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Experimental study of an Al_2O_3/WC–Co nanocomposite based on a failure analysis of hammer bit

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ABSTRACT

Percussion drilling has been widely used in oil and gas industry because of its significant increase in the rate of penetration (ROP) over ordinary mud drilling, yet the drilling tool (especially hammer bit) failures happen frequently, which restrict applications of percussion drilling. Using the method of the rock-breaking mechanism, the reasons for hammer bit failure are analysed, and the results show that the mechanical properties of the bit tooth material, which is WC–Co cemented carbide, are not suitable for the coupling action of impact spalling, impact fatigue and abrasive wear. Hammer bit failure is mainly caused by tooth loss, tooth fracture and tooth wear. To prolong the hammer bit life, an experimental study of an Al_2O_3/WC–Co nanocomposite was performed with relevant theories and nanotechnology. Nano-Al_2O_3 was doped into WC–Co cemented carbide to prepare the Al_2O_3/WC–Co nanocomposite. Then, the mechanical properties of the nanocomposite were tested. The results show that the mechanical properties of the nanocomposite, such as microhardness, bending strength and impact toughness, are much better than WC–Co cemented carbide. The impact and abrasion resistance of the nanocomposite improves, and the microstructure of the nanocomposite also improves markedly.

1. Introduction

In percussion drilling, rock is broken by repeated impact, and bit rotation is used to make the bit teeth impact new positions on the rock each time. When drilling into hard formations, the advantages of percussion drilling include improving ROP, reducing drilling cost per foot, less formation damage and less well deviation. As a result, the technique is widely used in the petroleum industry [1,2]. However, the drilling tool failures have been so severe that it restricts the further development of percussion drilling [3,4]. Failure analysis shows that tooth loss, tooth fracture and tooth wear are the main failure modes of hammer bit [4]. The fundamental reason is that the mechanical properties of the bit tooth material (WC–Co cemented carbide) cannot meet the demands of the downhole working conditions.

A nanocomposite is as a multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nanometres (nm), or structures having nano-scale repeat distances between the different phases that make up the material [5]. Nano-scale is usually defined as smaller than one-tenth of a micrometre in at least one dimension [6]. The mechanical, electrical, thermal, optical, electrochemical and catalytic properties of the nanocomposite are different from that of the component materials [5,7]. Birringer produced nanocrystalline materials first [8]. Rutgers University first developed nanostructure cemented carbide in 1989. Milman, Luyckx and Northrop studied the influence of temperature, grain size and cobalt content on the hardness of WC–Co cemented carbide [9]. Okamoto, Nakazono and Otsuka tested the mechanical

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