CERTAIN INVESTIGATIONS ON TURNING OF AUSTEMPERED DUCTILE IRON

ABSTRACT

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ABSTRACT

Hard turning is a turning of the hard material with a hardness ranging from 45 to 68 HRC. Generally, Ceramic, Cubic Boron Nitride (CBN), and Polycrystalline Cubic Boron Nitride (PCBN) inserts are used to turn the hard materials in CNC lathe and are widely accepted. Machining of hardened materials using CBN, PCBN, and ceramic tools are generally used and it is a good alternative to an expensive grinding operation. Hard turning has many advantages such as faster metal removal rate, reduced cycle time, good surface finish and environmental hazards free other than the cost advantage.

Austempered Ductile Iron (ADI) is a comparatively latest material than steel for industrial applications. ADI is a heat treated form of as cast ductile iron with a high strength-to-weight ratio. It is used in many engineering applications because of its high strength, high hardness, ductility, and toughness. The ADI 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 less cost compared to other materials.

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 ADI is subjected to strain hardened due to the presence of retained austenite. The strain hardening of retained austenite increases the mechanical loads and reduces the contact length on the cutting tool's edge. The higher cutting tool wear is observed in the 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 and adhesion resting on the cutting tool due to higher ductility of ADI while turning. In turning of ADI, the cutting tool's edges are

subjected to thermal softening due to higher cutting temperatures and low thermal diffusion of ADI.

The aim of the new machining industries is to produce components at low cost with good quality in minimum time. The surface finish is one of the qualities of the product. The good surfaces finish increases the fatigue strength, wear resistance, and minimizes the corrosion attack of the finished component. The surface finish depends on various parameters like material hardness, type of inserts, type of coating, heat transfer rate, and cutting parameters. The cost of the carbide tool is very low compared to Ceramic, CBN, and PCBN. Therefore, the optimization of cutting parameters is very important.

The decreased acceleration amplitude of tool vibration in machining process produces a good surface finish and reduced tool wear. Therefore, the prediction of acceleration amplitude of tool vibration is important to increase the quality of the machined part. Hence, study of the effect of cutting parameters on tool vibration is needed. Normally, the surface roughness of the finished parts is measured after machining. This method involves more cost in rework and production time. Hence, the in-process prediction of surface roughness and tool wear is the key research area.

Based on the literature survey, the prediction accuracy of the surface roughness and tool wear are increased after considering the tool vibration. Hence, modeling of surface roughness and tool wear prediction using tool vibration signals and cutting parameter are very important. The experiments are conducted in galaxy Midas 6 CNC lathe under dry cutting conditions. Machinability of ADI material is evaluated only by surface roughness and tool wear.

In phase one, the cutting parameters are optimized in hard turning of ADI using carbide inserts based on Taguchi Method. The cutting insert Chemical Vapor Deposition (CVD) coated with AL_2O_3/MT TICN is used. Experiments have been carried out in dry condition using the L_{18} orthogonal array. The cutting parameters selected for machining are cutting speed, feed, and depth of cut, each in three levels, nose radius in two levels while maintaining other cutting parameters constant. The ANOVA and signal to noise ratio are used to optimize the cutting parameters. It is observed that the cutting speed is the most dominant factor affecting the surface roughness and tool wear. The cutting parameters are optimized using Taguchi technique. In optimum cutting condition, the confirmation tests are carried out. The predicted and experimental values for surface roughness and tool wear adhere closer to 9.3% and 1.1% of deviations respectively.

In phase two, the prediction models have been developed to predict the acceleration amplitude of tool vibrations in hard turning. Online acceleration amplitude of tool vibrations in tangential and radial cutting force directions is measured. The material used for this experiment is ADI grade 3. The cutting parameters are cutting speed, feed, and depth of cut, all in three levels. The experiments are conducted as per Taguchi L_9 orthogonal array. ANOVA is used to calculate significant factors affecting the tool vibration amplitude. Linear square regression is used to estimate the acceleration amplitude of tool vibration in tangential and radial cutting force directions. Based on the ANOVA result, it is found that cutting speed and depth of cut affect the acceleration amplitude of tool vibration in tangential and radial cutting force directions respectively. The developed regression model is verified by the confirmation experiment. The estimated and experimental values for acceleration amplitude of tool vibration in tangential and radial cutting force directions adhere very much to 14.5% and 15% of maximum deviations respectively, which are acceptable levels of deviation.

In phase three, the in-process prediction model for surface roughness and tool wear is developed for the hard turning of ADI using cutting parameters and vibration signals. The material used for this experimental work is ADI grade 3 with hardness 45 HRC. The carbide cutting inserts CVD coated with AL_2O_3/MT TICN is used. The experiments are conducted based on the Box-Behnken Design of Response surface Methodology (RSM). The cutting parameters are cutting speed, feed, and depth of cut, all at three levels. The acceleration amplitude of tool vibrations in tangential and radial cutting force directions are measured online, surface roughness and tool wear are measured offline and other parameters are maintained constant. The regression analysis is made with and without considering tool vibrations for predicting the surface roughness and tool wear. Greater accuracy is achieved in the prediction of surface roughness and tool wear after considering the tool vibration signals. Pearson correlation coefficient is used to calculate the significant factors affecting tool wear and surface roughness. The developed model's reliability is validated by the confirmation experiment. The regression predicted values and confirmation experimental values are compared and it is found that there is a close adherence and a maximum of 7.5% deviation for surface roughness and 3.4% deviation for tool wear, which are permissible levels of deviation.

Based on the experimental work, it is concluded that the Taguchi method is successfully used in optimization of cutting parameters in turning of ADI using CVD coated carbide cutting tool. The effect of cutting parameters on tool vibrations in radial and tangential cutting force directions is successfully studied. The tool vibration prediction model is successfully developed using RSM. In-process prediction model is developed successfully for surface roughness and tool wear with greater accuracy using Box-Behnken Design of RSM. The accuracy of the prediction model is increased after considering the tool vibration signals. The results obtained in this research can be used as standards for both academic research and industrial applications. This experimental work helps to take effective steps to control the surface roughness and tool wear within this limit.