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ANALYSIS OF THE DISCREPANCIES BETWEEN PREDICTION AND EXPERIMENTAL RESULTS FOR A T-BEAM

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1. INTRODUCTION

At the INTERNOISE '95 meeting, structural power flow results were presented for a T–shaped beam with the configuration shown in figure 1. Three sets of results, independently obtained, were presented in three separate papers [1–3]. Two sets of the results came from numerical experiments, one using the Mobility Power Flow (MPF) approach [1] and one using McPow, which is a Finite Element (FE) based structural power flow approach [2]. The third set of results was obtained experimentally [3]. In general the results showed good agreement, as can be observed from figures (2) and (3). Some discrepancies exist between the two numeric methods, mainly in the prediction of the resonant frequencies. A Similar discrepancy occurs between the numerical and experimental results. Also, the experimental power input results show what look like antiresonances, which are not observed in either of the two numerical results. In this paper the possible cause of these discrepancies is investigated in terms of the values of the elastic properties (Young's modulus) and potential phase errors in the experimental measurements.

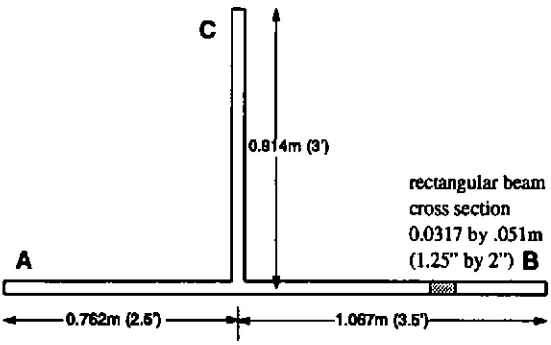

Figure 1. T–Shaped beam configuration.

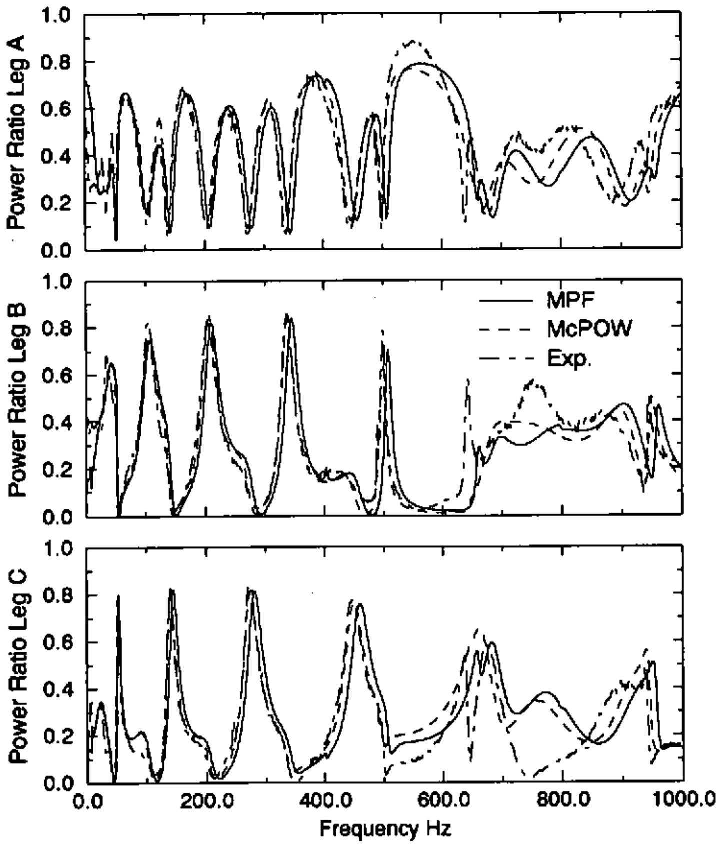

Figure 2. Power ratios for constant Young's Modulus [1–3].

2. SHIFT IN RESONANT FREQUENCIES

The shift in the resonant peaks between the two sets of numerical results [1,2], is attributed to the different type of dynamic model used in describing the out–of–plane dynamic behavior of the beam. The MPF approach is based on a Timoshenko (Mindlin) [4] thick beam representation, while it is understood that the McPow approach is based more on a thin beam pure bending type model. While this is offered as an explanation of the discrepancy between the two sets of numerical results it is not explored further in this paper. The difference in the location of the resonant peaks is in general the only difference between the two sets of numerical results.

The differences in the frequency location of the resonant peaks between the numerical results and the experimental results can in general be associated with either inadequate values of the elastic constants assumed in the numerical modeling ([1, 2] assume a constant value for the Young's modulus of 2.62×10^9 N/m^2), or inadequate representation of the boundary conditions. The T–beam was freely suspended on flexible supports, which should provide a very close approximation to free boundary conditions. Thus, the influence of the elastic constant is the one explored further.

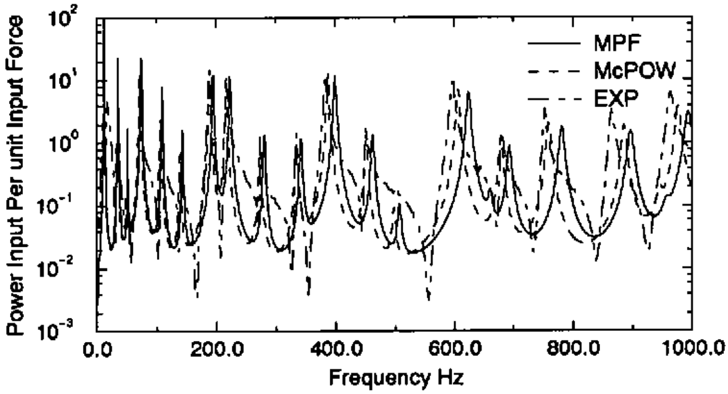

Figure 3. Power input results for constant Young's Modulus [1–3].

To investigate the influence of the Young's modulus on the location of the resonant peaks, a value is determined based on matching the resonant frequencies between the MPF [1] results and the experimental results [3]. The Young's modulus thus becomes a function of frequency (figure 4). The measured Young's modulus under static conditions [5] is 2.62×10^9 N/m^2.

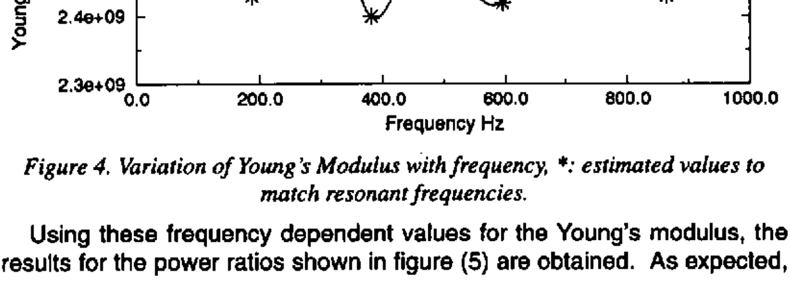

*Figure 4. Variation of Young's Modulus with frequency, *: estimated values to match resonant frequencies.*

Using these frequency dependent values for the Young's modulus, the results for the power ratios shown in figure (5) are obtained. As expected, the frequency dependent modulus of elasticity gives a much better agreement in the location of the resonant frequency peaks. The T–beam is made out of a plastic like material and a dependency of the modulus of elasticity with frequency is certainly reasonable. Thus, in comparing experimental to numerical data, especially if the numerical data attempts to estimates the modal frequencies, it is imperative that as part of the experimental measurements, an accurate estimate of the elasticity constants, mainly Young's modulus and shear be determined.

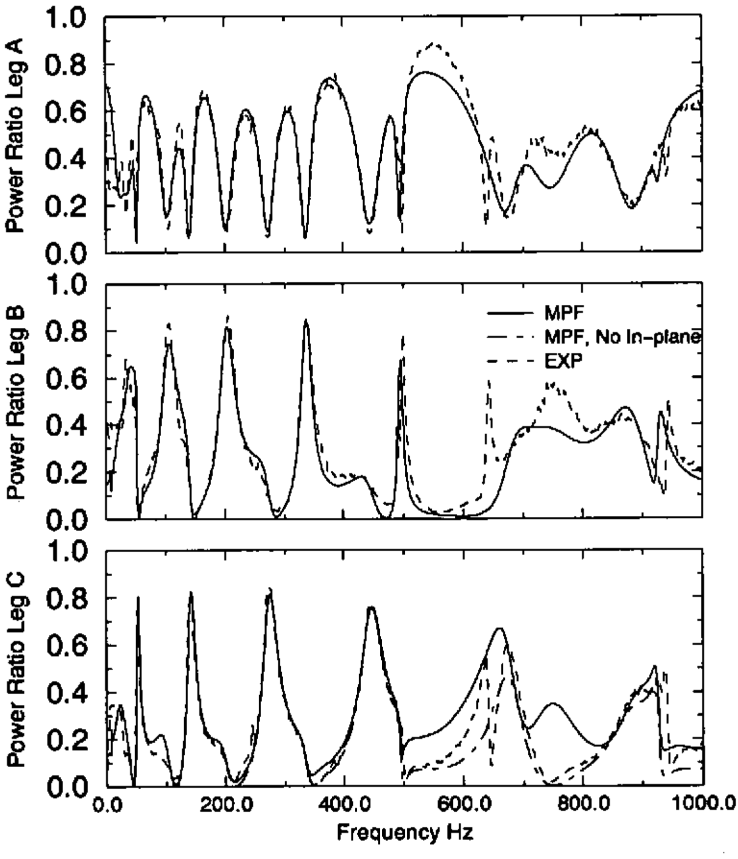

Figure 5 Power ratios using a frequency dependent Young's Modulus.

Also shown in figure (5), for the power ratio of leg C of the T–beam, are the results for the power ratio without including the in–plane contribution. It can be very clearly observed from this result that the experimental set–up did not measure the in–plane component of the power transmitted to the cross–wise component of the T–beam.

3. PHASE DEPENDENCY OF INPUT POWER

The results for the input power obtained by the two numerical approaches have a number of similarities. In fact, the only discrepancies are those discussed in the previous section regarding the location of the resonant peaks. Both numerical results for the power input have the expected shape based on the fact that the input power should not exhibit antiresonant type features, power flows only from the excitation source into the T–beam. The experimental results however show what look like antiresonances. Antiresonant features generally are indicative of a switch in the direction of the power flow, typical of reactive systems. In all instances a net positive power should flow from the excitation sources to the T–beam structure.

The discrepancies between the numerical results and the experimental results could be attributed to phase differences or errors in the experimental measurements. To explore this hypothesis, power input results have been generated for possible measurement phase differences (or errors) between the response and the excitation of 5, 10, 15, 45 and 90 degrees. Also considered is the absolute value of the normalized input velocity response, instead of only the real component of the input mobility. The absolute value of the input velocity response is not a representation of the net power input from the excitation source to the structure, but a measure of the total exchange of power between the structure and the excitation, which includes the reactive component. Shown in figure (6) are the numerically computed and experimentally measured power input results, and the normalized absolute value of the input velocity. The results for the different phase differences are not included in figure (6) for the sake of clarity.

Although the results for the different phase differences are not included, it was observed that not even a 90 degree phase difference would create the type of antiresonant behavior observed in the power input results. Furthermore, as can be observed from the results of figure (6), almost a perfect match is obtained between what is reported as the power input from the experimental measurements and the absolute value of the normalized velocity response. While this exceptionally good match could be coincidental, it points to the fact that detailed set–ups and procedures have to be recorded when comparing results by different organizations. The results shown in figure (6) include the modification to the Young's modulus to obtain the good matching in the resonant frequencies.

4. CONCLUSION

This paper attempts to explain the discrepancies between numerical and experimental results obtained by three independent organizations. The discrepancies that are explored are associated with the detailed modal behavior of the T–shaped beam structure. The first conclusion that can be drawn from the analysis presented here is that when the material of the structure is not a standard material, such as a metal, for which the elastic constants can be assumed to be independent of frequency, the measurement of the elastic constant as a function of frequency should be part of the experimental procedure. A measurement under static conditions may not be sufficient. In the results presented here the variation of the Young's modulus with frequency accounts for the shift in the resonant frequencies. However one must also consider the influenced of the boundary conditions when attempting to match modal frequencies. The second conclusion that can be made is with regards to the detailed reporting of the numerical and experimental procedures, if possible including the manipulations performed to extract the results from the analysis.

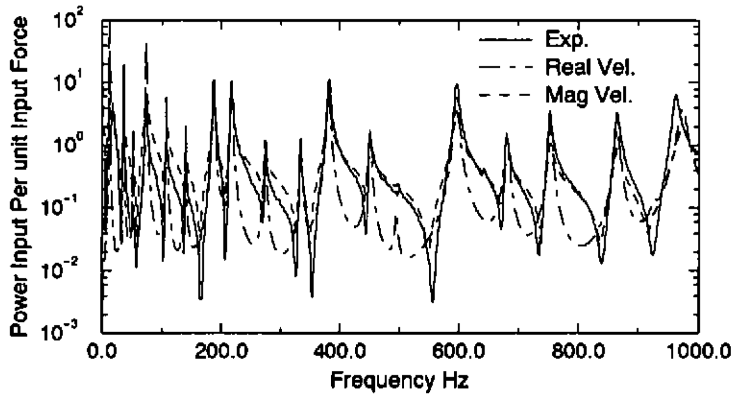

Figure 6. Comparison between numerically computed and experimentally measured power input, and the normalized absolute value of the input velocity.

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