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Machinability of Hybrid Metal Matrix Composites – Review

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ABSTRACT
The paper concentrates on the review of the machinability of various Hybrid Metal Matrix composite. It is well known that selection of suitable controllable parameters and its effective control to get desired output is an important process. In this regard, many researchers have made valiant efforts to identify those parameters that affects the entire outcome of the work and their appropriate levels to attain desired output. So, this work will conduct a review on turning of Hybrid metal matrix composites and their outcomes to help further in-depth studies.
KEYWORDS: Hybrid Metal Matrix composite, Machinability, Desired output, Control, Turning

TURNING

The process of removal of excess material by rotating the workpiece is called Turning Operation. It can be done in a traditional form of Lathe machine that requires continuous supervision by the operator. Also turning operation can be done by CNC lathe machine. The starting material is based on workpiece generated by other processes like casting, forging, drawing and extrusion.

Turning is the most common method for lathe machining operation. During this process, the cutting tool removes the material from the outer diameter of workpiece. The objective of turning process is to reduce the diameter of the workpiece for required dimension.

Dynamics of Turning

The dynamics of turning process is based on two major principals.

They are

- **Force**
  - Cutting or tangential force
  - Axial or feed force
  - Radial or thrust force
- **Speeds and feeds**

Force

Cutting or Tangential Force acts downward on the tool tip allowing deflection of the workpiece upward. It supplies the energy required for the cutting operation and the specific cutting force required to cut the material is called specific cutting force. Cutting force depends on the materials. Axial or Feed Force acts in the longitudinal direction. It is also called the feed force because it is in the feed direction of the tool. This force tends to push the tool away from the chuck. Radial or Thrust Force acts in the radial direction and tends to push the tool away from the workpiece.

Speeds and Feeds

Speeds and feeds for turning are chosen based on cutter material, workpiece material, setup rigidity, machine tool rigidity and spindle power, coolant choice, and other factors. The distance the tool advances into the material in one revolution is called "feed". It is specified as mm per revolution (mm/rev). Figure (1) shows the process of Turning operation.

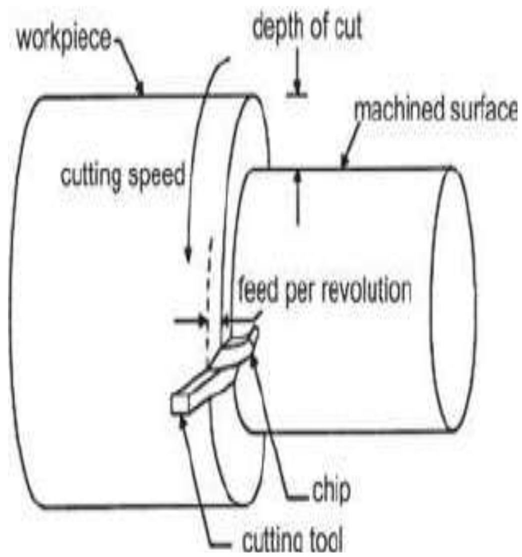

Fig (1) Turning operation

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Types of Turning Operation

- Step turning
- Taper turning
- Chamber turning
- Contour turning

Step Turning

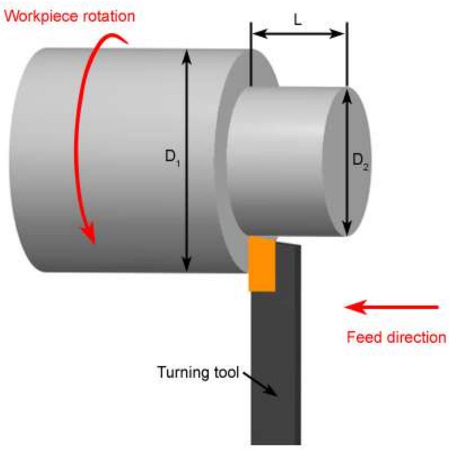

Fig (2) Step turning

Step turning is a turning process in which series of steps having different diameters is produced with the lathe machine. It creates two surfaces with an abrupt change in diameters between them. The final feature resembles a step. Figure (2) shows the Step turning process.

Taper Turning

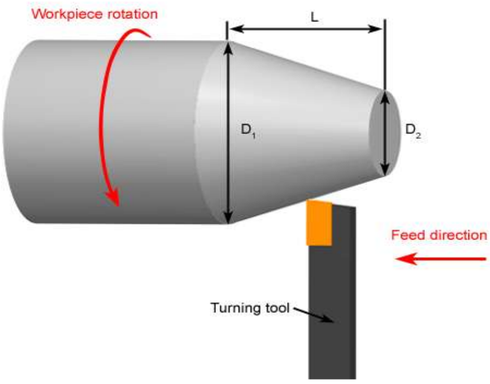

Fig 3 Taper turning

Taper turning is the turning process in which the cutting tool moves at an angle to the axis of the workpiece so that a tapered shape is obtained in the workpiece. It produces a ramp transition between the two surfaces with different diameters due to the angled motion between the workpiece and a cutting tool. Figure (3) shows the Taper turning process.

Chamber Turning

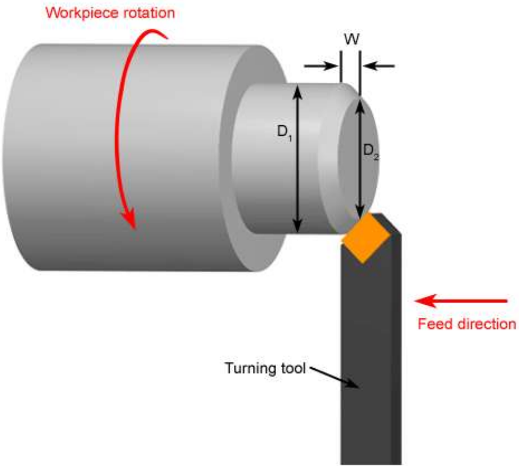

Fig (4) Chamber turning

Chamfering is the operation of beveling the extreme end of the work piece. The form tool used for taper turning may be used for this purpose. Chamfering is an essential operation after thread cutting so that the nut may pass freely on the threaded work piece. Similar to the step turning, chamfer turning creates angled transition of an otherwise square edge between two surfaces with different turned diameter. Figure (4) shows the Chamber turning process.

Contour Turning

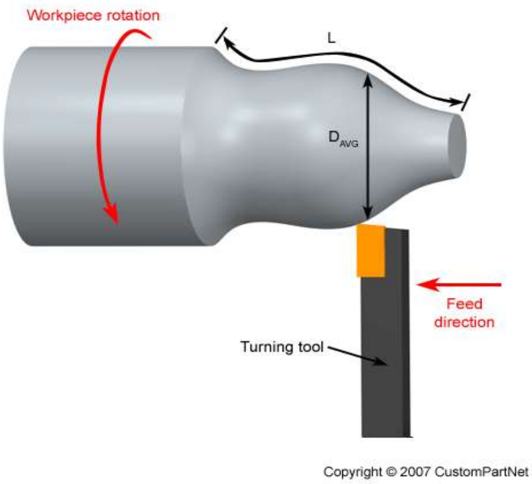

Fig (5) Contour turning

Contour turning is usually performed on a CNC lathe. Historically, tracers were used to create irregular shapes on a lathe. In contour turning operation, the cutting tool axially follows the path with a predefined geometry. Multiple passes of a contouring tool are necessary to create desired contours in the workpiece. However, form tools can produce the same contour shape is a single pass. Figure (5) shows the Contour turning process.

Advantages of Turning Process
- Materials are compatible.
- High tolerance.
- Time less.
- High skilled operator is not required.
- Material removal rate is flexible.

Disadvantages of Turning Process
- Limited to the rotational parts.
- High cost.
- Tool wear is significant.
- Scrap is produced.

Applications of Turning Process
- Making machine components, shafts and engine components.
- Produce rotational, axisymmetric parts like grooves, threads.

Fig. (6) CNC Machine

Figure (6) shows that the CNC machine.

FINDINGS FROM PREVIOUS WORK

Lavepreet Singh, et al. (2021) [1] This article shows an overview of the manufacturing processes and Different reinforcing elements used during the synthesis of Al-MMCs. Generally, the Reinforced particles like carbides, nitrides, and compounds of oxides are used. This paper gives A brief overview on various methods that are being used to manufacture aluminium metal Matrix composites. The main processing Methods for making or production of aluminium metal matrix composites (AMCs) are Thoroughly discussed.

Kannan, et al. (2020) [2] This paper shows that detailed study on optimization of turning parameters of Al7075/SiC/Gr metal matrix composites. The specimen contains mixtures of 90% of weight of Al7075 and 10 % of weight of SiC and Gr is fabricated by stir casting process. The minimum speed of 40m/min feed rate of 0.100mm/rev, high depth of cut of 0.3mm and material composition of 3% of SiC + 7% of Gr wee found as optimal level. SEM analysis is carried out to study microstructural variations after machining. The test shows that surface finish 16.02% is improved when tool wear and cutting force reduced by 22% and 32.30%.

Wei Bai et al. (2019) [3] This paper shows that particle reinforced metal matrix compsoir3es have good mechanical properties and thermal properties but their poor machinability is drawback for use in wide applications. The material used in SiCp/Al metal matrix composites continuous and Semi-continuous chips are formed.

Harish K. Gaug, et al. (2018) [4] Based onnthis review, the machining of HAMMC (Al/SiC/Gr and Al/Si10Mg/Fly ash/Gr) can be easily machined by EOM process and good surface smoothness can be obtained by controlling machining parameters. The problems caused during machining of HAMMC is overcome by EDM process.

HimaGireeshet al. (2018) [5] The demand for aluminum hybrid metal matrix composites has increased in recent times due to their enhanced mechanical properties for satisfying the requirements of advanced engineering applications. The ceramic particles, such as silicon carbide and aluminum oxide, are the most widely used reinforcement materials for preparing these composites. In this paper, an attempt has been made to prepare an Al6061 hybrid metal matrix composite (HAMMC) reinforced with particulates with different weight fractions of SiC and Al2O3 and a constant weight fraction (5%) of fly ash by a stir-casting processThe outcome of the experimental investigation revealed that the proposed hybrid composite with 20% of total reinforcement material exhibits high hardness, high yield strength, and low wear rate but no considerable improvement in impact strength. omposite increased by 8.2%, the yield strength increased by 36.48%, and the hardness increased by 20%. The increase of SiC and Al2O3 content from 5% to 10% leads to an increase of tensile strength and yield strength of the composite by 10.4% and 25%, respectively. However, the hardness of the composite decreased by 16%. On comparison with the base metal Al6061, the proposed composite exhibits a good improvement in tensile strength, yield strength, and hardness.

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However, no significant change is observed in impact strength.

Natarajet al (2017) [6] This study shows that machining of HMMC is difficult as it contains abrasives which results inn tool wear and vibrations. This study shows the vibration Vx, Vy, Vz were 41.59, 45.17, 26.55 m/s^2 and surface finish Rx, Ry, Rz were 1.76, 3.01, 11.9µm. wrok tool interface temperature 'T' of 51.74^0C where cutting speed 175m/min, depth of cut 0.25mm and feed rate at 0.1mm/rev.

Sai Chaitanya Ksihore, et al. (2014) [7] Al6061-TiC composite with 2% TiC and 4% TiC is produced by reaction K2πF6 and C with molten aluminium. SEM and EDX test were performed to know the present of TiC reinforcement. Vickers hardness test shows that hardness increase with TiC reinforcement. Taguchi design was used for designees the experiments cutting force and surface roughness were less in high cutting speed. Increase in feed rate, depth of cut, increase the surface roughness, flank wear.

Raindra Behera et al. (2013) [8] showed that the Machining parameters such as cutting forces and Surface roughness on Machining of LM6/SiCP metal matrix compsoites at different weigh of SiCp. Machining was carried out at a different cutting speed and depth of cuts at constant feed rate 0.05mm/rev. it is found that depth of cut and cutting speed at constant feed rate affects the surface roughness ad cutting forces during turning operation. It shows that high weight during turning operation. It shows that high weight percentage of SiCp reinforcement impacts a higher surface roughness and needs high cutting forces.

Himansheekala et al. (2014) [9] This paper shows a review on the material and tribiological properties of stir cast aluminium metal matrix composites containing single and multiple reinforcement. There is an increase in mechanical and tribological increase when alumina to aluminium is added also organic reinforcements like fly ash, coconut also improves the tensile and yield strength. Graphite improves the machinability of aluminium.

Poovazhaganet al. (2013) [10] V. hybrid nanocomposites based on aluminium alloy 6062 reinforced with SiuC and B4C. The cast specimens were characterised using SEM study with EOS analysis, hardness test, tendon test and impact test. SEM study shows that presence of SiC and B4C nano particles in aluminium matrix. When compared to normal alloy at room temperature hardness and Tensile strength of hybrid composites increase also decreases ductility and Impact strength. The combination of 1.0 volume % of SiC and 0.5 volume % of B$C gives the superior tensile strength.

Jin Kim, et al. (2019) [11] The MMC is used in various aerospace applications due to improved thermomechanical properties. The SiC reinforced aluminium metal matrix composite is used in this experiment. Machining process is challenge due to its high strength. The machining process is ultrasonically aerated turning of SiCp/Al workpiece then it is compared with conventional turning. UAT has better results.

Chennakesava Reddy, (2012) [12] This review paper illustrates that metal matrix composites in automobile and aerospace sectors due to their mechanical properties and applications. This paper explains briefly on turning operations carried on MMC using uncoated carbide tool and coated tool. Turning was conducted at various speeds, depth of cut and feed rate. It has poor machinability due to nature of reinforcements and hardness due to hardness and volume fraction of particle machinability decreases.

Ketan V, et al. (2018) [13] Based on this review, the machining of HAMMC (Al/SiC/Gr and Al/Si10Mg/Fly ash/Gr) can be easily machined by EOM process and good surface smoothness can be obtained by controlling machining parameters. The problems caused during machining of HAMMC is overcome by EDM process.

Jan C. Aurich, et al. (2016) [14] AMMC are difficult to machine the reinforcement of aluminym using ceramic particles increases tool wear. In the study the silicon carbide reinforcements particles on the surface layer of specimen were investigated on dry turning. The volume percentage (17% and 30%) and particle size (0.6µm and 0.3µm) and their non reinforced material were taken as workpiece. Greater volume particle increases surface roughness and decrease tensile stress. Smaller particle size is low tensile stress. Greater feed decreases tensile stress in surface, but increase the surface roughness.

Baburaj, (2016) [15] This paper explains the effect of turning parameters such as cutting speed, feed rate, depth og cut and cutti9ng tool nose radius on surface roughness of HMMC(Al/SiCp/Flyash). Experiment is based on orthogonal array and surface roughness was tested turned by CNC lathe. ANOVA was performed to know significant parameters. It has found that optimum condition of generic algorithm has better results than orthogonal array result and optimum condition of Taguchi method.

Rajeshkumar Bhushan, et al. (2010) [16] In this study is made to investigate the influence of cutting speed, depth of cut, feed rate on surface roughness during machining of Al7075 alloy and 10% weight of SiC. MMC experimental is done in CNC machine using tungsten carbide and polycrystal line diamond crystal inserts. Using tungsten carbide at feed 0.1 to 0.3 mm/rev and depth of cut range from 0.1 to 1.5mm the surface roughness is less than compound to surface roughness at other process parameters. Flank wear of carbide tool increases by factor 2.4 with increase in cutting speed from 180 to 2401 m/min at feed 0.1 mm/rev and depth of cut of 0.5mm.

Rajesh et al. (2016) [17] In this study developed aluminium metal matrix hybrid composite by reinforced aluminium 7075 alloy with silicon carbide (SiC) and aluminium oxide (alumina) by stir casting. The hardness test and wear test were made on the specimen. The results f=shows the addition of SiC and aluminium increase the mechanical properties.

Sucharithaet al. (2019) [18] AA6061 aluminium is foremost material through stir casting. AA6061has been all for 8% of Al2o3. It is made as cylindrical rod. AA6061 with aluminium oxide bolstered metallic matrix composites. The outcome parameters include cutting velocity, cutting force, feed rate intensity of cut is analysed by turning of aluminium matrix composites.

Metinkok (2008) [19] The machnicablity of Al2024/Al2o3 composite was analysed in terms of tool wear, tool life and surface roughness by turning specimen with Tin(k/o) coated and Hx uncoated carbide include in different cutting condition. Test results shows that tool life decreases with increasing cutting speed for both cutting tools but tool life of TIN(k/o) tool life was longer than Hx uncoated tool. The optimum surface roughness of workpiece was obtained at the cutting speed of 160m/min.

Sidappaet al. (2018) [20] AMMC have a combination of different superior properties compared to unreinforced matrix. This study shows the machinability parameters of Al6061/TiC MMC. The reinforced material is TiC particles is added in weight proportion of 3,6,9,12% through stir casting method. Cutting forces is obtained from varying cutting speed, feed rate and depth of cut for each % weight fraction. The result shows that cutting force increase with increase of feed rate and decrease with increase of cutting speed on all weigh fraction.

Manna, et al. (2004) [21] This paper gives an experimental investigation on the influence of cutting conditions on surface finish during turning of cutting conditions on surface finish during turning of Al/SiC-MMC. In this study Taguchi method is used to optimize the cutting parameters for turning Al/SiC-MMC. ANOVA is used to investigate the influence of cutting speed, feed rate, depth of cut.

Muthukrishnanet al. (2008) [22] This study machinability of A356/SiC/10p for turning using medium grade polycrystals tallies diamond (PCD-1500) inserts. Experimental were conducted on CNC lathe using PCD-1500 insert at various cutting conditions and parameters such as surface roughness. Tool wear were measured results show that PCD is best suitable for machining MMC at high cutting speed, good surface finish is obtained.

Seeman, et al. (2010) [23] In this study has made to model the machinability evaluation through surface methodology in machine of homogenized 20%. SiCpLM25 AlMMC. These effects of machining parameters like cutting speed, feed rate, depth of cut and machining time on basic of two performance characteristics of flank wear (VBnox) and surface roughness were investigated.

Tamizharasan, et al. (2019) [24] Effect of turning parameters on chip generation during machining aluminium composite is studied in this work. Turning of Al-4%, Cu-7.5% SiC composites is chosen as workpiece. Chips produced during machining were studied by measuring thickness and to determine chip thickness ratio 99.85% pure aluminium was added with 4% volume fraction of copper and with silicon carbide of 7.5%. From the analysis cutting speed influence the chip formation by 64.13% containing with depth of cut 35.26% was identified.

Suresh, et al.(2014) [25] The study attempts to find that optimal level of machining parameters in turning Al-SiC-Gr hybrid composites. The composite with 5%, 7% and 10% equal mass of fraction of SiC-Gr particle were used and tensile value Au170, 210, 204 Mpa. Al-10% (SiC-Gr) provides butter machinability when compared to 5 and 7.5 of SiC-Gr.

Bhattacharyya, et al (1995) [26] This study shows the machinability of AMMC (359/SiC/20P) with PCD insert, the cutting speeds Au 300, 500, 700 m/min^{-1} and feed rate of 0.1, 0.2, 0.4 mm rev^{-1} while depth of cut is 0.5mm. The time required to reach the tool wear limit decreased with increase of speed and feed. The volume of material removed before reaching the wear limit actually increase with the high feed rate.

Muhammed Yuruf, et al. (2014) [27] The present work is concerned with the effect of cutting parameters on the surface roughness and the chip formation in turning process. The machining results are compared with LM^ aluminium alloy and TiC reinforced metal matrix composite under same cutting condition. Results show the surface roughness of LM6-TiC are higher as compared to LM6 alloy at similar cutting condition with increasing inn cutting speed improves the surface quality. Surface quality increase with decrease of the feed rate and depth of cut.

M. Nataraj, et al. (2017) [28] The study is to evaluate the machining characteristics of hybrid metal matrix Composite, and a mathematical model was developed to know, surface finish, intensity of vibration and work-tool interface temperature for Known cutting condition while machining was performed in CNC lathe. Response surface methodology was employed to formulate a mathematical model. The experimental study inferred that the vibration in Vx, Vy, and Vz were 41.59, 45.17, and 26.45 m/s2, respectively, and surface finish Ra, Rq, and Rz were 1.76, 3.01, and 11.94 µm, respectively, with work-tool interface temperature 'T' of 51.74 °C for optimal machining parameters, say, cutting Speed at 175 m/min, depth of cut at 0.25 mm and feed Rate at 0.1 mm/rev during machining. Experimental results were in close conformity with response surface method overlay plot for responses.

Elisa Battistoni, et al. (2013) [29] In this paper we investigate the possible relationships among some optimization techniques used in Operations Management and the performance of SMEs that operate in the manufacturing sector. A model based on the Structural Equation Modelling (SEM) approach is used to analyse a dataset of small and medium-sized Italian enterprises. Our research highlights the importance of Operations Management for Italian SMEs operating in the manufacturing sector: OM practices are relevant indicators of these firms' performance. Model II points out the value of this positive association – to be carefully taken into account by management, in order to implement best practices that can affect revenue and internal efficiencyOur results are consistent with previous studies even if highly focused on the specific context of Italian SMEs. We suggest further research to further investigate the relationship between OM SC and performance, which is not significant in our case study, probably because of the proxy indicators used to express performance.

Halim NAGEM FILHO, et al. (2003) [30] This study evaluated the effect of surface finishing methods on the average surface roughness of resin composites. Seven composites and two polishing systems were used. One hundred and twenty-six conical specimens of each material were prepared in stainless steel molds against a polyester strip. Forty-two of them remained intact and were used as controls. Each half of the remaining samples was polished with either diamond burs or diamond burs + aluminum oxide discs. The results showed no statistical difference in average surface roughness (Ra, µm) between the polyester strip and aluminum oxide discs ($p>0.05$). However, finishing with diamond burs showed a statistically higher average roughness for all composites ($p<0.05$). Statistical differences were detected among materials ($p<0.05$) in the use of diamond burs. The flexibility of the backing material in whichthe abrasive is embedded, the hardness of the abrasive,and the grit size determine surface roughness.

CONCLUSION

1) The common input parameters are Cutting speed, Feed rate, Depth of cut and so on.
2) The common output parameters considered on the above operations are Surface Roughness, Tool wear, Power consumed, Specific power, Tool life, Chip Thickness Ratio, Feed wear.
3) Powders like Aluminium carbide and Titanium carbide are used.
4) Composites made of base material AA 8011, Reinforced material with TiC and Mica has not been evaluated for machinability.
5) For Aluminium, most preferred method is Stir casting.
6) The problems associated with turning hybrid metal matrix composites are
   i. Increased Surface Roughness while machining aluminium-based metal matrix composites.
   ii. Material Removal Rate is low when machining aluminium-based metal matrix composites.
   iii. Cutting force is uneven while machining aluminium-based metal matrix composites.

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