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Investigation and Failure Analysis for Camshaft

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Abstract: The main objective of writing this report on the failure of crankshaft is to investigate the characteristic of crankshaft after experienced complex of loading in a long period of services. Crankshaft is an important engine component of internal combustion engine with complex geometry which is subjected to fluctuating or cyclic loads often resulting in fatigue failures. The sudden failure of crankshaft made researchers and academia to investigate the problem. Accurate investigation of fatigue life is very important to insure safety of components and its reliability. This report presents an investigation on crankshaft by performing important experimental techniques. Hardness of the camshaft and bending test has been done to get the some characteristic of the camshaft. Last but not least, by using scanning electron microscopy, the microstructure of the fractured camshaft had been investigated. Discussion on preventing from failure on camshaft is also presented in this report.

Key words: *Crankshaft, Failure, Bending Test, Hardness.*

INTRODUCTION

The component that failure occur is CAMSHAFT. A Camshaft is commonly used to operate poppet valves in an internal combustion engine. A camshaft is situated in the cylinder block or cylinder head which has oblong lobes or cams which causes a tappet or lifter to open and close the intake and exhaust valves. This force is applied on the valve directly or through an intermediate mechanism such as a rocker arm, lifter, follower or tappet. Push rods are used to connect the camshaft to the rocker arm via the lifter. Each valve utilizes a spring which returns the valve to their original position. Proper design of cam and follower would facilitate in achieving the targets of high reliability & productivity and better product quality [1].

A camshaft is driven by the crankshaft via timing chain or belt. The timing belt or chain needs to be replaced per manufacturer's recommended intervals because they can wear out and fail without warning which will stall the engine. Refer the figure 1.1 below.

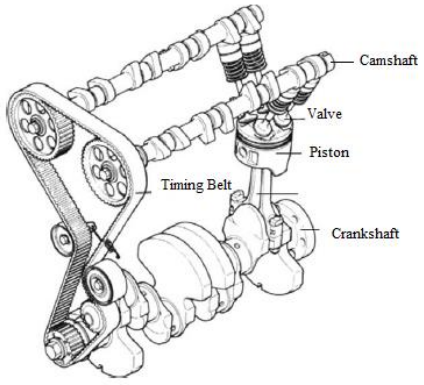

Figure 1 : Connection between camshaft and crankshaft

Camshaft followers or lifters have the capability to automatically adjust themselves utilizing motor oil pressure. To maintain proper operation service the engine oil regularly.

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EXPERIMENT

Type of Load

This camshaft Due to the cyclic impact loading on the contacting surfaces of the cam and the follower, it often gives rise to premature wear of cam profile and affects a routine run of the valve gear such as the rotational speed, valve displacement and the torque. On the other hand, simultaneously the most serious, under cyclic bending and torsion as a figure 2.1, fatigue fracture of camshaft initiating at stress concentration easily occurs. Therefore it demands the camshaft has not only excellent wear resistance but also adequate anti-impact toughness [2].

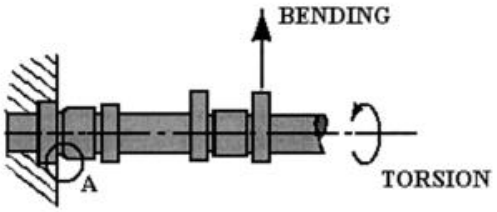


Figure 2. : The load for camshaft

Material of Camshaft

The camshafts are generally produced by casting or forging. The cast camshafts are made from modular cast iron. The cam surfaces and journal surfaces are heat treated to obtain hard surfaces. In table 3.1 show that the material properties and composition of the materials which was typical grey cast iron [3].

Table 1
Mechanical properties of grey cast iron

Young's modulus	170 GPa
Poisson's ratio	0.29
Yield stress	202 MPa ($\sigma_{0.2}$)
Ultimate strength	249 MPa

Table 2
Composition of grey cast iron (% weight)

C	S	Mn	Si	Ni	Cu	P	Cr
3.3	0.09	1.5	1.8	0.07	0.2	0.03	0.05

Table 1: Mechanical Properties of Grey Cast Iron
Source : (Wang et al., 2000)

Camshaft Failure Experience

Generally camshaft is manufactured by gray cast iron. Mass of the camshaft made up of gray cast iron is 5.9234 kg. The maximum load on the camshaft is during the engine speed of 1000 RPM to 2200RPM, because this is the initial stage of vehicle to move and acceleration is high [2]. Many studies have been carried out on the automotive failure analysis. Among these, has shown that the mostly failed parts are from engine and its components (41%) among the automotive failures. This is followed by the drivetrain failures (26%) [4].

Type of Failure Load

In this case, the cause of failure is the timing belt is broken. When it happen no more synchronize between piston movement and opening of valve. So cause of piston movement hit the valve, and valve hit the camshaft. Cause of that impact of the valve to the camshaft the failure occur.

METHODOLOGY

Mechanical and Materials Testing

a. Hardness Testing

Hardness measures the resistance of a sample to material deformation due to a constant compression load from a sharp object; they are primarily used in engineering and metallurgy fields. The tests work on the basic premise of measuring the critical dimensions of an indentation left by a specifically dimensioned and loaded indenter.
Common indentation hardness scales are Rockwell, Vickers, Shore, and Brinell and for our sample, Rockwell hardness is used. The hardness test was done 3 times for each location and average are taken as final result.

Hardness Test Specification

Model: Shimadzu Digital Rockwell Hardness Tester (DXT-1)
Hardness code: HRC
Preliminary test Force: 98.07N
Indenter: Diamond, tip angle;120°, Tip curvature radius; 0.2mm

Location 1

Location 2

Location 3

Figure 3 : Measurement are taken from three different location

b. Bending Test

A bending test, also known as a bend test, is used to determine the strength of a material by applying force to the item in question and seeing how it reacts under pressure. Typically the bend test measures ductility, the ability of a material to change form under pressure and keep that form permanently. In certain cases the bending test can determine tensile strength. When using the bend test for this purpose, testers examine which side of the material breaks first to see what type of strength the material has.

This test can also determine tensile strength. The test may be used when more brittle materials need to be tested such as cast iron. These brittle materials may not hold up well under a normal test for tensile strength, therefore a bending test is used. It is applied the same way as normal, by bending the material while applying force, and then the results are examined. If the material shows cracks on the bent side, this shows the material holds up better against compression than tension.

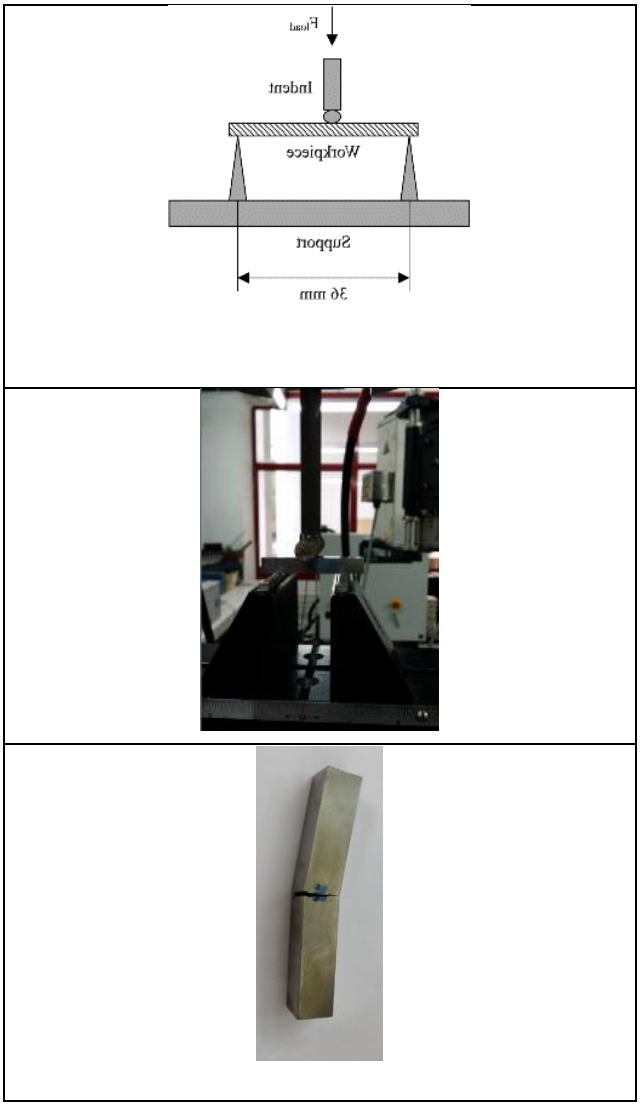


Figure 4: Bending Test

c. Microstructure

According Yu & Xu [5], chemical composition of the failed gear materials was determined by spectroscopy chemical analysis method. The microstructure of the sectional specimens was observed by scanning electron microscopy (SEM). Microstructure focuses on the art and science of preparing, interpreting, and analyzing microstructures in engineered materials, to better understand materials behavior and performance. The structure of a prepared surface will be revealed by a microscope above 25× magnification.

i. Fracture Surface

In this experiment we use the microscope to see what happen in the surface of fracture. There are three different place that we focus to capture the photo.

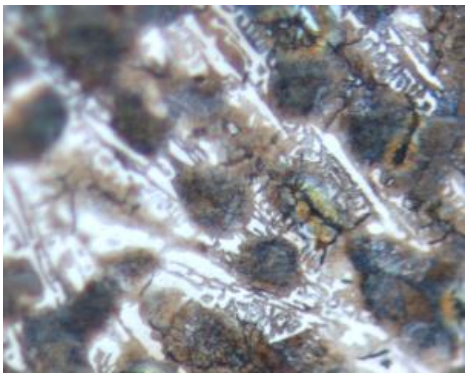
ii. Microstructure

Before we can see the microstructure of the camshaft, we have to cut the camshaft to sample as a figure below. At the bottom of the sample we have to do grinding and polishing to get very shining like the mirror then we can see the microstructure**.**

Figure 6 : Grinding and Polishing Process

The next step is etching process where the sample we put in nital 3%. Nital is a name and is a solution of alcohol and nitric acid commonly used for routine etching of metals. It is especially suitable for revealing the microstructure of carbon steels. The alcohol can be methanol, ethanol or methylated spirits. But in this case we use ethanol and nitric acid (3%). After take a sample to nital about 2 second and put the sample under microscope, we see the microstructure as below

there is a good nodularity of the graphite in a ferritic–pearlitic matrix structure. But some of the microstructure already burn. Maybe nital 3% that we use not comfortable with this material.



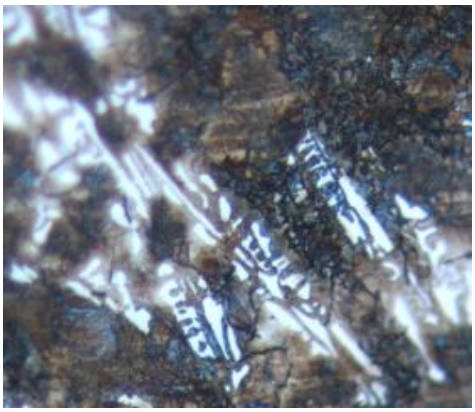


Figure 7 : Microstructure of the camshaft components.

Two types of microscope are used to analyze the microstructure of the sample:

i. Optical microscope:

The specimen should be flat, polished and etched specimens (etched with natal)

ii. Scanning electron microscope (SEM) :

For high-resolution information on metallurgical microstructures, electron microscopic methods can be employed.

RESULT AND DISCUSSION

a. Hardness Testing

Result :

No	Location	Hardness	Remarks
1	Location 1	35.80	Has finishing surface
2	Location 2	46.86	Surface is harden
3	Location 3	26.2	No harden surface

Table 2 : Hardness value for different place

Hardness testing result above show that at location 2 (surface harden) is the highest 46.86.

b. Bending Test

Result:

Maximum Flexure Stress: 660.81 MPa

c. Microstructure

i. Surface Fracture

From the photo its show that fracture will happen in brittle but have little bit ductile. If we focus to the fracture surface, the roughly that we can see its flat and but if really focus we can see it's not really flat. That mean it's have little bit ductile before it's failure. The photo of this experiment as below:

Figure 5 : Fracture Surface

ii. Microstructure

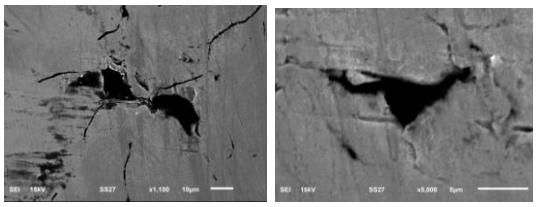


Figure 8 : Image from optical SEM

From the image that we capture from optical SEM, there is a we can see a hole inside the fracture camshaft.

CONCLUSION

Camshaft is one of the key parts or components in the engines of automobile and other vehicles. There are various factors which causes failure of camshaft :-

1. Cause of the broken timing belt, so the piston going to hit the valve and valve hit camshaft. The impact from the valve make the camshaft sudden fracture.
2. The failure is occurred as a sudden fracture at very close to journal location, where there is a stress concentration.
3. Another main reason of the fracture is manufacture defect.

To prevent premature wear and failure of the camshaft, we need to consider all the factors which may causes failure of camshaft and design it.

Suggestion to Prevent Similar Failures

i) To prevent that similar happen again is, beware of the mileage of timing belt. Refer the specification of timing belt, normal is 100,000 km. But change the timing belt around 70,000 – 80,000 km.

ii) Purify the melt iron to remove inclusion, and improve gating and riser system to prevent shrinkage defect and so on.

iii) Prevent the crack from initiation by carefully trimming adherent fins at the parting line of camshaft and avoid hard particle enter into the engine.

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