Structure Influence Coefficient Matrices

A method of structural analysis[1] was developed to enable the calculation of influence coefficient matrices used to derive:

1. Vibration modes in flutter calculation.

2. Elastic air loads, in which case an "incidence" matrix was derived. The method being tailored to the computing equipment then available, i.e. an IBM 609 - CPC. However, 60 nodes matrices were analyzed in two months with a personnel of four.

The calculated mode shapes and frequencies were compared with the results of ground resonance tests[2], and these indicated that the fuselage stiffness had been underestimated. The calculations were therefore repeated and the agreement was then satisfactory.

Two types of general analyses were then undertaken to assess:

1. The effects of kinetic heating on influence coefficients.

2. The effect of buckling due to high load levels.

The first analysis showed that the effects of thermal stresses could be neglected on either bending or torsional stiffness[3], kinetic heating effects can therefore be accounted for by introducing an overall decrease in stiffness proportional to the decrease in Young's Modulus.

The second analysis, however, demonstrated that an appreciable decrease of stiffness[4] (20%) could be expected locally wherever the skin buckled. This occured at about the 3 to 4 g level. This effect was not investigated further as the hysteresis damping produced would be large and the available stiffness reserve was greater than this decrease.

References

1. Aeroelastic Problems of Low Aspect Ratio Wings, Aircraft Engineering, February to June, 1956.

2. 71/Elastics/9 - Comparison of Estimated to Test Ground Resonance Modes.

3. 72/Elastics/7 - Effects of Spanwise Free Thermal Stresses on Wing Torsional Stiffness.

4. 71/Elastics/5 - Reduction of Wing Stiffness Due to Skin Buckling at Room Temperature

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Effects of Kinetic Heating on the Structure.

The preliminary assessment of this problem involved several investigations into the accuracy of the input data such as heat transfer, material properties, joint conductivity.[1,2,3]

Based on the fact that the input data suffered from an appreciable range of inaccuracies, it was decided to base the calculations on a heat transfer by the method of Van Driest[4,5] with an instantaneous skin temperature response. In addition, the mission could be represented by step function input[6]. The joint conductivity representing the largest source of errors, the calculations were made for two values of this parameter, one at each end of the practical range.

At first a finite difference technique[7,8] was used for the analysis. It was felt desirable to develop such a method to use in cases where the refined analysis was required. But later on the method of Biot[9] was extended and programmed for the computer to include assymetric heating and joint conductivity[10]. This approximation being very much faster and sufficiently accurate. Standard solutions were also derived by the Laplac transform method[11] for application to simplified cases.

In general, the results of all the investigations for the effects of kinetic heating at Mach 2, were found to be catered for by the decrease in allowable load levels at high altitude and speeds[12].

The effects of kinetic heating at higher speeds were also investigated for the same structure but with a change to an aluminum alloy with better elevated temperature characteristics (i.e. 2024 - T81 or T86 condition). A possible speed of Mach 2.5 could then be achieved by the structure and the speed limitation became a systems problem, in particular, fuel and airconditioning. To remove this limitation, the possibility of insulating the structure was looked into. This method offering the advantage that even higher speeds could be contemplated for combat periods of 10 - 15 minutes at Mach 3[13], as well as decreasing both the thermal stresses and the heat load on the systems.

References

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3. 70/Thermo/32 - Some Considerations in Establishing Distributions as Used for Thermal Stressing.

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5. Journal of Aero Sciences - Turbulent Boundary Layers in Compressible Fluids.

6. 70/Thermo/26 - Effect of Acceleration on Temperature and Thermal Stress Distribution.

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8. 70/Thermo/22 - Calculation of Two-Dimensional Temperature and Thermal Stress Distribution in Structures.

9. IAS Preprint 661 - New Methods in Heat Flow Analysis with Application to Flight Structures.

10. Some Effects of Internal Heat Sources on the Design of Flight Structures. Paper presented to the 1958 AGARD Structures and Materials Panel.

11. 70/Thermo/24 - An Exact Solution for Temperature Response in an Insulated Slab.

12. 70/Thermo/25 - Summary of Investigations of Temperature and Thermal Stress Distributions.

13. 73/Thermo/15 - Effect of Teflon and Micro-Quarz Insulations on Allowable Aircraft Time at Mach 3 and Altitude of 70,000 ft.