Investigation on Influence of Cutting Forces In Performance Evaluation of Machining Of Al/Sic Composite (LM-13) Using Cryogenic Liquid Nitrogen as A Coolant

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Abstract

Abstract—This paper reports influence of cutting forces using cryogenic Liquefied Nitrogen (LN2) lubricant in machining of (LM-13)Aluminum metal matrix composite compare to conventional coolant. The Silicon Carbide is used as reinforcement material in Aluminum Silicon alloy (LM-13). The various machining parameters such as machining force, radial force,feed force, and surface roughness were analysed under conventional and cryogenic nitrogen cooling environments. The experimental results under liquid nitrogen coolant and conventional coolant conditions were taken for evaluation. The results showed that cutting forces and surface roughness values of machined workpiece reduced considerably on applying of cryogenic LN2 coolant compared to conventional machined environments.

I. INTRODUCTION

The aluminium alloy composite is used in various industries and replacing existing materials in aerospace and automotive industries [1]. But its application in industries is restricted due to poor machinability in machining aluminium alloy composites [2]. The poor tooling and surface finish values are the main problem in machining of Al/Si alloy composites when we use carbide tools [3,4]. While turning Al/SiC-MMC, the particles of the aluminium alloy composite adhere with the edge of cutting tool because of highpressure and temperature developed by contact of work piece with a cutting tool edge. This is termed as Built up Edge (BUE) which leads to poor cutting tool nomenclature resulting inferior surface finish.

When turning AMMC at low cutting velocity, BUE is formed and chip fracture also causing the rough Surface finish [5]. When turning Al/SiC composites, the surface is deteriorated slightly due to removal of composite particles from the workpiece while we use conventional cutting fluid [6].

While turning AMMC, the usage of conventional coolants produce techno-environmental problems despite these coolants is efficient to little extent. So alternatively, environment friendly cryogenic coolant machining is developed to restrict above problems. When machining other materials using cryogenic

LN2 as a coolant, machining temperature, machining force, surface roughness and tool wear were reduced compare to conventional coolants [7,8,9]. When turning AISI 4045 Steel and Ti-6Al-4V alloy using cryogenic LN2,machining forces ,machining temperature , tool wear and surface roughness get reduced [10,11]. The gases also used as coolant and comparison work carried out with conventional and dry machining conditions [12].

This paper aims on studying and comparing the causes of cutting forces in experimental results in machining of workpiece.The reduction of surface finish values can be obtained when liquid nitrogen and conventional coolant are used in turning Aluminium Metal Matrix composite (LM 13)

II. EXPERIMENTAL PROCEDURE

The Aluminium silicon alloy (LM13) reinforced with SiC is considered for experimental work. The work piece dimension of 300 mm length and60mm dia was used for investigation work. TheAluminium silicon alloy is reinforced with SiC particles of volume fraction 20% and size 15 microns during casting process. The Table 1 showing machining parameters considered for the experimental work

Table : Machining conditions

Work piece	LM13 composite bar
Cutting velocity	61,145,226 [m/min]
Feed rate	0.159,0.205,0.24 [mm/rev]
Depth of cut	1 [mm]
Cutting tool	Un coated tungsten carbide
Tool rake angle	0º

Fig.1 shows Cryogenic machining set up utilized for machining Al/SiC composite bar. The high speed automatic lathes (NAGMATI175) were utilized for carrying various sets of experiments by utilizing liquid nitrogen and conventional coolant. The Piezoelectric Dynamometer of Kistler make was used for measuring machining forces
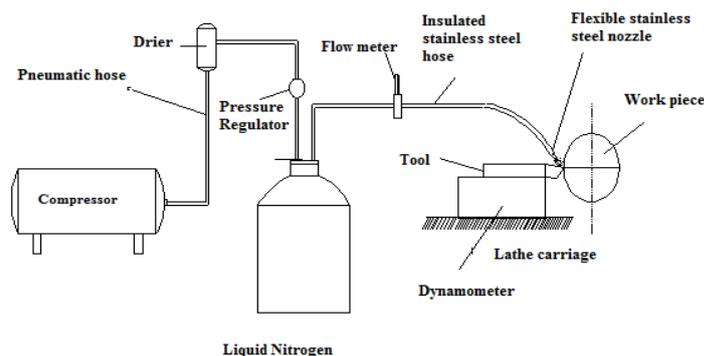

Fig.1 diagram of Experimental set up for cryogenic LN2 machining

The surface roughness measurement were carried outafter completingmachining work using conventional and liquid nitrogen coolant.The measurement carried out for specified machining conditions using a Talysurf surface roughness tester.

III. RESULTS AND DISCUSSIONS

3.1. Cutting force

Thecutting force was measured using lathe tool dynamometer .The machining force variation at constant at feedrate of 0.205 mm/rev with various cutting force is shown Fig 2.a.The fig 2.b shows machining force at constant cutting velocity and with different feed rates. It can be noted that at constant feed rate with increasing of cutting speed machining force was get reduced. This is because of reduced time of contact between tool and workpiece at higher cutting speed. It was also noted that due to applying of liquid nitrogen cutting force was decreasing.This is because of reduced tool wear due to effective heat reduction [8].It is also to be noted that when feed rate is increasing, machining force also increasing because of increase in work done. The experimental results showed 27–35% reduction of cutting force with usage of LN_2 compare to conventional machining condition
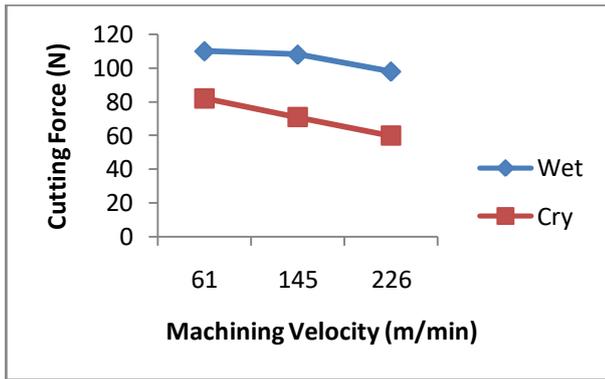
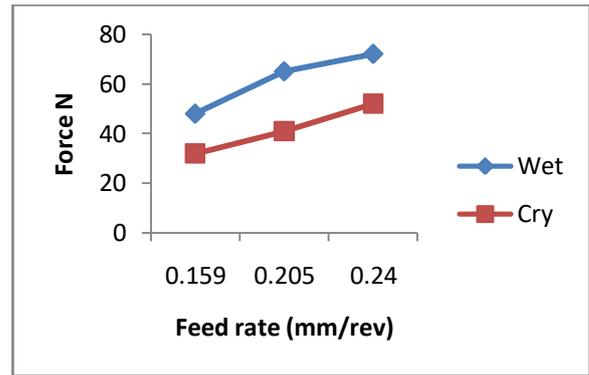Fig.2.a) Machining force at feed rate of 0.205mm/rev
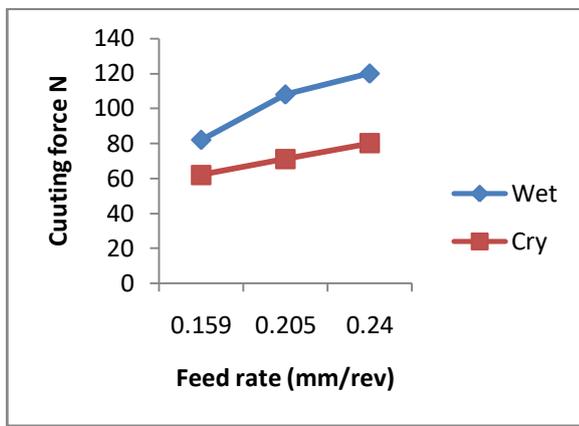

Fig.2.b) Machining force at machining velocity of 145

Mm/min

3.2. Feed force:

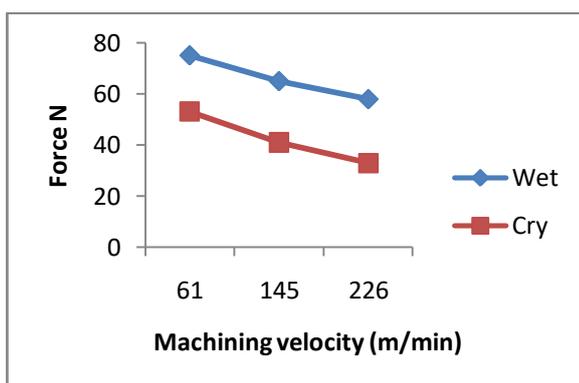Fig.3.a) Feed force at constant feed rate of 0.205mm/rev

Fig.3.b) Feed force at constant machining velocity

of 145 m/min

It can be noted that at constant feed rate with increasing of cutting speed feed force was also get reduced. This is because of decrease in amount of materialremoved. However by increasing feed rate with constant cutting speed, feed force was increased which is shown in Figure 3.b). The measured data showed at feed rate of 0.205 mm/rev and cutting speed of 145 m/min, feed force of 65Ncalibrated in conventional machining environments. In cryogenic LN2 machining conditions, for the same machineparametersthe feed force measured was 41 N . It is observed that36.9% of feed force in cryogenic LN2 cooling conditions wasgetreduced compared to conventional machining environments. This reduction is inbetween 22-43% in LN2 machining environments when conventional machining environments are compared
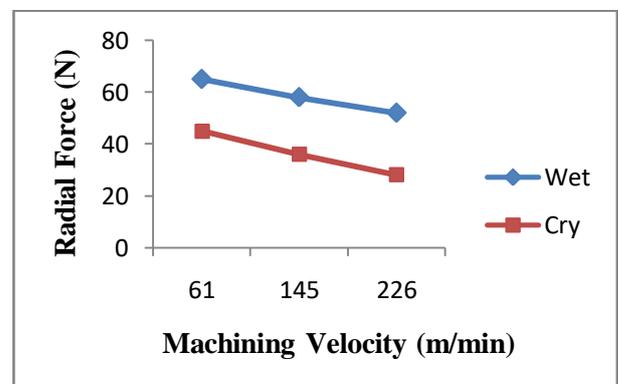
3.3. Radial force:

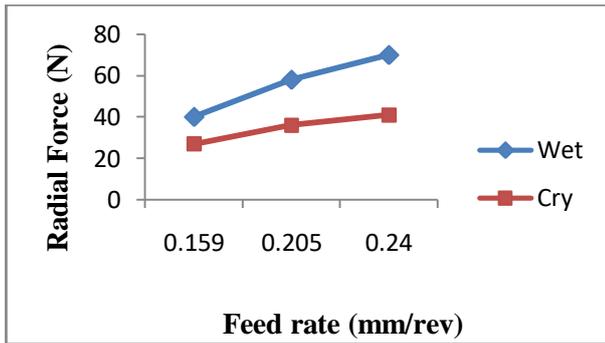Fig.4.a) Radial force at feed rate of 0.205mm/rev

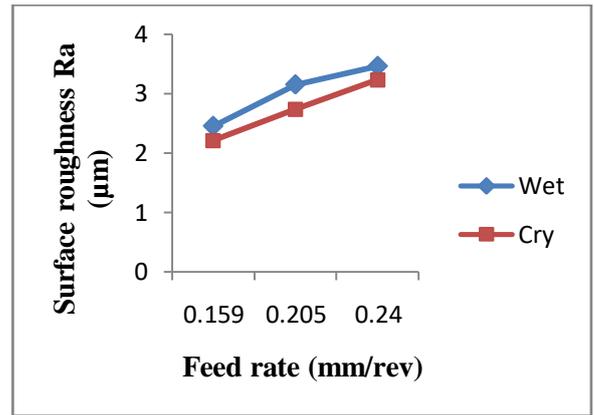Fig.4.b) Radial force at machining velocity of 145 m/min

3.4. Surface roughness

The surface roughness value is measured at two different machining parameters of constant feedrate of 0.205mm/rev and constant cutting velocity of 145m/min by varying other parameters cutting velocity and feed rate respectively. The mean values of surface roughness value (Ra) were taken for evaluation. The calibrated values plotted in Fig.5.a and Fig 5.b it is clear that when cutting velocity get increased surface roughness value is decreased. This is because of less contact time and area between work piece and cutting tool and subsequent reduction inremoval of metal andmachine forces. It was also noted that removal of SiC and Si particles from thecomposite workpiece also decreasing with increasing of cutting velocity.
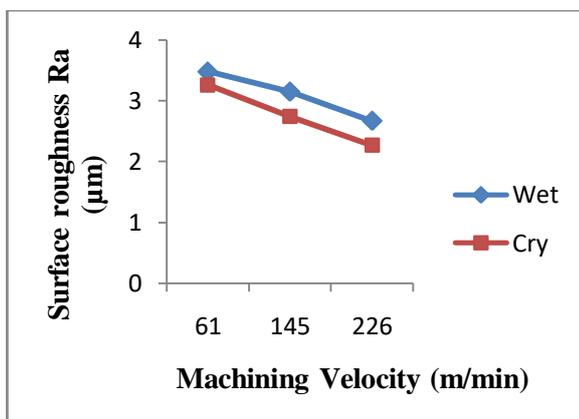

Fig.5.a)Surface roughness at constant feed rate of 0.205mm/rev

Fig.5.b) Surface roughness at machiningMachining Velocity of 145 m/min

It was noted that surface roughness value was decreasing when LN2 applied. This is because of reduction inmachining forces compare to conventional machining conditions. It is also observed that less quantity of SiC and Si particles were separated from the work piece because of reduced cutting forces. The surface finish values also improved due to low BUE formation and cushioning effect between work piece material and tool. The experimental result showed that application of cryogenic LN2 improved surface finish values about 10– 15% comparing to wet machining environments.

III. CONCLUSION

The machining of AMMC (LM-13) using cryogenic LN2 and conventional coolant was completed successfully. The experimental results indicated that machining forces and surface finish values improved significantly when cryogenic LN2 was used as coolant for turning AMMC (LM-13) composite material. The following experimental results can be summarized:

1. The application cryogenic liquid nitrogen reducedcutting force about 27-35% compared to conventional machining environments.

2. The reduction of radial force is about 26-46% when cryogenic liquid nitrogen lubricantis used in contrast withconventional machining environments.

3. The reduction of feed force is about 22-43% when cryogenic liquid nitrogen coolant is used comparing to wet machining environments.

4. The surface finish value improved when cryogenic LN_2 is used as lubricant. It was identified that   surface roughness value get reduced in the range of 10-15 % comparing to conventional machining environments

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