ATSB Australian Transport Safety Bureau

AUSTRALIAN TRANSPORT SAFETY BUREAU

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TECHNICAL ANALYSIS REPORT

OCCURRENCE 199804715

ENGINEERING TASK 199900004

ENGINE CYLINDER HEAD CRACKING – VH-XAJ

COMMONWEALTH DEPARTMENT OF TRANSPORT AND REGIONAL SERVICES

ENGINE CYLINDER HEAD CRACKING – VH-XAJ

1. Introduction

A Cessna 210 aircraft, registration VH-XAJ, was involved in an accident during a forced landing. The landing was prompted by the sudden onset of engine power loss and rough running. Subsequent examination of the Teledyne Continental Motors IO-520 engine revealed that a large crack was present in the #1 cylinder head.

2. Cylinder Head Failure Analysis

The crack present in the cylinder head extended from the lower spark plug hole over a distance of approximately half the circumference of the cylinder head — on the exhaust valve side, see figures 1 and 2.

The cylinder head was sectioned to allow the crack surfaces to be examined. It is evident that the cracking had occurred as a result of fatigue. Fatigue cracking initiated at the outer surface of the cylinder head, near the lower spark plug hole. Fatigue cracking extended inwards through the cylinder head wall and around the circumference on the exhaust valve side prior to final rapid crack extension (rapid crack extension occurs when the fatigue crack tip stress intensity exceeds the fracture toughness of the head material). The extent of fatigue crack growth prior to final rapid crack extension could not be determined due to the erosion of fine fracture surface detail by escaping exhaust gas.

2.1 Cylinder Head Fatigue Cracking

Fatigue cracks initiate and grow in response to the presence of alternating stresses in a component; important parameters are the range of the alternating stress, the frequency of stress reversal and the magnitude of the mean stress.

The cylinders of internal combustion piston engines are subjected to alternating internal pressures as a result of the combustion cycles. In the case of engines with air-cooled cylinder heads, the cylinder head is also subjected to alternating stress cycles that are developed as a result of heating during engine operation and cooling during engine shutdown. The alternating stresses of most significance to the continuing integrity of cylinders are those created by the thermal cycles.

It is common knowledge that fatigue cracks develop in air-cooled engine cylinder heads as a result of the alternating stresses developed by the sudden cooling of heated cylinders. The sudden cooling of the outer surface of a heated cylinder head creates a high tensile stress at the inner surface as the remainder of the cylinder contracts against the already cooled outer surface. If thermal stressing is repeated, fatigue cracking will initiate at the inner surface and extend towards the outer surface.

Air-cooled cylinder heads are also subjected to a tensile stress every time the cylinder head is heated as a result of the constrained thermal expansion, with repeated heating and cooling alternating tensile stresses will be created in the outer surface of the cylinder head. Stresses will be highest in the regions that are heated to the highest temperature and where the geometry of the head creates a region of high constraint.

The magnitude of stress created by constrained thermal expansion is normally limited by the control of the maximum temperature the cylinder head is exposed to during operation.

Examination of the outer surface of the #1 cylinder head (VH-XAJ) revealed that the paint applied to the cylinder head had changed colour in the vicinity of the fatigue crack initiation site. This type of paint discolouration indicates that this region of the head had been heated to a higher than normal temperature[1].
Measurement of the electrical conductivity of sections taken from near the lower spark plug hole and a valve rocker boss (an area that is cooled by engine lubricating oil) confirmed that the region near the lower spark plug hole had been subjected to higher than normal temperatures. The alloy from which the cylinder head is manufactured is heat treated to an overaged condition for stability of mechanical properties during operation. Excessive heating during operation results in further overaging as evidenced by an increase in electrical conductivity and decrease in hardness (lower spark plug region, electrical conductivity 33.6% IACS, hardness 65 HV10, rocker boss region, 31.6% IACS, 79 HV10).

3. Conclusions

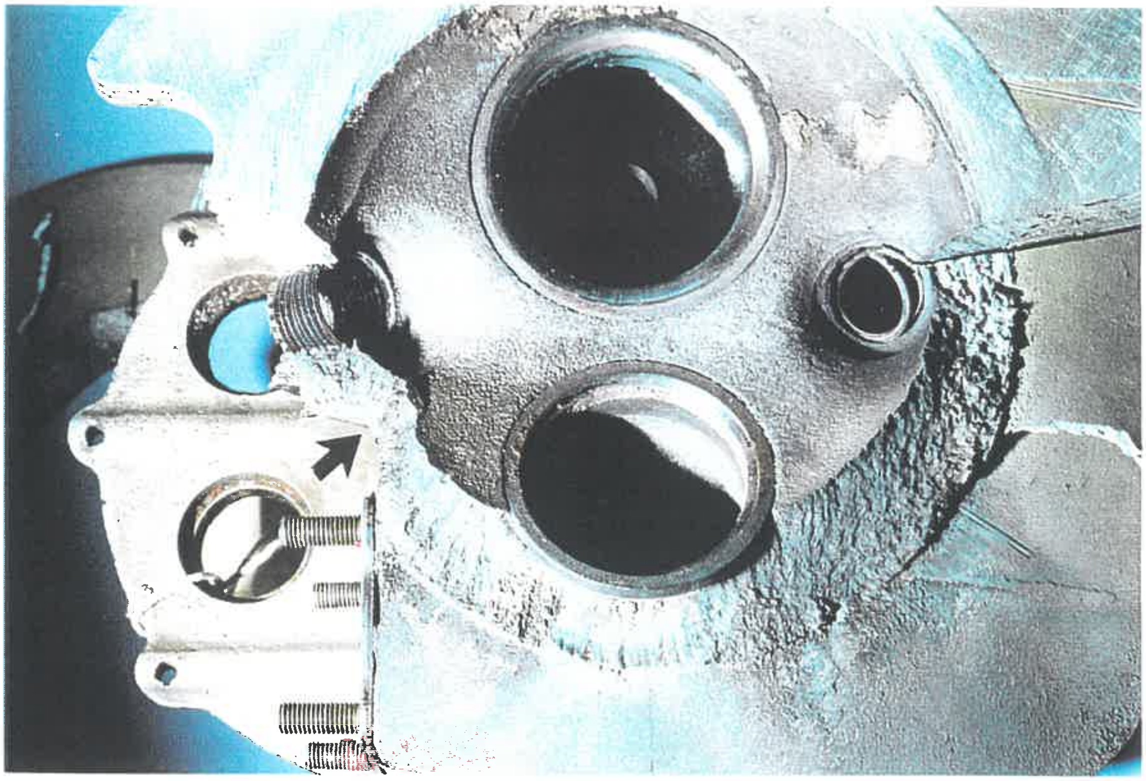
The crack in the #1 cylinder of the engine fitted to VH-XAJ was caused by fatigue. Fatigue cracking initiated as a result of overheating of the cylinder head.

4. Recommendations

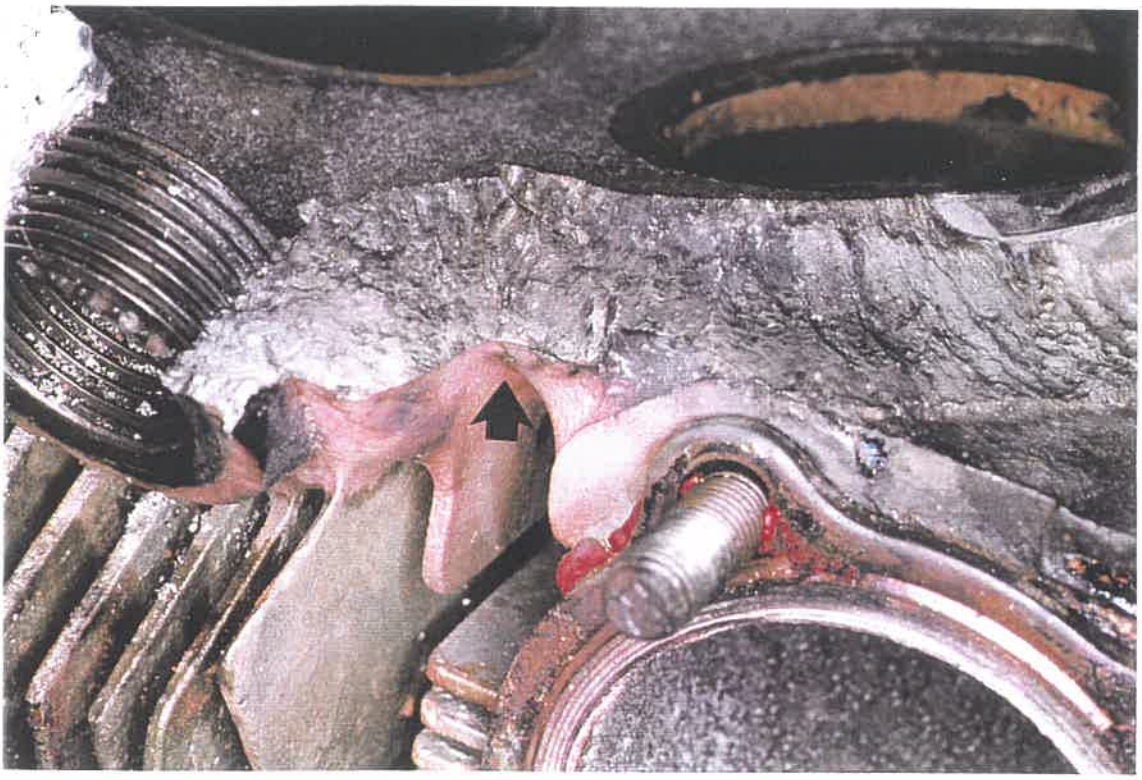
The factors leading to the overheating of the #1 cylinder head should be investigated.

Attachments: Detailed Photographs of cylinder head fracture

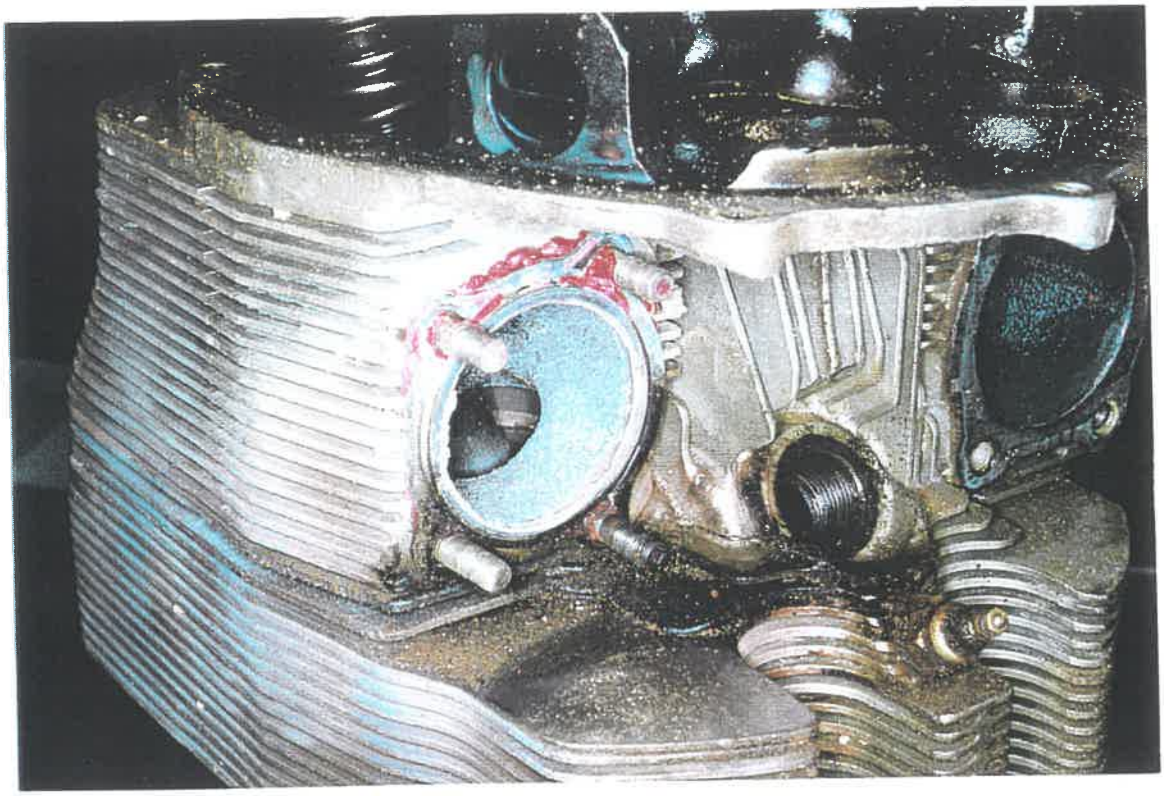
[1] Aircraft Powerplants fourth edition, R.D Bent, J.L. McKinley, 1978, p 38

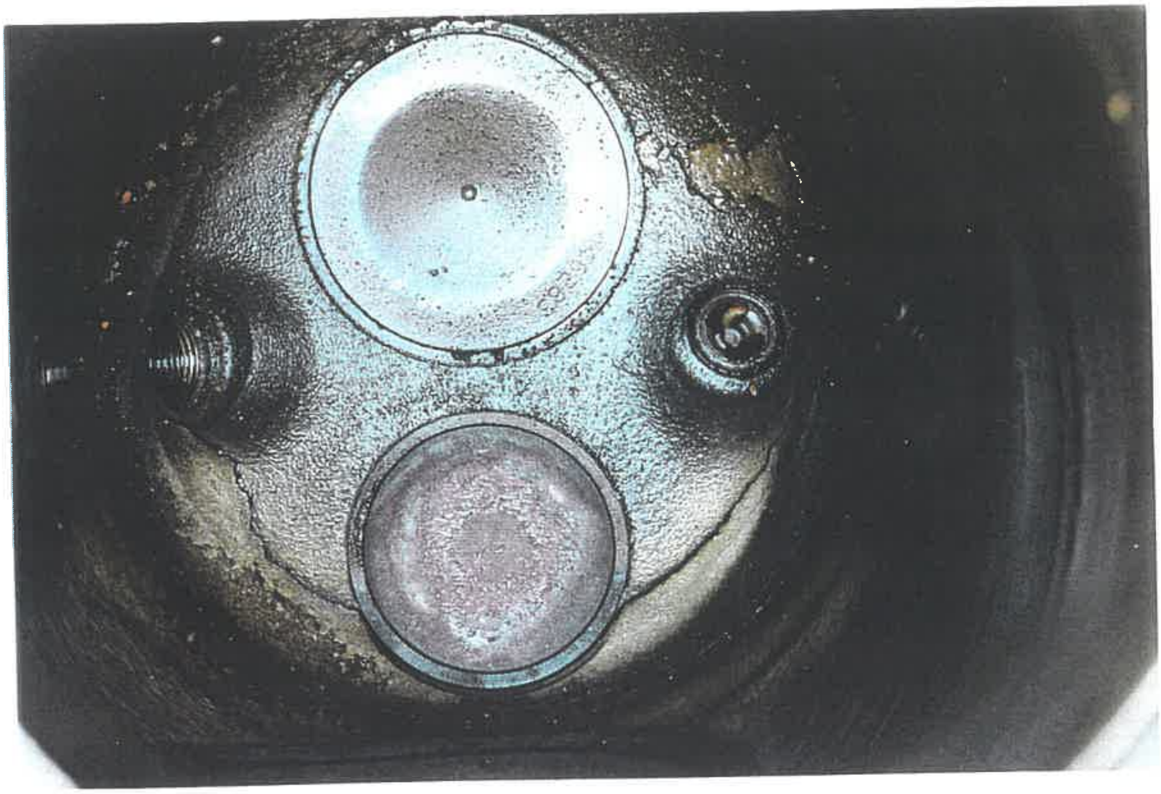


THE CRACK SURFACE EXPOSED AFTER SECTIONING THE CYLINDER HEAD
(THE SITE OF FATIGUE CRACK INITIATION IS ARROWED)



DETAILED VIEW OF THE FATIGUE CRACK INITIATION SITE





THE EXTENT OF CRACKING IN THE CYLINDER HEAD