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Vibrational Stability of Metal-Cutting Machines with Modified Frictional Conditions in the Slipping Guides

R. Sh. Khalimov
Stolypin Ul'yanovsk State Agricultural Academy, Ulyanovsk
e-mail: hrasp29@yandex.ru

Abstract—Electromechanical hardening with the formation of regular surface relief in the lathe guides is considered.

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Over time, the components of metal-cutting machines that affect the machining precision are subject to wear. Such wear is typical of machine tools that have been in industrial operation for a long period. The wear resistance is an important aspect of the vibrational stability, reliability, and durability of metal-cutting machines. The wear rate of frictional pairs depends on external factors and the surface properties of the components.

Along with design improvements, the hardening of machine-tool components—in their manufacture or repair—is an important means of increasing the life and reliability of metal-cutting machines. One option is electromechanical hardening with the formation of regular surface relief [1–6].

Consider a roller in contact with the horizontal surface of the guide in a machine tool (with a force of 20–50 N) [3]. The roller moves parallel to the V-shaped guide from the intake chamber of the metal-cutting machine at a speed of 0.8–1.5 m/min. At the end of each pass, it is shifted transversely by 4 mm. Electric current is supplied to the roller; the blank itself serves as the second electrode. At blank–roller contact, a current of 800 A is present. That heats local sections of the blank's surface at the roller's working surface. The surface layer of the blank is both heated and plastically deformed and is then rapidly cooled as the heat travels into the frame of the machine. Consequently, the surface is hardened and acquires regular relief.

This technology not only ensures regular surface relief on the guide but improves the structure of the surface layer. That increases the wear resistance of the frictional pair, by improving lubricant retention.

Tests demonstrate the expediency and effectiveness of this hardening technology, which permits the selection and specification of the hardening conditions for particular components—for example, the housing of metal-cutting machines [2, 6]. Note the following benefits of the technology: increase in wear resistance by a factor of 1.5–2; more than twofold increase in surface hardness; and reduced surface friction at the guides. This method is free of the problems that accompany hardening with high-frequency current—for example, buckling and the narrow specialization of the equipment and tool (inductor) employed.

The equipment for electromechanical hardening may be used both for hardening and for restoration of parts with different profile, size, and functions, and hence this method has a broad range of applications, both at large machine-tool factories and in repair shops at small and medium-sized enterprises.

As an example, consider the dynamic characteristics of UT-16 lathes with [6] and without electromechanical hardening of the guides, obtained by the test method developed at the Experimental Scientific-Research Institute of Metal-Cutting Machines [7]. The vibrational stability of the metal-cutting machine is determined by comparing the amplitude–phase–frequency characteristics before and after electromechanical hardening.

The spindle speed $n = 560–900$ rpm; the supply $s = 0.054–0.432$ mm/turn. A steel 45 blank (diameter 40 mm, length 150 mm, hardness 229 *HB*) held in a chuck is turned, by means of a pass-through cutter with a T15K6 hard-alloy plate ($\alpha = 60°$, $\lambda = 0°$, $\gamma = 0°$).

The experimental apparatus for determining the vibrational stability is a standard measuring system (Fig. 1a). The vibration is measured on certified high-pressure equipment, with recording and simultaneous analysis of the results. Numbered blanks *4* (Fig. 1a) are clamped in the three-jaw spindle chuck of the UT-16 screw-cutting lathe system. A B-480 analog–digital converter *2* is used to obtain electrical signals that may be displayed on the monitor, analyzed, and stored on the computer's hard drive. The signals are

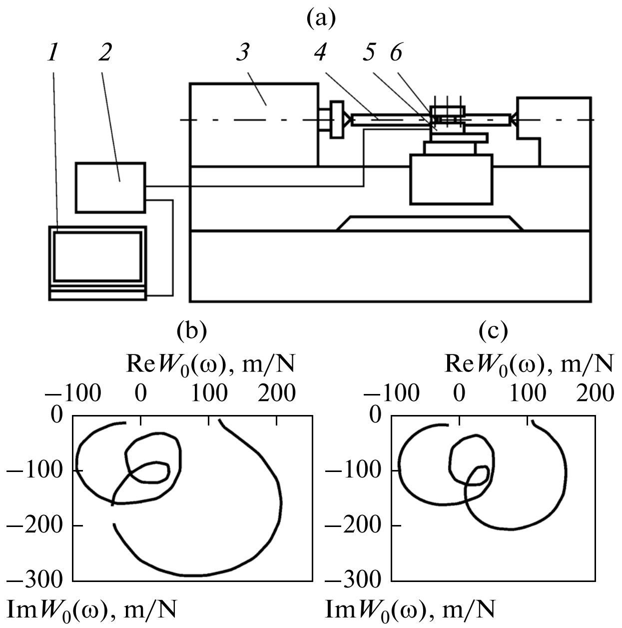

Fig. 1. Experimental apparatus (a) and amplitude–phase–frequency characteristics of the UT-16 lathe with (b) and without (c) hardening of the guides: (*1*) portable computer; (*2*) analog–digital converter; (*3*) UT-16 lathe; (*4*) blank; (*5*) vibrational converter; (*6*) cutter.

analyzed and recorded on an ASUS F3L portable computer *1* (running the Windows XP operating system). We use Powergraph 3.3 Professional software (http://www.powergraph.ru). A DN-3M1 vibrational converter *5* is attached to the cutter handle so as to record the signals; it operates on the basis of the direct piezo effect.

The table compares the vibrational stability of the UT-16 lathe with and without electromechanical hardening of the guides.

Comparative data

UT-16 lathe	f, Hz	A, m/N
Without hardening of the guides	48	1.221×10^{-3}
With hardening of the guides	48	0.558×10^{-3}

In Figs. 1b and 1c, we show the amplitude–phase–frequency characteristics of the UT-16 lathe when n = 560 rpm, s = 0.054 mm/turn, and the cutting depth t = 0.5 mm.

The results indicate that the dynamic characteristics of the metal-cutting machines are considerably improved after hardening of the guides and the creation of regular surface relief for lubricant retention: the resonant amplitude A of the dynamic pliability at the first resonant frequency (f = 48 Hz) is less than half of the value without hardening, as we see in the table.

To assess the effectiveness of electromechanical hardening of the guides, we measure the final surface roughness of the blanks. The mean deviation of the surface profile for steel blanks machined with hardened guides is R_a = 0.85–1.25 μm, as against R_a = 1.81–2.45 μm for the guides without electromechanical hardening . Metallographic data for sections of cast-iron samples show that plate graphite (in the form of small inclusions) dissolves under the action of the hardening tool. In the surface layer, the microstructure consists of ledeburite, cementite, martensite carbides, and troostite, which is converted to pearlite. Subsequently, the microstructure passes to the initial state.

Thus, electromechanical hardening with the formation of regular surface relief improves the surface layer of the machine-tool guides in boundary friction.

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