Heat treatment of bevel wheels

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Bevel gear transmissions are used in tractor and car production and in other branches of the engineering industry where it is necessary to transmit large loads at high speeds while ensuring smooth and noiseless running. In this the production of bevel gears is of decisive importance. One of the basic conditions determining the possibility of producing bevel gears with the required accuracy is minimal deformations in heat treatment.

The bevel gear (Fig. 1) for the tractor T-330 is made of steel 20KhNZA and is then nitrided for obtaining a case 1.5-2.0 mm thick. Carburization is carried out in an electrical shaft furnace Ts-105 at 930-940°C in two periods, the carburizer being natural gas. During the first period, which lasts for 2/3 of the process (gas supply 0.8-1.0 m³/h), the case forms, on the whole. In the second period the gas supply is reduced to 0.2-0.25 m³/h, and the carbon concentration in the case is equalized. The thickness of the case thereby increases only imperceptibly. After carburization the parts are furnace cooled to 850°C to reduce deformation, and then they are taken out. For this purpose a special fixture was devised in which the parts during carburization are prevented from touching. In addition to that, the fixture also ensures better washing of the parts by the gas during carburization.

After the second heating to 820°C the gears are placed in a die with forced oil feed. At first the gears were hardened in a die (Fig. 2) with ordinary releasing cams 1 and cone 2. In this die, the gear 3, heated to the quenching temperature, is placed on plate 4, is clamped by rings 5 and 6, and is cooled by oil fed through hole 7. The inner diameter of the gears is fixed by the releasing cams when the temperature has dropped to 700°C; this is ensured by locating the cams in a groove of the plate, and it continues up to complete cooling. However, since the final size of the inner diameter is not exactly fixed, case hardening in such a die does not ensure the required dimensional accuracy of the gears. According to the technical requirements, the inner diameter of the gears after heat treatment has to be $189.5 + 0.3$ mm, with maximum ellipticity 0.1 mm [1], whereas the actual diameter of the gears was $189.5 + 0.5$ with an ellipticity up to 0.3 mm. Then about 30% of the gears after final machining were not up to specification.

To improve the dimensional accuracy of the parts after heat treatment, the releasing cams and the cone of the quenching die were made with two steps (Fig. 3a), which has to ensure more accurate determination of the final size of the inner diameter, which also begins at 700°C. Since the hot part is ~1% larger than the part in the cold state, the hole is fixed at first by a cone with an angle of 90°, and then, when the part has cooled down, its inner diameter becomes smaller, and eventual fixing is effected by a cone with an angle of 20°. Such a design of the die ensures that different clamping pressures by the releasing cams are obtained. For instance, when the force of the cone is 5 kN, the clamping pressure of the cams on the cone with 90° is $F_p = 5/\tan 45° = 5$ kN, and with an angle of 20° it is $F_p = 5/\tan 10° = 28.4$ kN.

The hardening die with two-step fixing of the inner diameter makes it possible to obtain gears with a maximum ellipticity 0.15 mm.

To further improve the dimensional accuracy of bevel gears, a quenching die (Fig. 3b) with three-step fixing of the inner diameter was produced.* Initial fixing of the diameter at 700°C is effected in this die by a cone with an angle of 90°, intermediate fixing at

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More accurate dimensions of the hardened gears can be obtained when the cone and cams in the die have a curved intermediate surface (Fig. 3c). It is apparently expedient to harden large parts (600-1000 mm or more) in such dies.

Curves of the compressive and clamping pressures in dependence on the temperature of the part are presented in Fig. 4. Since the actual compressive forces of the part are not available, Fig. 4 presents the forces in relative units. The assumption was adopted that the compressive force of the part is proportional to the tensile strength of the material at the corresponding temperature. In this case the values of the strength of steel 40KhN [2] were used.