

## Application and Optimum Design of Diamond Saw Blade with Composite Matrix

Q.X. Dai, Y.H. Fu, Z.Z. Yuan and F. Cao

School of Materials Science and Engineering, Jiangsu University, Jiangsu, 212013, China

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**Abstract.** The effect of diamond mixture ratio on the cutting properties of saw blade with composite matrix is studied through practical production and experiments. The experimental results show that the diamond mixture ratio and the cutting parameters should be decided by the kinds of granites. The equation of maximum average cut depth and the optimum relationship between the parameters of diamond and cutting process have been established. This calculation can provide information and advice on the selection of cutting and design parameters of diamond saw blade.

### Introduction

At present, with the rapid development of decorating material such as marble and granite, key problems of granite cutting are its high cost and low efficiency. For the past years, adjustment of cementitious agent and plating of diamond saw blades are the focuses of intensive research [1-2]. A lot of achievements have been made in the research and development of diamond circular saw blade. The cobalt matrix blades are gradually replaced by other matrix blades because of their high cost [3]. As the reliability of properties of iron matrix blades and wearability of copper matrix blades are unsatisfactory, a new type three-edge blade with composite matrix is introduced in literature [4], which has been proved to cut better than others, for its higher efficiency is and its longer life-span. As a result the profit of board granite production may increase by 20~30%, while at the same time the cost of saw blade production decreases greatly. Diamond blade can be held steadily and the cutting edge can be easily formed if proper composition is achieved. The new type saw blade would be sharp and wearable [3-4], by using three-edge blades and optimizing the relationship between diamond composition and the cutting parameters. The optimum design of diamond mixture ratio for the new type saw blade is mainly introduced in this paper.

### Experiment

The main ingredients in the new type composite matrix are Tin Bronze-W (WC)-Ni-Fe-Co together with low-melting-point felting material and additives. The process of preparing, blending, etc. is strictly followed as is stipulated by actual production. The method of treatment and agglomeration of blades are expounded in literature [4]. The  $\Phi 1.6\text{m}$  blade has three edges [5]. The composition, viz. density, size, intensive grade are the key factors to sharpness and wearability of segments, which are designed to meet the requirements [6]. The average grain diameter ( $\bar{D}$ ), average distance ( $\bar{\lambda}$ ) between grains etc. in segments are selected on the principle of stereoscopy. In experiment single-armed type and bridge type cutting machines are used. Granites to be cut are 635#, 664#, 684# and 657#, whose properties are shown in Tab.1. The experiment was performed in NanAn Saw Blade Factory. The whole process was recorded in detail every other day with regard to cutting volume ( $\text{m}^2$ ), blade height, and wearing surface of the blade using magnifiers. The wearable microcosmic appearance of segments can also be observed by JXA-840 electronic probe.

### Results and Discussion

**Diamond Mixture Ratio Design.** The proper diamond mixture ratio is the prerequisite factor to

marvelous property of the blade. The granites, 657#, 635#, 684#, etc. in experiments are different in hardness. The diamond mixture ratio and the results of practical experiments are shown in Table 1, Fig.1 and Fig.2, where  $V_v$ —the concentration of diamond;  $gd$ —the size of diamond;  $K_g$ —the weight ratio of diamond;  $\bar{D}$ —the average grain diameter of diamond;  $\bar{\lambda}$ —the average distance between grains;  $Q$ —the amount of cut granite ( $m^2$ ). It is shown that for the harder and more wear-resistable granite (such as 657#), the percentages of harder grains and diamond grains with fine mesh number 50/60, 60/70 should be increased for the sake of greater resistance; Otherwise the percentage of 30/40, 40/50 should be increased and the toughness of diamond could decrease a little. Generally, proper diamond concentration will make the blade shape and wearable. But if the concentration is too high and there are more diamond grains of fine mesh number 60/70, 50/60, the blade will become blunt although wearable, which will affect the cutting efficiency. As No.g.5 and No.g.6, the distance between diamond grains is too short and then the maximum depth of cut will decrease. Most diamond grains are worn and become blunt, which results in the low efficiency and short life-span (Fig.2). For different kinds of granites, the diamonds mixture ratio should be adjusted to achieving optimum efficiency No.g.1, No.g.7, and No.g.8 in Table 2 are suitable for different granites for their different diamond grain distance.

Table 1 Properties of granites in experiment

No.	Density [ $g/cm^3$ ]	Compression strength [Mpa]	Flexural strength [Mpa]
635#	2.63	194.7	13.4
664#	2.63	149.6	13.9
657#	2.63	206.1	21.6
684#	2.98	109.7	28.6

Table 2 Effect of diamond mixture ratio on cutting technology

Test No.	$V_v$ [%]	$gd$ [%]				$K_g$ [%]		$\bar{D}$ [ $\mu m$ ]	$\bar{\lambda}$ [mm]	$Q$ [ $m^2$ ]	Efficiency [ $m^2/day$ ]	Wear	Granite type
		30/40	40/50	50/60	60/70	15-17	12-14						
g.1	10.2	17.4	55.5	21.7	5.4	72.9	21.7	284	1.63	225	14-16	general	635#
g.2	12.6	17.5	65.7	12.3	4.5	65.8	29.8	296	1.32	297	15-18	sharp	635#
g.3	13.3	15.0	60.0	16.7	8.3	36.5	51.8	281	1.20	334	15-18	sharp	635#
g.4	14.7	22.3	45.2	17.3	15.2	35.0	53.3	267	1.07	362	14-16	blunter	635#
g.5	15.5	21.4	43.0	17.8	17.8	20.5	64.5	262	0.98	363	12-14	blunt	635#
g.6	16.1	20.7	41.4	27.6	10.3	14.6	70.7	269	0.94	331	12-14	blunt	635#
g.7	13.3	20.9	62.5	8.3	8.3	24.3	64.0	289	1.28	475	45-55	sharp	684#
g.8	13.3	8.3	62.5	20.9	8.3	49.4	40.4	278	1.14	235	12-16	sharp	657#

**Diamond Parameters Matching with Cutting Process.** Diamond grain distributes stochastically in blade body. The size and shape of grain are different, and protrusion the height of diamond grain varies as well. Thus the depth of cut of diamond grain is a very complicated function affected by the cutting parameters and diamond properties.

As is shown in Fig.3, when the diamond grain (Point A) moves away from granite, the chip in section plan forms, which changes from 0 to maximum, and then diminishes. The average depth of cut is BC, i.e.  $\bar{h}_{max}$ . It's calculated by the following equation [7]:

$$\bar{h}_{max} = 2\bar{a} \cdot \frac{v_p}{v_s} \cdot \sqrt{\frac{a_p}{d_s}} \quad (1)$$

In the formula:  $\bar{a}$  is the average distance of diamond grain in the process of continuous cutting;  $v_p$  is the feeding velocity;  $v_s$  is the circular linear velocity of saw blade;  $a_p$  is the depth of cut of saw blade;  $d_s$  is the diameter of saw blade.

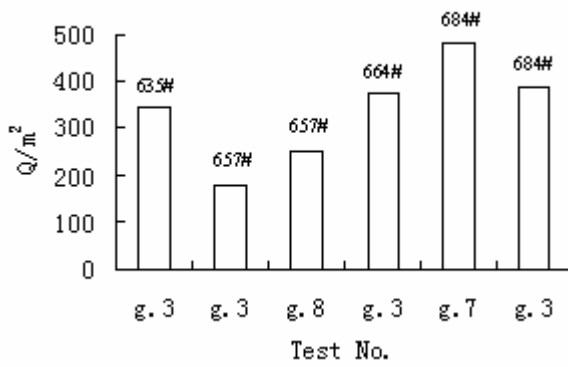


Fig.1 Experimental results

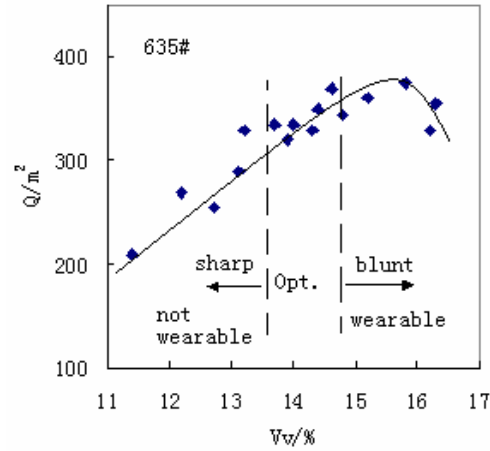


Fig.2 Effect of diamond density on cutting result

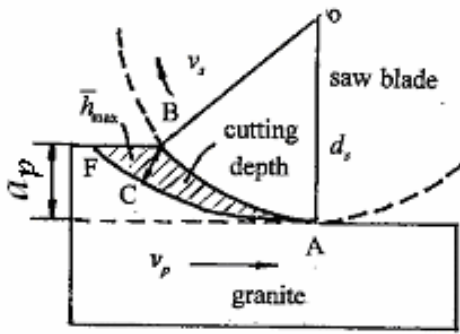


Fig.3  $\bar{h}_{max}$  and chip shape

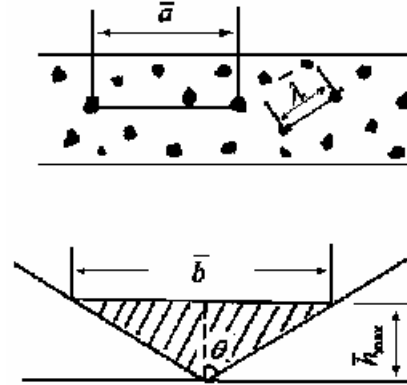


Fig.4  $\bar{a}$  and chip section

Relation between  $\bar{a}$  and  $\bar{\lambda}$  is:

$$\bar{a} = \bar{\lambda}^2 / \bar{b} \tag{2}$$

In the formula:  $\bar{b}$  is average width of milling striation on the surface,  $\bar{b} = 2\bar{h}_{max} \cdot \text{tg}\theta$  (shown in the Fig.4).  $\theta = 60^\circ$ .  $\bar{\lambda}$  is the average distance of diamond grains due to the special crystal structure of diamond.

Considering the factor of blade interval, we may introduce average actual equivalent  $\bar{\lambda}_e$  to suppose that valid milling grains account for 2/3 of the sum, and diamond impurity and burnout parameter is A, then we can have the following equation:

$$\bar{h}_{max}^2 = 1.3 \cdot \left( \frac{\bar{\lambda}_e}{A} \right)^2 \cdot \frac{v_p}{v_s} \cdot \sqrt{\frac{a_p}{d_s}} \tag{3}$$

In order to optimize saw blade and productivity, the parameters of diamond should match correspondingly with the cutting process. If  $d$  nominal diameter of diamond grain is  $D$ , the optimum depth of cut of diamond flat saw blade is  $(0.05 \sim 0.1) D$  [8], and the appropriate depth of cut of high efficient circular raw blade should be  $(0.1 \sim 0.2) D$  with a maximal diamond protrusion height of less than  $3/8D$ , for otherwise, diamond grains would fall off and the blades would smash easily, with the lower limit for hard rock, the upper limit for soft rock. The maximal depth of cut should approximate

the height of diamond protrusion from the body surface  $H$ , i.e.  $\bar{h}_{\max} \leq H$ , which can be adjusted by cutting parameter. Thus, Eq.3 is converted as follows:

$$\frac{v_p}{v_s} \cdot \sqrt{\frac{a_p}{d_s}} = 0.77 \cdot A^2 \cdot \left[ \frac{B\bar{D}}{\lambda_e} \right]^2 \quad (4)$$

here,  $B$  is granite influencing coefficient, 0.1~0.2. The cutting parameters could be estimated by a variety of matching parameters of diamond and granite so as to put forward the measure for improvement and the cutting efficiency to be controlled. The experimental results are listed in Table 3. Since the best depth of cut ( $\bar{h}_{\max}$ ) is 635#, 0.1  $\bar{D}$ ; 657#, 0.08  $\bar{D}$ ; 664#, 0.12  $\bar{D}$ ; 684#, 0.15  $\bar{D}$ , this optimized matching calculation can provide guidance to the choice of cutting parameters or design parameter of diamond.

Table 3 Determining the optimal cutting parameters by parameter of diamond

Diamond	Granite	$a_p$ [exp.]	$v_p$ [calc.]	$v_p \cdot \sqrt{a_p}$		Improvement	Efficiency
		[mm]	[m/min]	[exp.]	[calc.]		
No.g.1	635#	8	2.06	1.65	1.84	$v_p \uparrow$	14~16
No.g.2	635#	10	2.10	1.82	2.10		15~18
		10	3.05	3.20	3.06	Optimum;	25~30
No.g.3	664#	15	2.48	2.94	3.06	$a_p$ , 15 mm ;	25~30
		20	2.16	3.11	3.06	$v_p$ , 2.0~2.5 m/min	25~30
No.g.3	635#	10	2.12	1.72	2.12	$v_p \uparrow$	15~18
No.g.4	635#	10	2.03	1.70	2.03		14~16
No.g.5	635#	8	2.39	1.59	2.14	Adjusting diamond	12~14
No.g.6	635#	8	3.23	1.59	2.80	Parameters	12~14
No.g.7	684#	40	1.95	3.60	3.90	Optimum	50~60
No.g.8	657#	8	1.50	1.59	1.33	Optimum	12~14
No.Co-	635#	6	2.46	1.39	1.89	$v_p \uparrow$	11~13

The new type blade body with composite matrix possesses good strength and toughness. As a result, it's more wearable while it holds diamond grains firmly. And because of the three-edge structure, saw blade cuts in a collimating track with much less vibration. Consequently, power consumption is decreased while cutting stability and blade life span are improved. Thus the foundation to adjust diamond's parameter and to improve cutting's efficiency has been laid down. From test and calculation results, the matching rate of No.g.3, No.g.7 and No.g.8 are appropriate, which vouches the optimization of efficiency and benefit in respect to a variety of granite under a given cutting technology. If the diamond density equals or exceeds that of No.g.5 and No.g.6, or the number of diamond grains is or goes beyond that of 60/70, saw blade will be blunt, cutting efficiency will be low, and hence the overall benefit reduces. The body's strength and toughness results in the formation of a comet-shaped strong supporter behind diamond grains. Thus not only diamond's buffering capability is improved, but also effective cutting efficiency is increased. Sometimes some diamond grains may protrude from body surface to a height of 3/8~1/2D and yet don't drop off. A proper matching rate of diamond's size, strength and distribution is the guarantee of saw blade tartness and wearability.

## Conclusions

1. The diamond mixture ratio and parameter of technology should be decided according to the kinds of granites.

2. To  $\Phi 1.6\text{m}$  diamond saw blade with composite matrix, the maximal average depth of cut of diamond is:

$$3. \bar{h}_{\max}^2 = 1.3 \cdot \left( \frac{\bar{\lambda}_e}{A} \right)^2 \cdot \frac{v_p}{v_s} \cdot \sqrt{\frac{a_p}{d_s}}$$

4. The calculating formula of matching diamond's parameter with cutting technology is:

$$\frac{v_p}{v_s} \cdot \sqrt{\frac{a_p}{d_s}} = 0.77 \cdot A^2 \cdot \left[ \frac{BD}{\lambda_e} \right]^2$$

### References

- [1] P.A. Chalus: Industrial Diamond Review Vol. 54(4) (1994), p. 170
- [2] J. Konstany: Industrial Diamond Review Vol. 51(1) (1991), p. 27
- [3] Y.W. Zhu, X.M. Zhang, D.S. Ho, et al: Materials Review Vol. 14(10) (2000), p. 29
- [4] Q.X. Dai and M.S. Yang: China Mech. Eng. Vol. 10(1) (1999), p. 97 (in Chinese)
- [5] X.M. Dai, Q.X. Dai and D.C. Chen: *Proceedings of the Fourth International Conference on Progress of Cutting and Grinding (ICPCG'98)* (Beijing International Academic Publishers, China 1999).
- [6] Q.X. Dai and F. Cao: Tool Technology Vol. 32(11) (1998), p. 15 (in Chinese)
- [7] J.X. Ren: *Grinding Principle* (Xibei Industry University Publishing Company, China 1998). (in Chinese)
- [8] X.T. Qu: *Manufacture of Diamond Drilling Tools and Cutting Tools* (China Milling Material and Tool Industry Company, China 1990). (in Chinese)