

Analysis of Axial Pushing Force by New Machining Technology for Engineering Ceramics Based on Edge-chipping Effect

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Abstract: The cutting-pushing machining based on edge chipping effect is a kind of innovative machining technology, it applies stress concentration effect of precast construction mutation and broken edge effect of crack on new edge surface to process. Aim at the total difference between new machining technique and traditional contact processing, it deeply discussed the characterization of features during the machining process of Axial push force by establishment of feasible experimental scheme.

Introduction

Engineering ceramics is a hard and brittle materials. it is more sensitive to processing crack, residual tensile stress and other defects than metal material. The machining damage of engineering ceramics including cracking and fragmentation, and they become the processing problem of engineering ceramics due to randomness and difficult to be control[1,2].However, The "harm" and "benefit" of crack can be transformed each other in certain conditions. The push collapse to drive crack propagation machining technology based on the edge chipping effect make full use of the stress concentration effect[3] which is the common cause by prefabricated defect and the structure change of workpiece surface, as well as the edge chipping effect[4,5].

Experimental Method

The experiment applies Vertical 4 Axial machining center BV-75 made from Beijing Mechanical and Electrical Institute as experiment platform during the process of pushing. It also applies SDC-C4F, High-performance strain gauge universal milling drilling grinding dynamometer, made from Beihang University, which is mainly composed of a circular table and dynamometer body, the vertical component Fz measurement range of 0 ~ 4500N.

The experiment uses reaction sintering of Si₃N₄ specimen material size with a diameter of $\phi=26$ mm, height H = 60 mm. The main performance parameters of the material: density $\rho=2.73$ g / cm³, hardness HRA = 85, the modulus of elasticity E = 160 Gpa, breaking strength KIC = 2.85 MPa.m^{1/2}.

Work at a constant speed 150r / min is rotated. Experiment applies L16 (45) orthogonal table, pushing the tool against axial feed velocity V, the flange thickness A, the groove depth H of the three major processing parameters arrange 16 set of experiments, the measured three times at each set of parameters for each machining reservations mean axial flange after pushing force. Other factors and orthogonal experiments involving as shown in Table 1.

Table 1 Elements and Standard of Orthogonal Experiment

<i>Elements</i>	<i>Axial Feeding Speed</i> <i>V/mm.min-1</i>	<i>Depth of Groove</i> <i>H/mm</i>	<i>Thickness of Flange</i> <i>A/mm</i>
1	20	1.5	2
2	50	2	2.5
3	80	2.5	3
4	100	3	3.5

Results and Discussion

Tables 2 and Tables 3 are axial pushing force of visual analysis and variance analysis table. By range and variance ratio F can be informed of the processing parameters for each push Tool Wear of primary and secondary order. Wherein the turning axial feed rate, the flange thickness, groove depth ratio were 2.363,0.565,0.070 F; and wherein the axial feed rate, depth of the grooves, the flange width respective pushing force obtained were very poor as 198.392N, 34.378N, 91.661N. Influence of axial feed rate, the flange width, groove depth influence on the axial pushing forces are successively decreased, which is known in Visual Analysis Table and Variance Analysis Table.

Table 2 Visual Analysis

<i>S/N</i>	<i>Feed Speed</i> <i>V/mm/min</i>	<i>Depth of Groove</i> <i>H/mm</i>	<i>Thickness of Flange</i> <i>A/mm</i>	<i>Axial Push Force</i> <i>F/N</i>
Test1	1	1	1	368.2038
Test2	1	2	2	403.7513
Test3	1	3	3	435.9827
Test4	1	4	4	466.3526
Test5	2	1	2	355.7387
Test6	2	2	1	313.9725
Test7	2	3	4	410.5561
Test8	2	4	3	344.0363
Test9	3	1	3	356.1195
Test10	3	2	4	326.2746
Test11	3	3	1	253.4084
Test12	3	4	2	231.2057
Test13	4	1	4	262.8918
Test14	4	2	3	243.6786
Test15	4	3	2	210.3065
Test16	4	4	1	163.8473
AVG1	418.573	335.738	274.858	
AVG2	356.076	321.919	300.251	
AVG3	291.752	327.563	344.954	
AVG4	220.181	301.360	366.519	
Range	198.392	34.378	91.661	

Table 3 Variance Analysis

<i>Element</i>	<i>Square Deviations</i>	<i>DOF</i>	<i>Ratio F</i>
Feed Speed	87075.873	3	2.363
Depth of Groove	2580.761	3	0.070
Thickness of Flange	20814.895	3	0.565
Axial Push Force	110471.53	9	

Take pushing process of Visual analysis in Table 2 as abscissa , and under the conditions of each factor level, mean axial force pushing ordinate as vertical ordinate, plotted relationship between the processing parameters and the average axial pushing force pushing between As shown in Figure 1. Increasing axial feed rate may reduce the axial pushing force; groove depth increased, to some extent the pushing force is slightly smaller; flange thickness increased, axial pushing force becomes large.

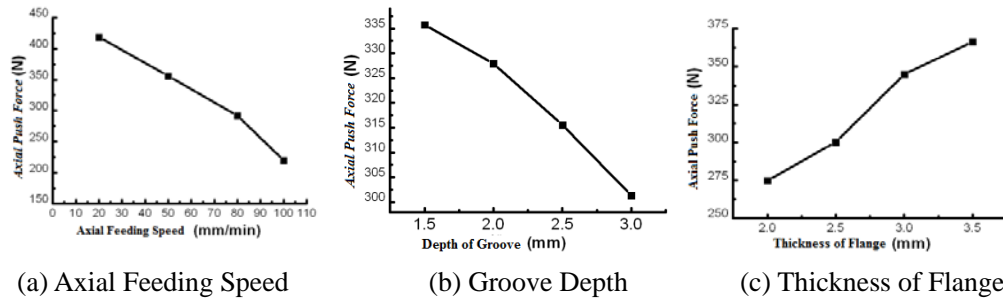


Figure 1 The impact of processing parameters on the axial pushing force

Establishment of Multivariate Nonlinear Regression Model

During the machining of ceramics cutting edge chipping - pushing process, if axial pushing force F with axial feed velocity V , the flange thickness A , the relationship groove depth H three main process parameters are likely to have similar metal cutting classic formula:

$$F = cA^m H^n V^k \quad (1)$$

By transformation, results of axial pushing force to solve the exponential regression model regression coefficients in orthogonal table are shown in Table 4.

It can uses R^2 statistical test value (goodness of fit test) and F test statistic value (significance test) of each model to value reasonable degree evaluation model. Statistical test to axial pushing force of the exponential model are shown in Table 5, the exponential model better fits a given level orthogonal experiment samples, data representation of regression equation is strong.

Table 4 Regression coefficient of axial pushing force in exponential model

Regression Coefficient	Regression Coefficient Estimates	Confidence Interval of RC	
$\ln c$	6.7854	[6.2028	7.3680]
m	0.5783	[0.2538	0.9028]
n	-0.2265	[-0.4883	0.0353]
k	-0.3639	[-0.4736	-0.2542]
<hr/>			
$R^2=0.8552$	$F=23.623$	$p=0.0000<0.0001$	$s^2=0.0155$

The fitting formula of axial pushing force is:

$$F = 884.8265A^{0.5783}H^{-0.2265}V^{-0.3639} \quad (4-14)$$

Conclusion

The influence to the axial pushing force are individually decreased by feed of axial direction, flange width and groove depth. Axial feed rate increases, the axial pushing force is reduced; the groove depth is increased to some extent, the pushing force is slightly smaller; flange thickness increases, the axial pushing force becomes large.

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References

- [1]. Tang XJ, Tian XL, Wu ZY, et al. Research progress of edge chipping behavior and mechanism of engineering ceramics[J]. China Mechanical Engineering, 2010, 21(1): 114-119
- [2]. Tian XL, Yu AB. Theory and technology of engineering ceramics processing[M]. Beijing: National Defence Industry Press, 2006
- [3]. Nishida Masako. Stress concentration [M]. Beijing: Mechanical Industry Press, 1986.
- [4]. Tang XJ, Tian XL, WANG WL, et al. Study on fracture regulars and mechanisms of edge chipping for engineering ceramics based on energy[J]. Journal of Synthetic Crystals, 2013, 42(10): 1-4
- [5]. Scieszka S F. Edge failure as a means of concurrently estimating the abrasion and edge fracture resistance of hard-metals[J]. Tribology International, 2005, 38(9): 834-842