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Failure analysis of tungsten carbide bearing on screw drill

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ABSTRACT

The tungsten carbide bearing (TC bearing) is the main factor affecting the safety and durability of a screw-drilling tool. The TC bearing transmits torque and is subjected to severe radial shock, contact fatigue and corrosion. The failure of TC bearings are analyzed in detail and characterized by optical microscope (OM) and high resolution scanning electron microscopy (HRSEM) with energy spectrometer (EDS), electronic probe microanalyzer (EPMA), X-ray diffractometer (XRD), Rockwell hardness tester, and differential thermal and thermo gravimetric analyzer (DTA-TGA). The results showed that hot cracking of cemented carbide block of YG8 (WC-92%, Co-8%) mainly results from the diffusion of Co elements entering into the solder and W_2C and Co_3W_3C brittle phases formation during heating and holding time. The W_2C and Co_3W_3C phases promote initiation and propagation of brittle crack in the cooling stage and during working, resulting in fracture and detachment of YG8. Based on these results and failure analysis of TC bearings, some effective measures proposed to optimize the production process.

1. Introduction

Radial TC bearing is an important part of a screw drill and it uses impact and rotation technology to allow drill function. High-pressure liquid supplies the kinetic energy of screw drilling [1]. The TC bearing must bear the lateral force of rotation and the impact force of rock (Fig. 1), and there is friction between the outer and the inner sleeve. The typical structure of a TC bearing is generally composed of YG8 and brazing filler metal as shown in Fig. 2. During preparation, YG8 is adhered to the cylindrical mould, and then the outer sleeve is covered. Casting tungsten carbide and filler metal are then mixed into gaps of YG8, and finally the brazing process is carried out.

Due to its characteristics of high hardness and corrosive resistance, YG8 is widely prepared by brazing to provide the abrasive resistance required for a TC bearing. TC bearings are divided into two parts, the inner and outer shaft sleeve. Increased attention has been focused on the use of YG8 [2–5]. Upadhyaya [6] reported that the use of W elements offers strength and abrasion resistance properties, and Co elements offer the ductility and toughness, respectively. The amount of the Co elements results in differences in the hardness of cemented carbide [7]. Cemented carbide YG8 has a high hardness [8–10], which is brazed on TC bearings by solder composed of Cu, Zn, Mn and Ni elements. To reduce the hardness gradient between the solder and YG8, casting WC particles are added into solder. Many studies have reported the brazing technology of YG8 [11–14]. In particular, the effects of two types of Cu-based solder on the quality of TC bearing have been described [15].

Overall, brazing process parameters seriously affect the quality of YG8 and its adhesive strength. Cracks and ecclasis of YG8 often occur, resulting in early failure of TC bearing during production or operation. In the present work, a detailed failure analysis of failure

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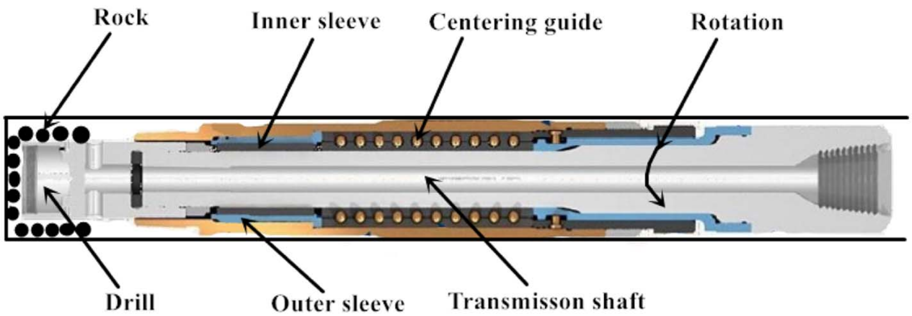

Fig. 1. Work principle of screw drill.

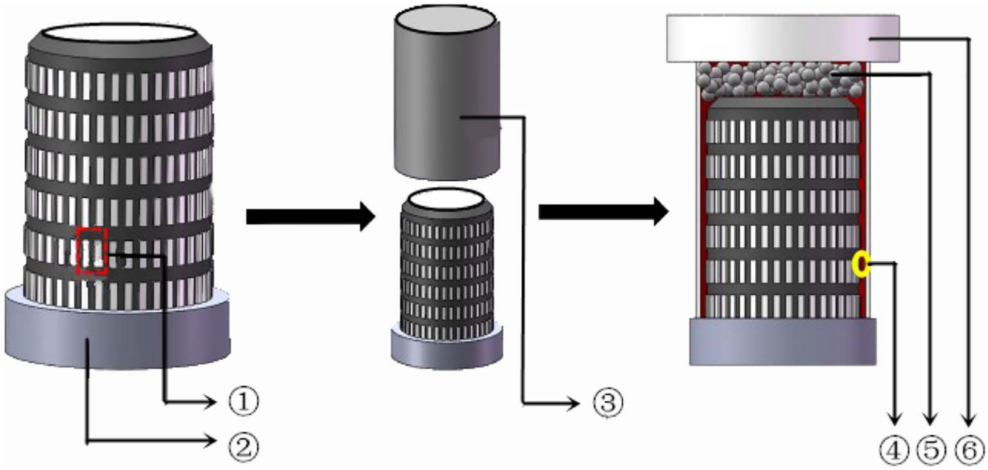

Fig. 2. The internal structure of production processing.
① YG8. ② The bolster plate of die. ③ Steel body of TC bearing. ④ Casting tungsten carbide. ⑤ Brazing filler metal. ⑥ Upper and cover of die.

TC bearing is given and a process optimization scheme is presented.

2. Experimental

For heat treatment, the TC bearing was heated in a furnace at the rate of 10 °C/min until reaching (1150 ± 10)°C, and then held at that temperature for 60 min, allowing the molten solder to infiltrate into the gaps of tungsten carbide with fine grain size. Finally, the TC bearing was cooled down to around (800 ± 10)°C in the furnace then cooled to room temperature by air outside of the furnace.

The YG8 used in these experiments had a chemical composition of 92 wt% WC and 8 wt% Co. The mechanical properties of the YG8 are shown in Table 1. YG8 samples of dimension 20 mm × 5 mm × 2 mm were cut from a TC bearing, as shown in Fig. 3. After slicing treatment, the samples were polished using diamond papers (#400 up to #2000) followed by diamond paste with a grain size of 0.35 μm.

The existing phases of YG8 were determined by X-ray diffraction (Rigaku D/max 2200 X-Ray diffractometer, Japan) using CuKα radiation (k = 0.1542 nm) with an acceleration voltage of 15 kV. Point and line analysis were performed for YG8 and the solder was analyzed by EDS (JXA-8230, Japan; acceleration voltage was generally 15 kV). The content and composition of elements in YG8 and solder were determined by quantitative analysis. In order to verify the binding force of YG8, the Rockwell hardness indentation test was used with a test load of 588.4 N and a holding time of 15 s, using Rockwell hardometer (HR-150A, the diamond indenter is used with an angle of 120 degrees). The melting point of the block and nano Ni solder was analyzed by DSC-TGA (SDT Q600 V20.9 Build 20; 220 V voltage is with nitrogen atmosphere, with a temperature range of room temperature to 1200 °C with a heating rate of 10 °C/min).

Table 1
The mechanical properties of the YG8.

Density	Impact energy	Hardness	Bending strength
14.5–14.9 (g/cm^3)	2.5 (J/cm^2)	89 (HRA)	1500 (MPa)