Dynamic Characterization of an Aluminum "F-Structure" Without Any Stiffener.

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ABSTRACT *This paper contains prediction of dynamic characteristics and behaviour of an aluminium 'F' structure, representing generalized machine tool structure, modelled using finite elements incorporating plane frame elements. There is no any structural modification.. A model of an aluminium'F' structure is simulated in MATLAB for the prediction of natural frequencies, Mode shapes for an undamped structure. Physical response and Frequency Response Function (FRF) are plotted for different configurations of the structure. The present model not only predicts the dynamic characteristics but also it gives significant analytical tool for further studies by an extension to mass modification.Simulation work is compared and validated with experimental results performed in the laboratory.*

Keywords:

Accurate dynamic mathematical model of a structure is essential for simulating reliably the dynamic characteristics. Such a model would allow in improving the dynamic design of a structure at the computer level resulting in an optimized design apart from savings in terms of money and time. In practice a mathematical model can be derived by analytical approaches such as by finite element method [1]. Detailed work in dynamic design using updated finite element model was carried out by Modak et.al. They have used the mass modification and beam modification for updated model for the prediction of dynamic characteristics [1,2].

Increasing demand for accuracy and out put has caused vibration problems to gain importance .Both forced and sustained vibrations are known to be prejudicial to accuracy and out put .All machine tools give rise to vibration. Deterioration in machine condition always produces a corresponding increase in vibration levels. Vibration signals are one of the most reliable parameter used in machine health monitoring to check machine condition .The purpose of the vibration analysis of machine tool structure is to sustain the useful oscillations and eliminate the unwanted ones. In general, machine structures are very complex due to various functional elements or components. There fore modelling and analysis of actual structure is expensive and it requires more computational effort. To simplify the work, F-structure is considered as generalized machine structure [3].

Methodology:

The present work aims at modelling and simulating the effect without anystiffening members at the locations where there are more chances of vibrations. The effect of stiffeners is observed .The method of predicting the dynamic behaviour of the structure with the help of simulation in MATLAB is proposed. Experimental validation is made by FFT analyser and simulated and experimental results are compared.

Details of F-Structure:

Material: Aluminium.
Overall height and width: 800 mm X 400 mm
Dimension of cross section: 25mmx25mm
Mass density of Aluminum: 2700 Kg/m ^{3}
Young's modulus of elasticity of Aluminum: $6.9x10^{10}$N/m^{2}
Mass moment of Inertia I:$3.25521x10^{-8}$ m ^{4}
Area of the elements:$6.25x10^{-4}$ m ^{2}
No. of elements:6
No. of nodes:7
No. of nodes per element: 2

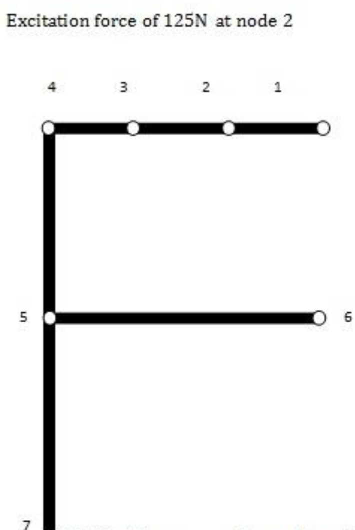
Assumption made while MATLAB simulation of structure:

- In practical case, the machine structure is three dimensional models but for simplification it is considered two dimensional.
- Joint and boundary conditions are considered to be rigid and fixed. The displacement at the grounded node is considered to be zero.
- Damping is neglected.
- Mass overlapping at cross joints are not considered.

Simulation Procedure:

1) The structure is divided into 6 two nodded plane frame elements and 7nodes. Each node has two translational and one rotational degrees of freedom.
2) Elemental connectivity table is prepared for the structure, which shows the connectivity of each pair of nodes. Database is prepared for the elements, element connectivity, material properties, geometry of the model and boundary conditions,
3) Elemental mass matrices and stiffness matrices are computed. Assembly of all the element stiffness and mass matrices is done for obtaining global mass and stiffness matrices.
4) Modal analysis is done by exciting a structure with a constant force of 125 N at node 2
5) Natural frequencies, Mass normalised mode shapes and physical responses at each nodes are obtained.

'F'-structure with a vertical stiffener



(a) Nodal representation of bare 'F'-structure.

(b) Experimental setup.

ELEMENT No.	NODE - 1	NODE - 2	Cross sectional area (m^2)	Moment of Inertia (m^4)	Element Length (m)	Angle with reference (X)
1	1	2	6.25E-04	3.25E-08	0.15	0
2	2	3	6.25E-04	3.25E-08	0.117	0
3	3	4	6.25E-04	3.25E-08	0.138	0
4	4	5	6.25E-04	3.25E-08	0.405	90
5	5	6	6.25E-04	3.25E-08	0.405	0
6	5	7	6.25E-04	3.25E-08	0.405	90
7	1	6	1.25E-04	2.60E-10	0.395	90

Table 1 Element connectivity table for bare 'F' structure.

Excitation of 125N force is applied at node 2 by impact hammer and obtained natural frequencies are compared in table 2. We can see that simulated results are reasonably matching with experimental results. Here first natural frequency of structure is 15 Hz which is almost unchanged after any structural modification.

Comparison of first three natural frequencies (Hz)			
Sr.No.	Experimental results(A)	Simulation results(B)	Error (%)
1	15	16.20	08
2	52.48	65.34	24.50
3	122.68	135.73	10.63
4	-	432.90	-

Table 2 Frequencies comparison of bare aluminum ‘F’ structure.

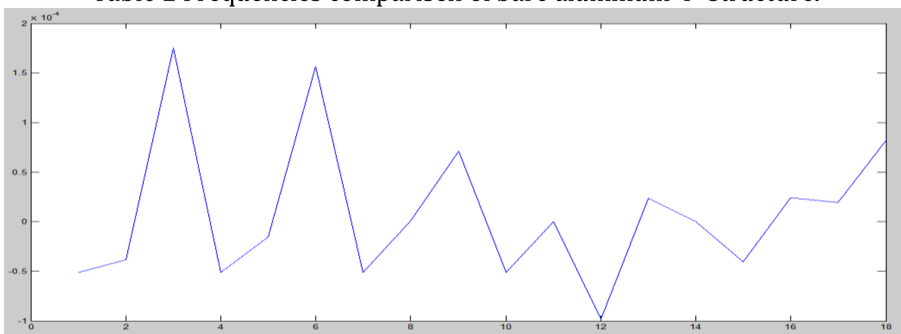


Figure 2(a) Simulated Physical response.

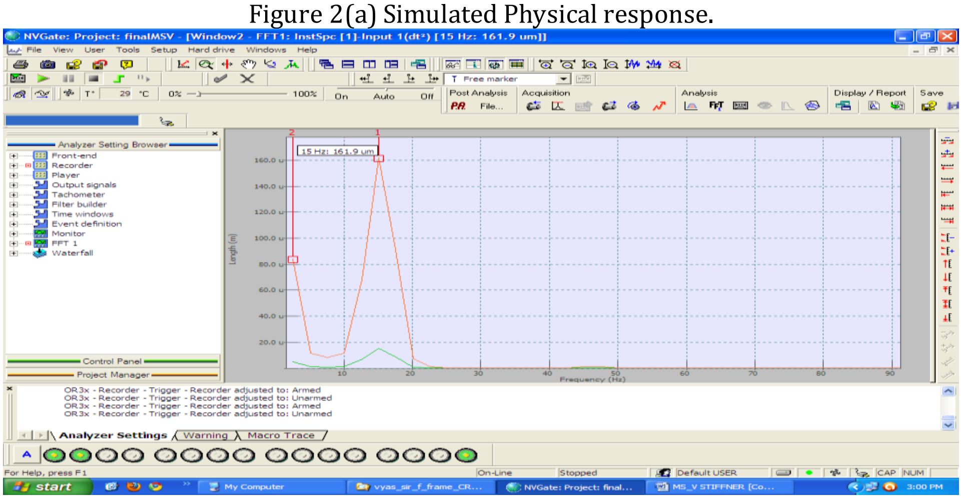


Figure 2 (b) Experimental physical response.

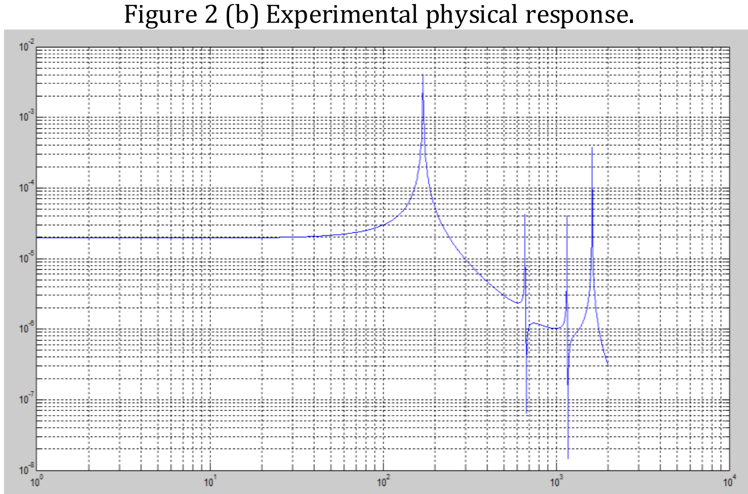


Figure 2 (c) Simulated FRF.

Figure 2 Simulated, experimental physical response and FRF for bare aluminum ‘F’structure.

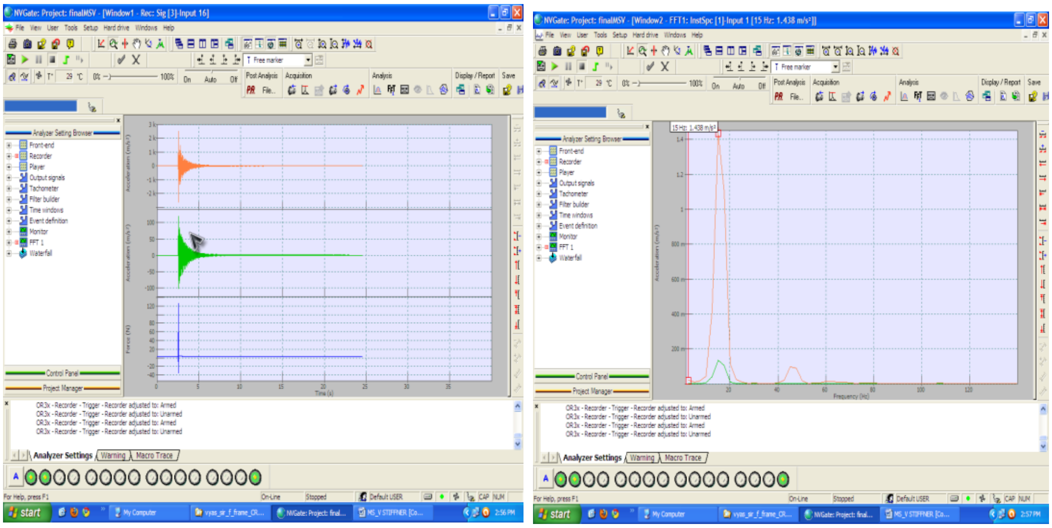


Figure 3 Experimental recorder and natural frequencies plotsforbare ‘F’-structure (Aluminum).

Conclusion:

As shown in figure 2 simulation physical response at nodes 1, 2, 3 and 6 is very much higher than nodes 4 and 5 as at these nodes vertical column element is welded with horizontal arms resulting in very high stiffness at these nodes. Whereas nodes 1, 2 and 6 are free to vibrate and hence shows positive response when excited whereas 4 and 5 shows negative response.

Value of experimental response is 161.9×10^{-6}m where as simulation shows 170×10^{-6}m response which are considerably close. As compared to structural steel, aluminum give more response to excitation. If we compare the response at node 6 shown by DOF 18, the results are dramatically similar. By experimental modal analysis we got response of 10×10^{-6}m where as simulation in MATLAB shows 7.5×10^{-6}m. This response is sensed by accelerometer 2 at channel 2. Green plot is showing the result in figure 2.

References:

For journal papers:

1. S.V.Modak et al. Prediction of dynamic characteristics using updated finite element models .Journal of Sound and Vibration (2002) 254(3), 447-467.
2. S.V.Modak et al. Use of an updated finite element model for dynamic design. Mechanical System and Signal Processing (2002) 16(2-3), 303-322.
3. J.S.Saini. Finding the Natural Frequencies and Mode Shapes for Vibration Analysis of Upright Drilling Machine. IE (I) Journal-MC, Vol 86, October 2005.

For books:

4. D.J.Ewins, Modal Testing: Theory, Practice and Application, Research studies press Ltd., 2000.
5. T.R. Chandrupatla, A.D.Belegundu, Finite Elements in Engineering, Pearson Education, 2005.
6. H.G.Vyas (Guided by prof.S.S.Pathan): Dynamic characterization of machine tool structures using simulated finite element model implemented in matlab and validation through experimentation. April -2011(M.E.Dissertation)