Symposium Paper

AEROMEDICAL PROBLEMS OF HIGH SPEED LOW ALTITUDE FLYING

Vibration and High Speed Low Level Flying

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Introduction

AIRCRAFT flying through a turbulent medium perforce experiences induced vibrations. The turbulence can be due to (a) weather phenomena (b) differential heating near the ground, (c) air movement and (d) various natural obstructions to air movement e.g. hill features. The vibrations are maximum closer to the ground and they are more frequent at higher speeds. Modern attack aircraft have to fly at low altitudes, often below 150 ft. to avoid radar detection. Their speeds are quite high and the speeds around 0.9 mach are often maintained to have the advantage of surprise. Some of these aircraft fly for reasonable long periods around 90-100 mts. Hunting in automatic flight control systems can add to the problem of vibrations, especially if the terrain and atmospheric turbulence is high.

Definition

Crede[1] defines vibration as a series of reversals of velocity whereas Guignard[2] defines it as a sustained structure borne disturbance, applying a translatory movement to the body and perceived by the senses other than hearing.

Vibration can be free or forced. Free vibration is like an oscillation of a pendulum disturbed from its equilibrium position whereas forced vibration is maintained by an applied vibrating force. In aviation most vibrations are of forced type.

Measurements

(a) Simple vibration: It is a sinusoidal vibration having a single unvarying frequency. The frequency is expressed as cycles/second or Hz. The amplitude is the maximum half-wave displacement and is expressed in inches or g units.

If the amplitude and frequency are known, the mean acceleration (accln) can be calculated as

$$\text{Accln} = 4\pi^2 f^2 x_0$$

where f is the frequency and x_0 is the amplitude. To obtain acceleration in g units, it is divided by 386.

(b) Complex vibration: This type of vibration is a combination of a number of simple vibrations of different frequencies. This can be either periodic or non-periodic. The frequency components can be analysed by spectral analysis or Fourier analysis. Non-periodic vibration is encountered especially due to turbulence or gust loads. A convenient measure of intensity is the root mean square (RMS) value. It is at times expressed as duration of the time for which a specific level of acceleration is exceeded.

Sources of vibration

(a) Engine vibrations: These are structure borne and reach the pilot as well as the instrument displays and controls.

(b) Armament vibrations: These depend on the type of armament used, rate of firing and the impact transmitted from gun base to aircraft structure.

(c) Gust induced vibrations: Intensity and frequency of these vibration depend on—

(i) severity of turbulence which is affected by the weather, altitude and terrain.

(ii) speed of the aircraft which determines the abruptness and frequency.

(iii) configuration, construction and trim of the aircraft.

(iv) position of the crew member in the aircraft.

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Preliminary estimations of the frequency and intensity of gust loads have been made, based on tropical atmospheric conditions [4]. These are given in Table I.

TABLE I

Estimation of the frequency and intensity of gust loads

Gust speed (ft/sec)	10.0	12.5	15.0	17.5	20.0
No. of gusts/miles	2.37	1.00	0.50	0.15	0.042

Nodal points

Most aircraft have predominant modes of vibration with their own natural frequency. Modern aircraft have a fundamental mode of vibration at frequencies below 10 Hz. At or near the nodal point the vibration is of low magnitude rotational type and at points away from the nodal point the vibration would be of high magnitude vertical translation type. In low level flights, amplitudes of 0.5g can be recorded often at crew stations.

Protection from vibration

The aims for protection are to

(a) prevent injury,

(b) enhance ability to perform,

(c) increase comfort and

(d) reduce fatigue.

These objectives at times clash with each other e.g. a soft, thick cushion is ideal for comfort and reduction of high frequency vibrations but is not acceptable for impact loads of escape. The protection is aimed at frequencies below 20 Hz and mostly below 12 Hz.

Methods

Reduction of Vibration at Source

(*a*) *Power Sources :* The vibration is periodic and of high frequency. Efforts to reduce the vibration at source is by better engineering design.

(*b*) *Interaction between Aircraft and Atmosphere:* Boundary layer turbulence can be altered by better aerodynamic design. Atmospheric turbulence or gusts can only be avoided—but not possible with operational role of fighter aircraft.

Reduction of Transmission to Man

(*a*) *Vibration isolation by Springing :* If a spring and damper can be interposed between man and the vehicle, some of the vibrations can be damped, but this is not easy to achieve for aircraft with conflicting requirements of the flight environment. Some springing can be provided by the airframe flexibility in aircraft. Ordinary spring and damper suspensions have a large number of disadvantages under different conditions. Pneumatic springs in which displacement is opposed under servo control may have applications in future aircraft.

(*b*) *Use of Nodal Positions :* Aircrew can be positioned at nodal points where amplitude of airframe vibration is the least.

(*c*) *Routes of entry of Vibration into Man :*

(i) Occupants usually sit upright and most vibrations are conveyed through the seat bottom. The seat bottom and cushions should be so designed that vibration is not amplified by their resonance.

(ii) Rigid arm rests and headrests in contact with body parts will directly convey the vibration to these parts of the body. This is also through control column, navigator's desk, sighting devices and even stiff breathing lines/pipes.

Redesign of these parts to reduce vibration reaching the man is essential.

Reduction of effects of Vibration on the Body

(*a*) *Posture and Orientation :* Major resonance in the body can be suppressed by suitable posture and orientation of man to the vibration and distributing the force over a larger area—thus reducing its magnitude. This can be achieved by slouching or by reclining back in a seat in place of sitting erect — for low frequency vibrations.

(*b*) *Design of Displays and Controls :* Displays should be best read during vibration. Deterioration of visual performance in vertical vibration is more with vertical display instruments compared to the horizontal display instruments. Vertical scale instruments require special evaluation before being used in such aircraft. Controls may be redesigned for operation by wrist and finger movements rather than whole arm movements e.g. fly by wire control systems.

(*c*) *Restraining Harness, Binders and Armour:* Safety harness provides some protection from low frequency vibrations due to gust loads. Special restraint harness may be necessary where severe jostling of multiple direction vibration is expected. Rigid or semirigid binders may reduce the resonance of human body. Tight strapping of abdomen is practiced by racing motorists, motor cyclists etc. Anti 'G' suits may help to some extent if properly used.

(*d*) *Restrict duration of Exposure:* If vibration cannot be avoided or reduced, the duration of exposure may be reduced to minimise ill effects.

(*e*) *Training and Experience:* Training, indoctrination and experience improve a man's ability to adjust to vibration environment and perform better under the stress.

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