NASA TECH BRIEF

Application of Distorted Models in Developing Scaled Structural Models

In the design and development of dynamically and geometrically similar structural models, it frequently occurs that the most convenient overall geometric scale factor for the model leads to skin panels whose thicknesses are so small, and manufacturing tolerances so fine, as to make such a model impractical. This is particularly true of honeycomb skins which, in many cases, are already very thin in the full scale structure. Very thin panels which are flat and unwrinkled are difficult to manufacture and hence are either not available commercially or are very expensive. Even when thin sheet materials are available, practical assembly problems arise in the installation of these panels on their mounting structures. Loads on the panel, due to handling, thermal stresses, and fastener pressures, are inconsequential for a normal size panel but can easily overstress and damage very thin panels, even when great care is exercised.

In an attempt to alleviate such problems, and at the same time retain the desired overall geometrical scale factor, a distorted model of the panel may be used in which the panel thickness is made larger than that dictated by geometric scaling, and the mass of the panel is increased by adding mass to the surface of the panel to counteract the additional stiffness obtained by the thickness increase. It is important that the added mass be attached so as not to add to the panel stiffness. This might be done by glueing lead pellets to the surface of the panel. In this process, the panel or sheet metal thickness is chosen on a practical basis; and then the amount of mass to be added to the panel is chosen on the basis that the model panel resonant frequencies be equal to those dictated by the overall geometrical scale factor, that is, the ratio of stiffness-to-mass for the distorted model is equal to the same ratio for the geometric model. If the overall edge dimensions of the model panel are obtained from the overall geometrical scale factor, then the distorted model of the panel is dynamically, but not geometrically, similar to the prototype panel. Dynamic similarity implies that the resonant frequencies and elastic wave length of the panel are equal to those of the prototype to within a constant factor. Since dynamic similarity is the all important factor to be simulated in model panels, it appears that the concept of distorted model panels has merit.

It is of interest to determine the amount of mass that must be added to the panel for certain increases in the panel thickness. Expressions are derived which relate the thickness increases with the mass increases; and, without loss of generality, the analysis is presented for a uniform beam (of arbitrary end conditions) in pure bending. Considering the beam to have a rectangular cross section, both a solid beam and a honeycomb beam are treated. In some cases, structural models contain solid and honeycomb components; and to show how a consistent distorted model can be constructed containing both such components, vibration amplitude levels for both types of beams are compared, and on this basis a distorted model criterion is established. Distorted models do not have unlimited application, since they cannot be used to obtain dynamic similarity in both extensional and bending type modes of vibration. The discussions are therefore concluded by developing a distorted model criterion for longitudinal vibrations of a rod, and showing that the distorted model criteria for bending and extensional modes lead to perfect geometrical scaling.

(continued overleaf)

Notes:

1. Dynamically similar distorted models of curved shells cannot be constructed because certain modes of vibration of shells involve only extensional strains, while other modes involve essentially pure bending, and still other modes involve coupled extensional and bending strains. The breathing mode of a thin circular ring or cylindrical shell is essentially a pure extensional mode, while the circumferential bending modes are essentially pure bending modes. The above type of distorted model may be used only if certain specific purely bending or purely extensional modes are of interest.
2. Inquiries concerning this innovation may be directed to:

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Patent status:

No patent action is contemplated by NASA.

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