Effect of Deep Cryogenic Treatment on Machinability of Al6061-SiC-B_4C Composites

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Abstract

Composite material is one where the combination of the two materials having different physical and chemical properties combined to produce a job which suits the customer requirements. Composite materials have high aspect ratio, durability and high impact strength. Through literature survey it was found that very few research scholars have made an attempt to subject hybrid metal matrix composites for deep cryogenic treatment. In this study an attempt has been made to add SiC and B_4C to Al6061 alloy by using Taguchi sampling techniques. The mechanical features of above-mentioned combination are used to inspect their deep cryogenic treatment response and selected the best one out of (1,2,3,4 wt.%) for the machinability process. 4% (2% SiC + 2% B_4C) combination has shown better mechanical properties, the optimized machining parameters are set to reduce the cutting forces and power required for the above said composites.

***KEY WORDS*: Composites, Deep Cryo-Treatment, Machinability, Cutting Forces, Power**

I INTRODUCTION

The Cryo Processor is a liquid nitrogen or helium medium that is used in the process of cryo treatment. The therapy for deep cryo is one in which material is treated at the -196^{0}C temperature. The material is cooled to 2^{0}C per minute at room temperature and maintained for 24 hours at that temperature, and it is again heated to 2^{0}C per minute until it reaches room temperature. Quenching and heating help to improve the desired strength of the structure. Researchers have observed that the B_4C particles alloy poses a high level of hardness because of B_4C ceramic particles that act as an obstacle to dislocation. Cryo therapy is a means to improve the wearing and durability of the al-SiC composites, as a metallurgical structure that has been born cold. In case of cryo therapy, the material is cooled down to the desired cryo temperature by adding SiC and B_4C, which improves composite hardness and wear strength.

The hybrid metal composites Al-SiC-B_4C for DCT have been tested in the course of this research. The work is submitted by means of Taguchi technique for workmanship in different parameters like speed and feed and the depth of the cuts, the parameters are defined and workmanship is carried out to know the temperature released during workmanship. Cryogenic treatments are applied i.e., below –190°C (−310°F) in order to remove residual stress and restore wear strength for composites in order to process the workpieces at cryogenic temperatures. In addition, cryogenic therapy improves stress relief and stability or wear resistance., while also accelerating microfine eta carbides to enhance corrosion resistance.

Machinability is an important factor to consider when choosing a material for commercial use.

Machinability refers to the affluence with which a given material can be machined under a given set of circumstances. Machinability is not the standalone property of the work piece material. It is the overall behavior of the work piece material when it is machined under certain condition. Used for highly precise shapes, excellent surface and complex geometry Typically.

Machining is a subordinate processing operation because it usually takes place on a piece produced by key processes like casting, forging, rolling etc.

For this study machinability study is being administered by subjecting the cast material to turning operation with on a coated Carbide tool insert, change the speed, the feed, and depth of cuts. The job's impact on various machining parameters is being assessed. The cutting speed and feed rate were of the greatest effect on tool wear under dry turning conditions. As cutting speed and feed rate increase, the rate of wear increases. When a carbide cutting tool was used, tool wear was decreased. Surface irregularity is influenced by cutting speed and feed rate, and improved surface quality results in greater cutting rates and lower feed.

Main parameters that depend on machinability are Speed feed and depth of cut analyzed in the current work using Taguchi technique with the help of experimental design. Since the variable parameters were three the suitable design was L9 Orthogonal Array so that was chosen and the experiment was carried. The X-ray diffraction method used to analyze the crystalline material structure is a non-destructive test method. XRD is used to identify and expose information on the chemistry of the crystalline phases in a material.

II EXPERIMENTAL DETAILS

2.1 Material Selection

Aluminium (Al6061) based metal matrix composite with 4% volume fraction of particulate silicon carbide and boron Carbide in equal weight percentage (2%+2%) has been selected for the present investigation processed by stir casting process.

2.2 Tooling Details

For the machinability study of the composites of the metal matrix Al-Sic-B_4C Coated Carbide tool has been selected for carrying out the machinability of Al-SiC-B_4C metal matrix composites. The insert used in this experiment has a rake angle of 7^0 and corner radius of 0.8 mm.

Fig. 2.1 Carbide Tool Insert and Tool Holder

2.3 Lathe Tool Dynamometer

A lathe-tool dynamometer is a cast-off dynamometer used to calculate forces when the machine tool is being used. This apparatus, known as lathe tool dynamometers, can be used to cross-check and verify practical measurements of these forces.

2.4 Cryogenic Treatment

The word 'cryogenic' is the Greek word 'krys' that means cold. Cryogenics treatment is used in the treatment of workpiece material under cryogenic temperatures i.e., below –190°C (−310°F) for avoiding residual stresses and restoring wear resistance of composites. Furthermore, the cryogenic treatment aims at improving stress relief and stability or at improving wear resistance, while also enhancing the corrosion resistance of nano -refrigerant eta carbides.

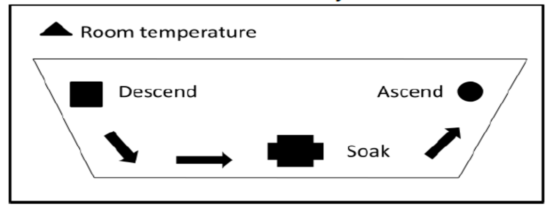

Fig. 2.2 Cryogenic Treatment Process

III EXPERIMENTAL PROCEDURE

Fabrication of Aluminium6061 combined with Silicon Carbide and Boron Carbide composites with varying percentage are produced using stir casting technique. A job of 1000mm length and 25mm diameter is casted in the furnace of stir casting.

The zirconium is placed in order to tolerate maximum temperature, a known quantity of Al6061 material block is placed in the furnace for melting. Al6061 melts at 660^0C, before that the crucible should be pre heated to a temperature range of 580^0C.Now according to the required amount of wt.% of silicon carbide and boron carbide are added in the furnace. Degassing element is used to degas the gas formed in the molten metal. Molten metal is stirred using a stirrer at a speed of 100-200 rpm, any slag formation should be removed using spoon. Add Silicon Carbide and Boron Carbide and mix it for 5 more minutes. Pour the molten metal into the mould box, cast specimen are removed from the mould box after solidification. Two sets of composites were produced of different weight percentage of 1%, 2%, 3%, and 4% respectively.

Fig. 3.1 Stir Casting Equipment

2

3.1 Turning

Turning is a process of machining the components round by a tool on a single point. The instrument is fed either linearly in a direction similar to the work-piece's spin axis, or on a certain path to create complex rotational forms.

3.2 Chip Formation

The creation of chips is part of each convectional machining method. Chip formation is a complicated phenomenon in which the workpiece is forced to remove the material. The metal is cut through the shear plane, which makes an angle Ø with the way to the instrument due to the shaving action.

3.3 XRD Analysis (X-Ray Diffraction)

The non-destructive method of testing is the X-ray diffraction method used to analyse crystalline material structures. XRD is used to identify and disclose information on the chemical composition of the crystalline phases in a material.

Due to more periodicity than other directions there is more diffraction here at 4% composite has more intensity. However, if the crystals are arranged in a chaotic arrangement, the height of the summit is low if the perfect crystal orientation is present. Increased variation of electron density is higher. The peak intensity is the crystal structure's atomic position. If the tests are conducted repeatedly with powder samples or defected solid samples there will decrease in peak intensity. Intensity means energy per unit time, more the intensity better will be the light absorption by the sample anyway that depends on the microstructure of the sample used. Fig. 3.2 and Fig. 3.3 shows the intensities for non-cryo and cryogenic sample respectively. 21100 arbitrary units for non-cryo and 25000 arbitrary units for cryogenic sample.

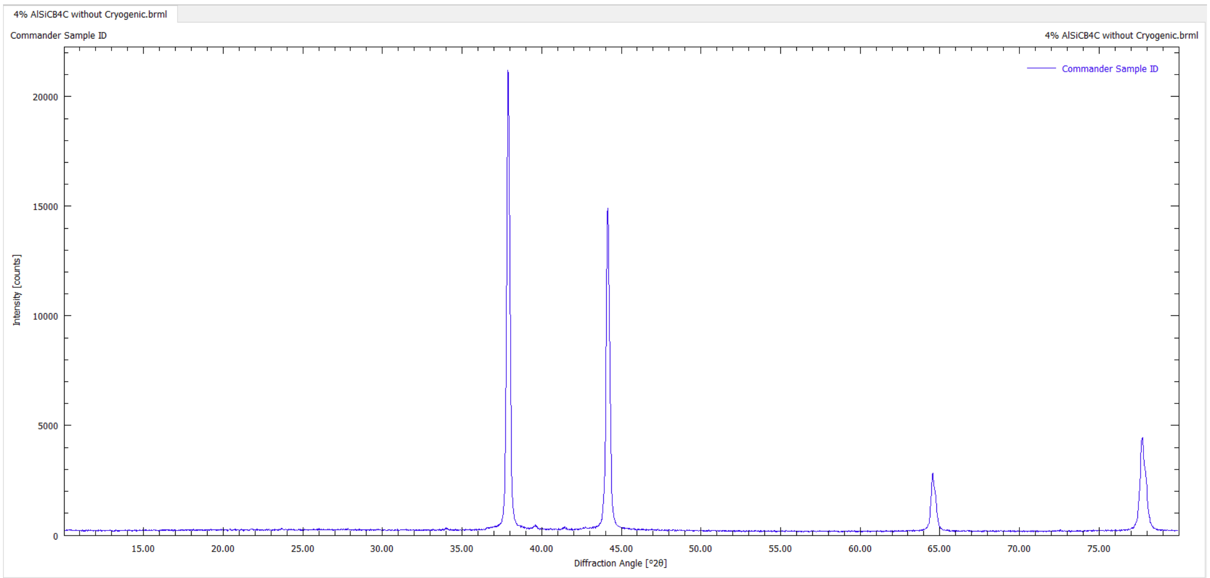

Fig. 3.2 XRD of 4% Non-Cryogenic Treated Composite

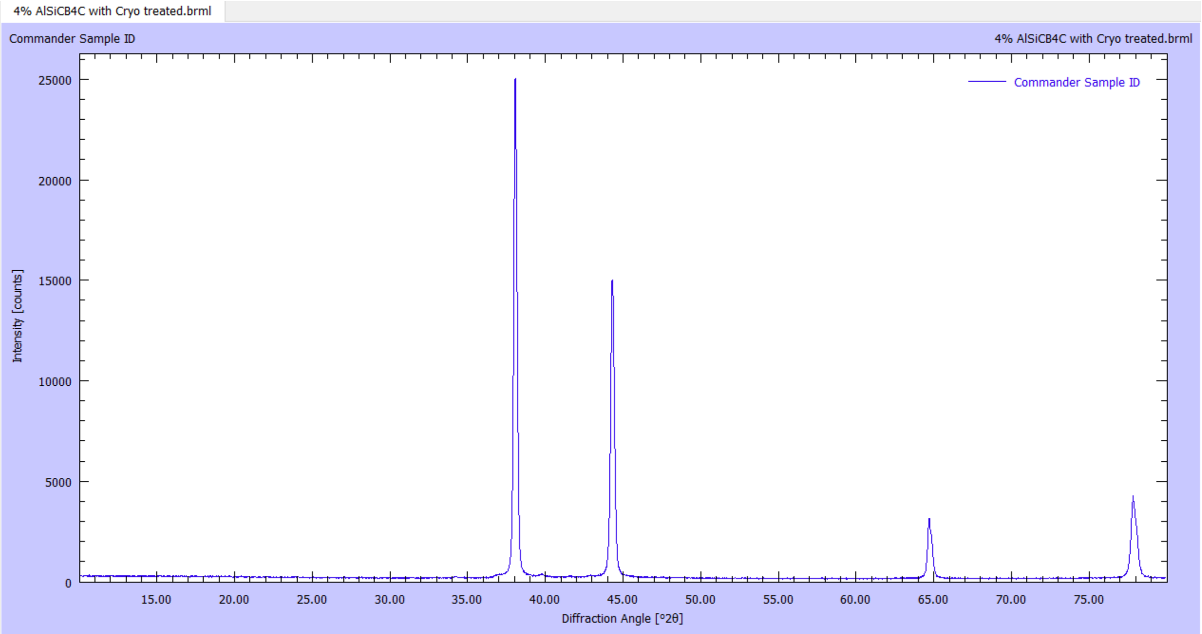

Fig. 3.3 XRD of 4% Cryogenic Treated Composite

4

3.4 Machinability Test

Table 3.1: Machinability Reading of 4% Non-Cryogenic Sample

SPEED	FEED	DOC	Fx	Fy	Fz	T ºC	t_2	r	r_c	Ø	R	POWER
230	0.5	0.25	6	22	4	27.5	0.15	0.6	1.66	32.72	19.23	0.0177
500	1	0.25	6	24	2	29.4	0.2	0.8	1.25	41.34	20.02	0.0384
775	0.75	0.25	6	23	4	30.1	0.16	0.6	1.56	32.72	19.23	0.0596
230	0.75	0.5	10	28	5	29	0.25	0.5	2	27.85	24.18	0.0295
500	0.5	0.5	6	23	3	29.4	0.26	0.52	1.92	28.88	19.10	0.0384
775	1	0.5	11	30	12	31	0.25	0.5	2	27.85	24.69	0.0109
230	1	0.75	17	41	14	29.8	0.32	0.42	2.3	23.71	38.32	0.0529
500	0.75	0.75	9	31	17	31	0.36	0.48	2.08	26.84	26.83	0.0769
775	0.5	0.75	9	25	18	30.8	0.24	0.32	3.12	18.28	26.07	0.0795

Table 3.2: Machinability Reading of 4% Cryogenic Sample

SPEED	FEED	DOC	Fx	Fy	Fz	T ºC	t_2	r	r_c	Ø	R	POWER
230	0.5	0.25	4	19	3	26.9	0.11	0.4	2.27	22.65	22.36	0.0118
500	1	0.25	3	20	1	28.7	0.15	0.6	1.66	32.72	24.08	0.0192
775	0.75	0.25	4	19	3	27.7	0.12	0.48	2.08	26.84	23.34	0.0397
230	0.75	0.5	6	24	3	27.4	0.2	0.4	2.5	22.65	28.44	0.0177
500	0.5	0.5	4	19	2	29	0.23	0.46	2.17	25.81	23.19	0.0256
775	1	0.5	7	23	9	29.7	0.21	0.42	2.38	23.71	32.31	0.0696
230	1	0.75	12	37	10	28.3	0.31	0.41	2.41	23.18	43.32	0.0373
500	0.75	0.75	6	24	12	29.6	0.23	0.30	3.26	17.17	35.35	0.0577
775	0.5	0.75	6	22	14	30.4	0.2	0.26	3.75	14.92	30.80	0.0596

Speed (rpm), Feed (mm/min), DOC: depth of cut (mm), Fx: Axial or feed Force (Newton), Fy: Tangential force (Newton), Fz: Radial or Thrust Force (Newton), r: chip thickness ratio, r_c: chip thickness coefficient, Ø: Shear Plane Angle (degree), R: Resultant Force (Newton), P: Power (kW)

Comparing both it was found that there was significant decrease in power consumption and tool temperature and there was improvement when it comes to chip thickness, shear plane angle and resultant force with 4% Cryo treated composite

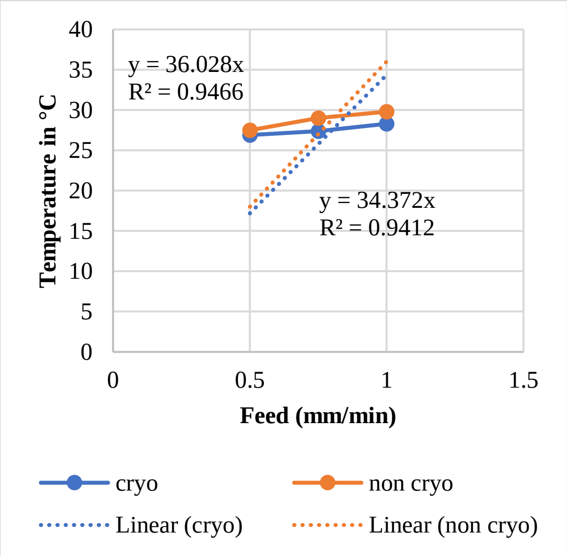

Fig. 3.4 (a) Temperature vs Feed at 230 rpm

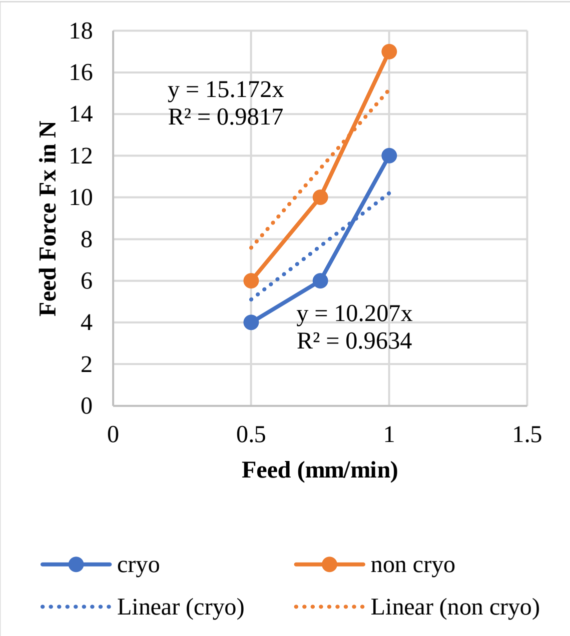

Fig. 3.4 (b) Fx vs Feed at 230 rpm

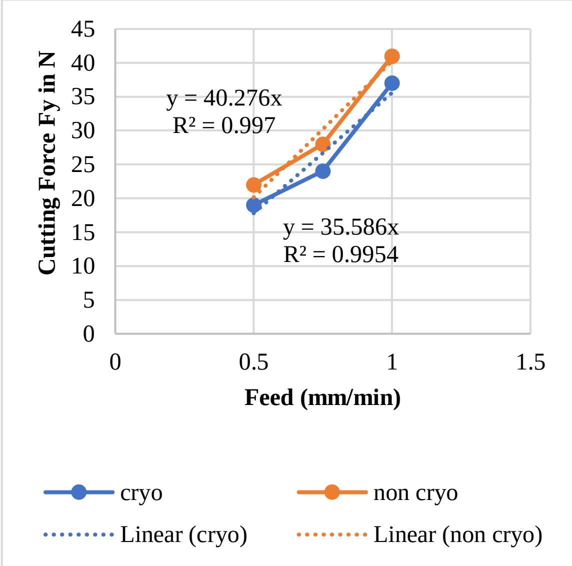

Fig. 3.4 (c) Fy vs Feed at 230 rpm

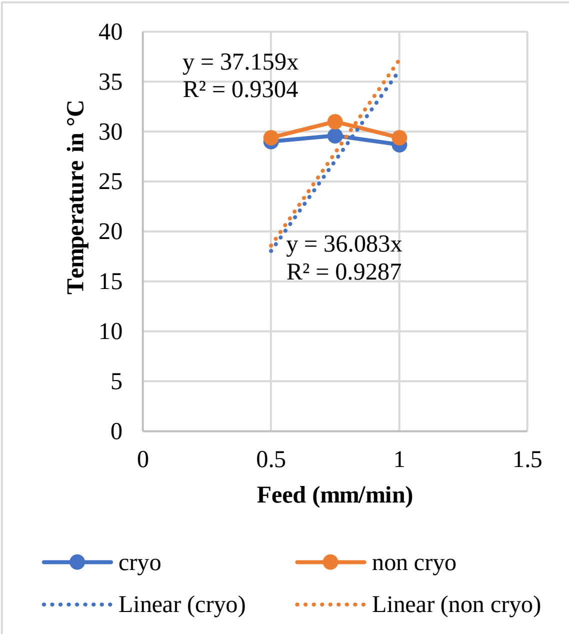

Fig. 3.4 (d) Temperature vs Feed at 500 rpm

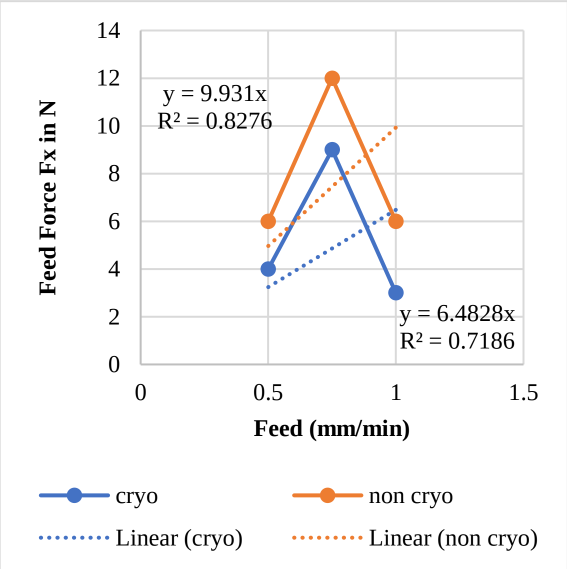

Fig. 3.4(e) Fx vs Feed at 500 rpm

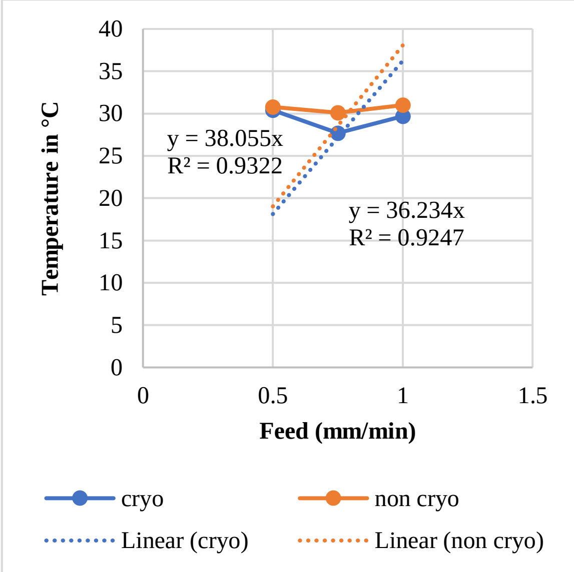

Fig. 3.4 (g) Temperature vs Feed at 775 rpm

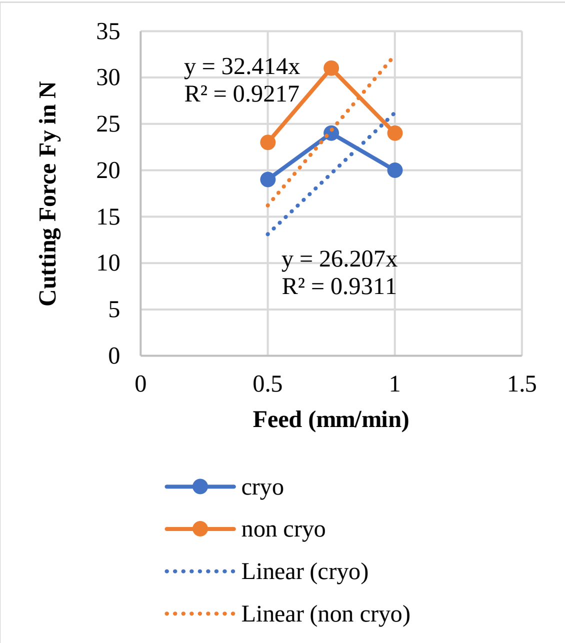

Fig. 3.4 (f) Fy vs Feed at 500 rpm

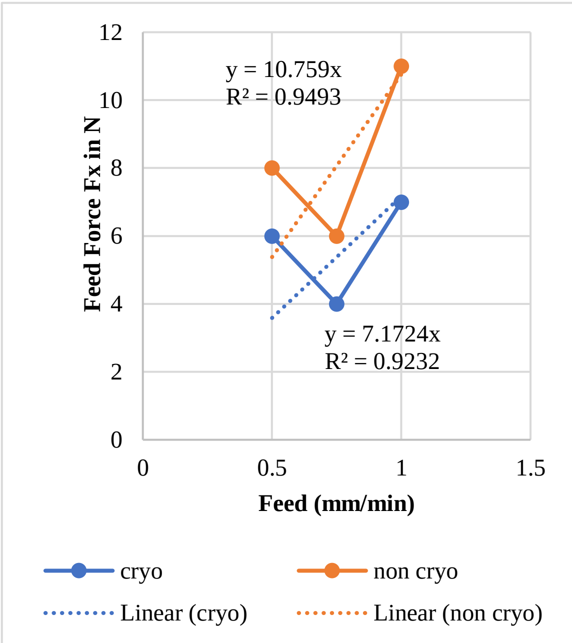

Fig. 3.4 (h) Fx vs Feed at 775 rpm

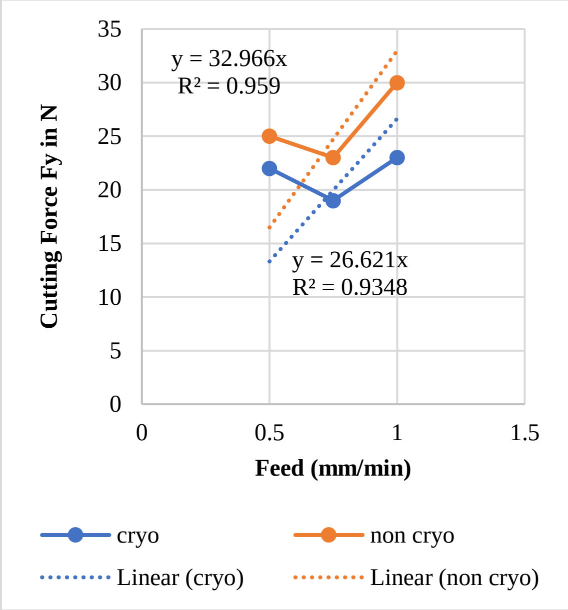

Fig. 3.4 (i) Fy vs Feed at 775 rpm

Figures 3.4 (a) to 3.4 (i) Shows the variation of Temperature, Cutting Forces and Feed Forces at various Speeds and Feeds for a 4wt.% of Al6061-SiC-B_4C Deep Cryo-Treated Sample and a Normal Sample.

IV RESULTS AND DISCUSSION

4.1 Effect of Speed on Deep Cryogenic Treated Al6061-SiC-B_4C

As the speed increases the amount of force required to machine the job increases but in case of deep cryogenic treated composite material the amount of force is less in contrast with untreated ones.
In order to surge the production rate, the speed has to be increased but the job wears out Because of high work-to-cutting friction.
Through deep cryogenic treatment the amount of force has been reduced in compared with normal ones hence less amount of power is required to machine the job.
It is in the consensus with the investigations covered out by the earlier research scholars.

4.2 Effect of Feed on Deep Cryogenic Treated Al6061-SiC-B_4C

As the speed increases the amount of force increases through the deep cryogenic treatment the amount of force has been reduced.
The tensile strength has been increased in case of deep cryogenic treatment of 4% (2%SiC+2%B4C) with Al 6061 alloy.
Due to increase in tensile strength the amount of chip formation has been increased.

4.3 Effect of Temperature on Deep Cryogenic Treated Al6061-SiC-B_4C

As the feed rate and the cutting depth increase over the temperature increases, through deep cryogenic treatment the temperature has been reduced at low-speed feeding and cutting depth at greater speed feeding and cutting depth respectively.
Deep cryogenic treatment on the above material has improved the material thermal conductivity thereby raises the heat deception rate and reducing the friction and force thus cultivating the surface finish and amount of power required for machining operation.

4.4 Effect of Deep Cryogenic Treatment on XRD analysis

As the fraction of SiC and B_4C increases the hardness increases the amount of grain thickness decreases and breakup into minute particles.
Through the XRD investigation it has been found that deep cryogenic treatment of 4% (2%SiC+2%B_4C) with Al 6061 alloy has helped in scattering the particles at wider rate in comparison with untreated ones.
The tensile test and hardness test have justified the existence of 4% (2%SiC+2%B_4C) with Al 6061 alloy.
Amount of increase in dispersion rate helped in improving the homogeneity which in turn helps in improving the structural properties.
To sum up this investigation, it is found that 4% (2%SiC+2%B_4C) with Al6061 alloy has amended the mechanical properties and machinability properties and XRD analysis of above Al6061 composite.

Fig. from 3.4 (a) to 3.4 (i) indicate 4% Cryo treated composite is better than all other variations that were carried out in the study.

8

V CONCLUSION

- Trough the investigation the wear rate hardness and tensile strength has been improved for deep cryogenic treatment compared to untreated ones.
- The presence of 4% (2%SiC+2%B_4C) with Al6061 alloy has improved the mechanical properties of deep cryogenic treatment compared to untreated ones.
- The tensile strength has been improved for 4% (2%SiC+2%B_4C) with Al6061 alloy
- The tensile strength has been increased by an amount of 30% without effecting the hardness.
- Hence it can be concluded that 4% helped in improving the mechanical properties and machinability.
- Through the structural and mechanical properties and other aspects, it can be concluded that addition of 4% (2%SiC+2%B_4C) with Al6061 alloy has helped in improving the machinability which in turn has helped in increasing the productivity corresponding to require applications.

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