APPLICATION OF FEM AND SEA IN PREDICTING VIBRO-ACOUSTIC BEHAVIOR OF A FLAT RIBBED PANEL STRUCTURE

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1. INTRODUCTION

In today's market the passenger comfort is driving the interior design of the aircraft. The basic requirement of the comfort is low noise and vibration environment. Considering the effect of extra mass on the performance of the aircraft and cost to improve the comfort later in the program, the fuselage structure must be designed for low noise at the early stages of design. This highlights the need for better design tools that can be used with a high confidence to design the cabin for acoustics and vibration comfort.

In this paper two major design tools in predicting acoustical response of the coupled structure-cavity are presented. The response of a structure (flat ribbed panel) excited by a point force is predicted using Finite Element Method (FEM) and Statistical Energy Analysis (SEA).

For FE modeling, structural testing was required to confirm integrity of the FE model of the structure. Modal testing was performed on the ribbed panel. First 5 non-rigid body modes and mode shapes were calculated and used for correlation. For SEA modeling all required parameters such as damping loss factor and absorption inside the box was measured and imported to the model.

2. Experimental Set-up

The experimental setup to measure vibro-acoustic response of a coupled structure-cavity is shown in Figure 1. The ribbed panel installed in the window of a reverberation box. The volume of the box is 0.6999 m^3. The size of the box restricted the low frequency limit of reliable measurement to 250 Hz. Above this frequency enough number of acoustical modes are available. It is assumed that the boundary of the panel installed in the window of the box is simply supported.

The ribbed panel shown in Figure 1 has three frame- stringer bays. Measurement was performed with the panel installed in the window. Response of the structure and cavity to a point force excitation was studied. A shaker was attached to the center of the middle frame-stringer bay. Random signal was used as the excitation signal at this location. The force at the excitation point was measured using a force sensor. Response of the interior cavity was measured with four microphones located randomly inside the box.

Figure 1:Experimental setup

Reverberation time of the box was measured using interrupted method. A speaker was located inside the box and generated burst random signal. Response of the cavity to this excitation was recorded at 4 microphone locations. The sound pressure data at these locations were used to calculate reverberation time and interior absorption.

Frequency Response Functions (FRFs) of the structure mounted in the box window were measured at three random points using impact hammer method. Modal damping of structure at each mode was extracted using half-power bandwidth method.

For FE model, the modal response of the structure is used for structural correlation. Fine FRF measurement was performed on the suspended ribbed panel. Modes and mode shapes of the ribbed panel structure were extracted from FRF data using LMS modal software.

Sound pressure data was used to correlate FEM and SEA prediction with measured interior noise.

3. FEM Modeling

The ribbed panel structure was modeled with 9600 Quad8 shell elements. The cavity inside the box was modeled with 31000 Hexa8 solid elements. Based on Structural FRF measurement viscous damping of 1-3% was considered for the FE model of the bare ribbed panel. Reverberation time measurement was shown that the acoustical damping of the cavity is around 0.5%.

FE model of coupled structure-cavity is shown in Figure 2. Measured excitation force at the center of the panel was imported to the FE model. Response of the structure-cavity to this excitation was predicted using LMS FE Acoustic Module.

Structural modes of the panel and cavity modes of the box were calculated up to 1500 Hz. Averaged sound pressure response of the cavity was predicted in 1/3-Octave bands. Predicted noise at four microphone locations were averaged and compared to the measured data. Figure 3 is the acoustical modes of the box as well as structural modes of the ribbed panel structure.

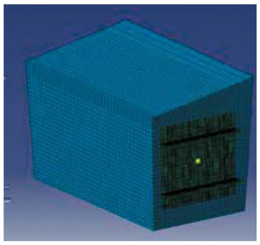

Figure 2: FEM Model of ribbed panel and box

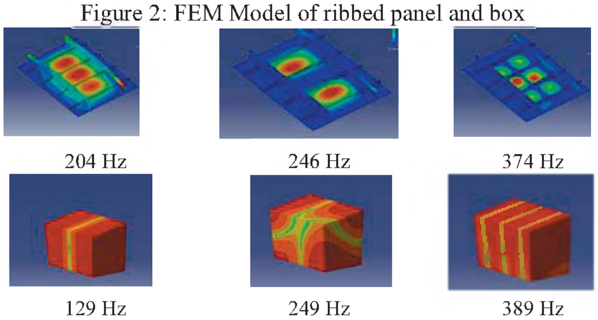

Figure 3:Structural and Acoustical Modes

4. SEA Modeling

The structure was modeled as a ribbed panel subsystem in SEA. Properties of the cross sections of the frames and stringers were calculated in MSC Patran and imported to the SEA model. Loss factor of the box cavity was measured using reverberation time method. 1% damping loss was considered for the ribbed panel structure. 1/3-Octave measured force data at the center of the panel was imported to the SEA model as the excitation. Averaged predicted sound pressure level was compared to the measurement at the four microphone locations. Figure 4 shows the SEA model of the panel-box.

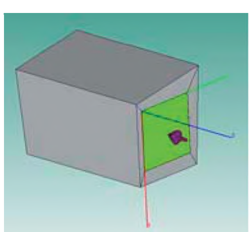

Figure 4: SEA Model of ribbed panel and box

5. RESULTS

Predicted response of coupled structure-cavity system using SEA is presented in Figure 5. The SEA prediction correlates well with the measured data above 400Hz. For mid-high frequencies range, SEA is the only tool to predict response of a vibro-acoustic system.

FE modeling is used to predict the response of the system for low-mid frequency range. Structural and acoustical modes of the system are shown in Figure 3. Predicted average interior noise of the box-ribbed panel system when excited by a point force is shown in Figure 5. FE predictions correlate well with the measured sound pressure level for frequency range of 200-1000 Hz.

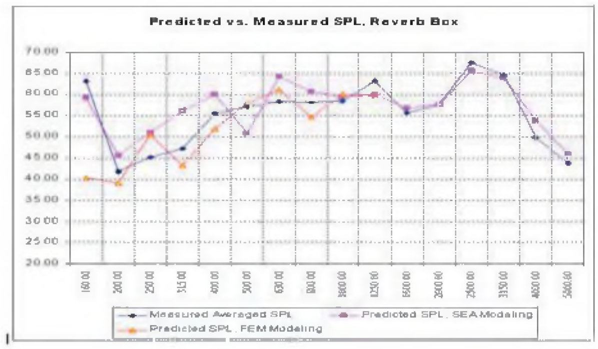

Figure 5: Measurement vs. Predicted Interior Noise, FEM and SEA Modeling

6. DISCUSSION

Predicting acoustical response of a coupled structure-cavity was presented in this paper. The FE modeling technique can be used to predict the response of the structure when excited by different sources. For low-mid frequency range the FE modeling technique gives detailed information on the sound pressure level distribution across the acoustic field. The SEA modeling should be used to predict average response of the system for mid-high frequency range.

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