Design and Analysis of A Camshaft using Al-Sic Composite with A Study of Latest Trends in Diesel Technologies

D Jagan
Department of Mechanical Engineering
Anurag College of Engineering, Hyderabad, Telangana, India

V Ganesh
Department of Mechanical Engineering
Anurag College of Engineering, Hyderabad, Telangana, India

Abstract- The project entitles mainly on the design and analysis of a camshaft along with the study of the trends in diesel technologies. The project is mainly focused across two areas, one is to observe and get enough hands on experience on automobiles at an automobile workshop and the other is to design and analyze the properties of various materials along with the composite material taken and producing an analogy with the analysis carried out. The work reports on studies on Al-SiC as a possible alternative material for a cam. Powder metal composite cams when mounted on hollow shafts provide high strength to weight ratio. The coefficient of thermal expansion is also very low. Global competition and the growing concern for the environment has forced the automobile manufacturers to meet conflicting demands such as increased power and performance, lower fuel consumption, lower pollution emission and decreased noise and vibration. Metal matrix composites offer outstanding properties for a number of automotive components. Silicon carbide particles have a high modulus of elasticity, high hardness, low coefficient of thermal expansion and density which when reinforced with aluminium alloys make them highly attractive materials, possessing properties which can be tailored to meet the diverse demands of various engineering applications. Cams are widely used in the automotive and other industries. The contact region of the cam and follower is subjected to very high stresses which cause wear of the cam. Owing to the eccentricity of the cam, high dynamic stresses are developed which result in noise, vibration and cyclic loading on the bearing of the camshaft and hence produce a reduction in bearing life.

Keywords – Cams, Al-SiC, bearing life, diesel technology, dynamic stress

I. Introduction

The project begins with a study and survey about the various diesel engines at an automobile workshop. Here in the workshop all kinds of vehicles like petrol, diesel, and cng variants are observed and their engine specifications are noted with varying capacities and performances. The engines with a higher capacity and performance run on diesel as a fuel. Engines with various capacities vary in their dimensions and appearance. The inner parts in engines also vary as per their respective engine blocks. Main focus is put on the camshaft of all the engines as the project is solely based on that crucial part of the engine.

Trends in Diesel Engine

Four stroke cycle

• Intake stroke: intake valve opens while the piston moves down from its highest position in the cylinder to its lowest position, drawing air into the cylinder in the process.

• Compression stroke: intake valve closes and the piston moves back up the cylinder.

This compresses the air & therefore heats it to a high temperature, typically in excess of 1000°F (540°C).

Near the end of the compression stroke, fuel is injected into the cylinder. After a short delay, the fuel ignites spontaneously, a process called auto ignition.

• Combustion stroke: The hot gases produced by the combustion of the fuel further increase the pressure in the cylinder, forcing the piston down

• Exhaust stroke: exhaust valve opens when the piston is again near its lowest position, so that as the piston once more moves to its highest position, most of the burned gases are forced out of the cylinder.

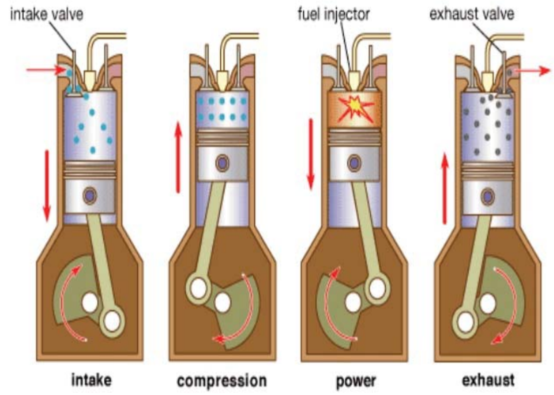


Fig No. 1.1 Valves of an Engine

Basic components of an I C Engine: Cylinder head, valves, Camshaft,The Piston,Crankshaft,

Compression Ratio

This is defined as the ratio of the volume of the cylinder at the beginning of the compression stroke (when the piston is at BDC) to the volume of the cylinder at the end of the compression stroke (when the piston is at TDC).
The higher the compression ratio, the higher the air temperature in the cylinder at the end of the compression stroke.
Higher compression ratios, to a point, lead to higher thermal efficiencies and better fuel economies.
Diesel engines need high compression ratios to generate the high temperatures required for fuel auto ignition.
In contrast, gasoline engines use lower compression ratios in order to avoid fuel auto ignition, which manifests itself as engine knock or pinging sound.
Common spark ignition compression ratio: 8:1 to 12:1
Common compression ignition ration: 14:1 to 25:1

1.1 Classification of Camshafts:

While today some cheaper engines rely on a single camshaft per cylinder bank, which is known as a single overhead camshaft (SOHC), most modern engine designs are in the overhead-valve or OHV engine being largely obsolete on passenger vehicles, are driven by a two camshafts per cylinder bank arrangement as in one camshaft for the intake valves and another for the exhaust valves. such camshaft arrangement is known as a double or dual overhead cam (DOHC), thus, a V engine, which has two separate cylinder banks, may have four camshafts.

Fig No. 1.2 Eight lobed DOHC

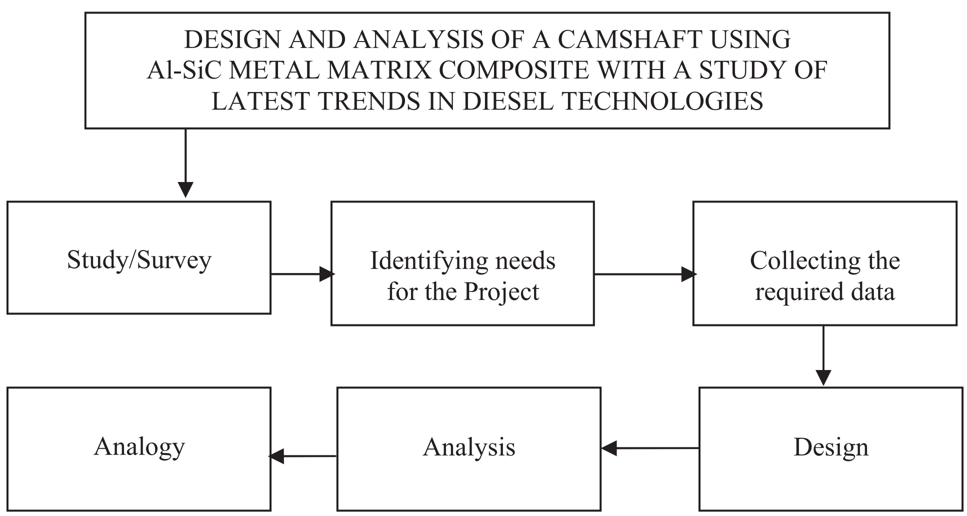
More unusual is the modern W engine that has four cylinder banks arranged in a "W" pattern with two pairs narrowly arranged with a 15-degree separation. Even when there are four cylinder banks, the narrow-angle design allows the use of just four camshafts in total. For the Bugatti Veyron, which has a 16-cylinder W engine configuration, all the four camshafts are driving a total of 64 valves.
The overhead camshaft design adds more valve train components that ultimately incur in more complexity and higher manufacturing costs, but this is easily offset by many advantages over the older OHV design: multi-valve design, higher RPM limit and design freedom to better place valves, ignition (Spark-ignition engine) and intake/exhaust ports.

Fig No. 1.3 Sixteen lobed DOHC

The rockers or cam followers sometimes incorporate a mechanism to adjust and set the valve play through manual adjustment, but most modern auto engines have hydraulic lifters, eliminating the need to adjust the valve lash at regular intervals as the valve train wears, and in particular the valves and valve seats in the combustion chamber.
Sliding friction between the surface of the cam and the cam follower which rides upon it is considerable. In order to reduce wear at this point, the cam and follower are both surface hardened, and modern lubricant motor oils contain additives specifically to reduce sliding friction.

II. PROPOSED ALGORITHM

2.1 Flow chart



All the steps are in an order and to be executed perfectly. The project entitles on the design and analysis of a camshaft along with the study of the trends in diesel technologies. The project is mainly focused across two areas, one is to observe and get enough hands on experience on automobiles at an automobile workshop and the other is to design and analyze the properties of various materials along with the composite material taken and producing an analogy with the analysis carried out.

2.2 Existing materials in Camshafts

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

Chilled Cast Iron:

Cast Iron is an alloy of iron that contains 2 to 4 percent carbon, along with varying amounts of silicon and manganese and traces of impurities such as sulfur and phosphorus. It is made by reducing iron ore in a blast furnace. The liquid iron is cast, or poured and hardened, into crude ingots called pigs, and the pigs are subsequently remelted along with scrap and alloying elements in cupola furnaces and recast into molds for producing a variety of products.

Most cast iron is either so-called gray iron or white iron, the colors shown by fracture. Gray iron contains more silicon and is less hard and more machinable than is white iron. Both are brittle, but a malleable cast iron produced by a prolonged heat treatment was developed in France in the 18th century, and a cast iron that is ductile as cast was invented in the United States and Britain in 1948. Such ductile irons now constitute a major family of metals that are widely used for gears, dies, automobile crankshafts, and many other machine parts.
Gray iron contains more silicon and is less hard and more machinable than is white iron. Both are brittle, but a malleable cast iron produced by a prolonged heat treatment

Fig No. 2.1 Camshaft made of blank chilled cast iron

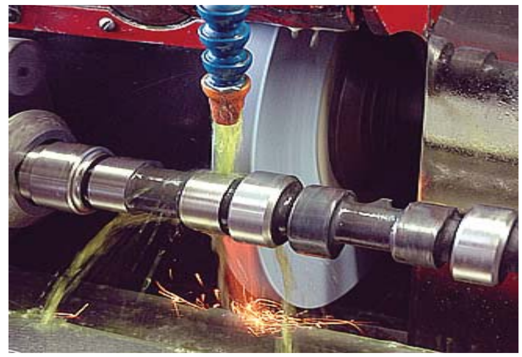


Fig No. 2.2 Grinding process of a chilled cast iron

Billet Steel:

A small, semi-finished piece of metal that is rectangular, circular, or square in shape. Billets are smaller than blooms. When a high quality camshaft is required, engine builders and camshaft manufacturers choose to make the camshaft from steel billet. This method is also used for low volume production. This is a much more time consuming process, and is generally more expensive than other methods. However the finished product is far superior. When making the camshaft, CNC lathes, CNC milling machines and CNC camshaft grinders will be used. Different types of steel bar can be used, one example being EN40b. When manufacturing a camshaft from EN40b, the camshaft will also be heat treated via gas nitriding, which changes the micro-structure of the material. It gives a surface hardness of 55-60 HRC. These types of camshafts can be used in high-performance engines. A steel billet racing camshaft with noticeably broad lobes.

III. EXPERIMENT

3.1 Dimensional values

The required data is collected using different tools for dimensions and material properties. Various gauges used for dimensional readings are like Vernier and Screw gauges. The Material properties are existing and ready for use. Values that are collected are stated in the table below.

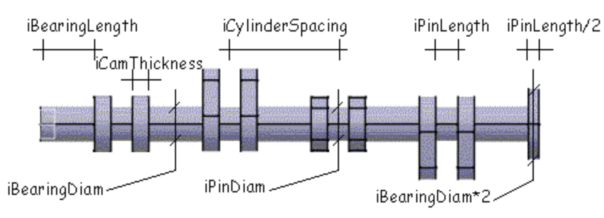


Fig No. 3.1 Camshaft and its dimensional properties

NOTE :
1. Bearing Length = Cylinder Spacing – Pin Length - 2*Cam Thickness
2. All values are taken from the existing camshaft.

3.2 Properties of Al-SiC, Cast Iron, Billet Steel

Model Type- Linear Elastic Isotropic Units- SI (Mpa)

No of Cylinders	4
Thickness of Cam	15mm
Cylinder Spacing	100mm
Pin Length	20mm
Pin Diameter	15mm
Bearing Length	50mm
Bearing Diameter	32mm

Table No. 1 Camshaft and its dimensional Values

Category- Metal Matrix Composite
Name- Aluminium Silicon Carbide Al-SiC
Description- The chosen composite is Al-SiC 12 (63%Al 37% SiC)

Property	Value	Units
Elastic Modulus	167000	Mpa
Poisson's Ratio	0.3	No Units
Bulk Modulus	139170	Mpa
Shear Modulus	64210	Mpa
Density	3100	Kg/m^3
Tensile Strength	220	Mpa
Compressive Strength	118	Mpa
Yield Strength	140	Mpa
Thermal Expansion Coefficient	0.22	/K
Thermal Conductivity	180	W/(m-K)
Specific Heat	808	J/(Kg-K)

Table No. 2 Properties of Al-SiC

Model Type- Linear Elastic Isotropic
Units- SI (Mpa)   Category- Metal
Name- Chilled Cast Iron
Description- The material chosen is Cast Iron which is chilled

Property	Value	Units
Elastic Modulus	190000	Mpa
Poisson's Ratio	0.27	No Units
Bulk Modulus	158330	Mpa
Shear Modulus	74803	Mpa
Density	7300	Kg/m^3
Tensile Strength	413.6	Mpa
Compressive Strength	140	Mpa
Yield Strength	275.74	Mpa
Thermal Expansion Coefficient	3.2	/K
Thermal Conductivity	47	W/(m-K)
Specific Heat	510	J/(Kg-K)

Table No. 3 Properties of Chilled Cast Iron

Model Type- Linear Elastic Isotropic
Units- SI (Mpa)
Category- Metal
Name- Billet Steel

Description- The Material chosen is Billet Steel and is a metal

Property	Value	Units
Elastic Modulus	193000	Mpa
Poisson's Ratio	0.27	No Units
Shear Modulus	75984.8	Mpa
Bulk Modulus	139868	Mpa
Density	8000	Kg/m^3
Tensile Strength	550	Mpa
Compressive Strength	140	Mpa
Yield Strength	137.9	Mpa
Thermal Expansion Coefficient	4.3	/K
Thermal Conductivity	16.3	W/(m-K)
Specific Heat	500	J/(Kg-K)

Table No.4 Properties of Billet Steel

3.3 Thermal properties

Metal matrix composites have been recently developed for electronic packaging application due to their attractive combination of physical properties, manufacturing flexibility and relatively inexpensive cost. One advantage of metal matrix composites is the ability to tailor the thermal properties, such as thermal conductivity and coefficient of thermal expansion, through the proper control of reinforcement and matrix. In addition, the manufacturing flexibility of the metal matrix composite by various processes allows the fabrication of complicated shaped parts. The metal matrix composites for electronic packaging application have been actively investigated since late 1980's and several electronic packaging components have been commercialized using metal matrix composites. The SiC/Al, diamond/Cu, and silver/nickel-iron are the important candidate materials for electronic packaging applications. Lanxide Electronic Component Inc. developed the microwave housing with SiCp/Al metal matrix composite, which is only one third in weight and has 6 times higher thermal conductivity compared to conventional microwave housing. Textron Special Material Inc. developed the heat sink in printed circuit board using the B/Al metal matrix composites, and PCast Co. developed the multichip module using SiCp/Al metal matrix composites. In order to use the metal matrix composite for electronic packaging application, it is very important to increase the volume fraction of ceramic reinforcement to over 50 vol% to reduce the coefficient of thermal expansion comparable to that of alumina substrate or semiconductor such as silicon and gallium arsenide, which coefficient of thermal expansion is ranged 6–7 ppm/K.

The fabrication of metal matrix composites with high volume fraction of ceramic reinforcement above 50 vol% is not easy due to the agglomeration of reinforcements and the pore formation in agglomerated reinforcements. In this study, the fabrication process of 50–71 vol% SiCp/Al metal matrix composites for electronic packaging applications was investigated. The thermal properties, coefficient of thermal expansion and thermal conductivity, and microstructures of high volume fraction SiCp/Al composites were characterized.

3.4 DESIGN, ANALYSYS AND RESULTS:

Needs for the design: The typical needs for a design of camshaft are the dimensional values and the accurate ways of design. The design mainly follows the following steps:

- Arrangement of the dimensions
- Defining the properties and
- Gathering everything

Steps: 1. Define the Plane 2. 2D Sketch 3. Trimming
4. Extrusion 5. Shaft 6. Assembly and Formatting

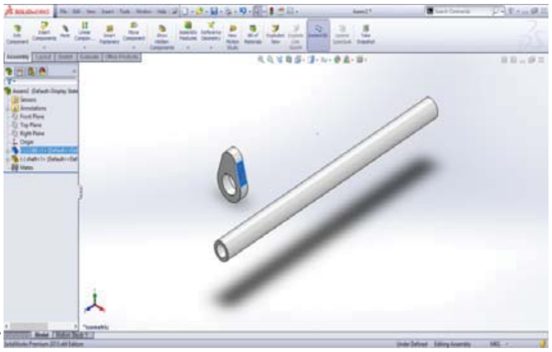


Fig No. 3.4 Inserting Components

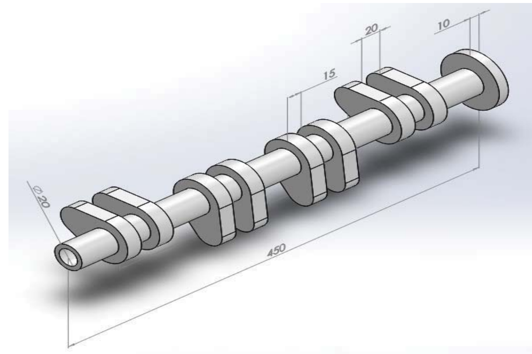


Fig No. 3.5 Camshaft with Dimensions

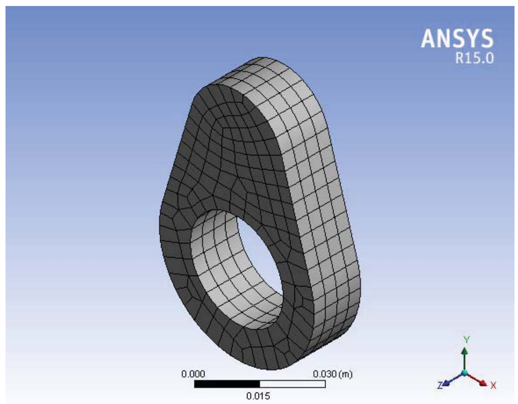


Fig No.3.6 Mesh generated in the lobe

Table No 5 Geometry of AlSiC lobe

Object Name	Lobe
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	50. mm
Length Y	75. mm
Length Z	15. mm
Properties	
Volume	31288 mm^3
Mass	9.6994e-002 kg
Centroid X	1.5012e-005 mm
Centroid Y	13.274 mm

Centroid Z	3.166e-003 mm
Moment of Inertia Ip1	42.577 kg·mm²
Moment of Inertia Ip2	18.321 kg·mm²
Moment of Inertia Ip3	57.261 kg·mm²
Statistics	
Nodes	2998
Elements	528
Mesh Metric	None

Table No. 6 Results

Object Name	Total Deformation	Directional Deformation	Equivalent Elastic Strain	Maximum Principal Elastic Strain	Normal Elastic Strain	Equivalent Stress	Maximum Principal Stress	Normal Stress	Shear Stress
Orientation		X Axis			X Axis			X Axis	XY Plane
Coordinate System		Global Coordinate System			Global Coordinate System			Global Coordinate System	
Results									
Minimum	0. mm	-6.6824e-008 mm	1.12e-010 mm/mm	3.0362e-011 mm/mm	-1.0976e-009 mm/mm	9.0454e-006 MPa	-8.2699e-004 MPa	-1.1221e-003 MPa	-7.0424e-004 MPa
Maximum	4.2218e-007 mm	6.6831e-008 mm	2.3862e-008 mm/mm	7.2748e-009 mm/mm	6.971e-009 mm/mm	3.9832e-003 MPa	6.7446e-004 MPa	5.6682e-004 MPa	6.9731e-004 MPa
Minimum Value Over Time									
Minimum	0. mm	-6.6824e-008 mm	1.12e-010 mm/mm	3.0362e-011 mm/mm	-1.0976e-009 mm/mm	9.0454e-006 MPa	-8.2699e-004 MPa	-1.1221e-003 MPa	-7.0424e-004 MPa
Maximum	0. mm	-6.6824e-008 mm	1.12e-010 mm/mm	3.0362e-011 mm/mm	-1.0976e-009 mm/mm	9.0454e-006 MPa	-8.2699e-004 MPa	-1.1221e-003 MPa	-7.0424e-004 MPa
Maximum Value Over Time									
Minimum	4.2218e-007 mm	6.6831e-008 mm	2.3862e-008 mm/mm	7.2748e-009 mm/mm	6.971e-009 mm/mm	3.9832e-003 MPa	6.7446e-004 MPa	5.6682e-004 MPa	6.9731e-004 MPa
Information									

IV. CONCLUSION

The work reports on studies on Al-SiC as a possible alternative material for a cam. Powder metal composite cams when mounted on hollow shafts provide high strength to weight ratio. The coefficient of thermal expansion is also very low.

The various properties of cams, namely, high strength to weight ratio, high stiffness, corrosion resistance, wear resistance, low coefficient of thermal expansion, closer dimensional tolerances and versatility to designer can be measured and their variation with reinforcement content are studied.

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