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Design Optimization and Fabrication of Spur Gear from Al7075-SiC-B_4C Composites

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***Abstract* - Spur gear is the simplest and widely used in power transmission system for various industrial and automobile applications. A spur Gear is generally subjected to bending stress which causes teeth failure. However, it is observed that performance of the spur gear is not satisfactory in certain applications and therefore it is required to explore some alternate materials to improve the performance of the spur gears. Composite materials provide optimum strength with weight reduction and they are emerging as a better alternative for replacing conventional metallic gears. In this work, a conventional metallic gear of Alloy Steel is replaced by the composite gear of aluminium with BORON CARBIDE and SILICON CARBIDE materials. Such Composites material provides much improved mechanical properties such as better strength to weight ratio, more hardness, and hence less chances of failure. In this work, an analysis is made with replacing metallic gear with composite material such as aluminium with Boron Carbide and Silicon Carbide so as to increase the working life of the gears to improve overall performance of machine. Finally, the Modeling of spur gear is carried out using CATIA software and structural analysis of spur gear is carried out using ANSYS software with different composition of the materials. From the optimized materials identified the suitable composition and further will be carried out the casting of the prototype of spur gear.**

Keywords - Aluminium, Boron carbide and silicon carbide.

1. INTRODUCTION

1.1 Background Overview

The spur gear transmits mechanical energy from a prime mover to an output device. The spur gears are used in heavy and low duty mechanical devices. But in this study we have emphasized on the low duty application like Textile machines, Printing press machines, Robotic mechanism etc. The major problems observed with existing metallic Spur gear are Existing gear is made of metal component provides poor weight to strength ratio. Metallic parts lead to corrosion so need to properly shielded. More wear in between the gears so required proper lubrication. Gears are getting costly due to increasing metal prices. Due to poor weight to strength ratio power losses in gear are higher. Thus gear needs to be redesigned providing energy saving by weight reduction, providing internal damping, reducing lubrication requirements without increasing cost. Such a scope is provided by application of composite material providing solution to other existing problems in current gears available. Therefore this work is concerned with the replacement of existing metallic gear with composite material gear in order to make it lighter and increasing the efficiency of mechanical machines.

1.2 Classification Based on Matrix Material

Composites cannot be made from constituents with divergent linear expansion characteristics. The interface is the area of contact between the reinforcement and the matrix materials. In some cases, the region is a distinct added phase. Whenever there is interphase, there has to be two interphases between each side of the interphase and its ad joint constituent. Some composites provide interphases when surfaces dissimilar constituents interact with each other. Choice of fabrication method depends on matrix properties and the effect of matrix on properties of reinforcements. One of the prime considerations in the selection and fabrication of composites is that the constituents should be chemically inert non-reactive**.**

1.3 Metal Matrix Materials Composites (MMC)

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminium, magnesium and titanium. The typical fibre includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibres such as silicon carbide.

1.4 Ceramics Matrix Composites (CMC)

Ceramic matrix composites have ceramic matrix such as alumina, calcium, Aluminosilicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture. Composites successfully made with ceramic matrices are reinforced with silicon carbide fibres.

1.5 Carbon and Graphite Matrix Composites (CGMC)

Ceramic matrix composites (CMCs) are a subgroup of composite materials as well as a subgroup of technical ceramics they consist of ceramic fibers embedded in a ceramic matrix, thus forming a ceramic fibre reinforced ceramic (CFRC) material. The matrix and fibres can consist of any ceramic material, whereby carbon and carbon fibres can also be considered a ceramic material.

2. MATERIALS AND METHODOLOGY

2.1 Composite

Composite is an _optimized and required properties that is applied to an object. The aim of applying composite materials (Aluminium with Boron Carbide) is to improve surface properties of a bulk material usually referred to as a substrate. One can improve appearance, adhesion, wettability, corrosion resistance, wear resistance, scratch resistance, etc.

2.2 Methodology

The methodology includes the process sequentially which carried out, this project includes the process of modeling and analysis of spur gear with different composition of aluminium with boron carbide composite material by FEA and Software's

2.3 Spur Gear

Gearing is one of the most critical components in a mechanical power transmission system, and in most industrial rotating machinery. It is possible that gears will predominate as the most effective means of transmitting power in future machines due to their high degree of reliability and compactness. In addition, the rapid shift in the industry from heavy industries such as shipbuilding to industries such as automobile manufacture and office automation tools will necessitate a refined application of gear technology. A gearbox as usually used in the transmission system is also called a speed reducer, gear head, gear reducer etc., which consists of a set of gears, shafts and bearings that are factory mounted in an enclosed lubricated housing. Speed reducers are available in a broad range of sizes, capacities and speed ratios. Their job is to convert the input provided by a prime mover (usually an electric motor) into an output with lower speed rbox was studied using nonlinear FEM.

2.4 Casting Process

Stir Casting

Stir Casting-Stir casting is a type of casting process in which a mechanical stirrer is introduced to form vortex to mix reinforcement in the matrix material. It is a suitable process for production of metal matrix composites due to its cost effectiveness, applicability to mass production, simplicity, almost net shaping and easier control of composite structure
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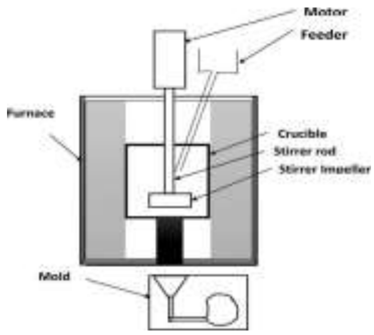

Figure 1
Schematic of Stir Casting Setup.

2.5 Ceramic Materials

Material Property

All of these temperatures could be reached with ancient methods that have been used since the Bronze Age. Since the oxidation rate of iron increases rapidly beyond 800 °C (1,470 °F), it is important that smelting take place in a low-oxygen environment. Unlike copper and tin, liquid or solid iron dissolves carbon quite readily. Smelting results in an alloy (pig iron) that contains too much carbon to be called steel.[2] The excess carbon and other impurities are removed in a subsequent step.

Silicon Carbide

Silicon carbide (SiC), also known as carborundum is said to be material a semiconductor containing silicon and carbon. It occurs in nature as the extremely rare mineral moissanite. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests.

Boron Carbide

The primary structural units of boron carbide are the 12-atom icosahedra located at the vertices of a rhombohedra lattice of trigonal symmetry (R3m space group), and the 3-atom linear chains that link the icosahedra along the (111) rhombohedra axis. This structure can also be described in terms of a hexagonal lattice based on a nonprimitive unit cell, in which case the axis of the hexagonal lattice corresponds to the rhombohedral direction . The presence of icosahedra within the boron carbide structure is a consequence of elemental boron's ability to form caged structures of a variety of sizes5,9; the icosahedra in boron carbide are essentially two pentagonal pyramids bonded together.10 As such, two types of chemically distinct sites, polar and equatorial, are possible within an individual icosahedron.

3. FINITE ELEMENT ANALYSIS

ANSYS is a complete FEA simulation software package developed by ANSYS Inc – USA

3.1 Structural Analysis

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

3.2 Types of Structural Analysis

The seven types of structural analyses available in the ANSYS family of products are explained below. The primary unknowns (nodal degrees of freedom) calculated in a structural analysis are displacements. Other quantities, such as strains, stresses, and reaction forces, are then derived from the nodal displacements.

3.4 Models and Drawings

Figure 2
Front View of Spur Gear

Analysis of AL 90% + SiC 5 %+ Boron Carbide 5% Composite

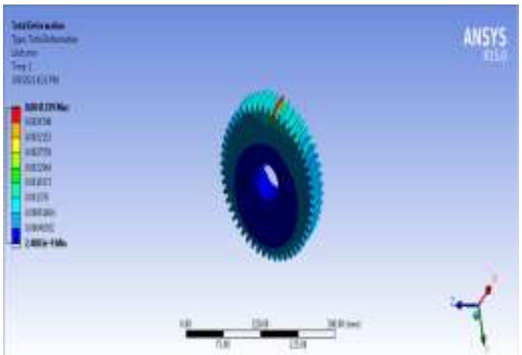

Figure 3
The analysis of spur gear AL 90% + SiC 5 %+ Boron Carbide 5% Composite was carried out on ANSYS for total deformation.

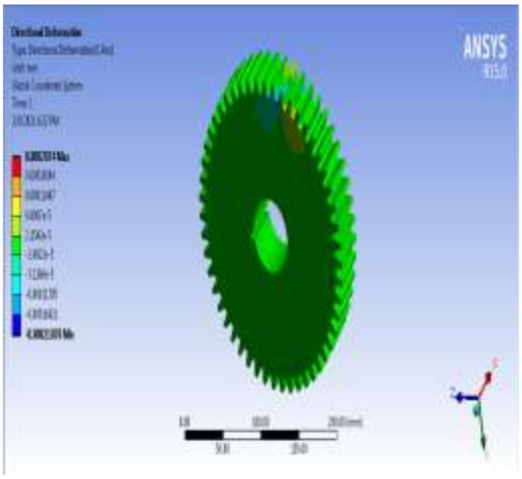

Figure 4
The analysis of spur gear AL 90% + SiC 5 %+ Boron Carbide 5% Composite was carried out on ANSYS for directional deformation along X axis. Similarly for other aluminium composites are also carried out.

4. RESULT AND DISCUSSION

The finite element method is most widely for find a real model of the geared set using the stress analysis in the pair of gears. The development off finite element analysis model of the spur gear assembly to simulate the contact stress calculation and bending stress calculation is play more significant role in the design of gears. The study is show that Hertz theory is the basis of contact stress calculation and Lewis formula is use for calculating bending stress is a pair of gear. The development off finite element analysis model of the spur gear assembly to simulate the contact stress calculation and bending stress calculation is play more significant role in the design of gears.

4.1 Comparison of Results

Table 5.1
Total Deformation Comparison

DESCRIPTION	TOTAL DEDFORMATION
Al 90%+SiC5%+ BORON CARBIDE 5%	0.0041339
Al 92%+SiC4%+ BORON CARBIDE 4%	0.0043701
Al 94%+SiC3%+ BORON CARBIDE 3%	0.0046351
Al 96%+SiC2%+ BORON CARBIDE 2%	0.0049343

Table 5.2
Equivalent Strain Comparison

EQUIVALENT ELASTIC STRAIN	
Al 90%+SiC5%+ BORON CARBIDE5%	0.0001122
Al 92%+SiC4%+ BORON CARBIDE4%%	0.00011852
Al 94%+SiC3%+ BORON CARBIDE4%3%	0.00012562
Al 96+SiC2%+ BORON CARBIDE4%2%	0.00013362

Table 5.3
Equivalent stress comparison

EQUIVALENT STRESS (MPa)	
Al 90%+SiC5%+ BORON CARBIDE5%	9.9362
Al 92%+SiC4%+ BORON CARBIDE4%%	9.9277
Al 94%+SiC3%+ BORON CARBIDE4%3%	9.9192
Al 96%+SiC2%+ BORON CARBIDE4%2%	9.9108

Figure 5
Fabricated Specimen of Al+SiC+B_4C Composite

5. CONCLUSION AND SCOPE FOR FUTURE WORK

From the obtained analysis results it was found that the best composition of aluminium with boron carbide for spurs gear. In this work the experiment and analysis on the fabricated composite material has been done successfully. The results of the composite material which is fabricated by using casting technique to determine Hardness, Impact, analysis test has been taken to find out the Hardness and corrosion test has been taken in the reinforcement particles of the boron carbide. This will increase the strength of the aluminium. It is observed that the investigational results meet the confidence limits.
From the foregoing review, it is evident that the future of Al composites in various industrial and commercial applications is very bright. Advanced technological developments in primary and secondary processing of Al will continue to give them a competitive edge over the alternative materials. New alloys of aluminium have been developed for application in such areas as crash management an area previously dominated by steel. These alloys offer new R&D opportunities for further development of Al composites and will redefine new roles and potential in automotive applications. Various researchers are also coming up with innovative cost-reduction techniques to bring down the cost of replacing conventional ferrous materials with aluminium metal matrix composites.

REFERENCES

[1] S. S. Maheedhara and F. Pourboghrat. 2007. Finite element analysis of composite worm gears, Journal of Thermoplastic Composite Materials, Vol. 20, January.

[2] Jaroslav Mackerle. 2003. Finite element analysis and simulation of quenching and other heat treatment process Abibliography (1976-2001), Computation materials science Vol. 27, pp. 313-332.

[3] Prášil, Ludvík, Mackerle and Jaroslav. 2008. Finite element analyses and simulations of gears and gear drives. A bibliography 1997-2006, Engineering Computations: International Journal for ComputerAided Engineering and Software, Vol. 25, No. 3, pp. 196-219.

[4] Vijaya Kumar Ambarisha and Robert G. Parker. 2007. Nonlinear dynamics of planetary gears using analytical and finite element models, Journal of sound and vibration Vol. 302, pp. 577-595.

[5] Kahraman A., Kharazi A. A., Umrani M. 2003. A deformable body dynamic analysis of planetary gears with thin rims, Journal of sound and vibration, Vol. 262, pp. 752-768.

[6] S. S. Maheedhara and F. Pourboghrat. 2007. Finite element analysis of composite worm gear, Journal of thermoplastic composite materials, Vol. 20, January.

[7] Lin Tengjiao, Ou H., Li Runfang. 2007. A finite element method for 3D static and dynamic contact/impact analysis of gear drives, Computer Methods in Applied Mechanics and Engineering, Vol. 196, No. 9-12 (February 1), pp. 1716-1728.

[8] Rehabilitation Bridges: Carbon Fiber-reinforced Polymer Shows Promise for Repairing. [9] Structures. 1999. Advanced Materials & Composites News.

[9] Deepa Nair. 2005. Gear Modeling by Simulating the Fabrication Process, Master thesis, University of Cincinnati.

[10] http://www.ptc.com/products/proengineer/

[11] Abaqus/CAE User's Manual

[12] .www.utm.edu/departments/engin/lemaster/Machine%20Design/Lecture%2021.pdf.

[13] Norton R. L. 1992. Machine Elements in Mechanical Design, 2nd ed., Merrill, New York, USA.

[14] Bernard J. Hamrock, Bo Jacobson and Steven R. Schmid. 1999. Fundamentals of Machine Elements, McGraw-Hill.

[15] R. Muthukumar And M. R. Raghavan, "Estimation of Gear Tooth Deflection by the Finite Element Method",Mech. Mach. Theory Vol. 22, No. 2, PP. 171-181, 1987.

[16] Celik, M, "Comparison of Three Teeth and Whole Body Models in Spur Gear Analysis", Mechanism and Machine Theory Vol. 34, Issue: 8, November, 1999. PP. 1227-1235.

[17] Chung-Biau Tsay, Wen-Yao Liu, Yi-Cheng Chen, "Spur Gear Generation by Shaper Cutters", Journal of Materials Processing Technology. 104 (2000) 271-279.

[18] Chien-Hsing Li_, Hong-Shun Chiou_, Chinghua Hung, Yun-Yuan Chang, Cheng-Chung Yen , "Integration Of finite Element Analysis And Optimum Design On Gear Systems" ,Finite Elements In Analysis And Design 38 (2002) 179-192.

[19] Akanda, M. A. Salam Ahmed, S. Reaz; Uddin, M. Wahhaj , "Stress Analysis of Gear Teeth using Displacement Potential Function and Finite Differences", International Journal for Numerical.