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THE PHASE FACTOR AS A PREDICTOR OF THE INITIAL CON-DITIONS FOR THE HIGH-SPEED END MILLING OF THIN-WALLED PARTS

The development of high-tech sectors such as the aerospace industry, satellite systems and power plants is driven by the need to reduce the weight of equipment whilst maintaining its reliability and structural integrity. This objective is largely achieved through the use of thin-walled parts (TWP) made from a variety of metals, steels and alloys. Thin-walled parts are those in which the ratio of wall thickness to the shorter side lies within the range from 0.01 to 0.2. Such structures include: skins, stringers, frames, stiffeners, turbine blades, casings, etc. The most common method of machining such structures is milling, which is a complex task for production as the low rigidity of the parts leads to vibrations that significantly affect the micro- and macro-relief of the machined surface, its deformation and residual stresses.

The effect of vibrations on the machined surface relief depends on the initial cutting conditions [1]. Vibrational phenomena typical for high-speed milling are observed under the following conditions [1]:

$$D_R = t_c f_n < 1, \tag{1}$$

where t_c – cutting time, f_n – machined part natural vibration frequency, Hz.

Under these conditions, the initial vibration pulse consists of the damped natural vibrations from the previous pass and the forced vibrations associated with the cutting cycle. The sum velocity (V_s) will consist of the velocities of natural (V_n) and forced (V_z) vibrations. The vector equation of the sum velocity will look as follows (Eq. 2):

$$\vec{V}_s = \vec{V}_n + \vec{V}_z. \tag{2}$$

Considering the generated vibrations as harmonic oscillations, the following can be written:

$$F_n(t) = A_n \sin\left[\frac{2\pi}{T_n}t - \pi\right], \tag{3}$$

$$F_z(t_1) = -A_z \sin\left[\frac{2\pi}{T_z}(t_1 - t)\right], \tag{4}$$

where A_n, A_z – amplitude of a natural and forced vibration correspondently, mm; t, t_1 – time in sec and $t_1>t$, T_n, T_z – period of a natural and forced vibration correspondently, sec.

After rearranging equations (2) – (4), the final expression for the summation velocity can be expressed not in terms of time, but of the phase factor μ that determines the fraction of the angular period – 2π and thus changes from 0 to 2.

The relationship between the vibrational energy during cutting and the quality of the machined surface is direct. The greater the fraction of energy conveyed to the oscillatory actions of the system, the more the micro- and macro-geometric parameters of the surface worsens. The energy, in the meantime, is directly proportional to the square of the oscillatory velocity. An additional factor that directly influences vibratory activity is acceleration. The relationships between the square of the total velocity and acceleration as a function of the phase factor are shown in Fig. 1.

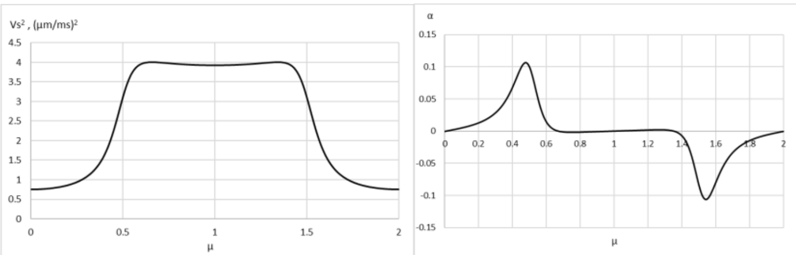

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Figure 1 - Typical relationships between total velocity and acceleration index as a function of the phase factor.

An analysis of the dependencies, examples of which are shown in Fig. 1, indicates that the less favourable initial conditions for the generation of vibrations are observed when the phase coefficient lies within the range from 0.3–0.4 to 1.4–1.5.

The effective phase factor characterizing the initial cutting conditions is determined by the following equation:

$$\mu = 2\left\{\frac{f_n}{f_z} - \frac{1}{2}\right\}, \tag{5}$$

where f_z – frequency of forced vibration, Hz. The expression in curly brackets denotes the fractional part.

REFERENCES

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