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RESEARCH ARTICLE

Synergetic effect of cryogenic treatment and laser surface texturing of tungsten carbide cutting inserts on machinability of EN31 steel

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ABSTRACT
This study aims at investigating the synergetic effect of deep cryogenic treatment and Laser Surface Texturing (LST) on the machinability characteristics of EN31 steel using CVD-coated Tungsten Carbide (TT8125) cutting inserts in a turning operation. The Taguchi L16 orthogonal array was used to design the experiments with the type of cutting insert, test condition and cutting speed as control factors. The effect of these control factors was studied on flank wear of the tool and work-piece surface roughness. The experimental results of these response variables were analysed by utilising Taguchi's S/N ratio analysis and ANOVA (analysis of variance). The results reveal that cryo-treated textured inserts offer minimum tool flank wear and surface roughness of work-piece compared to other inserts. Further, LST significantly reduces the flank wear of the tool and workpiece surface roughness compared to cryogenic treatment; however, both offer better performance individually than untreated-untextured cutting inserts. It was revealed that the flank wear and surface roughness reduced in the range of 78.06%–81.3% and 73%–82% due to cryogenic treatment coupled with laser surface texturing.

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1. Introduction

Every machining process aims to reduce costs while maximising productivity and quality. This objective can be achieved by operating at the highest cutting conditions without compromising tool life. However, machining hard materials presents significant challenges, primarily due to reduced tool life. The process generates high cutting forces and elevated temperatures, which, if the tool lacks sufficient hardness, leads to rapid wear, increased cutting forces, dimensional inaccuracies, and shorter tool life. Cryogenic treatment is a technique applied to cutting tools to extend their life and mitigate rapid wear, especially during the machining of difficult-to-cut materials across various operations [1]. This treatment improves the material's properties to enhance overall productivity. It is not a replacement for conventional heat treatment but rather an additional process performed after quenching and before tempering [2]. Contrary to being a supplementary process, cryogenic treatment is sometimes described as a reverse heat treatment technique [3], carried out directly after quenching and followed by tempering. During this process, samples or cutting tools are gradually cooled to cryogenic temperatures (around −196°C), maintained at these low temperatures for extended periods, and then slowly warmed back to room temperature. This approach enhances tool wear resistance and dimensional accuracy by inducing microstructural changes at the molecular level, typically within a temperature range of −150°C to −273°C [4]. These microstructural changes result in improved surface finish, increased tool hardness, reduced cutting temperatures, and enhanced wear resistance. Such benefits ultimately contribute to prolonged tool life, improved productivity, and reduced operational costs, making cryogenic treatment a vital economic consideration in machining [5]. The improvement in the mechanical properties of cutting tools depends largely on factors like the selection of the heat treatment cycle, soaking temperature, cryo-soaking duration, and controlled cooling and heating rates [6].

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