The wear resistance of tool steels under dynamic loads that are characteristic in continuous machining and many hot and cold deformation processes depends not only on the hardness but also the strength and toughness of the steel. Under these conditions the wear resistance depends on the composition and operating conditions; with the same hardness the wear resistance should be superior for steel with an even distribution of the excess phase and small internal stresses. There are well-known data on the wear resistance of nitrided cases and other hard cases under static loading conditions [1]. The effect of chemico-thermal treatment on the wear resistance under dynamic loading conditions has been studied very little.

The study was made of the following tool steels:

1) high-speed steels (R9, R12, R18) undergoing secondary hardening during tempering that embrittles the steel;

2) tougher high-chromium die steels with 6–12% Cr (Kh12M, Kh6VF);

3) chromium–tungsten steels for hot deformation (3Kh2V8F, 4Kh5V2FS) tempered to troostosorbite, with high toughness.

The steels were heated to quenching temperature so as to obtain the same grain size (grade 10) ensuring the best combination of mechanical properties. The steels were tempered under standard conditions to the following hardnesses: HRC 62–63 for steels of the first group, HRC 58–60 for the second group, and HRC 40–45 for the third group. The toughness was 3–3.5 kg/cm² for steel R18, 4.5–5.0 kg-m/cm² for Kh12M, and 4.0–5 kg-m/cm² for steel 3Kh2V8F.*

*The toughness was determined on notched samples (r = 1 mm) of steel 3Kh2V8F and smooth samples of steels R18 and Kh12M.
Fig. 2. Wear rate of nitrided tool steels under impact-abrasion conditions. 1) Steels Kh12M and 3Kh2V8F; 2) Kh12M after nitriding at 520 °C for 6 h, case depth 0.06–0.07 mm; 3) steel Kh12M after nitriding at 520 °C for 12 h, case depth 0.10–0.11 mm; 4) steel 3Kh2V8F after nitriding at 520 °C for 6 h, case depth 0.12–0.13 mm.

Fig. 3. Wear resistance of nitrided steel R18 (quenched from 1280 °C tempered at 560 °C) under impact-abrasive conditions. 1) Unnitrided; 2) nitrided case 0.015–0.020 mm deep; 3) nitrided case 0.04–0.05 mm deep; 4) nitrided case 0.10–0.12 mm deep.

The wear resistance was determined by the method given in [2] (120 impacts per minute, work of impact 0.5 kgem, testing time 20–25 min). The criterion of wear resistance was taken as the reduction in the weight and length of the sample in the test.

The wear resistance was highest for the first group of steels. The linear wear of steel R18 (3.5·10^{-2} mm after testing 6 min) was smaller by a factor of 3–3.5 than that of steels in the second and third groups, since the hardness of steel R18 is higher than that of steels Kh12M and 3Kh2V8F (see Table 1), although there is little difference in the mechanical properties (strength and toughness).

To improve the wear resistance the steels were nitrided in ammonia with 15–30% dissociation at 520 °C for 1, 6, and 12 h. The case depth is given in Table 1.

Nitriding raises the hardness and substantially increases the wear resistance. This confirms with the data in [3] concerning the fact that nitriding improves the wear resistance of parts subject to impact loads or moving at high speed under load.

Microanalysis of the worn surfaces showed traces of plastic deformation in uninitrided steels caused by penetration of abrasive grains; particles of the metal were also broken out of the surface. In tests of the nitrided steels we observed particles of metal broken out of the surface, the depth of penetration of abrasive grains was smaller (Fig. 1), and the rate of wear decreased by a factor of two (Fig. 2).

However, the wear resistance of the nitrided case may differ even with the same hardness. This depends on the structure of the nitrided case (the size, shape, nature, and distribution of nitrides and carbonitrides in the case) and also the strength and toughness of the case, which depends on the composition of the steel.

The increase in the wear resistance due to nitriding is smaller for high-speed steel with an original hardness of HV 740–780, somewhat higher for high-chromium steel Kh12M with HV 580–600, and highest for die steel 3Kh2V8F with HV 430–450.

The wear resistance of high-speed steel increased when the case depth was 0.015–0.02 mm; the total linear wear decreased to 2·10^{-2} mm (compared with 3.5·10^{-2} mm for the uninitrided steel).

An increase of the case depth to 0.04–0.05 mm on high-speed steel, achieved by increasing the length of the nitriding process from 1 to 6 h (at 520 °C), is accompanied by an increase of the total linear wear to