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MANUFACTURING AND TESTING THE CHARACTERISTICS OF HELICAL GEAR BY CASTING FOR AUTOMOBILE

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ABSTRACT

Over the past forty years, Particulate reinforced aluminum-matrix composites (PAMC) have been experiencing the attention of researchers. This is because of their low cost and near-isotropic properties especially in those applications not requiring extreme loading or thermal conditions. Liquid phase fabrication of composite materials using solidification and casting techniques has long been considered economically viable owing primarily to low viscosity of liquid metals, Netscape-manufacturing capability of casting processes and flexibility in designing the structure by controlled solidification. While looking for enhanced Mechanical properties in Particulate reinforced MMCs, Percentage fraction of particulate additions and the solidification rate becomes the most dominant parameters during solidification processing. In this project, we mainly focused on the composite material for aluminium based composite system using particulates of Mechanical properties have also been investigated. However, very little work has been reported so far on Al/Zircon particulate composites. Among ceramics, Zircon (ZrO_2) is chemically very stable and is known to possess high hardness and elastic modulus with excellent thermal stability.

This projects deals with the "Manufacturing and testing the characteristics of helical gear by casting for automobile application" for mechanical properties and wear behavior of aluminium – zirconium composite gear.

Key works: ***Aluminium, zirconium, Mechanical properties, testing and characteristics***

INTRODUCTION

During the past two decades, material design has transferred emphasis to pursue light weight,

environment friendliness, low cost quality, superior service temperature, enhanced elastic modulus and enriched wear resistance and performance. The foremost objectives of using composite material is the advantage of attaining property combination that can result in the number of service benefits. Ceramic particulates incorporated aluminum matrix composites are a new generation of metal matrix composites which have the potential of sustaining the emerging demand for advanced engineering applications. The most widely employed composite matrix materials are magnesium, aluminium, zinc and titanium and the typical reinforcements are titanium carbide(TiC), silicon carbide (SiC), boron carbide (B_2C), zirconium oxide (ZrO_2), titanium oxide (TiO_2), aluminium oxide ($Al2O_3$), silicon oxide (SiO_2), silicon nitride (Si_2N_4), boron nitride (BN), titanium diboride (TiB_2) and zirconium diboride (ZrB_2) etc,. zirconium diboride (TiB_2), is a naturally inherent reinforcement material for aluminium based composites as it possesses the effective combination of physical and mechanical properties like high melting point, superior hardness, low density, high elastic modulus and outstanding wear resistance. Especially utilization of ZrB_2 particles as reinforcement has always improved the mechanical properties of AMCs.

1.1 COMPOSITE MATERIAL:

A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, it produce a material with characteristics different from the individual component.

The typical engineering composite materials are

1.Reinforced concrete.
2.Composite wood.
3.Fibre-reinforced polimer.
4. Ceramic matrix composite.
5. Metal matrix composite.

In our project, we are going to prepare the composite on metal matrix composite and the materials used to make the composite are

1.1.1 ALUMINIUM:

Aluminium alloy is widely used in various industries due to the combination of good mechanical properties and light weight. However, Al alloy is susceptible to localized corrosion because of the distribution of intermetalic compounds (IMCs). Chromate treatments had played an important role for corrosion protection on Al alloy owe to their self repairing ability, simple application and high efficiency / cost ratio. Moreover, they provided the best corrosion resistance and facilitated the application of further treatment. But, Cr (VI) has been identified as a carcinogen. Cr(VI)-based treatments are being phased out. Due to above reasons, new alternative and more eco-friendly surface treatments need to be studied. Rare-earth element such as cerium seems to be a feasible placement for chromates which acts as a cathodic inhibitor by forming a cerium-riched layer. Phosphate is a another alternative of chromates. It is usually used in conversion solution to form an insoluble phosphate layer. Titanium and zirconium coating are studied actively because of their excellent corrosion resistance. In these non-chromate conversion coating. however, only titanium and zirconium conversion coatings are used to substitute for chromate based conversion occasionally at low demands.

1.1.2 ZIRCONIUM

Zirconium alloys have been utilized as fuel cladding materials in nuclear power plants owing to their superior properties: low thermal neutron absorption cross section, high mechanical strength, and acceptable corrosion resistance. However, many studies have shown that zirconium alloys have some disadvantages under accident conditions. One of the most critical drawback is their oxidation rate at high-temperature above 1000^{o}C. Performed oxide formed on a zirconium alloy can also enhance the oxidation resistance. According to previous studies performed oxide significantly reduces the degree of oxidation below 1100^{o}C, and the extent of the reduction cannot be explained by the parabolic rate law. In addition, performed oxide is effective for enhancing the breakaway oxidation resistance; breakaway oxidation is a phenomenon that occurs on a zirconium alloy during oxidation, and it causes rapid increases in the oxidation and hydrogen absorption rates. In a previous study, a non-oxidized zirconium alloy oxidized at 1000^{o}C exhibited breakaway oxidation at 2130$_s$, whereas a pre-oxidized zirconium alloy oxidized ay the same temperature did not exhibit breakaway oxidation until 5130$_{s.}$

1.1.3 CASTING:

Casting is a manufacturing process in which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting materials are usually metals or various time setting materials that cure after mixing two or more components together. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods. Heavy equipment like machine tool beds, ships' propellers, etc. can be cast easily in the required size, rather than fabricating by joining several small pieces. Casting is a 7,000-year-old process. The oldest surviving casting is a copper frog from 3200 BC. In metalworking, metal is heated until it becomes liquid and is then poured into a mold. The mold is a hollow cavity that includes the desired shape, but the mold also includes runners and risers that enable the metal to fill the mold. The mold and the metal are then cooled until the metal solidifies. The solidified part (the casting) is then recovered from the mold. Subsequent operations remove excess material caused by the casting process (such as the runners and risers).

2. LITERATURE SURVEY

The objective of this phase 1 project was to develop a ceramic composite with superior fracture toughness and high strength, based on combining two toughness inducing materials: zirconia for transformation toughening and SiC whiskers for reinforcement, in a controlled microstructure alumina matrix. The controlled matrix microstructure is obtained by controlling the nucleation frequency of the alumina gel with seeds (submicron alpha-alumina). The results demonstrate the technical feasibility of producing superior binary composites ($Al2O_3$-ZrO_2) and tertiary composites ($Al2O_3$-ZrO_2-SiC). Thirty-two composites were prepared, consolidated, and fracture toughness tested. Statistical analysis of the results showed that: (1) the SiC type is the key statistically significant factor for increased toughness; (2) sol-gel processing with a-alumina seed had a statistically significant effect on increasing toughness of the binary and tertiary composites compared to the corresponding mixed powder processing; and (3) ZrO_2 content within the range investigated had a minor effect. Binary composites with an average critical fracture toughness of 6.6MPam sup 1/2, were obtained. Tertiary composites with critical fracture toughness in the range of 9.3 to 10.1 MPam sup 1/2 were obtained. Results indicate that these composites are superior to zirconia toughened alumina and SiC whisker reinforced alumina ceramic composites produced by conventional techniques with similar composition from published data.[1]

Due to their outstanding mechanical properties and excellent biocompatibility, zirconia-toughened alumina (ZTA) ceramics have become the gold standard in orthopedics for the fabrication of ceramic bearing components over the last decade. However, ZTA is bioinert, which hampers its implantation in direct contact with bone. Furthermore, periprosthetic joint infections are now the leading cause of failure for joint arthroplasty prostheses. To address both issues, an improved surface design is required: a controlled micro- and nano-roughness can promote osseointegration and limit bacterial adhesion whereas surface porosity allows loading and delivery of antibacterial compounds. In this work, we developed an integrated strategy aiming to provide both osseointegrative and antibacterial properties to ZTA surfaces. The micro-topography was controlled by injection molding. Meanwhile a novel process involving the selective dissolution of zirconia (selective etching) was used to produce nano-roughness and interconnected nanoporosity. Potential utilization of the porosity for loading and delivery of antibiotic molecules was demonstrated, and the impact of selective etching on mechanical properties and hydrothermal stability was shown to be limited. The combination of injection molding and selective etching thus appears promising for fabricating a new generation of ZTA components implantable in direct contact with bone. Zirconia-toughened alumina (ZTA) is the current gold standard for the fabrication of orthopedic ceramic components. In the present work, we propose an innovative strategy to provide both osseointegrative and antibacterial properties to ZTA surfaces: we demonstrate that injection molding allows a flexible design of surface micro-topography and can be combined with selective etching, a novel process that induces nano-roughness and surface interconnected porosity without the need for coating, avoiding reliability issues.[2]

3.METHODOLOGY

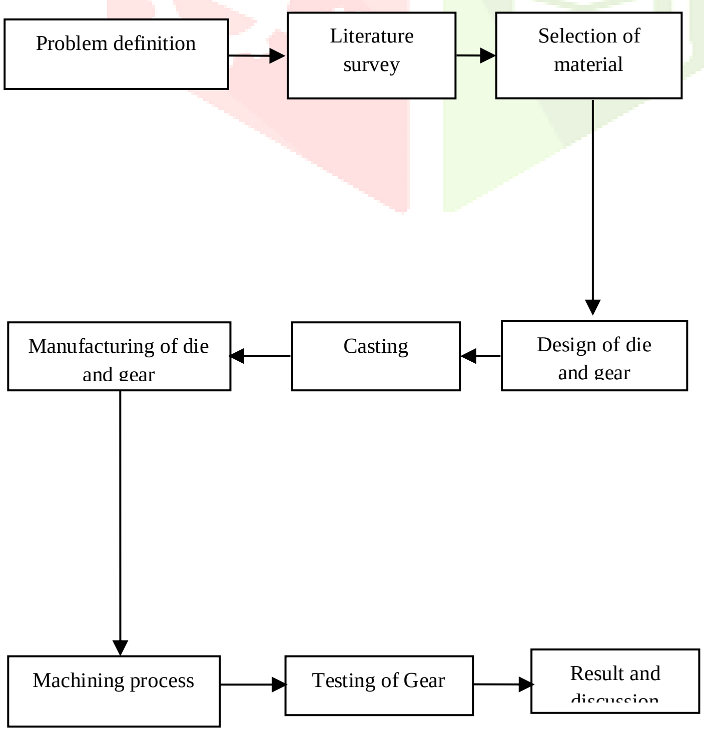

Fig: 3.1 Project methodology.

3.1 SELECTION OF MATERIAL

3.1.1 Aluminium:

It is a chemical element with the symbol Al and atomic number 13. It is a silvery white, soft, non-magnetic and ductile metal in the boron group. By mass, aluminium makes up about 8% of the Earth's crust; it is the third most abundant element after oxygen and silicon and the most abundant metal in the crust, though it is less common in the mantle below. The chief ore of aluminium is bauxite. Aluminium metal is highly reactive, such that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 270 different minerals. We use 90% of aluminium for making the helical gear.

Fig 3.1. Aluminium

3.1.2 Zirconium Dioxide(ZrO_2):

Zirconium Dioxide otherwise known as Zirconia is a white crystalline oxide of zirconium. It is most naturally occurring form, with a monoclinic crystalline structure, is the mineral baddeleyite. A dopant stabilized cubic structured zirconia, cubic zirconia, is synthesized in various colours for use as a gemstone and a diamond simulant.

Zirconium dioxide is one of the most studied ceramic material. ZrO_2 adopts a monoclinic crystal structure at room temperature and transitions to tetragonal and cubic at higher temperatures. The change of volume caused by the structure transitions from tetragonal to monoclinic to cubic induces large stresses, causing it to crack upon cooling from high temperatures. When the zirconia is blended with some other oxides, the tetragonal and/or cubic phases are stabilized.

sufficient quantities of the metastable tetragonal phase is present, then an applied stress, magnified by the stress concentration at a crack tip, can cause the tetragonal phase to convert to monoclinic, with the associated volume expansion. This phase transformation can then put the crack into compression, retarding its growth, and enhancing the fracture toughness.

Fig:5.1 Zirconium

3.1.3 Epoxy resin:

Epoxy resins are advanced thermosetting resins used in composites for a variety of manufactured products and use our epoxy resin for all the casting and coating.

Table: 3.1. Ratio of material

Sl.no	Materials	Percentage %	Weight in gram.
1.	Aluminium	90	900
2.	Zirconium	10	100

Table: 1.2 General properties of material

4. DESIGN AND CALCULATION

4.1 HELICAL GEAR.

Helical is the most commonly used gear in transmissions. They also generate large amount of thrust and use bearings to help support the thrust load. Helical gears can be used to adjust the rotation angle by 90 degree when mounted on perpendicular shafts. Its normal gear ratio range is 3:2 to 10:1.

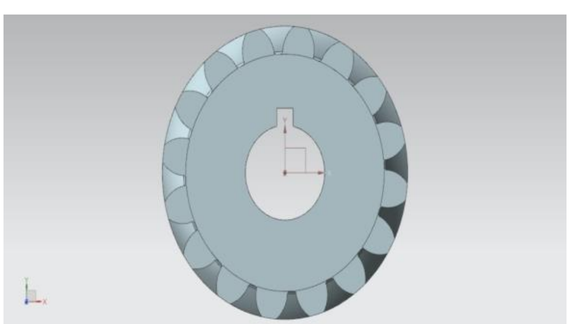

Fig:4.1 Front view of helical gear.

Fig:4.2 3D model of helical gear.

Sl.no	Properties	Aluminium	Zirconium
1.	Melting point in (K)	933.47	2128
2.	Density in (g/cm³)	2.70	6.52
3.	Thermal expansion in °C	25	25
4.	Thermal conductivity in W/(m.K)	237	2.5-3
5.	Young's modulus in GPa	70	88
6.	Vickers hardness in MPa	160-350	820-1800

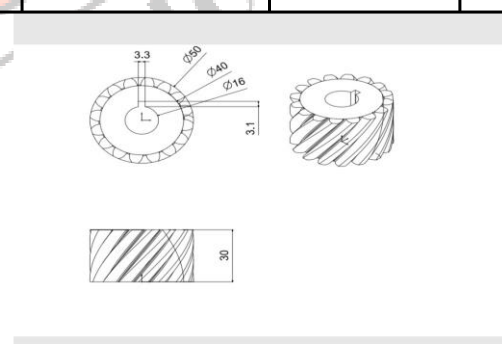

Fig:4.3 Line diagram of helical gear.

4.2 DESIGN CALCULATION

- Pitch circle diameter (Dp) = diameter of the blank(D) – (2 module(m))

= 48 – (2 X 2)

(Dp) = 44mm

- Number of teeth (Z) = pitch circle diameter / module

  = 44/2

  (Z) = 22

- Circle pitch (Pc) = π X Dp/Z

  = 3.14 X 44/22

  = 6.28mm

- Helix angle, tanα = πDp/L
  ie.α = 15°

  where(L) = lead of the helix

  tan(15) = 3.14 X 44/ L

  L = 539.05mm

- Index calculation = 40/Z

  = 40/23

∴ If we write into mixed fraction is

=1X17/23

ie. 1 full revolution and 17 holes for the setting hole of 23 in index of milling machine.

5. CASTING AND MANUFACTURING PROCESS

The process of converting raw materials, components or parts into finished goods that meet a customer's expectations or specifications. Manufacturing commonly employs a man-machine setup with division of labor in a large scale production.

5.1 CASTING:

It is the mixing of different powder particles to impart wide ranging physical and mechanical properties. Lubricants can be added during the blending process to improve the flow characteristics of the powder particles reducing friction between particles and dies. In this, we used the coke as a fuel to mix the molten aluminium and powdered Zirconium Oxide at 1000ºC in the graphite bowl.

5.1.1 SAND CASTING:

Sand casting is also known as sand molded casting, is a metal casting process characterized by using sand as the mold material. Sand castings are produced in specialized factories called foundries. Over 70% of all metal castings are produced in sand casting process.

Molds made of sand are relatively cheap and sufficiently refractory even for steel foundry use. In addition to the sand, a suitable bonding agent is mixed or occurs with the sand. The mixture is moistened in typically with water, but sometimes with other substances to develop the strength and plasticity of the clay and to make aggregate suitable for molding. The sand is typically contained in the system of frames or mold boxes known as the flask.

Fig: 5.1 casting of materials

5.2 METAL CUTTING PROCESS:

Metal cutting is the process of producing a job by removing a layer of unwanted material from a given work piece. Fig. shows the schematics of a typical metal cutting process in which a wedge shaped, sharp edged tool is set to a certain depth of cut and moves relative to the work piece

Under the action of force, pressure is exerted on the work piece metal causing its compression near the tip of the tool. The metal undergoes shear type deformation and a piece or layer of metal gets repeated in the form of a chip. If the tool is continued to move relative to work piece, there is continuous shearing of the metal ahead of the tool. The shear occurs along a plane called the shear plane.

All machining processes involve the formation of chips; this occurs by deforming the work material on the surface of job with the help of a cutting tool. Depending upon the tool geometry, cutting conditions and work material, chips are produced in different shapes and sizes. The type of chip formed provides information about the deformation suffered by the work material and the surface quality produced during cutting process.

Fig:5.2 Machining of composite material.

5.3 MILLING:

It is the process of machining using rotary cutters to remove material by advancing a cutter into a work piece. This may be done varying direction on one or several axes, cutter head speed, and pressure. Milling covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes for machining custom parts to precise tolerances.

Milling can be done with a wide range of machine tools. The original class of machine tools for milling was the milling machine (often called a mill).)

Fig:5.2 Milling of composite material.

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Fig:5.3 Milling of composite material.

5.4 Surface Finishing

Surface finishing is a broad range of industrial processes that alter the surface of a manufactured item to achieve a certain property. Finishing processes may be employed to: improve appearance, adhesion or wettability, solderability, corrosion resistance, tarnish resistance, chemical resistance, wear resistance, hardness, modify electrical conductivity, remove burrs and other surface flaws, and control the surface friction. In limited cases some of these techniques can be used to restore original dimensions to salvage or repair an item. An unfinished surface is often called mill finish.

Surface finishing processes can be categorized by how they affect the workpiece:

- Removing or reshaping finishing
- Adding or altering finishing

Surface of gear teeth produced by any of the generating process is not accurate and of good quality (smooth). Dimensional inaccuracies and rough surface generated so become the source of lot of noise, excessive wear, play and backlash between the pair of gears in mesh. These all result in loss of power to be transmitted and incorrect velocity ratios. This can be summarized as inefficient power transmission. In order to over come these problems some finishing operations are recommended for the produced gears. Sometimes poor quality of finish and dimensional inaccuracies occur due to hardening of a produced gear.

CONCLUSION

The following conclusions were observed in this present study The Al6061-ZrO2 composites were developed through stir casting technique for 0%, 3%, 6%, 9% and 12% of Zirconium dioxide reinforcement.

The various treatment have to been taken for this project we have manufactured the helical gear with composite material, mainly over aluminum Zirconium Oxide further the testing will be carried out on upcoming papers.

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