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Short communication

Forensic investigation of a failed connecting rod from a motorcycle engine

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ABSTRACT

In the present work, a failed connecting rod from a motorcycle engine 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 this study was to possibly improve the existing designs or practices to avoid similar failures in future. These results were validated using a finite element analysis (FEA) simulation. A Scanning Electron Microscope was used for investigating the mechanisms of fracture modes, optical microscopy for studying the microstructures and visual inspection were primarily utilised 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 build-up inclusions, which led to micro cracking during fatigue loading of the component.

1. Introduction

A 4-stroke internal combustion engine was used to power a Global GT1 race car. Although commonly used to power Global Class race cars, the engine was not designed for this application. The engine was acquired by the University of Derby; after which it was rebuilt. It was then mounted transversely as a stressed member of the GT1 chassis. Throughout its track life, the engine was run at very high speeds, exceeding 11,000 revolutions per minute (RPM). After the engine rebuild, the car had run for around 50 race hours before failing. During a race the engine failed catastrophically with a sudden loss of power. Upon dismantling the engine, a connecting rod was found to have failed along with one of its bolts and its slip bearings. Fig. 1a shows a typical connecting rod with key features highlighted and Fig. 1b shows an intact connecting rod next to the failed connecting rod. Connecting rods undergo cyclical tensile and compressive loading during the combustion cycle, suggesting fatigue could be the cause of a failure. At the point of failure, the brake and throttle were being applied, increasing the magnitude of these forces.

This study aims to find the mechanism of failure for the failed connecting rod. An investigation was conducted by inspecting the fracture surface, microstructure and hardness of the component and validated using a finite element analysis (FEA) simulation. The failure analysis was conducted in the hope that designs or practices can be improved, and failures such as this avoided in future.

2. Methodology

A visual inspection was first conducted on the failed components, after they had been removed from the engine, as well as other components such as the oil filter and sump. Statements were also taken from interviews with people involved in refurbishing the car

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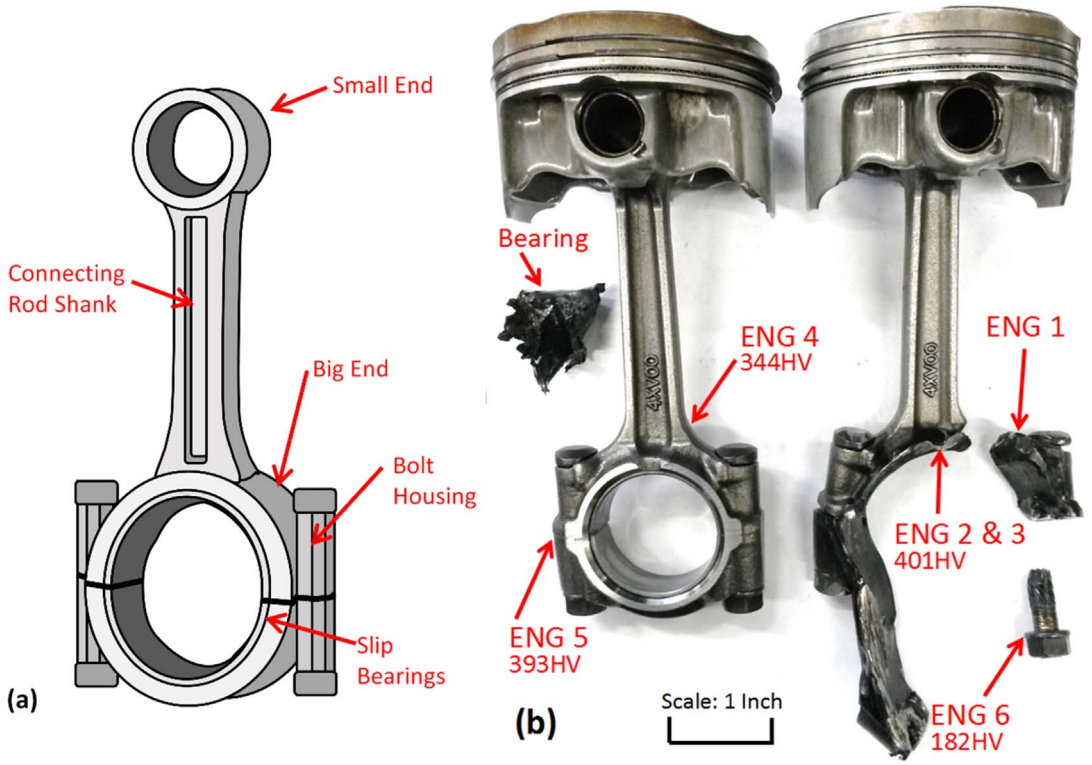

Fig. 1. (a) Diagram of an assembled connecting rod, rod cap, bolts and slip bearing with key features and components annotated in red; (b) The intact and failed connecting rod and piston assemblies, left and right consecutively, are shown with the failure.

prior to failure. Data from the on-board event data recorder (EDR) was obtained and analysed to accurately assess the condition of the engine during the failure event.

Six specimens were collected and tested, ENG1 to 6, some from the failed connecting rod and some from an intact connecting rod from the same failed engine. Each of the rods was sectioned in various places and cross sections of bolts from each connecting rod were also made. One specimen from each of the failed and intact connecting rods as well as the two bolt cross sections were mounted in MetPrep TRI-HARD compound and polished using MetPrep SILICO 0.06 μm colloidal silica paste. The specimen identification system used for all samples is outlined in Table 1 and shown Fig. 1.

As part of the fractography investigation, ENG1 was examined using a 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, ENG3 to 6, then went under an Olympus BX51M optical microscope and a digital video recorder was used to capture images of the specimens' microstructures at multiple magnifications.

After identifying key areas to investigate further, most of the fractography was conducted by placing specimens in a scanning electron microscope (SEM); the Zeiss LEO 1550 field emission SEM, to observe surfaces at further magnifications. Unmounted samples were cleaned in an ultrasound bath and mounted samples were also etched using 1 M hydrochloric acid, to reveal their microstructures. Energy dispersive spectroscopy (EDS) was also conducted on specimens in the SEM to determine chemical composition.

Hardness tests were conducted on mounted samples using an in size ISH-TDV2000 Vickers hardness tester by applying a 5 kgf force for 5 s. An average hardness value was determined by repeating the test 5 times at random locations on each sample surface.

Finally, a finite element analysis (FEA) was conducted to determine the stress distribution in intact connecting rod geometry. The

Table 1
Specimen identification system codes and corresponding descriptions for samples analysed.

Specimen Identification	Specimen Description
ENG1	Unmounted failed connecting rod piece consisting of bolt housing and fracture surface.
ENG2	Unmounted section from the top of the failed connecting rod big end with fracture surface.
ENG3	Mounted and polished section from the top of the failed connecting rod big end, corresponding to sample ENG2.
ENG4	Mounted and polished section from the beam of the intact connecting rod.
ENG5	Mounted and polished cross section of a bolt from the intact connecting rod.
ENG6	Mounted and polished cross section of the failed bolt from the failed connecting rod.