DESIGN ANALYSIS OF CAM SHAFT USING Al-SiC COMPOSITE

Ujjal Kalita*
School of Mechanical Engg.,
Lovely Professional University, Phagwara, Punjab, India
*ujjal.19355@lpu.co.in

Abstract: A cam and follower are subjected to very high stresses which cause wear of the cam. Owing to the eccentricity of the cam, high dynamic stresses are developed which results in noise, vibration and cyclic loading on the bearing of the camshaft and hence produce a reduction in bearing life. The work will report on studies of Al-SiC as a possible alternative material for the camshaft. (AlSiC) Metal matrix composite offers outstanding properties for a number of automotive components. 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, we performed SEM with EDS to get the microscopic structure at an accuracy. Here we have also used Vickers hardness test to check the strength of material for best results this method was used and at last the final impact test was performed to see the maximum energy this composite could withstand before fracture. For impact testing Charpy impact test was 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: Cam, Aluminium Silicon Carbide, EDS, Impact test

I. **Introduction:** Cam is a rotating or sliding piece in a mechanical used especially in transforming rotary motion into linear motion. It is often a part of a rotating wheel or shaft that strikes leveret one or more points on its circular path. The cam can be a simple tooth, as it is used to deliver pulses of power to a steam hammer, for example an eccentric disc or other shape that produces a smooth reciprocating motion in the follower, which is a lever making contact with the cam. In internal combustion engines, the camshaft is used to operate poppet valves. It consists of a cylindrical rod running the length of the cylinder bank with a number of cams protruding from it, one for each valve. The camshaft is driven by the crankshaft through timing gears cams are made as integral parts of the camshaft and are designed in such a way to open and close the valves at the correct timing and to keep them open for the necessary duration.

Figure 1: Camshaft

Camshafts can be made out of several types of material. These include:

1.1 Chilled iron castings: Chilled-Iron castings are made by casting the molten metal against a metal chiller, resulting in a surface of white cast iron. A constant chill depth may be obtained by using a combination of alloying elements that have opposite effects. Since nickel reduces chill depth, it is common practice to add chromium produce the opposite effect. The normal ratio employed in this purpose is 3 parts of nickel to 1 of chromium. Commonly used in high volume production, chilled iron camshafts have good wear resistance since the chilling process hardens them.

1.2 Billet Steel: The billets are used to manufacture steel bars. The raw material for this process is iron scrap. This iron scrap is melted in furnace, the liquid material so obtained is then poured into CCM (continuous casting machine). The continuous casting machine then makes the Billets of required cross section and length. When a high-quality camshaft or low volume production is required, engine builders and camshaft manufacturers choose steel billet. This is a much more time-consuming process, and is generally more expensive than other methods.

1.3 Composite materials: A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different 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 we have used for cam shaft is Aluminium Silicon Carbide.

Aluminium-(Silicon Carbide) is a metal-ceramic composite material consisting of silicon carbide particles dispersed in a matrix of aluminium alloy.

1.4 Stir Casting: To design a camshaft at low cost using Al-SiC composite we defined a method of reinforcing the SiC particulates at different percentage (4%, 8%, and 12%) to get different readings and choose the best reinforcement for designing the shaft.The method used for reinforcement is Stir casting 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

1.5 Machining Process: After doing the stir casting process to make the sample of three different reinforcement we performed the machining process in lathe machine. The processes that were performed in lathe machine were facing and turning operation for getting a good surface finish.

1.6 Grinding Process: As the workpiece is done with machining process, we observed that the surface finish of the sample is still a little rough to get a smooth surface with least scratches and a well observed microstructure and good hardness we have done grinding using emery paper of different grit sizes and rotating the workpiece regularly as the grit paper size changes.

II. **Review of Literature:** V.Radmilovic et. Al. **i**n their work explained the microstructures of high temperature monolithic Al-Fe-V-Si alloy and SiC particulates which visualized that no segregation of iron, vanadium or silicon at the SiC matrix [1]. D.L.Davidson concluded that there are many factors which can affect fatigue crack initiation, small and large cracks can be correlated with stress intensity factor and fracture toughness is mainly related to matrix plasticity but is strongly influenced by particle characteristics[2]. R.Sagar et. al. recalled that Aluminium alloys provide a good matrix for the development of particulate composites which are less expensive and exhibit high mechanical properties [3]. T.S.Srivatsan **i**n his project visualized the discontinuous reinforcement of silicon carbide particulates in aluminium (6061) alloy which was cyclically deformed to failure at ambient temperature under stress-amplitude controlled condition [4]. Dunia Abdul Saheb told that to obtain a specific mechanical or physical property, the MMC should consist of ne particles distributed uniformly in a ductile matrix and with clean interfaces between particle and matrix [5]. Ramanpreet Singh et. al. visualized that Aluminium Metal Composites are combinations of materials in such a way that the resulting materials have certain design properties on improved quality. Mechanical alloying is a unique process for fabrication of several alloys and advanced materials at room temperature. An effort has been made to study hardness and wear properties with varying weight fraction of SiC in particle reinforced MMCs developed with the help of mechanical alloying method of powder metallurgy technique. ASTM International organisation explains us about the ASTM E23 that is used as standard test method by American Society of Testing Material for Charpy Impact test of notched bars [6]. R.Sagar et. al. fabricated the composite wit SiC percentage of 10, 15, 20 and 25 percent through powder metallurgy and gravity die casting process [7]. Samta Jain et. al. used two materials Copper and Iron were taken into consideration. The results of Stress and maximum displacement are calculated and compared for all the above material [8]. The values in the FEM analysis were compared with theoretical values and then it was concluded that Iron will be the best suited material for camshaft [9].

III. **Research Methodology:** Step 1: Creo Model of Cam Shaft:

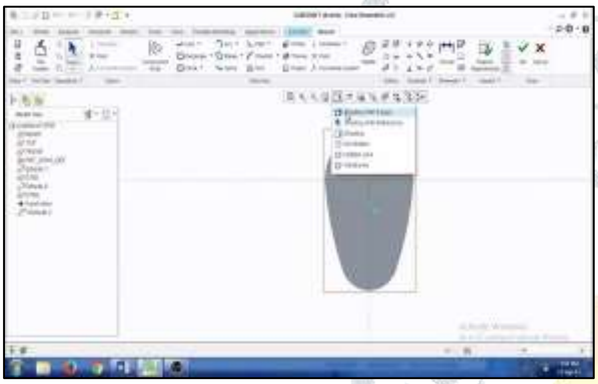


Figure 1: Creo modelling of camshaft

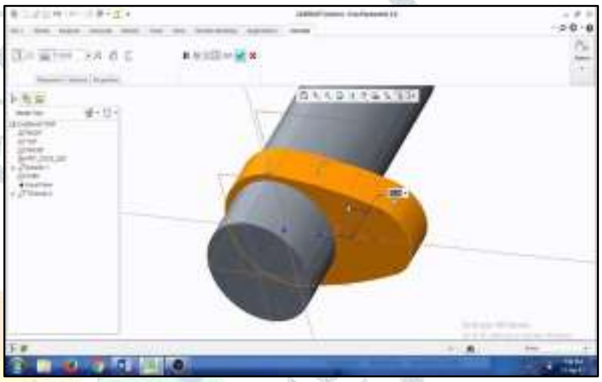


Figure 2: Creo assembly of camshaft

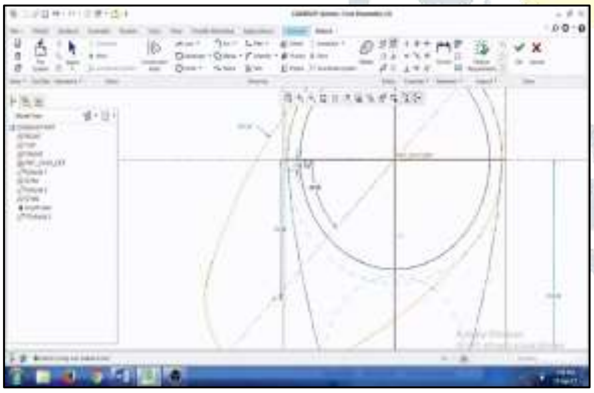


Figure 3: Creo model of cams

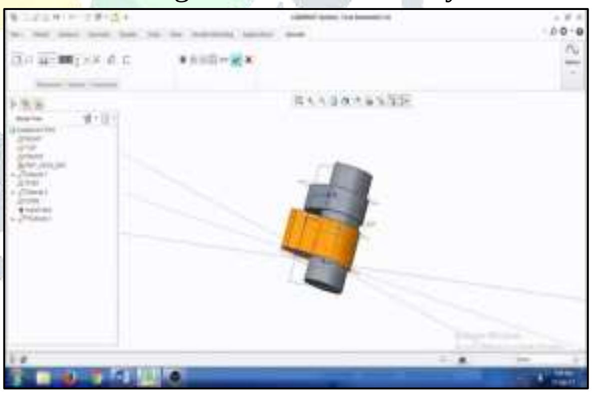


Figure 4: Assembly of camshaft

FEM analysis: The Finite Element Material analysis of shaft with diameter 23mm and length 200mm was performed with the help of Ansys Workbench of the composite material. Here 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 max. And min. displacement in stress analysis. The results obtained were as follows:

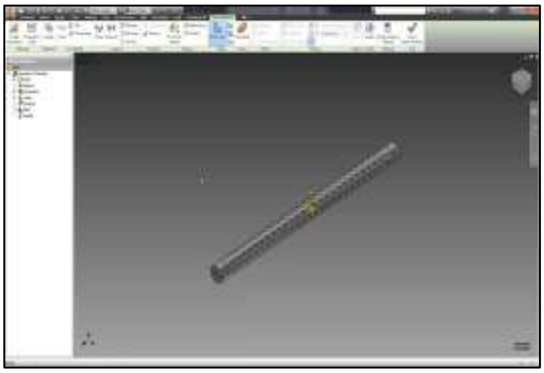


Figure 5: Meshing of Shaft

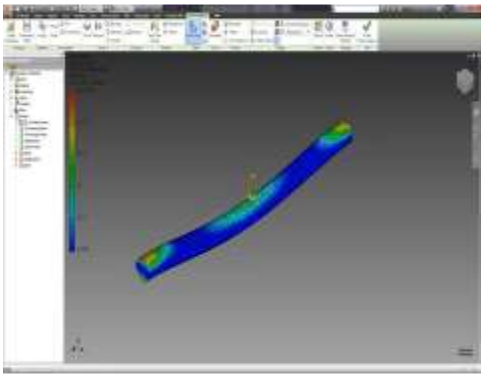


Figure 6: Fixed support on Camshaft

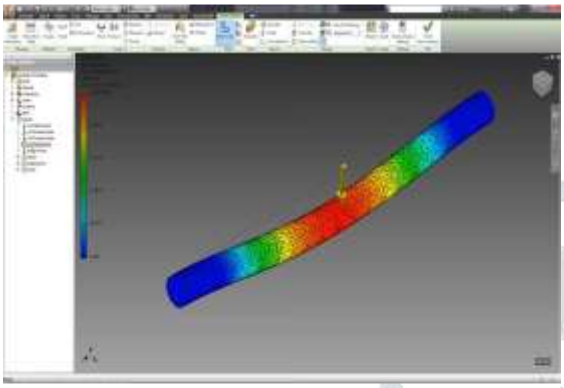


Figure 7: Load applied on camshaft

Procedure:-

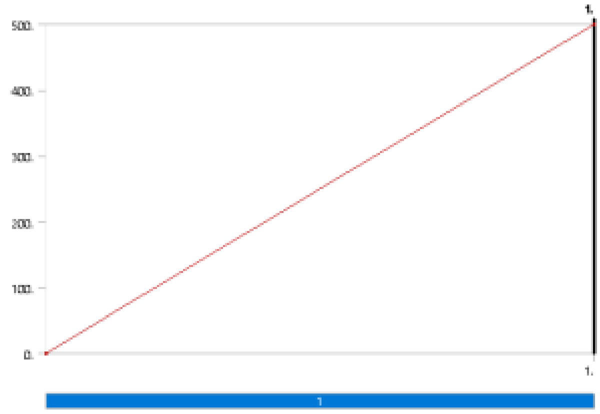
1. First we made a creo model of shaft of the above defined specifications i.e. diameter of 23 mm and length of 200mm.
2. Then using Ansys workbench we opened a static structural model and from that engineering data is edited.
3. In engineering data, the material of the shaft i.e., Aluminium silicon carbide (composite materials) is selected.
4. After selecting the material, we import our geometry saved in its format and then generate the modal.
5. After generating the model, we create mesh on all the faces and apply force at the centre and do the displacement and stress analysis of the shaft.
6. At last, the solution of the test is seen and report is added[10,11].

IV. Result & Discussion

This project was 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. We have done different testing on it such as Impact test, Vickers Hardness test and have seen its microstructure.

Report of model is given as

Model (A4) > Static Structural (A5) > Force



Solution(A6): TABLE 9
Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done

TABLE 10
Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 11
Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Equivalent Stress*	*Total Deformation*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Equivalent (von-Mises) Stress	Total Deformation
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Suppressed	No	
Integration Point Results		
Display Option	Averaged	
Results		
Minimum	7.3576e+005 Pa	0. m
Maximum	1.9103e+006 Pa	2.2279e-006 m
Minimum Value Over Time		
Minimum	1.4715e+005 Pa	0. m
Maximum	7.3576e+005 Pa	0. m
Maximum Value Over Time		
Minimum	3.8206e+005 Pa	4.4558e-007 m
Maximum	1.9103e+006 Pa	2.2279e-006 m
Information		
Time	1. s	
Load Step	1	
Substep	4	
Iteration	5	

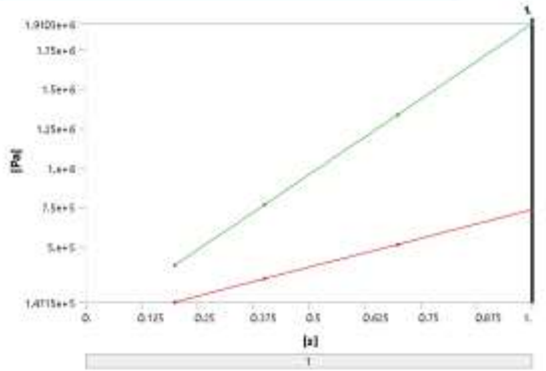


TABLE 12
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

Time [s]	Minimum [Pa]	Maximum [Pa]
0.2	1.4715e+005	3.8206e+005
0.4	2.943e+005	7.6412e+005
0.7	5.1503e+005	1.3372e+006
1.	7.3576e+005	1.9103e+006

FIGURE 3
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

TABLE 13
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

Time [s]	Minimum [m]	Maximum [m]
0.2	0.	4.4558e-007
0.4		8.9115e-007
0.7		1.5595e-006
1.		2.2279e-006

Material Properties:

Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	Aluminium Alloy NL
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	2.e-002 m
Length Y	2.e-002 m
Length Z	0.1 m
Properties	
Volume	3.1416e-005 m^3
Mass	8.7021e-002 kg
Centroid X	3.905e-013 m
Centroid Y	-1.4545e-013 m
Centroid Z	5.e-002 m
Moment of Inertia Ip1	7.4464e-005 kg·m^2
Moment of Inertia Ip2	7.4465e-005 kg·m^2
Moment of Inertia Ip3	4.3218e-006 kg·m^2
Statistics	
Nodes	2550
Elements	500
Mesh Metric	None

V. Conclusion

After the fabrication and testing was done of the camshaft made from the chosen material Al-SiC composite we have concluded that the strength of the camshaft is increased it is less ductile but has a good hardenability to high loads. It is light in weight which will help in increasing the efficiency of engine. The fatigue life of the shaft is also more than that of previous models of camshaft. This is due to good material properties of Al-SiC metal matrix composite. The initialization cost of camshaft is less. Thus, it can also be concluded that more power, more life and lesser cost of the vehicle.

Figure 8: Al-SiC composite sample for shaft

References

1. V.Radmilovic and G.Thomas "Microstructure of α-Al base matrix and SiC particulate composite" University of California and Lawrence Berkeley Laboratory, USA. (1990); 171-179.
2. D.L.Davidson "Fatigue and fracture toughness of aluminium alloys reinforced with SiC and alumina particles" Southwest Research Institute, USA (1992); 24(3); 248-255.
3. K.C.Ramesh and R.Sagar "Fabrication of metal matrix composite automotive parts" The International Journal of Manufacturing Technology. (1999); 114-115
4. T.S.Srivatsan "Influence of silicon carbide particulate reinforcement on quasi- static and cyclic fatigue fracture behaviour of 6061 aluminium alloy composite" University of Akron, Akron, USA. (2002); 202-214.
5. Dunia Abdul Saheb "Aluminium silicon carbide and aluminium graphite Particulate composites" ARPN journal of Engineering and Applied Sciences, Iraq. (2011); 6(10); 41-46.
6. Ramanpreet Singh, Er. Rahul Singla "Tribological Characterization of Aluminium-Silicon Carbide Composite Prepared by Mechanical Alloying" International Journal of Applied Engineering Research. (2012); 2(3); 148-150
7. ASTM International "Standard Test Method for Notched bar impact testing of metallic materials" Journal of ASTM International. (2016) ;1-28
8. R.Purohit and R.Sagar "Fabrication of Al-SiC composite valve seat inserts" International Journal of Advanced Manufacturing Technology. (2016) ;29(1);922-928
9. Samta Jain, Mr. Vikas Bansal "Stress analysis of camshaft and choosing best manufacturing material" International Journal of Engineering Research Technology and Sciences [IJERTS]. (2017) ;4(5);753-757
10. Jing Liu, Zhanglin Yan, Yimin Shao, "An investigation for the friction torque of a needle roller bearing with the roundness error," ELSEVIER, vol. Mechanism and Machine Theory 121 (2018), no. 259–272, (2018)
11. C.E. NORTON, P.J. BAKER, "The Effect of New Material and Processing Developments on Ball Bearing Fatigue Life" SAE Technical Paper 2018-779B