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NATURE OF THE DEFECT "BRIGHT RING" FORMING IN FRICTION WELDING OF TOOL STEEL

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When end milling cutters break in the region of the welding seam, a defect is found which in the literature is called "bright ring" [1, 2]. The cause of this defect is ascribed to incomplete fusion, and the defect is also called incomplete fusion [1, 2]. To eliminate the defect "bright ring," the All-Union Tool Research Institute recommends raising the temperature and pressure in welding.

At the Pavlodar plant making special tools and technological equipment, friction welding of end milling cutters is used, and the defect "bright ring" is fairly widespread. Acting on the recommendations of the Tool Research Institute did not yield any positive results.

The object of the present work is to study the nature of the defect "bright ring" and to find ways of eliminating it.

We investigated welding seams on tool blanks of steel R6M5 welded to steel 45 on a machine MST-35. Fractures in the region of the welding seam were investigated on a scanning electron microscope REM-200 with magnification up to ×4000, the microstructure in the region of the welding seam was investigated on a transmission microscope and on a scanning electron microscope. We investigated tools both in the annealed state and after final heat treatment. From the blank in the region of welding we cut out a cylindrical specimen. Part of the cylinder was cut off in such a way that a plane perpendicular to the welding seam formed. On it we made a microsection on which we investigated the microstructure both without etching and after etching in 2% solution of HNO_3. By scratching or making indents on a PMT-3 instrument we marked the parts where the appearance of "bright rings" was expected in case of fracture. Fracture of the specimens was carried out by bending without damage to the microsection. The kind of fracture and the microstructure were compared.

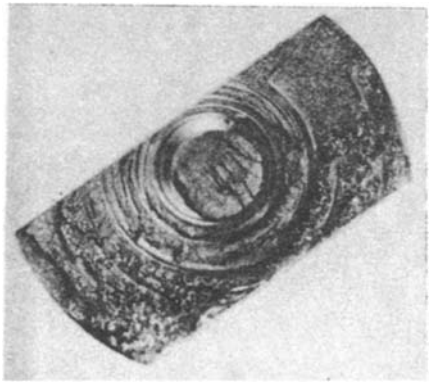

Fig. 1. "Bright rings" in the fracture of a tool blank.

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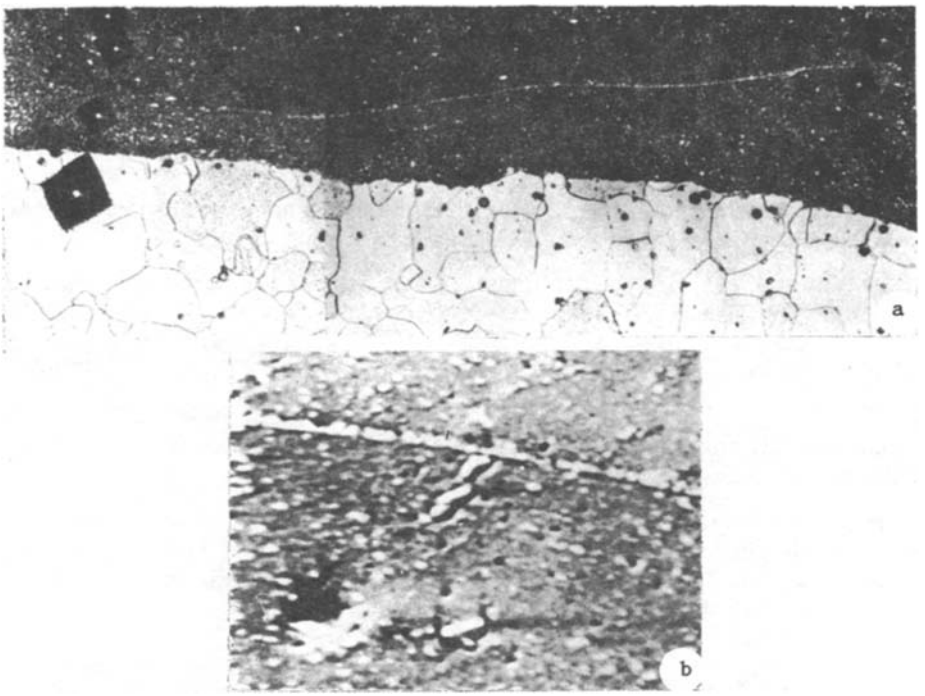

Fig. 2. Microstructure of an annealed blank (a) and a carbide band (b) in the region of the welding seam: a) light microscope, etched microsection, ×400; b) scanning electron microscope RÉM-200, unetched microsection, ×1025.

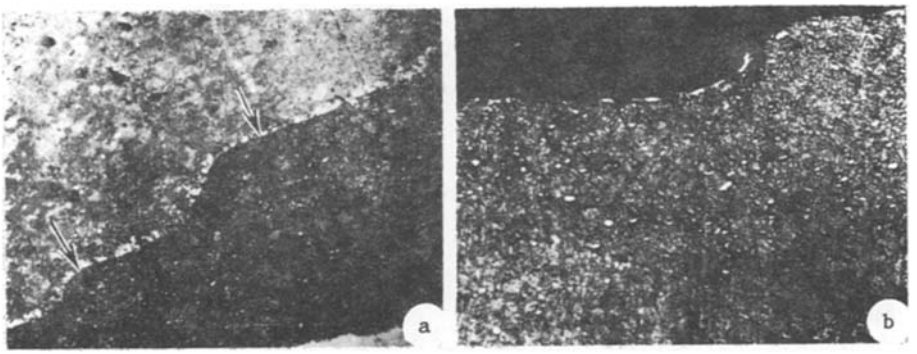

Fig. 3. Carbide band near the welding seam in an annealed blank (a) and part of the profile of the fracture with remains of the carbide band (bounded by arrows in Fig. 3a) (b): a) light microscope, etched microsection, ×400; b) ×5.

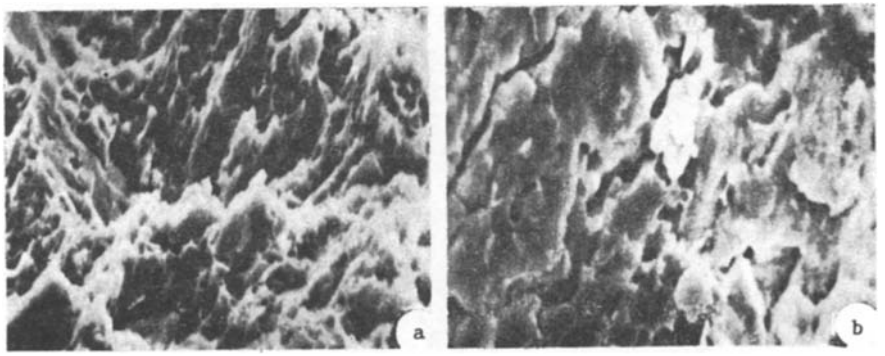

Fig. 4. Fractogram of an annealed blank of high speed steel (RÉM-200): a, b) outside and in the region of the "bright ring," respectively; a) ×4300; b) ×4500.

As a result of the investigation of the microstructure no signs whatever of incomplete fusion in the welding seams were discovered in the microsections that had not been etched, although when these specimens were fractured, "bright rings" were well visible in the fractures (Fig. 1). Consequently, the "bright rings" are not signs of incomplete fusion.

On etched microsections of specimens of high speed steel near the welding seam we discovered badly etchable bands, similar in etchability to carbides (Fig. 2a). Investigation of an unetched microsection with a RÉM-200 confirmed tht these bands are formed by caribides. Their reflecting power is the same as of carbides (Fig. 2b).

A comparison of the aspect of the fracture with the microstructure showed (Fig. 3) that the "bright rings" coincide with the carbide bands. In Fig. 3a the carbide band in the microstructure of the specimens is shown, and in Fig. 3b this same band is shown on the profile of the fracture after the specimen had been fractured. The "bright ring" in the fracture corresponds to the carbide band.

Thus it was shown that the "bright rings" are carbide segregations occurring near the welding seam in high speed steel.

When a tool breaks in the region of the welding seam, the crack passes through the high speed steel. Figure 4 shows fractograms made with a RÉM-200 in the region of the "bright ring" and outside the region. In the region of the "bright ring" the fracture is comparatively flat, it cosists of shear facets separated from each other by cracks. The fracture outside the "bright ring" has a pitted structure.

An analysis of the results of the investigation permits the assumption that the "bright rings" in fractures of tools made by friction welding are due to overheating of high speed steel in welding to temperatures causing the formation of eutectic melts at places where carbides accumulate (carbide lines). In upsetting (forging) liquid flows in the direction of the fibers of the material and solidifies, forming near the welding seam carbide bands situated at different angles to the welding seam. Near the carbide bands the metal is weakened, and when it is bent, it yields fractures in the form of "bright rings." If the above considerations correspond to reality, then the welding temperature has to be reduced to eliminate defects "bright ring" in the welding seams. In welding rods of steel R6M5 with 20 mm diameter to steel 45 we succeeded to eliminating this defect by reducing the heating time. At the same time, to prevent incomplete fusion, the upsetting force was increased.

CONCLUSIONS

1. The defect "bright ring" in fracture is not due to incomplete fusion, as has been commonly assumed.

2. The defect "bright ring" originates at places where there are carbide bands in high speed steel near the welding seam.

3. Carbide bands form in consequence of overheating of high speed steel in friction welding.

4. To eliminate the defect "bright ring," the heating temperature has to be reduced in welding.

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