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# Use of New Multi-layered Coated Carbide Insert for Machining Aluminium Metal Matrix Composites Reinforced with Alumina Particles – Experimental Approach

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## ABSTRACT

The usage of aluminium based metal matrix composite (MMCs) materials has been increasing day by day in the areas of aerospace, automotive, marine, recreational, construction industries etc. due to its superior characteristics over unreinforced alloy. The conversion of these MMCs into industrial products is always associated with machining. The hard reinforcing particles in the MMCs pose a continued challenge to the machining research group. Though a lot of research work done for the machining of MMCs, still there is a scope for study due to the arrival of new cutting tools in the industry. The main objective of this paper is to study the effect of Multi-layered Coated Carbide Insert (CNMG 120408 TN 8135 FR) on machinability of Al-6063 matrix reinforced with $Al_2O_3$ particles. Composites are fabricated using stir casting technique for reinforcement volume fraction of 15% $Al_2O_3$ particles. Based on Taguchi L9 orthogonal array, three levels of cutting speed, feed rate and depth of cut are considered during the experimentation. Machinability index such as surface roughness and the tool wear are analyzed to study the machining performance. The experimental results were analysed by analysis of means using *Minitab* software by which optimal combination of cutting parameters, 100m/min of cutting speed, 0.103 mm/rev of feed, 0.6mm depth of cut are obtained. The experimental results show that the feed rate significantly affects the surface quality of machined surface. Tool wear analysis shown that the removal of coating only occurs on the tool gradually and there is almost no wear observed on the tool.

**Key words:** MMCs, Stir casting, Multi-Layered Coated Carbide Insert, Machinability index.

## 1. Introduction

Metal matrix composites (MMC) are the new class of materials and are rapidly replacing conventional materials in various engineering applications such as the aerospace and automobile industries [1]. The density of most of the MMCs is very less and is approximately one third that of steel, resulting in low weight, high strength and stiffness [2]. This property makes the immense use of MMCs in military, aerospace and automobile industries. The particle-reinforced aluminium alloy composites are among the most widely used metal matrix composites which are mainly reinforced with ceramic particles like $Al_2O_3$, SiC, $B_4C$. Alumina ($Al_2O_3$) is one of the most widely specified, general purpose technical ceramics which is very hard and wear resistant, with high compressive strength even against extreme temperatures and corrosive environments [3].

Ceramic particles are abrasive in nature. Due to their hardness and abrasive action these materials are difficult to machine which results in wear of the tool [4]. Surface roughness is one of the characteristic that is considered while machining a component. Gradual wear of the tool may result in poor surface finish of the work piece [5].PuneetBansalandLokeshUpadhyayfound that the cutting speedis moreinfluencingparameter than feed rate on the tool wear, surface roughness and material removal rate. But as feed rate increases, the wear of cutting tool also increases [6]. Tamer Ozbenet al found that higher the reinforcement ratio lesser the removal rate [7]. According to Sahin et al the major wear form of the TiN and TP30 coated carbide tools were the combination of flank wear and rounding of the nose, where removal of coated layer from the substrate material and BUE formation were appeared when cutting the composites at lower speed [8]. According to GeYingfeia et al Microwear, chipping, cleavage, abrasive wear and chemical wear were the dominating wear patterns of SCD tools, while PCD tool mainly suffered from abrasive wear on the rake face and adhesive wear on the flank face. The graphitization of SCD tool when machining SiCp/2009Al took place at relatively low temperature (about 500 °C) [9].

From the above literature survey it is found that aluminium MMC possess superior properties when compared to alloy [10]. Many researchers have carried out their research works on machining properties of MMCs using various tools and studied the wear and surface finishing properties of those materials. But very limited research work is available in literature on effect of Multi-layered Coated Carbide Insert (CNMG 120408 TN 8135 FR) on machinability of Al-6063 matrix reinforced with $Al_2O_3$ particles. Composites are fabricated using stir casting technique for reinforcement volume fraction of 15% $Al_2O_3$particles.The main aim of the present work is to optimize the process parameters using Taguchi design of experimental approach for experimental planning during turning of Al6063-$Al_2$O3 MMCs [11,12]. The effects of different cutting parameters are analyzed by S/N ratio and ANOVA analysis to achieve optimal surface roughness values of Ra, Rt and Rz. Also the tool wear study was carried using optical tool maker's microscope for different cutting conditions [13].

## 2. Experimental Procedure

The machining investigation is carried out on Aluminium 6063-T6 as base matrix alloy reinforced with 15% volume fraction of $Al_2O_3$ particles. Initially, composite bar of 15% alumina reinforcement volume of the base metal, which is of 30 mm diameter and 250 mm length are fabricated using bottom pouring stir casting process.

**Table.1 Chemical Composition of AA 6063**

| %Si | %Mg | %Fe | %Ti | %Cu | %Zn | %Pb | %Sn | %S | %P | %Cr | %Mn | %Al |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.48 | 0.71 | 0.29 | 0.02 | 0.03 | 0.06 | 0.02 | 0.04 | 0.008 | 0.01 | 0.04 | 0.23 | 97.96 |

Fabrication of composite bar is done by melting the alloy to 750˚C temperature in the crucible. Meanwhile, alumina reinforcement is preheated to 900˚C in preheating furnace for 1-3 hrs to avoid the surface oxidation. Magnesium (1%) is used as wetting agent and the melt is then automatically stirred by graphite coated stirrer. After stirring process the mixture was poured into the mild steel mould to get composite bar of specified dimensions.

Later, the reinforcement composite bar is turned on automatic lathe and is reduced to 28.5mm diameter bar. The bar is then machined on self-centred high speed lathe of spindle power 7.5 kW for turning operation. Where multi layered coated carbide cutting tool is used**.** This operation is carried out by dividing the bar into 3 equal parts and each part is given 3 trials of machining according to the parameters as shown in table 2, which follows the Taguchi L9 orthogonal array as shown in table 3. Accordingly, the surface roughness average values in microns were tabulated for different parameters of $R_a$ and $R_t$ using a surf test (Make-Mohr–Model Mar Surf GD120) measuring instrument with the cut off length 5.6mm and the tool wear is observed under optical microscope.

**Table. 2 Process parameters and their levels**

| Parameters | Cutting Speed (m/min) | Feed (mm/rev) | Depth of cut (mm) |
|---|---|---|---|
| Level 1 | 80 | 0.103 | 0.3 |
| Level 2 | 100 | 0.206 | 0.6 |
| Level 3 | 120 | 0.296 | 0.9 |

In addition to surface roughness analysis, the tool wear at each trial of machining as machining the composites is a challenge and therefore, tool wear is considered as one of the important factors for analysing the machinability.

## 3. Results and discussion:

The experimental results show that the burr formation is high when the depth of cut is low (80m/min, 0.103mm/rev, 0.3mm) as in fig1 and it is low at high cutting speeds as in Fig. 2 at a constant cutting speed and the wear of the tool is almost absent (80m/min,0.296mm/rev,0.9mm) and fig.3 shows that there is only the removal of tool coating till last trial (120m/min, 0.296mm/rev, 0.9mm) which is due to the abrasive nature of the alumina particles in the composite.

**Table. 3 Taguchi's L9 orthogonal array and the corresponding results**

| Trial | Cutting Speed (m/min) | Feed (mm/rev) | DOC (mm) | Ra (microns) | Rt (microns) |
|---|---|---|---|---|---|
| 1 | 80 | 0.103 | 0.3 | 0.91603 | 6.8265 |
| 2 | 80 | 0.206 | 0.6 | 1.8047 | 10.987 |
| 3 | 80 | 0.296 | 0.9 | 2.1827 | 20.4166 |
| 4 | 100 | 0.103 | 0.6 | 0.8254 | 5.8002 |
| 5 | 100 | 0.206 | 0.9 | 2.245 | 18.2658 |
| 6 | 100 | 0.296 | 0.3 | 1.8053 | 14.1863 |
| 7 | 120 | 0.103 | 0.9 | 1.9132 | 13.17266 |
| 8 | 120 | 0.206 | 0.3 | 3.0085 | 16.7439 |
| 9 | 120 | 0.296 | 0.6 | 2.5137 | 14.7867 |

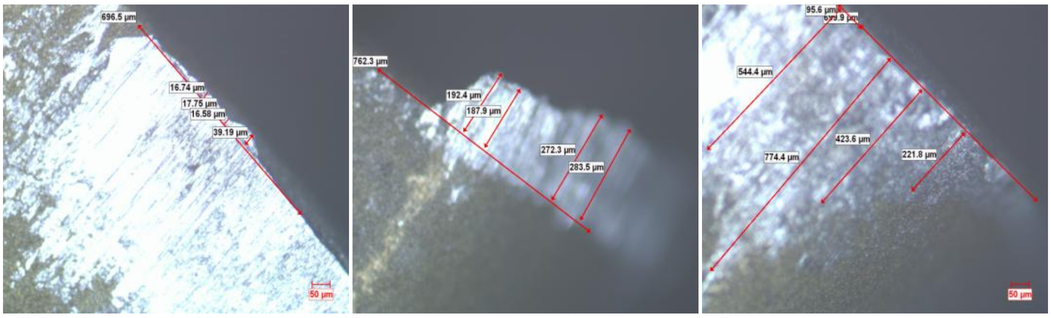

**Fig.1 Tool wearprogression with increasing cutting speed**

The experimental results were analyzed with analysis of means (ANOM). The analyses have been done by using the statistical software MINITAB. Analysis of means (ANOM) is the process of estimating the factor effects. Based on the ANOM, one can derive the optimum combination of the cutting parameters [15]. Irrespective of the objective function whether maximization or minimization, the larger S/N ratio corresponds to the better quality characteristics. Therefore, the optimal level of the process parameters is the level with the highest average S/N ratio. Based on both mean and S/N ratio values, the optimal level setting is explained below:

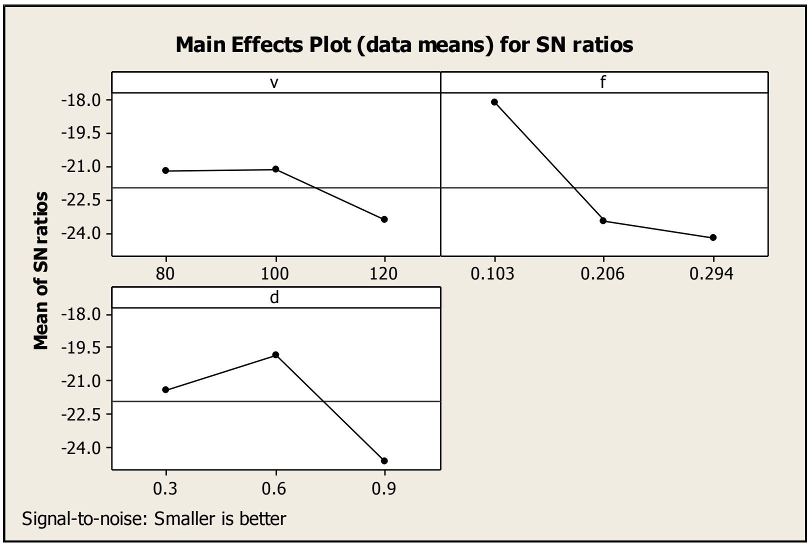


**Fig. 2 S/N ratio main effects plot for $R_a$**

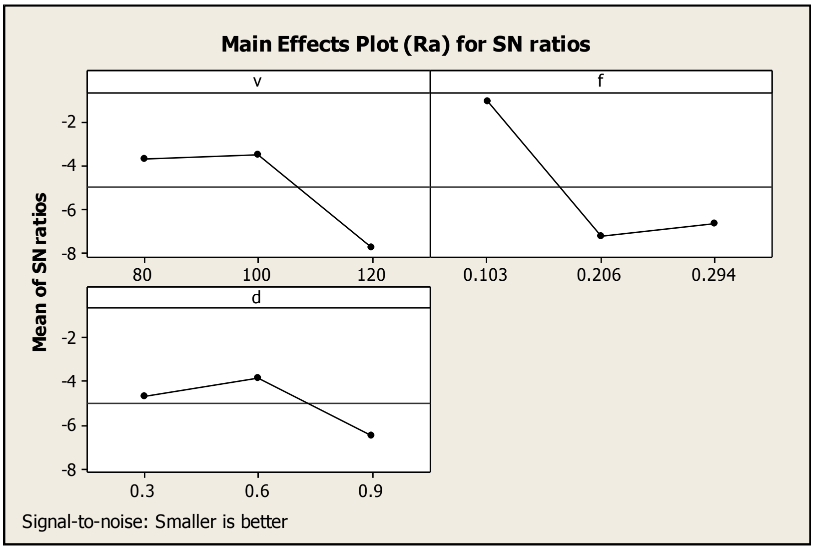


**Fig. 3 S/N ratio main effects plot for $R_t$**

**Table.4 Response table for S/Noise $R_a$**

| Level | V | F | D |
|---|---|---|---|
| 1 | -3.715 | -1.069 | -4.645 |
| 2 | -3.496 | -7.240 | -3.823 |
| 3 | -7.736 | -6.6639 | -6.480 |
| Delta | 4.240 | 6.171 | 2.657 |
| Rank | 2 | 1 | 3 |

**Table.5 Response table for S/Noise $R_t$**

| **Level** | **V** | **F** | **D** |
|---|---|---|---|
| 1 | -21.23 | -18.12 | -21.40 |
| 2 | -21.18 | -23.51 | -19.83 |
| 3 | -23.42 | -24.21 | -24.61 |
| Delta | 2.24 | 6.10 | 4.78 |
| Rank | 3 | 1 | 2 |

From Fig 2, it is observed that optimum $R_a$ value occurs at 100m/min cutting speed, 0.206mm/rev feed and 0.6mm depth of cut as these parameters possess the highest average S/N ratio values. From the table 4, it is observed that the order of dependence of machinability on cutting parameters is Feed, Cutting Speed and Depth of cut.Similarly, from Fig 3, it is observed that, optimum $R_t$value occurs at 100m/min cutting speed, 0.103mm/rev feed and 0.6mm depth of cut. From the table 5, it is observed that the order of dependence of machinability on cutting parameters is feed, depth of cut, cutting speed.

## 4. Analysis of variance

The experimental results were analysed using analysis of variance(ANOVA) for identifying the significant parameters affecting the performance measures[14]. From the tables we can conclude that F ratio factor for feed rate is higher than the other parameters for affecting surface roughness $R_a$ and $R_t$. It is found that, percentage contribution of influencing factor feed is 56% for both $R_a$ and $R_{t.}$ Consequently, percentage contribution of cutting speed is 36% for $R_a$ and 4.7% for $R_t$.Percentage contribution of depth of cut is 6% for Ra and 37.4 for $R_t$.

**Table.6Analysis of Variance for Ra**

| Source | df | SS | MS | F | %P |
|---|---|---|---|---|---|
| V | 2 | 1.4404 | 0.7202 | 33.82 | 36.0 |
| F | 2 | 2.2222 | 1.1111 | 52.18 | 56..0 |
| D | 2 | 0.2389 | 0.1194 | 5.61 | 6.0 |
| Error | 2 | 0.0426 | 0.0213 | | 2.0 |
| Total | 8 | 3.9441 | | | 100 |

**Table.7 Analysis of Variance for Rt**

| Source | df | SS | MS | F | %P |
|---|---|---|---|---|---|
| V | 2 | 9.28 | 4.64 | 2.52 | 4.7 |
| f | 2 | 108.44 | 54.22 | 29.45 | 56 |
| d | 2 | 72.04 | 36.02 | 19.56 | 37.4 |
| Error | 2 | 3.68 | 1.84 | | 1.9 |
| Total | 8 | 193.44 | | | 100 |

Where, df- Degree of freedom, SS- Sum of squares, MS- Means square, F- Fisher ratio, %P- Percentage contribution.

## 5. Conclusions

This paper has discussed an application of the Taguchi method for optimizing the cutting parameters in turning operations. From this investigation, following conclusions are drawn:

- Feed rate is most significant factor which has maximum level difference (Max-Min) value of 6.1 when the minimization of the surface roughness is considered.
- From the analysis of variance it is shown that the error value is 2% (approximately).
- This study concluded that optimum cutting speeds and optimum depth of cuts provide for higher surface finish.
- In addition, tool wear analysis shown that the removal of coating on the tool wear gradually increased and there is almost zero wear of the tool.

As reported in this study, the Taguchi method provides a systematic and efficient methodology for the design optimization of the cutting parameters with far less effortthan would be required for most optimization techniques. It has been shown that surface roughness can be improved significantly for turning operations. The improvement of surface roughness from the initial cutting parameters to the optimal cutting parameters is realized with this approach.

## References

1. D.B. Miracle and B. Maruyama, "Metal Matrix Composites for Space Systems: Current Usesand Future Opportunities," *Proceedings of National Space and Missile Materials Symposium,* Ed. M. Stropki (Dayton, OH: Anteon Corp.), 2000.
2. Quan Y, Ye B (2003), "The effect of machining on the surface properties of SiC/Al composites". J. Mater.Process. Tech. 138:464–467.

3. Y. Zhu, H.A. Kishawy,"Influence of aluminaparticles on the mechanics of machining metal matrix composites", Int. J. Mach. Tools Manuf., 45 (2005), pp. 389–398.
4. M.K. Brun, M. Lee, F. Gorsler, "Wear characteristics of various hard materials for machining SiCp reinforced aluminium alloy", Wear, 104 (1985), 21- 29.
5. Ding X, Liew WYH, Liu XD "Evaluation of machining performance of MMC with PCBN and PCD tools", Wear, 259(2005), 1225–1234.
6. PuneetBansal,LokeshUpadhyay "Experimental Investigations To Study Tool Wear During TurningOf Alumina Reinforced Aluminium Composite", Procedia Engineering 51 (2013) 818 – 827.
7. Tamer Ozben, ErolKilickap, Orhan C¸ akır "Investigation of mechanical and machinability propertiesofSiC particle reinforced Al-MMC", journal of materials processing technology 198 (2008) 220–225.
8. Y. Sahin, M. Kok, H. Celik(2002)," Tool wear and surface roughness of Al2O3 particle-reinforced aluminium alloy composites", J. Mat. Process. Tech., 128, 280 – 291.
9. GeYingfeia, XuJiuhuab, Yang Huic(2010),"Diamond tools wear and their applicability when ultra-precision turning of SiCp/2009Al matrix composite", Wear,Vol.269, No.11–12, 699–708.
10. Metinkok, "A Study on the machinability of AL2O3 Particle reinforced Aluminum Alloy Composite" International inorganic- Bonded Fiber Composites Conference (2008) 11:272-281.
11. Montgomery Douglas C., "Design and analysis of experiments", Wiley India (P) Ltd, New Delhi, 2007.
12. Quazi t z, Pratik More, Vipulsonawane "A case study oftaguchi method in optimization ofturning parameters", International Journal of Engineering Research and Applications (IJERA), Vol. 1, Issue 4, pp.1268-1273.
13 M.Seeman, G.Ganeshan, R.karthikeyan, A.Velayudham (2009)," Study on tool wear and surface roughness in machining of particulate aluminium metal matrix composite-response surface methodology approach",The International Journal of Advanced Manufacturing Technology, Vol. 48, Issue 5-8, pp. 613-624.
14. Rama Rao. S, Padmanabhan. G (2012), "Application of Taguchi methods and ANOVA in optimization of process parameters for metal removal rate in electrochemical machining of Al/5%SiC composites",International Journal of Engineering Research and Applications (IJERA) Vol. 2, Issue 3, pp. 192-197.
15. R.Ramanujam, K.Venkatesan, S.Vjayan, R.Raju, "Multi-response optimization of machining parameters in turning hybrid metal matrix composites reinforced with Graphite particles for tribological applications", International Journal of Applied Engineering Research, Vol.8 (11), 2013, pp.1315-1326.