Optimization of forces of feed, cutting and thrust based contribution parameters in machining with cutting fluid

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Abstract: The optimization of the parameters needed to identify the optimum inputs to get the desirable output of the particular process or the machining. Normally so many investigation focused to the optimization on the composites. In this investigation also metal matrix composite of the aluminium alloy reinforced with Boron carbide (B4C) and the Zirconium oxide (ZrO2) each have the four percentage of total volume contributed in the aluminium alloy of Al6061. The composite specimens were prepared by the molding process. Then the specimens were machined in the Lathe. There are so many factors considered for the machining among that cutting speed, depth of cut and the cutting fluid flowing nozzle diameter were taken for optimization (by Minitab 2013) for this investigation with respect to the three forces such as force of Feed, force of cutting and force of thrust. The corresponding regression equations were recommended for these forces. For the combination of these three forces based most favorable considerations were found as cutting speed of 60 m/min, cutting depth of 0.6 mm and the cutting fluid flowing nozzle diameter of 3 mm.

Keywords: aluminium reinforcement, optimization, feed force, cutting force, thrust force.

1. Introduction
The suitable method selection is depend on the application and the suitable parameter selection for the greatest required results leads to the reduction of the time and increase the level of the reliability of the particular machining. For these all are complete by the optimization of concern parameters of the machining process. Prantik Mukhopadhyay et al. [1] clearly examines the different research articles regarding AA6XXX series of aluminium alloy for the clear vision of the compositions, different properties comparison as well as different parameters for the different alloys combination with the another materials. They clearly mentioned that the compositions of 0.37% of Chromium, 0.15% of manganese, 0.38% of copper, 1.15% of Magnesium, 0.75% of silicon and the remaining volume percentage are occupied by the aluminium alloy.
Gurusami K et al. [2] put in plain words on the subject of stir casting process based optimization for the concern parameters for the corrosion rate behaviour on the composites of the reinforced aluminium boron carbide. Raviraj Shetty et al. [3] from top to bottom argue on the subject of the metal matrix composite associated with optimization in special tool used turning process. They used the 5 various inputs parameters which all are related to the 5 various responses. They used the steam pressure as a cutting fluid. And the cutting fluid flowing nozzle parameters like flowing pressure and diameter of the nozzle also bring in to play.

Optimization technique focused Aluminium alloy based machining were explained in the articles [4], [5] and [6] with various example diagrams. Sathish et al. [7] evidently explained about the optimization on the parameters of unconventional machining process such as electrochemical machining. Dinesh Kumar et al. [8] clearly focused with the Naval Steel A-GTAW Welding operation parameters optimization with the comprehensible explanation and the method of optimization. Similarly a variety of optimization process by way of an assortment of machining through dissimilar parameters depend up on the responses are recognized in the company of an assortment of investigations from [9] to [12].

Balaji P et al. [13] studied about the reinforcement of Aluminium alloy of Al 6061 by Magnesium Oxide based on the various volume percentage variations. They mentioned that the increasing percentage of weight create considerable impact on their properties with Al 6061 alloy importance and application. M. Trimurthulu et al. [14] investigate about the composite of the 10%, 15%, 20% and 25% of boron carbide with the aluminium alloy for the comparison of mechanical behavior. They concluded that the Impact strength decreased with increase of the boron carbide content similarly hardness and ultimate tensile strength enhanced with increase of the boron carbide percentage concentration in the total composite.

R.M. Mohanty et al. [15] discussed about the reinforced aluminium 1100 composites with Boron carbide based characteristics identifications and production methods. Daulat Kumar Sharma et al. [16] compared the properties of Aluminium alloys properties with the composites of the 10%, 20%, 30% and 40% of Boron carbide and Al6061 Aluminium alloy composites. With respect to the increase of the Boron carbide percentage produce increased tensile strength, hardness, compression strength and wear resistance also reduced coefficient of friction properties. They also used the SEM images and nano particles used comparison plot for the clear observations of the results.

Udayashankar.S et al. [17] mainly studied the three to twelve percentage of ZrO2 with three percentage increment with Al6061composites by the stir casting method. The greater results of the ultimate tensile strength, Brinell hardness were obtained the composite with nine percentage of the zirconium oxide used aluminium alloy when compared to remaining other composites. K.B Girisha et al [18] studied with zirconium particles with aluminium alloy. They mentioned that the ZrO2 is the easily available and low cost material with improved wear characteristics. Especially Zirconia have greater strength, maximum wear resistance and hardness.

Prashanth N et al. [19] obviously mentioned about both Al6061 alloy and Zirconium oxide properties highlights. Similarly Aasiya Parveen et al. [20] reviewed the about the zirconium oxide based aluminium alloy composites with the help of nearly forty six research articles. They also discussed about the microstructural behaviour, density values and wear rate enhancement [21]. From all these literatures Aluminium reinforcement with Zirconium oxide composites and Aluminium reinforcement with Magnesium oxide composites can be identified clearly [22-32].

In this investigation focused with the composites of Aluminium alloy with Magnesium oxide and Zirconium oxide reinforcement composite machining parameters optimization in Lathe machine based on the forces participated in the turning operation.

2. Experimental procedure
The aluminium 6061 alloy is taken for reinforcement with the Boron carbide and the Zirconium oxide. There are four percentage of boron carbide and four percentage of zirconium oxide used in the
total volume percentage of the composite and remaining ninety two percentage of the composite is influenced by the Aluminium alloy Al6061. These all materials are in powder form. These all are well mixed and placed in the high grade electric heating chamber with the capacity of 2000OC, total volume of 10 m3, with power of 10 kW. Then the molten metal is pouring into the mold cavity to produce the large sized specimens. The specimens for the testing were conducted with the size of the 70 mm of diameter and 130 mm long cylinders. Same dimensional specimens were used for all the testing condition.

External threading operation is performed in the specimens. The Lathe with specification of the 5kW power and 3000 rpm of maximum speed motors with five different speed changing mechanism. Feed mechanism is also connected with the screw rod on the machine attachment. The Lathe tool dynamometer is fixed on the tool post on the lathe bed to identify the forces acted on the machine at the time of machining. In this operation steam is act as cutting fluid with the pressure of ten bars. This steam is created with the separate steam boilers with capacity of one and half tons with coal feed. The sizes of the nozzle used such as diameter get varied to optimize.

**Figure 1.** Lathe machine used for the investigation

**Table 1.** Parameters variation for the experimental trails

| Experimental Trail Number | Cutting speed (CS) in m/min | Depth of cut (DC) in mm | Nozzle diameter (ND) in mm |
|----------------------------|-----------------------------|-------------------------|---------------------------|
| ETN 1                      | 60                          | 0.6                     | 3                         |
| ETN 2                      | 60                          | 0.9                     | 4                         |
| ETN 3                      | 60                          | 1.2                     | 5                         |
| ETN 4                      | 90                          | 0.6                     | 4                         |
| ETN 5                      | 90                          | 0.9                     | 5                         |
| ETN 6                      | 90                          | 1.2                     | 3                         |
| ETN 7                      | 120                         | 0.6                     | 5                         |
| ETN 8                      | 120                         | 0.9                     | 3                         |
| ETN 9                      | 120                         | 1.2                     | 4                         |

There are three machining parameters considered for this investigation such as first one is speed of cutting (CS) with the variation of 60 m/min, 90 m/min and 120 m/min. The second one is Cutting
depth (DC) with the variation of 0.6 mm, 0.9 mm and 1.2 mm. The last one is the cutting fluid flowing nozzle diameters like 3 mm, 4 mm and 5 mm. All of these factors considered experimental trails combination were created as per the L9 ANOVA table which is mentioned in the table 1. The experimental trail numbers were named as ETN 1 to ETN 9 in the same table and throughout the investigation.

3. Results and discussion

The investigational results were gained and tabulated in the table 2 with respect to the experimental trails. There are four types of the parameters optimization done. Three optimizations done with the individual three responses of the experiments with minimum force required condition. Then the fourth one is the combination of the all the three responses with the requirement of minimum force.

| Experimental Trail Number | Feed force in N | Cutting force in N | Thrust force in N |
|----------------------------|-----------------|--------------------|-------------------|
| ETN 1                      | 50.78317        | 84.66375           | 23.42872          |
| ETN 2                      | 61.95087        | 86.88375           | 34.87168          |
| ETN 3                      | 73.11857        | 89.10375           | 46.31464          |
| ETN 4                      | 66.91932        | 80.89875           | 34.822            |
| ETN 5                      | 78.08702        | 83.11875           | 46.26496          |
| ETN 6                      | 70.73842        | 99.33375           | 36.84232          |
| ETN 7                      | 83.05547        | 77.13375           | 46.21528          |
| ETN 8                      | 75.70687        | 93.34875           | 36.79264          |
| ETN 9                      | 86.87457        | 95.56875           | 48.2356           |

3.1 Feed force

![Main Effects Plot for SN ratios](image)

**Figure 2.** Central result produced diagram for SN relation for force of feed (Cutting speed (CS) in m/min, Depth of cut (DC) in mm, Nozzle diameter (ND) in mm)

The experimental results based on the central result produced diagram depend on the SN relation for force of feed was obviously brought up in the figure 2. From this plot the greater results of the feed force in the condition of minimum is suitable. The point above -37.0 mean of SN ratios values can be considered. For the minimum feed force can be achieved in 60 m / min of cutting speed, 0.6 mm of depth of cut and 3 mm of the nozzle diameter of cutting fluid flowing pipe.
**Figure 3.** Central result produced diagram for means for force of feed (Cutting speed (CS) in m/min, Depth of cut (DC) in mm, Nozzle diameter (ND) in mm)

**Figure 4.** Contour diagrams for force of feed (Cutting speed (CS) in m/min, Depth of cut (DC) in mm, Nozzle diameter (ND) in mm)

In the same way central result produced diagram for data means for force of feed was noticeably carry in figure 3. For the cutting speed of 120 m/min, 0.6 mm of cutting depth and 3 mm of the nozzle diameter produced the greatest result such as minimum amount of the feed force requirement based optimum participation parameters of the machining. These also help to prove the same data of the SN ratio-based outcome of the image from the figure 2 for the force of feed response in machining. For the further clear identification of the separation and involvement of the forces on the corresponding parameter-based identification were clearly expressed in the figure 4 as a Contour
diagram for force of feed. It has the three plots such as depth of cut versus cutting speed, nozzle diameter versus cutting speed, nozzle diameter versus depth of cut in the sequence order. In each comparison have variations with each other parameters considered.

3.2 Cutting force

From the figure 5 the central result produced diagram for SN relation for Cutting force were plotted with respect to the investigational outcomes. From this figure the superior results of the cutting force in the condition of lowest is appropriable. The point above -38.8 mean of SN ratios values can be considered. For the smallest cutting force can be achieved in 60 m / min of cutting speed, 0.6 mm of depth of cut and 5 mm of diameter of cutting fluid flowing nozzle.

![Main Effects Plot for SN ratios](image)

Figure 5. Central result produced diagram for SN relation for Cutting force (Cutting speed (CS) in m/min, Depth of cut (DC) in mm, Nozzle diameter (ND) in mm)

In the equivalent approach mentioned in the figure 6 explained the central result produced diagram for means for Cutting force. From these two diagrams the optimized contribution of parameters were obtained as the cutting speed of 60 m/min, 0.6 mm of cutting depth and 5 mm of the nozzle diameter for the minimum cutting force. Similarly for the maximum cutting force is obtained from the cutting speed of 120 m/min, 1.2 mm of cutting depth and 3 mm of the nozzle diameter.

Also the figure 7 give the force of feed based contour diagrams of nozzle diameter versus cutting speed, depth of cut versus cutting speed, nozzle diameter versus depth of cut were mentioned as a single diagram with different representation range with different colours. The range of the cutting force is in between 80 N to 96 N. The hold values were obtained from the contour plot are mentioned as the cutting speed of 90 m/min, 0.9 mm of cutting depth and 4 mm of the nozzle diameter.
Figure 6. Central result produced diagram for means for Cutting force (Cutting speed (CS) in m/min, Depth of cut (DC) in mm, Nozzle diameter (ND) in mm)

Figure 7. Contour plot for Cutting force (Cutting speed (CS) in m/min, Depth of cut (DC) in mm, Nozzle diameter (ND) in mm)

3.3 Thrust force
From the figure 8 without a doubt demonstrate the central result produced diagram for SN relation for thrust force from the experimental results and the figure 9 also confirm the same. By theses figure 8 and figure 9 the optimum parameters for the thrust force based on the minimum force is desirable condition the following were considered. For minimum thrust force can be obtained from the
parameters were the 60 m/min of cutting speed, 0.6 mm of cutting depth and 3 mm of the nozzle diameter. Similarly, the maximum thrust force can be achieved at the 120 m/min of cutting speed, 1.2 mm of cutting depth and 5 mm of the nozzle diameter.

Figure 8. Central result produced diagram for SN relation for Thrust force (Cutting speed (CS) in m/min, Depth of cut (DC) in mm, Nozzle diameter (ND) in mm)

Figure 9. Central result produced diagram for means for Thrust force (Cutting speed (CS) in m/min, Depth of cut (DC) in mm, Nozzle diameter (ND) in mm)

In addition, the figure 10 produced the nozzle diameter versus depth of cut, nozzle diameter versus cutting speed, depth of cut versus cutting speed combination of these three as a single contour for Thrust force with various shade variations for the various regions. Here also the contour plot is point out as the cutting speed of 90 m/min, 0.9 mm of cutting depth and 4 mm of the nozzle diameter as hold values.
Figure 10. Contour for experimental results of Thrust force (Cutting speed (CS) in m/min, Depth of cut (DC) in mm, Nozzle diameter (ND) in mm)

Table 3. Response table for three forces related with the lower is preferable condition

| Level | Cutting speed (CS) in m/min | Depth of cut (DC) in mm | Nozzle diameter (ND) in mm | Cutting speed (CS) in m/min | Depth of cut (DC) in mm | Nozzle diameter (ND) in mm | Cutting speed (CS) in m/min | Depth of cut (DC) in mm | Nozzle diameter (ND) in mm |
|-------|-----------------------------|------------------------|---------------------------|-----------------------------|------------------------|---------------------------|-----------------------------|------------------------|---------------------------|
| 1     | 35.75                       | -36.34                 | -36.23                    | -38.78                      | -38.15                 | -39.30                    | -30.52                      | -30.51                 | -30.01                    |
| 2     | 37.12                       | -37.09                 | -37.04                    | -38.83                      | -38.86                 | -38.85                    | -31.82                      | -31.82                 | -31.78                    |
| 3     | 38.25                       | -37.68                 | -37.84                    | -38.92                      | -39.52                 | -38.38                    | -32.76                      | -32.77                 | -33.31                    |
| Delta | 2.50                        | 1.35                   | 1.61                      | 0.14                        | 1.36                   | 0.92                      | 2.24                        | 2.26                   | 3.29                      |
| Rank  | 1                            | 3                      | 2                         | 3                           | 1                      | 2                         | 3                           | 2                      | 1                         |
Table 4. Regression equation table

| Equation No. | Response     | Regression Equation                  |
|--------------|--------------|--------------------------------------|
| 1            | Feed force   | $2.348 + 0.3321 \text{CS} + 16.65 \text{DC} + 6.172 \text{ND}$ |
| 2            | Cutting force| $83.09 + 0.03000 \text{CS} + 22.95 \text{DC} - 4.665 \text{ND}$ |
| 3            | Thrust force | $-15.29 + 0.1479 \text{CS} + 14.96 \text{DC} + 6.955 \text{ND}$ |

From the table 3 ranking of the individual responses-based parameters were mentioned. For feed force based produced preference order of the parameters is cutting speed, nozzle diameter and depth of cut as one, two and three respectively. For the cutting force based produced order of the parameters preference order is depth of cut, nozzle diameter and cutting speed as one, two and three correspondingly. Similarly for the cutting speed based produced order of the parameters preference order is nozzle diameter, depth of cut and cutting speed as one, two and three in that order. All these three have the same condition such as minimum is better bet each having the different preference of parameters order. Each response’s regression equations were mentioned in the table 4.

3.3 Combination of all forces (Feed force, cutting force and thrust force)

![Main Effects Plot for SN ratios](image)

Figure 11. Central result produced diagram for SN relation for all the forces (Cutting speed (CS) in m/min, Depth of cut (DC) in mm, Nozzle diameter (ND) in mm)

After the variation of the preferences identified in the table 3 the combination of these three responses (feed force, cutting force and thrust force) were taken based on the minimum is suitable condition for the machining. The corresponding central result produced diagram for SN relation and means where shown in figure 11 and figure 12 for all the three forces such as feed force, cutting force and thrust force. From these figures 11 and 12 the optimum parameters for these three responses were mentioned as 60 m/min of cutting speed, 0.6 mm of cutting depth and 3 mm of the nozzle diameter for the cutting fluid flow for the minimum of feed force, cutting force and thrust force. Similarly for the maximum feed force, cutting force and thrust force can be obtained at 120 m/min of cutting speed, 1.2 mm of cutting depth and 5 mm of the nozzle diameter for the cutting fluid flow.
Figure 12. Central result produced diagram for means for all the force (Cutting speed (CS) in m/min, Depth of cut (DC) in mm, Nozzle diameter (ND) in mm)

Table 5. Combination of the three responses response table

| Level | Cutting speed (CS) in m/min | Depth of cut (DC) in mm | Nozzle diameter (ND) in mm |
|-------|-----------------------------|-------------------------|---------------------------|
| 1     | -36.23                      | -36.15                  | -36.63                    |
| 2     | -36.82                      | -36.83                  | -36.79                    |
| 3     | -37.41                      | -37.49                  | -37.04                    |
| Delta | 1.17                        | 1.34                    | 0.41                      |
| Rank  | 2                           | 1                       | 3                         |

The combination of three responses such as feed force, cutting force and thrust force-based table is mentioned in the table 5 which mentioned that the first rank is provided to the depth of cut, second rank to the cutting speed at last the third rank is provided to the nozzle diameter for the cutting fluid flow. So the most important parameter is depth of cut for all these three forces.

4. Conclusions
From this optimization of forces of feed, cutting and thrust based contribution parameters in machining such as cutting speed, cutting depth and the nozzle diameter for the cutting fluid flow were produced the following as conclusions.

- For feed force based optimum parameters are mentioned as cutting speed of 120 m/min, 0.6 mm of cutting depth and 3 mm of the nozzle diameter for the cutting fluid flow.
- For cutting force based optimum parameters were mentioned as cutting speed of 60 m/min, 0.6 mm of cutting depth and 5 mm of the nozzle diameter for the cutting fluid flow.
- For the thrust force based optimum parameters were mentioned as the cutting speed of 60 m/min, 0.6 mm of cutting depth and 3 mm of the nozzle diameter for the cutting fluid flow.
- But combination of the three forces such as feed force, cutting force and thrust force based optimum parameters were mentioned as 60 m/min of cutting speed, 0.6 mm of cutting depth and 3 mm of the nozzle diameter for the cutting fluid flow.
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