Modal Vibration Analysis of Large Castings

Massive objects can be tested *in situ*, without precisely controlling boundary conditions.

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The art of experimental modal vibration analysis (MVA) has been extended to apply to large castings. This extension was made to enable the use of experimental MVA as a relatively inexpensive, simple means of assessing the internal structural integrity of tread shoes of crawler transporters used to move spacecraft to the launch pad at Kennedy Space Center. Each tread shoe is made from cast iron and weighs about a ton (has a mass ≈907 kg). The present extended version of experimental MVA could also be applied to other large castings. It could be especially useful to manufacturers as a means of rapidly discriminating against large castings that contain unacceptably large concentrations of internal defects.

The use of experimental MVA to assess structural integrity is not new. What are new here are those aspects of the extension of experimental MVA that pertain to the application of MVA to objects so massive that it may not be practical or cost effective to mount them in special test fixtures that impose special test boundary conditions to test them in place under normal conditions of use.

Some background information on experimental MVA is prerequisite to a meaningful description of the extension of experimental MVA to crawler tread shoes and similar large castings. In experimental MVA, one measures the vibrational response of a structural component to an impulse and/or to a continuous vibrational excitation. The measurement data are processed to obtain modal parameters that characterize the response: these parameters include modal frequencies [resonance (natural) frequencies of vibrational modes], mode-shape parameters, and modal damping parameters. The structural response as thus characterized is a unique signature that is a function of the geometry and the characteristics of the material (mass density and moduli of elasticity and rigidity, among others) of the component. Structural flaws, which are significant, show as changes to this modal signature. This concludes the background information.

The **Setup for Experimental MVA** on a massive crawler tread shoe is simple and can be implemented easily: The placements of the modal-hammer blow and accelerometer are not critical.

In experimental MVA of a crawler tread shoe or a similar large object, one excites vibrations by use of an instrumented modal hammer, which is a hammer designed for use in experimental MVA and, more specifically, to apply an impulsive force of sufficient magnitude for a sufficiently short time to excite all of the vibrational modes within a wide frequency range of interest. The vibrational response is measured by use of an accelerometer mounted on the shoe (see figure). The modes of greatest significance for assessment of the structural integrity of the shoe are first three or four bending modes and an axial mode (typically, the first one).

In experimental MVA in general, the natural frequencies are global properties of the structural component under test and manifest themselves as peaks in the frequency spectra of the responses of the component. In the case of a crawler tread or other casting, a crack, void, slag inclusion, or porosity reduces stiffness in a global sense, reducing the natural frequencies of one or more modes. Such reductions in natural frequency are measurable and are useful for assessing structural integrity, operational safety, and reliability.

Data from finite-element analysis and experiments on the crawler tread shoes confirm the experimental modal results showing that the tread shoes are relatively insensitive to boundary conditions, such that experimental MVA *in situ*, without modifications to control boundary conditions, can be used to assess the structural integrity of the shoes. More specifically, the results have been found to be largely insensitive to the locations of the hammer hit and the accelerometer location and to be repeatable after crawler motion and after changes in tension applied by pins that hold the shoes in place.

This work was done by Rudolph J. Werlink and Ravi N. Margasahayam of Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13155