International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 05, May-2019

OPTIMIZATION OF MACHINING PARAMETERS USING ROTARY ULTRASONIC MACHINING OF BRITTLE MATERIAL: A REVIEW

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Abstract

Advanced ceramics such as aluminium oxide, silicon nitride are on the attractive side for various applications due to their valuable properties but the reason for their limited use in the market is their high cost of machining through the conventional process like ultrasonic machining, so to reduce their machining cost and make them valuable and competitive in market there is need for the development of machining process which not only reduces the machining cost but also able to achieve high Material Removal Rate. One such process for that is Rotary Ultrasonic Machining (RUM) which is a combination of Ultrasonic Machining and Diamond Grinding. This paper reviews the effect of various process variables on Material Removal Rate, Tool Wear, Surface and Sub-surface Cracks of ceramic component with Rotary Ultrasonic Machining and compares them with the conventional Ultrasonic Machining.

Keywords – Ceramics, Ultrasonic Machining, Rotary Machining, Sub-surface, Material Removal Rate, Tool Wear.

I. INTRODUCTION

The structural ceramics are used for many applications due to their valuable properties like high strength at elevated temperatures, resistance to chemical degradation, low density, wear resistance. But its use in the market is limited due to their high fabrication cost. So, there is development of other machining process for advanced ceramics [1].A frequently used method for machining ceramics is diamond grinding but in this the surface and sub-surface damage to the machined parts are highly prominent. Another frequently used machining process is Ultrasonic Machining [2,3].

Figure 1 shows the schematic view of Ultrasonic Machining. It involves a tool made of ductile and tough material vibrating at ultrasonic frequency (typically20 kHz) and is feed into the work material. A continuous flow of abrasive slurry in small gap between the tool and the work piece is provided. The limitation of Ultrasonic Machining is very low Material Removal Rate, only small depth of holes and cavities can be produced, high Tool Wear.Here comes the role of Rotary Ultrasonic Machining which is a combination of Diamond Grinding and Ultrasonic Machining and results in high Material Removal Rate. It also improves the hole accuracy with superior surface finish.

Figure 2 shows the schematic view of Rotary Ultrasonic Machining in which the tool rotates at very high rpm and slurry is replaced with the abrasives bonded to the tool. In Rotary Ultrasonic Machining micromachining up to 100 micrometers is possible.

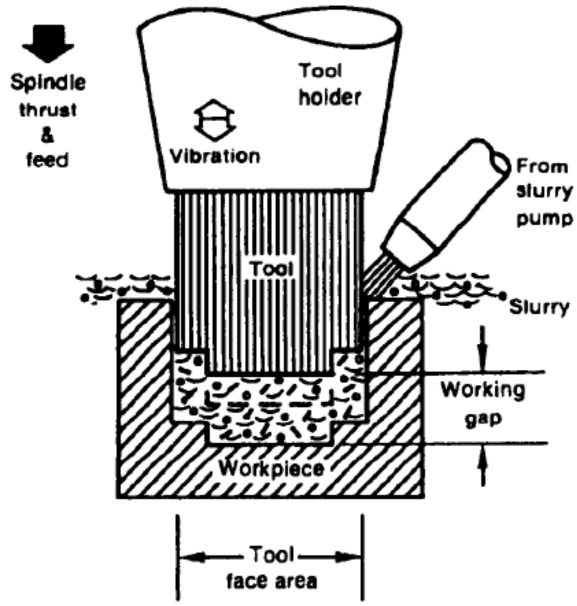

Figure 1 : Schematic Illustration of Ultrasonic Machining [1]

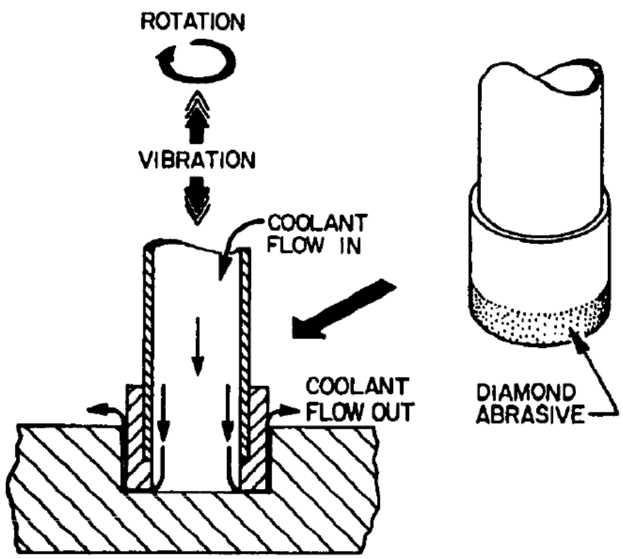

Figure 2: Schematic Illustration of Rotary Ultrasonic Machining [1]

II. LITERATURE SURVEY

Markov [4] has worked on theextension of Rotary Ultrasonic Machining to machine flat surface or milling slots. He then concluded the results of his research by using a rotary metal bonded diamond tool with ultrasonic vibration.He found very good results in machining of deep holes and slots which otherwise was the limitation of Rotary Ultrasonic Machining.

Tyrrel [5] also worked on the extension of Rotary Ultrasonic Machining to machine flat surface or milling slots. He concluded that slotting could be achieved with diamond wheel only when the wall of the diamond wheel would be the cutting surface .He then describe the method as Surface Grinding.

Tinschert and Natt[6]uses the Computer Aided Design and Computer Aided Manufacturing. (CAD/CAM) technology to manufacture dental ceramics. However commercially available dental CAD/CAM system usually use the process like diamond grinding and milling. The major disadvantage of these processes are surface defect (such as scratches and chipping) and sub-surface defect (such as residual stress) are very prominent.

Narasimha and Komaraiah [7] has studied the influence of fracture toughness and hardness on Material Removal Rate of brittle materials by using Ultrasonic Machining and Rotary Ultrasonic Machining and made the comparison between both and comes with the conclusion that Material Removal Rate improves quite significantly if we use Rotary Ultrasonic machining in comparison to conventional Ultrasonic Machining.

Mult and Ing [8]has worked on Ultrasonic assisted grinding of silicon nitride and alumina. Based on the grinding forces he analyzed the parameters like Surface Roughness and Tool Wear with and without vibration and finds a very conclusive results that Surface Roughness and Tool Wear reduces to a greater extent.

Sindel et al. [9]does the experimental investigation onaluminium oxide dental ceramics with Rotary Ultrasonic Machining and compares it with the diamond grinding. In diamond grinding a lot of surface and sub-surface cracks are found and depth of cracks ranges from a very few micrometers to few tens of micrometer. In Rotary Ultrasonic Machining very less sub-surface cracks are found and their depth is less than five micrometer.

Aspinwall and Kasuga [10] have reported that if he use coarser grain structure high static force and hollow tool having high power rating then optimum Material Removal Rate and Tool Wear can be achieved in Ultrasonic Machining of ceramics.

Kumabeand Nishimoto[11] reported a new method for precision machining of ceramics. In this method both the ceramic work piece and tool(diamond) were ultrasonically vibrated. In addition to that the tool was vibrated at a low frequency (nearly 50 Hz). So, by considering this method he found that Material Removal Rate and Tool Wear improved significantly.

Kelly and Peterson [12] does the experimental investigation into the effects of ultrasonic vibration on the surface and sub-surface cracks in Rotary Ultrasonic Machining of aluminium oxide dental ceramics and concluded that if we use ultrasonic vibration than a better surface quality can be expected for grinding of dental ceramics.

Yue and Ping [13]finds Rotary Ultrasonic Machining a very reliable and cost-effective machining technique and they performed their experiments on calcium aluminium silicate and magnesia-stabilized zirconia as their ceramic materials and they found that the Material Removal Rate obtained from Rotary Ultrasonic Machining is 6 to 10 times higher than a conventional grinding process under same conditions.

Jahanmir and Peterson [14] studied the effect of various process parameters like static pressure, rotational speed, ultrasonic vibration, diamond type on the process performance parameters (Material Removal Rate, Tool Wear) and it has been found experimentally that Material Removal Rate due to Rotary Ultrasonic Machining increases to a great extent.

Komaraiah and ping[15]has worked on Rotary ultrasonic Machining of ceramics by using three process variables (spindle speed, feed rate and ultrasonic power) and found that all these process variables affect the Material Removal Rate significantly

Jadoun[16]investigated the tool wear rate in Ultrasonic machining of advanced ceramics. He also studied the effect of four important input process variables-tool material, grit size, power rating and slurry concentration on tool wear rate. He uses Taguchi's method for his analysis and concluded that these four input variables significantly affect the tool wear rate in Ultrasonic Machining.

Li and Pei [17] has worked on Edge-chipping reduction in Rotary Ultrasonic Machining of ceramics. He uses Finite Element Analysis (FEA) model to study the effect of parameters like cutting depth and supporting length and through his experimental research he found a solution to reduce the edge chipping through Finite Element Analysis simulations

Nikhiet al. [18] has worked on the Rotary Ultrasonic Machining of silicon carbide. He presented the results of design experimental investigation into Rotary Ultrasonic Machining of silicon carbide. He takes into consideration the effect of four process variables (spindle speed,

III. CONCLUSIONS

From this review, the following conclusions can be obtained:

1. Manufacturing of Rotary Ultrasonic Machining is a mature technique.

2. The feed rate, spindle speed and the grit size have significant effect on surface roughness.
3. The tool material, power rating and slurry concentration significantly affect the Tool wear of Ceramic materials.
4. Experimental work on Rotary Ultrasonic Machining has been conducted in UK, USSR, United States and Japan since 1960s. Theoretical work on Rotary Ultrasonic Machining started in 1990s.

IV. FUTURE SCOPE

Direction for future scope include determining the effects of machining parameters on subsurface damage, evaluating the correlation between strength degradation and machining parameters, developing the dressing techniques for tools, determining the effects of different types of coolant and carrying out further study of ductile material removal mode in Rotary Ultrasonic Machining.

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