No: 10/90 **Ref: EW/C1150** **Category: 1c**

Aircraft Type and Registration:	Brooklands Aerospace Group plc OA7 Optica, G-BMPL
No & Type of Engines:	1 Lycoming 10.540 V4A5D piston engine
Year of Manufacture:	1987
Date and Time (UTC):	11 March 1990 at 1045 hours
Location:	Royal Navy Air Station, Lee-on-Solent, Hampshire
Type of Flight:	Commercial (Observation)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to fan and hub assembly; minor airframe damage
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	44 yrs
Commander's Total Flying Experience:	Approximately 2500 hrs
Information Source:	AAIB Field Investigation

Circumstances

The aircraft, which was operated by the Hampshire Constabulary, commenced its take-off roll with pilot and an observer onboard from approximately one third along runway 23 (due to the activities of a gliding club operating from the same runway). All relevant checks had been completed without any problem and there was no discernible vibration from the engine.

The take-off and initial climb (at an airspeed of 70kts) were normal until, at an altitude of approximately 160ft, there was a loud "bang" followed by a severe vibration. The pilot immediately lowered the nose of the aircraft and throttled the engine back to idle in order to reduce the vibration. It was apparent that a forced landing was necessary but the pilot assessed that the remaining runway ahead was insufficient and would result in an overrun onto a public road. He therefore put the aircraft into a 30° banked turn to the left with the intention of making a downwind landing on runway 10. The observer made a radio call informing the tower of the pilot's intentions. With full flap selected, the aircraft touched down two thirds along runway 10, although not aligned with it, at an airspeed of 60kts. With a wind of 230/15kts, this resulted in a groundspeed of approximately 75kts. The engine was still at idle rpm as the aircraft rolled onto the grass on the left side of the runway and came to a stop. There were no injuries and no apparent additional damage, although a small amount of fuel was observed to be leaking from the bottom of the engine pod.

A quantity of debris was recovered from the runway close to where the bang had been heard; this consisted mainly of fan and shroud fragments, together with two fairing plates which had come from the hub assembly.

Examination of the aircraft

It was quickly apparent that although the wooden fan blades had been severely damaged, this had resulted from one of the two fairing plates that had been released becoming trapped between a blade tip and the shroud, the ensuing debris causing consequential failures of the remaining blades. The plate was badly damaged and exhibited black marks that were later considered to have come from heavy contact with the rubber seal between the engine pod and the airframe, this junction being immediately forward of the fan shroud. Approximately 25% of the seal was missing between the 12 and 3 o'clock positions, viewed from the rear of the aircraft. Pieces of the seal were found among the debris on the runway.

The fan shroud, which consisted of a foam abrasion strip on a light alloy backing, had been penetrated in a number of places, leading to debris being found within the inboard wing structure. One small alloy fragment had become trapped between a cable and pulley in the flap operating circuit, although the operation of the system had not in fact been impeded.

The fuel strainer was located on the underside of the airframe immediately forward of the shroud. Damage to the latter had resulted in the fuel strainer mounting plate being deflected downwards slightly which had in turn caused minor distortion in an associated length of pipe, together with a small amount of fuel seepage from a nearby pipe union. At the time of inspection there was in fact no leak. However it was considered that this had been the source of the fuel leak observed after landing.

The remainder of the damage was confined to small indentations on two of the stators (which mount the engine to the inside of the pod) and a partially failed exhaust manifold mounting where it attached to the oil cooler at the rear of the engine, the latter most probably having occurred as a result of the severe vibration following the fairing plate separation and blade failures.

Detailed examination of the fan assembly

The pod was removed from the airframe to allow access to the fan/hub assembly. A diagram of the latter is presented at Figure 1. The assembly essentially consists of fixed pitch blades attached to a fabricated hub. The hub is built up from front and rear alloy ring plates held together by five steel flanged webs arranged radially in line with, but not attached to, the blades. The sheet alloy fairing plates are riveted to the ring plates. Access to the hub interior is gained via cut-outs in the ring plates, each being fitted with five lightweight cover plates. Once these were removed, it was observed that one of the radial webs had failed along two of the three flanges and most of the third, only being retained by a small uncracked portion close to the hub. A photograph of the web is presented at Figure 2, and it can be seen that it has hinged about the rear flange into the plane of hub rotation. It had been prevented from lying flat against the ring plate by a bolt tail, the fretting mark it had made on the web displaying evidence of corrosion, indicating that the condition had existed for some time. In addition, it was observed that three of the remaining four webs displayed cracks at the outer ends of their flanges. The detached fairing plates had come from the positions either side of the failed web.

The hub was removed from the engine and disassembled into its component parts. The torque settings of the bolts retaining the blades and webs were checked during this process and most were found to be in excess of the values specified by the manufacturer. Slightly low values were recorded for the outermost bolts of each radial web.

The webs were subjected to a detailed metallurgical examination by the Materials and Structures Department at RAE Farnborough where it was discovered that all the cracks had developed by fatigue. On the forward side of the failed web the crack had started close to the outermost bolt hole, but the fracture had occurred along the flange radius. On the rear side, the crack had started close to the bolt hole and then run into the bend. The general appearance of the fractures and the evidence of cracking in other webs suggested that failure had originated at the outer ends of the flanges but, because of heavy rubbing damage in these areas, it was not possible to identify the precise positions of crack initiation. However, away from the outer ends, multiple origins were visible along both surfaces of each flange, indicating that crack growth had occurred under reverse bending conditions.

The cracks in the other webs typically passed close to the outermost bolt holes, forming tangents to the outer rims of the washers. On all the webs, fretting was observed along the lines of the cracks between the flanges and ring plates.

When the cracks were broken open, the surface features were consistent with fatigue growth from multiple origins on one or both surfaces of the flanges. Metallographic examination of a section from the region of a short crack in one of the webs revealed a number of microcracks originating from small, oxide filled pits in both surfaces. A hardness test showed that the tensile strength of the material was slightly in excess of the maximum for British Standard S515 steel from which the webs had been manufactured.

The fracture faces of the 12 rivets that had retained each of the fairing plates were examined and it was found that there was an approximately even split between fatigue and overload. Although some smearing had occurred during the separation, the remaining evidence indicated that the fatigue fractures were of high cycle type.

The rivets retaining the remaining three fairing plates were examined by filing off the heads and pressing the shanks out. One rivet, in an end position, was in two halves as a result of a fatigue failure. Four others, all in end positions, after being sectioned longitudinally, were found to have short cracks or crack-like defects. Three of these were considered to have been initiated by a shearing effect and showed some fatigue growth. The cracks in the remaining rivet were characteristic of fretting damage. All the rivets, cracked or otherwise, were generally tightly fitting and the low number of defects suggested that the fatigued rivets in the separated fairing plates were consequent upon the web failure. However, when the manufacturer carried out a similar examination on another hub, it was found that most of the fairing plates had one or more cracked rivets. None of the webs had failed, although some had small cracks.

Finally, two each of the forward and rear cover plates were found to have cracks in the outboard lobes in which were drilled 5mm holes for the attachment bolts (see Fig 3). The cracks varied in length between 8.5 and 23mm and all initially followed the line of the edge of the washer beneath the bolt head, suggesting that their growth had been influenced by the local change of stiffness, particularly where the washer crossed an adjacent 3mm tab washer hole.

Hub history

The hub had achieved 1320 hours at the time of the incident. A 250 hour inspection had been carried out 160 hours previously, although this was basically an in-situ examination of the blades, the engine pod not having been removed. New blades had been fitted 307 hours before the incident, which coincided with a 500 hour check. The hub had been subjected to a visual internal inspection following removal of the engine pod and cover plates.

Since this incident the manufacturer has found cracks in the webs of two hubs that had achieved 50 and 900 hours respectively.

Summary

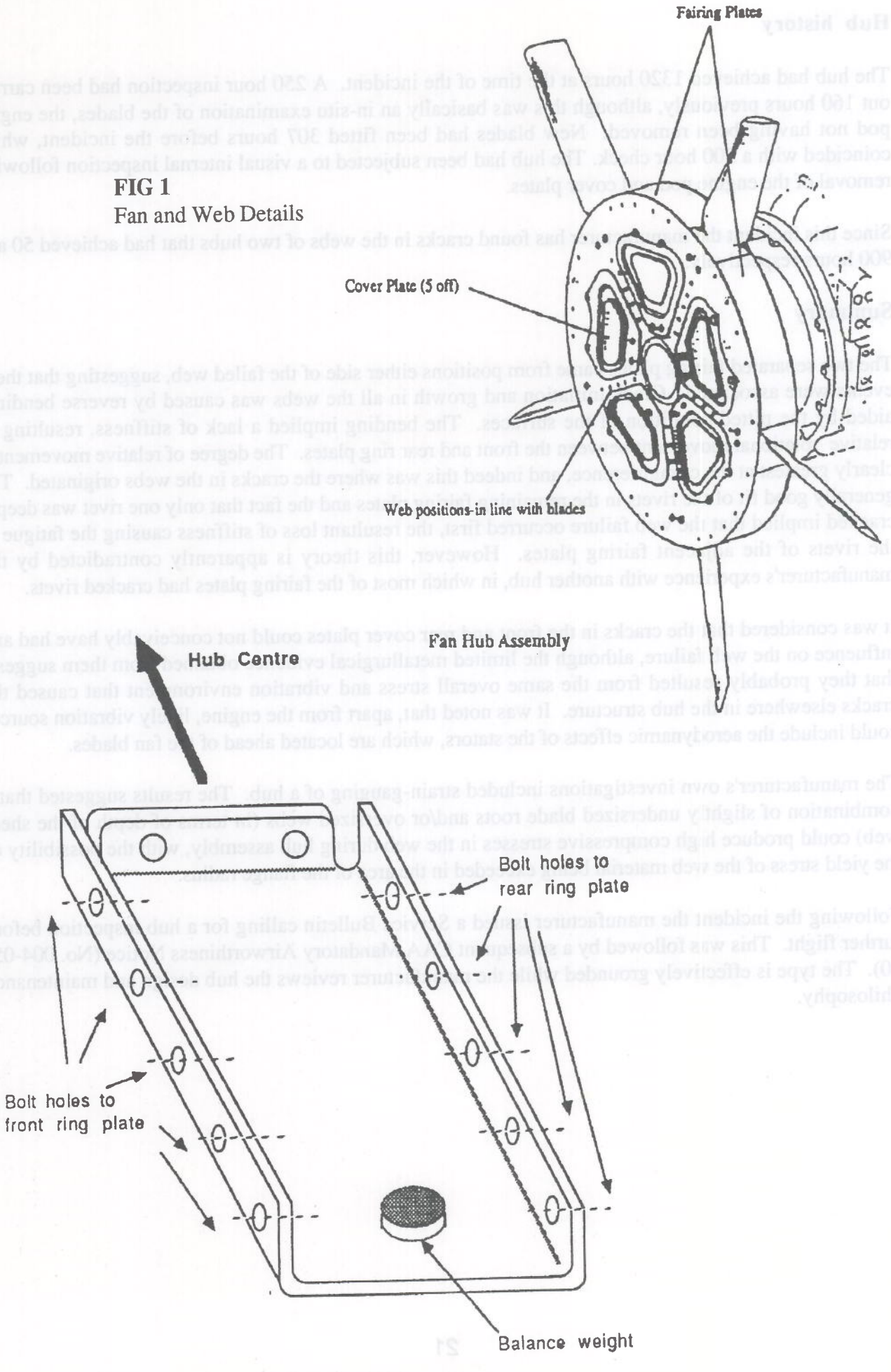
The two separated fairing plates came from positions either side of the failed web, suggesting that these events were associated. Crack initiation and growth in all the webs was caused by reverse bending, aided by the pitted condition of the surfaces. The bending implied a lack of stiffness, resulting in relative rotational movement between the front and rear ring plates. The degree of relative movement is clearly greatest at the circumference, and indeed this was where the cracks in the webs originated. The generally good fit of the rivets in the remaining fairing plates and the fact that only one rivet was deeply cracked implied that the web failure occurred first, the resultant loss of stiffness causing the fatigue in the rivets of the adjacent fairing plates. However, this theory is apparently contradicted by the manufacturer's experience with another hub, in which most of the fairing plates had cracked rivets.

It was considered that the cracks in the front and rear cover plates could not conceivably have had any influence on the web failure, although the limited metallurgical evidence obtained from them suggests that they probably resulted from the same overall stress and vibration environment that caused the cracks elsewhere in the hub structure. It was noted that, apart from the engine, likely vibration sources could include the aerodynamic effects of the stators, which are located ahead of the fan blades.

The manufacturer's own investigations included strain-gauging of a hub. The results suggested that a combination of slightly undersized blade roots and/or oversized webs (in terms of depth of the shear web) could produce high compressive stresses in the web during hub assembly, with the possibility of the yield stress of the web material being exceeded in the area of the flange radius.

Following the incident the manufacturer issued a Service Bulletin calling for a hub inspection before further flight. This was followed by a subsequent CAA Mandatory Airworthiness Notice (No. 004-05-90). The type is effectively grounded while the manufacturer reviews the hub design and maintenance philosophy.

FIG 1
Fan and Web Details



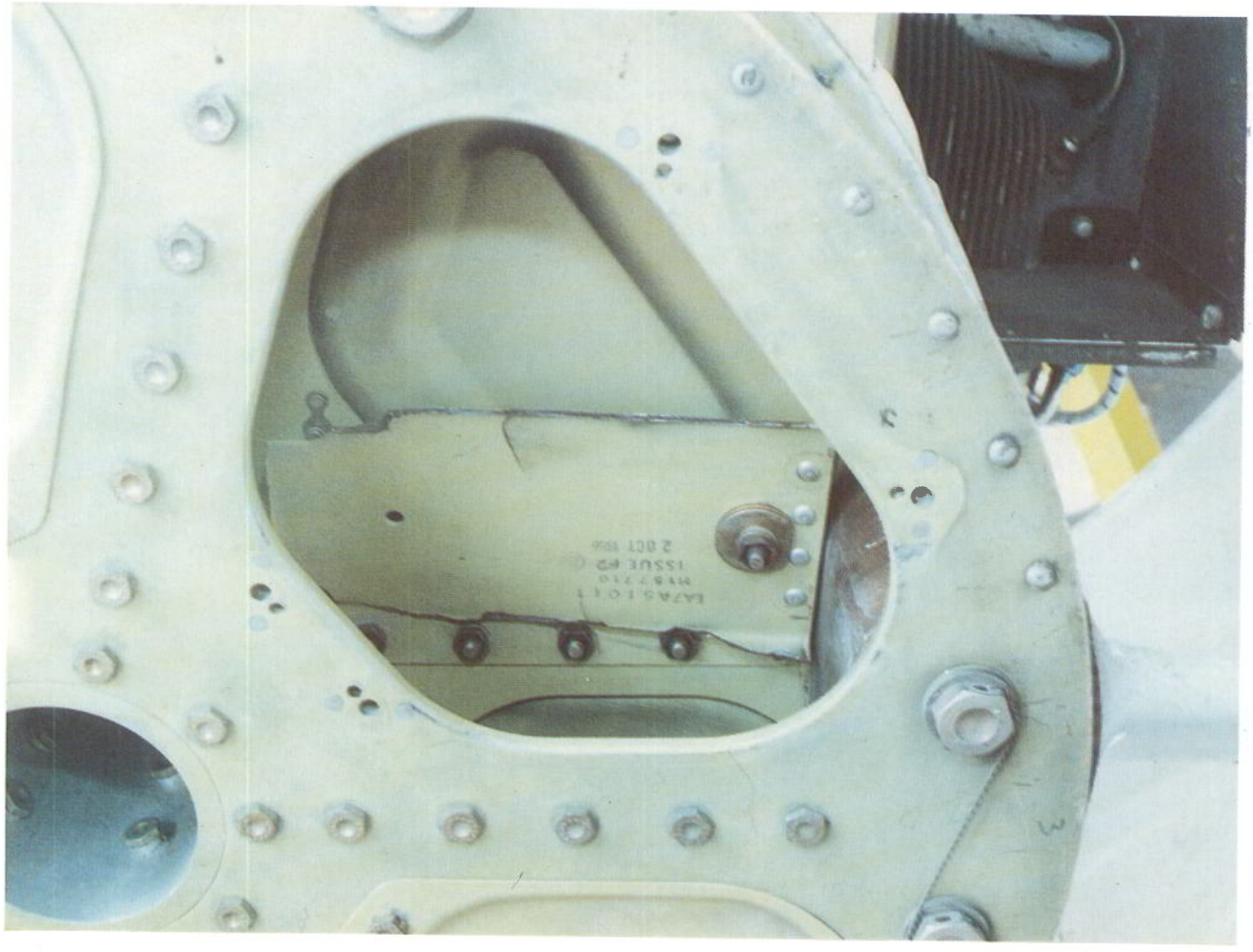


FIG 2 View of failed web following removal of cover plate

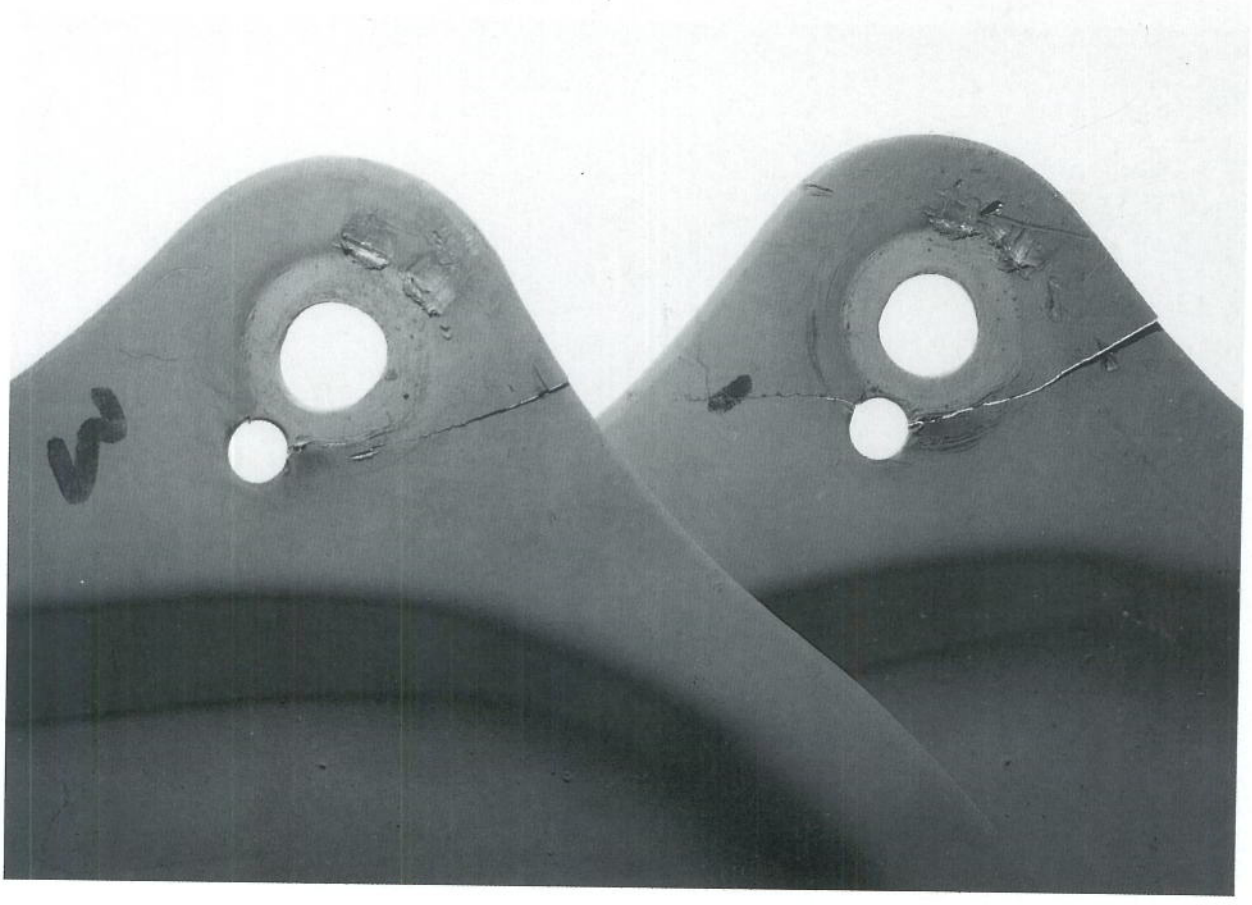


FIG 3 Cracks around cover plate bolt holes