IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 11, May 2025
Impact Factor: 7.67

A Survey of Failure in Automobile Engine Crankshaft

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Abstract: *The crankshafts of piston engine with circular cross section are invariably used for transmission of power. In this survey, failure analyses of different engine crankshafts are studied. In crankshaft the failure is occurred due to fluctuating load called as fatigue failure. Mechanical fatigue failure and thermal fatigue failure are probably the most common cause of crankshaft failure. The fatigue crack initiated from the web-fillet region, crank pin region and lubricating holes. Stress concentration occurring at the key way root radius & sharp changes in cross-sectional area of shaft.*
For analysis, different methods are used such as visual analysis, microscopic analysis using SEM (Scanning electron microscope) and by conducting some laboratory test. To prevent the failure of crankshaft, operating, mechanical and repairing sources of failure are to be controlled. Also machining and final grinding has to be done carefully to prevent formation of discontinuities or crack like defect in fillet region. Induction hardening or nitriding of fillet region is required also fillet radius need to be increased.

Keywords: Engine, Crankshaft, Fatigue failure

I. INTRODUCTION

The crankshaft transfers the linear piston movement to curvilinear motion while the force of the connecting rod is transformed to torque. The crankshaft is designed by consideration of number and placements of pistons, number of bearings and ignition order etc. The crankshaft also drives the camshaft and some other elements using a chain or a belt drive system.

Crankshafts are made from materials which can be readily shaped, machined, and heat-treated and which have desirable mechanical properties such as adequate strength, toughness, hardness, and high fatigue strength. Generally, these shafts were forged, which gives all the necessary properties but with the improvement in foundry techniques the casting of crankshaft is also available. The cast iron crankshafts are used for moderate loads and only for heavy-duty applications forged shafts are used. The dead weights provide the static and dynamic balance caused by different ignition sequence during working. The blank produced is then heat treated to remove residual stresses and machining to final dimension. The main bearing journal and crank-pin journal are hardened up to 2–3 mm by means of some surface hardening methods. The lubrication of the bearings is provided by lubrication holes drilled in the crankshaft. [2]

The crankshaft works under highly variable loading condition. Due to this, failure may be originated at different places. The most common cause of failure of crankshaft is fatigue. In fatigue failure mechanical fatigue failure and thermal fatigue failure are probably the most common cause of crankshaft failure. Mechanical fatigue failures may have some sources such as misalignment of the shaft, vibration due to some problem with the main bearings, high stress concentrations caused due to an incorrect fillet size. Also it may be due to absence of surface hardening heat treatment, absence of oil, or defective lubrication of one or more journals, or high operating oil temperature, etc. [1]Thermal fatigue failure occurs due to overheating of crankshaft during grinding operation. Due to overheating the small cracks developed at the surface of journals. The damage of the journals originates by the small cracks at the surface of the journals [1].

On the crankshaft, cracks initiated from the fillet region of the crankpin journal- web and main bearing journal – web. Also a crack initiates from the edge of oil hole and its orientation was parallel to longitudinal section of shaft [7].

Fatigue crack may initiate at the stress concentrations occurring at the keyway root radius and sharp changes in cross-sectional area of the shaft. In fatigue failure the cracks propagate in weaker region where fatigue strength reduce and lead to premature fatigue fracture.

The failure analysis is to be done by using detailed metallurgical investigation on failed crankshaft, visual analysis of failure zone, characterization of the material is to be done by spectroscopy and fractographic analysis by using Scanning Electron microscope (SEM).[1-5]

The possible failure reasons are studied so that the precaution to be adopted during the fabrication of crankshaft. The precautions are recommended for controlling of operating, mechanical & repairing sources of failure. Induction hardening or nitriding of fillet region resulting in tempered martensite structure. Also machining and grinding has to be done carefully to avoid premature failure.[1,3].

II. CRANKSHAFT

Crankshaft is the engine component from which the power is taken. It receives the power from the connecting rods in the designated sequence for onward transmission to the clutch and subsequently to the wheels. The crankshaft assembly includes the crankshaft and bearings, the flywheel, vibration damper, sprocket or gear to drive camshaft and oil seals at the front and rear.

2.1. Construction

Crankshaft is a shaft consisting of the following major parts:

1. Main journals
2. Crank pins
3. Crank webs
4. Counter weights
5. Oil holes

A simplified sketch of the crankshaft for a 4 cylinder in-line engine is shown in Fig. 3.1.

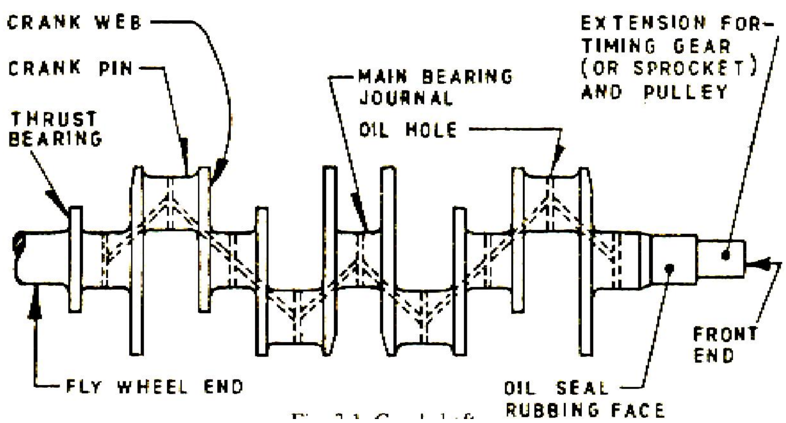

Fig. 3.1 Crankshaft.

Main journals are supported in main bearings in the crankcase. These form the axis for the rotation of the crankshaft. Their number is always one more or one less than the number of cylinders. The crankpins are the journals for the connecting rod big end bearings and are supported by the crank webs. The crank webs should be adequately strong to withstand the twisting and the bending loads.

The distance between the axis of the main journal and the crankpin centre lines is exactly one half of the engine stroke and is called the crank-throw, which determines the crankshaft turning effort. Oil holes are drilled from main journals to the crankpins through crank webs to provide lubrication of big end bearings. Main bearings are lubricated from oil galleries in the cylinder block.

When the engine is running, the centrifugal forces acting at each crankpin due to rotation of both the crankshaft as well as the big end of the connecting rod tend to bend and distort the crankshaft .To counter this tendency, the counterweights are either formed as integral part of the crank web or attached separately, on the side opposite to the crankpin.

On one of the main bearing journals usually near the flywheel end thrust bearing is located so as to support the loads in the direction of the shaft axis. Such loads may arise due to clutch release forces, forces in the helical gear valve-timing gear train when accelerating or deceleration, forces in the gear train when driving various auxiliary components such as the oil pump, water pump, and supercharger.

The crankshafts are generally of two types-

- One piece and
- Built up.

In the built up construction the crank pins and journals are bolted to crank arms, which also serve as flywheels. One-piece construction is almost universally used for automotive crankshafts. [9]

2.2 Materials

The crankshaft must be adequately strong, tough, hard and should possess high fatigue strength. As such proper material has to be selected and suitable fabrication processes and heat treatment process has to be used. Earlier the crankshafts were only forged, but with the improvements in foundary techniques, the casting of crankshafts has also become quite common.

S.A.E. steels 1045 and 3140 are the commonly used steels for forged crankshafts. S.A.E. 1045 contains manganese (0.6-0.90 percent), whereas S.A.E. 3140 contains nickel (1.10-1.40 percent), chromium (0.55-0.75 percent) and manganese (0.70-0.90 percent). Chrome-vanadium and chrome molybdenum steels have also been used.

The steel used for heavy duty diesel engine forged crankshaft has the following chemical composition:

Material	Carbon	Nickel	Chromium	Molybdenum
Steel	0.3%	2.5%,	0.65%	0.55%.

Here nickel refines the grain and prevents grain growth during heat treatment due to which strength and toughness is improved. However, its tendency to convert the carbon into its soft graphite form is compensated by chromium which forms hard wear-resisting carbides.

In case of cast crankshafts, both casts steel as well as S.G. iron have been used. Typical cast steel for crankshafts has the following chemical composition:

Material	Carbon	Silicon	Chromium	Manganese	Copper	Phosphorus	Sulphur
Cast	1.35-1.6%	0.85-1.1 %	0.05-0.5 %	0.6-0.8 %	1.5-2.0 %	0.10 % (max.)	0.9% (max.)

The Spheroidal Graphite type or commonly called S.G. iron is a high strength cast iron in which the carbon present is in the form of spherical modules of graphite (compared to flakes in the grey cast iron). Due to spherical form, the S.G. iron has high strength, improved ductility and larger toughness than the grey cast iron and is thus able to take up the type of stresses that are imposed on the crankshaft while running. [9]

2.3 Steps in Fabrication of Crankshaft

Bloom → Forging to shape→ Trimming→ Quenching→ tempering → Machining → Induction hardening / Nitriding → Stress relieving annealing→ mechanically grinding. [5]

III. MODES OF FAILURE

A mechanical component may fail, that is, may be unable to perform its function satisfactorily, as a result of anyone of the following modes of failures.

3.1 Failure Due To Static Load

A static load is defined as a force which is gradually applied to a mechanical component and which does not change its magnitude or direction with respect to time. The failure due to static load is illustrated by the simple tension test. In this case, the load is gradually applied and there is sufficient time for elongation of fibers. In ductile materials, there is considerable plastic flow prior to fracture. This results in a silky fibrous structure due to the stretching of crystals at the fractured surface. In case of failure under static load, there is always sufficient plastic deformation prior to failure which gives warning well in advance. It is relatively easy to design a component for static load. Due to static load the failures occurs are elastic deflection, general yielding and fracture.

3.1.1 Failure by Elastic Deflection

In applications, like transmission shaft supporting gears, the maximum force acting on the shaft, without affecting its performance, is limited by the permissible elastic deflection. Sometimes, the elastic deflection results in unstable conditions, such as buckling of columns or vibrations. The design of the mechanical component, in all these cases, is based on the permissible lateral or torsional deflection.

3.1.2 Failure by General Yielding

A mechanical component made of ductile material loses its engineering usefulness due to a large amount of plastic deformation after the yield point stress is reached. A considerable portion of the component is subjected to plastic deformation, called general yielding. The yield strength of a material is an important property when a component is designed against failure due to general yielding.

3.1.3 Failure by Fracture

Components made of brittle material cease to function satisfactorily because of the sudden fracture without any plastic deformation. The failure in this case is sudden and total. The ultimate tensile strength of the material is an important property for determining the dimensions of these components.

3.2 Failure Due To Fluctuating Stresses

The components are subjected to forces which are not static, but vary in magnitude with respect to time. The stresses induced due to such forces are called as fluctuating stresses. Due to these stresses the failure occurred is called as fatigue. It is observed that about 80% of failures of mechanical components are due to fatigue.

3.2.1 Fatigue Failure

The behavior of materials under variable loading or fluctuating loading is called as fatigue**.** It has been observed that components of different materials fail under fluctuating stresses, at a stress magnitude which is lower than the ultimate tensile strength of the material. Sometimes, the magnitude is even smaller than the yield strength. Also the magnitude of the stress causing fatigue failure decreases as the number of stress cycles increases. This phenomenon of decreased resistance of the materials to fluctuating stresses is called fatigue.

The fatigue failure begins with a crack at some point in the material. The crack is more likely to occur in the following regions:

(i) Regions of discontinuity, such as oil holes, keyways, screw threads, etc.

(ii) Regions of irregularities in machining operations, such as scratches on the surface, stamp mark, inspection marks, etc.

(iii) Internal cracks due to defects in materials like blow holes.

These regions are subjected to stress concentration due to the crack. The crack spreads due to fluctuating stresses, until the cross-section of the component is so reduced that the remaining portion is subjected to sudden fracture.

There are two distinct areas of fatigue failure -

Region indicating slow growth of crack with a fine fibrous appearance,

Region of sudden fracture with a coarse granular appearance.

Fatigue cracks are not visible till they reach the surface and by that time the failure has already occurred. The fatigue failure is sudden and total. The fatigue failure, however, depends upon a number of factors, such as number of cycles, mean stress, stress amplitude, stress concentration, residual stresses, corrosion and creep.[10]

IV. CAUSES OF FAILURE IN CRANKSHAFT

The crankshaft works under highly variable loading condition. Due to this, failure may be originated at different places such as main journal surface, crankpin surface and fillet regions (crankpin-web fillet & journal-web fillet region).The possible sources of causes of failure in crankshaft are-

4.1 Operating Sources

Operating sources were included

1. Oil absence;
2. Defective lubrication on journals;
3. High operating oil temperature;
4. Improper use of the engine (over-running).

Operating sources such as oil absence or defective lubrication of journals would be enough to damage the journals. The contact between the bearings and the journals would develop a rougher surface of the journals. The heat and stresses during the contact would also eventually promote the propagation of existing cracks as shown in fig. 4.1.

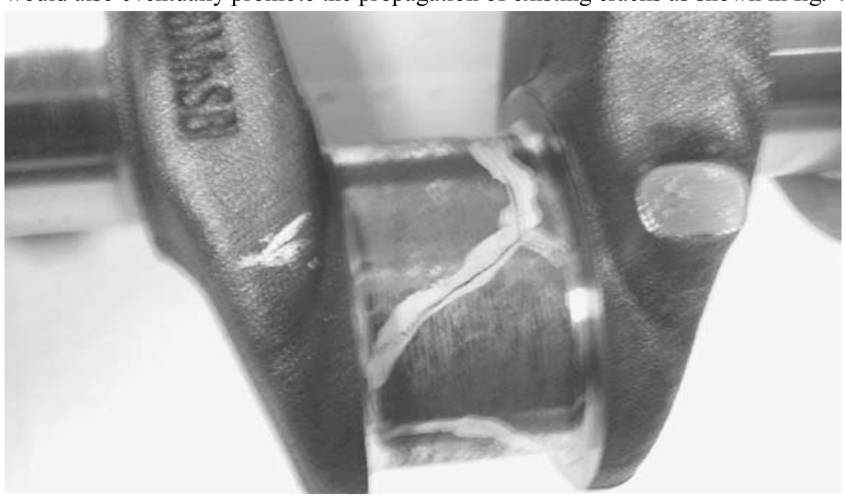

Fig. 4.1 Propagation of existing cracks

4.2 Mechanical Sources

Mechanical sources were included

1. Misalignments of the crankshaft on assembly;

2 Improper journal bearings (wrong size);

3. No control on the clearance between journals and bearings;
4. Crankshaft vibrations.

Misalignments of the crankshaft on assembly are due to improperly straightened cranks during repairing, also worn bearings would create a bending moment and higher stresses at the crankshaft. This would also be the effect of vibrations. These higher stresses would originate mechanical fatigue cracks at the weakest points of the crank, namely at the stress concentrations. Cracks would develop at those weaker points, and the crank would fail by fracture. Figure 5.2 shows an example of a train crankshaft that failed due to mechanical fatigue.

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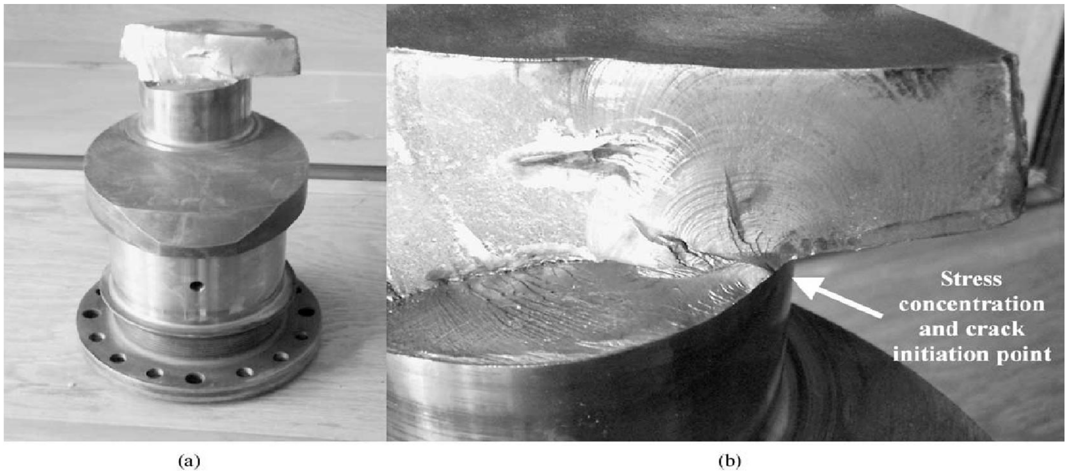

Fig.4.2 a) Part of crankshaft,
b) Detail of mechanical fatigue crack which developed at a stress concentration.

4.3 Repairing Sources

Repairing sources were included:

1. Misalignments of the journals due to improper grinding.
2. Misalignments of the crankshaft due to improper alignment of the crankshaft.
3. High stress concentrations due to improper grinding at the radius on both sides of the journals.
4. High surface roughness due to improper grinding, originating wearing.
5. Improper welding or nitriding
6. Defective grinding.
7. Straightening operations

Some crankshaft repair shops, in order to straighten the cranks, use a hammer or a press to bend the cranks. Both of these methods could fracture the crank by bending it. If cracks appear due to the bending, they would also appear at the stress concentrations. [1]

4.4 Manufacturing Sources

4.4.1 Machining

The intergranular network of cracks in crankshaft and other crack-like surface discontinuities in crankshafts have been developed during the machining due to generation of heat. [3]

4.4.2 Grinding

In grinding process journal rotates with a low rotation speed and the grinding wheel rotates with a high rotation speed. During the grinding process following features causes some small cracks.

i) Excessive depth of cut

If during the first few revolutions there is an excessive depth of cut the material may burn. There are cases where the surface of the material even changes color, becoming blue. It is common that, when the grinding process is finished, the journals seem normal because on the last revolutions, the operator works with a normal depth of cut, and the blue color (burnt surface) disappears. This 'burning' may cause small cracks which do not disappear with the last revolutions. Also heat is developed at the contact surface between the grinder wheel and the journal which expands grinding wheel. Thus, the excessive depth of cut becomes even bigger and consequently more detrimental.

ii) Defective lubrication: This is another source of heat at the journal surface. The type and quantity of the coolant are very important in the grinding process, in order to prevent the surface of the journal burning. Defective lubrication may cause small cracks.

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iii) Dressing of the grinding wheel: The grinding wheels must be dressed from time to time. If this operation is not observed the wheels may become 'pasted', and this effect will produce poorer cutting characteristics and a higher generation of heat at the contact surface. Again the heat may produce small cracks.

iv) Over grinding: During manufacturing of crankshaft after surface hardening (nitriding or induction hardening) grinding operation is required. Due to improper grinding removal of nitriding layer is takes place at the fillet radius region which reduces the fatigue strength at these places to initiate fatigue and propagate fatigue in the weaker region and to lead to premature fatigue fracture.[1]

4.4.3 Surface Hardening Heat treatment Process

During surface hardening of crankshaft only crank pin and journal regions has been induction hardened. In the fillet region fatigue strength is less due to absence of heat treatment and more stress concentration is occurred. To avoid fatigue initiation from the - fillet region, induction hardening of the fillet resulting in a tempered martensite structure is desirable. [3]

V. FAILURE MECHANISM

Fatigue and force of friction are dominant mechanism of failure. In fatigue failure mechanical fatigue failure and thermal fatigue failure are probably the most common mechanism of crankshaft failure. [3]

5.1 Mechanical Fatigue Failure mechanism

Mechanical fatigue failures may have some sources such as misalignment of the shaft, vibration due to some problem with the main bearings, high stress concentrations caused due to an incorrect fillet size. It may be due to absence of surface hardening heat treatment, or defective lubrication of one or more journals, or high operating oil temperature, etc.

5.1.1 Surface Contact Fatigue Mechanism

Surface Contact Fatigue occurred due misalignment or axial movement of the shaft. Due to some axial load on the shaft, the bearing has moved causing it to rub constantly against the journal web. The fatigue crack had originated at the web radius region. The fatigue crack initiation seems to be due to the degradation of the shaft during service. Mechanical degradation such as pitting and spalling were occurred. This has led to a situation of surface contact fatigue resulting in extensive pitting and spalling of the nitrided layer at the web radius region of the journals. Under the cyclic loading, fatigue cracks have initiated at these stress concentration points leading to fracturing of the shaft. Fig. 5.1 shows the schematically damage of the nitrided layer.[4]

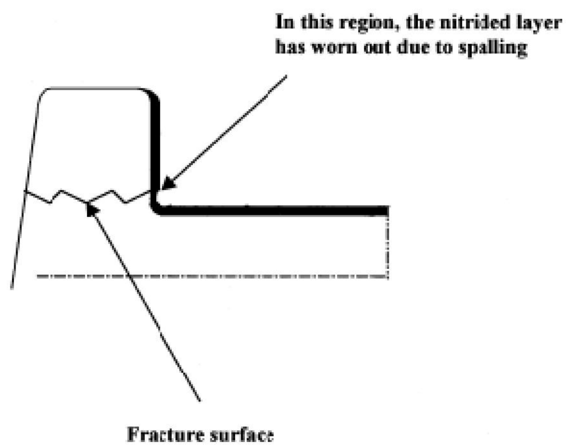

Fig. 5.1 Damage of nitrided surface in web radius due to pitting and spalling.

DOI: 10.48175/IJARSCT-27205

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International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
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5.1.2. Improper Surface Hardening Fatigue Mechanism

Surface hardening Fatigue occurred due to absence of nitrided layer or induction hardening heat treatment process in the fillet region during the fabrication of crankshaft. The absence of nitrided layer may be due to over-grinding after nitriding. Surface hardening by nitriding or induction hardening can raise the fatigue strength of the material. Initiation of fatigue has been influenced by local surface conditions occurred in the fillet region. In the absence of the hardened layer in the fillet region, the stress required for fatigue initiation would decrease. Once a fatigue crack has nucleated from the surface in combination with occasional high stress and propagate in the weaker region and leads to premature fatigue fracture. [2, 5]

5.1.3 Sharp Fillet Fatigue Mechanism

The fatigue crack initiated at the sharp fillet region as shown in fig.6.2 The sharp fillet creates relatively high stress concentration for the crankshaft subjected to bending and torsional loading during a stroke process. The failure has began at the sharp fillet region and the diagonal lubrication holes in the Crankshaft cause to turn the crack propagation direction and speed up the propagation process. [2]

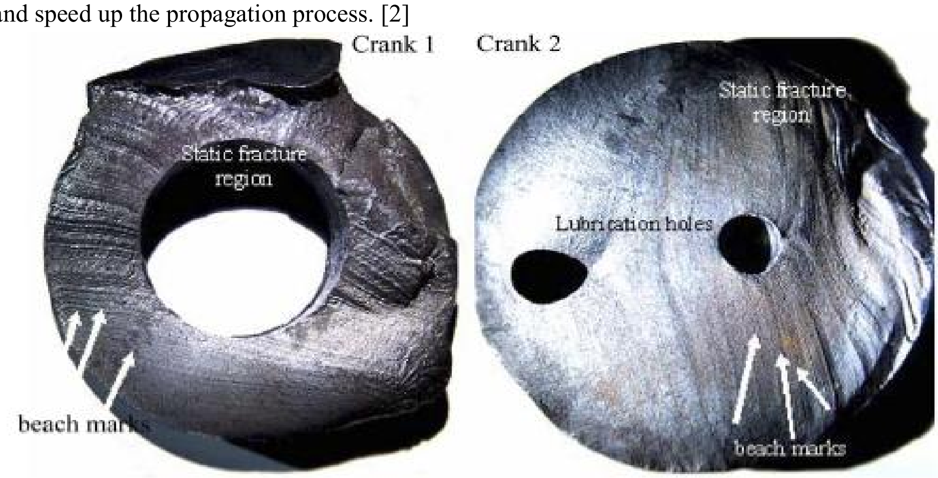


Fig .5.2.Failed crankshaft and their fracture surfaces at sharp fillet region.

5.2 Thermal Fatigue Failure Mechanism

Thermal fatigue failure is occur due to overheating of crankshaft during grinding operation. Due to overheating the small cracks originated at the surface of journals. The damage of the journals was originated by the small cracks at the surface of the journals.

A thermal gradient in a body creates thermal stresses due to expansion in warmer areas. If this temperature gradient is repeated for several times, e.g. an area is heated and then cooled, and heated and then cooled, and so on, these stressed areas will suffer thermal fatigue. After tens or hundreds of cycles small thermal fatigue cracks appear at these stressed areas. This is exactly occurring during the grinding process. Each time an area of the journal comes into contact with the grinding wheel that area is heated. During the rest of the rotation the area undergoes cooling. This means that each portion of the journal surface as shows in fig. will be under a thermal gradient, or under a stress gradient, which will be repeated. When the surface warms, compressive thermal stresses occur at that surface (position A in fig.5.3), and when that same surface cools, tension stresses occur at the same surface (position B in fig.5.3). As a consequence, small fatigue cracks, as shown in fig.5.4, will develop at the journal surface.

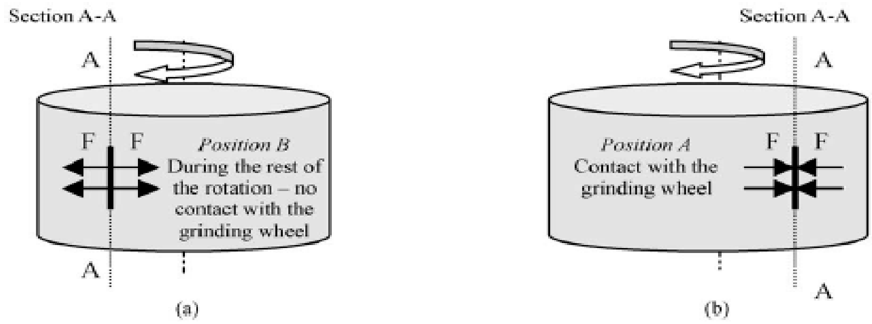


Fig. 5.3 Grinding operation heat production scheme.

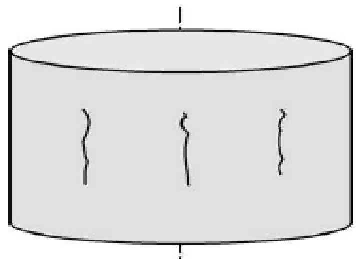
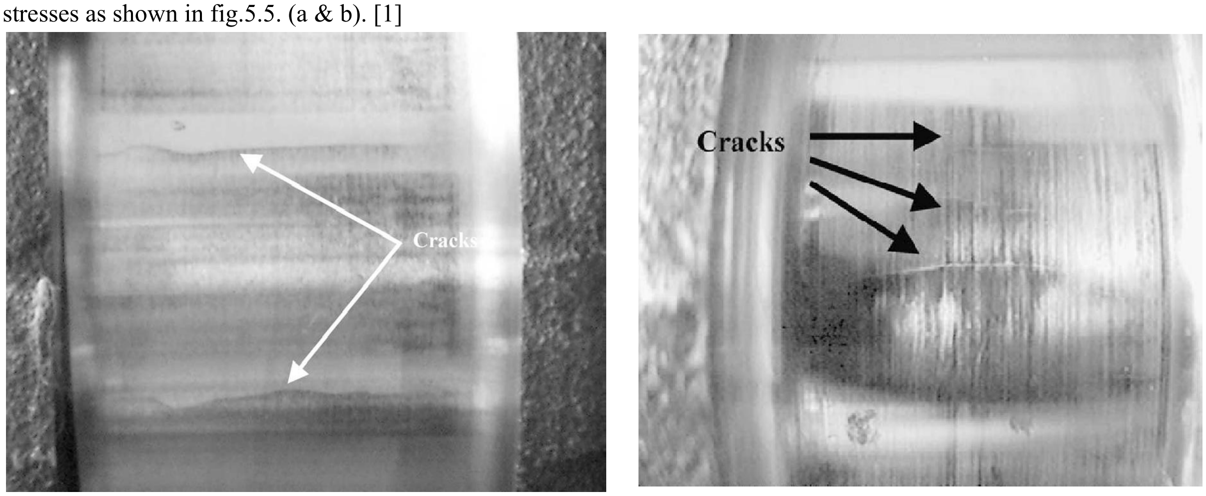


Fig.5.4 Thermal fatigue cracks aspect.

Thermal fatigue cracks develop parallel to the thermal gradient. Also thermal fatigue cracks may be long but with a small depth. These cracks nucleated due to thermal fatigue from the grinding process, and propagated due to heat and stresses as shown in fig.5.5. (a & b). [1]



(a) **(b)**

Fig. 5.5 Cracks parallel to the thermal gradient.

5.3 Force of Friction Failure Mechanism

5.3.1 Shearing Stress Failure Mechanism

The crankshaft cracked by shearing stresses, caused by unusual friction between surface of shaft and the main bush. Because of improper assembling of shaft exceptional friction between the shaft and main bush was induced. Thus the temperature of shaft and main bush went up rapidly while engine works going on. Friction can cause slip on the surface of friction boundary, when the temperature goes up to a critical level. For metal 300^{0}C –600 ^{0}C is a special temperature which may lead to temper brittleness. The material below the surface must yield, parallel to the force of friction. It is

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also possible that molten copper from the bearing shell caused liquid metal embrittlement in the crankshaft journal. Due to this the crack was initiated from the edge of oil hole and its orientation was parallel to the longitudinal section of shaft.[7]

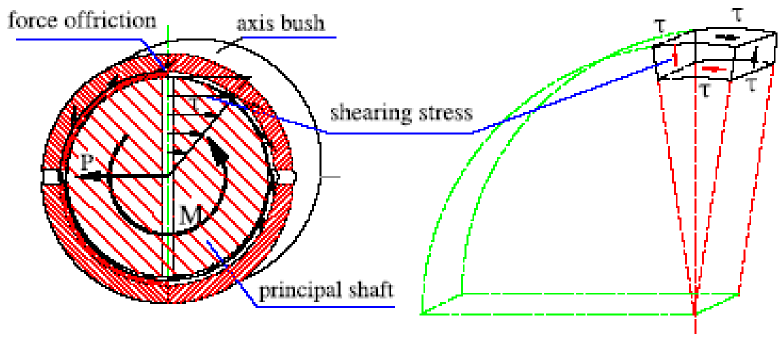

Fig .5.6 Schematic representation of friction force between shaft and bush

5.4.2 Bending And Torsional Stress Failure Mechanism

Failure of the crankshaft occurred because of a combination of bending and torsional stressed beyond design. The stresses were caused by imbalance of the shaft due to localized heating. Due to presence of foreign object like a metallic fragment, harder than the journal surface in between the pad and the journal cause scoring of the journal surface. The frictional forces may detach the pad and block the lubrication hole in the shaft. Such an event will cause localizes heating, softening, wear and squeezing out of the bearing metal and imbalance of the shaft. The unexpected combination of bending and torsion stresses thus produced exceeded the design limits of the shaft which gave way along its weakest plane and failure occurred from a fillet to a diagonally opposite fillet and further extended through the wall, thus leaving the crankshaft in three pieces.[8]

VI. ANALYSIS OF CRANKSHAFT FAILURE

The failure analysis of crankshaft should be conducted as per following scheme.

1. Visual Analysis of failure zone.
2. Chemical analysis of crankshaft material.
3. Evaluation of mechanical properties of material.
4. Study of microstructure of material.
5. Study of Failure mechanism using scanning electron microscope (SEM).

6.1 Visual Analysis of Failure Zone

Visual analysis gives the location of failure zone in crankshaft. Also it gives location of crack initiation and direction of crack propagation.

6.1.1 Case 1

The damaged crank shaft assembly removed from the engine was examined visually. From fig.6.1 the crankshaft was found to have fractured at the No. 2 and No. 3 journals. In both the cases, the fracturing took place along the web radius. Careful examination revealed that the failure had occurred transverse to the axis of the crankshaft, with no evidence of plastic deformation around the fracture zone. The fracture surfaces showed beach marks typical of fatigue failure, and both the fractures were found to have initiated at the web radius region. In journal 3, the fatigue crack had propagated to about 80% of the web section before giving rise to the final, overload fracture. In the case of journal 2, the fatigue crack propagation was about 40% of the web cross section. Also it was seen that the split ring bearing of journal 3 had suffered heavy damage resulting in metal flow and ridging at its edge .This ridging had resulted in the formation of a groove in the softer crankshaft casing made of Al alloy. [4]

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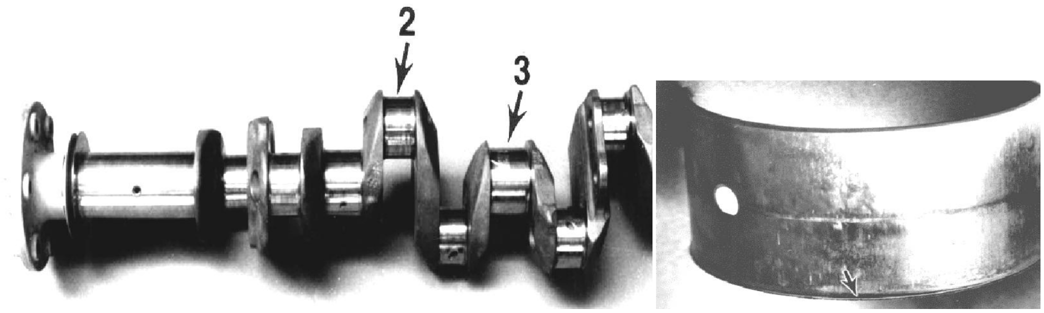


Fig. 6.1 Photograph of failed crankshaft and damaged split ring bearing.

6.1.2 Case 2

Fig 6.2 shows failed webs of the different crankshafts .The fracture surface presents typical features of fatigue failure. From the orientation of beach marks and other features, the fatigue appears to have initiated from the fillet region interfacing pin and web, and progressed almost over the entire cross section of the web. In some cases multiple origins from the fillet were also noticed. On the other hand, fatigue could also be found to have initiated from the journal side fillet in some other cases and the two fatigue zones culminated near the oil hole resulting in final separation. The overall fatigue surface has about a 45 ^{0}inclination with respect to the shaft axis.[3]

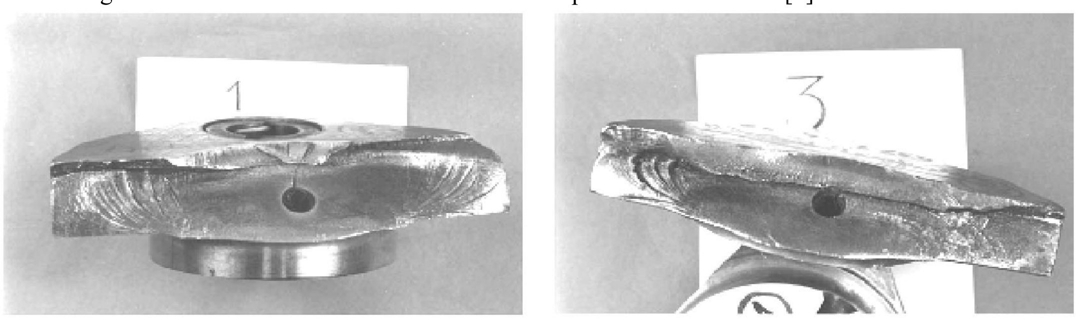


Fig. 6.2 Photographs of failed webs

6.2 Chemical Analysis of Crankshaft Material

The chemical analysis of failed crankshaft gives the chemical composition of the material. Then this chemical composition is compared with the specified chemical composition of crankshaft material. This gives the chemical composition of material for failed crankshaft is within specified range or not. [2, 5, 8].

Element	Composition wt. %(SAE 1536)		Composition wt. %(AISI 4140)	
	Analyzed	As Specified	Analyzed	As Specified
Carbon	0.37	0.30-0.37	0.414	0.37-0.44
Manganese	1.24	1.20-1.50	0.735	0.65-1.1
Phosphorus	0.008	0.040 max.	0.022	0.035 max.
Sulphur	0.056	0.050 max.	0.026	0.04 max.
Silicon	0.30	0.15-0.30	0.293	0.15-0.3
Chromium	<0.06	--	0.933	0.75-1.2
Nickel	<0.06	--	--	--
Molybdenum	0.03	--	0.175	0.15-0.3

6.3 Evaluation of Mechanical Properties

6.3.1. Tensile Properties

Standard cylindrical tensile specimens were machined from the failed crankshaft portion .The tensile properties were evaluated by breaking the specimen in tension. The tensile properties are shown in table. It can be noted that whether the tensile properties are within the expected range or not. [5]

Properties for 42Cr Mo forging steel crankshaft.	Measured	Required
Yield strength (MPa)	735	> 680
Tensile strength (MPa)	885	>880
Elongation (%)	17	>15
Reduction in area w (%)	60.5	>48

6.3.2 Hardness

The surface hardness (HV1) at the journal and micro hardness (HB) of the crankshaft material were measured, and average values of five readings are listed in table. This gives the measured hardness values are within specified range or not. [5]

Hardness for 42Cr Mo forging steel crankshaft.	Value measured	Value specified
Surface hardness (HV1)	593	> 550
Micro hardness(HB)	278	217-300

6.4 Study of Microstructure of Material

6.4.1 Case 1- The microstructures of the crankshaft materials are given in fig.6.3. The difference between the two microstructures also gives the clue of hardening treatment. From fig. 6.3 (a & b) crank 2 has a hardened surface layer while crank 1 has not. The crank 2 has a tempered martensite structure near the surface regions. The black points observed in the matrix are possibly carbide inclusions grown to very large sizes due to improper production and heat treatment conditions. These inclusions are larger in crank 1 than crank 2 and the difference can be observed in fig.6.3 C .The inclusions in both materials are larger than normal sizes [2].

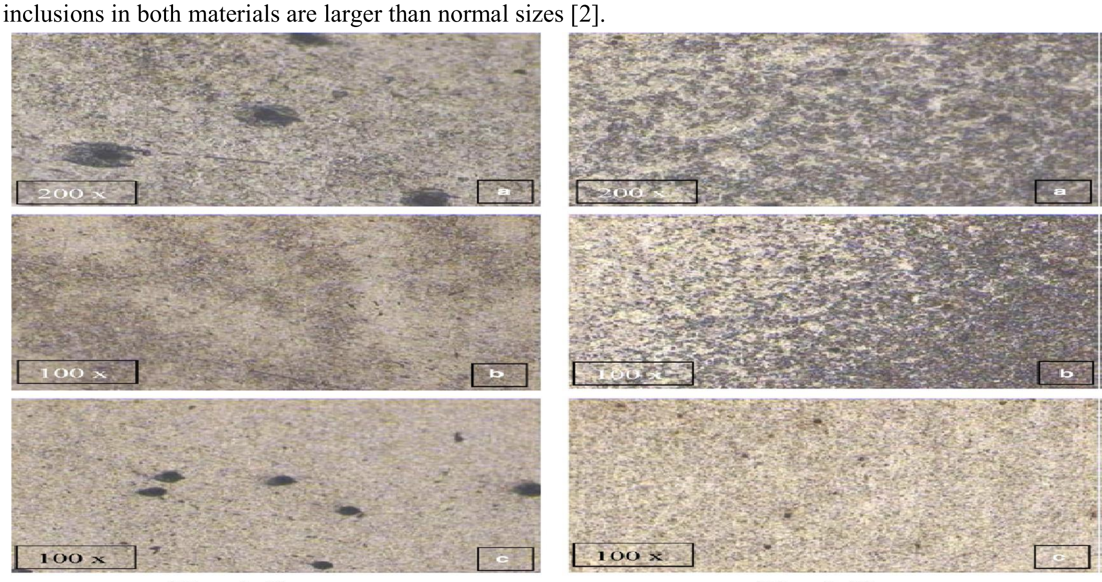
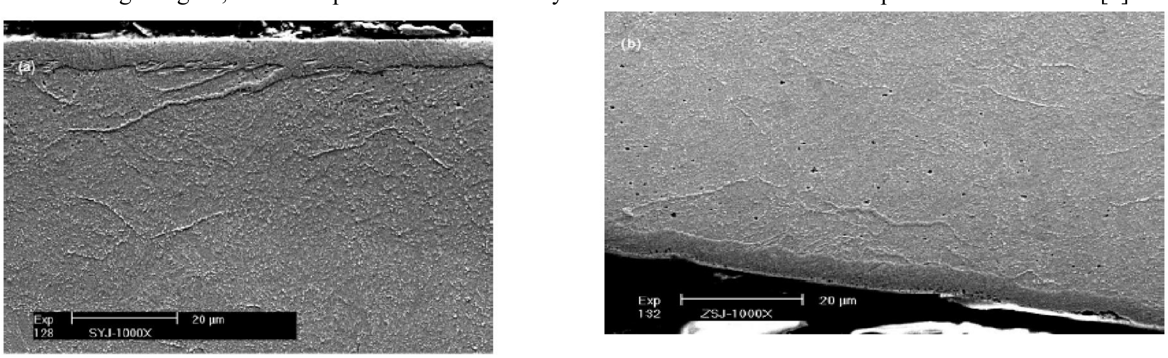


Fig 6.3 Microstructures of the crankshaft materials

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 11, May 2025
Impact Factor: 7.67

6.4.2 Case 2- Cross sectional specimens of the failed crankpin-web region were prepared to examine microstructure, depth of the nitrided layer, and micro-hardness in order to determine the nitrided layer or the hardened layer. The matrix microstructure of the failed journal and crankpin-web were observed by SEM, and is composed of normal tempered sorbite. By observation of the cross sectional specimens it can be concluded that the crankshaft was nitrided to obtain a compound layer of about 3–6 μm in general as shown in fig 6.4. However, it is found that there is a zone without compound layer in the fillet region on the failed crankpin-web, about 1.6 mm from the fracture origin region as shown in fig. 6.5.

The microhardness profiles from surface to the interior were performed. The results show that a nitrided layer depth of 0.26–0.30 mm can be obtained in general, which is within the range of the technical demand, except for the fillet zone close to the fracture. The microhardness profiles of the two positions in the fillet region of the failed web were measured, one in the fillet zone close to the web or close to the fracture origin region, the other in the fillet zone close to the pin. The measured results are shown in fig. 6.6. It can be seen that there is no hardened layer in the fillet zone close to the fracture origin region, but the depth of the hardened layer in the fillet zone close to the pin is about 0.25 mm.[5].



(a) **(b)**

Fig. 6.4 Microstructure of nitriding layer (a) Journal (b) Crankpin web.

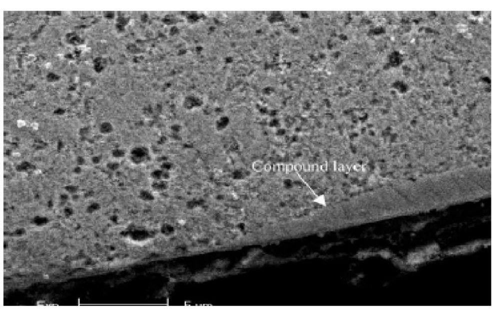


Fig. 6.5 Microstructure of the region close to fracture

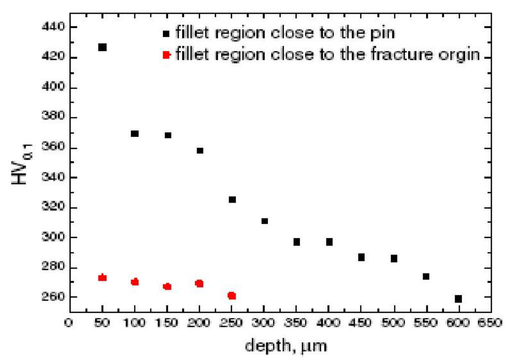


Fig 6.6 Microhardness profile of fillet region of failed crankpin-web.

6.5 Fractographic Analysis by Scanning Electron Microscope (SEM)

The scanning electron microscopy photographs of the different crankshaft fracture surfaces at appropriate magnifications to study the mechanism of failure initiation and propagation

6.5.1 Case 1: Failure Due To Material Defect and Improper Heat Treatment

In fig. 6.7 (a) the black regions in fig. 6.3 are visualized as cavities and mounds as indicated by arrows. These locations may lead to initiation of fatigue crack. However smaller carbide inclusions may delay the growth of crack but inclusions of the present size cause faster failure of the cross sections. The fracture is occurred after a fatigue process as can be concluded from the benchmark striations in the fracture surfaces (fig.6.7 b–d).

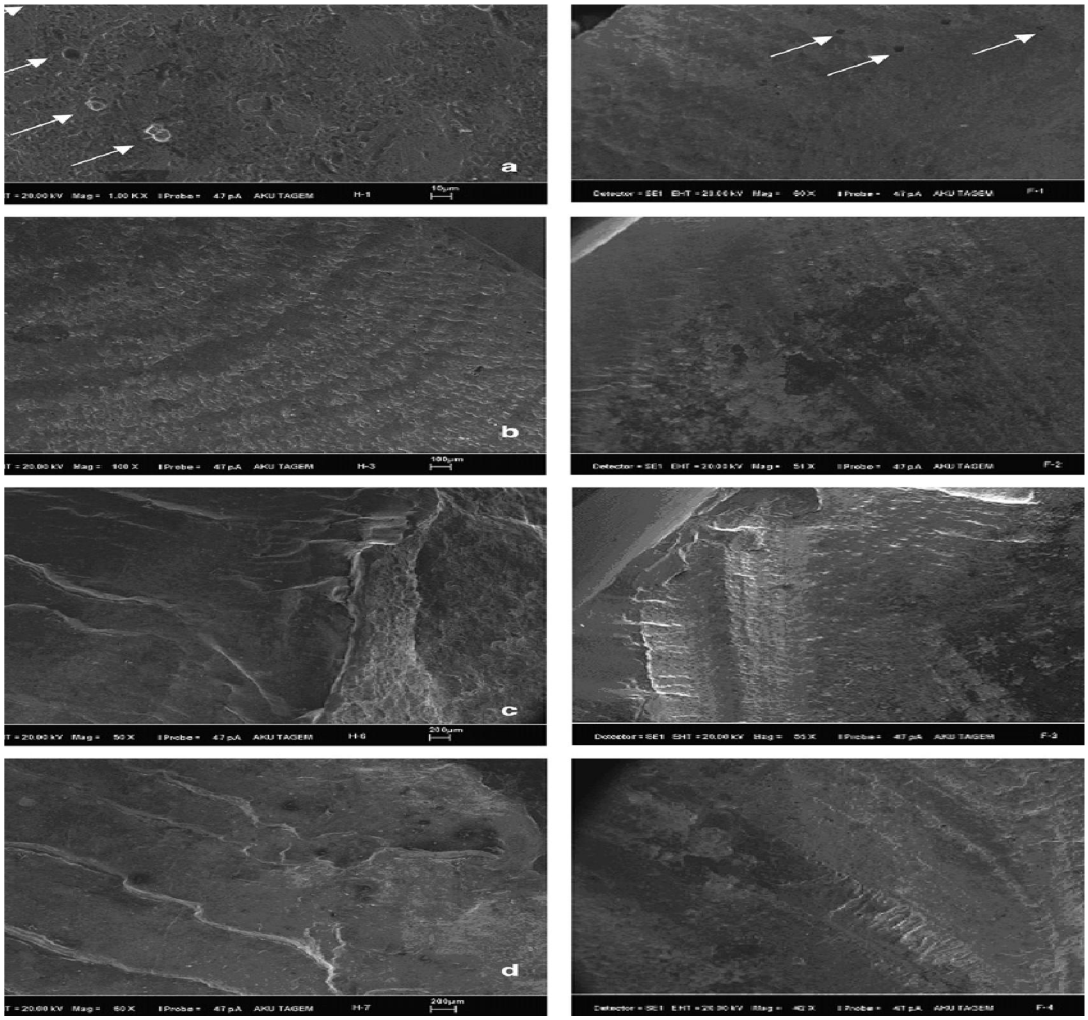


Fig.6.7 Scanning electroen microscopy (SEM) photographs

The diagonal lubrication holes in the Crank 2 might cause to turn the crack propagation direction and speed up the propagation process. The plastically deformed benchmark lines in fig. 6.7 (c and d) exhibit the unhardened feature of the crank 1. [2]

6.5.2 Case 2: Failures Due To Improper Induction Hardening

This crankshaft had multiple nucleation of fatigue cracks form the pin-web fillet region. At least two nucleation sites were found to be present. The initiation zone was relatively smooth and did not show unusually long or deep inclusions or cracks. In the fillet region a zone of scattered micro cracks could be seen which appeared to be intergranular in nature as shown in fig.6.8. The fatigue appears to have initiated due to relatively high stress during the fatigue cycle at the initiation stage

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

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ISSN: 2581-9429 Volume 5, Issue 11, May 2025 Impact Factor: 7.67

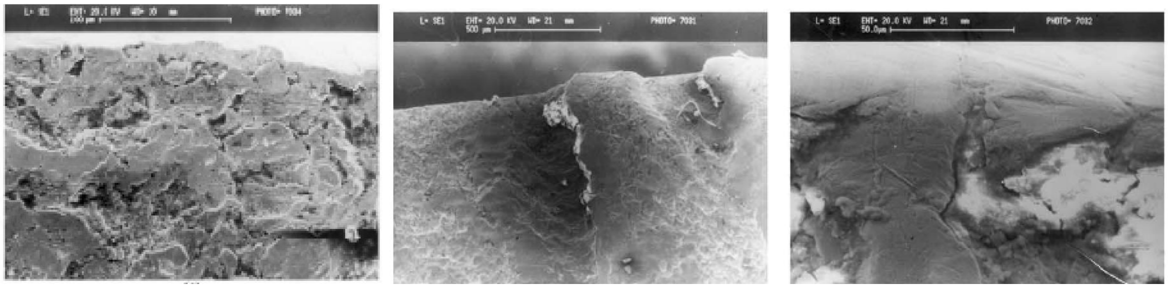
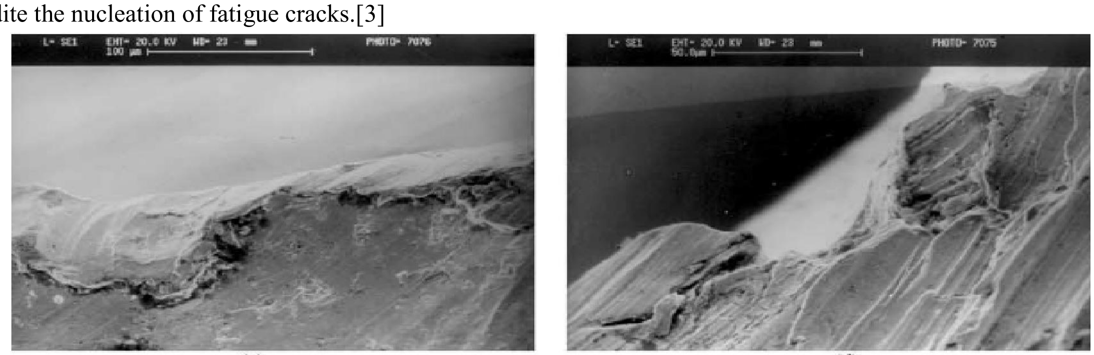


Fig.6.8 SEM photograph

In the pin fillet where fatigue had apparently nucleated, a number of long and deep inclusions of the order of 200–600 mm length and cracks about 100 mm long parallel to the interface as shown in fig.6.8. The inclusions were poorly bonded to the matrix as they had separated at the interface. No intergranular cracks were observed. The fatigue appears to have initiated through the above surface defects which were likely to be the source of fatigue cracking. In the presence of long and deep inclusions and micro cracks, the stress required for fatigue initiation would be reduced.

In this crankshaft, multiple nucleation of fatigue at the pin-web fillet was evident from the nature of beach patterns in the initiation zone. Very close to the surface, long discontinuous cracks (about 400–800 mm length) as shown in fig.6.9 (a). In another location, a surface discontinuity (micro notching, looking like chipping-off of material) was also noticed shown in Fig. 6.9(b) followed fatigue propagation by fine scale cleavage. The presence of such defects is likely to expedite the nucleation of fatigue cracks.[3]



(a) (b)

Fig.6.9 SEM photograph

6.5.3 Case 3: Failure Due To Improper Machining

In the fatigue initiation zone of this crankshaft, large scale intergranular cracking and a network of grain boundary cracks were noticed (Fig 6.10). In addition, some cracks were noticed at the surface. The intergranular cracking zone extended over a distance of the order of 600 mm and more. [3]

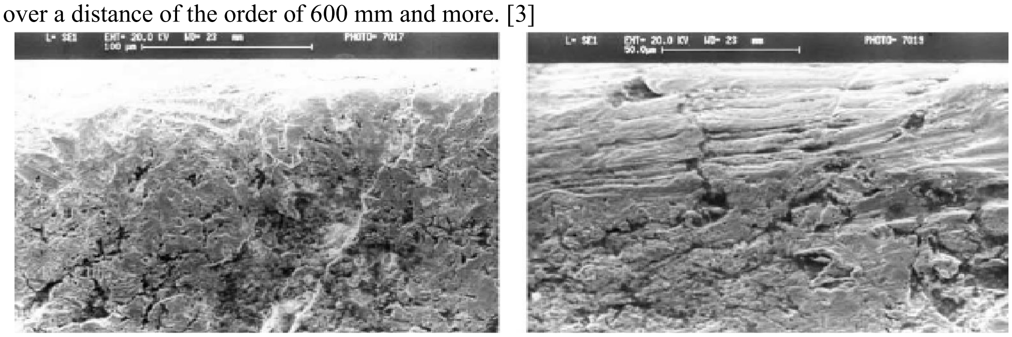


Fig.6.10 SEM photograph

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6.5.4 Case 4 : Failure Due To Surface Contact Fatigue

The low magnification fractograph in Fig.6.11 shows the fracture surface at journal. Beach marks, typical of fatigue, are clearly visible. Tracing the beach marks, the fatigue crack origin could be determined and is shown by an arrow in Fig.6.12 The higher magnification view did not show any material defects at the crack origin. However, spalling of the hardened surface layer was observed at several areas (Fig. 6.12). The web radius region at the crack origin is shown in Fig. 6.13. Extensive pitting, spalling and surface cracking can be seen at the crack origin. In addition, scoring marks along the circumference of the web can also be seen. The surface cracks were found to be in a direction perpendicular to that of the scoring marks. [4]

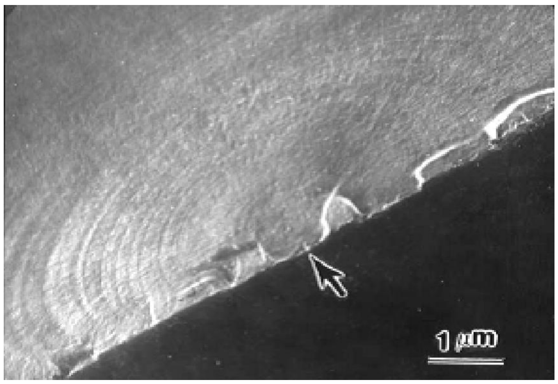

Fig.6.11 SEM of the fractured web at journal showing beach marks and crack origin

Fig. 6.12 SEM shows pitting, spalling and surface cracking at web radius

VII. FAILURE CONTROL METHODS

In crankshaft failure occurred at different places such as main bearing journal, crank pin journal and fillet region. After studying the possible failure reasons the following precautions to be adopted during fabrication of crankshaft and also during working of crankshaft in engine.

- Provide proper lubricant and lubrication system.
- Avoid over-running of engine.
- Proper alignments of the crankshaft on assembly.
- Proper control on the clearance between journals and bearing.

The machining and final grinding of crankshaft to be done carefully to control the overheating of crankshaft and to prevent discontinuities or crack like defect.[1,3]

Surface hardening heat treatment is to be done on journals and the fillet region of crankshaft resulting in a tempered martensitic structure.[2,3]

To prevent fatigue initiation avoid sharp fillet region or fillet radius need to be increased.[2,3]

To prevent fatigue initiations in fillet region the grinding amount must be controlled to down the nitriding layer.[5]

To improve the fatigue lives of crankshaft fillet rolling process to be used. The fillet rolling process induces compressive residual stresses near fillet surface. The compressive residual stresses lower the fatigue driving stresses near the fillet surface due to operating load and increase fatigue lives of crankshaft.[6]

VIII. CONCLUSION

1. The failure mechanisms of different crankshafts are studied. The mechanism includes fatigue process and force of friction.

2. The possible region where failure occurred are crankpin journal–web fillet region, main journal –web fillet region, oil holes and surface of journals.

3. The main reasons for failure in fillet region are sharp fillet region and absence of surface hardened heat treatment process like induction hardening or nitriding. Also on journal surface failure initiated by thermal fatigue due to overheating during machining and the grinding operation.
4. Mechanical fatigue failure, thermal fatigue failure, shearing stress and combined bending & torsional stress failure are probably the most common mechanism of crankshaft failure.
5. In order to prevent the failure of crankshaft, operating, mechanical and repairing sources of failure are to be controlled. Also machining and final grinding has to be done carefully to prevent formation of discontinuities or crack like defect in fillet region. Induction hardening or nitriding of fillet region in tempered martensite structure is required also avoid sharp fillet or fillet radius need to be increased.

REFERENCES

[1] F.S.Silva, “Analysis of a vehicle crankshaft failure”, Engineering Failure Analysis, 2003; 10, pp 605-616.
[2] H.Bryrakceken, S.Tasgetiren and F. Aksoy, “Failure of single cylinder diesel engines crank shafts”, Engineering Failure Analysis, 2007; 14, pp 725-730.
[3] R.K.Pandey, “Failure of diesel engine crankshafts”, Engineering Failure Analysis, 2003; 10, pp 165-175.
[4] S.K.Bhaumik, R. Rangaraju, M.A. Venkataswamy, T.A. Bhaskaran and M.A.Parameswara, “Fatigue fracture of crankshaft of an aircraft engine”, Engineering Failure Analysis, 2002; 9, pp 255-263.
[5] Zhiwei Yu and Xiaolei Xu,“Failure analysis of a diesel engine crankshaft”, Engineering Failure Analysis, 2005; 12, pp 487-495.
[6] W.Y. Chien, J. Pan, D. Close and S. Ho, “Fatigue analysis of crankshaft sections under bending with consideration of residual stresses”, International Journal of Fatigue, 2005; 27, pp 1 – 19.
[7] Changli Wang, Chengjie Zhao and Deping Wang, “Analysis of an unusual crankshaft failure”, Engineering Failure Analysis, 2005; 12, pp 465-473.
[8] www.inspecttest.com.
[9] Dr. Kripal Singh, “Automobile Engineering,Volume-2 , Standard Publishers.
[10] V.B.Bhandari, “Design of machine elements”. Tata Macgraw Hill