The development of a coupled dynamic model for thermoelastically loaded aluminium composite sandwich plates for satellite applications

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Abstract. An analytical-numerical coupled model has been developed to predict the effects of dynamic thermo-mechanical loading on aluminium composite panels in the form of metallic skin sandwich structures, for the enhanced design of spacecraft structures where the environmental conditions comprise combined mechanical and thermal loading. The model is explored for a centrally located static mechanical loads in conjunction with thermal loading in the form of various controlled and elevated environmental temperature functions, for prescribed physical boundary conditions.

Introduction

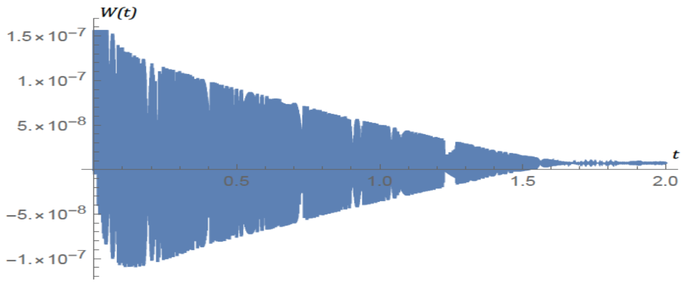
The materials used on the exterior of spacecraft are subjected to many environmental threats that can degrade them and as a spacecraft moves in and out of sunlight during its orbit around Earth the material experiences thermal cycling temperature extremes, depends on many physical conditions [1]. The problem has to be treated as a *coupled* process, and here we use a third order theory with thermomechanical coupling [2] giving results mostly as accurate as those from CUF, and comparable to previous experimental results [3].

Modelling Strategy

Despite the fact that finite element analysis is widely used for thermo-mechanical analysis there is an industrial need for a modelling capability that avoids the need for major re-definition of statically and dynamically correlated spacecraft system level models. To keep the model as tractable as possible it was decided to develop a partially coupled model, demonstrating high accuracy when compared with fully coupled CUF.

Results

The physics of dynamic thermal and mechanical loadings have been integrated into a partially coupled modelling procedure coded in the *Mathematica*™ language which can easily accommodate different boundary conditions and dynamically varying thermal properties. The full nonlinear dynamic thermomechanical model comprises three coupled nonlinear ordinary differential equations, and results have been obtained for a simply supported aluminium honeycomb composite panel under thermo-mechanical loading conditions, see Figure 1.



These results show the displacement response in the time domain when subjected to a thermal load of ($20 + 10t$) °C and a constant mechanical load of 10N, with core thickness of 0.01924m and total plate thickness of 0.02m. Displacement in metres, time in seconds. Note also the dc offset.

Figure 1: Typical numerical results from the analytical thermomechanical model

Conclusions

The configuration can be altered in terms of panel aspect ratio, boundary conditions, and load location. Broadly similar qualitative responses are observed for a linearly increasing thermal load temperature, but with the stabilisation showing close coupling to the rising environmental temperature. Thinner panels display a more pronounced thermo-mechanical response than thicker components. For pure mechanical loading, at a constant but arbitrary low level initially, the panel behaves as normal theory predicts, with a small dc offset in the displacement. The temperature profile shows a thermal response which reduces to zero in time, indicating that the internal and environmental temperatures generally equalize.

References

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