

Restoration of Machine-Tool Body Components

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Abstract—The article examines technologies for repairing machine-tool components, such as headstock and tailstock housings. The specific features of their restoration, as well as the technologies and equipment used for this purpose, are considered.

Keywords: component repair technologies, machine tools, restoration features

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INTRODUCTION

Typical defects in the housings of metal-cutting machine tools made of gray cast iron include wear of the bearing-seat and bearing-cup bores, threaded holes, holes for gear-shift shafts, and holes for locating pins, as well as chips, cracks, and warping of the mating surfaces. The defects most frequently encountered are those affecting the bearing-seat and bearing-cup bores. Eliminating these defects represents the greatest difficulty in the technological process (TP) for restoring the housings. Wear, material aging, and deformation of the housings resulting from dynamic loads during operation lead to deviations from the specified diametral dimensions of the bores, changes in their relative positions, and deviations from the parallelism and perpendicularity of the bore axes with respect to one another and to the datum surfaces.

EXPERIMENTAL

The technological process for restoring housings must ensure that the holes are brought to their nominal dimensions and that their spatial positions are corrected, while maintaining the specified accuracy parameters. Deviations from these parameters must not exceed 1–3 mm; the permissible deviations include interaxial distances of 0.03–0.1 mm, deviations from hole coaxiality of 0.02–0.05 mm, deviations from the parallelism of the axes of 0.05–0.17 mm over a length of up to 350 mm, deviations from the perpendicularity of the hole axes to the datum surfaces of 0.03–0.08 mm over a length of 100 mm, and others.

When restoring housing components, it is necessary to select an appropriate method for applying a coating to the worn surfaces, as well as a suitable workholding scheme, clamping method, and machining technology. These measures must ensure the resto-

ration and wear resistance of the surfaces and compliance with the specified accuracy requirements.

For restoring most housings, the most rational datum scheme is the one used by the original manufacturer. However, using the manufacturer's process datums without making appropriate adjustments to the restoration process is not always efficient.

For most housing components, the set of process datums used during manufacture consists of a plane and two datum holes located in that plane. In housings sent for repair, the diameters of these holes usually differ from the dimensions specified in the working drawings. During the manufacture of housing components, repeated installation and removal from fixtures cause the datum holes to wear by 0.04–0.25 mm. In addition, when the holes are arranged diagonally, the interaxial distance between them is frequently altered during operation. Therefore, when designing fixtures intended for the restoration of housings, it is necessary to take into account both wear of the datum holes and changes in the distance between their axes. Installation error can be reduced by including, in the housing-restoration process, a fitting operation for reaming the datum holes by no more than 0.1 mm, with a corresponding increase in the diameters of the fixture locating pins.

It should also be taken into account that the datum surfaces of housing components requiring restoration generally contain galling marks and dents caused by dismantling the assemblies and transporting the housings. The presence of such defects at the contact points between the housing's process (locating) datum and the fixture locating plates increases the machining allowance for the main holes and disrupts the relative position of their axes and the plane surfaces, as well as the position of the threaded-hole axes relative to the restored holes. As a result, difficulties may arise in

ensuring proper fit and assembly of the mating components. Therefore, the housing-restoration process should include cleaning and dressing the datum surfaces at the points of contact with the fixture locating elements.

When restoring housing components, all principal holes that are dimensionally interconnected by stringent tolerances and have an important functional purpose, such as bearing holes and holes for bearing sleeves, gear-shaft holes, or holes defining the relative position of attached parts and assemblies, should be bored in a single setup, regardless of whether all the holes or only some of them are worn. In this case, the datum scheme used in the original manufacturing process should be retained. The restoration process should include countersinking and reaming the datum (locating) holes to the repair size using a surface-mounted jig. The jig must be located from the design datum of the housing component. The repair sizes of locating holes that are not used as assembly datums must not exceed their nominal diameters by more than 0.2 mm.

On the fixture, the support plates should be positioned opposite those areas of the component's process locating datum that have the smallest deviations from flatness. They should also be set 2–5 mm inward from the external contour of the component. Failure to meet this requirement causes deformations during clamping of the housing component that are comparable in magnitude with the tolerance on the interaxial distance. If the process holes in the housing are used for pins or fastening bolts, these holes should be filled by welding or fitted with plugs. The process holes should then be drilled and reamed using a jig.

For restoring the main (fitting) holes of housings, methods should be selected that apply a material layer at least 1 mm thick to the hole surfaces, thereby enabling their subsequent precision machining with cutting tools on standard production equipment. Such methods include thermal spraying of powdered materials, metallizing, and installing repair sleeves.

The main holes of housing components can also be restored by installing wrapped thin-walled rings and subsequently securing them in the holes by roller expansion. The holes in the housing being restored are first bored to remove 0.9–1.0 mm per side. Helical grooves with a triangular profile are then cut into the holes. The included angle at the groove apex is 60–80°, and the groove depth is 0.3–0.5 mm. Depending on the hole length, the pitch of the helical grooves is selected within the range of 3–5 mm. During boring, the cutting speed is maintained at 80–100 m/min, while the feed is 0.12–0.20 mm/rev. Wrapped rings made of 1.2–1.5 mm thick carbon-steel sheet are then pressed into the holes and expanded using a multi-roller differential expansion tool. During expansion, the ring material is plastically deformed and fills the helical grooves. This ensures high joint strength and

reliable operation of the mating surfaces. Expansion can be performed on radial drilling machines, horizontal boring machines, or special-purpose production machines.

The minimum expansion interference depends on the ring material and the diameter of the hole being restored. For example, taking into account the tolerances of the pre-bored holes and the sheet thickness, the expansion interference for main holes with diameters of 80–160 mm, using rings made of St3, 20, or 30 steel, is 0.16–0.55 mm at a roller rotational speed of 150–300 rpm. The larger the hole diameter, the lower the specified rotational speed of the expansion tool. The feed is maintained within 0.2–0.5 mm/rev.

Securing the wrapped rings by expansion provides favorable conditions for subsequent finish boring.

During expansion of the wrapped rings, the walls of the housing-component holes are subjected to substantial radial loads and undergo elastic deformation. As a rule, the wall thickness of housing holes is not uniform; that is, the walls have different stiffnesses. Consequently, the deformation of the housing walls varies along the circumference. As a result, expansion of the rings does not ensure the required dimensional and form accuracy of the holes or the required mutual positioning of the holes.

In this case, finish boring is used to restore the relative position of the main holes. The machining allowance is 0.1–0.3 mm per side, the cutting speed is 90–130 m/min, and the feed is 0.05–0.10 mm/rev. A reduction in the roughness of the restored hole surfaces is achieved by combining boring with surface-strengthening burnishing. To perform this combined machining operation, a single-ball burnishing tool is installed and secured in the socket of the arbor or boring bar, behind the cutting tool. The allowance for burnishing is 0.01–0.02 mm.

This method of hole restoration is efficient and has the following advantages: simplicity and the possibility of implementation on standard production equipment; the use of inexpensive sheet metal as a wear-compensating material; physical and mechanical properties of the restored surfaces that are practically equal to those of new components; minimum weakening of the housing webs; no heat transfer to the housing material; the possibility of repeatedly restoring the main holes.

The restoration procedure described above (see Fig. 1) ensures the specified relative positioning of all working surfaces of housing components. The preferred diameters of the holes to be restored range from 40 to 250 mm.

Worn housing holes can also be restored using dimensionally accurate wrapped rings installed in the holes at low temperatures. In this case, the process involves boring the hole to the specified size and installing a wrapped ring, cooled in liquid nitrogen, into the hole. The housing component may be pre-

heated. After installation, the wrapped ring is finally formed to its nominal diameter by mandrel expansion. This process eliminates the roller-expansion operation, which is particularly important for housings made of aluminum alloys, as well as final finish boring. It also reduces the need for expensive and complex roller-expansion tools, which are difficult to use in repair facilities.

Housings can also be restored by filling worn holes with epoxy resin containing a filler consisting of fine calcined cast-iron chips or graphite powder. This method does not require special equipment, fixtures, or tools. For example, when restoring bearing holes, there is no need to bore the holes to a larger diameter for the bearing or for press-fitting rings or sleeves, nor is there any need to rebore them to the required final size. The technological sequence for restoring rolling-bearing holes in housings by this method is as follows: Disassemble the assembly; Clean the housing of grease and dirt; Wash the housing; Increase the roughness of the surface of the hole being restored by making rough scoring marks with a coarse file or scraper; Prepare the epoxy compound: 150 parts by weight of crushed calcined cast-iron chips or graphite powder per 100 parts by weight of resin; Degrease and dry the surface of the hole; Apply a layer of the mixture to the surface of the hole being restored; Allow the mixture to stand until it has partially thickened; Assemble the shaft with the bearings and other components; Assemble the unit; Allow the assembly to stand for 8–15 h; Remove any excess material or flash.

During operation, the threaded holes in housings become worn. They can be restored by installing threaded helical inserts. The insert is made in the form of a helical spring from corrosion-resistant wire with a diamond-shaped cross-section. Its outer surface forms a threaded connection with the hole in the housing, while its inner surface engages with a stud or bolt. Restoration of threaded holes includes the following operations: drilling the holes to a larger diameter, tapping the thread for the helical insert, installing the insert in the prepared hole, and removing the driving tang from the installed insert. A tool kit for restoring threaded holes includes drills, taps, an installation wrench for fitting the helical insert, a punch for removing the driving tang, and standard inserts of various sizes.

Worn housing holes for shift-control rollers are restored by installing bushings [4, 5].

Cracks that develop in housing components during service are eliminated using profiled metal inserts made of low-carbon steel. The crack edges are drawn together by installing the inserts in specially prepared grooves. The inserts are made in the form of cylinders connected by webs. The shape of the groove prepared in the cracked housing must correspond to the shape of the insert.

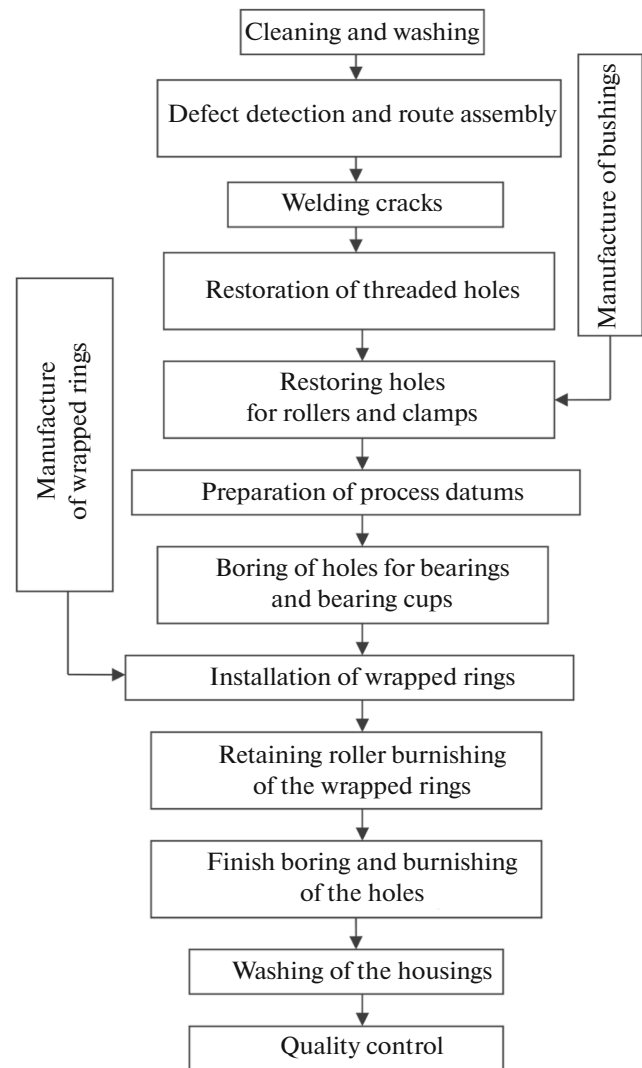


Fig. 1. Process flow diagram for the restoration of housing components.

The groove consists of a series of cylindrical holes connected by a slot whose width is equal to the width of the web of the profiled insert. Leak-tightness of the crack is ensured by pressing the insert into place using an epoxy-based composite material.

The procedure for eliminating cracks with profiled inserts includes the following operations: preparing the groove, pressing the insert into the groove, and cleaning the surface around the insert. If the crack is more than 0.2 mm wide, it should first be clamped using a clamp. The groove is prepared as follows. First, holes are drilled with the aid of an overlay jig, perpendicular to the crack. The webs between the holes are then removed with a special punch. The grooves for the inserts are arranged parallel to one another at a distance of 25–50 mm. If the crack is no more than 50 mm long, one insert is installed. The crack-closing effect is achieved by the difference in pitch, 0.2 mm,

between the axes of the drilled holes and those of the cylinders in the insert. Cracks and fractures in housing components can also be repaired by welding.

When welding cracks in cast-iron housings with special electrodes, studs are sometimes used. These are screwed into threaded holes prepared in advance along the length of the crack. The stud diameter is 0.3–0.5 times the wall thickness of the component; the stud insertion depth is 1.5 times its diameter, and the portion protruding above the surface is 4–6 mm. This increases the bonding area between the deposited metal and the housing material, thereby providing additional resistance to the shearing forces generated by dynamic loads acting on the housing component. The presence of studs in the welding zone reduces internal stresses in the deposited metal and prevents the weld from separating during cooling as a result of the different coefficients of contraction of steel (the deposited metal) and cast iron (the housing component).

When preparing the housing for crack welding, the crack edges are beveled at an angle of 90° – 120° before the studs are installed. Welding of the crack begins by welding around the studs with ring-shaped beads, allowing pauses for cooling. Metal is then deposited in the usual manner along both sides of the crack edges.

CONCLUSIONS

The restoration technologies discussed for machine-tool body components ensure a long service life.

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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