FLIGHT TESTING AIR-TO-AIR MISSILES FOR FLUTTER

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Abstract

The philosophy of the design of air-to-air missiles and hence of flight testing them for flutter differs from that of manned aircraft. Hughes Aircraft Company puts primary emphasis on analytical and laboratory evaluation of missile susceptibility to aeroelastic and aero-servo-elastic instabilities and uses flight testing for confirmation of the absence of such instabilities. Flight testing for flutter is accomplished by using specially instrumented programmed missiles, air or ground launched with a booster to reach the extreme flight conditions of tactical use, or by using guided missiles with telemetered performance data. The instrumentation and testing techniques are discussed along with the success of recent flight tests.

INTRODUCTION AND DESIGN PHILOSOPHY

The philosophy of the design of air-to-air missiles and hence of flight testing them for flutter differs from that of manned aircraft. The primary consideration in piloted military or civil aircraft is safety of crew and passengers. Elimination of the occupant from a missile, however, does not eliminate the need for a flutter-free vehicle but a different philosophy prevails. The emphasis is shifted from personnel safety to weapon reliability. Weight and size are extremely important parameters in the design of an air-to-air missile, even more so than in other types of missiles; therefore, reliability must be compromised and an overdesigned structure cannot be tolerated. Flutter margins have to be decided upon in the light of reliability of other components of the system. For example, if the system failure is one in ten, the missile need not be designed for a failure due to flutter of one in a thousand. Thus, it may even be found advisable to permit occasional occurrence of flutter if total prevention of flutter results in a large increase in size and weight. Another important consideration is the tactical use of the missile and its speed-altitude profile. A salvo-type missile, for instance, need not have as high an individual reliability as that of a singly launched missile.

It is clear then, that in designing air-to-air missiles, flutter has to be kept in view right from the initial stages of design and has to be given its rightful place within the overall weapons system.

We at Hughes put primary effort on analytical and laboratory evaluation of missile susceptibility to aeroelastic and aero-servo-elastic instabilities and use flight testing for confirmation of the absence of such instabilities. As is common practice, previous experience on successful designs and parametric studies of the type given in Reference 1 can be used to advantage in the preliminary design stage of a missile. By the time the missile development reaches the flight test stage, considerable confidence can be gained in the structural integrity of the missile through classical studies or through analog studies and wind-tunnel testing of designs with unusual features. However, effects of aerodynamic heating and stabilities at large angles of attack and large control-surface deflections can, at present, be evaluated only through flight tests under actual flight conditions and time histories.

INSTRUMENTATION AND FLIGHT TESTING FOR FLUTTER

Flight testing for flutter of air-to-air missiles may be divided into three phases, namely,

(1) Captive flight

(2) Specially instrumented programmed flight

(3) Monitored guided flight

Captive Flight

Transonic speeds are usually one of the critical speed regimes for the incidence of flutter. Captive flights can be used to detect any flutter tendencies at transonic speeds even though such flights are only partially representative of free flights due to support characteristics. This can be done simply as visual inspection of the missile after a captive flight or more thoroughly with the use of strain gauges, recorders, or telemetry. Using conventional methods of airplane flutter flight testing, one can also add shakers or impulse devices and measure the decay rates. This phase of flight testing for flutter can be carried out at relatively low cost and yields spot checks of the analytic work early enough to add confidence in the structural design.

Instrumented Programmed Flight

Normally, the missile structure and its control system are available long in advance of the aircraft which is to carry the missile as a part of the weapon system. Flutter flight testing can then be carried out either in the speed and altitude capabilities of an existing aircraft which may not meet the critical design conditions of tactical use, or it has to be delayed until the availability of tactical aircraft. In order to bridge this gap, we, in cooperation with the Lockheed Aircraft Corporation, have developed a booster technique for our missiles which has proved very successful.

A number of experimental missiles are equipped with special instrumentation for monitoring performance and flutter data, and their guidance units are replaced by program control timers. The instrumentation can thereby be optimized to measure the response of predetermined missile maneuvers at prescribed launch altitudes and speeds. The missile-booster combination is carried aloft by a suitable aircraft and released by it when the attitude, speed, and altitude of the aircraft are such that after booster rocket-engine burnout the combination would be at the desired flight angle and the maximum critical design launch speed, or slightly in excess of it. Timers and acceleration switches carried in the booster delay its ignition by a preselected drop time and ignite the missile rocket-engine after booster burnout. The missile then carries out programmed maneuvers.

Three types of flutter instrumentation have been used successfully in flight tests using the booster technique. They are as follows:

The first consists of a pair of aft-looking 16 mm. modified GSAP* Fairchild cameras mounted in a special recoverable nose section. These cameras have all four control surfaces in their view (see Figure 1) and photograph them in flight. This optical instrumentation was used in early flight tests of missiles ground launched with a booster to observe control-surface flutter, if any, and separation of booster from the missile.

*Gun Sight Aiming Point

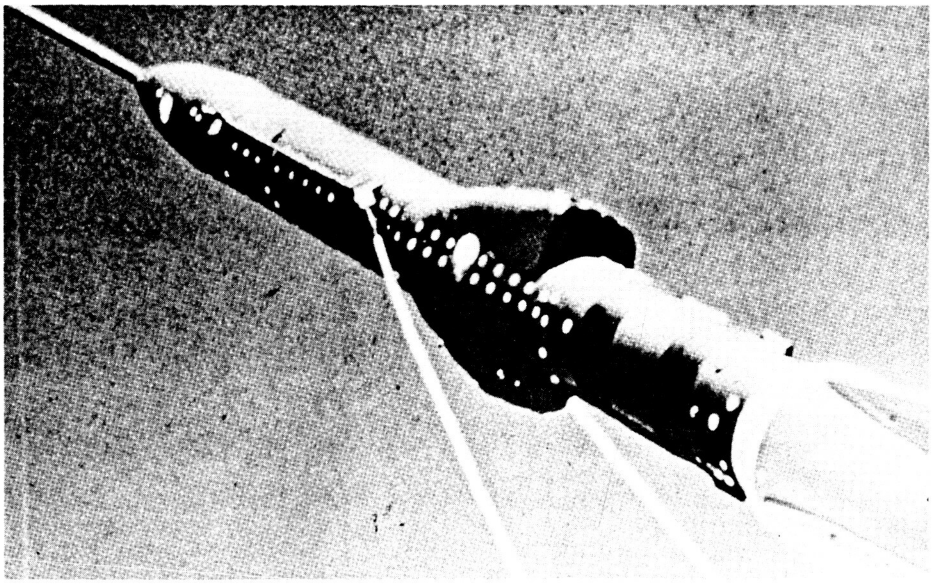

Figure 1.

MAGNETIC PICKUP

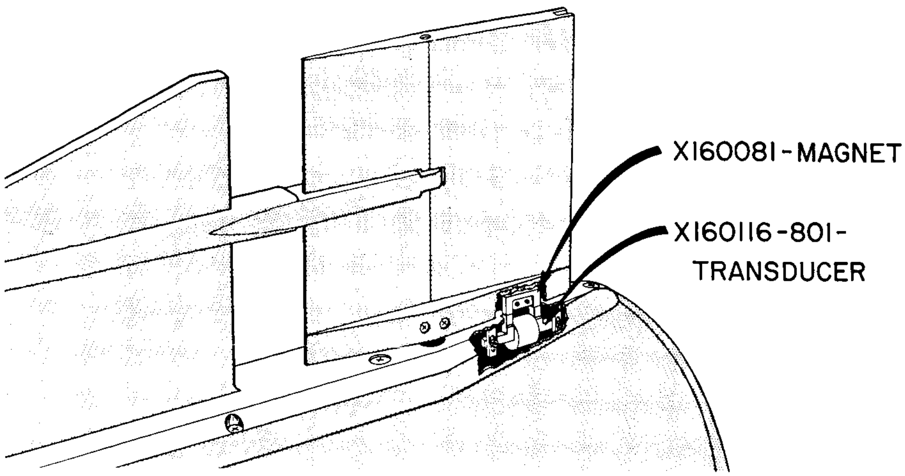

Figure 2.

The second type of instrumentation is a motional pickup developed at Hughes. This consists of a small horseshoe permanent magnet installed in the foot of the control-surface and a coil wound on a horseshoe core mounted opposite this magnet and in the foot of the stabilizer or wing (see Figure 2). Relative motion caused by vibrations generates an AC signal whose magnitude depends on the frequency and amplitude of vibration, and control-surface deflection. This signal is suitably filtered to flatten its frequency response and is fed into the coder of a telemeter unit having 2000 sample per second pulse duration modulation. The frequency, the amplitude, and the rate of subsidence or divergence of any buzz or vibration can be obtained by this type of instrumentation.

The third type of instrumentation is a self-generating type vibration pickup mounted in the aft end of the missile. The output of this pickup is fed into the same type of telemeter unit as mentioned above. Destructive flutter can also be detected by simply looping a wire into the control-surface in series with the pickup. Loss of a control-surface is then indicated by a step change in telemeter level. Further verification of flutter of a destructive nature can be made by regular 30 sample per second telemetering of control-surface position and missile response in body angular velocities and accelerations.

The above three types of instrumentation have been used successfully by us at Hughes to confirm the absence of flutter in the tactical speed-altitude profile of a missile.

Monitored Guided Flight

For missiles designed with very low flutter margins, a continuous monitoring of experimental, prototype, and production missiles is necessary in order to maintain a check on manufacturing tolerances and fabrication techniques. This can be accomplished by regular telemetering of control-surface position and the three body angular rates. Addition of pitch and yaw accelerometers is useful in determining proper aerodynamic performance, thereby assuring the absence of instabilities which might impair the guided flight of a missile and reduce the overall weapon realiability considerably.

In closing, we are happy to say, in all humility, that all the Falcon series air-to-air guided missiles designed so far have not experienced a single case of flutter, and hope that we shall continue to design them that way.

REFERENCES

1. Chawla, J. P., Aeroelastic instability at High Mach Number, journal of the Aeronautical Sciences, Vol. 25, No. 4, April 1958, pp. 246-258.