Energy effectiveness achieved by orienting prototype of a laparoscopic instrument handle using polyjet additive manufacturing technology

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Abstract: Additive manufacturing (AM) technology can be considered as an answer to energy effective system as it is capable of reducing manufacturing time. In this research, an attempt is made to find the best among the 64 orientations, which gives minimum energy and material consumption using polyjet AM technology. This study provides an additional benefit to AM towards further reduction of product lead time to market. Orientations 0-0-0, 0-0-30 and 0-0-45 have been slightly higher build time comparing to 0-0-90. Imparting maximum strength to the build parts, 0-0-0 is selected as preferred orientation and build mode as high speed, which consumes 1.05 kWh of energy. This paper provides an outline for a possible way to energy-efficient manufacturing method, and it is recommended that orientations 0-0-0 and 0-0-45 can be used for auto orienting the part in any AM machines.

Keywords: additive manufacturing; polyjet; energy effectiveness; material consumption; orientation; laparoscopic instrument handle.

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Research paper

Multi-Objective Optimization and Modeling of Surface Roughness in Inconel 718 using Taguchi Grey Relational Analysis and Response Surface Methodology

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Abstract

Nickel-based super-alloys have been widely used in aircraft, nuclear industry, transfer rolls, single crystal turbine blades, heat treating trays, and die blocks due to their thermal resistance and their ability to retain mechanical characteristics at high temperatures. In this work, dry turning experiments on Inconel 718 have been performed using uncoated carbide inserts at various cutting speeds, feeds and a constant depth of cut. Taguchi based Grey Relational Analysis (GRA) optimisation has been used to optimise the surface roughness parameters namely Ra and Rt. Taguchi GRA has established optimal machining conditions for machining Inconel 718 considering cutting tool vibrations, temperature and tool wear as input parameters. The optimised machining conditions are 80m/min cutting speed and 0.1mm/rev feed rate, and considering other parameters, it is 9 g for cutting vibration, 95°C for temperature and 0.08mm for tool wear. Analysis of Variance (ANOVA) showed that feed rate (70.35%) is the most significant factor influencing surface roughness parameters followed by cutting speed (16.12%), tool wear (9.8%), vibrations (3.4%) and temperature (0.4%). Response Surface Methodology has been used to develop multiple regression models to predict surface roughness. The quadratic model developed has a R2 value of 0.917 and results in a prediction accuracy of 75% for Ra and R2 value of 0.906 with prediction accuracy of 75% for Rt.

Keywords: *Surface roughness, Cutting speed, feed , RSM, GRA*

1. Introduction

Nickel based alloys such as Inconel 718 has application in aero engine parts, rotor blades, engine parts etc. and is classified as difficult to cut materials [1]. Surface finish is a primary requirement for designing mechanical parts and it indicates quality of manufacturing processes. In machining process of Inconel 718, the surface roughness is mainly affected by rate of feed, cutting edge angle, nose radius and plan approach angle [2]. The poor thermal conductivity of Inconel 718 leads to high temperatures in the cutting zone
resulting in heat dissipation during machining process [3]. The unavoidable dynamic interactions between the cutting tool and work material cause vibrations and hence chatter. This chatter has adverse effect on various parameters like surface roughness, dimensional accuracy, tool wear etc.[4]. R Thirumalai et al (2012) conducted study on surface roughness and flank wear in turning of Inconel 718. Feed rate had significant effect on surface roughness, whereas the cutting speed had a medium effect. Depth of cut had no significance [5]. RSM is a useful mathematical and statistical technique for modelling of problems in which dependent parameters are affected by several independent parameters. A number of researchers have applied RSM for modelling and analysis of process parameters in machining [6]. Grynal D'Mello et al (2013) investigated the influence of cutting parameters on two surface roughness parameters i.e R_a and R_t , during high speed turning of Ti-6Al-4V.The surface roughness modelling was done using RSM. The experimental studies showed that surface roughness parameters R_a and R_t increases with increase in feed rate and cutting tool vibrations, while increase in cutting speed and tool wear decreased the surface roughness [7]. Grey system theory gives a proficient control on the uncertainty, various inputs parameters and incomplete data. The main limitation of the Taguchi S/N ratio method is that it can only be applied to solve single-output optimization problems.
To optimize multiple responses, Taguchi design with GRA is employed to choose the optimum conditions for machining process [8]. N Manikandan et al (2014) performed multiple outputs optimization in electrochemical drilling of Inconel 625 using Taguchi based GRA. Feed rate was the significant variable for the desired output characteristics. The optimal solution for the outputs are feed rate at 0.20 mm/min, electrolyte concentration at 25% and flow rate at 0.60 lit/min [9]. In this study, the turning process was conducted using uncoated carbide inserts by varying the cutting speed, feed rate and having a constant depth of cut. The effects of temperature, vibration and tool wear were also analysed. These parameters are generally considered as outputs of a machining process. This study is different in this regard, where these parameters are being used as inputs. This study aims to perform multi objective optimisation using GRA and RSM for modelling surface roughness obtained in turning Inconel 718 in terms of R_a and R_t .The goal is to achieve optimisation and modelling results for making significant conclusions regarding surface roughness.

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Research paper

Thermal Properties Characterization of Glass Fiber Hybrid Polymer Composite Materials

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Abstract

In the current work characterization of thermal properties are find out to the prepared specimens of silicon filler hybrid composite materials (silicon filler glass – fiber chop strand). The specimens were prepared by hand layup followed by compression molding machine by non-heating molding technique. Thermal conductivity (K), Coefficient thermal expansion (CTE) and Thermal gravimetric analysis (TGA) are found by composite slab method and by thermal muffler oven in a laboratory. The guard heater is used to supply heat which is measured by voltmeter and ammeter. Thermocouples are placed between the interface of the copper plates and the specimen of silicon filled hybrid polymer composite material (HPC), to read the temperatures. By the experimental readings it is found that the K of silicon filler hybrid composite material directly proportional to the % of silicon fillers for the different trails. The CTE inversely varies with % of silicon fillers and in thermal gravimetric analysis the failure of material takes place at 300°C for a time of 20 minutes and also reduction in mass of silicon inserted hybrid composite material. From the results it has been concluded that the considerable enhance in thermal conductivity with negligible decrease in CTE and increase in thermal resistivity of hybrid composite materials.

Keywords: *Thermal conductivity (K), Coefficient of Thermal Expansion (CTE), Thermal Gravimetric Analysis (TGA), Silicon.*

1. Introduction

The polymer composites are the solution for low density high strength materials as compared to the metals and alloy metals. Further the polymer composites found failure under variable temperature conditions in different applications like military weapons, medical instruments, Automobile sectors and Aerospace body building etc. As a solution to this problem, hybridisation of reinforcements is tried in the polymer composites, known as hybrid polymer composites [HPC]. In regular polymer composites by adding small percentage of filler materials which will vary the overall thermal properties and try to make hybrid polymer composites stable under variable temperature conditions without altering the strength of polymer composite materials.

1.1 Thermal Properties.

The following thermal properties, 1) Thermal conductivity, 2) Coefficient of thermal expansion, and 3) Thermo gravimetric analysis are found experimentally and specimens and experimental setups are prepared as per the ASTM standards. Thermal properties of any materials decides withstanding and sustainability of that material under variable temperature conditions it may be high temperature or low temperature.

Thermal Conductivity: The measurements of K carried out under variable heat inputs at ATP condition. According to ASTM E1530 circular slab type HPC specimen diameter 150 mm and thickness 5 mm to 10 mm are used as shown in figure 1. A known value of heat is applied from one side of the composite slab wait till the system reach steady state, the temperature of each interface surfaces were measured by thermocouples. Thermal conductivity determined by using one-dimensional Fourier's law of conduction equation. The conduction equation can be stated as "The rate of heat conduction in a given direction is proportional to the temperature gradient in that direction". This statement can be represented by equation

$$Q = -KA \frac{dT}{dX} = -KA \frac{(T1 - T2)}{L}$$

Where,
Q = Heat Supplied (W).
K = Thermal conductivity (W/m °C).
A = Area (m^2).
L = Thickness of the HPC specimen (m).
T_1= Temperature of lower interface surface of HPC Specimen (°C).
T_2= Temperature of upper interface surface of HPC Specimen (°C).

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Research paper

Wear and Water Absorption Behaviour of Banana and Sisal Hybrid Fiber Polymer Composites

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Abstract

Natural fibers are available naturally from geological, animals and plants. The composite materials can be produced by using these fibers for good properties. In this present work the hybridization of randomly oriented Banana [B] and Sisal [S] of proper composition 20%B 30%S, 30%B 20%S and 25%B 25 %S using 50% Epoxy L-12 resin with the hardener K6 in the 10:1 ratio under cold process method was used. According to ASTM G99 specimens are used to calculate the specific wear rate by pin on disc method and using Taguchi technique. The test specimen with 12 X 12 X 40 mm3 was used to calculate the percentage of water absorption.

Keywords: *Taguchi, Banana, Sisal, Tribology*

1. Introduction

Natural fibers are obtained naturally. Because of demand in needs of earth's resources day to day life, polymer based composite fiber reinforced have been mainly used. The natural fibers are renewable resources now-a-days used by researchers and many industries. Natural fibers like banana, jute, hemp, sisal etc, have good mechanical, physical and thermal properties [2-3]. By use of hybrid mixture, that is mixing of two or more fibers in one makes the composite advantages altogether, with proper composition of reinforcement and matrix [4].

The banana fibers are obtained from banana plant which is largely cultivated and available in nature having relatively good characteristic and mechanical properties [5]. Sisal fibers can be easily grown and harvested from sisal plant having relatively good wear and tear properties [6]. With the mixing of both banana and sisal as reinforcement and epoxy resin with hardener as the matrix the material obtained is of low cost, high strength to weight ratio, increases fatigue life, wear, durable and water absorption.

The rice husk of an agricultural waste is available by rice producing counties. It can be used to produce a composite of light weight, using epoxy resin and fibers of modified and unmodified rice husk as reinforcement to study tribological properties [7-8].

Wear and friction is a defined by tribology. There are different types of testing of wear, each type differ with their operation and application [9]. Solid particle erosion strongly affected by material properties. Banana fiber used as reinforcement and epoxy as resin for the calculation of wear property in the laboratory to collect the data to prove the very low density [10]. Carbon-epoxy composite were fabricated using vacuum bag moulding technique. Hardness and wear properties are evaluated. Plain journal bearing with strength and wear resistance are tested for centrifugal pump [11].

Water absorption for the polymer composites include amount of water absorbed with particular duration of time and it is affected by plastic type, additives used and temperature [12]. The hybrid composite finds major applications in aircrafts, automotive, biomaterials and industries.

In the present work, specimens prepared are tested for tribological and water absorption properties, to calculate the amount of wear with respect to time and also percentage of water absorbed.

2. Material, Methods and Experimental Details

There are different types of composite materials like polymers, ceramics and metals. Polymers composites are used because of less cost, complex parts can be fabricated easily and properties of room temperature is excellent, than metals and ceramics. The most commonly used resin epoxy, polyester, vinylester and phenolics.

2.1 Material Used

2.1.1. Sisal Fiber

Sisal fiber is also known as Agave sisalana. These are basically from sword-shaped leaves and are biodegradable. Each leaf having several numbers of long fibers, which can be removed by decortications process. A sisal fiber does not attract any dust particles and moisture. It has very low maintenance with wear and tear rate. The microfibrillar angle is 20^0 for sisal fiber, which is much higher than any other natural fibers [20]. The Table I shows the chemical and mechanical properties of a sisal fibers.

Development of customized orthosis for congenital deformity using additive manufacturing

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Abstract

Purpose – This paper aims to develop a customized orthosis for treating congenital talipes equinovarus (clubfoot) deformity. Complications from non-surgical treatment method such as Ponseti method leads to relapse/recurrence of the foot after treated.

Design/methodology/approach – An alternate approach for treating clubfoot deformity can be seen as a viable approach to overcome the above-mentioned difficulties. Customized orthosis is designed and developed for a subject affected with right clubfoot deformity through fused deposition modeling of additive manufacturing (AM) technology with ABS plastic as base material. A unique mechanism is used to develop customized orthosis for achieving rotation of the foot along the three axis and range of motions.

Findings – Developed orthosis is incorporated with a unique mechanism that can be rotated and arrested at the specified angle along the three principle ranges of motion of the foot. Overall weight of the developed customized orthosis achieved is about 284 g, which has a significant 25 per cent reduction in weight when compared to traditional Ponseti casting method. Overcoming the difficulties faced in Ponseti method, customized orthosis can be an alternative method for treating clubfoot.

Originality/value – Developed orthosis will be an alternative approach for treating clubfoot deformity, and it overcomes the drawbacks faced by Ponseti method.

Keywords Healthcare, Fused deposition modelling, Additive manufacturing, Clubfoot, Customized orthosis

Paper type Research paper

1. Introduction

Additive manufacturing (AM) technology is suitable for developing customized products of complex geometry, which can be used for different applications by reducing time to market. AM technology applies to a wide range of industrial sectors such as mechanical, aerospace, automobile, electronics, garments, healthcare and biomedical engineering (Chua and Leong, 2000). Potential requirements of customized products in health care such as prosthetic and orthosis can be more accurately produced through AM technology (Goiato *et al.*, 2011). In this research, identifying a complex geometrical product that can be manufactured through AM technology is explored.

Health-care sector can be broadly classified as hospitals, pharmaceuticals, diagnostics, medical equipment and supplies, medical insurance and telemedicine (IBEF, 2016). Out of these six sectors, customization of the products can be give only in the medical equipment sector (IBEF, 2016). This paper focuses on identifying a product under medical equipment of health-care sector while other sectors are beyond the scope of this work.

Understanding the need for a product that requires complex geometry and that could be easily manufactured in AM, focus was in the area of congenital deformities. Categories of products such as external prosthetic and orthotic devices that aid in supporting for the treatment process of congenital deformities that utilizes complex mechanisms were concentrated. Deformity is considered as abnormal growth in the shape of the body due to genetic and hormone disorder leading to structural changes which can be either congenital or acquired deformity (Brent, 2004; Donkelaar *et al.*, 2014).

According to Agrawal and Suresh (2005), congenital talipes equinovarus (CTEV or Clubfoot) is a musculoskeletal foot deformity present at birth where the feet is rotated inwards

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TECHNICAL PAPER

Processing and Microstructural Characterization of Cermet-Reinforced Aluminium Matrix Composite by Solidification Process

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Abstract The present work deals with the preparation of the aluminium matrix composite using a ceramic and metallic combination as reinforcements and using liquid metallurgy route of solidification process. The desired properties of composites have been influenced by the solidification behaviour of the cast metal matrix composites, which has been imposed to study the solidification behaviour of metal matrix at different weight fraction of reinforcement particulates. Al7075 was used as matrix and tungsten carbide, and cobalt particulates were used as reinforcements. During the preparation, an addition of magnesium was used to increase the wettability of the particulates during the mixing. XRD/EDX/SEM characterizations of the prepared composites were conducted, where a fairly uniform distribution of the reinforced particulates was found over the matrix.

Keywords Microstructure · Cermet · Solidification · SEM

1 Introduction

Aluminium (Al) alloys offering predominant properties in view of strength and corrosion resistance along with its light weight are preferred as matrix materials in metal matrix composites for extensive use in the fields of aerospace, automobile industries and structural applications [1]. Al7075 alloy has relatively better strength amongst aluminium series alloys and high corrosion resistive than other class of aluminium alloys [2]. As of late, aluminium matrix composites with particulate reinforcements have picked up consideration as a result of good wear resistance and many other completing qualities like specific modulus and a low coefficient of thermal expansion. Many of these qualities make them ideal materials in the application of space and automotive sectors [3–5]. For aluminium alloys, hard ceramic particles of B_4C, TiC, SiC, Al_2O_3 and graphite are chosen as reinforcements to overcome its low elasticity and hardness and endure temperature. Tungsten carbide has excellent features such as high hardness, high wear and corrosion resistance and is a candidate material for reinforcement [6, 7] in Al alloys.

Keeping in mind the end goal to build up another composite material, the present work is taken up in which Al7075 alloy is reinforced with cermet. The WC–Co cermet is produced using high-energy ball milling process. In WC–Co cermet, WC being exceptionally hard material and Co known for its toughness can be very effective when reinforced in the form of cermet in Al matrix. The cermet produced in turn is used to produce Al7075 + WC–Co composite by stir-casting technique. These arranged composites have been described by microstructure studies using SEM/EDX and XRD.

2 Experiment Details

2.1 Selection of Materials

Al7075 combination is chosen as matrix for the present investigation, whose mechanical properties can be custom

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TECHNICAL PAPER

The Effect of Thermal Ageing on Solder/Substrate Interfacial Microstructures During Reflow of Sn–37Pb and Sn–3Ag–0.5Cu

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Abstract In the current study, the influence of thermal ageing on evolution of microstructures in the interfacial region between solders (Sn–37Pb, Sn–3.5Ag–0.5Cu) and copper substrates was investigated. Pb-containing and Pb-free solders were reflowed on Cu substrates at 230 °C for 15 min and were isothermally aged at 100 °C for 24 h. As-reflowed Sn–Pb solder/Cu substrate interfacial region exhibited continuous and layered type of IMC at the interface, and this IMC morphology changed to scallop type with isothermal ageing. SAC solder/Cu as-reflowed samples showed continuous and needle-shaped Cu_6Sn_5 and Ag_3Sn IMCs at the interface. However, in an isothermally aged condition, plate-shaped Cu_6Sn_5 and flower-shaped Ag_3Sn IMCs were found inside the solder matrix. Scanning electron microscopic (SEM) study showed that the thickness of Cu_6Sn_5 IMC was higher in reflowed Sn–Pb/Cu region than in SAC/Cu region.

Keywords Solder joint · Reflow · Microstructures · IMC layer · Isothermal ageing

1 Introduction

Soldering is defined as a process of joining metallic materials at a low temperature by using a filler material that melts below 400 °C [1]. Reflow soldering is the most widely used method of attaching surface mount components (SMCs) to printed circuit boards (PCBs). The aim of the reflow soldering is to form acceptable solder joints by first pre-heating the components/PCB/solder paste and then melting the solder without causing damage by overheating. Lead (Pb)-containing solder alloys are used commonly in electronic applications because of their distinctive combination of properties and less cost [2]. Environmental considerations, global economic pressures and legal implications have justified the elimination of Pb from solder alloys. Even though there is no drop in substitute for the Pb-containing solders. At present, Sn–Ag, Sn–Cu, Sn–Ag–Cu lead-free solders are preferred to replace Pb-containing solders due to their good wetting characteristics and mechanical properties [1–3]. Copper is extensively used as a substrate material for ball grid array (BGA) applications. During reflow when liquid (molten) solder reacts with base substrate by the dissolution of Cu into the molten solder, intermetallic compounds (IMCs) grow at the interface [4]. These IMCs provide a strong bond to the solder joints. However, in microelectronic industry, especially in flip chip packaging process, package undergoes repeated reflow process, due to which IMCs grows rapidly at the solder/substrate interface [4–7]. Like reflow, thermal ageing of solder joints under service conditions greatly varies the growth of IMCs that can strongly influence the life of the soldered joints [5]. Thus, in the present study, the effect of isothermal ageing on microstructure evolution during reflow of Sn–37Pb and Sn–3Ag–0.5Cu solders on copper substrates has been investigated.

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Studies on Dry Sliding Wear Characteristics of Cermet WC-Co Particulate Reinforced Al7075 Metal Matrix Composite

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Abstract

In the present work, an attempt is made to synthesize cermet (WC-Co) reinforced Al7075 metal matrix composite by liquid metallurgy route. The dry sliding wear behavior of these prepared composites was studied with varying sliding speed, load and sliding distance. Cermet in an amount of 6 wt% is used as reinforcement in Al7075 matrix. Microstructural characterization of the prepared composites is carried out using SEM/EDX and XRD studies. X-ray diffraction studies have revealed the peaks corresponding to α-Al, WC, Co and minor Al_5W phases. SEM/EDX characterization revealed the uniform distribution of cermets in Al matrix. Dry sliding wear characteristics of the prepared composites were studied using a pin-on-disc testing machine. The wear rate for alloy and composites decreased with increase in sliding speed and increased with increase in applied load and increasing sliding displacement. The worn surfaces of the composites were investigated using optical microscope.

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Keywords: Cermets, Al7075; SEM; XRD; Wear rate;

1. Introduction

Metal matrix composites (MMCs) provide improved properties over other monolithic materials, like high strength to weight ratio, high temperature working temperature, wear and corrosion resistance [1]. AMMCs are gaining importance due to light weight and good formability. Al7075 is the type of Al alloy containing Zn and Mg as major alloying elements commonly used for automobile, aerospace and gas cylinders. Al7075 is heat treatable, can be easily welded and good finishing characteristics. Al7075 has high strength among aluminium series and highly corrosive than other aluminium alloy [2]. Particulate composites are widely used due to their low cost and manufacturing ease. Ceramics are commonly used as reinforcements. The reason of metal reinforced with hard ceramic particles provides high strength, wear resistance, stiffness etc [3]. Fabrication of composites is commonly done by stir casting route due to simple, economical and fabrication ease [4, 5]. Eunji Hong *et al.* [6] studied the wear property of copper alloy reinforced with WC. They carried macro and micro level pin-on-disc wear testing analysis.

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