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FATIGUE ANALYSIS OF MINI-MAST SPACE TRUSS

by

Shoi Y. Hwang
Professor
Department of Civil & Mechanical Engineering
South Carolina State College
Orangeburg, SC 29117

The functional, structural adequacy of a 20-meter-long generic space truss (Mini-Mast), subjected to fatigue loading, has been examined with respect to the failure modes which are most likely to occur during services. The space truss is made of thin-walled tubes having unidirectional, zero degree layups of Celanese G50 Graphite fibers/Narmco 5217 Epoxy composite. There is an additional one 5.5 mil, 90 degree E-Glass fiberglass wrap placed in the mid-wall as a strengthening mechanism in the tube circumferential direction. The delta shape truss beam contains eighteen bays, each of which consists of three parallel chords (longerons) with web members (diagonals and battens) in five planes connecting the chords. Such an assemblage of truss members forms a self-stabilizing structure.

In this study, the approach used to investigate the most probable failure mode of the truss under fatigue loading is to determine the stress level, including the types of stress, in the member first, then followed by failure mode analysis based on the stress level just determined. To begin, an approximate beam-parameter truss (BPT) model is analyzed first, followed by a detailed analysis of the truss using a finite element model (FEM) run with NASTRAN code. The BPT model assumes that the longerons are designed as tension or compression members to resist bending moment, the web diagonal members also as tension or compression members to resist shear force, and the remaining web batten members as lateral bracing for stability. The advantage of investigating the BPT model first enables one to assess the relative importance of each parameter, such as damping, natural and forcing frequencies, modes, and types and locations of loads, on the truss dynamical responses in terms of stresses and displacements. Additionally, the response results of the BPT model can also be used to compare FEM results and to check any major deviation of trend derived from the FEM. Once the dynamical stress level and types of stress are determined, the next step is to assess whether any truss member will perform adequately under the most likely failure mode caused by the stress level.

It is important that any structure of composite material under cyclic load needs to include fatigue strength as one of primary design criteria. Stress analysis of the truss shows that the predominant stresses in the truss members are the bending-action induced axial tension or compression stresses in longerons and the shear-force induced axial tension or compression stresses in diagonals. Torsionally induced shear stresses in longerons are found to be negligibly small.

In composite material, initial damage usually appears very early in the fatigue life. Its propagation may be arrested by the internal structure of the composite. The initial and the subsequent damages are evidenced by the continuing loss of stiffness. This could eventually lead to its structural failure such as excessive deformation. In critical application, fatigue failure criterion would be defined by the loss of a predetermined percent of the original stiffness rather than by a complete separation of a member. The loss of stiffness in a member could be caused by many different damage mechanisms, among them the most likely one to occur may be fiber buckling in extensional mode or in shear mode. It may also be possible that a truss member is not failed by fatigue, but by the buckling of compression member itself.

Data for fatigue properties, such as reduced stiffness versus cycles, for a unidirectional composite of zero degree layups thin-walled tube are very limited. Among the few available, the fatigue properties are largely derived from the flat specimen tests. At present, it has not been able to find fatigue test data for thin-walled tubes made of same graphite/epoxy composite and having the zero degree layups. Based on the stress analysis of the truss and the few available fatigue data for tubes of not exactly same composite, the fatigue life for the truss member is estimated. It is found that buckling failure in a compression member precedes fatigue failure of other truss members.

The purpose of the work this summer was to search available fatigue data of the tube material, to conduct approximate dynamical stress analysis of BPT model, to run detailed dynamical stress analysis of FEM model using NASTRAN code, and to predict fatigue life of truss member based on limited fatigue data.

Any space truss under dynamical load needs to include fatigue as one of the design criteria. To this end, there are few areas which need to be addressed. First, it is necessary to compile as complete as possible the fatigue data of the composite tube. Secondly, torsional buckling analysis for a unidirectional composite of zero degree layups thin-walled tube needs to be investigated if the torsionally induced shear stresses are not negligibly small. Third, it may be necessary to include geometric nonlinearity in the analysis unless the deformation can be intentionally kept small and within elastic range.