TRIBOTECHNICAL PROPERTIES OF DEPOSITED METAL OF 50Kh9S3G TYPE WITH INCREASED SULPHUR CONTENT

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Steels alloyed with sulphur (for instance, silchrome) are widely applied in manufacture of tools for cold rolling of metal. Their reconditioning repair requires materials ensuring deposited metal composition close to that of baze metal. The work is a study of sulphur influence on tribotechnical properties of deposited metal of 50Kh9S3G type. Sulphur content in the deposited metal was varied in the range of 0.02 to 1.70 %. Investigations revealed that sulphur forms complex sulphides, which prevent seizure of interacting metal surfaces, thus increasing deposited sample wear resistance. To ensure optimum tribotechnical properties of deposited metal, volume content of complex sulphides of the main alloying elements should be within 1.5 to 2.0 %, and their dimensions should be ≤0.02 mm. This condition is ensured at total content of sulphur of 0.5–0.8 % in the deposited metal. At lower sulphur content the quantity of forming sulphides is insufficient to make an essential influence on deposited metal properties. At higher sulphur content the forming coarse sulphide inclusions are less strongly retained by deposited metal matrix and during testing they crumble and are removed from the wearing zone. This adversely affects wear resistance of deposited metal and contacting part. 10 Ref., 2 Tables, 3 Figures.

Keywords: *deposition, deposited metal, sulphur alloying, sulphides, tribotechnical properties*

Steel 50Kh9S3G, known as «silchrome» trade mark, is quite widely applied for manufacturing metal cold working tools, in particular, for deep cold drawing dies, as well as heavy-duty parts of some friction pairs. These parts operation process is characterized by significant mechanical loads and they fail most often as a result of seizure wear. For reconditioning cladding of cold drawing dies PWI developed flux-cored wire PP-Np-50Kh9S3G, providing deposited metal similar to base metal as to its composition [1]. Increase of seizure resistance of deposited metal of this type remains to be an urgent problem.

Table 1. Composition and hardness of metal deposited with test flux-cored wires

Flux-cored wire designation	Weight fraction of elements, %					*HRC* hardness
	C	Mn	Si	Cr	S	
PP-Np-50Kh9S3G-Op-1	0.55	0.52	2.65	9.23	0.02	56
PP-Np-50Kh9S3G-Op-2	0.50	0.81	2.80	9.04	0.27	58
PP-Np-50Kh9S3G-Op-3	0.64	0.55	2.65	9.25	0.70	58
PP-Np-50Kh9S3G-Op-4	0.62	0.52	2.80	8.65	1.05	55
PP-Np-50Kh9S3G-Op-5	0.67	0.58	2.65	8.80	1.30	56

From scientific-technical publications [2–8] and earlier wear resistance studies at different kinds of wear of 23Kh5M3FS deposited metal [9] alloyed with sulphur, it is known that inclusions of complex sulphides prevent seizure wear, lower the friction coefficient, and improve the quality of deposited metal wearing surfaces. An objective was set to improve the tribotechnical characteristics of deposited metal of 50Kh9S3G type due to sulphur alloying.

Considering the experience of earlier studies [9], sulphur content in deposited metal of this type was varied within 0.02–1.30 % (Table 1).

Wear resistance and friction coefficient of deposited metal were assessed using an all-purpose component of friction machine, designed for laboratory-experimental evaluation of tribotechnical properties of friction pairs at room and elevated temperatures [10]. Wetting was assessed by the presence or absence of increase of counterbody or sample mass. Testing was conducted by hole abrasion method by «shaft-plane» schematic without additional lubricant feeding into friction zone. Samples for tribotechnical studies, cut out of deposited metal third-fourth layer, had the dimensions of 3 × 17 × 25 mm. Wearing surface was 3 × 25 mm. Counterbody in the form of a ring of 40 mm diameter and 12 mm width was made from quenched steel 45 with hardness *HRC* 42.

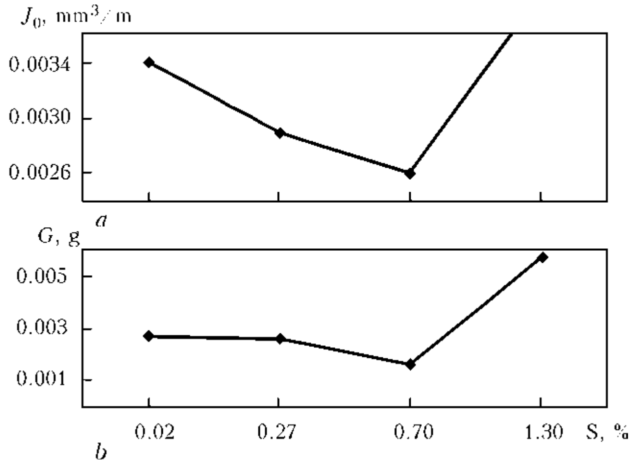

Figure 1. Wear of samples of 50Kh9S3G deposited metal with different content of sulphur (*a*) and counterbodies tested in pair with them (*b*)

The following test mode was selected by the results of pre-testing: sliding velocity of 0.06 m/s, 30 N load, test duration of 60 min after run-in and sliding distance of about 227 m. This mode ensured stabilization in time of tribotechical characteristics of all the studied materials. At testing sample wear was determined by the volume of abrasion hole, and counterbody wear — by the difference in its mass before and after testing.

Wearing characteristics of deposited samples and counterbodies at metal-over-metal friction at room temperature are shown in Figure 1. As is seen from the given data, wear of deposited metal of 50Kh9S3G type at metal-over-metal friction at room temperature first decreases with increase of sulphur content to 0.7 %, and then, at increase of its content to 1.3 %, wear is intensified again. Counterbody wear is similar to wear of deposited metal samples. No seizure wear was detected as shown by test results. In sample–counterbody friction pair the best wear resistance was provided at sulphur content within 0.5–0.8 %. At increase of sulphur content in the sample up to 1.3 % counterbody wear was also somewhat increased.

Sulphur influence on friction coefficient of 50Kh9S3G deposited metal was studied (Figure 2). Deposited metal friction coefficient decreases up to sulphur content of 0.7 % and then, with increase of sulphur content to 1.3 %, it remains at approximately the same level. As in the case of wear, sulphur content of 0.5 to 0.8 % should be regarded as the optimum one.

A similar dependence of sample wear on sulphur content was observed also in [9]. Apparently, sample wear resistance and, consequently counterbody wear resistance, is associated with morphology and quantity of sulphide inclusions.

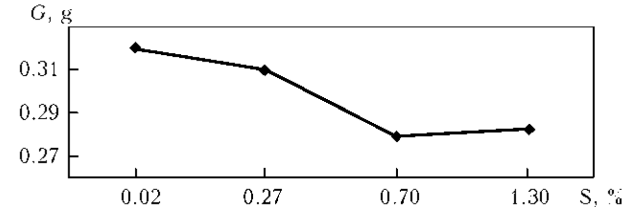

Figure 2. Sulphur influence on friction coefficient of 50Kh9S3G deposited metal

Investigation of microstructure of 50Kh9S3G deposited metal with different sulphur content was performed. Microstructure of 50Kh9S3G deposited metal without sulphur consists of martensite and residual austenite with a small amount of nonmetallic inclusions — silicates and oxides (Figure 3, *a*).

With addition of 0.27 % S, sulphide and oxysulphide inclusions appear in deposited metal microstructure (Figure 3, *b*). With further increase of sulphur content up to 0.7 %, deposited metal microstructure is refined, quantity and size of sulphide and oxysulphide inclusions increasing (Figure 3, *c*). In samples with sulphur content of 1.3 %, a multitude of individual sulphides of globular and elongated shape, as well as fine sulphide clusters are observed (Figure 3, *d*). Scarce very coarse sulphides and oxysulphides are also revealed, whereas practically no silicates are observed.

Sulphur content influence on nonmetallic inclusion volume fraction in unetched polished sections was studied in quantitative analyzer «Omnimet» at 600 magnification when scanning through 100 fields of view. At 0.7 % S content in the deposited metal, volume fraction of sul-

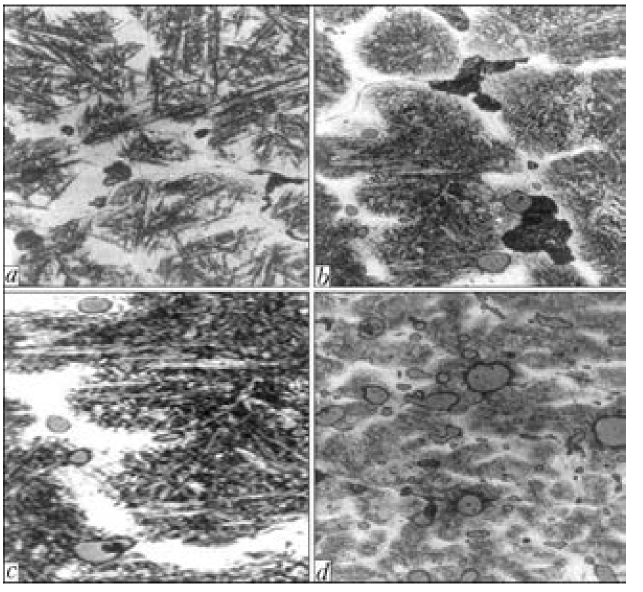

Figure 3. Microstructure (×1000) of 50Kh9S3G deposited metal with different sulphur content, %: *a* — 0.02; *b* — 0.27; *c* — 0.70; *d* — 1.30

Table 2. Composition of sulphide phase of 50Kh9S3G deposited metal with 0.7 % S

Deposited metal type	Analyzed section	Weight fraction of elements, %				
		S	Si	Mn	Cr	Fe
50Kh9S3G	Sulphide	12.53	1.22	28.81	13.15	44.28
	Matrix	0.03	3.40	0.59	9.27	86.26

phides in upper deposited layers reaches 1.99 % (by volume), and at 1.3 % S content it is ≤3.21 %.

Dimensions of sulphide inclusions are greater than those of silicate ones, and sulphide inclusions become coarser with increase of sulphur content. At sulphur content of 0.7 %, sulphide inclusions size is from 0.007 to 0.02 mm, and at sulphur content of 1.3 % it is from 0.025 to 0.05 mm, and single inclusions of 0.075 mm size were also found.

Microhardness of nonmetallic inclusions was determined in the LECO hardness meter M-400 at 10 g load. Sulphides have essentially lower microhardness than silicates, average microhardness of sulphides is 2835 MPa, and that of silicates is 9130 MPa. Results of X-ray microprobe analysis show that manganese and chromium actively react with sulphur, making up almost half of sulphide phase volume (Table 2). Fraction of iron sulphides is also high, while silicon is mostly present in the composition of complex sulphides.

Comparing the results of studying the microstructure of 50Kh9S3G deposited metal with the results of its wear resistance studies, leads to the conclusion that in order to ensure optimum tribotechnical properties of 50Kh9S3G deposited metal, volume fraction of complex sulphides of the main alloying elements in its structure should be within the ranges of 1.5 to 2.0 %, and their dimensions should be ≤0.02 mm. In order to satisfy these conditions, it is necessary for sulphur content in the deposited metal to be equal to 0.5 to 0.8 %.

At lower content of sulphur the quantity of forming sulphides is insufficient for them to make a significant influence on properties of 50Kh9S3G deposited metal. At greater sulphur content, the forming coarse sulphide inclusions are weakly retained by deposited metal matrix, and during testing they are crushed and removed from the wearing zone. This impairs the wear resistance of deposited metal and mating part. Moreover, sulphide crushing out can be promoted by the combination of low microhardness and large volume fraction of sulphide inclusions, that may lead to inability to resist high contact pressures in the friction zone.

Conclusions

1. It is established that at sulphur alloying of 50Kh9S3G deposited metal, sulphides of the main alloying elements prevent seizure of wearing surfaces under the conditions of dry metal-over-metal friction.

2. To ensure optimum tribotechnical properties of 50Kh9S3G deposited metal, volume fraction of complex sulphides in its structure should be equal to 1.5–2.0 %, and their dimensions should be ≤0.02 mm. To satisfy this condition, sulphur content in the deposited metal should be within 0.5–0.8 %. At lower sulphur content sulphides cannot have any essential influence on deposited metal tribotechnical properties. At higher sulphur content the forming coarse sulphides are weakly retained by deposited metal matrix and crush out during wear and are removed from the wearing zone that impairs the wear resistance.

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