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Optimization of surface roughness and tool wear in hard turning of austempered ductile iron (grade 3) using Taguchi method

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Abstract

In this work, the cutting parameters are optimized in hard turning of ADI using carbide inserts based on Taguchi Method. The cutting insert CVD coated with AL_2O_3**/** MT TICN. Experiments have been carried out in dry condition using L_{18} orthogonal array. The cutting parameters selected for machining are cutting speed, feed rate and depth of cut with each three levels, nose radius in two levels maintaining other cutting parameters constant. The ANOVA and signal to noise ratio are used to optimize the cutting parameters. The cutting speed is the most dominant factor affecting the surface roughness and tool wear. In optimum cutting condition, the confirmation tests are carried out. The optimum cutting condition results are predicted using signal to noise ratio and regression analysis. The predicted and experimental values for surface roughness and tool wear adhere closer to 9.27 % and 1.05 % of deviations respectively.

Keywords: Austempered ductile iron; Surface roughness; Taguchi; Tool wear.

1. Introduction and literature review

Hard Turing is a turning of hard material with a hardness range from 45 to 68 HRC. Generally, coated carbide, cubic boron nitride (CBN), Ceramic and polycrystalline cubic boron nitride (PCBN) inserts are used to turn the hard materials in CNC lathe. The machining of hardened materials using CBN, PCBN and ceramic tools are generally used and it is a good alternate to expensive grinding operations [1]. Hard turning has many advantages other than the cost advantage such as faster metal removal rate, reduced cycle time, good surface finish and environmental free [2].

ADI materials have been used in many engineering applications because of their high strength, high hardness, ductility and toughness. These materials have been widely used for many applications such as automotive, agricultural, railroad, construction and mining industries due to their excellent mechanical properties, such as high strength to weight ratio, high wear resistance and inexpensive material compared to other materials [3]. Austempered ductile iron (ADI) is a comparatively latest material for industrial applications. ADI is a heat treated form of as cast Ductile Iron. The Austempering process consists of three stages they are austenitizing, isothermal quenching and cooling to room temperature. Austempering results, the microstructure consists of ferrite in high carbon austenite matrix [4].

ADI is difficult to machine compared to ductile cast irons in the austempered condition, because of relatively high hardness and high strength. In machining, the material is strained hardening takes place due to the presence of retained austenite. The strain hardening of retained austenite increases mechanical loads and reduces the contact length on the cutting insert tool's edge [5]. The higher cutting tool wear was observed in machining of ADI in austempered condition, when compared to other hardened material.   The higher tool wear occurs at the cutting tool's edge due to high temperature, adhesion resting on the cutting tool and higher ductility of ADI [6]. In turning of ADI, the cutting tool's edge subjected thermal softening due to higher cutting temperatures and low thermal diffusivity of ADI [7].The aim of the new machining industries is to produce components at low product cost with good quality in minimum time. To achieve a good cutting performance in turning, selection of optimum cutting parameters is important. Machinability of hardened materials was evaluated by cutting force surface roughness and tool wear.

Turning the hard material to get a minimum surface roughness with minimum tool wear is difficult. The following literature survey indicates that most of the hard material is turned by CBN, PCBN and ceramic inserts. Katuku et al. [8] conducted experimental work in dry cutting condition on austempered ductile iron (ASTM Grade 2). The cutting forces, chip characteristics and tool wear were analyzed with PcBN cutting tools. The result revealed that the optimum cutting speed for better tool life and flank tool wear is 150 to 500 m/min. In another work Marcelo Vasconcelos de Carvalho et al. [4] investigated machinability of ADI (ASTM grades 2 and 3). It has been reported that, minimum surface roughness and higher tool wear observed when turning ADI grade3 with higher tool nose radius. In another work, Tuğrul Özel and, Yiğit Karpat [9] developed the prediction model using regression and neural networks in hard turning for surface roughness and tool wear by