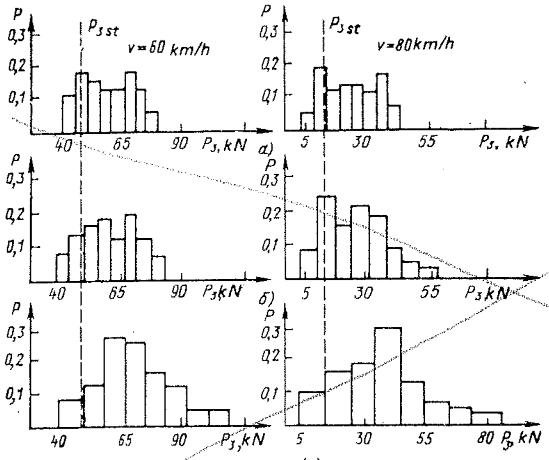

(c)

Рис. 2

Service life from beginning of operation (thousand km)	Train speed v (km/h)	R.m.s. deviation of reduction unit casing acceleration (m/s²)		
		Line tests	Rig tests	Calculated
Gear and pinion – 800	20 60	3,1–3,8 18,5–24,3	3,0 17,4	3,4 16,2
Gear – 580; pinion – 870	20 60	7,3–8,4 44–53	7,1 42,7	6,6 39,6
Gear – 800; pinion – new	20 60	8,7–11,2 55–67	8,5 52,4	11,2 57,8

EXTENDING THE SERVICE LIFE OF RAILROAD TRACTION GEARS

Vestnik Mashinostroyeniya, Vol. 61, Issue 2, 1981, pp. 45–46

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U.D.C. 621.787.4

The development and study of surface plastic deformation treatment of railway traction gears and the effect on their strength are described.

With the increasing loading intensity of railways, and train speed and mass, growing attention is being paid to the problem of raising the strength and durability of traction reduction gearing. One of such reduction gears is the traction gear of metro (underground) coaches with cylindrical helical gears (m = 7mm, the number of teeth of the shaft-pinion and gears respectively 15 and 80, tooth helix angle 8°). The shaft-pinion is made of the 20KhN3A steel, the gears are of the 38KhN3MFA steel (HB250–285). The finishing operation for the shaft-pinion is gear grinding after chemical-thermal treatment (carburizing with high tempering and quenching with low tempering to a hardness of HRC55–60), and of the gear, finish hobbing.

The high hardness differential of the gearing pair increases the load carrying capability, and improves the working-in of the gear so that it can be made to a lower accuracy than high strength gears[1].

However, under conditions of high dynamic loads these elements show insufficient load carrying capacity and durability. The main causes of failure of the shaft-pinions and the gears are fatigue damage of the teeth (spalling of the working surfaces, fractures) and their wear.

One of the main quality characteristics that influence the performance features, including the load carrying capability of traction gearing, is the surface finish of the teeth which depends upon the manufacturing process.

The grinding of shaft-pinions not always ensures the desired microtopography, and as a result of the inability of this process to be controlled in production conditions, tooth damage occurs in the form of grinding cracks, burns and also adverse residual tensile stresses.

An increase in the service life of the traction reduction gears for a metro coach and a reduction in the manufacturing effort of its gears can be achieved through finishing-strengthening treatment by surface plastic deformation (FST SPD) of the teeth[2].

A combined strengthening treatment has been developed currently for shaft-pinions that includes SPD as the finishing operation after heat treatment (carburizing, quenching, tempering to HRC50–53). The finishing operation in the making of the gear teeth is hobbing which does not permit us to obtain a tooth flank surface finish $Rz < 20\mu m$. The technical specifications stipulate $Ra = 1{,}6\mu m$; such surface finish is usually achieved by gear grinding. The time required for the FST SPD process is much shorter than for grinding. The SPD process for helical gear teeth developed by the authors makes it possible to improve tooth surface finish to $Ra = 0{,}5$ to $0{,}8\mu m$; at the same time its strength properties are improved.

The accuracy parameters of the toothed rim after SPD meet the requirements placed upon shaft-pinions and gears manufactured by large batch production methods (8–7–6–A accuracy grade). An experimental production installation with exchangeable strengthening stands has been developed for the FST SPD of shaft-pinion and gear teeth.

Figure 1 shows the finishing-strengthening treatment by surface plastic deformation of a shaft-pinion. The strengthening fixture for treating the teeth of traction type shaft-pinions by SPD consists of a welded, rigid frame and three hydraulic cylinders with tooth strengthening rollers, arranged at 120° to each other. Fig. 2 shows the design of the strengthening fixture for FST SPD of traction gear teeth, also consisting of a welded closed frame with two hydraulic cylinders and tooth strengthening rollers. Two axes are located in a horizontal plane that passes through the centre-line of the installation. The strengthening rollers freely rotate on their axes. The radial travel of the rollers (up to 40mm) and the strengthening force (up to 70kN) are provided by a pump unit.

The process parameters for strengthening traction type shaft-pinions and gears in production conditions are determined through comprehensive investigation of the strengthened layer thickness and the degree of work hardening, micro-structure, surface finish, accuracy (based on the statistical analysis of measurement results obtained by the small samples method), residual stresses of the first and second kind, degree of dispersion of the block fracture in the work hardened layer (obtained by X-ray structural analysis), the fatigue strength and durability of the teeth, and also by wear resistance.

The radial force in strengthening shaft-pinions and gears amounts to 35–40 and 15–20kN respectively. The rotation frequency of the shaft-pinion and the gear is respectively 20–25 and 6–10rev/min, tool feed during strengthening is 1–1,2 and 1,4–1,6mm/rev respectively. The process is conducted in two passes (with opposite directions of the main motion) and with copious coolant supply to the strengthening zone.

The SPD treatment of a shaft-pinion done under the above stated conditions requires 0,25h, and of a gear 0,4h, which is 5–6 times faster than gear grinding.

Studies of the physical-mechanical and performance characteristics of the surface layer in strengthened gear teeth have shown that the service life of the reduction gear is extended.

It should be noted that the SPD treatment also creates micro-deviations of a specific form which in this case increases the bearing area and thus has a favourable effect not only upon the wear resistance but also on the contact stiffness of the part. An important role is also played by the uniformity of the hardness obtained. Analysis of the results obtained when studying these parameters was conducted using statistical methods[3]. The scatter of the surface hardness at a degree of strain hardening of 10–12% is reduced 1,5–2 times compared with the conventional technology.

The SPD of the teeth in traction type shaft-pinion and gears of metro coaches makes it possible to increase the residual compressive stresses 1,3–1,5 times and the micro-deformations 1,2–1,4 times, and reduce the dimensions of crystal blocks 1,5–1,7 times.

Based on these studies, an experimental batch of batch of shaft-pinions and gears strengthened by SPD was made at the Moscow Workshops for the Maintenance of Electric Traction Equipment. Currently over 200 gears and pinions of the traction transmission are successfully employed in coaches of the Moscow metro, and have run over 1 million km.

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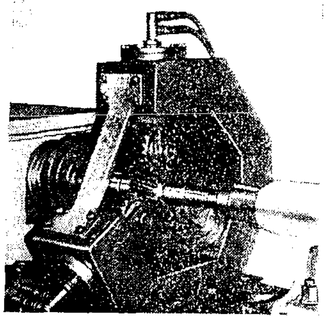

Рис. 1

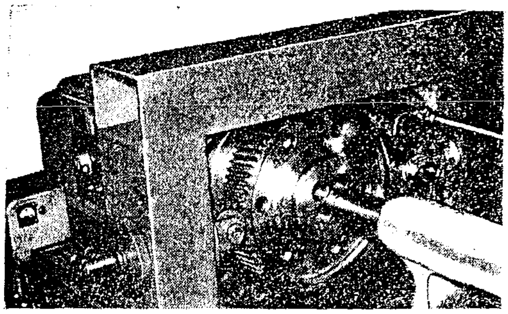

Рис. 2

THE EFFECT OF AUTOFRETTAGE ON THE STRENGTH PARAMETERS OF GEARS

Vestnik Mashinostroyeniya, Vol. 61, Issue 2, 1981, pp. 46–48

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U.D.C. 621.833.001.24

The special features of three-dimensional (volume) deformation strengthening of gears by autofrettage that involves elastoplastic bending of the teeth in the direction of the working load are analysed. The mechanism of increasing the bending strength as a result of such factors as the rational texture and volume work hardening of the plastically deformed metal layers, generation of an extensive field of compressive residual stresses and attainment of high surface finish for the load carrying parts of the teeth are investigated by the example of epicyclic gears for a combine harvester. The design of a machine for the autofrettage of epicyclic gears is described.

The fracture of teeth is a dangerous and most frequently encountered form of gear destruction. The strengthening methods employed (thermal, chemical-thermal and other surface treatment) frequently increase contact strength,