FLAKES AND CRACKING IN STEEL 45

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Flakes in structural steels, which cannot be eliminated by annealing or reforging, are associated with segregation, the presence of large numbers of nonmetallic inclusions, and large amounts of gases in the melt [1].

Experimental work at the Kuznetsk Metallurgical Plant [2], the Frezer Plant [3], and elsewhere indicates that flakes induce fracture of machine parts. However, there is still no standard scale for determining the extent of the flakes in fractures. The GOST standard for the macrostructure of carbon steels does not give a specification for fracture. Delle [4] considers that the question of the amount of permissible flakes must be resolved in each separate case.

During heat treatment of structural steels with flakes, stresses occur between microvolumes with different coefficients of expansion due to the difference in their chemical composition [5]. The presence of elongated chains of nonmetallic inclusions leads to the conclusion that there is a relationship between flakes and cracking.

Figure 1 shows cracks in parts of steel 45 with flakes. The parts were heated to the quenching temperature of 820°C in the N-85 and N-6 electric furnaces without a protective atmosphere and cooled in running water until the surface temperature reached 60-80°C. They were tempered 4-6 h at 540-560°C. The surface hardness after tempering was HB 212-248.

Susceptibility to cracking increases with the ratio of d/l. Thus, for identical flaking of the fracture surface the rejects due to cracking amount to 35% of total production for bearings (Fig. 1a) and 10% for shafts (Fig. 1b). Reforging followed by normalization of the blank cut from the rolled bar leads to grain refining in the surface of the finished piece (bearing) but does not eliminate flakes or the susceptibility to cracking during subsequent heat treatment.

In large numbers of collars rejected due to cracking flakes were noted in the fracture (Fig. 2). The collars, 24 mm in diam., were manufactured from steel 45 of the following chemical composition: 0.48% C, 0.24% Cr, 0.76% Mn, 0.023% P, 0.028% S, 0.23% Ni, 0.30% Si.

Experiments were made with collars 22 mm in diam. and 4.5 mm thick with center holes 6.5 and 9 mm in diam.

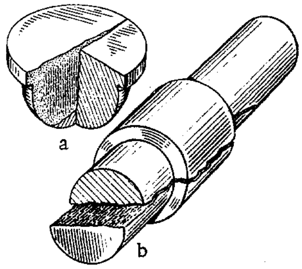

Fig. 1

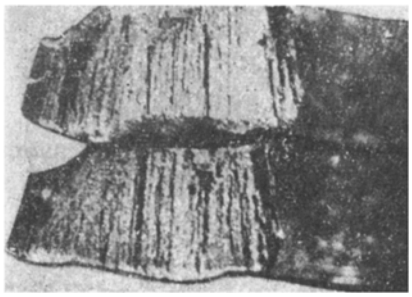

Fig. 2

Fig. 1. Cracks in steel 45 with flakes after quenching in water: a) bearing (diam. 220 × 170 mm); b) shaft (diam. 210 × 1020 mm).

Fig. 2. Macrostructure of fracture in collar of steel 45. × 5.

Kiev Bol'shevik Plant. Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 1, pp. 75-78, January, 1969.

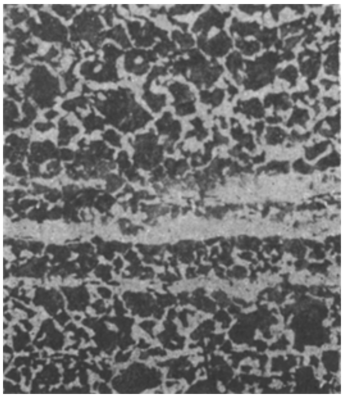

Fig. 3. Banding in the original microstructure of collars.×100.

The original microstructure was ferritic—pearlitic with a grain size of grade 7. There were long ferritic bands surrounding chains of nonmetallic inclusions oriented in the rolling direction (Fig. 3).

Groups of collars from six bars were given the same heat treatment — loaded in the electric furnace, heated to quenching temperature (with spent carburizer on the fettling to prevent decarburizing), held 10 min, and cooled in running water (20°C) for 10 sec. Three groups of samples were treated at each quenching temperature. Cracks were detected by magnetic defectoscopy. In all cases where cracks were formed in collars of steel 45 the character of the cracks themselves was the same. Circular cracks up to 2 mm deep occurred primarily on one side of the collars (Fig. 4a). Evidently these circular cracks are due to changes in volume during quenching and the presence of flakes. Thc weakened section (microheterogeneity) between the inner and outer rings fractures as the result of the quenching stresses.

Overheating or underheating of the collars during quenching reduced the number of cracks, probably due to reduction of the change in volume. When the same collars prepared from steel U8 with less banding of the structure were overheated in quenching the cracks were mainly radial and deeper (Fig. 4b).

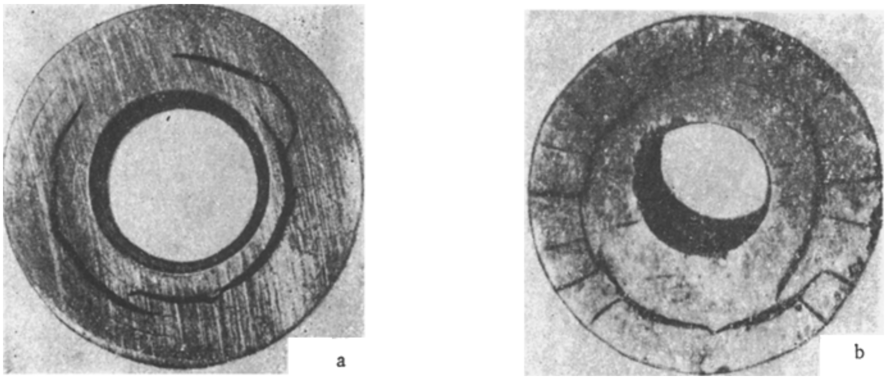

Fig. 4. Cracks after quenching in water: a) steel 45 with flakes, quenched from 840°C; b) steel U8, quenched from 880°C.

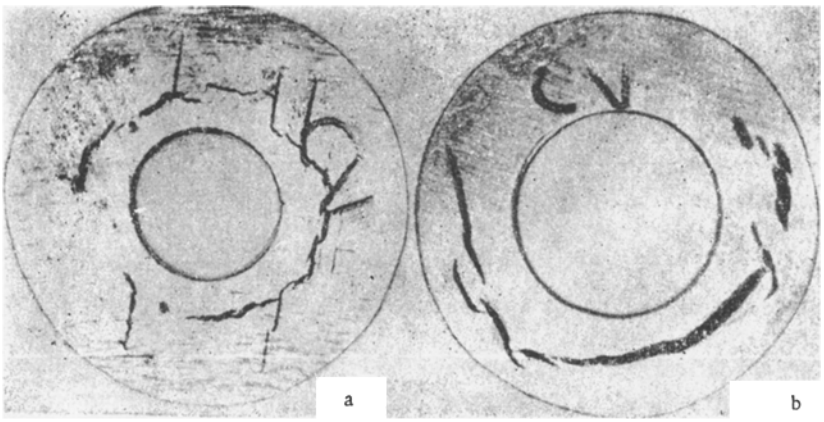

Fig. 5. Linear cracks in collars of steel 45: a) quenched once from 820°C; b) quenched four times from 820°C.

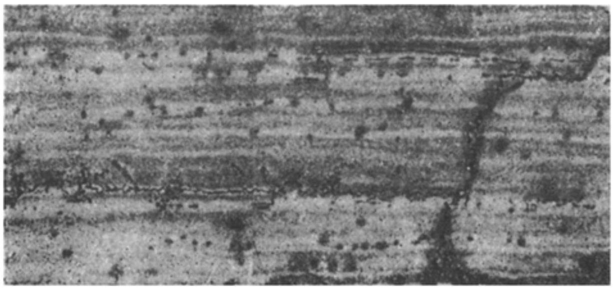

Fig. 6. Linear crack in chain of nonmetallic inclusions in collar of steel 45 (the same collar shown in Fig. 5a).

To clarify the relationship between flakes and susceptibility to cracking we prepared collars of steel 45 (from bars 50 mm in diam.) with coarse flakes so that the face of the collar coincided with the orientation of the flakes in the bar. On quenching from 820, 900, and 1000°C we obtained circular as well as linear cracks. It can be seen in Fig. 5a how the linear cracks change to circular and in Fig. 5b that all cracks deepen with quenching four times. The banding due to the microheterogeneity in carbon, chains of nonmetallic inclusions, and a linear crack along one of these chains are visible in Fig. 6.

The experimental data (average values for three groups of six samples) were as follows:

Quenching temperature, °C	Number of samples with cracks, %
Flakes oriented perpendicular with sample	
780	50
800	10
820	83.7
830	66.6
840	83.7
850	100
880	100
950	33.3
Flakes oriented parallel with sample	
820	33.3
900	33.3
1000	33.3

Most of the cracks occurring in parts manufactured from rolled stock with flakes are oriented in the direction of the grain. They can occur even under the most favorable heat treatment conditions — with no decarburizing or overheating. In parts made from high-quality steel, even when the treatment deviates somewhat from that prescribed, no flakes are observed. The data presented indicate that flakes are one of the most dangerous defects in parts of steel 45 that are heat treated.

Neither commercial practice nor GOST provide any standard for flakes in this steel, and a standard scale should be developed to supplement GOST specifications on structural steel that is heat treated.

LITERATURE CITED

1. E. Houdremont, Special Steels [Russian translation], Metallurgizdat, Moscow (1959).
2. N. M. Chuiko, Stal', No. 6 (1946).
3. E. S. Fedotenko, Zavod. Lab., No. 7 (1956).
4. V. A. Delle, Alloying Structural Steel [in Russian], Metallurgizdat, Moscow (1953).
5. E. I. Malinkina, Crack Formation During Heat Treatment of Steel [in Russian], Mashgiz, Moscow (1958).