Diamond & Related Materials 69 (2016) 40–48

Contents lists available at ScienceDirect

Diamond & Related Materials

journal homepage: www.elsevier.com/locate/diamond

A new frame saw machine by diamond segmented blade for cutting granite

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ARTICLE INFO

Article history:
Received 5 May 2016
Received in revised form 6 July 2016
Accepted 11 July 2016
Available online 16 July 2016

Keywords:
Granite
Eccentric hinge guide mechanism
Matrix tail
Self-sharpening
Cutting efficiency

ABSTRACT

An investigation has been undertaken into the stone processing machines. Diamond circular saws and diamond wire saws present some technological limits, and the marble frame saw cannot process granite by now. The present work shows an innovative frame saw machine to cut granite, the eccentric hinge guide mechanism is introduced into the machine. A sawing test and a simulation were carried out to analyze the sawing trajectory, the surface topography of the segments and the percentage of worn diamond particles. In addition, both cutting efficiency and slab flatness were recorded. The results show that the contact area between the blade and granite is not following a straight line, and the time required for stone sawing is only one half of the full sawing cycle. The eccentric hinge guide mechanism facilitates the formation of both matrix tails on the segments and a group of more new micro cutting edges, which improve diamond stability as well as self-sharpening. The proportion of micro-fractured and good diamonds in the new frame saw machine are 45% and 25%, respectively, and the productivity of the new machine is between 6 and 15 m^2/h. These values are significantly larger than that of the marble frame saw. Thus, the new prototype machine is suitable for sawing granite.

1. Introduction

The use of natural granite and other stones as structural engineering materials continues to increase due to its hardness, its wear resistance and its aesthetic properties [1]. In recent decades, the processing of granite has been mainly depended on diamond circular saws and diamond wire saws. Therefore, there are many studies on the sawing performance of stone processing. Material removal mechanisms [2–5], cutting forces and energy [6–9], wear characteristics of diamonds [10–13] are well-documented. Other studies focused on the sawability of rocks [14–16], the effect of rock properties on sawing performance [17–19], sawing performance prediction [20–22], and so on.

While there are various technological limits for diamond circular saws and wire saws. For example, the effective cutting width reaches only 30–35% of the diameter of circular saw blade [3], which is applicable to cut narrow slab. In addition, the saw kerf width of the saw blade is large (about 8 mm), which increases material waste. In the diamond wire saw, the kerf is restricted by the diameter of the diamond beaded rope and the frequent break of beaded ropes during cutting limits the development [23]. Furthermore, the high speed of machining tools produces noise, dust and other pollution, which is seriously harmful to the health of operating workers.

At present, marble frame saws are widely used to cut stone because of their high processing efficiency, high processing quality and great potential for reducing processing cost. The marble frame saw machine is capable of fitting more than 25 blades of length 3000–4000 mm [24]. The thickness of the blade is 3.0–3.5 mm with a height of 180 mm, and about 29–39 diamond segments are welded on the bottom of the blade, as shown in Fig. 1. The stone block can be cut into slabs by the reciprocating linear movement and vertical dawn feed of blades at the same time.

Despite the widespread use of the marble frame saw machine, only few studies can be found in the literature. Brook [25] analyzed the working principle of frame saw for cutting rock, and developed a new index test, called the Brook hardness, to predict the consumed energy. Wang et al. [24] systematically studied the cutting mechanism of marble frame saw, discussed the kinematic behavior of the blade and analyzed the factors that influence the sawing force using a single point tool and segment cutting test with different parameters. Konstanty et al. [26,27] presented a theoretical model of diamond frame saw, and proposed severe wear conditions of segments than the circular saw since there is no build-up of matrix tail and the forces act on diamond in alternating directions, while the conclusion was not validated by experiments. Özçelik [28] carried out sawing tests with diamond frame saw on different marbles, investigated the relationships among the marble textural and mineralogical properties, unit wear on diamond segments and average sawing speed. Wang and Clausen [29] simulated the process of diamond frame saw cutting stone by a computer. The results demonstrated that the cutting feed and segments cutting performance

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http://dx.doi.org/10.1016/j.diamond.2016.07.003
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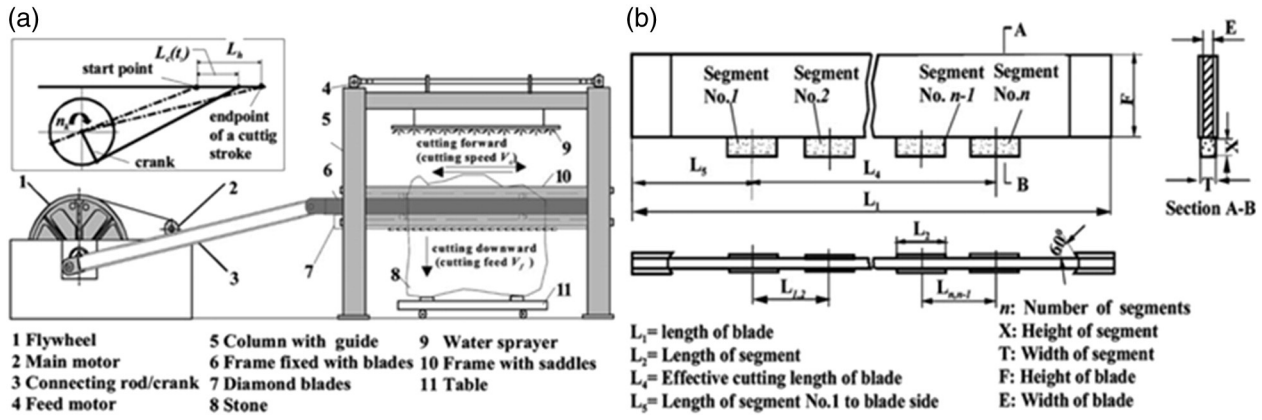

Fig. 1. Schematic of the marble frame saw: a frame saw machine and b diamond saw blade [24].

Fig. 2. The sawed slabs in marble frame saw machine.

were the main effect factors of cutting force and segment wear. Clausen and Stangenberg [30] conducted tests on a model sawing machine and marble frame saw machine to investigate the cutting force and segment wear characteristics. The results indicated that the model machine with a single-segment tool cannot adequately reproduce the frame sawing process, while the wear behavior and cutting force with a three-segment blade were similar to that produced in the frame saw machine.

Unfortunately, these literatures rarely mention granite processing, and the marble frame saws are generally designed for sawing marble, sandstone and so on. Until now, it cannot process granite. This is due to the rectilinear motion of the marble frame saw, which makes it difficult to remove debris from the kerf in the cutting process, and the diamond particles wear off easily and lose their self-sharpening effect [31]. Moreover, the new particles are difficult to come out and lose the cutting performance, resulting in the deflection of blades [32], deviating from the original trajectory [33], seriously affects the processing quality and efficiency, as shown in Fig. 2.

The present work shows an innovative prototype machine to cut granite. The developed prototype has an eccentric hinge guide mechanism that makes the saw blade left granite a certain height, instead of keeping it along a straight line. At the same time, the contact time between saw blade and granite could be reduced to make the diamond particles more effective and give full play to its sharpness. In the following, a series of sawing tests and simulations were conducted on the new prototype machine. Moreover, the wear of segments, the proportion of worn diamond particles, the cutting efficiency and slab flatness were accepted as the main performance criteria for these machines.

2. The new diamond frame saw for cutting granite

Fig. 3 shows a schematic of the new diamond frame saw for cutting granite. The diamond blade welded with segments moves forward and backward alternatively at a low speed, particularly when compared to circular saws. The reciprocating movement is achieved by the rotation of crank connected with the rod, and the feed motor drives the lifting mechanism with the granite block to move upward, at the same time.

The rotating speed can be changed from 0 to 90 r/min, and the feed rate can be adjusted from 0 to 200 mm/h. The stroke of the machine is 600 mm. The saw frame is capable of fitting 100 blades with a length of 4500 mm, and the blade thickness is 3.5 mm with a height of 180 mm. The diamond segments are welded on the thin and long blades with unequal spacing.

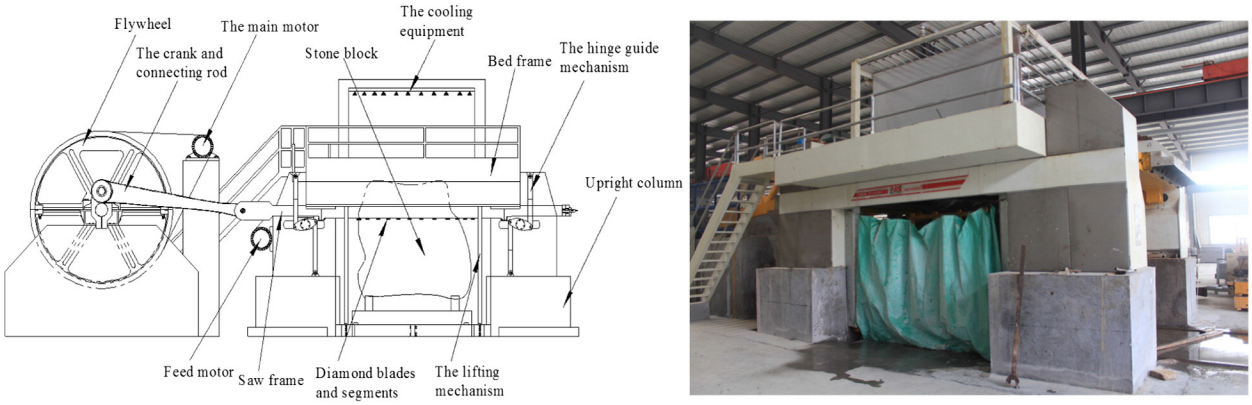

Fig. 3. Schematic of the new prototype machine.