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A perspective on shaping of advanced ceramics by electro discharge machining

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Abstract

Advanced ceramics possesses properties like high corrosion resistance, high temperature resistance, high wear resistance and high refractoriness; they can retain high hardness at elevated temperatures etc, these properties renders them as potential candidates for various applications. Due to such excellent properties these materials have overcome the limitations offered by metals and can withstand severe wear and tear at elevated temperatures and hostile working environments. Therefore the need to process these materials has elicited a deeper interest amongst engineers and scientists alike. Due to such outstanding properties these hard and brittle materials cannot be machined by conventional techniques. The traditional sintering process utilized to shape these materials is ineffective to generate fine shapes without micro cracks. Electro discharge machining offers an opportunity to machine complex shapes and geometries of such ceramics. The aim of this review is to explore the candidature of EDM as a viable option in shaping of these materials. The paper addresses machining of different ceramics and advanced ceramics by Electro discharge machining. This overview emphasizes on unfolding numerical models and experimental work carried out by past researchers and further identifies challenges in effective machining of these advanced ceramics by EDM.

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Keywords: EDM; Ceramics; CMC; MMR; TWR

1. Introduction

Technological advancements have provided impetus to develop materials with superior properties. Among these materials advanced ceramics have found a novel place in today's industrial world, due to their excellent properties.

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These properties have allowed ceramics to exceed the performance limitations offered by metals. Advanced ceramics has replaced metals in various applications involving reduced density and higher melting points which can enhance the speed of operation and increases efficiency. They can potentially be used at temperatures from 400 to 900°F above the maximum operating temperature for super alloys. These materials can retain high hardness at elevated temperatures and maintain properties like strength, hardness, corrosion wear resistance [1]. Due to such significant properties they offer an alternative to conventional materials. Advanced ceramics offer a huge potential to engineers to exploit them industrially as well as commercially for numerous applications. They have found a wide usage in machine tools, automobiles, aerospace and industrial electronics [2, 3, 4].

2. Challenges in shaping of advanced ceramics

Excellent properties like high hardness, superior wear resistance, chemical resistance, low density, high strength to wear ratio are significant from application point of view [5, 6]. The fabrication and shaping of these materials is rather difficult, therefore limiting their usage. Conventional sintering processes lag behind in providing a near net shape to the products due to hardness and brittleness. Therefore researchers are in look out for methods to fabricate and shape them [7]. The conventional machining of these materials results in low material removal rates, poor surface quality, and sub surface damages. The essential perquisite is to generate these complex shape and sizes without micro cracks, which is difficult to achieve by convention methods. Traditional cutting and grinding leads to lower machining rates and larger tool wear despite being expensive too [8]. Advanced machining methods can overcome the challenges offered by these materials as they offer a better material removal rates.

3. Potential of EDM for shaping advanced ceramics

Advanced machining processes are utilized to machine ceramics. These processes significantly overcome the drawbacks of conventional machining by offering a better material removal rates. Based on the phenomena of material removal mechanism these processes are summarized as.

1. Mechanical Material Removing mechanism [eg. Abrasive water jet, abrasive jet, ultrasonic machining etc]
2. Thermal Material Removing mechanism [eg. Electro Discharge Machining]
3. Chemical Material Removing mechanism [eg. Chemical Machining]

Ultrasonic Machining: The quality of the surface obtained for the work piece is better when compared with other traditional machining methods. However lower material removal rates and cost ineffectiveness renders it as an unfavorable candidate [9].

Abrasive water jet Machining: This technique utilizes water jet pressure to machine ceramic surface. It offers higher cutting speeds, no thermal damage to surface, less in operational costs. However surface quality is poor and it is difficult to produce complex shapes and it fails to cut thick parts [10].

Laser Machining: This machining offers poor surface quality, as the machined surface it heated due to laser, which leads to reduction in yield stress and deformation of the surface from brittleness. This in turn leads to micro cracks. This technique is difficult to cut large surfaces and formation of recast layer takes place [11].

Chemical Machining: This is good for shallow machining cuts, requires less equipments. No residual stress is left behind. The cost increases due to addition of handling and disposal of chemicals used [12].

Electro Chemical Machining: Intricate contours, profiles and complicated shapes are easily obtained by this process, but on the contrary MRR is less and the handling of chemicals makes it expensive [13].

In EDM, a high frequency electric discharge flows through the work piece and the electrode, as there is no physical contact between them. Due to intense heat generated by this process the material of the work piece melts leading to thermal mode of material removal [8]. The debris left behind is flushed out by the dielectric fluid. When the electric discharge runs through the tool electrode to the work piece, the distance between them leads to formation of plasma,