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The Experimental Investigations into Dry Turning of Austempered Ductile Iron

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Abstract

Austempered ductile iron (ADI) formed by austempering of nodular cast iron (NCI). ADI has good mechanical properties due to the matrix of ausferrite.Use of carbide forming elements such as molybdenum and manganese while alloying form carbide. This carbide segregates towards cell boundaries during casting and form carbide in metal matrix. When high normal force is applied to ADI while machining, austenite on surface undergoes strain induced transformation (SIT) and form martensite. This transformation right in front of tool face makes it more difficult to machine. These issue reducing tool life significantly and making hurdle for further applications of ADI.

In the present work, experimental investigations have been carried out into dry turning of ADI using response surface methodology(RSM) with central composite design(CCD). The performance of cemented carbide tool while machining ADI (austenitised at 850 °C for 2 hr, austempered at 350 °C for 1 hr) has been presented. The effects of speed, feed and depth of cut on cutting force, surface finish and microhardness have also been investigated with surface plots. The adequacy of these models has been checked by using analysis of variance. The predictability of main cutting force has been found to be greater than 95 %. The R- squared value for surface roughness model has found to be 0.9288. The main cutting force found to be influenced mainly by depth of cut while, the surface roughness by cutting speed.

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Keywords: ADI, austempering, graphite nodules, phase transformation, RSM

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1. Introduction

Now a day's many industries have interest to develop lightweight material to reduce weight of existing material without negotiating their mechanical properties. In the automotive industries, attempts have been made to replace cast iron, steel and aluminium components with austempered ductile iron. ADI is basically nodular or ductile cast iron which is subjected to heat treatments called austempering, as it has access to achieve desire mechanical properties by changing treatment parameters[1] [2][4].

Machining of ADI conducted prior to heat treatment, offers no significant difficulty. Machining post heat treatment is demanding due to maintaining tight tolerances and requirement of better surface finish [5]. This often avoided because of phase transformation (SIT) of retained austenite to martensite, this phenomenon making hurdle for the further applications of ADI [6][3].

It has been found that, mechanical and metallurgical properties of ADI component depends on initial microstructure of ductile iron, selected austempering parameters, media for quench, section size of component and addition of alloying elements. Austempering offer an access to achieve desired mechanical properties by selecting proper heat treatment cycle. Over the years, the temperature of 350 °C acting as a threshold for various mechanical properties of ADI. Selection of proper austempering parameters is the key part to achieve desire mechanical properties. Austenitizing temperature play vital role for the control of carbon content of austenite, this affects structure and properties of austempered casting. It has been found that, the austempering temperature range 350- 400 °C will give an ADI with lower strength and hardness but higher elongation and fracture toughness (coarse ausferrite matrix). While, below 350°C will produce an ADI with higher strength and greater wear resistance. To achieve the optimum mechanical properties, in present work ADI rods austenitised at 850 °C for 2 hr soaking period and austempered at 350°C for 1 hr soaking period [4][7][10].

According to Polishetty, high rate of plastic deformation and generation of high heat or combination of both are responsible for strain induced transformation while machining ADI. It is expected to machine ADI before the formation of martensite, by using ultra hard cutting tools at low cutting speed with high penetration (feed rates); or to use different machining approaches to minimize or completely eliminate the formation of martensite, by avoiding strain induced transformation [5] [6][13].

RSM is a collection of statistical and mathematical techniques useful for developing, improving and optimizing processes. Most real world application of RSM will involve more than one response.There are two methods widely used for fitting quadratic model, central composite design and box- behnken design. It is good to choose design that requires somewhat fewer runs than budget permit,so that canter point runs can be added to check for curvature in a 2-level screening design and backup resources are available to redo runs that have processing mishaps. Therefore in present work central composite design used for better accuracy and precisions than box-behnken method [14].

2. Experimental work

The workpiece material used in the present work is ductile iron grade (700/3). Austempered at parameters mentioned earlier. The chemical composition of the ductile iron is given in table 1.

Table 1Chemical composition of ductile iron

Elements	C	Si	Mn	P	S	Cr	Mo	Ni
Wt %	3.57	2.59	0.25	<0.010	0.019	<0.0300	<0.0500	0.2685

Al	Cu	Ti	V	Mg	B	Sn	Fe
0.0116	0.7229	0.0307	<0.0100	0.0463	<0.0100	<0.0100	93.22

Ductile iron has 76.44 % pearlite and 23.55 % ferrite structure. The workpiece material has 90 % nodularity and nodule count is about 200 nod/mm^2. It has hardness 200 BHN, tensile strength 700 N/mm^{2}and elongation is 3%. Figure 1 shows flakes and matrix microstructure of ductile iron.