R. Richardson April 1959

ARROW

THE ARROW FLUTTER PROGRAMME

The flutter clearance of the Arrow was based on a combination of analysis, model testing and flight flutter testing. The two major problems were main surface flutter and control surface buzz. Coupled flutter of the main surfaces and controls was not a problem because of the high stiffness of the power-operated control surfaces.

1) Main Surface Flutter

Preliminary analysis showed the usual type of flexure-torsion flutter to be possible on both the cantilever wing and the complete aircraft. However, another type of flutter involving coupling of wing bending and body bending was shown to occur at a lower speed. The analysis also showed that the most critical regions were at high subsonic speeds and at very high supersonic speeds. Work was therefore concentrated on these critical regions.

a) Incompressible Case

Extensive model testing was carried out with both cantilever wing and fin, and with the complete aircraft model. Analysis with both strip theory and lifting surface theory predicted the correct type of flutter but gave conservative flutter speeds. This poor correlation however did not extend to the sub-critical damping since both analysis and experiment showed very low damping over the whole range of speeds.

b) High Subsonic Case

Transonic model tests were made with models of various stiffnesses. Both cantilever wing and symmetric aircraft models were tested in this way. Analysis using strip theory did not give very good correlation, but lifting surface theory (ref.3) gave excellent agreement with the model tests.

c) High Supersonic Case

Analysis using both strip theory and piston theory showed a good margin between flutter speed and design diving speed. Model tests were not carried out in this range.

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2) Control Surface Buzz

There are two types of control surface buzz at transonic speeds. One type occurs in potential flow and is due to the downwash from the wake travelling in the same direction as the control surface at low frequencies. The other type is a non-linear effect due to shock waves interacting with flow separation.

Two-dimensional analysis showed the possibility of the first type occurring at about M = 1.2. However, an analysis with wing modes included showed that coupling would get rid of the region of instability. In addition, it is known that three-dimensional effects increase the stability of the system.

The other type of buzz is not amenable to analysis. However, the design of the control surfaces (with shallow angle between the upper and lower surfaces and blunt trailing edges) reduced the probability of this type of buzz.

Final clearance of the buzz problem was obtained by flight flutter testing.

3) Flight Flutter Testing

Since only a few channels were available on telemetry the accelerometers on the trailing edges of the three control surfaces were considered the most important measurements. These showed the high frequency oscillations of the control surfaces (for buzz detection) and when filtered gave the lower frequency motion of the main surfaces. Excitation was by means of stick taps. Runs of increasing speed at various constant heights were made, and in addition taps were made at various heights in a climb at M = 0.88.

The main results of these tests were as follows:-

a) No buzz problem was encountered at transonic speeds.
b) The damping of the fundamental wing mode (about 5 c/s) was poor over most of the flight envelope. It reached a minimum at about M = 1.4 and increased at higher Mach numbers.
c) When the dampings from the constant Mach number climb were extrapolated to negative altitudes they showed the approach to flutter (at high subsonic M, and high EAS) as predicted by both analysis and model test.

References

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