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Design and Analysis of Cam Shaft Using Al- Sic Composite

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Abstract

The study is mainly entitled on the design and analysis of a camshaft material using the metal matrix composite of Aluminium (6061) reinforced with SiC particulates. The main focus is on the design and analyse the properties of composite material (Al-SiC). Very high stresses on the cam and follower leads to the wear of the cam. Since the cam has eccentricity, vibration and cyclic loading on the bearing of the camshaft are the result of high dynamic stresses and hence the bearing life plummets. The work is reported on studies of Al-SiC as a possible alternative material for the camshaft. Al-SiC metal matrix composite provides exceptionally good properties for innumerable automotive components. Silicon carbide particles possess low coefficient of thermal expansion, high strength, high modulus of elasticity and density which when reinforced with aluminium alloys make them highly attractive materials which can meet the diverse demands of many engineering applications. In the present work, camshaft is designed in Creo Parametric 2.0 software. An attempt is made to study static and thermal analysis of the cam. Finite Element Analysis (FEA) is performed to see the stress variations at critical locations using ANSYS 14.0 software on camshaft periphery by applying the boundary conditions. The mixing of material is done using Stir casting which is simple and less expensive as compared to other types of casting. For the analysis of Aluminium Silicon Carbide sample, SEM with EDS is performed to get the microscopic structure at an accuracy. Vickers hardness test is used for the best results to check the strength of material and at last the final impact test is performed to see the maximum energy this composite could withstand before fracture. For impact testing, Charpy impact test is performed at different notch angles of 30^0, 45^0, 60^0 at three different temperature points: a) Room temperature, b) 50^0C and c) 100^0C.

Keywords: Al-SiC metal matrix composite; Stir casting; Vickers hardness test; Charpy impact; Notch angles

1. Introduction

A composite material is a material made from two or more constituent materials with significantly different chemical and physical properties that, when combined, result in a material with different characteristics from the individual components. The individual components remain separate and distinct within the finished structure. There are different types of composite materials like concrete, Aluminium Silicon Carbide, Wood, Resin etc. The composite material used here for cam shaft is Aluminium Silicon Carbide. Aluminium-Silicon Carbide is a metal-ceramic composite material having silicon carbide particles spread in a matrix of aluminium alloy. It combines the benefits of low CTE (coefficient of thermal expansion) and high thermal conductivity of metal of ceramic. It has high thermal conductivity, light weight and high strength. It is cheap for high production. Al-SiC allows for a new packaging technology that can substitute conventional W-Cu, Mo, BeO, Kovar, Mo-Cu, AlN, AlSi, and Al2O3. Al-SiC, pronounced "alsick", is a metal matrix composite consisting of aluminium matrix with silicon carbide particles. This study focuses on the use of composite material (Al-SiC) as a possible alternative material for the Camshaft and its advanced properties such as Tensile strength, Corrosion resistance, High strength to weight ratio etc. and comparing the results with conventional used Cam Shaft. In addition, to check the impact strength of the material at different temperature, hardness of the material and make out the conclusion for fatigue life and fracture toughness of the camshaft which would be build using this material matrix composite. The main purpose of using

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this composite is to build the camshaft at minimum cost with most benefits.

2. FEM analysis and procedure

The Finite Element Material analysis of shaft with diameter 23 mm and length 200 mm is performed with the help of Ansys Workbench of the composite material. The static structural analysis of the component is done in which two fixed supports were given to shaft faces on either sides and force was applied at the centre to get the solution of maximum and minimum displacement in stress analysis. Firstly, a Creo model of shaft of the above defined specifications is made. Using Ansys workbench, a static structural model is opened and engineering data is edited. In engineering data, the material of the shaft i.e. Aluminium silicon carbide (composite materials) is selected. Importing of the geometry saved in its format is done and after generating the model, the mesh is created on all the faces and the force is applied at the centre, and the displacement and stress analysis of the shaft is done.

3. Fabrication process

3.1 Stir Casting:

To design a camshaft at low cost using Al-SiC composite, a method of reinforcing the SiC particulates at different percentage (4%, 8%, and 12%) is defined to get different readings and choose the best reinforcement for designing the shaft. The aluminium alloy used is Al (6061) alloy because of its weldability, high strength and ductility. Stir casting is used for reinforcement because it is simple and less expensive and also easy to use. Stir Casting is the most common method for fabrication of aluminium alloy composites. There are many parameters involved in reinforcing the SiC particulates in Aluminium using stir casting process. Parameters for mixing the composite in this process are as follows:-

- Material mixing speed: 170rpm
- Material mixing time: 20 minutes
- Compacting Load: 150 kN
- Sintering Temperature: 830^0C
- Rate of Heating: 15^0/min
- Dwell Time: 5 minutes
- Sintering time: 40 minutes

It is the process in which discontinuous reinforcement is stirred into molten metal alloy and is then allowed to solidify. In making our Al-SiC composite, Aluminium (6061) alloy is heated at a temperature range of 830^0C and then the powdered silicon carbide is kept in muffle furnace to maintain at temperature of 450^0C and then the melted alloy is stirred with the silicon reinforcement for 5 minutes and hence the sample is kept to solidify after stirring mixture properly of reinforcement 4%, 8% and 12%.

3.2 Machining Process:

After stir casting process is done to make the sample of three different reinforcement, the machining process is performed in lathe machine. The processes that are performed in lathe machine are facing and turning operation for getting a good surface finish. Facing is done using a single point cutting tool, and the tool post onto the lathe machine is adjusted so that the tip of the tool point to the centre of the face. Turning operation is used to reduce the diameter of the workpiece.

3.3 Grinding Process:

To get a smooth surface with least scratches and a well observed microstructure and good hardness, grinding using emery paper of different grit sizes and rotating the workpiece regularly is done as the grit paper size changes. The different size of grit papers used are 150 ppi, 220 ppi, 600 ppi, 1200 ppi, 1500 ppi and 2500 ppi. Firstly, the purpose of using different size emery paper is to remove the scratches and dents and level the surface of the sample so that the grains of the Aluminium (6061) and Silicon Carbide are clearly seen in the microstructure and grain boundaries that are separating these grains. Secondly, different grit sizes give material a perfect shine on the surface that makes it scratch free. Now, as mentioned above, firstly, the emery paper of 150 ppi is used to remove the deep scratches and then 220 ppi paper and the sample is rotated at an angle of 90^0 because if rotation of the sample is not done as we move on to the next grit size paper, then scratches become more deeper and while doing the grinding of this composite material Al-SiC, grinding of the material should not be done for long time because this could affect the microstructure of the sample.

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3.4 Polishing Process:

It is the process of smoothening the surface of the workpiece using an abrasive and a rotating disc with a polishing cloth that is made of leather or velvet or any other light material. In this study, Alumina spray and Silica diamond paste are used as an abrasive material to smoothen the surface of the workpiece.

4. Testing of Sample of Al-SiC

4.1 Optical Microscopy:

In this study the microstructure of all the three samples with different reinforcements came out to be different, each having different grains, and grain boundaries are spread differently. The microscopic view of the sample is done with magnification lens of 10x to see the clear view of grains of Aluminium and silicon carbide being separated. It is observed that the grain boundaries of the microstructure of composite with reinforcement of 8% are giving a clear separation of aluminum (6061) and silicon carbide powder while those of 12% and 4% are lagging at some parts where grains are not properly mixed.

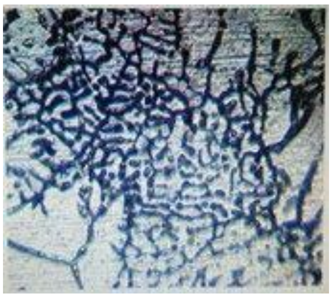

Figure 4.1: Microstructure of 4% reinforcement

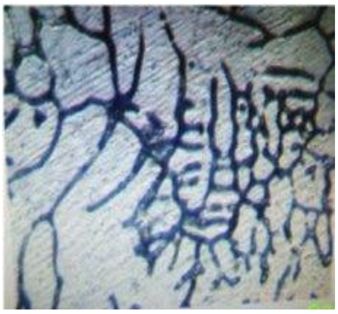

Figure 4.1: Microstructure of 8% reinforcement

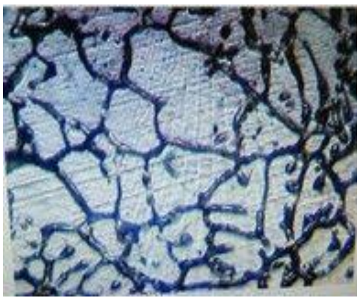

Figure 4.1: Microstructure of 12% reinforcement

4.2 Vickers Hardness test:

In this study, the micro hardness test of the composite material i.e. Aluminium (6061) Silicon Carbide is checked under the ASTM E-384 standard that indicates about the hardness testing of various materials using a diamond indenter. According to the study and performance, Vickers Hardness number is calculated using the formula given below:

$$HV = 1000 * P * \frac{\sin\left(\frac{\alpha}{2}\right)}{2 * d * d}$$

Where,

P= Load applied on the surface of the material

α= Angle between the two faces of the diamond tip (136^0)

d= mean diagonal length of the two diagonals of the tip ($(d_1 + d_2)/2$)

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S.no	Hardness (HV) for 4%	Hardness (HV) for 8%	Hardness (HV) for 12%
1	24	28	32
2	25	26	30
3	24	27	33
4	26	28	29
5	23	29	34
Average Hardness (HV)	24.4	27.6	31.6

Table 4.1: Hardness Values

It is observed that hardness value HV increases as the composition of the secondary particle is increased in the composite. The above values of hardness are measured under a constant load of 100 gf.

4.3 Charpy impact test:

Charpy impact testing of the sample is done using three different parameters for impacting. The parameters include the temperature, reinforcement and notch angle. The temperatures that are allowed to perform study are 25^0C (room temperature), 50^0C and 100^0C and the notch angles used for the samples are 30^0, 45^0 and 60^0 each for all three reinforcements (4%, 8% and 12%). ASTM E23 standard is used for performing the Charpy impact test and making notches. To prepare the samples for impact testing using ASTM standard, Taguchi method is used to make an L9 configuration table using three different parameters including Temperature, Reinforcement and Notch Angle. The dimension of the samples made for charpy test are of 55mm length and 10 * 10 mm^2 cross-section.

Sr.No.	Reinforcement (%)	Notch Angle (^{0})	Temperature (^{0}C)	Impact Energy (J)
1.	4	30	25	280
2.	8	45	25	286
3.	12	60	25	282
4.	4	30	50	278
5.	8	45	50	259
6.	12	60	50	284
7.	4	30	100	282
8.	8	45	100	264
9.	12	60	100	286

Table 4.2: Results of Impact Energy

Charpy test is performed at different temperatures for each reinforcement with same notch angle individually but notch angle differs from one another. Therefore, it is seen that for 4% reinforcement the constant notch angle is 30^0 but the absorbed energy is changed with change in temperature. It is observed that the absorbed energy for this reinforcement is maximum at 100^0C and minimum at 50^0C but the difference in energies is not more. Hence, there might be slight change in its mechanical properties. For 8% reinforcement with the constant notch angle of 45^0, the absorbed energy changes with change in temperature. Here the absorbed energy is maximum at room temperature (25^0C) and minimum at 50^0C. It is seen that there is a large variance in energies with temperature. Thus, the mechanical properties of 8% have major changes as the temperature is varied. For 12% reinforcement with constant notch angle of 60^0, the absorbed energy changes with change in temperature. The absorbed energy is maximum at

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100^0C and is minimum at room temperature (25^0C). It is observed that the energy increases for 12%. Therefore, there is less change in mechanical properties of 12% due less alteration in energy.

5. Results and discussion

This study is done to analyse the different loads on cam shaft on its working condition and also check the fatigue life and design and analyse the properties of new cam shaft using the alternative material, that is, Metal matrix composite of Aluminium (6061) alloy and Silicon Carbide. Different testing is done on it such as Impact test, Vickers Hardness test and its microstructure has been seen.

The microstructure of the sample is observed and have saved it for the future analysis. Hardness test is done and it is found that using different compositions of silicon carbide changes the hardness value, and the value increases with the increased percentage of silicon carbide up to certain extent. There was rapid increase on the hardness value from 4% to 8% composition compared to 8% to 12% composition.

Also, Charpy impact test is done on different notch angles and temperatures using ASTM E23 standard and it is found that the 12% composition of silicon carbide with notch angle 60^0 and 4% composition mixture with notch angle 30^0 absorb the maximum energy at 100^0C temperature before getting fracture which shows that they have higher strength at higher temperature compared to 8% composition mixture. At 25^0C temperature, 8% composition mixture absorbs the maximum energy as compared to the other two composition mixture.

6. Conclusions

This study investigated that the metal matrix composite material of aluminium silicon carbide on designing camshaft could replace the traditional one. It could also increase its fatigue life and after impact loading. Camshafts made with this composite would be strong enough to bear the tensile and bending strength.

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