# Cutting Force Analysis of AA6061 Fabricated Rods Reinforced With $Al_2O_3$

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***Abstract*----Aluminium alloys have been increasingly applied as a structural material in composite materials using metal matrix due to their excellent mechanical properties and low weight. Aluminium is among those metals which are difficult to be welded by normal fusion welding processes. Aluminum MMC was particularly selected as it possesses increased elevated temperature strength and wide range of extensive applications. The excellent mechanical properties of these materials and relatively low production cost make them a very attractive candidate for a variety of applications both from scientific and technological viewpoints. Low melting point and high thermal conductivity are the two major factors contributing to this phenomenon. In our present work we have fabricated AA6061 composite material (in the shape of rod), an aluminium alloy, which is reinforced with $Al_2O_3$ in different quantities to improve machinability. Later we determined the cutting forces of each rod using lathe machine with dynamometer for better selection of rod. We found that the parameters like cutting speed, feed rate, depth of cut severely influences the cutting force. This analysis of cutting force provided better selection of tool for Friction Stir Welding.**

***Keywords*----metal matrix composites, friction stir welding, cutting force, dynamometer**

## I. INTRODUCTION

MMC (Metal matrix composites) are metals reinforced with other metal, ceramic or organic compounds. They are made by dispersing the reinforcements in the metal matrix. Reinforcements are usually done to improve the properties of the base metal like strength, stiffness, conductivity, etc. Aluminium and its alloys have attracted most attention as base metal in metal matrix composites. Aluminium MMCs are widely used in aircraft, aerospace, automobiles and various other fields. The reinforcements should be stable in the given working temperature and non-reactive too. The most commonly used reinforcements are Silicon Carbide (SiC) and Aluminium Oxide ($Al_2O_3$). SiC reinforcement increases the tensile strength, hardness, density and wear resistance of Al and its alloys. The particle distribution plays a very vital role in the properties of the Aluminum MMC and is improved by intensive shearing. $Al_2O_3$ reinforcement has good compressive strength and wear resistance.

Industrial technology is growing at a very rapid rate and consequently there is an increasing demand and need for new materials particulate reinforced composites constitute a large portion of this new advanced materials. The choice of processing method depends on the property requirements, cost factor consideration and future application prospects. Incorporation of hard second phase particles alloy matrices to produce MMCs has also been reported to be more beneficial and economical due to its high specific strength and corrosion resistance properties. In the present work, different percentage (4%,6%,8%) of $Al_2O_3$ has been reinforced with AA6061 alloy matrix composite by stir casting method and the produced rods were examined to study the difference in the mechanical behaviour produced MMC composites samples. The cutting forces are highly essential in selection of tool, especially in tools used for friction stir welding.

## II. CUTTING FORCES

Cutting is a process of extensive stresses and plastic deformations. The high compressive and frictional contact stresses on the tool face result in a substantial cutting force F.

Knowledge of the cutting forces is essential for the following reasons:

- proper design of the cutting tools
- proper design of the fixtures used to hold the workpiece and cutting tool
- calculation of the machine tool power
- selection of the cutting conditions to avoid an excessive distortion of the workpiece

In orthogonal cutting, the total cutting force F is conveniently resolved into two components in the horizontal and vertical direction, which can be directly measured using a force measuring device called a dynamometer. If the force and force components are plotted at the tool point instead of at their actual points of application along the shear plane and tool face, we obtain a convenient and compact diagram.

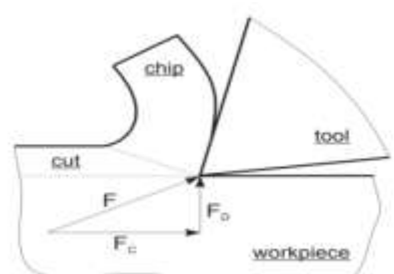


Fig. 1 Schematic view of Orthogonal Cutting Force

The two force components act against the tool:

***Cutting force* $F_C$**: This force is in the direction of primary motion. The cutting forceconstitutes about 70~80 % of the total force F and is used to calculate the power Prequired to perform the machining operation,

$P = VF_C$

***Thrust force* $F_D$**: This force is in direction of feed motion in orthogonal cutting.The thrust force is used to calculate the power of feed motion.

In ***three-dimensional oblique cutting***, one more force component appears along the third axis. The thrust force $F_D$ is further resolved into two more components, one in the direction of feed motion called *feed force* $F_f$, and the other perpendicular to it and to the cutting force $F_C$ called *back force* $F_p$, which is in the direction of the cutting tool axis.

**Cutting speed**: It is defined as the speed at which the work moves with respect to tool. Usually measured in metre per minute(m/min), denoted by ‘V’ or ‘C’

**Feed**: Feed rate is defined as the distance the tool travels during one revolution of the part.

Measured in mm per revolution(mm/rev) and denoted by‘*f* ’

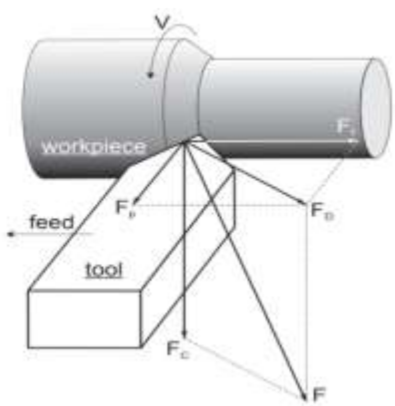


Fig. 2 Force components in three-dimensional oblique cutting

## III. DETERMINATION OF CUTTING FORCE

Cutting forces are either

- *measured* in the real machining process, or
- *predicted* in the machining process design.

Cutting forces are *measured* by means of special device called tool force *dynamometer* mounted on the machine tool.

For cutting force *prediction*, several possibilities are available, for approximate calculations of sufficient accuracy for all practical purposes, the so-called *specific cutting force* (*cutting force per unit area of cut*) $k_C$ is used:

$F_C = k_C.h_D.b_D$

This parameter is well tabulated and could be found in the most handbooks. For small cut thickness and dull cutting tools $k_C$ must be increased. The value of thrust force $F_D$ is taken usually as a percentage of $F_C$.

more advanced options for cutting force prediction are based on *analytical* or *numerical modelling* of metal cutting. Due to the complex nature of the cutting process, the modelling is typically restricted to orthogonal cutting conditions.

## IV. STANDARDS

ASTM: American Society for Testing Materials

ISO : International Organization for Standardization

Different forms and tempers of 6061 aluminium alloy are discussed in the following standards:

- ASTM B 209: Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
- ASTM B 210: Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes
- ASTM B 211: Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire
- ASTM B 221: Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
- ASTM B 308: Standard Specification for Aluminum-Alloy 6061-T6 Standard Structural Profiles
- ASTM B 483: Standard Specification for Aluminum and Aluminum-Alloy Drawn Tube and Pipe for General Purpose Applications
- ASTM B 547: Standard Specification for Aluminum and Aluminum-Alloy Formed and Arc-Welded Round Tube

ISO 6361: Wrought Aluminium and Aluminium Alloy Sheets, Strips and Plate.

## V. EXPERIMENTAL PROCEDURE

After finishing our project design with required dimensions, we performed stir casting process and fabricated AA6061+ $Al_2O_3$ rods. Then cutting forces were calculated for each rod individually for proper selection of tool. After the fabrication of rods, cutting forces are to be calculated for selection of rod for preparing tool. Cutting forces were calculated with help of lathe machine to which dynamometer is attached.

Fig. 3 Lathe with dynamometer

Before finding the cutting forces, various parameters like depth of cut, feed, cutting speed, power required are to be known. All the parameters are considered on a lathe machine with a dynamometer attached to it.

The fabricated rod was first machined on a normal lathe so as get uniform diameter all over the rod. Then the machined rod is placed in lathe with dynamometer.

To find out the cutting forces of each rod, each rod is rotated with three different speeds with three different federate under constant depth of cut. Therefore total nine passes were made for each rod and thus total nine readings of cutting forces were taken.

Fig. 4 Fabricated Rods

## VI. VARIOUS PARAMETERS FOR CUTTING FORCE

- Speed (C) - (500, 775, 1200) rpm
- Feed (f)- (0.1, 0.15, 0.2)mm/rev
- Depth of cut (d) -(0.4, 0.6,0.8) mm
- Wattmeter reading - kW (Power,P)
- Cutting speed (v) - m/min

Cutting speed, V = $\frac{\pi \times d \times N}{60}$ m/min;

d= diameter of rod, N= speed

Cutting Force (F) =$\frac{P \times 60 \times 1000}{d \times f \times v}$ N/mm$^2$

## VII. RESULTS AND DISCUSSIONS

- Cutting forces of different fabricated rods are found using lathe machine (with dynamometer attached).
- Cutting forces has been found at different speeds, feed and depth of cut for each rod individually.
- The initial and final readings of wattmeter are noted manually; then the cutting speed and the cutting forces are calculated.

CUTTING FORCE ANALYSIS OF AA6061 + 4% $Al_2O_3$ SPECIMEN:

| **SL.NO.** | **SPEED (rpm)** | **FEED (mm/rev)** | **DEPTH OF CUT (mm)** | **WATTMETER READING (kW)** | | **CUTTIG SPEED (m/min)** | **CUTTING FORCE (N/m m²)** |
|---|---|---|---|---|---|---|---|
| | | | | Initial | Final | | |
| 1 | 500 | 0.1 | 0.4 | 0.13 | 0.15 | 35.66 | **841.28** |
| 2 | 775 | 0.15 | 0.4 | 0.15 | 0.17 | 55.27 | **361.86** |
| 3 | 1200 | 0.2 | 0.4 | 0.22 | 0.32 | 85.58 | **876.37** |

CUTTING FORCE ANALYSIS OF AA6061 + 6% $Al_2O_3$ SPECIMEN:

| **SL.NO.** | **SPEED (rpm)** | **FEED (mm/rev)** | **DEPTH OF CUT (mm)** | **WATTMETER READING (kW)** | | **CUTTIG SPEED (m/min)** | **CUTTING FORCE (N/mm²)** |
|---|---|---|---|---|---|---|---|
| | | | | Initial | Final | | |
| 1 | 500 | 0.1 | 0.6 | 0.13 | 0.15 | 35.66 | **560.85** |
| 2 | 775 | 0.15 | 0.6 | 0.14 | 0.19 | 55.27 | **603.09** |
| 3 | 1200 | 0.2 | 0.6 | 0.18 | 0.38 | 85.58 | **1168.49** |

CUTTING FORCE ANALYSIS OF AA6061 + 8% $Al_2O_3$ SPECIMEN**:**

| **SL.NO.** | **SPEED (rpm)** | **FEED (mm/rev)** | **DEPTH OF CUT (mm)** | **WATTMETER READING (kW)** | | **CUTTIG SPEED (m/min)** | **CUTTING FORCE (N/m m²)** |
|---|---|---|---|---|---|---|---|
| | | | | Initial | Final | | |
| 1 | 500 | 0.1 | 0.8 | 0.13 | 0.15 | 35.66 | **420.64** |
| 2 | 775 | 0.15 | 0.8 | 0.15 | 0.20 | 55.27 | **452.32** |
| 3 | 1200 | 0.2 | 0.8 | 0.19 | 0.39 | 85.58 | **876.37** |

From the above data it is clear that the feed rate, speed, depth of cut influence the cutting forces. It is also found that AA6061 rod reinforced with 6% of$Al_2O_3$ recorded higher cutting forces when compared with other rods. So we have selected this rod for tool preparation.

## VIII. CONCLUSION

The conclusions were made from the present work are as follows:

- AA6061 have been successfully fabricated by stir casting technique with reinforcement of $Al_2O_3$ particles with different percentages (4%, 6%, 8%).

- The effects of Cutting speed, depth of cut and feed rate have major influence on cutting forces.
- At 700 rpm, 0.2 mm/rev and at a depth of cut of 0.6mm; the maximum cutting force obtained.
- The primary factor in choosing feed and speed is the material to be cut. However, one should also consider material of the tool, rigidity of the workpiece, size and condition of the lathe, and depth of cut.

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