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EVALUATION OF DYNAMIC PARAMETERS OF ADHESIVELY BONDED STEEL AND ALUMINUM PLATES

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ABSTRACT
Weight reduction remains one of the key factors for various industries. Inevitably this will result in multi-material designs where the most appropriate material is selected for each part. A key enabler for such a multimaterial design is joining two materials with optimized weight which is balanced with the need to keep manufacturing costs down. Further, it is well known that these parts are subjected to dynamic load while in service conditions, and in order to evaluate dynamic parameters for design purpose an adhesively bonded dissimilar joint between Aluminium and Mild steel plates has been investigated experimentally through traditional “strike method” of modal testing. FE simulation is also carried out and are compared with experimental results and found to be in good agreement.

Keywords: weight reduction, material joining, steel, aluminium plates, natural frequencies, mode shapes, cantilever, dynamic testing.

1. INTRODUCTION
In the last decade, there is a growing interest in dissimilar material combinations as an integrated unit so as to achieve the best combinations of properties. In all the industrial sectors, the main goal of these developments is weight reduction and increased functional performance, even corrosion resistance of combined material is also appreciably high. However, flexible structures usually have low flexible rigidity and low material damping ratio. A little excitation may lead to destructive large amplitude vibration and long settling time. These can result in fatigue, instability and poor operation of the structures. Vibration control of flexible structures is an important issue in many engineering applications, especially for the precise operation performances in aerospace systems, satellites, flexible manipulators, etc.

Experimental modal analysis is the process of determining the modal parameters (Natural Frequencies, damping factors, modal vectors, and modal scaling) of a linear, time-invariant system. The modal parameters are often determined by analytical means, such as finite element analysis. One common reason for experimental modal analysis is the verification/correction of the results of the analytical approach. Often, an analytical model does not exist and the modal parameters determined experimentally serve as the model for future evaluations such as structural modifications. Predominately, experimental modal analysis is used to explain a dynamics problem (vibration or acoustic) whose solution is not obvious from intuition, analytical models, or previous experience. After this many numerical methods are often adopted to predict the behavior of the dissimilar systems under dynamic loading conditions, both for scientific and practical applications.

The driving force for joining aluminum and steel arises from the need for weight savings, thus essentially, from a need for energy-efficiency in automobile industry [1] and [2], and the requirement for chemical plants and cryogenic and also they have many applications in engineering fields, however, dynamic characteristics is of major concern and it is difficult to predict the dynamic response for dissimilar material combination using well established empirical relationships for normal isotropic simple structures like plates, beams etc. as provided by D Blevins [3].

2. PROPERTIES OF MATERIALS
The properties of aluminum and mild steel are listed in Table-1.

Table-1. Mechanical properties of aluminum and mild steel.

Properties	Aluminium	Mild steel
Elastic modulus E(GPa)	65	200
Shear modulus G (GPa)	26	77
Density ρ (Kg/M^3)	2700	7900
Poisson’s ratio υ	0.28	0.3

3. EXPERIMENTATION
An 8 channel FFT analyzer has been used for Modal Testing. Experiment is conducted with a roving hammer test where the accelerometer is fixed at a location (Figure-1) where there is maximum displacement and the structure is impacted at as many DOFs as desired to define the mode shapes of the structure. Post-processing is done to obtain the required FRFs. By these FRFs natural frequencies, mode shapes and damping ratio were obtained. Experimental and FEA values were then compared.

This software is a complete, integrated solution for tested-based engineering, combining high speed multiple-channel data acquisition with a suite of integrated testing, analysis and report-generation tools. LMS Test is designed to make testing more efficient and more convenient for each and every user. In this work, LMS Test Lab Impact Testing software has been used with FFT

Analyzer with Impact Hammer and an Accelerometer. Initially structure is set for experimentation checking the boundary condition and initial setup for FFT analyzer. Geometry of the panel under consideration is defined. Optimum bandwidth/frequency range, within which suitable FRFs is obtained.

Results from experiments are presented in Table-2 along with the estimated values from ANSYS. Results are found to be in good agreement. Mode Shapes are shown in Figure-2 and Figure-3.

Table-2. Natural frequencies of aluminum and mild steel combination.

Mode numbers	Frequency (Hz)	
	Experimental	FE (ANSYS)
1	100	104
2	394	410
3	451	454
4	995	998
5	1126	1176

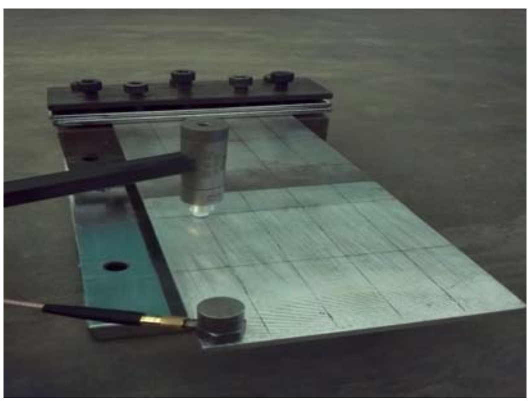

Figure-1. Experimental modal testing (Impulse hammer and Accelerometer).

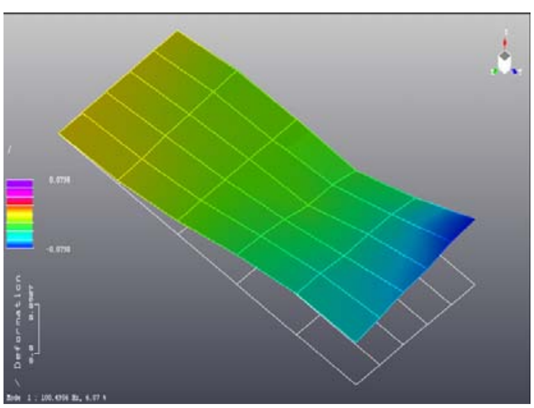

Figure-2. 1st mode shape-cantilever.

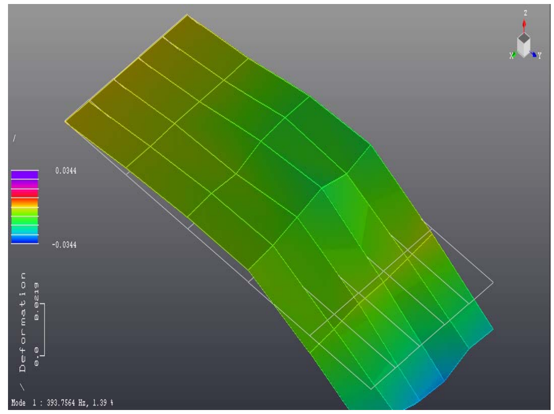

Figure-3. 2nd mode shape-cantilever.

It has been observed experimentally that second mode for both aluminum and mild steel were pure torsion but for dissimilar combination of the same it is second bending.

Table-3. Comparison of natural frequencies of aluminum, mild steel and their combination.

Material	Fundamental frequency (Hz)		
	Experimental	ANSYS	Blevins formula
Steel	61	66	67
Aluminum	61	65	65
Dissimilar joint (steel end fixed)	100	104	-

It was found that there is a 36% increase in fundamental frequency if steel end is fixed. When aluminum end is fixed the Natural Frequency drops to 39 Hz. his amounts to 40% decrease in fundamental frequency. The results point to the usefulness of constructing composite plate-like structures in this fashion, thus enabling control of their dynamical behavior by efficient use of the materials heterogeneity and their geometry.

4. E MODELING

Plates are modeled using commercially available finite element package ANSYS in order to obtain the dynamic parameters such as natural frequencies and corresponding mode shapes. The plates are meshed using SOLID186 element available in the elements library. The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions. Plate dimensions maintained throughout the analysis was 250 x 100 x 5mm. The necessary input for FE model is provided as shown in the Table-1 above. Figure-4 depicts the meshed model of joined plates with cantilever boundary conditions.

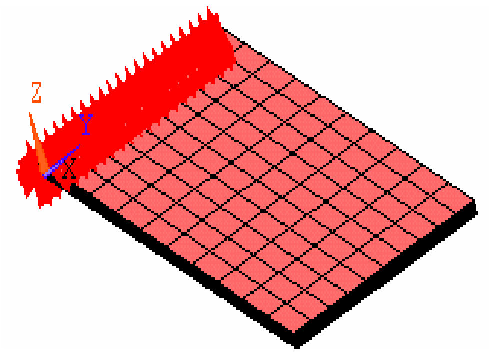

Figure-4. Finite element meshing of aluminum and mild steel combination (Cantilever).

The results obtained by ANSYS are presented in Table-4, for the first five un-damped natural frequencies for Cantilever boundary condition simulated with corresponding first and second mode shapes are shown in Figures 5 and 6.

Table-4. Natural frequencies of aluminum and mild steel combination.

Material	Fundamental frequency (Hz)		
	Experimental	ANSYS	Blevins formula
Steel	61	66	67
Aluminum	61	65	65
Dissimilar joint (Steel end fixed)	100	104	-

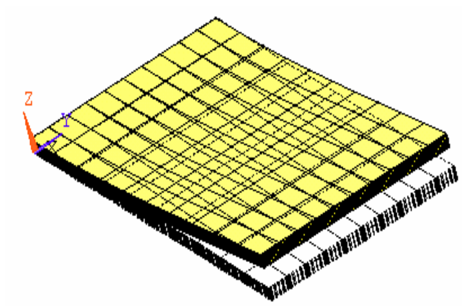

Figure-5. 1st mode shape-cantilever.

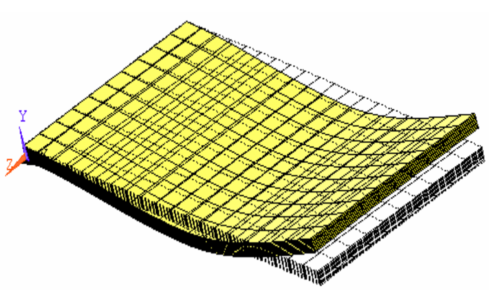

Figure-6. 2nd mode shape-cantilever.

5. CONCLUSIONS

In this work, the dynamic characteristics of dissimilar materials have been analyzed by both experimental and FE simulation with one end fixed i.e., cantilever boundary condition. The Natural Frequency of the dissimilar combination either increases or decreases depending on the distribution of stiffness and mass. If the stiffness is less and mass is large, the Natural Frequency decrease and vice versa. This concept can be beneficially exploited in various engineering applications. It has also been found that the results from both experimental and FE simulation are very close and within acceptable range.

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