METALLOGRAPHY OF STEEL WITH SELENIUM, TELLURIUM, AND LEAD

A. Ya. Zaslavskii, Ya. E. Gol'dshtein, and R. I. Shenk

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One method of improving the machinability of high-strength steels is microalloying with selenium, tellurium, and lead.

We investigated the mechanical properties and machinability of experimental melts which were forged into bars 32 mm square and rounds 90 and 150 mm in diameter.

TABLE 1

Steel	Composition, %											
	C	Mn	Si	P	S	Cr	Ni	Mo	Ti	Se	Te	Pb
35Kh2GSM	0.36	1.10	0.87	0.018	0.022	1.44	—	0.33	—	—	—	—
35Kh2GSM + Se	0.36	1.05	0.88	0.018	0.023	1.47	—	0.33	—	0.148	—	—
45G2	0.44	1.21	0.27	0.023	0.023	0.11	—	—	—	—	—	—
45G2 + Se	0.45	1.33	0.23	0.021	0.021	0.11	—	—	—	0.08	—	—
45G2 + Te	0.45	1.33	0.27	0.023	0.024	0.11	—	—	—	—	0.12	—
45G2 + Se + Pb	0.45	1.32	0.27	0.023	0.022	0.12	—	—	—	0.035	—	0.07
Kh18N9T	0.10	1.21	0.65	0.030	0.008	17.0	10.0	—	0.43	—	—	—
Kh18N9T + Se	0.09	1.25	0.63	0.031	0.008	17.5	10.0	—	0.47	0.194	—	—
Kh18N9T + Se + Pb	0.09	1.30	0.64	0.029	0.008	18.0	10.6	—	0.44	0.05	—	0.08
15Kh2G2SV	0.15	2.09	0.87	0.02	0.005	2.1	0.18	0.89	—	—	—	—
15Kh2G2SV + Se	0.15	2.09	0.87	0.02	0.005	2.1	0.18	0.89	—	0.2	—	—
15Kh2G2SV + Te	0.15	2.09	0.87	0.02	0.005	2.1	0.18	0.89	—	—	0.1	—
15Kh2G2SV + Se + Pb	0.15	2.09	0.87	0.02	0.005	2.1	0.18	0.89	—	0.1	—	0.1

TABLE 2

Steel	Normalization		Improvement	
	V_{60}, m/min, for 1 h of cutter life	increased cutting rate factor	V_{60}, m/min, for 1 h of cutter life	increased cutting rate factor
35Kh2GSM	—	—	22	1
35Kh2GSM + 0.15% Se	—	—	41	1.86
45G2	88	1	47	1
45G2 + 0.08% Se	142	1.62	80	1.70
45G2 + 0.12% Te	137	1.56	82	1.71
45G2 + 0.0.35 Se + 0.07% Pb	170	1.93	118	2.51
Kh18N9T*	13.7	1	—	—
Kh18N9T + 0.194% Se*	29	2.3	—	—
Kh18N9T + 0.05% Se + 0.08% Pb	26	2.06	—	—
15Kh2G2SV*	14.1	1	20	1
15Kh2G2SV + 0.2% Se*	20	1.42	51.5	2.53
15Kh2G2SV + 0.1% Te*	17	1.20	21.8	1.10
15Kh2G2SV + 0.1% Se + 0.1% Pb	25	1.77	53.5	2.68

* Tested with high-speed steel cutters (others with hard-alloy cutters).

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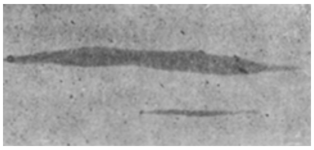

Fig. 1. Nonmetallic inclusions in steel 35Kh2GSM + 0.15% Se. × 400.

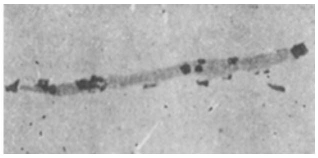

Fig. 2. Nonmetallic inclusions in steel 15Kh2G2SVA + 0.1% Te. × 300.

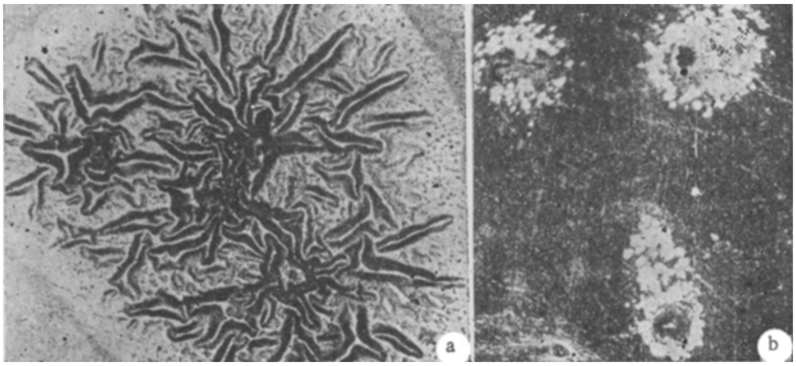

Fig. 3. Exudation of lead during heating of microsection (× 300). a) Steel 15Kh2G2SN + 0.1% Se + 0.1% Pb; b) 1Kh18N9T + 0.05% Se + 0.008% Pb.

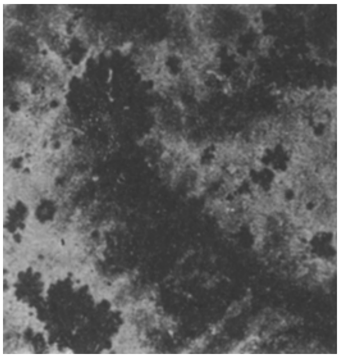

Fig. 4. Precipitates of lead in microsection of steel 12Kh-N3A + 0.07% Se and 0.07% Pb after etching in Oberhoffer's reagent and heat tinting at 350°C. × 70.

The chemical composition of the melts is given in Table 1 and the results of machinability tests in Table 2.*

The machinability of the steel not containing the additional elements was taken as unity. As the criterion of machinability we used the rate (V_{60}, m/min) which under the given conditions corresponded to one hour (60 min) of life of the cutter blades.

The improvement of the machinability of the steel with added selenium, tellurium, and lead depends on the presence of lead and nonmetallic inclusions of the type of selenides, sulfoselenides, and tellurides in the structure. These inclusions reduce the coefficient of friction between the cutters and the metal being machined and facilitate the breakdown of the structure.

In forged bars the selenides (or sulfoselenides) appear as elongated light-gray inclusions (Fig. 1). The tellurides are less lamellar than the selenides. They are of irregular form and frequently in contact with the nitrides (Fig. 2). They are dark to light gray in color. The presence of lead was not observed in unetched microsections. Attempts were made to reveal the lead by special polishing with paraffined paper. On the microsections of the steel containing lead dark tongues of lead accumulations were formed around the other nonmetallic inclusions.

Reliable and very clear results are given by heat tinting of the microsections of steel containing lead. The microsections were heated in a lead bath or in a vertical tubular furnace. The etching temperature must be higher than the melting point of lead (327° C) but below 400° C (for structural steel)

* The machinability tests were made at the Kurgansk Machine Construction Institute under the direction of Yu. A. Rozenberg.

because of the oxidation of the lead particles which exude and the formation of a thick layer of oxides which distorts the picture. After heating, microblobs of lead are visible on the surface; the longer the heating time, the bigger and more spread over the surface they become. The lead occurring around precipitates has an iridescent tarnish which is usually of a lighter shade than on the rest of the surface of the microsection (Fig. 3a). To obtain such precipitates on microsections of stainless steel containing lead the heating temperature must be increased to 650-700° C. However, in this case the particles of lead on the surface of the microsection are considerably finer than in ordinary structural steels and the blobs do not spread over the surface (Fig. 3b).

To determine the distribution of lead particles in microvolumes, microsections of case steel 12KhN3A containing 0.11% Se and 0.08% Pb were etched in Oberhoffer's reagent (to reveal the dendrites) and heat tinted at 350° C. As can be seen in Fig. 4, the lead particles occur in interdendritic areas.

When steel parts are machined the heat evolved in cutting heats the surface layer of the part to a temperature which substantially exceeds the melting point of lead. The lead in the steel is partially exuded, forming a liquid lubricant between the cutter and the piece which reduced the friction and prevents the cutting tool from gripping the piece being machined.

Selenium and tellurium reduce the wear of cutting tools in a different way. As a consequence of the high temperatures occurring during machining, the selenides (tellurides) break down, forming a film which reduces the friction and adhesion between the cutting tool and the surface being machined. Nevertheless, the existence of selenides (tellurides) in the form of metallic inclusions promotes fine chips and facilitates their detachment from the piece being machined.

The process of decomposition of selenides (tellurides) and formation of a protective-lubricating film occurs at higher temperatures than the exudation of lead. Consequently, alloying with lead provides the greatest improvement in machining steels with high-speed cutters. For machining the same steel with hard-alloy cutters at high rates, when the surface reaches very high temperatures, alloying with selenium or tellurium is more effective.