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DAMPING OF CUTTING TOOL'S VIBRATIONS IN TRACE TURNING

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Uncontrolled vibrations occurring during metal working process considerably diminish the surface purity of detail and may cause breaking the cutter. The necessity to inquire into the origin of those vibrations initiated a number of investigations studying the influence of different factors upon the occurrence as well as their nature. Experimental analysis and simulation proved that autovibrating process in metal cutting could be satisfactory described only with regard to the mechanism of "track regeneration ", i.e., the influence of unevenness formed during the previous turn of detail upon the cutter movement. Increasing stability domain is a matter of great importance for metal working on turner's bench in trace turning. Investigation of the model of cutting process provides a possibility to substantiate the phenomenon that fast oscillating stochastic perturbations of parameters of dynamical system increase stability domain. This result was formerly observed in practice. We provide the mathematical proof of this fact by means of asymptotical methods of stability investigation of stochastic dynamic model based on averaging principle.

Suppose the turning process on a turner's bench. The detail under processing moves with linear velocity v. Let us denote rigidity of cutter fastening c, energy dispersion proportional to the velocity of cutter vibrations with coefficient α, cutter mass m, the force P_n of normal pressure of shavings upon the front side of the cutter, the force P_f of friction, d_0 the desired depth of cutting, τ the time of one turn of spindle. Suppose $x(t)$ to be the deviation of the cutter from the undisturbed cutting position at the time moment t. The actual cutting depth declines from desired value as $d(t) = d_0+x(t)-x(t-\tau)$. According to experimental data force P_n is proportional to the thickness of cut off layer $P_n = qd(t)$. Considering the velocity of shavings v_0 with regard to cutter and the cutter velocity itself $\dot{x}$ we obtain $P_f = -f(v_0+\dot{x})P_n$ where f is a friction coefficient. Hence we have an equation of cutter movement $m\ddot{x} = P_f+P_\alpha+P_c$ or $m\ddot{x}(t) = -f(v_0+\dot{x}(t))q(d_0+x(t)-x(t-\tau))-\alpha\dot{x}(t)-cx(t)$. Denoting $z(t) = x(t) - \bar{x}$ the deviation from statical equilibrium position $\bar{x} = c^{-1}f(v_0)qd_0$ we have functional differential equation for cutter declination from equilibrium

$$\ddot{z}(t) + \gamma_1\dot{z}(t) + a_1z(t) + b_1(z(t) - z(t-\tau)) = l_1F(\dot{z}(t))(d_0 + z(t) - z(t-\tau)) \tag{1}$$

where $\gamma_1 = \frac{\alpha}{m}$, $a_1 = \frac{c}{m}$, $b_1 = \frac{f(v_0)q}{m}$, $l_1 = -\frac{q}{m}$, $F(\dot{z}) = f(v_0 + \dot{z}) - f(v_0)$. We propose the following algorithm of stability investigation of equation (1). Initially by means of D-partitioning of parameters' a_1 and b_1 plane we analyze stability domain of linear equation. Then with the rest of parameters chosen from the stability domain of linear equation we find restrictions on function F providing global asymptotical stability of trivial solution of equation (1). Currently let us suppose the time of one turn of spindle be a time function $\tau(t)$. It may be periodic or stochastic function. For example: $\tau(t) = \Delta(1 + \varepsilon\cos t)$ or $\tau(t) = \Delta(1 + \varepsilon\xi(t))$, where $\xi(t)$ is an ergodic Markov process with two states 0 and 1. It is proven that under certain conditions on parameters of the model this variable rotation speed may act as a damper of cutter vibrations and increase the stability domain.