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Design and Analysis of Ternary Coupling Bionic Bits

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Abstract

In order to improve the penetration rate and the life of impregnated diamond bits, bionic coupling concept was introduced to the design of impregnated diamond bits. Ternary coupling bionic bits (briefly named bionic bits) were renascent non-smooth framework (three dimensional) manufactured by coupling physical and chemical methods from non-smooth shape and material. Experimental results show that bionic bits have higher penetration rate and longer life only when matrix material, matrix hardness and non-smooth ratio of the bits adapt to the strata to be drilled. Compared with the conventional impregnated diamond bits, the drilling rate and the life of bionic bits were increased by 43% and 74%, respectively.

Keywords: impregnated diamond bit, bionic coupling, coupling element, non-smooth ratio, optimization

1 Introduction

At present, the conventional rock-breaking bits used in the geological core drilling and petroleum drilling mainly include the Polycrystalline Diamond Compact (PDC) bit, roller bit, surface-set diamond bit, impregnated diamond bit and so on. However, when drilling in hard rocks, these conventional bits are far from the national demand to explore the mineral and energy resources because of their low drilling speed, short service life and large energy consumption. It is urgent to develop a new rock-breaking bit with high efficiency, wear reduction and energy-saving capability.

Basing on bionics study, Ren *et al*.[1] found that the solutions of some modern science and technology problems can be subtly obtained from nature. To survive and adapt to the environment, many creatures evolve themselves into various morphologies and complex structures and develop the maximal adaptive and harmonious system to the surrounding environment by optimal coupling[2]. Based on bionic engineering, the non-smooth creature surface analysis showed that the wear performance is affected by many factors such as morphology, structure, material and so on[3–8]. These factors form the biological coupling by interaction[9]. The artificial technology integration system, which can obtain the maximal environmental adaptability through minimal energy, is named bionic coupling[10,11]. The non-smooth coupling surfaces of creatures mainly have the performances of wear and resistance reduction, desorption, noise reduction and so on. The application of non-smooth theory based on the creature surface covers the areas of fluid (gas, liquid), plastic body (soil), elastic-brittle body (mechanical component, rock) with remarkable effect.

In this paper, the bionic coupling theory was applied in the design of the impregnated diamond bit. The ternary coupling bionic bit (briefly named bionic bit) was developed and an in situ test was performed.

2 Ternary coupling bionic design of diamond bit

2.1 Non-smooth coupling element design

The convex non-smooth shape almost exists in all

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the interfaces between animal surface and soil, where compaction and heavy friction exist. Take the dung beetle for example (Fig. 1), the bulldozing plate of its head can excavate the soil like an excavator. Its fore feet have evolved into the digging ones which can pull the soil back with great force. The convex closures (Fig. 2) are distributed in the bulldozing plate of its head, which can not only reinforce the excavation capacity of its head but also reduce the contact area during the relative movement in the soil. Thus the high efficiency, wear and resistance reduction can be obtained.

Fig. 1 Dung beetle (male).

Fig. 2 Micrograph of dung beetle head.

The concave non-smooth shape almost exists in all the sites where the soil is loose with low cohesion and interface pressure. When the dung beetle excavates the soil, the loose soil will drop on its cuirass tergum where the concave pits are distributed (Fig. 3). The concave pits can reduce the contact area[12,13]. Furthermore, the gas or liquid can play a great role in lubrication and temperature transfer. Thus the reductions of viscosity, resistance and wear can be reached.

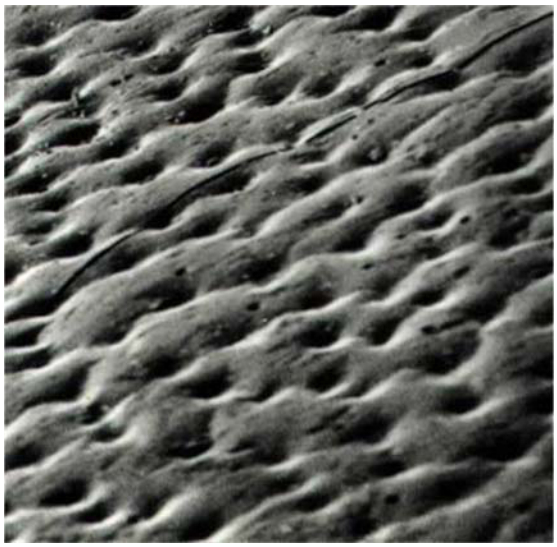

Fig. 3 Micrograph of dung beetle tergum.

The concave pits and convex closures form the non-smooth shape of creature surface, evolved for adaptation to different survival environment. They have different contact types. The bit needs not only the high rock-breaking capacity but also the low wear and resistance during rock-breaking process. Thus it is conceived that the bit can be developed by coupling micro convex non-smooth material (diamond) and macro smooth pit, which may lead to the high efficiency and low wear. The former tests showed that the non-smooth shape of bottom surface is the most important factor to affect the bionic coupling diamond bit.

2.2 Coupling design of the material

The steel body of the bionic bit was steel 45#, and the work layer material was composed of matrix material and bionic non-smooth material (micro convex and macro pit). The compositions and proportion of matrix powder material are shown in Table 1. The skeletal material WC and YG6 perform high melting point, high hardness, low wear and low linear expansion coefficient. They also resist heat to some extend with low corrosion

Table 1 Material compositions and proportion of bit matrix

	Skeleton material		Bond metal		
	YG6	WC	Ni	Mn	663 Bronze
Proportion (%)	15%	40%	5%	5%	35%