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A STUDY ON PROCESS PARAMETER OPTIMIZATION USING POLYMER MATRIX COMPOSITES

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ABSTRACT

The purpose of this study is to demonstrate how, despite the machine tool industry's recent exponential growth in production capabilities, machine tools are still being used to their full potential. This restriction arises from the failure to operate the machine tools under ideal conditions. For a very long time, researchers and practical engineers have been interested in the subject of determining the ideal operating parameter levels. Metal matrix composites are being used more frequently as industrial materials, however since the reinforcements are so hard and abrasive, MMC is very challenging to machine. The MMC is machined as the reinforcement particles are broken and dragged out of the matrix, which results in decreased product surface quality, tool flank wear, and higher machining costs. Additionally, early tool failure increases production time and costs by necessitating frequent tool changes. This method has been suggested by Litak as a way to test the effectiveness of the ripping machine and as a way to keep track of the condition of the tools. Investigating the effects of various machining process factors was the paper's main goal in order to improve the quality of the machined products. The use of the Grey relation, Desirability function, Genetic Algorithm, and Fuzzy logic for multi-response optimization were found to be widely employed, according to a thorough assessment of the literature on the optimization of machining parameters.

As a result, it was also attempted through this research project, and the aforementioned techniques were assessed in order to achieve the goal of choosing the proper process parameters for drilling the Al-SiC MMCs.

KEYWORDS: Reinforcement, Machine Tool Industry, Parameters, Optimization Process**.**

Introduction

Due to their major advantages over other materials, Metal Matrix Composites (MMC) are widely used in technical applications such as the automobile, aircraft, and production of spacecraft and sea vehicles sectors. For many years, composite materials have been one of the main topics of scientific and applied research. However, they have just been used and considered as engineering materials in the last ten years. The knowledge of these materials and their metallurgical behaviour has today made substantial strides.

Because of their high specific strength and stiffness, superior corrosion resistance, light weight design, low thermal conductivity, high fatigue strength, capacity to burn, and resistance to chemical and microbiological attacks, Metal Matrix Composite (MMC) materials are among the most well-known composites. The growing number of MMC applications has led to a significant increase in the importance of research into these materials' machining. Particulate metal matrix composites have outstanding mechanical and thermal qualities, but their low machinability prevents them from replacing metal parts. Since machining is a method of removing material, it is crucial for the last phase of manufacture before application. as a result, the One of the key issues that needs to be resolved is the development of efficient machining techniques that will lower the overall cost of components. To determine the ideal parameters for drilling composite materials, a multi-objective optimization method based on the Taguchi method and utilising a variety of optimization methodologies is presented in this study. The experimental data was used to create the models of the attributes that were employed. This study looked into drilling aluminium silicon carbide (Al/SiC). This study aims to investigate the impact of cutting speed, feed, cut diameter, and machining time on the rate of metal removal, specific energy, surface roughness, volume fraction, and flank wear.

The tests were performed with the L27 orthogonal array, and an effort is made to develop a thorough mathematical model for correlating the interactive and higher-order affects of different machining settings using the Taguchi method.

For the purpose of predicting each characteristic, second order polynomial models for metal removal rate, specific energy, surface roughness, volume percentage, and flank wear were created using SPSS software.

To confirm the sufficiency and fitness of the created mathematical models, analysis of variance (ANOVA) has been done.

The volume fraction increases with an increase in average drill flank wear. Although the surface roughness lowers as the volume fraction of SiC increases, specific energy increases.

With an increase in feed rate, specific energy and flank wear rise. As drill speed increases, flank wear also increases. While increasing surface roughness, drilling speed decreases specific energy. The models were made simpler by removing the irrelevant terms using the T-test.

In many cases, combining several materials produced better goods. Composites have been created by combining various materials. There isn't a single, accepted definition of "composite materials" as of yet. Any substance that comprises of two or more materials that are purposefully combined to create heterogeneous structures with designed or intended could be described in this way. Those are the two stages of composite materials:

I. Matrix phase.

II. Reinforcement phase.

Matrix Phase

The matrix performs two crucial tasks. In response to an applied force, it deforms and distributes the stress to the constituents of the reinforcement phase. The matrix itself can occasionally act as a key to strengthen the element. This happens certain metal matrix composites. Metals and polymers have both proven to be quite effective as potential matrix materials. With varied degrees of effectiveness, inorganic materials like glass, plastic, Portland cement, carbon, and silicon have also been employed as matrix materials.

Types of matrix materials

i. Metal Matrix Materials.

ii. Polymer Matrix Materials.

iii. Ceramic & glass matrix materials.

iv. Carbon / Graphite matrix materials.

Metal Matrix Materials

An MMC is a composite material in which one of the constituents is a metal or alloy that forms at least one percolating network, while the other ingredient is immersed in this metal matrix and typically acts as reinforcement. In MMC, the reinforcement may take the form of fibres, whiskers, or particles with volume fractions ranging from 0% to 40%. Typically, the metal matrix composites are made of the alloy 2124 aluminium. The silicon carbide particles are adhered to the soft aluminium alloy. Bonding material's primary purpose is to reinforce and distribute the load to the reinforcement (SiC). The bonding surface between the reinforcement and matrix, as well as the production method, affect load transfer. Strength and stiffness improvement is the main purpose of the fibres or particles. Greater strength and stiffness are supplied by metal matrix composites than by polymer-based materials. Compared to their polymeric counterparts, metal matrix composites have better fracture toughness but offer less in oxidising situations. Due to the weight penalty associated with using heavier metals, temperature applications in the majority of metals and alloys are severely constrained to the lighter metals. The three metals that are most frequently used as matrices are aluminium, titanium, and magnesium, which are ideal for usage in aeroplanes.

The melting point of the matrix material determines the service temperature of a composite. From the cryogenic range of 0°C to 2760°C, a large variety of fiber/metal combinations can be employed. However, machining, whether by turning or drilling, is always involved in the final conversion of these composites into engineered products. Due to the extreme hardness and abrasiveness of the reinforcing particles, MMCs continue to be challenging to process. The particles utilised in MMCs are tougher than the majority of the materials used in cutting tools. According to numerous studies, the best material for tools to use for machining MMCs is diamond (Chadwick et al 1990; Andrewes et al 2000; Paulo Davim 2003). The reinforcement particles are fragmented and dragged out of the matrix during the machining of MMC, which results in deterioration of the product surface, quick tool wear, and higher machining costs.

Additionally, early cutting tool failure results in frequent tool changes, which extends production time and raises costs (Looney et al 1992). However, by properly choosing the reinforcing phase, its volume fraction, size, and shape, as well as the composition and hardness of the matrix material, the machinability of these materials can be improved (Barnes et al 1995).

Manufacturing Methods of MMCs

Based on the matrix's operational status, there are various techniques for manufacturing MMC that can be split into two types metal: Solid state operations & Liquid state operations. Diffusion bonding, vapour deposition, and powder metallurgy procedures are examples of solid-state techniques.

A stir casting, a gas pressure infiltration technique, a squeeze or pressure casting, a vortex casting, a method of injection, and so forth are examples of liquid state processes. Particle reinforced metal matrix composites are frequently made using melt-based or powder-based techniques. Both approaches have the potential to result in a "near net shape" product that reduces the need for additional machining. The liquid state processing approach is recommended among the aforementioned technologies for fabricating composites due to its affordability and simplicity. Basavarajappa et al. (2006); Brain Ralph et al. How a composite's components merge during fabrication is a crucial factor to take into account when producing composites. They shouldn't interact chemically or hurt each other in a metallurgical alloy. They shouldn't typically have separate linear expansion coefficients. The qualities of the matrix and how the matrix impacts the reinforcement's properties heavily influence the fabrication process. Metal matrix composites can be created using a variety of methods and processes. The traditional approach is powder metallurgy (PM). The best strategy is the direct casting approach, which was created at the Indian Institute of Science in Bangalore. Stir casting and vortex casting are examples of direct casting. The procedure involves using a resistive furnace, where Alloys of aluminium are melted in a confined setting (sometimes nitrogen atmosphere is maintained). The melt is then removed from the bottom of the crucible and poured into the mould after the powder is added. Sand casting, diecasting, or centrifugal casting are all common methods for producing castings. So, a billet is created. A billet that has been thusly produced can be moved to a location where it can be remelted and once again moulded casting made. Distribution of the reinforcement then becomes more or less uniform. In this kind of material, homogeneity is quite challenging to attain.

DIFFICULTIES WITH MACHINES

The machinability of AMCs has been researched by Tomac (1992). According to his findings, the amount of hard silicon carbide particles in AMCs causes cutting tool flank wear to occur very quickly when these materials are being machined. (The micro hardness of the aluminium matrix ranges from 100HV to 120HV, whereas the hardness of silicon carbide particles is approximately 2700HV.) The cutting force component has not been greatly increased by the rather full cutting edge. The depth of cut is reduced and friction is greatly increased as a result of flank wear.

AMC APPLICATIONS

These materials' strong mechanical and physical qualities combined with weight reduction and relatively low production costs make them particularly appealing for a range of technical applications, including aerospace (space shuttle, Hubble telescope, aircraft), defence, and medical devices (armour plates and ballistic armour precision applications). Precision applications (Missile guidance systems), sports (golf sticks), automotive (piston, connecting rod, drive shaft, and cylinders), and have the potential to replace beryllium in inertial guidance systems and components needed for space transportation In the United States of America, lightweight bridges and spacecraft are both often used. In addition to the newly developed inexpensive processing technology that combines quality and frequency of operations, reasonable cost is a crucial element for applications in the automotive, transportation, construction, and leisure industries. Al/SiC is specifically used for cylinder blocks, cylinder heads, pistons, and value lifters in the automotive industry. Despite their widespread use in terminological purposes, they are susceptible to seizures in unfavourable lubrication environments.

Commercial aeroplanes like the Boeing 777 also use MMCs. Instead of using carbon/epoxy composite, Pratt and Whitney engines use MMC for the fan-exit guiding vanes. MMC is used to make missile wings and fins because it is stronger, stiffer, and lighter than steel and titanium (Kunz & Bampton, 2001). Golf club shafts, heads, skate shoes, track shoe spikes, baseball shafts, horseshoes, and bicycle frames are all produced of MMC in the sports and recreation business (Zhu et al 2005). On the other hand, it has been applied to electronic packaging as a microwave housing, carrier plates, and integrated heat sink (chawla et al 2006).

TECHNIQUES FOR OPTIMIZATION

Evolutionary algorithms are stochastic optimization approaches that simulate the human species' natural evolutionary process. When applied to challenging real-world issues, evolutionary algorithms frequently outperform conventional optimization techniques.

In this piece of research, the relationship between the input and output variables is represented by a multiple regression model. The process is optimised using a multi-objective strategy based on a Genetic Algorithm, Taguchi Grey Relational Analysis, Desirability Functional Analysis, and Fuzzy Logic techniques. The mathematical model that was created is used to forecast the features of the machining. The product quality significantly improved along with the utility for machining economics when machining settings were optimised. When machine tools are chosen for machining, it is crucial to choose the right machining parameters in order to ensure the quality of the finished products, lower machining costs, and boost machining efficiency.

COMPOSITES OF POLYMER MATRIX (PMC/FRP)

Polymer matrix composites are made of fibres reinforced within a polymer matrix. It is made up of fibres and resins, and Figure 1 depicts the many categories for each. Primary reinforcement (fibres) and Secondary reinforcement are two categories of reinforcement (fillers).

Thermoplastic and thermoset polymers (resins) are categorised as Polymer Matrix. Different techniques can be used to create novel composite materials, which demonstrates the outstanding rate of expansion of a number of applications, including biomedical and civil structures.

CONCLUSION

The research looks at the optimization of Al/SiC MMC drilling multi-response process parameters. Metal removal rate, surface roughness, flank wear, and power usage are the responses that are taken into account for optimization. Four multi-response optimization **strategies were used to** identify the relevant process parameters and determine the optimum levels of the process parameters (TGRA, DFA, FL and GA-NLGP). The silicon carbide metal matrix composite comprising rectangular bars containing 10%, 15%, and 20% silicon carbide particles (grain size 25 m) was the subject of experimental research.

The Tungsten Carbide tool was used for drilling. The metal removal rate (MRR), surface roughness (SR), flank wear (FW), and specific energy (SE) of the machined components were all taken into account to determine the best settings.

The following conclusions were drawn from this paper: The optimal process parameter changed with respect to maximising metal removal rate, minimising surface roughness, flank wear, and specific energy. For homogenised 10%, 15%, and 20% SiC reinforced Al-MMC material, the suggested machining parameters are silicon carbide (10%), cutting speed (1500m/min), feed rate (0.12mm/rev), diameter of drill (10mm), and machining time (2min).

Because there is less friction at the contact between the tool and the work piece, power consumption is lower at lower feed rates. The specific energy and wear increase as the feed rate rises.

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