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FAILURE ANALYSIS OF CONNECTING ROD

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***Abstract*— In the present work, a failed connecting rod from a motorcycle and a diesel generator was investigated for the root cause of and possible mechanisms leading to its premature failure. In addition to finding the root cause, the expectation from the study was to possibly improve the existing designs or practices to avoid similar failure in future. These results were validated using a finite element analysis. A scanning electron microscope was used for studying the microstructure and visual inspection was primarily utilized to determine the root cause of the failure. In conclusion, it was determined that the root cause for the premature failure of the connecting rod was the presence of scale built up inclusions, which lead to micro cracking during fatigue loading of the component**

***Keywords*— connecting rod, Fatigue failure Scanning electron microscope**

I. Introduction

Connecting rods are generally manufactured using casting or forging, and in use support a variety of loads such as Compressive loading in the longitudinal direction, as a result of gas pressure on the piston crown. Alternate tensile and compressive loads, as a result of changing piston velocity, bending loads in the connecting rod's shank, as a result of the oscillating motion about the gudgeon-pin axis. Buckling stress as result of large compressive loads the frequency of the alternating loading increases rapidly with an increase in the engine's rpm. In many cases a catastrophic engine failure is caused by a connecting-rod failure and sometimes the broken connecting-rod's shank may even be pushed through the side of crank-case, thereby rendering the engine irreparable. There are any other reasons for such a failure, e.g., the overheating of the engine, cracking, deficiency of the bearing lubrication, poor maintenance etc.

II. Literature Review

During a catastrophic failure one of the four connecting rod of a 1.8 litre 16 valve internal combustion car engine while traveling at 100 km/hr. on a motorway. The side of the crank-case was ruptured and the corresponding piston was very deformed. While in another incident a 4-stroke internal combustion engine was used to power a Global GT 1 race car which was not designed for this application. Throughout its track life, the engine was run at very high speeds, exceeding 11,000 rpm, the car had run for 50 race hours before failing. During a race the engine failed catastrophically with sudden loss of power. Upon dismantling the engine a connecting rod had found to have failed along with one of its bolts and its slip bearing. In case of an diesel engine of the 4 stroke used in the generation of the electricity energy. The connecting rod was fractured in the body section close to the head. All these failed connecting rod was sent to laboratories for investigation during which several experiments were conducted, its material composition were studied and the failed and fractured portions were analyzed and their results were concluded

III. Experimental Work Review

The analysis of the fracture consisted of a visual examination, hardness measurements and a metallographic examination. The specimen for the metallographic and scanning electron microscope (SEM) examinations was cut from the connecting rod shank near the fractured surface. The double T cross section of the shank's fractured surface is shown in the figure 1, and the rods microstructure is shown in figure2.

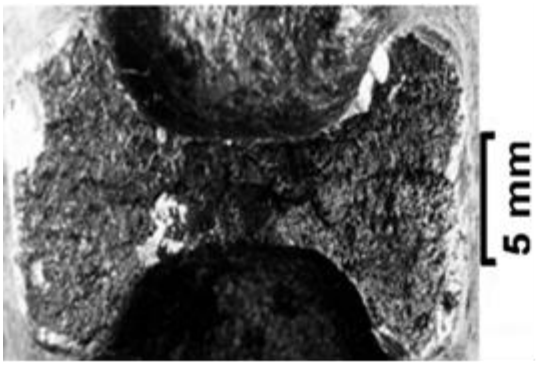

Figure 1. Fractured surface near the shank

The microstructure shown in the figure 2 is typical for ductile ion (nodular graphite iron) with a fine lamellar perlite matrix and small inserts of ferrite (approximately 5%) around the graphite nodules.

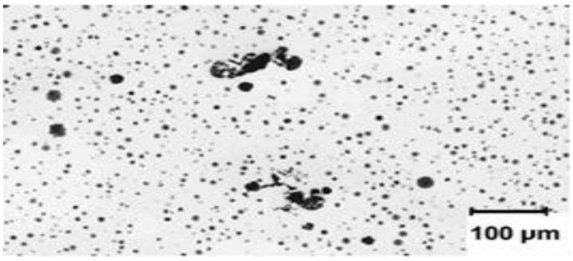

fig 2. Specimen's microstructure small end of the connecting rod shank

The whole surface of the connecting rod's two halves was examined carefully and numerous surface casting defects were found. One of which is shown the figure 3.

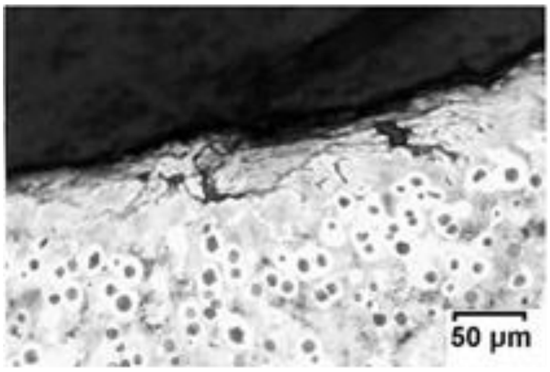

Fig 3. Casting defects on the surface of the connecting rod

Whereas from the motorcycle engine the a visual inspection was conducted on the failed components figure 4, after they had been removed from the engine, as well as other components such as oil filter and sump. Statements were also taken form interview with people involved in the refurbishing the car prior to failure.

Fig 4. Connecting rod from the motorcycle

Six specimens were collected and tested, ENG 1 to 6, some from the failed connecting rod and some from an intact connecting rod from the same failed engine. One specimen from each of the failed and intact connecting rods as well as two bolt cross sections were mounted in Met Prep TRI-HARD compound and polished using MetPrep SILICO 0.06 micrometer colloidal silica paste. As a part of the fractography investigation, ENG 1 was examined using limited zoom, full colour digital microscope; the Nikon ShuttlePix P-400R, to identify areas to be looked at in greater detail using other devices. Polished samples, ENG 3 to 6 then went under an Olympus BX51M optical microscope and a digital video recorder was used to capture images of the specimen's microstructures at multiple magnifications. Most of the fractography examinations were conducted under SEM and mounted samples were also etched with 1M hydrochloric acid to reveal their microstructure. Energy dispersive spectroscopy (EDS) was also used on samples under SEM to determine their chemical composition.

Hardness tests were conducted on mounted samples using an in size ISH-TDV2000 Vickers hardness tester by applying a 5kgf force for 5 seconds. An average hardness value was determined by repeating the test 5 times at random locations at each sample surface. Finally a finite element analysis (FEA) was conducted to determine the stress distribution in tact connecting rod geometry. The model for the simulation was imported from a 3D scan laser camera. A uniform distributed loads was applied to 1200C of the small end journal, while 1800 of the rod cap journal was kept fixed on the cylindrical faces, to stimulate tension stress in the operating conditions.

IV. Results and Discussion

The connecting rod is made of perlite ductile iron (nodular graphite cast iron), which is frequently used to substitute wrought or cast steel components. The benefits of using ductile iron in this application are lower manufacturing costs. Residue of aluminum on the big end fractured surface was found as result of the connecting rod being pushed through the aluminum crank-case. the connecting rod supports a complex fatigue load and because of this loading, every casting defect has a potential to become the initial point for fatigue-crack initiation where the local stress in the defect tip is increased because of the " notch effect". it is concluded that the final fracture occurred with a very small plastic deformation preceding the opening crack. The final rupture was thus very severe.

visual analysis was done on the failed connecting rod from the motorway and it was found that the plastic deformation is due to heat built-up during operation causing a drop in yield strength whereas from the previous inspection it was revealed that the connecting rod was prone to fail across the lubrication channel, since the highest deformation and level of stress, according to finite element simulations occur in this location. Fatigue cracking initiates in multiple sites at the lubrication channel.

In case of fractography analysis evidence of heat tinting was found suggesting that thermal hotspots inside the material were contributing factor to its failure. The blue section represents a temperature of around 3300C, the violet represents temperatures of approximately 2800 C and the yellow area represents temperature ranging from 2100 C. Further magnification of surface SEM imaging reveals the mud type micro crack that exists on the surface of the connecting rod. These cracks were initiated from sulphur-rich scale that builds up during environmentally corrosion process, creating sulphide brittle phase inclusion. While no sulphur content were found in the fractured region. This could be either the engine oil has sulphurized due to a sealing defect in the cylinder

hardness test revealed that the intact bolts showed hardness level above the standard level whereas the hardness of the fractured bolts were found to be significantly low due to the manufacturing defects which resulted in the elongation of the bolts which lead to its failure

V. Conclusions

The fractured connecting rod had a microstructure of pearlite ferrite ductile iron with a normal size and shape of graphite nodules. The morphology of the fractured surface indicates that the fracture occurred instantaneously. Observations of the fractured surface revealed sulphide brittle inclusions due to either sulphurized oil or inappropriate refurbishing process. One of the bolts had lower hardness than the others, which resulted in excessive elongation during the operation and imposed a cyclic impact stress on the journal's surface. Failure occurred at the body of the con-rod, close to the head, and involved the propagation by a fatigue mechanism, it was also due to insufficient to detect the surface defects and prevent the use of the connecting rod in the engine.

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