



AEROSPACE INFORMATION REPORT

AIR1289™

REV. A

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Superseding AIR1289

Evaluation of Helicopter Turbine Engine Linear Vibration Environment

RATIONALE

AIR1289A has been reaffirmed to comply with the SAE Five-Year Review policy.

A reaffirmed status is given to technical reports that have been reviewed by the technical committee and deemed to be current with no need for immediate revision. No changes have been made to this document as a result of this review.

1. SCOPE:

This SAE Aerospace Information Report (AIR) outlines a recommended procedure for evaluation of the vibration environment to which the gas turbine engine powerplant is subjected in the helicopter installation. This analysis of engine vibration is normally demonstrated on a one-time basis upon initial certification, or after a major modification, of an engine/helicopter configuration.

This AIR deals with linear vibration as measured on the basic case structure of the engine and not, for example, torsional vibration in drive shafting or vibration of a component within the engine such as a compressor or turbine airfoil.

In summary, this AIR discusses the engine manufacturer's "Installation Test Code" aspects of engine vibration and proposes an appropriate measurement method.

2. REFERENCES:

There are no referenced publications specified herein.

3. BACKGROUND:

- 3.1 The vibratory excitation which a gas turbine engine experiences is a function of the vibration produced by the engine and the vibration produced by the installation. A satisfactory system requires that this combined vibratory level be within a range to which the engine is tolerant.
- 3.2 The vibrations measured on the engine casing may provide only an indication of the state of vibratory motions and stresses of individual components within the engine. The method of measurement, the chosen limits, and the location of the sensor should ensure a credible evaluation appropriate to the majority of cases.

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- 3.3 The source of a vibratory input is normally detectable by the frequency of the excitation which is measured in cycles per second and expressed as "Hertz" (Hz). The gas turbine engine may produce frequencies from approximately 60 to 15 000 Hz; however, frequencies above 2000 Hz are generally of no interest due to the low input energy level.

Engine-generated vibration may be produced at frequencies corresponding to the rotational speeds of the engine output shaft, the gas generator and power turbine rotors, major accessories and at gear tooth meshing frequencies, bearings, and harmonics of this and possible subharmonic resonance of shafting.

- 3.4 The helicopter may expose the engine to vibratory inputs from 3 Hz to as high as approximately 1000 Hz if the engine is direct-mounted to the main transmission. The major sources of low frequency excitation from the helicopter are:

- a. Main rotor forces and moments at one-per-rev
- b. Main rotor blade passing frequency (main rotor frequency times the number of blades)
- c. Harmonics of the latter

Tail rotor and drive shafting produce other higher frequency vibrations. Airframe-generated vibrations may be amplified or attenuated by the airframe structural dynamics.

The stiffness and/or damping characteristics of the engine mounts are important factors of the engine/airframe dynamic response to vibratory inputs.

- 3.5 The vibration spectrum to which the sensor is subjected is composed of a number of superimposed harmonic (sinusoidal) vibrations of different frequencies expressed by the general function:

$$x_i(t) = x_i \sin \omega_i t \quad (\text{Eq.1})$$

where:

- x_i = Peak value of $x_i(t)$
 ω_i = Angular frequency of the excitation

3.5 (Continued):

In a helicopter installation there are several main sources of excitation: helicopter main rotor frequency (ω_{mr}), helicopter rotor blade passing frequency ($N \omega_{mr}$, N = number of blades), gas generator rotating frequency (ω_{gg}), engine drive shaft and reduction gearbox rotating frequency (ω_{ds}) and when applicable free power turbine rotating frequency. The summation S of the response to these excitations is:

$$S(t) = \sum_{i=1}^{i=n1} x_i \sin i \omega_{mr} t + \sum_{j=1}^{j=n2} y_j \sin j \omega_{bp} t + \sum_{l=1}^{l=n3} z_l \sin l \omega_{gg} t + \sum_{m=1}^{m=4} \omega_m \sin m \omega_{ds} t \quad (\text{Eq.2})$$

In practice the contributions from higher level harmonics corresponding to $n > 2$ are generally quickly decreasing, have low energy, and therefore the significant vibratory signal can be limited to the second harmonic of each excitation (i.e., 2/rev of each excitation mentioned).

In cases where the response to $n > 2$ is significant, there usually is a resonance of an engine mode with that harmonic.

3.6 Vibration measurements may be accomplished by sensing various parameters which are characteristic of the excitation:

- a. Displacement magnitude "d" in microns (.001 mm) or mils (.001 in)
- b. Velocity magnitude "v" in centimeters per second or inches per second
- c. Acceleration magnitude "a" in meters per second per second or in g's (vector quantity, 980 cm/s² = 1 g or 386 in/s² = 1 g)
- d. Frequency "f" in hertz (cycles per second)

In practice accelerometers and velocimeters are used to measure the vibration. The overall acceleration signals may be processed through different signal conditioning methods:

- a. Peak value method, correct only for a pure sinusoidal vibration signal
- b. Average value method, defined as

$$\frac{1}{T} \int_0^T | \sum x_i(t) | dt \quad (\text{Eq.3})$$

3.6 (Continued):

which consists in averaging the signal. This method has the advantage of automatically compensating for frequency but has the disadvantage of masking peak values by flattening the sampling. (T being the period of the sinusoidal function over which the average is calculated.)

- c. Root mean square value method (rms) which is more representative of the energy content of the vibration.

The first two methods are only mentioned for information, the rms value is the basis of the method used in this AIR, although any of the three can be used successfully as long as it is used consistently throughout engine development.

3.6.1 RMS Value Method: For an instantaneous value of the general function

$$x_i(t) = x_i \sin \omega_i t \text{ (where } x_i \text{ is the peak value)} \quad (\text{Eq.4})$$

the rms value is given by:

$$x_{rms} = \sqrt{\frac{1}{T} \int_0^T x_i^2(t) dt} \quad (\text{Eq.5})$$

where:

T = Period of the sinusoidal function

For a given harmonic,

$$x_i \text{ rms} = \frac{x_i}{\sqrt{2}} \text{ is the rms value of } x_i(t) \quad (\text{Eq.6})$$

A typical vibration spectrum is given in Figure 1.

Acceleration, velocity, and displacement are used to characterize the oscillating motion with regard to the limits to be adopted for an engine. By measuring the acceleration through sensors fitted on the engine structure, the processing to transform it into displacement and velocity is directly provided from the equation of the harmonic function:

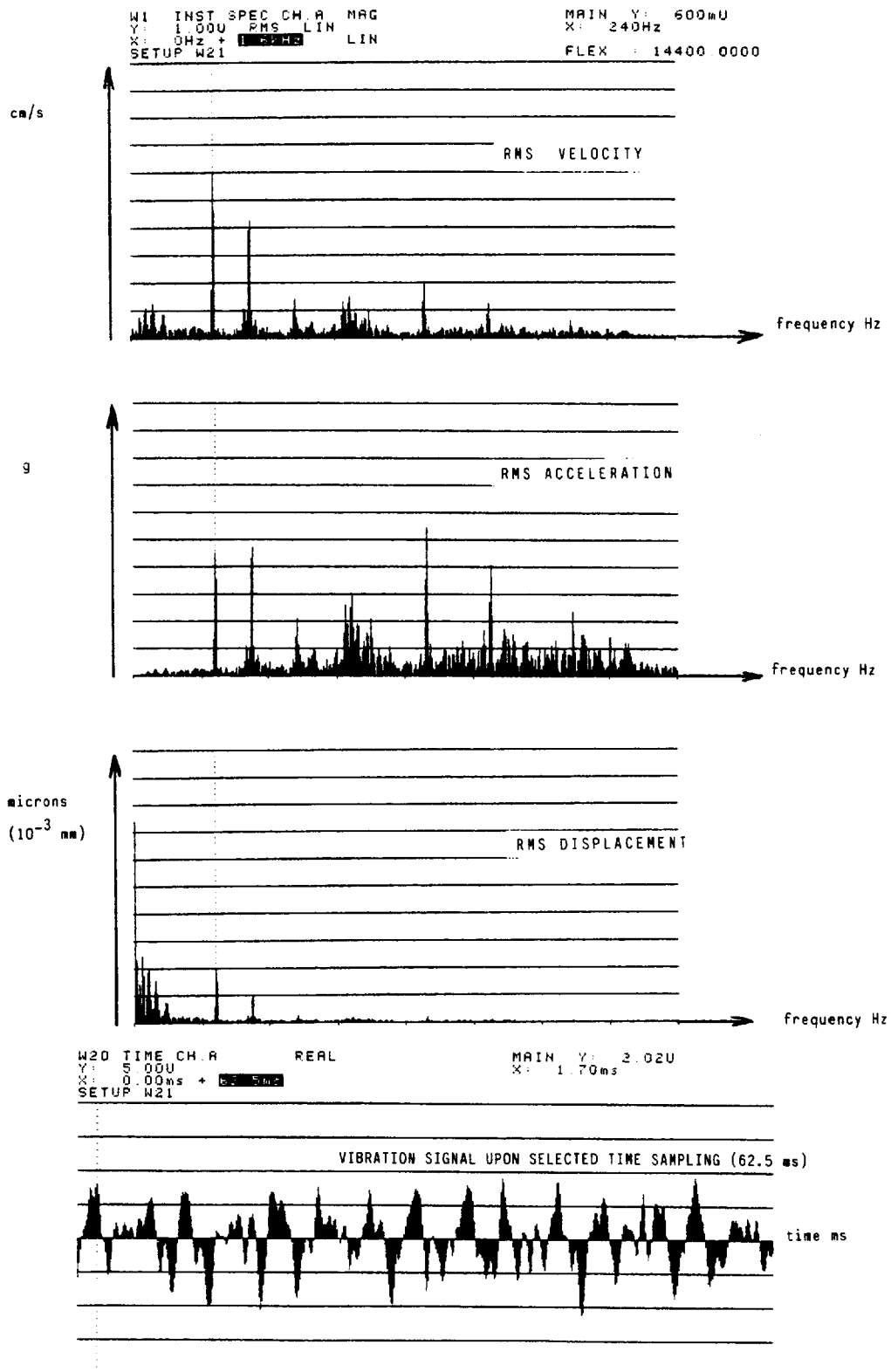


FIGURE 1 - Typical Vibration Spectrum