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Review

Influence of Cryogenic Treatment of Cutting Tools on the Machinability Characteristics of Materials: A Comprehensive Review

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Abstract

The cryogenic engineering is a vast and important field of engineering. The effect of cryogenic treatment on performance parameters of cutting tools directly affects the tool life and productivity and same has been analyzed in this review paper. The tool wear increase, dimensional inaccuracy, rough surface finish and increased production cost is encountered by cryogenic treatment of tool materials. This review gives analysis about the cryogenic treatment process, cryogenic fluid used, temperature/pressure maintained, and desired improvements achieved. The literature survey applied clearly signifies that cryogenic treatment improves the machinability characteristics compared to the untreated tools. A lot has been achieved and further improvements are poised with future challenges to be encountered. The paper analyses the studies on HSS, and carbide tools done through cryogenic treatment and ascertains that better tool life and productivity can be achieved by cryogenic treatment through reduced tool wear.

Keywords

cryogenic treatment, tool wear, machinability, manufacturing

1 Introduction

Cryogenic treatment, a low temperature supplementary process to traditional heat treatment that enhances the material characteristics to increase the overall productivity is not new, but in comparison with the conventional or traditional heat treatment process it is truly believed to be in its infancy. Cryo-treatment is not a substitute for traditional heat treatment; rather is an additional process to traditional heat treatment to be done after quenching and before tempering [1]. In cryo-treatment samples are being cooled down to very low temperatures (−80°C to −196°C) in order to enhance the desirable properties like good surface finish, less tool wear, lower cutting temperatures etc through morphological changes that occur during this cryo-treatment process. The main aim of this cryogenic treatment is to increase the tool wear resistance, surface hardness and toughness of cutting tool resulting in increase in cutting tool life which ultimately leads in increasing productivity and consequently reduction in cost hence, considered an important economic factor [2].The improvement in mechanical properties of cutting tool materials primarily depends upon selection of heat treatment cycle process, soaking temperature, cryo-soaking period and cooling as well as heating rate [61]. Cryo-treatment is categorized in two levels such as shallow cryo-treatment (SCT) from (−80°C to −145°C) and temperature range for deep cryogenic treatment (DCT) is −145°C and below.

Gill et al. [3] investigated the influence of SCT and DCT on tungsten carbides and found that life of carbide tool is increased by 35.85% for DCT inserts in comparison with the subsequent increase of 26.80% for SCT inserts. Besides, Cryo-treatment also enhances thermal conductivity by dissipating the heat to the surroundings results in cooling the tool tip. Nursel et al. [4] also found in their investigation that the enhancement in tool life of deep cryogenic treated (DCT) tungsten carbide tools by 14.5% than untreated tools. Also, results revealed that the tool hardness is increased by 10.87% and work-piece surface roughness is improved up to 16.5% in comparison with untreated tools. In another study, Firouzdar et al. [5] cryogenically treated high-speed steel (HSS) tools and found 77% increase in tool life. Reddy et al. [6] experimentally proved the enhancement in tool life of deep cryogenically and normal treated tungsten carbide by an amount of 21.8% and 9.58%, respectively. Besides, the execution of the cryogenic treatment after quenching and before tempering on HSS tools has shown an increases tool hardness and improves the homogeneity, reduction in consumption of tool material and reduces the rest time for the installation of equipment set up, thus results in cost reduction 50% [7].