundary condition, test object was hung by 4 bungee cords and excited by using impact hammer. Modal test data are analyzed by using TDAS (Test Data Analysis Software). As the result, modal parameters and mode shapes below 100Hz of the 2^{nd} stage were identified. Also, comparison of mode shape between test and FEM analysis is performed.

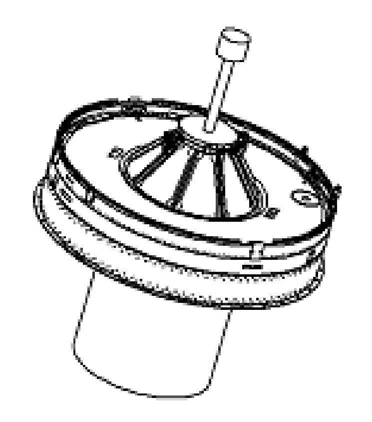
INTRODUCTION

The structure of small launch vehicle can be divided into engine section and payload section. The payload section is composed of PLF (Payload Fairing), satellite, PLA (Payload Adapter), VEB (Vehicle Equipment Bay), KM (Kick Motor), and which are made of metal and composite material. This paper describes the modal test result for verification of modal parameters about the 2^{nd} stage structure of small launch vehicle. The purposes of these test is to verify dynamic model of the 2^{nd} stage structure system. The verified dynamic model enables us to calculate the 1^{st} lateral natural frequencies of the 2^{nd} stage structure system. From these test results, the dynamic model (numerical) of the 2^{nd} stage structural system of small launch vehicle will be modified so that it reflects real joint or boundary conditions between structural components. The modified dynamic model will be CLA (Coupled Load Analysis) input data.

TEST OBJECT AND INSTRUMENTS

Test object

Figure 1(a) illustrates the 2nd stage structures for modal test. Test object is composed of satellite simulator, PLA, VEB, KMS, interstage simulator, KM simulator and mass simulators for electronic equipment. Satellite simulator was specially made to have same weight and lateral natural frequency. KM simulator was made to have same weight and the other components are real scale model.



(a)

(b)

Figure 1 – The 2nd stage structure for modal test
(a) The 2nd stage structure model (b) Free boundary condition for modal test

Test instruments

To simulate free-free boundary condition, test specimen was hung by 4 bungee cords. The bungee cord has a spring so that frequencies of rigid body motion of test specimen occurred at 0.23Hz (lateral) and 3.6Hz (axial). Figure 1(b) shows the 2nd stage modal test composition simulating free-free boundary condition.
Figure 2 illustrates tri-axial accelerometer location to obtain mode shape of lateral direction bending mode. Total measurement positions are 67 points. Test object is excited at KM simulator by heavy type impact hammer for low frequency region. This excitation position was decided through coherence function of pre-test in order to excite well full structure.

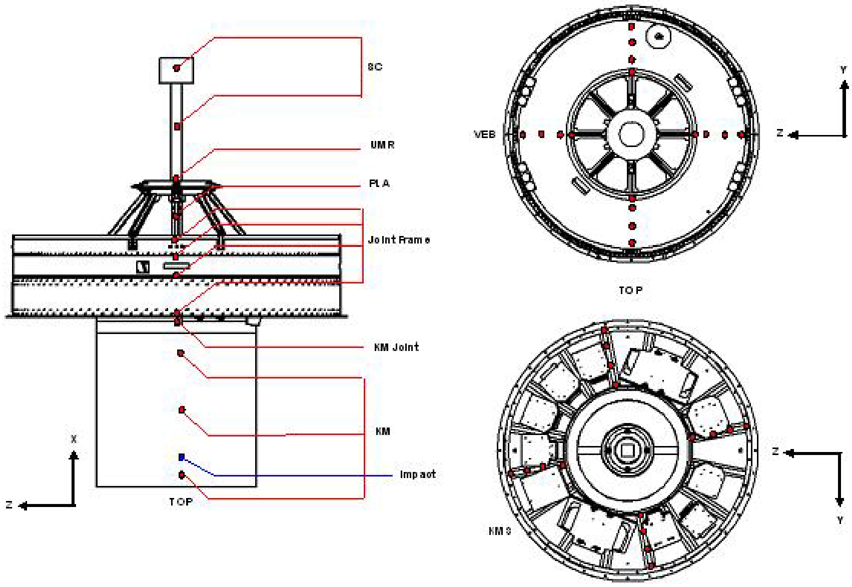


Figure 2 – Sensor locations (90 ° interval in circumferential direction)

TEST RESULT

Modal parameters

FRF data from modal test was analyzed by TDAS (Test Data Analysis Software). TDAS enables us to obtain modal parameters from FRF data of modal test and shows mode shape conveniently.
Figure 3 illustrates TDAS model showing sensor location to obtain mode shape of this test. This model was applied to local coordinates which are coincident with real coordinates of sensors at each nodal point.

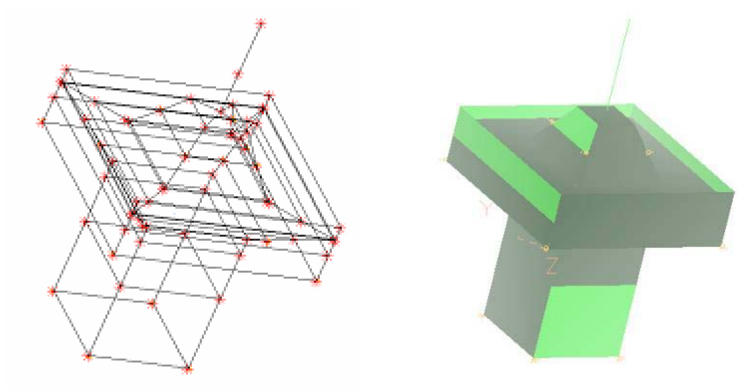


Figure 3 – TDAS model for test analysis

Single-reference technique is used in this test because of excitation by impact hammer. Through MIF (Mode Indicator Function) which represent modal density of total measured FRF, natural frequencies of the 2nd stage structure are selected by TDAS. Figure 4 shows MIF curve of this test. We obtain natural frequencies by finding valley on MIF curve. Figure 5 illustrates SDOF (Single Degree of Freedom) curve fitting to obtain modal parameter. Modal parameters of the 1st and 2nd bending mode below 100Hz are shown in Table 1.

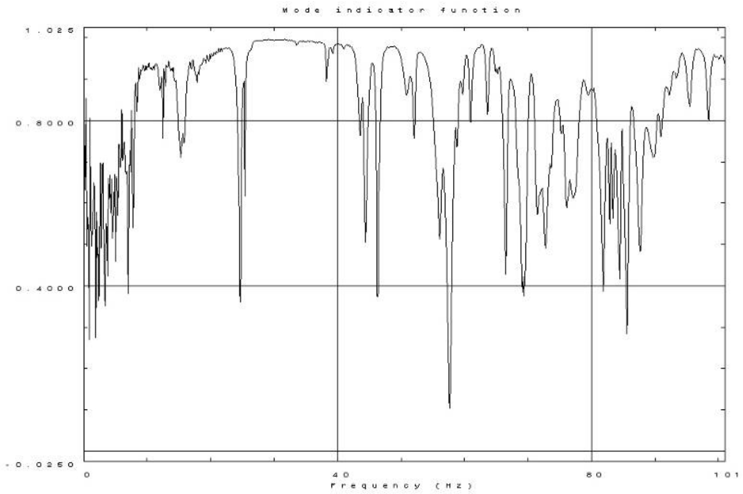


Figure 4 – MIF curve of test result

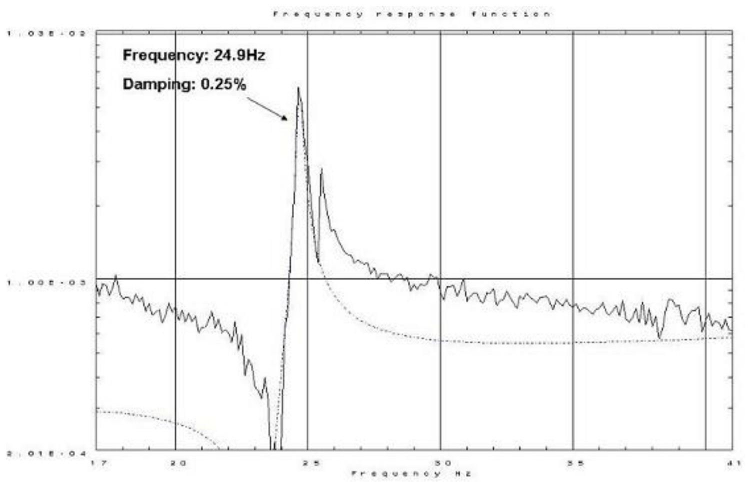


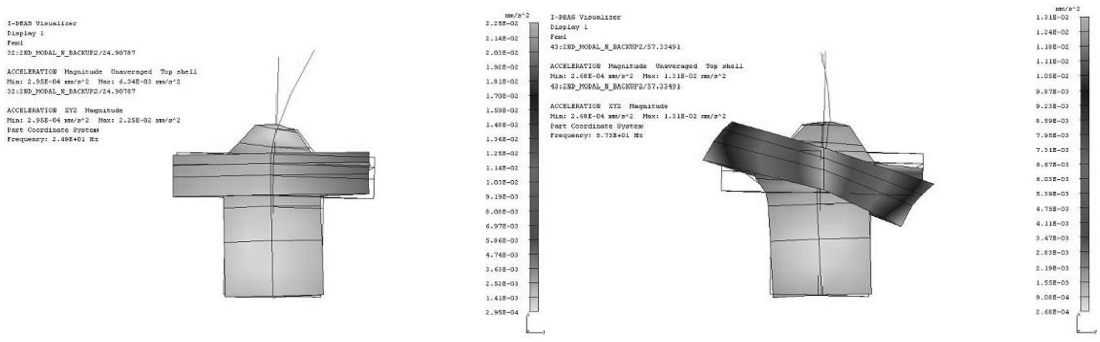
Figure 5- SDOF curve fitting (Y-Axis)

Table 1 – Modal parameters

Frequency (Hz)	Mode shape	Damping (%)	Amplitude	Phase
24.9Hz	1st bending mode	0.25	4.39E-3	-1.571
57.3Hz	2nd bending mode	0.59	5.85E-3	-1.571

Mode shape

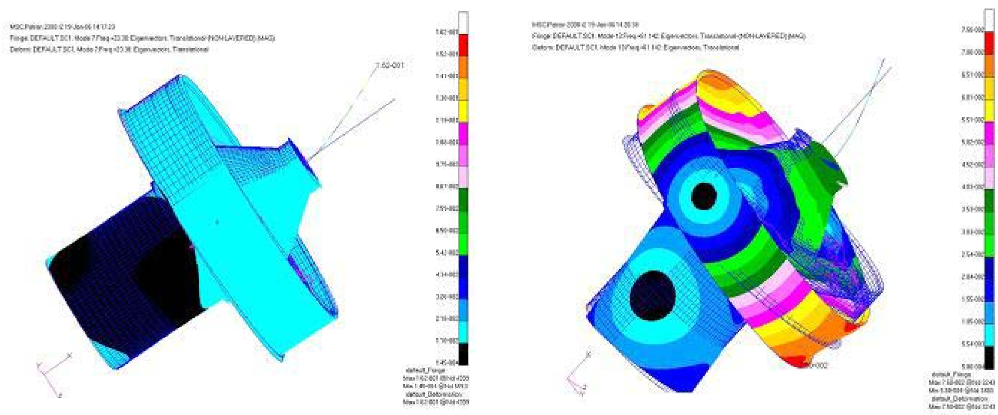
Figure 6 illustrates the 1st and 2nd bending mode shape from modal test. . The 1st bending mode is dominant mode of satellite. The 2nd bending mode is dominant mode of satellite and KM.



(a) *(b)*

Figure 6 – Bending mode of the 2nd stage (Test)
(a) 24.9Hz (b) 57.3Hz

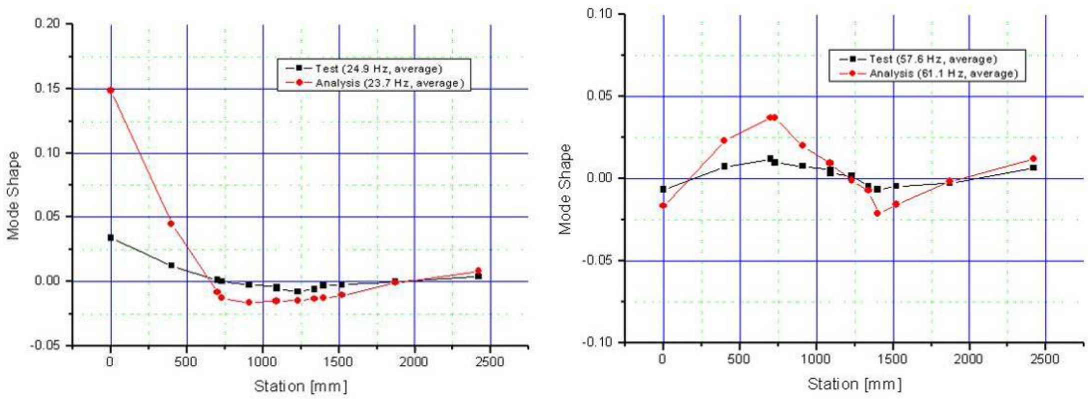
From modal parameters of modal test, analytic model is modified by correcting stiffness and boundary condition of real joint. Figure 7 shows mode shape of analytic model. Natural frequency is similar within 10% between test and analysis. Also, mode shape is nearly coincident. This modified analytic model is used by CLA input data.



(a) *(b)*

Figure 7 – Bending mode of the 2nd stage (FEM Analysis)
(a) 23.4Hz (b) 61.1Hz

In order to compare mode shape between test and analysis, mass normalized mode shape is required. Generally FEM analysis output mass normalized eigenvector but test data needs conversion which puts modal mass to unit mass. Figure 8 shows comparison of mass normalized mode shape between test and FEM analysis.



(a) *(b)*

Figure 8 – Comparison of mode shape between test and FEM analysis
(a) 1st bending mode (b) 2nd bending mode

SUMMARY

This paper shows modal test of the 2nd stage of small launch vehicle on free boundary condition. FRF data from modal test is analyzed by TDAS. Through this test, the 1st and 2nd bending mode of the 2nd stage structure is identified. Obtained modal parameter from this test is used to modification of FEM analysis for CLA input data. Also, it is used to predicting dynamic characteristics of full launch vehicle model including the 1st stage of engine section.

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