ISSN: 2278-0181
ETEDM - 2018 Conference Proceedings

Review on Aluminum Oxide(Al_2O_3) – Zirconia(ZrO_2) Nano Particle Reinforced Nickel based Metal Matrix

Dr. S. R. Rajabalayanan [1 *] Sundaramoorthy. R[2], Justin Maria Hillary[3]
[1]Professor & Head, Dept of Mechanical Engineering, Hindusthan Institute of Technology,Coimbatore.
[2]Asst Professor, Dept of Mech Engg, Hindusthan Institute of Technology, Coimbatore, Tamilnadu, India.
[3]Asst Professor, Dept of Mech Engg, Hindusthan Institute of Technology, Coimbatore, Tamilnadu, India.

***Abstract*:- Most of the Industries are utilizing Nickel based alloys, which are light weight, having good excellent mechanical strength, resistance to thermal creep deformation, good surface stability, and resistance to corrosion or oxidation. High machinability and workability of nickel alloys are prone to porosity due to gases dissolved during melting processes. However, in the engineering application still have some problems such as Nickel-base super alloys are generally known to be one of the most difficult materials to machine because of their high hardness, high strength at high temperature, affinity to react with the tool materials and low thermal diffusivity. The microstructure can be modified and mechanical properties can be improved by alloying, cold working and heat treatment in this regards, this paper reports the influences of some alloying elements on the microstructures and mechanical properties of Nickel-Aluminum Oxide, Zirconium alloys and its composites.**

Keywords: Nickel- Al2O3-Zirconia alloys, CNC machining, Composites, Ceramic reinforcements.

1. INTRODUCTION

The implementation of metal matrix composites (MMCs) into jet engines of aircraft provides a multitude of benefits, and drastically increases engine efficiency. The enormous turbines, compressors, and shrouds of most current jet engines are constructed from nickel based super alloys. MMCs, in this case aluminum oxide, zirconium (zro_2) reinforced with nickel, aim to replace these super alloys by offering substantially better thermal capabilities and much lighter weights. Manufacturing these MMC parts has proven to be the biggest challenge in their implementation; however, mass production methods involving numerous heat treatments are becoming more viable. As this process continues to improve, an increasing amount of aircraft engines will be able to use these lighter, more durable parts. A jet engine running with MMC components has shown to yield fuel savings of up to 10% to15% when compared to an engine of traditional nickel based super alloys. This fuel reduction not only saves companies money, but it lessens the harsh carbon footprint of air travel, making MMCs both economic and environmentally sustainable. Aircraft are currently responsible for around 11% of the carbon dioxide emissions released in the United States, and it is estimated that these values will triple by mid-century. The immediate benefits of MMC usage in aircraft engines are apparent, but analyzing the less obvious results is just as necessary. Currently, options for reusing MMCs are slim, but future research may be able to change this. The introduction of MMCs into the aircraft industry is a promising step towards a cleaner future.

Nano machining processes like micro cutting, micro electrical discharge, laser micro machining and focused ion beam machining are widely used in most of the manufacturing industries due to its capability of producing complex geometric surfaces with reasonable accuracy and surface finish along with flexibility and versatility. Proper selection of machining parameter is an important step in process planning in order to build up a bridge between quality and productivity and to achieve the same in an economic way. This paper focuses RSM for the multiple response optimizations in CNC machining operation to get maximum material removal rate, minimum surface roughness and less force. In this work, second-order quadratic models were developed for cutting forces, surface roughness and machining time; considering the speed, feed rate, depth of cut and angle as the cutting parameters using central composite design. Significant parameters are found out by analysis of variance test. The developed models were used for multiple-response optimization by desirability function in conjunction with response surface methodology to determine the optimum machining parameters.

2. ORIGIN OF THE PROJECT

For fields such as rocketry and aviation, the automotive and chemical industries, electrical constructions and many other areas, composites are indispensable in a variety of applications today.

The advantage of composites as structural materials is to obtain a material of a higher strength, toughness, stiffness, but also a higher resistance to creep, corrosion, wear or fatigue compared to conventional materials. In addition, with a suitable combination of components we can also obtain a composite of specific properties (thermal, electrical, optical). The disadvantage of composite materials, in comparison with traditional materials, is its difficult workability and relatively higher price.

The term composite means composed; therefore it should be material that is composed of two or more components. However, this would mean that most natural and synthetic materials and alloys belong to this category. The definition should be clarified.

The matrix combines the individual particles of reinforcement, protecting them against external influences and prevents their violation. The basic function of the matrix is to transmit the external load onto the reinforced phase. For the matrix, a good bond strength with the reinforcing phase material (i.e. perfect wet ability without chemical interaction at the interface of the matrix and reinforcement) is required. Among other requirements for the matrix, a low weight is commonly included. In comparison with the reinforcement phase, a matrix has generally lower strength and greater plasticity.

The reinforcement phase transmits the bulk of the external loads. It is expected to have high strength and a modulus of elasticity E (E is about one order higher than that of the matrix), as well as a small deformation at a fracture with a high proportion of elastic deformation. Regarding the tensile behavior of the composite it is given by the shape, concentration and orientation of reinforcement.

The shape of reinforcement particles can be considered approximately as a sphere (the powder form of reinforcement) or as a cylinder (fibers). Their size and distribution then determine the texture of the composite.

The concentration is a density of the reinforcing phase, expressed in terms of volume or the quantity of weight. It is one of the most important parameters that affect the properties
of the composite material.

The orientation of the reinforcing phase affects the isotropy of the system. If the reinforcing particles have the shape and dimensions in all directions about the same (for example powders), the composite behaves basically as an isotropic material, and therefore its properties are the same in all directions. On the contrary systems reinforced with cylindrical reinforcement (fibers) show anisotropy of properties.

According to the matrix material

- Metal Matrix Composites (reinforced metals, cermets, alloys) - MMC
- Polymer Matrix Composites based on macromolecular substances (reinforced polymers) - PMC
- Ceramic Matrix Composites (ceramic and other inorganic composites: ceramics, glass, carbon) – MMC

According to the structure or geometry of the reinforcement

- dispersive composites - contain very fine particles, dispersion particulate composites (particulate, granular) - contain larger particles of regular shapes (spheres, platelets) or irregular shapes
- fibrous composites - contain long or short fibers that may be oriented or un oriented, be of various origins (glass, carbon, polymeric, textile, etc.)

3. CERAMIC REINFORCEMENTS

Ceramics are inorganic non-metallic materials with a heterogeneous structure. They consist of glass, pores and minerals of different compositions. Material based ceramics have high strength at elevated temperatures and are resistant to oxidation. Their main disadvantage is their brittleness.

Advantages of metal composites (compared with metals)

- low density
- low coefficient of thermal expansion
- higher hardness
- higher temperature and corrosion resistance and even wear resistance
- higher melting point and the stability of mechanical properties in a wide temperature range

Disadvantages of metal composites

- the final product of ceramics cannot be subsequently modified by any thermal or
Mechanical processing
- low fracture toughness
- brittleness
- difficult reproducibility of complex shapes
- difficult bonding of ceramics with each other and with other materials as well

Ceramic matrix composite requirements

- to increase the toughness of the metal matrix
- to even the strength - especially tensile strength, to suppress the dependence of the
Ceramic matrix strength on the type of stress and the dimensions of the components
- to increase the abrasion resistance in extreme conditions
- to increase heat resistance in extreme conditions
- to improve the machine ability of the metal matrix

Particulate metal matrix composites

For the reinforcement of the metal matrix there are suitable only synthetically prepared metal powders based on oxides, nitrides, or carbides respectively borides. Matrices have a similar base; oxides, carbides, nitrides, borides, or graphite as well.

These include the composites systems:
Ceramics - ceramics
Ceramics - metal
Composites based on graphite

Ceramics - ceramics

In ceramics – the metal system there is a secondary metal phase dispersed in the base of a metal matrix. For example in the Si_3N_4 matrix there are dispersed particles of SiC or B_4C. Both phases shall contribute to the improvement of properties for use on the component in the course of applications in aircraft and rocket technology.

Ceramics - metal

These systems are generally referred to as **cermets**. They are oxide or carbide-based (Al2O3, WC, TiC). As cermets is considered a composite material with the content of a metal component of more than 50 %, the rest is metal.

Their properties are a combination of both materials, i.e. good thermal and electrical conductivity, heat resistance, chemical stability. The main areas of their use are the rocketry and aviation industry, electronics, nuclear engineering, mechanical engineering and metallurgy.

Oxide-based cermets (Al2O3-Cr, Al2O3-Fe, Al2O3-W) are used for cutting tools, the thermocouple sleeves etc.

Carbide-based cermets (WC-Co) are used for components with a very high surface hardness, valves, nozzles, accurate gauges.

The systems of ceramics - metal and composites based on graphite are prepared via processes such as sintering or skeletal type of systems where the matrix and the secondary phase are mechanically penetrated and create a so-called skeletal structure.

Graphite-based composites

Composites based on graphite are represented by a graphite skeleton impregnated with metal. Currently, it is the most widely used composite. They have very good mechanical properties and are chemically resistant. They are used for sliding bearings, sealing rings, (the slides of pantographs) on trolleybuses, trams or trains.

Fiber metal matrix composites

Ceramic matrices are brittle, have poor fracture toughness, but on the other hand, they have excellent high temperature properties and chemical resistance. To increase the fracture toughness there are fibers with a higher modulus of elasticity than that of ceramics introduced into the metal matrix. Fibers that are used are metal (tungsten, molybdenum),metal (SiC) and carbon. The strongest types are metallic and metal whiskers.

When using whiskers, the matrix is formed by ceramics based on Al2O3 or ZrO2 and dispersion is formed by whiskers, mostly SiC. There are newly used also Al2O3 whiskers. The composite has high tensile and compressive strength at both normal and high temperatures. Whiskers increase resistance to creep and erosion, and reduce the coefficient of friction.

Short fibers are prepared for example from SiC, Si-Ti-O-C, Al2O3, Si3N4 and other materials. They are used to increase the fracture toughness and reduce the creep of conventional metal matrices from oxide or non-oxide ceramics.

Carbon or graphite fibers can be incorporated into a matrix of a suitable polymer which is subsequently graphitized. A basic semi-finished product with a plastic matrix is produced by conventional methods for the preparation of PMC and further graphitized. Graphitization is a relatively difficult process because fibers must not be degraded during the course. These composites are used for example in the most demanding parts of space shuttles (the leading edge). A carbon fiber must be (also) often protected against oxidation by SiC coating.

Ceramic coatings

Ceramic coatings are applied in difficult operating stress, in an aggressive environment and while working at increased or high temperatures. They provide higher wear resistance, avoid fatigue failure and also serve as an effective heat and corrosion barrier. Commonly used technological processes for their preparation include CVD and thermal spraying. Typical compounds - nitrides (TiN, Si3N4), carbides (TiC, WC, and SiC) and oxides(Al2O3, TiO2, ZrO2, and MgO).

4. CONCLUSION

In this work, Hybrid nickel based composites are produced by conducting DOE and second-order quadratic models were generated and developed for cutting forces, surface roughness and machining time; considering the speed, feed rate, depth of cut and angle as the cutting parameters using central composite design. Significant parameters are found by analysis of variance test. The developed models were used for multiple-response optimization by desirability function in conjunction with response surface methodology to determine the optimum machining parameters with best combination of materials is suggested for replacement of conventional materials to obtains the optimum values to improve their better corrosive and reduced wear rate with low cost.

REFERENCES

[1] Khalid mahmmoodghauri, AkhalqAhamad, Synthesis and Characterisation of Al/Sic Composite made by Stir Casting Method,Pak J.Egg.&Appl.Sci.Vol12,Jan2003.

[2] Rajesh Purohit, R.S. Rana, C.S.Verma, Fabrication of Al-SiC Composite Through Powder Metallurgy Proceesing and Testing of Properties, International Journal of Engineering Rsearch and Application,Vol 2,Issue 3,May-June 2012,pp.420-437.

[3] Suryanarayanank.,RPraveen,s.Raghuraman,Silicon carbide reinforced aluminium metal matrix composite for aerospace application,International Journal of Innovative Rsearch in Science, Engineering and Technology, vol 2 Issue 11,2013.

[4] V. Auradi, Rajesh G.L, S.A. Kori, Processing of B4C Particulate reinforced 6061 Al metal Matrix Composites by melt Steering Involving Two Step Addition, Science Direct, Procedia Material Science 6 (2014) 1068-1076.

[5] Poovazhgan L., Kaliachelvan K, Rajdurai A. and senthilvelanV ,Charaterisation of Hybrid Silicon Carbide and Boron carabide Nanoparticles-Aluminium alloy Composites, Science Direct, Procedia Engineering 64 (2013) 618-689.

[6] David RajaSelvam. J., Robinson Smart D.S. Dinaharan I., Synthesis and characterisation of Al 6061-Fly Ash-SiCpatriculate composite by steer casting and compocasting, Science Direct ,energy procedia 34(2013),637-646.

[7] Rampreet Singh, Er. Rahul Singla, TribologicalCharacterisation of AL-SiC Composite Prepared by Mechanical alloying,

International Journal of Applied Engineering Research, Vol 7 No.11 (2012).
[8] M. Dhanashekhar, V.S. Senthil Kumar, Squeeze Casting of Aluminium Metal Matrix Composites- An Overview, Science Direct, Procedia Engineering97 (2014) 412-420.
[9] Dora Siva Prasad, CintadaShoba, NalluRamanaiah,Investigation on mechanical properties of alulinium hybrid omposites,JMR&T,2014,3(1),79-85.
[10] MohanakumaraK.C,Rajshekhar. H,Ghanaraja.S., Ajitprasad.S.L,Development and Mechanical Properties of SiC reinforced Cast and Extruded Al Based Metal Matrix Composite, Science Direct, Procedia Material Science 5 (2014) 934-93.