Influence of Single and Double Stage Forging on Cutting Forces of Al 7075/BSF Metal Matrix Composites

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***Abstract*— In the present study, an attempt has been made to investigate the influence of the forging parameters on cutting forces for different cutting speed, depth of cut, and feed rate during machining of Al 7075 alloy and Al 7075 alloy with short basalt fiber reinforced metal matrix composites. The experiments were conducted by using a lathe machine with tool dynamometer setup.**

Keyword- Forging effect, Metal Matrix Composites, stir casting, tangential force, SEM

I. INTRODUCTION

Metal matrix composites are produced by combination of metal matrix and stiff and hard reinforcing phase. Incorporation of reinforcements enhances the properties like adhesive, abrasive, diffusion wear resistance, thermal properties, hardness, and stiffness. The mechanical properties can be fine tuned to the requirement by choosing the size, shape, and distribution of reinforcement. In the last decades, Al metal matrix composites have been increasingly used in the aerospace industry and advanced arm systems such as satellite bearing, inertia navigation system, and laser reflector. Al metal matrix composites (AMMCs) are most commonly manufactured by a stir-casting technique or powder metallurgy technique [1]. Stir casting is the simplest and the most commercial technique. The development of MMCs by stir casting technology has been one of the unique and feasible processes because of producing better matrix particle bonding, easier control of matrix structure, simplicity, higher production rate, and low cost [2]. It involves stirring the melt along with reinforcement's s and then allowing the mixture to solidify. Due to the addition of reinforcing materials, which are normally harder and stiffer than matrix, machining becomes significantly more difficult than those of conventional materials [3].

The study the influence of cutting parameters on machinability of Al 7075 alloy and Al 7075 alloy/basalt short fiber in turning operation using coated cemented carbide tools for all three conditions like as cast, single forged and double forged has been carried out. Cutting parameters are important both from a design and process planning perspective. Concerning the cutting parameters, cutting speed, depth of cut and feed are the three most relevant factors to be consider, since they directly affect the machining forces, and also because they can be relatively changed. Cutting width is more related to the component configuration and the selected tool geometry.

II. COMPOSITES PREPARATION

The furnace and crucible were cleaned properly. After ensuring the proper electric connections, the furnace was switched on. The temperature of the furnace was set to 120°C and maintained at the same temperature for 15 minutes time duration. This helps in drying the moisture content of the furnace. About 10 kgs of Al 7075 ingots were pickled in 10 percentage sodium hydroxide solution at 25 °C for 10 minutes. Pickling was done to remove surface impurities. The smut formed was removed by immersing the ingots for one minute in a mixture of one part nitric acid and one part water followed by washing in methanol. These cleaned ingots after drying in air were immediately charged into crucible for melting. The furnace lid was sealed to make it airtight. Out of the two tubes on the lid, one of the tubes is used to pass nitrogen gas from cylinder to maintain inert atmosphere during the preparation of the composite. The other tube is used for adding the reinforcement. Later the furnace was switched ON and temperature was set to 750°C. Temperature was recorded from time to time using a calibrated chromel - alumel thermocouple with the help of partially integrated differential digital electronic temperature controller. The temperature was raised to 750°C and retained at that temperature for 15 minutes. This helps in complete melting of the alloy. The degassing tablets were added into molten metal and stirred for 3 minutes to remove dissolved gases, oxides and other impurities in the melt and to enable the slag formation. Degassing of the melt reduces blowholes and porosity in the casting. The stirrer was rotated at a speed of ≈ 550 rpm and a vortex was created in the melt. The depth to which the impeller was immersed was approximately one third the height of the molten metal from the bottom of the crucible. Vortex on the surface of the melt was necessary to disperse basalt fibers in molten Al 7075 alloy. Stirring the molten metal at the higher speeds would have created more intense vortex, but at very high speeds there is a danger of air entrapment. Hence an optimum speed of 550 rpm was used. The slag was prevented from entering the moulds while pouring through the spout. An inert atmosphere was maintained by nitrogen gas sending inside to prevent further oxidation of Al 7075.

The preheating of the reinforcement is necessary in order to reduce the temperature gradient between the molten metal and the reinforcement. A muffle furnace was used to preheat the basalt fibers to a temperature of about 500 °C and maintained at that temperature till it was introduced into the Al 7075 alloy melt. The copper coated basalt short fibers, which were preheated in the furnace, introduced into the vortex at the rate of 50 gm/min. A small amount of magnesium to improve the wettability of the basalt fibers was added along with the reinforcement. Rate of addition of basalt fibers played an important role in obtaining uniform dispersion and distribution of fibers in the composites casting. When the rate of addition was increased above 50 gm/min to 60 gm/min, basalt fibers were found to segregate on the surface of the melt. However, when the rate of addition of basalt fibers was less than 50 gm/min the residence time of the fibers was too large and it resulted in segregation of the fibers at the surface of the melt. The optimum rate of addition of reinforcement was determined to be 50 gm/min. stirring was continued and the furnace was switched off to enable fall of temperature, so that slurry was formed. The slurry was poured out of the furnace through the spout by tilting the furnace and then poured in to required preheated die

A. Forging operation

Forging was carried out in an open die in both single and double stage, using a 20 MN press and a graphite-based lubricant. The temperature of the composites at the beginning of the process was about 500 °C, while at the end of the forging it was 425 °C. The forging parameters were: temperature of the die 400 °C; initial billet diameter 75 mm, final billet diameter of 25 mm, deformation ratio 3:1; average engineering strain rate 0.1 s^{-1} as per Hong. [4]. The second stage forging ratio 5:4 that is reduction of 25 mm to 20 mm diameter. The forged specimens are heat treated to remove residual stress which is accumulated at the time of forging.

III. EXPERIMENT

The machinability tests were carried out by turning the specimens by using a lathe as shown in fig.1. The cutting speeds selected were 200, 300, 400 and 500 rpm. The depth of cut was 0.2, 0.5, 0.8 and 1 mm and the feed rates were 0.1, 0.2, 0.3 and 0.4 mm/min. Meanwhile the cutting forces were measured by dynamometer.

Fig 1. Conduction of machinability test using lathe tool dynamometer

A. Effect of forging on Machinability forces

The choices of using forging specimens produced lower surface roughness at low feed rate and high cutting speed, but the cutting forces are same in the case of forging condition. The outcome of the experiments given in Fig.2 (a,b,c&d).The deviation from ideal surface roughness can be caused by work material factors such as built up layers, built up edge formation, chip interface, chip squeezing, tool vibration, tool wear, work piece vibration, temperature and cutting speed variations. The probability of built up edge formation and cracks in cyclical is higher at a lower feed rate. Chip interface and squeezing are the most significant factors in this experiment. When a low feed rate is applied the chips are small, curl and spacious. Moreover, the movement of feed is very slow. Therefore, chips are curling back to the work piece, trapped in between the tool and work piece, pressing against the work piece surface. This causes scratching on the new surface as the chip pass. Finally, at lower feed rate, the roughness of the specimen is more at higher feed rate it decreases. Similarly at lower cutting speed the higher the roughness in the other hand at higher cutting speed lower the roughness.

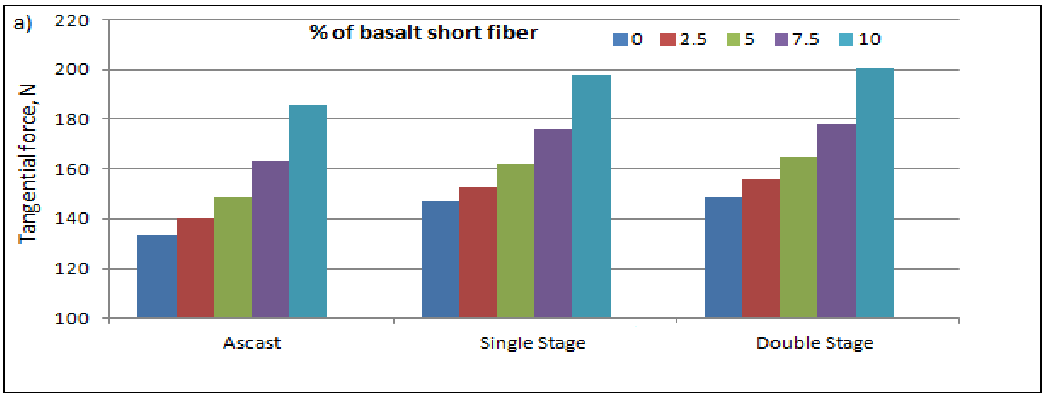

Fig. 2 a. Effect of weight percentage in forging condition on aggregated average machining force (Tangential force) of Al 7075 alloy and Al 7075/basalt composites for different weight percentage of basalt short fiber,

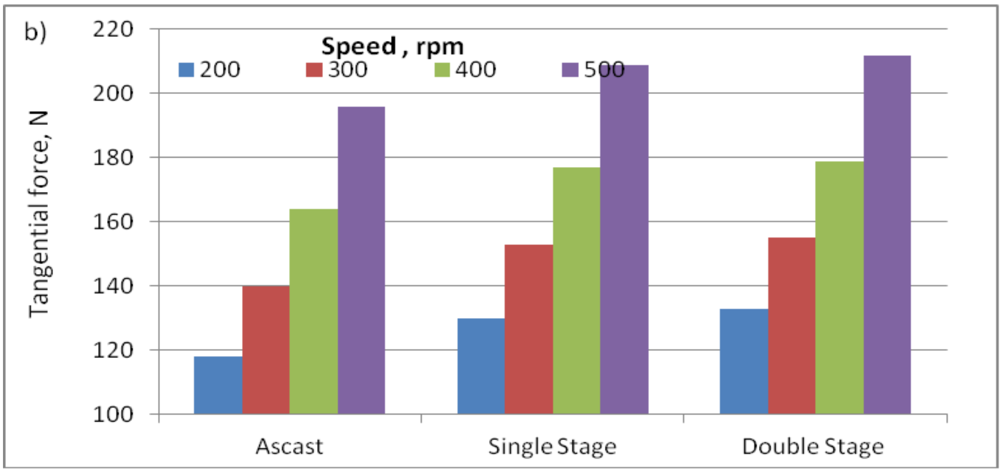

Fig.2 b. Avg. Machining force (Tangential force) of Al 7075 alloy and Al 7075/basalt composites for different cutting speeds

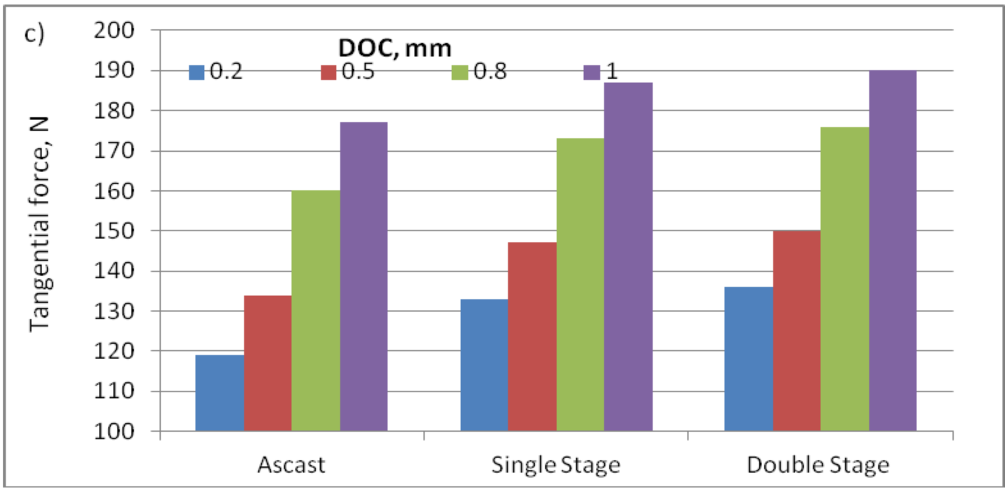

Fig. 2 c. Aggregated average machining force (Tangential force) of Al 7075 alloy and Al 7075/basalt composites for different depth of cut

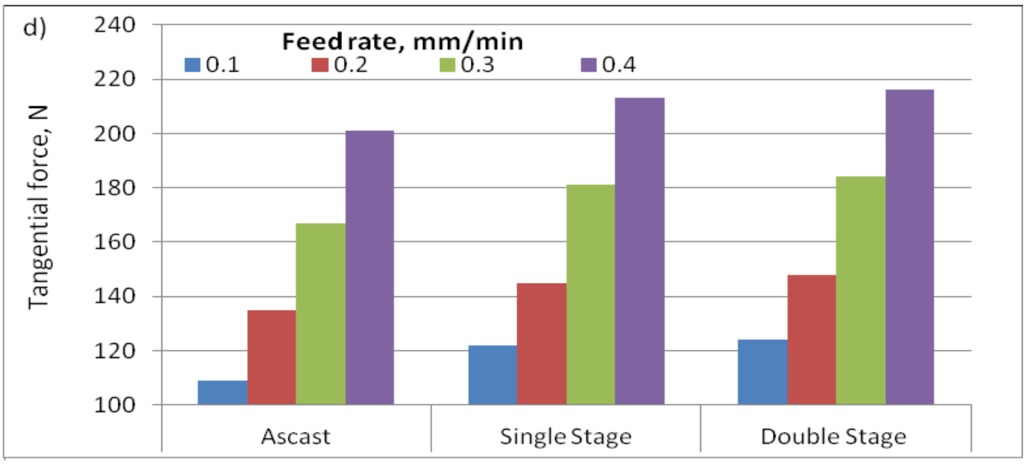

Fig. 2 d. Aggregated average machining force (Tangential force) of Al 7075 alloy and Al 7075/basalt composites for different feed rates

B. Study of machining surfaces

The SEM images of machined surface of Al alloy as cast, single forged and double forged surfaces are shown in Figure 3 & 4 at a speed of 500 rpm, DOC of 0.5 mm and feed rate of 0.3 mm/min. The increased surface roughness is due to the poor selection of machining parameters. The surface damages are clearly observed from the figures. Etching will not affect this phase, and hence in the SEM micrographs they appear to protrude out of the surface of the material. The some, which are multiple carbides of tungsten and binder, appear as brownish specks.

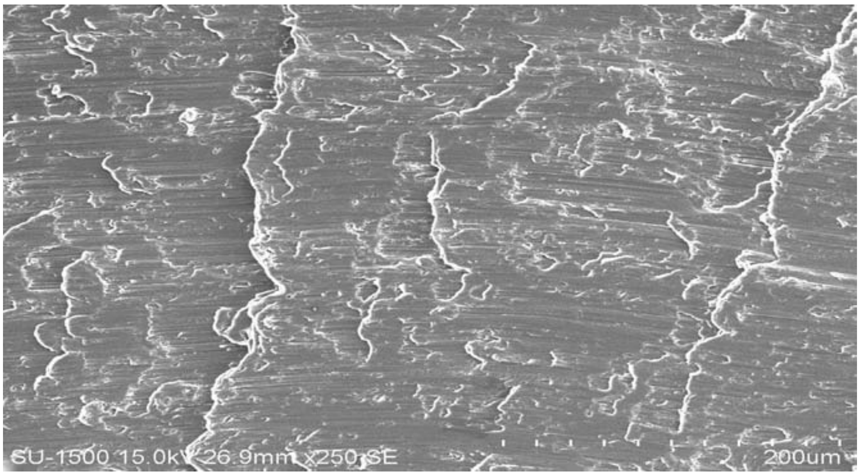

Fig.3. Machining surface of Al 7075 as cast specimen at cutting speed of 500 rpm, DOC of 0.5 mm and feed rate of 0.3 mm/min

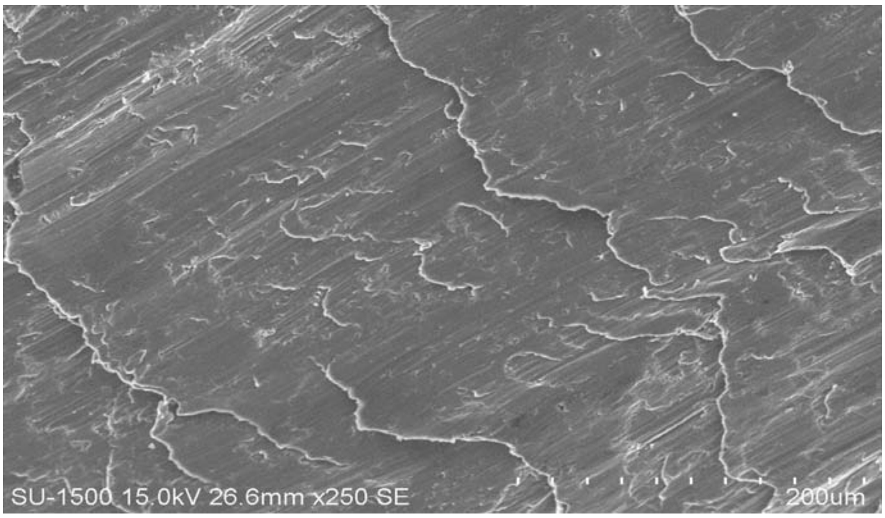

Fig.4. Machining surface of Al 7075 single stage forged specimen at cutting speed of 500 rpm, DOC of 0.5 mm and feed rate of 0.3 mm/min

The SEM images of machined surface of Al 7075 alloy /10 weight percentage basalt short fiber composites as cast, single forged surfaces are shown in Figure 5&6 at speed of 500 rpm, DOC of 0.5 mm and feed rate of 0.3 mm/min. The fiber pullout, fiber damages and cracks in matrix material are observed. Under specific conditions the surface of machined specimen is damage free. Compare to forging, the damages observed more in as cast condition. More number of porous sites and damage zones are observed in the case of as cast conditions.

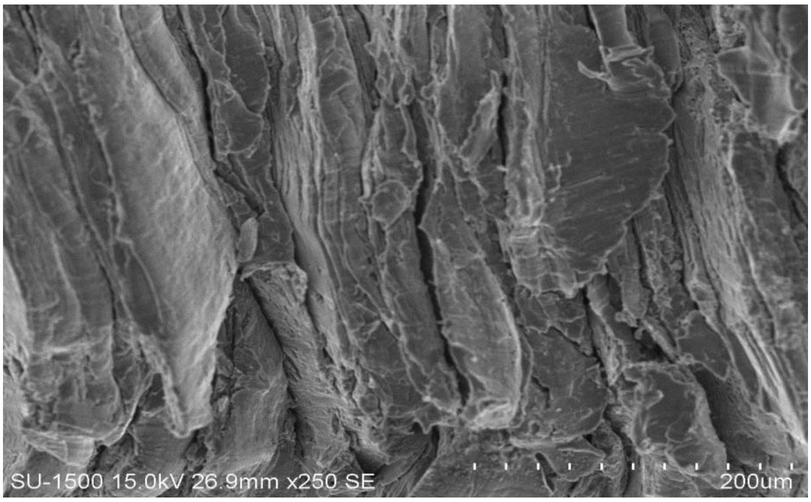

Fig.5. Machining surface of Al7075/10 weight percentage basalt short fiber as cast, specimen at cutting speed of 500 rpm, DOC of 0.5 mm and feed rate of 0.3 mm/min.

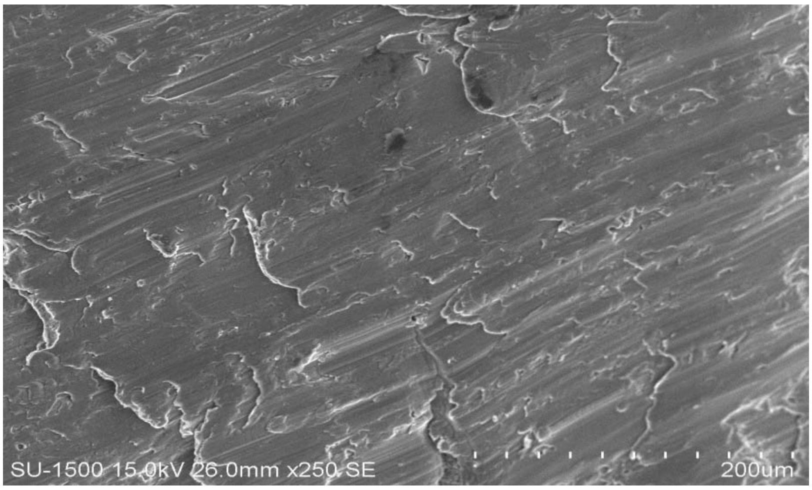

Fig. 6 Machining surface of Al7075/10 weight percentage basalt short fiber single stage forged and specimen at cutting speed of 500 rpm, DOC of 0.5 mm and feed rate of 0.3 mm/min.

IV. DISCUSSION

The machinability of the composite material in terms of turning was performed using a lathe machine under dry condition without the use of coolant. It has been reported by various researchers like Shaw [5], and Kronenberg [6] that no specific relationship exists between the cutting forces at the start of the machining process and the cutting speed being used. It was found that the cutting forces increased with increasing cutting speed while machining. The effective area of contact between the tool and the work piece increased significantly thus increasing the frictional forces at the tool work piece interface. The difference in the effective contact area at the tool cutting surface explains the high force components involved in machining. When compared to the base alloy the cutting forces measured during the test shows that the forces required for machining the composite material increased. Though, the increment in the amount of force required is not too high. The useful life of the tool is depending on the sum of wear in tool. Assessment of the wear on the tool tip showed significantly scratched grooved corresponding to the chip flow direction and the specimen movement. Such grooves are usually found in MMCs reinforced with hard dispersoids short fiber and are formed by a mixture of two body and three body abrasions between the work piece and the tool due to the hard nature and irregular shape of the reinforcement and the loose particles found during machining. Since basalt short fiber is also a hard reinforcement, noticeably grooves were found parallel to the direction of chip flow and work piece measurement. The material removal rate depends on the cutting speed. The cutting forces concerned in machining the composites with varying basalt short fiber content is found to be greater than that involved in machining the base alloy. Examination of the cutting tools acknowledged that the chip-tool contact lengths were smaller with the MMCs than the base alloy. Hence it appears that the increase cutting forces are interpreted by the presence of basalt short fiber, which reduces chip/tool adhesion and shear at the interface. The cutting forces are not drastically depending upon the physical and mechanical properties of the tools. The cutting forces in the cutting zone are obviously larger because as per Newton III law the action and reaction forces acting directly on the tool at cutting zone. Thus, the cutting force is high. At the time the cutting speed increases, the tangential force increase and reach into a stable state. But effect of both Depth of Cut (DOC) and feed rate trend are same on cutting speed that means the increasing machining forced with increasing feed rate and DOC. But only small changes in cutting forces can be seen for the forging conditions. The double forged condition shows higher cutting forces due to the formation of the precipitate in the specimen that leads to hardened MMCs.

V. CONCLUSION

- This investigation shows that depth of cut, feed rate and cutting speed increases with tangential forces irrespective of material and forging conditions.
- The addition of basalt short fiber enhances mechanical properties (hardness) of course more machining forces required to machining the MMCs.
- Both forging conditions show significant effect on machining forces due to fiber fracture and improve the quality of MMCs during forging conditions.
- Machining surfaces show the addition of basalt short fiber increases the surface roughness but forging improves the surface quality of the both matrix and composites.

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