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Short communication

# Wear resistance of high-speed steels and cutting performance of tool related to structural factors

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ABSTRACT

The dry, abrasive wear and cutting resistance of a high-speed steel has been investigated for both the cast and wrought states. The presence of a network of eutectic carbides in the cast material is shown to enhance its wear resistance because the network prevents excessive plasticity at the contact surfaces. In contrast, the isolated carbides in the wrought form are less effective so that the wear surfaces show roughness caused by plasticity, leading to an enhanced wear rate. Similar conclusions are reached with respect to the cutting behaviour of tool inserts made from the cast and wrought steels.


## 1. Introduction

It is known that microstructure contributes significantly to the performance of high-speed steels [1]. Thus, tool materials of identical hardness but differing distributions of carbides can vary in their resistance to wear [2–10]. Indeed, such differences are apparent between the cast and rolled states, possibly because of the eutectic carbide networks present in the cast state even after the quenching and tempering heat-treatment [11–21]. Cast high-speed steels therefore also have poor toughness even in the fully heat-treated condition, when compared with the wrought alloys [22]. On the other hand, the wear resistance is enhanced by the presence of the three-dimensional networks of eutectic carbides in the cast microstructure. Given these factors, a compromise must be reached to obtain an optimum combination of toughness and wear resistance in the context of tool materials [23].

The aim of the present work was to examine tungsten–molybdenum high-speed steels in both the cast and wrought conditions and evaluate their performance with respect to sliding friction and cutting processes.

## 2. Experimental materials and methods

The as-cast M2 steel was prepared by melting in a high-frequency induction furnace with acidic lining. The killing was conducted using ferromanganese, ferrosilicon, and aluminium. The metal was cast into preheated graphite chill moulds. The solidified castings isothermally annealed. Some rolled bars of the same composition were obtained commercially (Table 1). Specimens for mechanical tests, metallographic analysis and cutting tools (cutting-inserts) were fabricated. All samples were quenched from 1220 °C and triple tempered at 560 °C for 1 h.

The hardness and red hardness of the heat-treated specimens was measured using the Rockwell C Scale, with 10 measurements being made for each specimen, and calculating an average for them. The red hardness of the steels was evaluated on the basis of hardness measurement at room temperature on specimens, which, after full heat treatment, had been subjected to additional tempering at 620 °C, for 4 h. Micro-hardness measurement was carried out using the Vickers micro-hardness test with 0.1 kg load. Ten measurements were made for each sample to obtain satisfactory statistical reliability. For determining impact toughness, Charpy unnotched impact tests were carried out at room temperature with a striking energy of 50 J using specimens with dimensions of 10 mm × 10 mm × 55 mm. Each value reported is the average of five tests.

Wear resistance was characterized in terms of mass loss of a specimen with dimensions of 10 mm × 10 mm × 30 mm during abrasion with a hardmetal counterbody disk 55 mm in diameter and 2.5 mm in thickness made of a Co-bonded WC alloy with 90 HRA hardness versus sliding distance (time). The tribological tests were carried out in unlubricated unidirectional sliding friction at 0.58 m/s and a load of 200 N, as shown in Fig. 1. Each test was of 20 min duration, hence a sliding distance of 696 m. The mass losses of the specimens were measured at the end of the tests using

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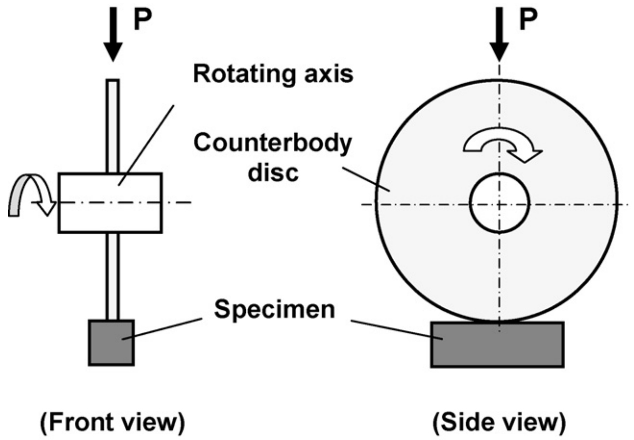


**Fig. 1.** Schematic diagram of the experimental arrangement for the wear tests.

a balance with an accuracy of 0.1 mg. Wear tests were repeated three times to ensure an acceptable degree of repeatability. Thus, the wear rate, shown in Table 2, was found from:

$$Q = \frac{m_1 - m_2}{t}, \quad (1)$$

where $Q$ is the wear rate, mg/h; $m_1$ and $m_2$ are the initial and final mass of the test specimen, mg; and $t$ is the duration of the wear test, h. The resulting worn surfaces were observed on the bottom of a circular crater formed by counterbody disk on the test specimen surface using a Neophot-2 optical microscope.

Longitudinal turning tests were carried out on cylindrical blanks of low-alloy steel containing 0.45 wt% C and 0.45 wt% Cr with 198 HB hardness. The test cutting-inserts had a cross-section of 12.5 × 12.5 and 5 mm thick. The insert cutting-edge geometry was as follows: the main clearance angle $\alpha = 10°$; rake angle $\gamma = -10°$; cutting edge angle $\varphi = 45°$, cutting edge radius $r_e = 10\,\mu m$, and corner radius $r = 0.5$ mm. The cutting conditions were: speed—38 m/min;

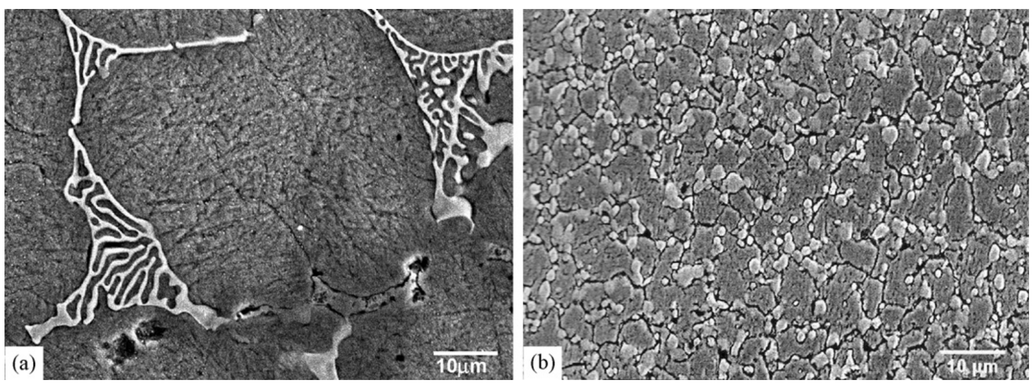


**Fig. 2.** Structure of the high-speed steel after complete heat treatment under conditions: (a) as-cast; (b) rolled.

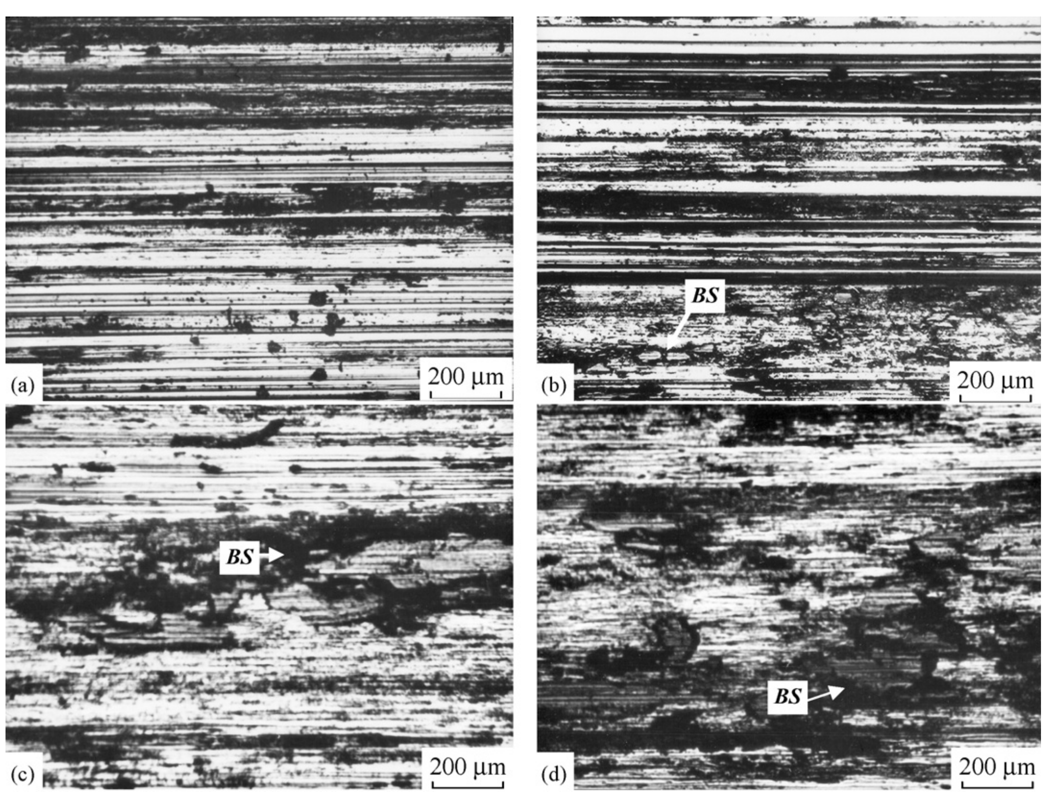


**Fig. 3.** Worn surfaces of the tribological test specimens from (a and c) as-cast and (b and d) rolled M2 high-speed steels. "BS" indicates breakdown sites of oxide films.