Optimization of Cutting Parameters for Aluminum and Silicon Carbide Composite using Taguchi’s Techniques

V.P.Krishnamurthy¹ M.Magudeswaran² S.A.Srinivasan³ K.Rubha⁴ K.Kokilavani⁵
¹,²,³Assistant Professor ⁴,⁵Student
¹,²,³,⁴,⁵Department of Mechanical Engineering
¹,⁴,⁵Sasurie College of Engineering, Vijayamangalam Tamilnadu-638056, India. ²,³Nandha College of Technology, Erode, Tamilnadu, India-638052

Abstract—Metal –Matrix composites (MMCs) are relatively new class of materials characterized by lighter weight and greater wear resistance than conventional materials. Considering that cutting conditions regulate the machining process, through developed cutting forces, the surface finish of the pieces for machining and tool life, it becomes of high importance for the optimization of machining parameters. MMC material is prepared by using the furnace. The prepared material involves the drilling process, at the time speed, feed and depth of cut are the input parameters mean while surface finish, thrust force, torque and tool wear are the output parameters. Output is obtained by connecting the drill tool dynamometer is connected with the Radial drill machine. The cutting tool wear is measured with a Mitutoyo shop microscope with 30x magnification and 1 µm resolution. The surface finish is evaluated with a profilo meter. The machining parameters are tabulated by using Taguchi techniques. Point out the optimal solution from the tabulated values. Composite materials becoming an essential part of today’s materials because they offer advantages such as low weight, corrosion resistance, high fatigue strength, faster assembly, etc., composites are used as materials in making aircraft structures to golf clubs, electronic packaging to medical equipment and space vehicles to home building.

Key words: Metal –Matrix composites (MMCs), Taguchi’s Techniques, Matrix Alloy Systems

I. INTRODUCTION

Metal composite materials have found application in many areas of daily life for quite some time. Often it is not realized that the application makes use of composite materials. These materials are produced in situ from the conventional production and processing of metals. Here, the Dalmatian sword with its meander structure, which results from welding two types of steel by repeated forging, can be mentioned.

Materials like cast iron with graphite or steel with a high carbide content, as well as tungsten carbides, consisting of carbides and metallic binders, also belong to this group of composite materials. For many researchers the term metal matrix composites is often equated with the term light metal matrix composites (MMCs). Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications. In traffic engineering, especially in the automotive industry, MMCs have been used commercially in fiber reinforced pistons and aluminum crank cases with strengthened cylinder surfaces as well as particle-strengthened brake disks.

These innovative materials open up unlimited possibility science and development; the characteristics of MMCs can be designed into the material, custom-made, dependent on the application. From this potential, metal matrix composites fulfill all the desired conceptions of the designer. This material group becomes interesting for use as constructional and functional materials, if the property profile of conventional materials either does not reach the increased standards of specific demands, or is the solution of the problem.

However, the technology of MMCs is in competition with other modern material technologies, for example powder metallurgy. The advantages of the composite materials are only realized when there is a reasonable cost performance relationship in the component production. The use of a composite material is obligatory if a special property profile can only be achieved by application of these materials металл gives the opportunity for unlimited variation. The properties of these new materials are basically determined by the properties of their single components.

A. Various Types of Materials

The reinforcement of metals can have many different objectives. The reinforcement of light metals opens up the possibility of application of these materials in areas where weight reduction has first priority. The precondition here is the improvement of the component properties.

B. The development objectives for light metal composite materials are:

Increase in yield strength and tensile strength at room temperature and above while maintaining the minimum ductility or rather toughness. Increase in creep resistance at higher temperatures compared to that of conventional alloys. Increase in fatigue strength, especially at higher temperatures. Improvement of thermal shock resistance. Improvement of corrosion resistance. Increase in Young’s modulus, Reduction of thermal elongation. To summarize, an improvement in the weight...
specific properties can result, offering the possibilities of extending the application area, substitution of common materials and optimization of component properties. With functional materials there is another objective, the precondition of maintaining the appropriate function of the material.

C. The Following Demands Are Generally Applicable

- Low density,
- Mechanical compatibility (a thermal expansion coefficient which is low but adapted to the matrix),
- Chemical compatibility,
- Thermal stability,
- High Young’s modulus,
- High compression and tensile strength,
- Good process ability,

These demands can be achieved only by using non-metal inorganic reinforcement components. For metal reinforcement ceramic particles or, rather, fibers or carbon fibers are often used. Due to the high density and the affinity to reaction with the matrix alloy the use of metallic fiber usual fails. Which components are finally used, depends on the selected matrix and on the demand profile of the intended application. Information about available particles, short fibers, whiskers and continuous fibers for the reinforcement of metals is given, including data of manufacturing, processing and properties. The production, processing and type of application of various reinforcements depends on the production technique for the composite materials, see. A combined application of various reinforcements is also possible (hybrid technique).

D. Matrix Alloy Systems

The selection of suitable matrix alloys is mainly determined by the intended application of the composite material. With the development of light metal composite materials that are mostly easy to process, conventional light metal alloys are applied as matrix materials. In the area of powder metallurgy special alloys can be applied due to the advantage of fast solidification during the powder production. Those systems are free from segregation problems that arise in conventional solidification. Also the application of systems with oversaturated or meta stable structures is possible. Examples for matrix configurations are given:

![Fig. 1: Production and Metal Matrix Composites](image1)

![Fig. 2: Production and Processing Of Metal Matrix Composites](image2)

Metal matrix composite materials can be produced by many different techniques. The focus of the selection of suitable process engineering is the desired kind, quantity and distribution of the reinforcement components (particles and fibers), the matrix alloy and the application.

By altering the manufacturing method, the processing and the finishing, as well as by the form of the reinforcement components it is possible to obtain different characteristic profiles, although the same composition and amounts of the components are involved. The production of a suitable precursor material, the processing to a construction unit or a semi-finished material (profile) and the finishing treatment must be separated. For cost effective procedures are used, which can minimize the mechanical finishing of the construction units.

In general the following product engineering types are possible:

- Melting metallurgical processes infiltration of short fiber partial or hybrid performs by squeeze casting, vacuum infiltration or pressure infiltration reaction infiltration of fiber- or particle performs processing of precursor material by stirring the particles in metallic melts, followed by sand casting, permanent mold casting or high pressure die casting
- Combination of Materials for Light Metal Matrix Composites
- Powder metallurgical processes pressing and sintering and/or forging of powder mixtures and composite powders
extrusion or forging of metal-powder particle mixtures
extrusion or forging of spraying compatible precursor materials
Hot isostatic pressing of powder mixtures and fiber clutches
Further processing of precursor material from the melting metallurgy by thixocasting or -forming, extrusion forging, cold massive forming or super plastic forming
Joining and welding of semi-manufactured products
Finishing by machining techniques
Combined deformation of metal wires (group superconductors).

Melting metallurgy for the production of MMCs is at present of greater Technical importance than powder metallurgy. It is more economical and has the advantage of being able to use well proven casting processes for the production of MMCs. Shows schematically the possible methods of melting metallurgical production. A composite material is a material composed of two or more distinct phases (matrix phase and dispersed phase) and having bulk properties significantly different from those of any of the constituents.

E. Metal Matrix Composites (MMC)

Metal Matrix Composites are composed of a metallic matrix (aluminum, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase.

F. Applications of Metal-Matrix Composites

Metal-Matrix Composites (MMCs) could claim only a few significant applications as recently as the 1980s. None of these were aeronautical applications. Since that time, however, dramatic advancements have been made in the areas of material and process development, design, manufacturing scale-up, and certification of MMCs.

As a result, a number of significant MMC applications are now in service in the aeronautical field. Metal-matrix composites are used in both military and commercial aeronautical systems. Major applications exist for aero structural and parts in aero propulsion systems, and a growing number of uses in aeronautical subsystems is evident. The current generation of MMC applications largely includes structural components and applications for thermal management, but important applications for wear resistance have also been considered.

a) Aero structural Applications
   - Ventral Fin.
   - Fuel Access Door Covers
   - Helicopter Blade Sleeve
   - TMC Nozzle Actuator Piston Rod.

b) Aero propulsion Applications
   - Fan Exit Guide Vane.

c) Aeronautical Subsystem Applications
   - T-1 Racks.
   - Hydraulic Manifold in V-22 Osprey Tilt rotor and F-18 E/F.

II. LITERATURE REVIEW

A. Study of Drilling Metal –Matrix Composites Based on the Taguchi Techniques

This paper presents the study of influence of cutting parameters (cutting velocity and feed rate) and cutting time on drilling metal matrix composites. In this experiment MMC material is chosen. Dynamometer is fitted with radial drilling machine to evaluate the torque (B) and feed force (F). The specific cutting pressure (ks) was calculated using the equation $ks = 8B/fd^2$. Where B is the torque, ‘f’ feed rate and ‘d’ the diameter of the drill. The cutting tool wear was measured with a Mitutoyo optical microscope with 30X magnification and 1 µm resolution. The holes surface roughness was evaluated with a profilometer.

B. Optimization of cutting conditions in machining of aluminum matrix composite was using a numerical and experimental method.

In this paper, a methodology aiming at the selection of optimized values for cutting conditions in machining process as turning and drilling aluminum matrix composites is proposed. The machining forces, the surface finish and the tool wear are experimentally measured considering the feed and the cutting velocity as pre-determined parameter. At the end of this work we thought of establishing a few valid conclusions for drilling MMCs considering the methodology used. Cutting time is the factor which has influence on the tool wear (50%) followed by feed rate (24%). Feed rate is the cutting parameter which has greater influence on the specific cutting pressure (63%) followed by cutting velocity (14%) and cutting time (14%). Feed rate is the cutting parameter which has greater influence on surface roughness (43%) followed by cutting velocity (41%). The interaction cutting velocity/feed (14%) is the most important to the interaction analyzed in the holes surface roughness.

The error associated to the ANOVA table (maximum value 1.9% and minimum 0.3%) for the factors and the coefficients of regression obtained with the multiple regression (maximum value 0.86% and minimum 0.82) shows that satisfactory correlation was obtained.
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The confirmation tests showed that error associated to tool wear (maximum value 7.5% and minimum 3.1%) and holes surface roughness (maximum value 10.1% and minimum 6.3%) is higher than the error associated with the specific cutting pressure (maximum value 2.3% and minimum 2.8%).

C. Optimization of Cutting Conditions in Machining Of Aluminum Matrix Composites Using a Numerical and Experimental Model

In this paper, a methodology aiming at the selection of optimized values for cutting conditions in machining process as turning and drilling aluminum matrix composites is proposed.

The machining forces, the surface finish and the tool wear are experimentally measured considering the feed and the cutting velocity as pre-determined parameter. The optimization based on genetic algorithms has proved to be very useful dealing with discrete variables defined on a population of cutting condition values obtained from time scale dependent experiments.

The obtained results show that machining (turning and drilling) of composite materials made of metal materials with PCD tools is perfectly compatible with the cutting conditions for cutting time of industrial interest and in agreement with the optimal machining parameters (cutting forces, work piece surface finish and tool wear). Finally it should be referred that the optimization of machining parameters using numerical and experimental models based on genetic algorithms is a matter of scientific interest and large industrial application.

III. OUTCOMES AND DISCUSSION

By using taguchi techniques using non-linear goal programming the optimal cutting conditions (i.e) optimal cutting speed, feed, diameter of cut, machine time can be found out for different volume fractions of the AL/SiC along with the minimized optimum deviation values and optimum output values i.e goal values.

By analyzing some decision could be taken, depending upon specific conditions of the desired drilling process. Increase in volume fraction increase average drill flank wear linearly in all direction. The increase in volume fraction of SiC increases the specific energy but decreases the surface roughness.

The increase in drill speed increases the flank wear. The increase in drill speed decreases the specific energy, but increases the surface roughness. The increase in feed rate increases the specific energy and wear. The increase in drill diameter has less effect on specific energy and has no effect on surface roughness.

IV. CONCLUSION

The application of multi-objective optimization, which is based on an a Taguchi Method, increases the flexibility on selecting the optimal cutting parameters for drilling processes of composite materials. Simultaneously considering productivity and surface quality, as optimization objectives, one can choose the most adequate solution for each particular operation.

After a computational experimentation the proposed Taguchi Method is found to yield much better quality solutions.

REFERENCES