

Restoration of Parts of Keyed Connections

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Received May 13, 2024; revised July 22, 2024; accepted October 8, 2024

Abstract—This article examines various technological methods for repairing components of keyed connections. It presents different designs of keyed connections and various methods for their restoration.

Keywords: technological repair methods, keyed connections, different designs of keyed connections, various restoration methods

DOI: 10.3103/S0967091226700762

INTRODUCTION

Keyed connections are used to transmit torque from the shaft to the hub of a gear, pulley, bushing and other similar parts mounted on it, and conversely, from these parts to the shaft. The connecting element is the key. In addition, keys fix the axial position of parts on the shaft. The main types of keys and their dimensions are standardized [1]. Keyed connections (Fig. 1) are characterized by simplicity and ease of assembly, disassembly, and repair.

Their main drawback is weakening of the parts' cross-sections due to keyways and a reduction in torsional stiffness. This often leads to failure of the connection parts. The cross-sections of keys and keyways in mating parts are chosen depending on the shaft diameter and the nature of the joint.

EXPERIMENTAL

By operating conditions, keyed connections are divided into preloaded (stressed), in which internal elastic forces resulting from initial tightening act even in the absence of external forces and moments, and non-preloaded. For the latter, prismatic and segmental keys are used; these transmit load through their side faces.

Prismatic keys (see Fig. 1a) are made in standard and tall versions, with rounded or flat ends. They are used for rigid (non-moving) connections of the shaft and hub.

Guide keys (see Fig. 1d) are used when the hub must move along the shaft. These keys are fastened to the shaft with screws.

Sliding keys (see Fig. 1c) move along the shaft together with the hub. These keys are used instead of guide keys (Fig. 1d) when significant axial movement

of the hub along the shaft is required. The sliding key is mated to the hub by a cylindrical projection.

Segmental keys (see Fig. 1b) are used only for transmitting relatively small torques. If necessary, two and sometimes three such keys can be installed along the length of the shaft. An advantage of segmental keys is the ease of manufacturing both the keys themselves and the keyways; a disadvantage is the need to cut deep keyways in the shafts, which reduces their strength.

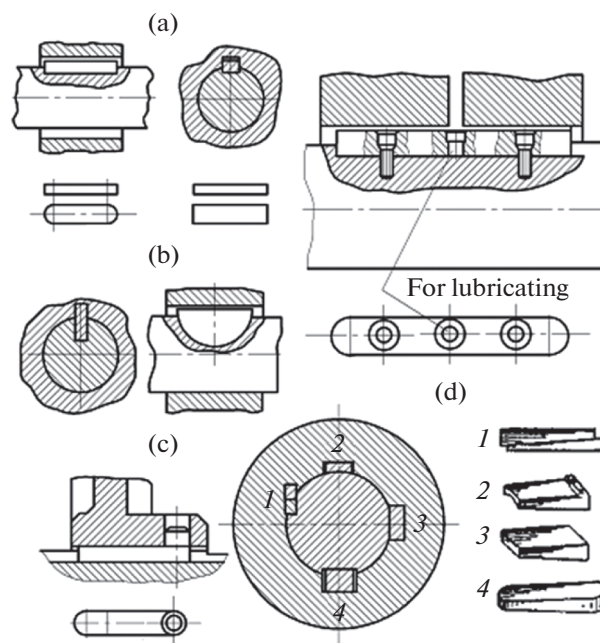


Fig. 1. Key designs: (a) prismatic; (b) segmental; (c) sliding; (d) guide; (e) wedge: (1) tangential; (2) frictional; (3) on a flat; (4) sunk.

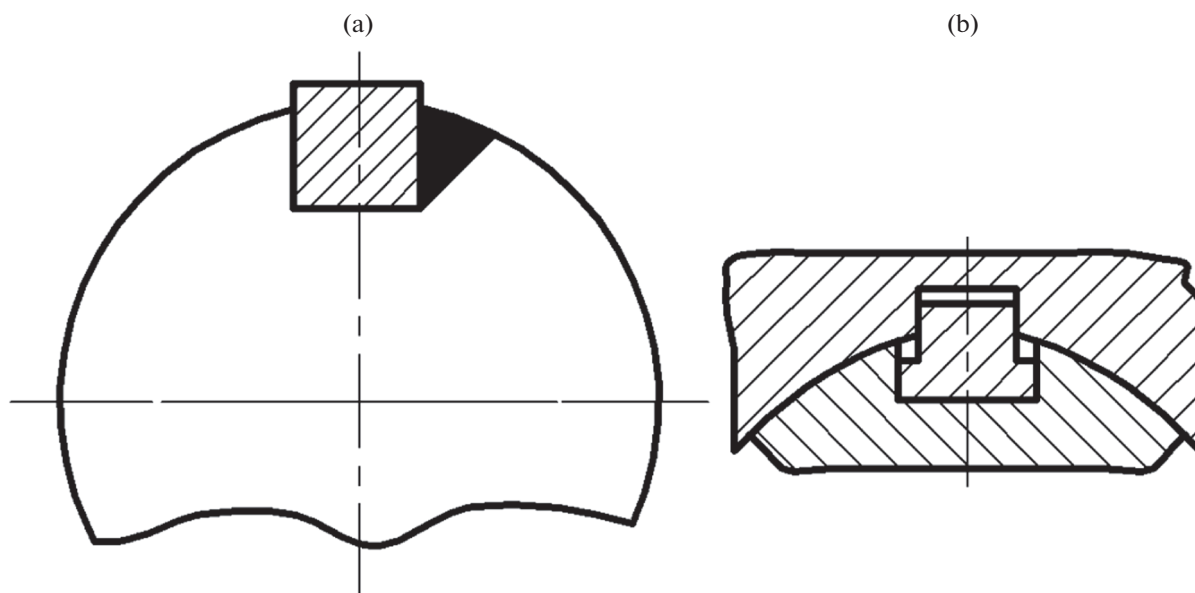


Fig. 2. Repair of keyways: (a) by welding the face; (b) by installing a stepped key.

Wedge keys with a taper of 1 : 100 (see Fig. 1d), together with the shaft and bushing, form preloaded (stressed) keyed connections. This group includes four types of keys: sunk, on a shaft flat, friction, and tangential.

A sunk key has a rectangular cross section. These keys are installed in keyways made in both the hub and the shaft. A sunk key provides a reliable connection and transmits relatively large torques; however, the keyway reduces the shaft strength by 6–10%.

A key on a shaft flat is mounted on a special flat machined on the shaft. The flat slightly weakens the shaft. However, such keys provide a poorer fit between the part and the shaft than sunk keys.

A friction key has a spherical recess on its bearing surface that matches the shaft diameter. Using such keys does not reduce the shaft strength. However, they cannot transmit large torques and are therefore mainly used in instrument engineering.

A tangential key consists of two wedges placed facing each other in a longitudinal groove in the shaft. Such a key transmits torque in only one direction. For reversing, two keys placed at an angle of 120° can transmit considerable torque but reduce the shaft strength.

Prismatic keys transmit torque via their side faces and therefore are pressed in with a guaranteed interference fit on the sides of the groove. Guide (prismatic) keys are mounted with a freer fit. Wedge keys are pressed between the mating parts. The difficulty in fitting such keys is that the taper angle of the groove in the installed part must match the taper of the key. Fitting is carried out by filing and scraping in place, checked with marking dye.

During operation, parts of keyed connections wear under dynamic loads. One of the main causes of

improper load distribution and key crushing is an increase in clearance in the joint. Crushing can also result from incorrect positioning of the keyway on the shaft. Misalignment of the groove axes causes tilting of the mating part on the shaft and accelerated wear of the connection parts.

Various methods are used to restore keyways. When the keyway is heavily worn, it is repaired by overlay welding the face (Fig. 2a) followed by milling, or by installing a stepped key (see Fig. 2b). During machining it is necessary to maintain the keyway dimensions specified by the standard. Vibro-arc cladding (Fig. 3) can be used for repair; its main advantage is the low heating of the part (no higher than 90–100°C). Such heating does not cause deformation or a reduction in hardness of the adjacent hardened areas of the repaired part. A metal layer up to 4 mm thick can be built up. During cladding the electrode is vibrated at a frequency of 50–100 Hz with an amplitude up to 4 mm, and a cooling fluid (a 5% solution of sodium carbonate) is supplied to the arc zone. This fluid reduces the thermal effect of the arc on the repaired part and increases the cooling rate of the base and deposited metals. As a result, deformations are reduced and the tempering effect on areas adjacent to the repair is mitigated. The cooling fluid also protects the molten metal from the harmful effects of oxygen and nitrogen.

Repairs are performed on a lathe whose carriage is fitted with a vibro-head that provides longitudinal or transverse feed (see Fig. 3).

Electric current is supplied to the workpiece and to the electrode, which is fed from a drum by rollers. The workpiece is held between centers or in a chuck. Because of the electrode vibrations, a spring-electromagnetic device repeatedly makes and breaks the elec-

trical circuit at the contact between the electrode and the part surface. Due to the high current density (up to 400 A/mm^2), when the electrode touches the part the contact area is fused and the electrode deposits part of the molten metal onto the part surface. The process repeats at the set vibration frequency. Electrode vibration reduces penetration into the base metal and increases the electrode melting coefficient. Consequently, metal losses and power consumption are decreased. During vibro-arc cladding the repaired parts become magnetized, so they must be demagnetized after restoration. Thanks to the vibrations, cladding can be carried out at a low voltage (12–18 V). The approach angle of the electrode wire to the workpiece is 15° – 30° . Electrode feed speed should not exceed 1.65 m/min, and the cladding speed should be 0.5–0.65 m/min.

The structure and hardness of the deposited layer depend on the chemical composition of the electrode wire and the amount of cooling liquid. When cladding with Np-80 wire (carbon content 0.75–0.85%), the deposited bead is quenched in the cooling liquid to a high hardness and partially tempered. This produces a heterogeneous structure ranging from quenched martensite to troostite-sorbite (tempered) with a hardness of 25–55 HRC. When cladding with low-carbon Sv-08 wire, a surface hardness of 14–19 HRC is obtained [2–6].

The technological sequence for vibro-arc cladding of the worn face of a keyway is as follows: removal by machining of deep scores and galling caused by wear; preparation of the part for cladding (cleaning, washing, degreasing); cladding (if necessary in several passes); demagnetization of the part; inspection to determine machining allowances.

All keyways and holes that are to be preserved are filled with graphite or copper inserts so that they project above the surface by an amount greater than the thickness of the deposited layer. This allows them to be easily removed after cladding. Surfaces not to be clad are covered with wet asbestos.

One possible repair method is as follows: the worn keyway is widened and deepened by milling, thereby completely removing the effects of wear; a special stepped key is manufactured (see Fig. 2b).

However, such a repair does not provide high accuracy or connection quality. Therefore it should be used only in exceptional cases (during inspections or routine repairs). If the part drawing contains no indication of a fixed position for the keyway, it is permissible to re-make the keyway in a different location (no more than one per cross section) without filling the worn keyway. The new keyway is made parallel to the previous one in the diametral plane at an angle to the worn keyway of 90° , 135° , or 180° .

When repairing keyed connections, worn keys are not repaired but replaced with new ones. Exceptions are wedge keys: they are pressed into the keyway by hammer blows through a soft pad so that they wedge in

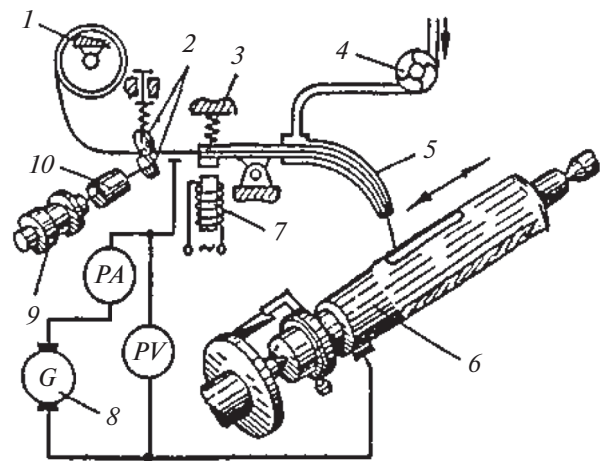


Fig. 3. Diagram of vibro-arc cladding: (1) drum with electrode wire; (2) feed rollers; (3) spring; (4) pump; (5) guide tip; (6) part to be repaired; (7) electromagnet; (8) generator; (9) motor; (10) gearbox.

height. In addition, the wedge key must be installed so that, if it loosens, it can be driven down. There should remain a distance between the head of the key and the end face of the part equal to the height of the key.

During repair, removal of keys from keyways is usually carried out with soft drift punches (see Figs. 4a, 4b). Prismatic keys can be removed from keyways without damage. A through threaded hole is made in the middle of the key into which a screw is threaded (see Fig. 4c). When the screw is turned, its end bears against the bottom of the groove and pushes the key out.

Wedge keys are extracted using a special tool (see Fig. 4d). The tool is fitted over the head of the key 1 and secured with ring 2 and screw 6. Weight 3 can move freely along rod 4, which has a stop 5 at its end. When the weight strikes the stop, axial forces are generated that drive the key out of the keyway. Lever-type tools are also used to remove wedge keys. If the embedded wedge key can be accessed from the side opposite its head, the key is driven out with a special knockout punch. It is forbidden to use a hammer and chisel to remove wedge keys. Driving a chisel between the key head and the hub leads to bending of the key, damage to the hub end face, and in some cases deformation of the shaft. After repair, assembly of joints with prismatic keys must be carried out in the following order: deburr and blunt the sharp edges of the keys and their keyways; fit the key to the shaft keyway in accordance with the fit specified on the drawing; fit the hub keyway to the key in accordance with the fit specified on the drawing; install the key into the shaft keyway using a copper hammer, clamps, or a press; check with a feeler gauge that there is no lateral clearance between the key and the keyway; check with a feeler gauge the presence of radial clearance between the key and the hub (the size of this clearance is standardized) [7].

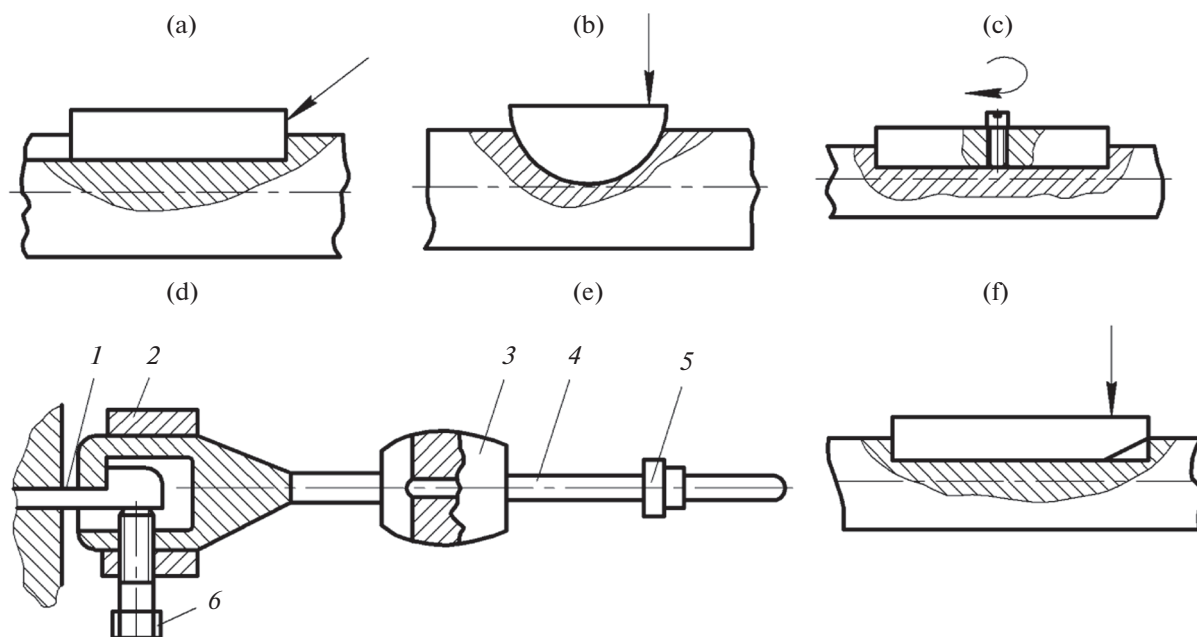


Fig. 4. Methods of removing keys from keyways: (a, b) by applying a blow when extracting prismatic and segmental keys (arrows show direction of the blow); (c) by means of a screw; (d) using a tool to remove wedge keys; (e) by making a chamfer on the key.

When fitting and assembling prismatic keys during repair, it is recommended to make a special chamfer (see Fig. 4e) and to mark the opposite side accordingly. This allows the key to be driven out with a drift and hammer: place the drift against the marked end of the key on the chamfered side and strike it with a hammer; on that side press the key end down against the base, while lifting it from the opposite side.

Key fitting is performed in the following sequence: place the shaft horizontally on V-blocks mounted on the plate; scrape the side walls of the shaft keyway to ensure their parallelism (allowable deviation from parallelism no more than 0.01 mm per 200 mm of keyway length); check wall parallelism with an indicator and keyway width with a gauge; after installing the key in the slot, check the height of its protruding part; use an indicator to control the relative positions of the keys on the shaft.

CONCLUSIONS

Thus, the above restoration technology and the schematic solutions applied in the repair processes of keyed connections make it possible to increase their service life.

FUNDING

This work was supported by ongoing institutional funding of Penza State University. No additional grants to carry out or direct this particular research were obtained.

CONFLICT OF INTEREST

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

REFERENCES

1. Skhirtladze, A.G., Skryabin, V.A., and Boriskin, V.P., *Remont tekhnologicheskikh mashin i oborudovaniya* (Repair of Technological Machines and Equipment), Stary Oskol, Belgorod oblast: TNT, 2011.
2. Pekelis, G.D. and Gel'berg, B.T., *Tekhnologiya remonta metallorazhuchikh stankov* (Metal Cutting Machine Tool Repair Technology), Moscow: Mashinostroenie, 1976.
3. Skryabin, V.A. and Skhirtladze, A.G., Technology of component of the threaded connections overhaul, *Tekh. Mashinostr.*, 2014, no. 4, pp. 23–34.
4. Skhirtladze, A.G., Skryabin, V.A., and Zotov, E.V., Technological and design features of shaft repair, *Mashinostroitel'*, 2014, no. 4, pp. 30–34.
5. Skhirtladze, A.G., Grigor'ev, S.N., and Skryabin, V.A., *Osnovy remonta i vosstanovleniya proizvodstvennykh mashin i oborudovaniya. Uchebnik* (Fundamentals of Repair and Restoration of Production Machines and Equipment: A Textbook), Yoshkar-Ola: Povolzhskii Gosudarstvennyi Tekhnicheskii Universitet, 2012.
6. Skhirtladze, A.G., Technology of restoration of hull parts, *Tekhnol. Met.*, 2001, vol. 12, pp. 30–33.
7. Skhirtladze, A.G., Gear pump repair, *Remont. Vosstanovlenie. Modernizatsiya*, 2003, vol. 8, pp. 16–23.

Translated by I. Moshkin

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