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Application of microscopy techniques for forensic analysis of a failed aircraft crankshaft

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Microscopy techniques are of paramount importance as complementary aiding tools for supporting the aircraft accident investigators' job. In this case, the inspection of damaged components will determine whether the failure resulted as a consequence of the crash itself or from other causes prior to the accident [1-3]. If a component failed before a crash then the judicious use of microscopy techniques allow to assess distinct damage mechanisms based in the observation of fracture surfaces which in turn identify the root causes of the failure (e.g., material's defect, inadequate design or fabrication technique or unappropriated operational conditions).

This work presents a microscopy analysis of the fracture surface of a failed crankshaft from an aeronautical internal combustion engine which culminated in the crash of an ultralight aircraft. The crankshaft's catastrophic failure occurred in the interface region between cylinder #2 connecting rod journal and the adjacent web (Fig. 1(a)). At an initial stage, efforts were directed towards the microscopy observation of this region of interest to characterize the fracture surface pattern and other features that could provide significant information about the failure mechanisms. From these observations it was found that the fracture features were compatible with a cyclic load dependent crack front propagation related to a mechanical fatigue process (Fig. 1(b)). A particular attention was addressed to the identification of the crack initiation site in order to determine likely contributing factors in the base of the cyclic damage mechanism, such as stress raisers and imperfections. By resorting to SEM analysis, striation marks were found (Fig. 2(a)) along the crack propagation path which besides confirming the cyclic plastic process also provide meaningful information regarding the crack propagation rate and consequently the number of cycles to failure [4]. Additionally, SEM observations focused in the crack initiation site allowed the detection of a possible forging defect concomitant to the onset of the fatigue process (Fig. 2(b)). The characterization of this defect was attained by using an energy dispersive spectrometer (coupled to the SEM equipment) in order to undertake a chemical composition analysis of the neighbouring region and confirmed possible segregation mechanisms resulting from the forging process in the course of the crankshaft's fabrication. Finally, the fractured component was chemically etched to confirm the existence of a case-hardened surface region which was then visualized by means of an optical microscope to determine its depth. The dimension of the surface layer was not perfectly uniform along all the perimeter of the section and the nominal case depth was found to be around 0.2 mm.

The visual and microscopic inspection of the fracture surface permitted to conclude that the crankshaft failed as a result of a high cycle fatigue process with the crack initiation region in the interface of the crankpin journal and the adjacent web. As a result of the combined contribution of the adjacent undercut fillet and lubrication hole as stress raisers and the possible forging defect. The stress concentration in the adjacent of the fillet region should be stressed out has the major likely root cause for the failure of this component.

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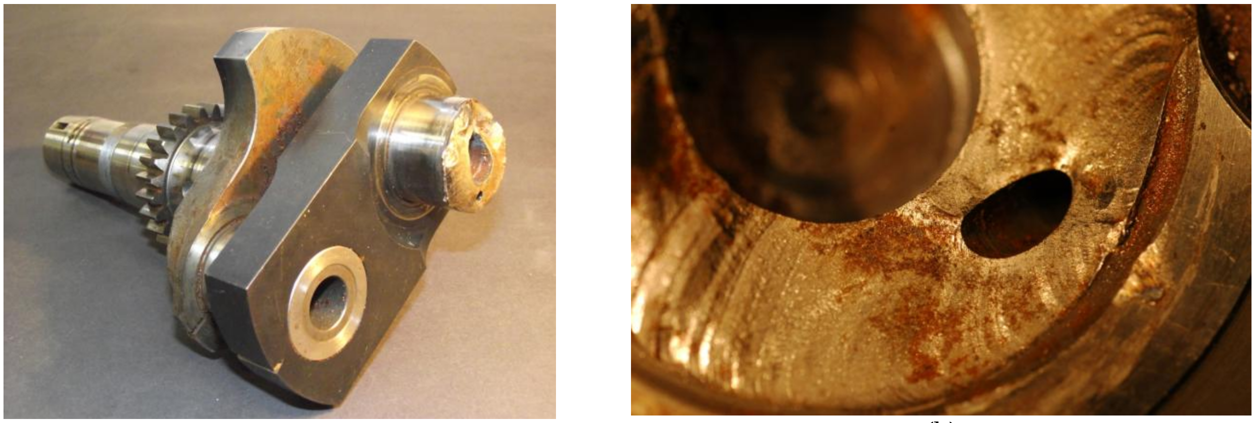
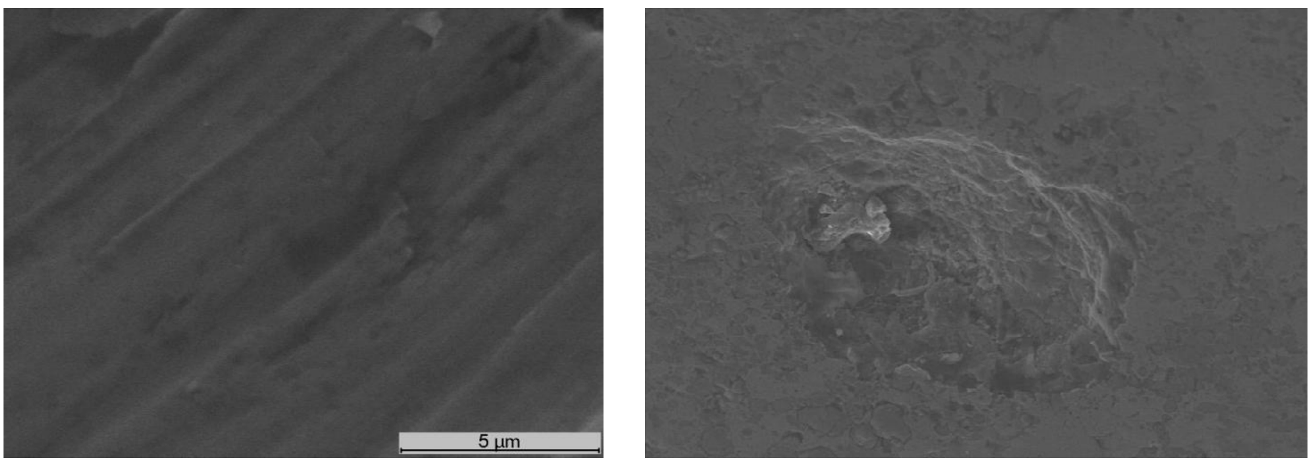


(a) (b)

Fig.1 – Failed crankshaft; (a): failure occurred in the interface region between cylinder #2 connecting rod journal and the adjacent web; (b): fracture surface.



(a) (b)

Fig.2 – SEM analysis of the fracture surface of a aircraft crankshaft; (a): striations due to cyclic plastic deformations related with fatigue mechanisms; (b): possible forging defect close to the crack initiation region.

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