Effect of Machining Parameters on the Surface Roughness in Grinding of Silicon Carbide using Taguchi's Method

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Abstract

Advanced structural ceramics like silicon carbide, silicon nitride, alumina and zirconia are frequently used due to their strength at elevated temperature, resistance to chemical degradation and wear resistance. But the machining costs and subsurface damages that may occur during ceramic grinding demand careful study of this process. In the present work, an attempt has been made to investigate the effect of grinding parameters such as grit size, depth of cut, feed and speed on the surface roughness of a silicon carbide work-piece using a suitable design of experiments and analysis of variance (ANOVA). Optimization of parameters using Taguchi's method indicated that optimum surface roughness of 0.25 microns was obtained at grit size 500, feed 0.5mm/rev, depth of cut 5 microns and speed 80m/s.

Key words: Advanced ceramics, Ceramic grinding.

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1. Introduction

The increase in applications of advanced ceramic materials is because of their unique physical and mechanical properties. The present market for such materials in the United States is estimated to be $2-2.5 billion with a worldwide figures of $5-6 billion and it is expected to grow rapidly [1]. The problems commonly associated with the grinding of ceramics are low grinding efficiency and large wheel wear as compared with the conventional metal grinding. To circumvent these problems, near neat shape processes such as casting, cold compacting, injection molding and hot pressing were developed. However these processes are lacking in producing close dimensional tolerances and highly surface-finished parts, which require additional finishing operations. One of the non-oxide ceramic materials is silicon carbide (SiC) in which the ratio of covalent bonding is 9:1. Low thermal coefficient of expansion and relatively high thermal conductivity are special features due to which SiC is expected to be used increasingly.

Anne Venu Gopal et. al [2], Mayer et. al [3] and Inaski [4] have reported the effect of grit size, feed and depth of cut on the surface roughness in silicon carbide, silicon nitride, aluminium oxide and zirconia respectively. It was found that surface roughness increased with depth of cut and feed rate, and decreased with grit size. Inaski found that surface roughness reduced as speed increased. Liuetal [5] studied machining characteristics and surface integrity of alumina and alumina-titania. The increased depth of cut did not deepen the subsurface damage layer. Higher wheel speed also slightly improved the surface finish. In the present work, an attempt has been made to investigate the effect of the four machining parameters, namely the speed, feed, depth of cut and grit size simultaneously.

2. Experimental Set up and Procedure

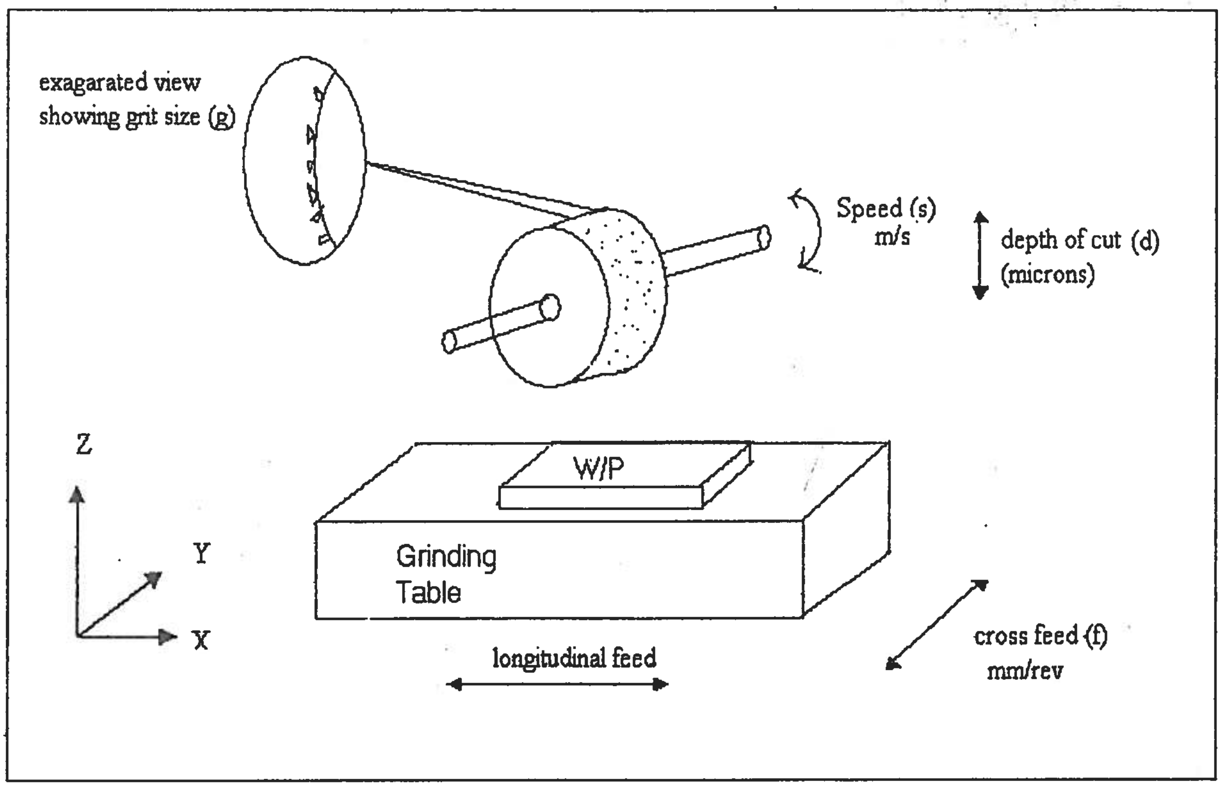


Fig. 1 Experimental Set -UP

Figure 1 shows the experimental set up of surface grinding of SiC. The experiments were carried out on a surface grinding machine. The longitudinal feed, cross feed and depth of cut were taken along x, y and z axes respectively. The size of SiC work-piece was 5cm X 5cm X 3cm The experiments were planned according to Taguchi's orthogonal array [6] as given in table1. Table 2 shows the range of control parameters. Based on the literature survey and machine limitations, three levels of the factors were selected to study the non-linearity in the results, if any. Two repetitions of each experiment were carried out randomly in order to account for the experimental error.

Table No. 1: Taguchi's orthogonal array (3 level, L_9)

Expt. No.	Coded (absolute) Values of Control factors			
	Grit size (no.)	Feed (mm/rev)	Depth of Cut (µm)	Speed (m/s)
1	1 (120)	1 (0.5)	1 (5)	1 (40)
2	1 (120)	2 (1.0)	2 (10)	2 (80)
3	1 (120)	3 (1.5)	3 (15)	3 (120)
4	2 (240)	1 (0.5)	2 (10)	3 (120)
5	2 (240)	2 (1.0)	3 (15)	1 (40)
6	2 (240)	3 (1.5)	1 (5)	2 (80)
7	3 (500)	1 (0.5)	3 (15)	2 (80)
8	3 (500)	2 (1.0)	1 (5)	3 (120)
9	3 (500)	3 (1.5)	2 (10)	1 (40)

Table No. 2: Range of Control Parameters

Control Parameters	Unit	Range
Grit Size	No.	120-500
Feed	mm/rev	0.5-1.5
Depth of Cut	µm	5-15
Speed	m/s	40-120

Three different diamond-grinding wheels were used for experimentation namely ASD126R75B2, ASD240R75B2, ASD500R75B2. All wheels were having outer diameter of 100 mm, 12 mm thickness, 1.5 mm of grit depth, 31.5 mm bore diameter of and a synthetic resin bond with concentration of 75.

Surface roughness was measured, using the surface roughness indicator instrument, Surfest, at four different locations at a fixed distance (marked as crosses in the Fig. 2) of 3 mm from each face. Final value of surface finish was taken as the average of four readings. The stroke of diamond probe was selected for 12 mm and surface roughness up to 0.01 microns was measured. Sub surface cracks were measured using ultrasonic flaw detector.

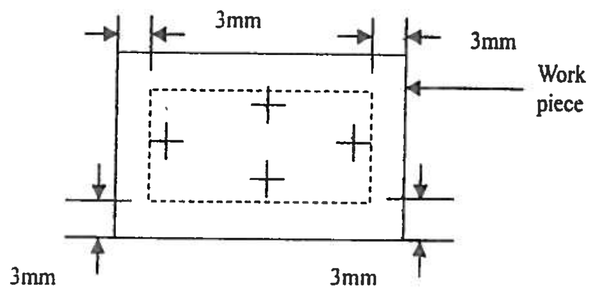
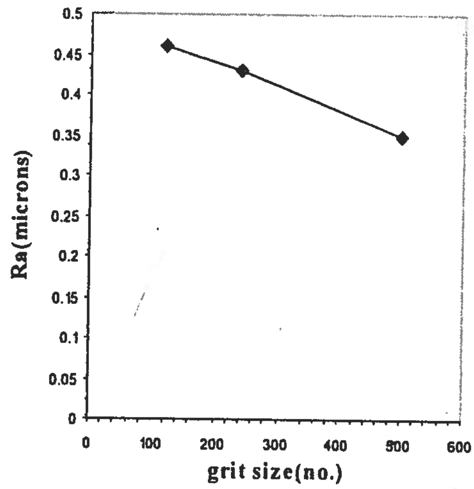


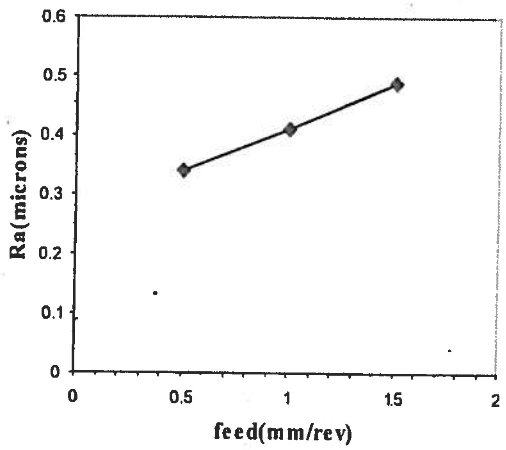
Fig 2 Different locations used for measurement of surface roughness.

3. Results And Discussion

The surface roughness obtained as a function of four parameters namely grit size, speed, depth of cut and feed was studied. ANOVA table indicates that speed was an insignificant factor.

Fig. 3 and Fig. 4 show that surface roughness values and subsurface cracks are influenced predominantly by control parameters such as grit, speed, and depth of cut and feed.





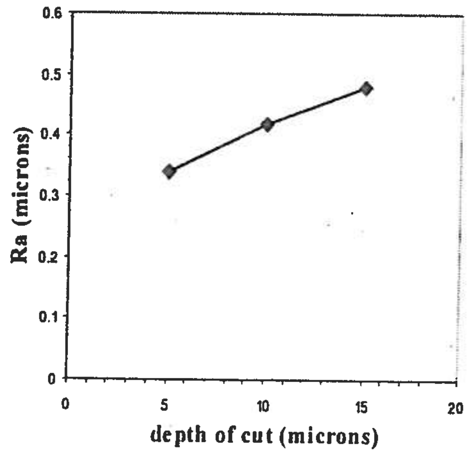
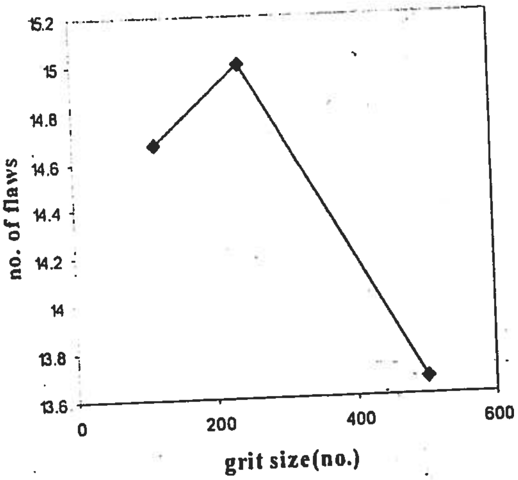
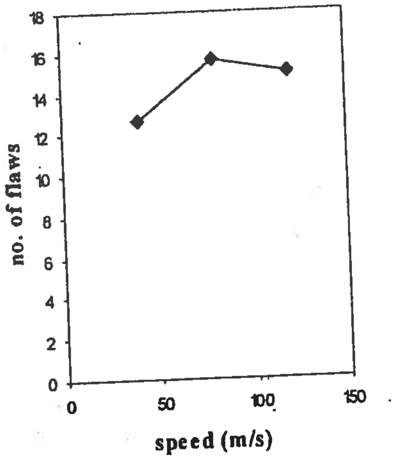
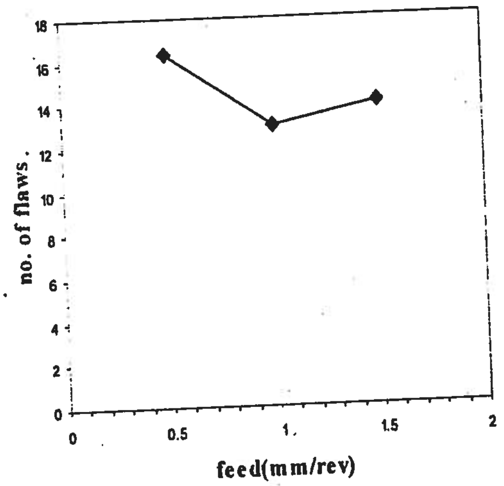


Fig3 Effect of grinding parameters on surface roughness for different grit size, feed and depth of cut.







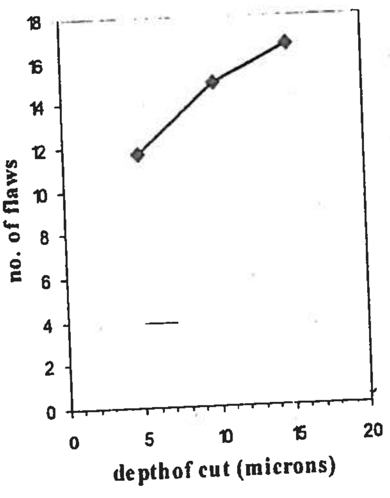


Fig 4 Effect of grinding parameters on no. of subsurface cracks for different grit size, feed and depth of cut.

At a higher grit size, the number of grains per unit area is larger, which leads to a larges number of fine cutting edges. These fine cutting edges give rise to more number of crests with smaller peaks and valleys and lesser subsurface cracks. As grit size was increased from 120 to 500, the surface roughness decreased by 24% (0.46 to 0.35) and the number of cracks decreased by 7% (15-14).

As the feed increased from 0.5 to 1.5 the surface roughness increased by 44% (0.34 to 0.49) and the number of subsurface cracks reduced by13% (16-14). The exposure of the work-piece surface below the cutting edges decreases as the feed increases.

As the depth of cut increased from 5 to 15 microns, surface roughness increased by 41% (0.34 to 0.48) owing to the increase in the cutting force causing high friction, which leads to the damage of cutting edges, and increase in surface roughness. The number of subsurface cracks increased by 42%(12-17). as the speed increased number, of cracks increased by 15% (13-15).

Table no.4 ANOVA Table For Surface Roughness

Source of variation	SS	DOF	MSS	F_0	F $(f_1, f_2)_{95\%}$
GRIT	0.0175	2	0.0088	40	19.48
FEED	0.0334	2	0.0167	75.91	19.50
DOC	0.0265	2	0.0133	60.46	19.49
SPEED	0.0040	2	0.002	9.09	19.45
ERROR	0.0001	18	2.2×10^{-4}		
TOTAL		26			

Table no 5 ANOVA Table For Number of Flaws

Source of variation	SS	DOF	MSS	F_0	F $(f_1, f_2)_{95\%}$
GRIT	116.67	2	58.33	277.76	1.81
FEED	131.33	2	65.66	312.67	1.81
DOC	152.67	2	76.33	363.48	1.81
SPEED	128.67	2	64.33	306.33	1.81
ERROR	1.66	8	0.21		
TOTAL	531	16			

The Effect of speed on surface roughness was insignificant which was confirmed from ANOVA table (4) for surface roughness. The subsurface cracks increased with increase in sp

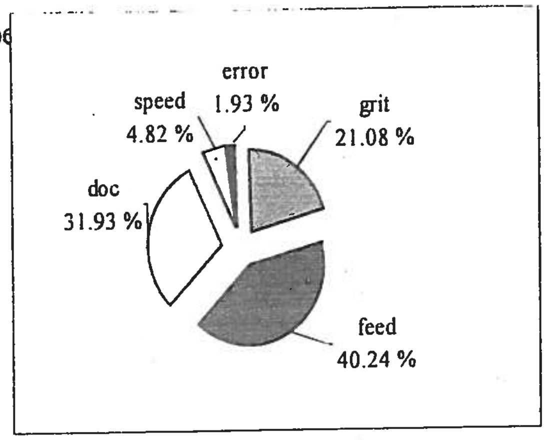
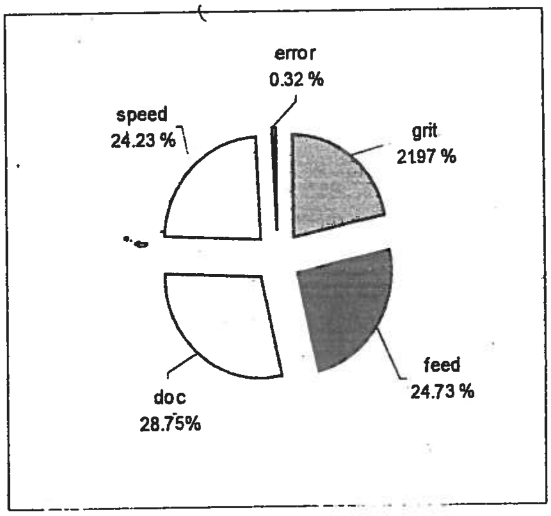


Fig 5 % Contribution of factors for surface



roughness.

Fig 6 % Contribution of factors for number of cracks

Fig. 5 and Fig. 6 Show the % contribution of the factors for surface roughness and number of cracks.

Parametric Optimization: Optimum parameters were selected by using target performance measure and noise performance measure [7].

Target performance measure: It is that level of the control factor at which the average value of response is desired. It is less for surface roughness and subsurface cracks in this case. It can be found out from graphs of grit size vs surface roughness, feed vs surface roughness, speed vs surface roughness and depth of cut vs surface roughness as well.

Noise performance measure: It is that level of the control factor at which average signal to noise ratio (S/N) is high. A high S/N ratio correspondence to less spread around the mean value.

Table No. 6 Optimal Level Setting for surface roughness

CONTROL FACTORS	Target Performance Measure (TPM)	Noise Performance Measure (NPM)
Grit Size	500	500
Feed	0.5	0.5
Depth of Cut	5	5
Speed	80	80

Table No. 7 Optimal Level Setting for Number of Flaws

CONTROL FACTORS	Target Performance Measure(TPM)
Grit Size	500
Feed	1.0
Depth of Cut	5
Speed	40

Since the levels of control factors for TPM and NPM are same in table no. 6 and table no. 7, optimum level is achieved and corresponding optimum values are given in table no 8.

Table 8. Optimum value of control factors

Control Parameters	Coded Value	Absolute Value
Grit Size	3	500
Feed	1,2	0.5,1*
Depth of Cut	1	5
Speed	2	80

*needs further investigation.

Conclusions: Depth of cut was found as the most influencing factor in achieving the minimum surface roughness. Speed was observed as the least significant factor. Surface roughness was found inversely proportional to grit size and directly proportional to infeed and depth of cut

In case of the number of flaws, depth of cut was found to be a major influencing factor and grit size as the least influencing factor. It was observed that decrease in depth of cut and increase in feed caused decrease in number of flaws. Increase in speed increases number of flaws.

Acknowledgement: Authors would like to express their sincere thanks to Mechanical engineering department and Workshop department, Government College of Engineering Karad for their financial support to this work also, we are thankful to Prof. Sane, from Metallurgy department, College of Engineering, Pune for valuable guidance.

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