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A comparative study on machinability of cryo-treated and peak aged 15Cr-5Ni precipitation hardened stainless steel

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ABSTRACT

Cryogenic treatment is a competent approach to improve the mechanical properties and microstructure of 15-5 PH stainless steel by considering the economic and other beneficial effects. This study brings out the correlation between the microstructure, mechanical properties and experimental examination on the machinability of 15-5 PH stainless steel. Cryogenic treatment with aging and conventional heat treatment process was done on the as received samples before machining. Mechanical properties and microstructure were evaluated at different treated conditions. This present investigation is to explore the effect of machining variables on performance measures namely tangential cutting force, tool wear, chip form analysis and surface roughness. The hardness and strength of cryogenically treated with aged samples were high while comparing with conventional heat treated samples. From the experimental investigation, it was observed that the cutting force and surface roughness are minimum at lower rate of feed and higher cutting speed for all the machined samples. The surface finish was found to be better for the cryo-treated with aged samples.

1. Introduction

Precipitation hardenable 15-5 PH martensitic stainless steel exhibits superior mechanical and metallurgical properties. Hence it is used in enormous applications in engineering domains such as nuclear reactor components, actuator parts of modern fighter aircraft, oil field valve parts, missile fittings and cryogenic applications [1]. PH martensitic stainless steel can be heat treated to attain several combinations of desired mechanical properties [2]. Cryogenic treatment of PH steel improves the yield strength by retained austenite to martensite transformation and hence it is used for enhancing the dimensional stability of aerospace components. The microstructure analysis and mechanical properties of different PH stainless steel were examined at various heat treatment conditions. It was concluded that the cryo-treatment with aging on PH stainless steel provides a combinatorial property of high strength and ductility, due to precipitation of fine Mo_2C particles and the transformation of retained austenite [3–6].

Prieto et al. [7] analyzed the influence of cryogenic treatment on martensitic AISI 420 stainless steel and found that there was a considerable enhancement in mechanical properties due to the precipitation of fine carbides. Zhirafar et al. [8] compared the mechanical properties of cryogenically treated 4340 steel with conventional heat treated steels. It was concluded that the hardness and fatigue strength were improved, while the toughness was lowered for the cryo-treated steel due to the formation of carbide and transformation of retained austenite to martensite.

The effect of cryo-treatment on mechanical properties of different materials was investigated and proved that the cryogenic treatment enhanced the properties such as fatigue resistance, wear resistance, compression strength and hardness while the toughness and bending strength remained unchanged [9–11]. The influence of the heat treatment on mechanical properties and microstructure of different materials have been investigated and was concluded that the hardness increases with rise in temperature due to dissolution of $M_{23}C_6$ carbides [12–14]. The benefits of hard turning over traditional form grinding was investigated and it was stated that the cutting tool geometry, workpiece hardness and cutting parameters are the main factors that affects the cutting forces, surface residual stress, surface roughness, surface integrity, tool wear and tool life [15].

Investigation on martensitic transformation through continuous cooling of AISI D2 tool steel was performed and it was concluded that martensitic start temperature, strength of austenite and microstructural heterogeneity were found as significant factors which influences the martensite morphology [16]. Hard machining assisted with cryogenic cooling has the capability of improving surface quality and tool life [17,18]. Adem cicek et al. [19] investigated the performance of

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