No: 1/92 **Ref: EW/C91/10/2** **Category: 2a**

Aircraft Type and Registration:	Bell 214ST, G-BKJD	
No & Type of Engines:	2 General Electric CT7-2A turboshaft engines	
Year of Manufacture:	1982	
Date & Time (UTC):	2 October 1991 at 1010 hrs	
Location:	81 nm east of Aberdeen	
Type of Flight:	Public Transport	
Persons on Board:	Crew - 2	Passengers - 4
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Failed tail rotor counterweight bearing journal	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	43 years	
Commander's Flying Experience:	8,600 hours (of which 1,000 were on type)	
Information Source:	AAIB investigation of failed parts submitted by operator	

Circumstances

The helicopter had departed from the Maersk Highlander platform at 0836 hrs on a flight to Aberdeen when, some 34 minutes later and at 2,500 feet, a severe high frequency vibration was felt and heard. At the time of the occurrence the helicopter was 81 nm east of Aberdeen. The commander immediately initiated a gentle descent, whilst reducing the speed to 80 kt, and made a PAN call to Aberdeen radar, declaring his intention to seek an immediate diversion. Although the vibration was still severe at 80 kt, it had reduced slightly and the helicopter was fully controllable in level flight.

Just before 0912 hrs, ATC informed the commander that "Sedco 701" was 20 nm behind him, available for landing and standing by for his arrival. However, the commander identified "Kittiwake", which was only 12 nm behind, as the closest suitable landing deck and turned towards it. When inbound to Kittiwake at a range of 1nm, a low speed (35 kt) handling check was carried out and confirmed that they still had tail rotor control. Although the vibration level had increased slightly, the descent was continued to an uneventful touchdown on the deck. Following disembarkation of the passengers it was noticed that, during the shutdown, the amplitude of the vibration increased significantly before ceasing as the rotors stopped.

Subsequent inspection revealed that one of the two tail rotor counterbalance weight bellcrank assemblies was missing from the helicopter and that in separating it had struck the blade grips and the blade surface of one of the tail rotor blades. A complete replacement tail rotor assembly and gearbox were despatched from Aberdeen and fitted to the helicopter. Following test running, the helicopter was flown back to Aberdeen later in the day. The only other damage apparent was a broken left hand life-raft deployment handle cover, which was made of Perspex and roof-mounted behind the crew. Particularly severe vibration had been observed in the area of the roof console.

Examination of failed component

The failure concerned the tail rotor crosshead, P/N 214-010-806-101, which is splined onto the tail rotor shaft. The tail rotor pitch change links are attached to lugs on the crosshead, which moves axially on the shaft under the action of the yaw control servo. The two counterweight bellcranks are mounted on lugs, or journals, positioned at 90° relative to the pitch link lugs. The relevant components are shown on the diagram at Figure 1. The failure had occurred in the machined undercut at the base of one of the journals. Photographs of the crosshead are shown at Figure 2.

The primary function of the counterweights is to reduce the steady loads in the yaw control system produced by the centrifugal pitching moment of the tail rotors, thereby permitting operation in the event of hydraulic servo failure. This is achieved by the centrifugal force generated by each set of counterweights producing a pitching moment about the bellcrank pivot. The pitching moment loads are fed to a collar on the rotor hub by means of a link attached to a third arm on the bellcrank. This results in a force in the blade coarsening direction, and therefore counteracts the tendency of the blades to 'fine-off' due to the centrifugal pitching moment. The magnitude of this opposing force is dependant upon the radius of rotation of the counterweights and is controlled by the angle of the bellcrank axis relative to the axis of rotor rotation. This in turn is a function of the axial position of the crosshead on the rotor shaft, *ie* the yaw pedal position. The centrifugal force produced by the counterweight on each bellcrank arm can be resolved into two components; *ie* in the plane of the bellcrank and at 90° to it. The former produces the blade coarsening moment on the bellcrank whilst the latter results in a tensile load on the bellcrank bearing journal. However, the inboard counterweight has more than twice the mass of the outboard one, resulting in a bending element in the load applied to the journal.

The fracture surface was examined by the Materials and Structures Department of the Royal Aerospace Establishment, Farnborough. It was found that the fracture area consisted of a 50% division between fatigue and fast fracture, with fatigue origins within the inboard arc of the fracture, emanating from 'grooves' in the undercut at the base of the journal. Although it initially appeared that these grooves were machining marks, it was later found that they were in the plating material, and hence would not have been directly responsible for the fatigue initiation. Fatigue striations are invariably difficult to discern in this type of material, but were visible under a scanning electron microscope, and were parallel to the line that divided the two parts of the fracture. Figure 3 shows a view of the fracture face, with superimposed lines indicating the approximate counterweight bellcrank axis position for the yaw pedal positions. Note that the fatigue direction is consistent with the bellcrank being close to the mid position. The maximum centrifugal force generated by the counterweights (and hence the maximum tensile/bending stress in the journal) occurs at maximum radius of rotation, *ie* full left pedal, with the minimum occurring when the bellcrank is aligned with the rotor axis. It therefore appeared that the fatigue progressed with the bellcrank close to a typical cruise position, although the initiation may have occurred towards the position of highest stress. Dye penetrant and magnetic particle inspections revealed no cracks in the intact journal.

The metallurgical examination also revealed a degree of porosity in the microstructure which, although typical of a cast alloy, would have tended to reduce the fatigue life. However, none of the voids was associated with the fatigue origin. In addition, it was observed that the undercut area had not been shot-peened which, although not required for this component, would have improved the fatigue resistance. Finally, some fretting marks were observed on the casting at the base of the undercut. This was attributed to flexing of the journal as the crack progressed, causing relative movement between the shoulder of the bellcrank bearing and the casting. It was noted that this feature could also have been caused as a result of a loose bellcrank retaining nut. This item should be torqued to 175 inch pounds; thus any loss of torque would result in some loss of preload in the journal, with an attendant increase in susceptibility to fatigue.

Previous occurrences

Two similar instances of failed crosshead journals were notified to the manufacturer, leading to the issue, in February 1987, of Alert Service Bulletin No 214ST-87-38. This suggested that excessive 'brinelling' of the bellcrank bearings had been a possible cause and called for repetitive inspection of the bearings for wear and smoothness. In July 1989, Technical Bulletin No 214ST-89-104 was issued; this informed operators that a new design of crosshead was being made available, as a product improvement, to be incorporated as a customer's option. The component had a new part number, 214-010-806-105, and the main differences were larger diameter bearing journals, and a higher torque, (220-600 inch pounds), for the bearing retaining nut.

There was no evidence of brinelling on the surviving bellcrank bearing from G-BKJD which, in common with the operator's other 214ST helicopters, was fitted with the older -101 crosshead. The last 250 hour inspection was carried out 10 hours before the incident, and the bellcrank bearings were last replaced in January 1990. The crosshead itself had achieved 7000 hours.

Discussion

The journal stresses occurred as a result of the centrifugal forces generated by the counterweights; thus engine-on/engine-off cycles appeared to be the major consideration with regard to the progression of the fatigue crack. The journal load profile was therefore a square wave modified by the position of the yaw pedals. Although brinelled bearings were cited in the previous occurrences, it is difficult to understand how this condition contributed to the fatigue process. Any brinelling would result in some resistance to rotation of the bellcrank, but would introduce only small torsional elements to the journal load. This was acknowledged by the aircraft manufacturer: however, they indicated that damaged bearings may have been responsible for a resonant vibration in the counterweight assembly.

As a result of this incident, this operator has equipped its 214ST fleet with the later standard, -105 crosshead.

In addition, as a result of the findings associated with this investigation the following Safety Recommendation has been made to the CAA, recommending that:

> The CAA confer mandatory status on Bell Technical Bulletin No 214ST-89-104, to ensure that all Bell 214ST helicopters which are registered in the UK will be equipped with the latest standard of tail rotor crosshead.

The safety of flight operations in the North Sea

This incident has highlighted some deficiencies in routine offshore aviation communications. Certain additional facilities are planned and the system is being investigated by the AAIB in the light of these developments.

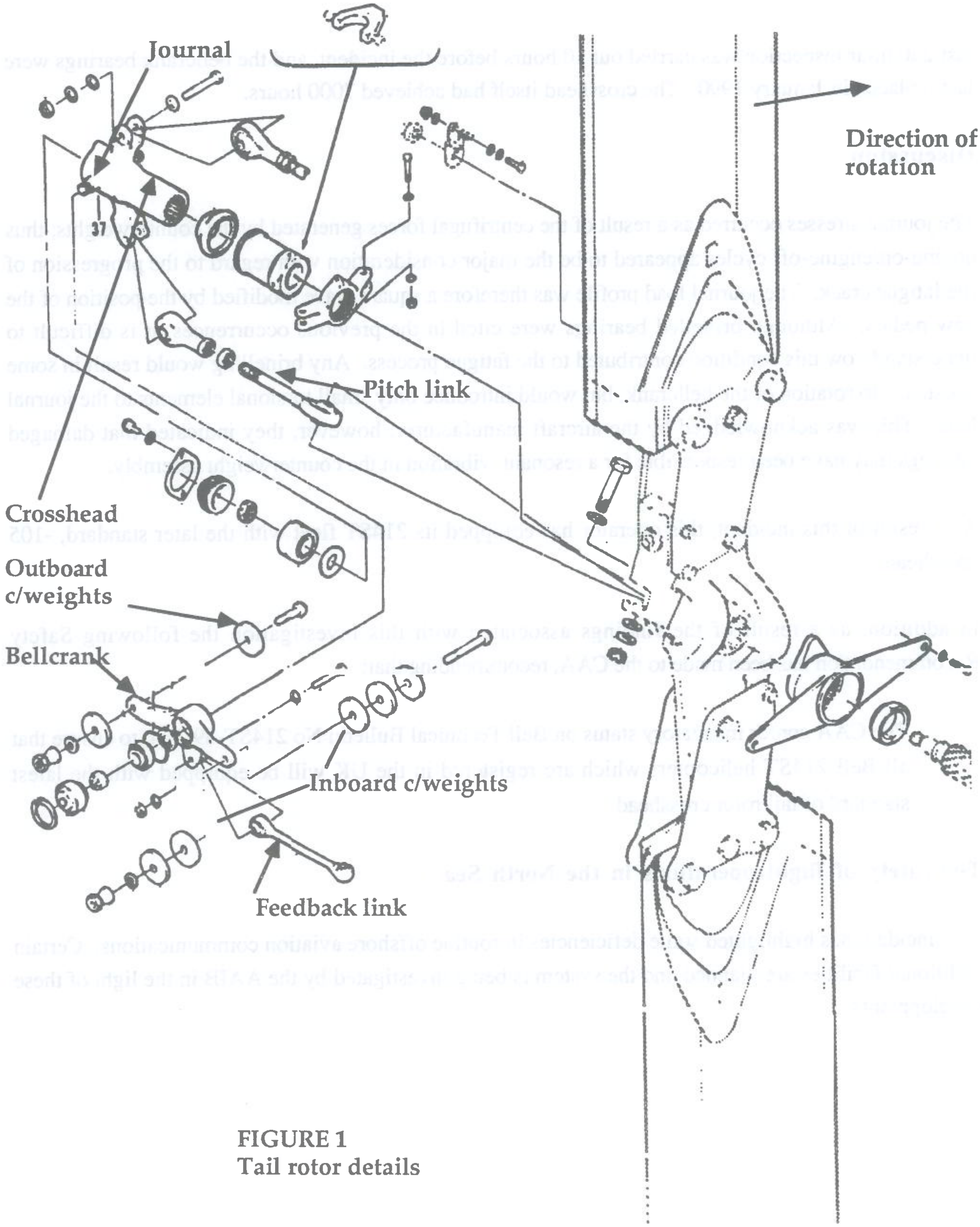

FIGURE 1
Tail rotor details

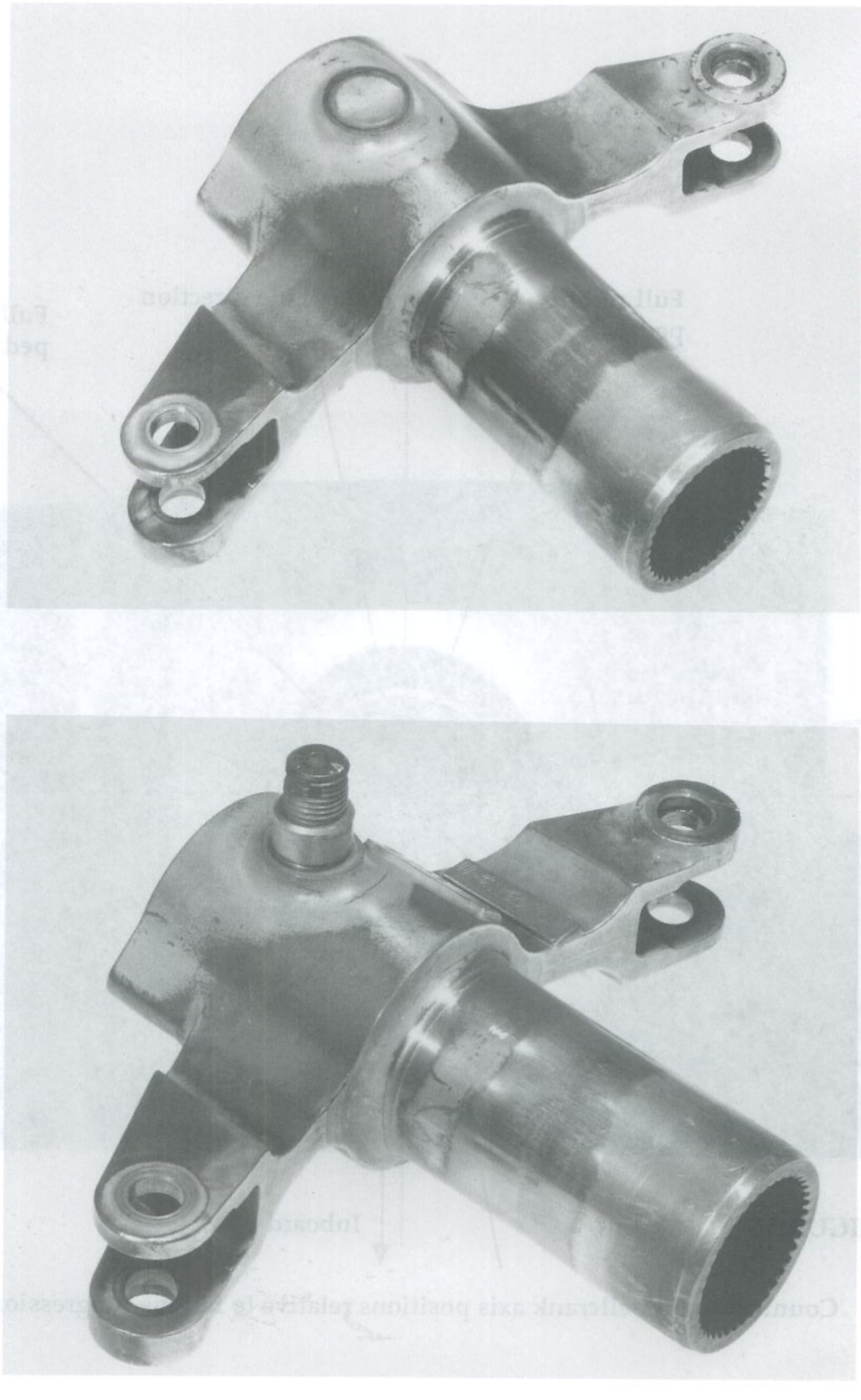

FIGURE 2 Views of crosshead showing failed and intact journals

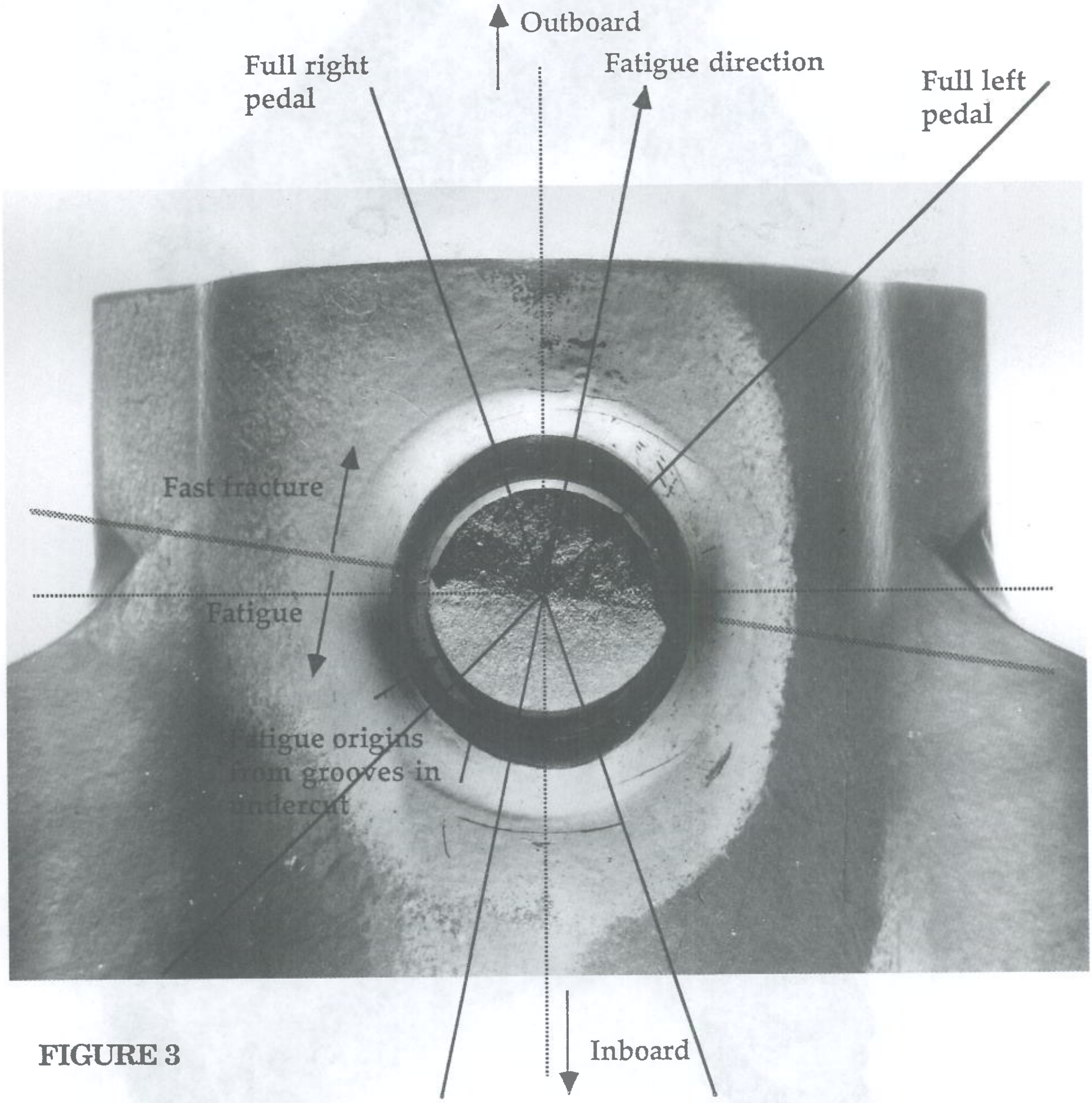

FIGURE 3

Counterweight bellcrank axis positions relative to fatigue progression