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Experimental investigation of rotary ultrasonic face milling on red granite: A comparison with conventional grinding

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Abstract

Long-term sustainability with cost-effective machining and materials are used in many companies these days. Also, precise machining on brittle and hard materials is becoming a challenge for production engineering. Rotary ultrasonic face milling (RUFM) is an unconventional milling process that is preferred to perform precise surface machining on such materials. The research work aims to analyse the enhancement in conventional diamond grinding (CG) due to the addition of ultrasonic vibration and compare both processes (RUFM and CG). Analysis of variance (ANOVA) technology was applied for the analysis. The scanning electron microscopy (SEM) technique was used to analyse the tool wear after milling operation. The controlling factors used for the study were feed rate, depth of cut, and ultrasonic power. The outcomes of the study showed an increment in material removal rate during RUFM compared to CG. Material removal rate (MRR) also increases with increment in each level of controlling factors. Surface roughness (SR) increases with the addition of ultrasonic vibration during RUFM. Also, SEM technology shows the complete removal of diamond grits at the bottom surface of the tool. The research concluded that tool life and material removal rate get improved but the reduction in surface finish during RUFM while comparing to CG.

Introduction

Granites are the hardest stone after diamond in the world. Superior properties like resistance to scorching, cracking, blistering, and scratching made granites more useable for flooring, statue, temples, and commercial use. Grooving and surface machining was required to transform granite material into the desired shape. The conventional method (surface grinding) was used for a long time for the same purpose. Later, RUM was introduced for drilling and hole generation purposes. In drilling, there was various investigation performed for analysis of edge chipping defects during RUM. Also, the relative variation of responses with process parameters was optimized and analysed for better machining conditions [1], [2], [3]. In 2005, Z. J. Pei performed experiments for feasibility analysis of RUM for drilling and it was concluded that the addition of vibration in machining provides an increment in machinability [4]. The application of RUM for surface machining (milling) was initiated by Z. J. Pei in 1995. A new approach with the developed design of the cutting tool was mentioned in the paper [5]. Later in 1999, Z. J. Pei once again applied the milling approach on RUM with a set of experiments. The fractional design of the experimental investigation was with five variables of two-level and four output responses (MRR, cutting force, material removal, and surface roughness) [6]. C. Zhang initiated the comparative experimental investigation of diamond milling and RUFM. It was concluded in the paper that cutting force gets reduced during RUFM due to vibration which increases tool life but it reduces surface finish [7]. KUO Kei-lin experimentally compared RUFM and conventional diamond milling processes on float glass. The effect of feed rate and the axial cut was analysed on surface roughness response. It was concluded that surface roughness different variation due to tear-out of diamond grits from cutting tool. Repetitive contact of tool to hard