Instrumentation for vibration measurement

5.1 General properties of measuring instruments

Considering an instrumentation system (Fig. 5.1), having an input \( x_i(t) \) and an output \( x_o(t) \), a system frequency response function can be established, having two parts — the amplitude spectrum (Fig. 5.2 a) and the phase spectrum (Fig. 5.2 b). These spectra describe how the input signal is altered when passing through the instrumentation system: the frequency components falling within the flat passband of the system remain unaltered, the others being attenuated and shifted in phase.

It is important that the system input-output characteristic be linear in the operating region (Fig. 5.3 a). The output versus
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input ratio is called sensitivity. Non-linear regions of the $x_i - x_0$ characteristic lead to amplitude distortions (clipping). A sine wave applied to the measurement system (Fig. 5.3 b) appears at the output as a complex periodic wave (Fig. 5.3 c). In the case presented in Figure 5.3, the harmonic distortion (creation of spurious harmonic components) is due to the fact that the input amplitude is too large, overpassing the linear operating region of the instrumentation system.

Usually, any instrument has a maximum signal amplitude, curve A in Figure 5.4, determined by the maximum permissible distortion level, and a minimum signal amplitude, curve B, determined by the inherent electrical noise (or by the sensitivity of the mechanical equipment), occasionally increased by picking-up extraneous electromagnetic fields.

The ratio, measured in dB, between the maximum amplitude (defined at some specified maximum harmonic distortion) and the minimum amplitude of the signals which can be measured is called the system dynamic range. Any signal whose level is outside this range is either distorted beyond the permissible limit, or buried in the hum.

Modern analog instruments have a dynamic range of 60 dB, which corresponds to a 1000 : 1 ratio of the extremal measured amplitudes. Digital equipment has greater dynamic range. For voltage functions, a 16-bit result has a theoretical dynamic range of 96-dB (6 voltage-dB per bit). Power or squared functions also have a 96-dB dynamic range if double precision results are used (32 bits times 3 power-dB per bit).

The measurement accuracy depends on other properties of the measurement system components such as: precision, resolution, sensitivity, drift, distortion, hysteresis, backlash, friction, as well as the dynamic response, i.e. the capability of the instrumentation system to follow the variations of the measurand.

Resolution is the smallest increment of the input signal which can be distinguished by the instrument. It defines the minimum value of the signal-to-noise ratio.

Instability refers to unpredictable variations of the sensitivity. In electronic instruments, it is determined by ageing of components and in mechanical devices by strain relaxation phenomena, leading to "zero" shift.