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Self-rotatory performance of conical cutter interacted with rock material

Xiaohui Liu[a,b,*], Ping Tang[c], Xuan Li[a,b], Mingrui Tian[a,b]

[a] School of Construction Machinery, Chang'an University, Xi'an 710064, China
[b] Key Laboratory of Road Construction Technology and Equipment of MOE, Chang'an University, Xi'an 710064, China
[c] Xi'an Xinzhu Group, 710075, China

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ABSTRACT

Conical cutters work on high impact and stress condition, which easily results in failure. The percentage of failure due to wear is about 75%. More importantly, self-rotatory ability of conical cutters is the key factor on its wear. However, the mechanism of self-rotatory has not been further studied until now. Thus, firstly in this paper, three probable rotating states of cutter interacted with rock material were analyzed in theory, and the hypotheses about influence of rotary kinetic and resistance torque were proposed. Then, the influence of cutting types, working angle parameters and structural parameters on self-rotatory performance of cutter was studied using cutting test-bed for rock material. The experiment results indicate that, conical cutters really have self-rotatory ability when interacted with rock material, which owes to asymmetrical cutting load; the rotatory angle of cutter decreases gradually with cutting angle, and increases with incline angle; the change of rotatory angle caused by cutting angle is about 60°, while almost 360° for incline angle when the rotation angle of cutter is less than 360° in a certain cutting time; the rotatory angle almost shows a linear increasing trend with cutter-body length and the interval between cutter-handle and cutter-holder, decreases linearly with cutter-handle length, while increases at first and then decreases with cutter-handle diameter; among these four structural parameters, the influence of interval between cutter-handle and cutter-holder is greatest about 200°, followed by cutter-body length, and the last is cutter-handle length and cutter-handle diameter. At last, comparing the experiment results and hypotheses about influence of rotary resistance torque, it can be seen that, the dominant factor on self-rotatory ability of cutter is not friction resistance between cutter and cutter-holder but the duration that cutter with no rotary resistance torque.

1. Introduction

Conical cutter is widely used on working mechanism of tunneling and milling equipment, shown in Fig. 1 [1]. Its performance has direct influence on cutting performance and efficiency of working mechanism. It generally consists of carbide tip, cutter-body and cutter-handle, which is installed on cutter-holder or bushing and fixed by spring flange. It is used to break rock material through welding cutter-holder on cutting mechanism [2].

Initially, researchers mainly focused on the cutting performance of cutter during utilization and research, and lots of them studied the cutting load [3], lumpiness [4] and specific energy consumption [5] by simulations and experiments. For simulation, researchers

* Corresponding author at: School of Construction Machinery, Chang'an University, Xi'an 710064, China.
E-mail address: chd160039@chd.edu.cn (X. Liu).

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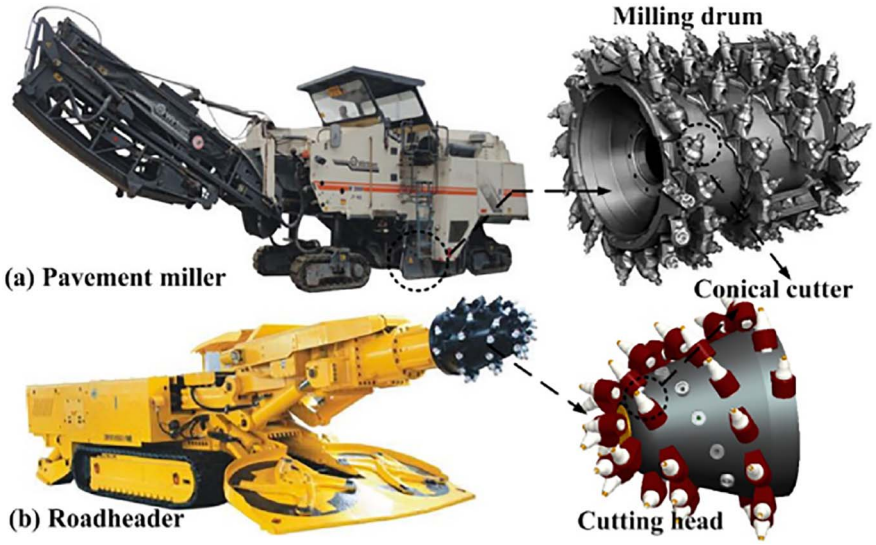

Fig. 1. Working mechanism of tunneling and milling equipment.

mainly used finite element method [6–7] and discrete element method [8–9]. For experiment, researchers established different test apparatus, such as Coal-Rock Cutting Test-Bed [10], Automated Rotary Coal/rock Cutting Simulator (ARCCS) [11–13], Single cutter Cutting Test-Bed [14], full-scale cutting rig [15–16] and reconstructive test apparatus [17–18].

Then, it has been found during utilization that, the working condition of cutter is severe, complex and changeful. Conical cutters work on high impact and stress condition, which easily results in failure. More concerning, the failure percentage due to wear is about 75%. Thus, many researchers have paid more attention to study cutters wear, which not only contains interference theory of cutter [19] and experiment study on cutters wear [18,20–21], but also study on reducing cutter load and wear by changing material [22] or using water jet [23–24].

It has been pointed out further that the conical cutter has self-rotatory ability when interacted with rock material. The so-called self-rotatory ability is an ability that can make cutter interacted with rock material rotate relative to cutter-holder, and the wear around the cutter is uniform. The principle is shown in Fig. 2(a), and the wear condition of cutters with different self-rotatory ability is shown in Fig. 2(b) and (c).

Fig. 2(b) shows the conical cutter used on road-header. It can be seen that, it has great self-rotatory ability; though most of the cutter-body got worn in the process of its usage, the cutter tip is still showing cone-shaped. Fig. 2(c) shows the conical cutters used on shearer and in experiments. Those cutters have weak self-rotatory ability, which results in eccentric wear in the process of its usage. The eccentric wear of cutter means that severe wear on one side and almost no wear on the other side, and even premature wear. The life of those cutters decreases obviously compared with cutters in Fig. 2(b).

Though some researchers pointed out that the conical cutter has self-rotatory ability owe to its specific structure and installation, self-rotatory performance are different for cutters with different structural and working angle parameters, and cutter cannot reach the effect of uniform wear, even with no self-rotatory ability at all. The mechanism of self-rotatory has not been further studied until now. For this reason, the mechanism of self-rotatory and the influence of cutting types, working angle parameters and structural parameters on self-rotatory performance of cutter were studied through experiment and theory analysis in this paper.

Fig. 2. Self-rotatory principle and wear condition of cutters with different self-rotatory ability.