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Effect of Machining Environment on Turning Performance of Austempered Ductile Iron

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ABSTRACT

The turning experimental work carried on 700/3 grade austempered ductile iron using coated tungsten carbide insert using cutting speed from 50 to 200 m/min, feed from 0.1 to 0.3 mm/rev and depth of cut from 0.1 to 1.0 mm. The microstructure, surface roughness, wear mechanism and chip characteristics examined using Leica Microscope, Nikon Measuroscope and Mitutoyo Surface Roughness Tester. The adhesion and abrasion wear observed on tool in different machining environment. Nose wear observed in flood environment at 200 m/min cutting speed while chipping observed in minimum quantity lubrication (MQL) and dry environment. The comparison of dry, MQL and flood coolant environment studied on basis of analysis of extreme level of cutting parameters. The comparative study revealed MQL environment has lower tool wear and surface roughness value, therefore percentage increase in surface roughness and tool wear of dry and flood environment over MQL examined. The sustainability assessment suggested MQL effective machining environment for moderate machining parameters.

Introduction

Coolants and lubricants are extensively used in machining application for improving tool life, reducing friction on tool face and to attain easy chip breaking phenomenon. Today, industrial sector is facing problems of waste disposal, human health hazard and environmental pollutions besides expenditure on cooling lubricants, their rectification and maintenance. Therefore, it is vital to minimise the consumption of coolants and lubricants. In recent years, the minimum quantity lubrication (MQL) emerges as eco-friendly approach stepping towards cleaner production and conservation of global environment with minimum cost. Minimum quantity lubrication is a fluid supply technique in which aerosols of fluid with compressed air is sprayed on required area of applications. The oil consumption rate in a typical industrial application for MQL ranges from 10 ml/hr to 300 ml/hr for machining operation.

Austempered Ductile Iron (ADI) is an austempering heat treated cast ductile iron. Austempered ductile iron has been replaced steels in many automotive and fabrication components which include connecting rod, crank shaft, camshaft, gears and rail road [1]. It has poor machinability but possess high strength to weight ratio, high stiffness, wear resistance, fatigue strength and flexibility in design characteristics. At present, dry and flood coolant is widely used in industries in machining steels, cast irons and nonferrous materials. In consideration to environmental approach, Minimum Quantity Lubrication (MQL) is emerging as a promising alternative for cooling and lubrication.

Over the years, the machinability of austempered ductile iron has been tested by researchers. Most of these studies involve use of different cooling media. Moreover none of literature has referred the use of minimum quantity lubrication technique as cooling and lubrication in turning machinability of austempered ductile iron. However, the investigations on MQL have been reported on few other materials. Li and Liang [2] conducted designed experiments to compare dry, flood and MQL cooling on high carbon steel. They observed 31.4% reduction in cutting temperature by using flood coolant whereas it is 22.1% under MQL environment. Low tool wear is found by MQL as compared to dry cutting. Machinability performance due to application of MQL is found better because of higher evaporative enthalpy which increase the stability of lubricant in cutting zone. Gaitonde et al. [3] investigated the machinability of brass and reported formation of thinner chips at lower cutting speed by MQL due to capillary effect which removes heat more significantly and

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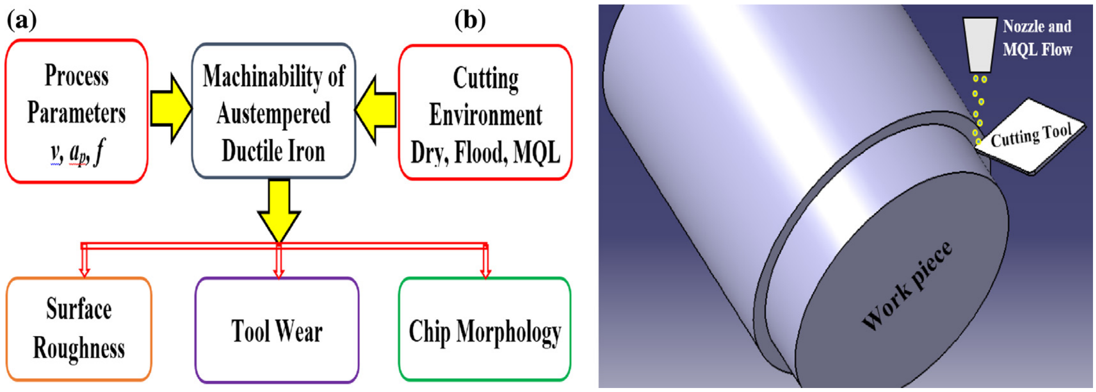

Fig. 1. (a) Theme of experimental work and (b) tool-workpiece geometry.

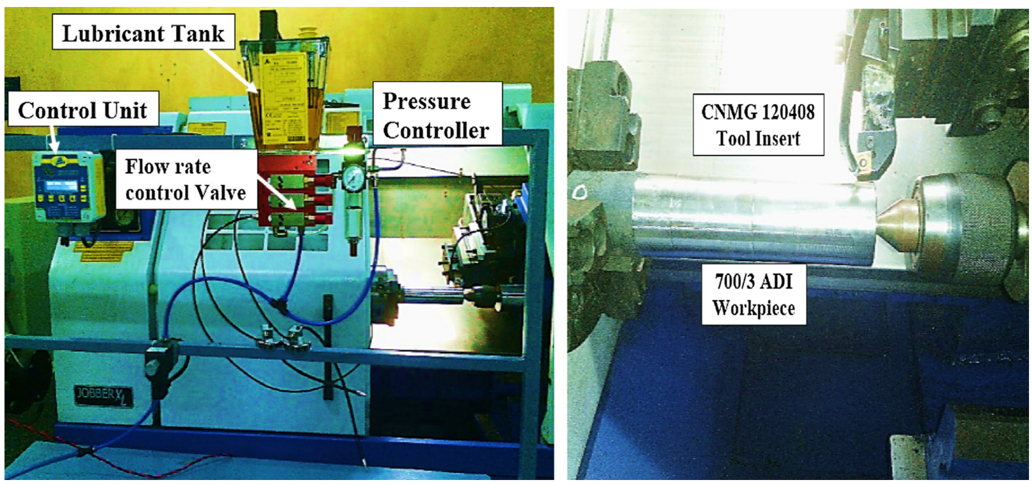

Fig. 2. (a) Experimental set up for MQL environment. (b) Position of nozzle for MQL supply.

decreased the surface roughness and tool wear. Nikhil et al. [4] observed better cutting performance in term of surface finish and tool life in MQL than dry and wet cutting because of reduction in cutting temperature which improved chip-tool interaction and help to maintain sharpness of cutting edge in turning of AISI 4340 steel. Navas et al. [5] demonstrated surface integrity of AISI 4150 steel using dry, MQL and liquid nitrogen (LN_2). Better surface integrity and improved tool life was achieved with MQL than dry and liquid nitrogen cooling. Excessive abrasive tool wear was observed in dry machining due to tool softening at high temperature. A white layer formation was noticed due to micro structural changes at 1–2 micron beneath the surface in dry turning whereas it is absent in the case of MQL and Liquid nitrogen. Kamata and Obikawa [6] observed the best performance in respect of tool life and surface finish using CVD triple coated ($TiCN/Al_2O_3/TiN$) tungsten carbide inserts than TiN/AlN and TiAlN coated inserts while turning of Inconel 718. Performance of different types of MQL mixture was measured to determine effective surface finish and tool wear in machining. A mixture of liquid lubricant and compressed air showed better performance

Table 1
Chemical composition of austempered ductile iron.

Fe	C	Si	Mn	P	S
93.2203	3.576	2.596	0.253	<0.010	0.0192
Ni	Cu	Ti	Mg	Cr	Mo
0.2685	0.7229	0.0307	0.0463	<0.03	<0.05

than that of carrier gasses and MQL vapour. Eric et al. [7] examined heat treatment of ductile iron and observed the effect of alloying element on microstructure and mechanical properties of austempered ductile iron. The strength of ADI is increased by adding Cu, Ni, and Mo elements which promoted the formation of spheroidal graphite. Distribution of alloying element and spheroidal graphite is the primary criteria in maintaining toughness and strength during austempering operation. Klocke et al. [8] concluded that higher thermal load on cutting tool with flood coolant suppressed the crater wear on the rake face. But the flank wear increased due to plastic deformation on cutting edge. Chips observed in machining of ADI were smaller with segregated in nature and harder. Saini et al. [9] applied the conventional flood coolant and found that the cooling and lubrication is not effective at the chip-tool interface at higher temperature. The bulk contact of flowing chip with tool rake surface does not allow cutting fluid to penetrate into the tool-work interface, therefore increase in surface roughness and tool wear was noted. Further reduced fume generation was observed when MQL is applied in the tool-work interface. Ali et al. [10] presented experimental study to analyse the effect of cutting environment on medium carbon steel in turning. They concluded that conventional method of cutting fluid is less effective at higher cutting speed and feed rate. Cutting fluid cannot properly enter into chip-tool interface that cool and lubricate interface owing to bulk plastic contact of chip with the cutting tool. It was found that the built up edge formation prevailed at lower cutting speed which degraded surface finish, however on other hand, feed marks and flattening of tool tip was

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