Enstrom F-28F Falcon, G-BXXW

AAIB Bulletin No: 6/2004	Ref: EW/C2003/08/03	Category: 2.3
Aircraft Type and Registration:	Enstrom F-28F Falcon, G-BXXW	
No & Type of Engines:	1 Lycoming HIO-360-F1AD piston engine	
Year of Manufacture:	1990	
Date & Time (UTC):	6 August 2003 at 1530 hrs	
Location:	10 miles south of Wellesbourne, Warwickshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 2
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Damage to main rotor gearbox, main and tail rotor drive train and tail boom	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	52 Years	
Commander's Flying Experience:	134 hours (of which 47 were on type)	
	Last 90 days - 8 hours	
	Last 28 days - 4 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The pilot of the helicopter was forced to carry out an autorotative landing due to the failure in flight of the Main Rotor Gear Box (MRGB) rear bearing brought about by inadequate lubrication. The reason for the reduced level of oil in the MRGB could not be ascertained. The impending failure of the bearing did produce metal chips and conductive debris sufficient to activate the chip detector warning in the cockpit. The cockpit warning, however, was not generated because of a defective crimp connector in the chip detector wiring.

History of flight

The pilot flew with his family to stay overnight with friends near Wells, Somerset. By prior arrangement he landed on a village cricket pitch, close to the house where they were staying and the helicopter remained there overnight. The following day he intended to return with his family to Sheffield, stopping on the way at Wellesbourne Mountford Airfield.

Prior to their departure the pilot conducted a normal pre-flight check on the helicopter which included a check of the main rotor gear box oil level. He described this check as requiring some dexterity and

being awkward to carry out, because of the position of the oil level sight glass and the need to use a torch. He stated the oil level appeared to be normal and that the floor of the gear box mounting was clear of any oil spillage or seepage. He also checked the engine oil, which required an additional pint of oil to restore the contents to the correct level. The rest of the pre-flight checks revealed no apparent problems.

The helicopter took off at approximately 1415 hrs and headed towards RAF Lyneham, maintaining an altitude of about 1,500 feet and an IAS of 85 mph. As it passed overhead Lyneham, heading towards Kemble, the pilot requested a radar service from RAF Brize Norton. This however was not available and he was instructed to remain clear of the Brize Norton Control Zone (CTR).

Approximately 10 nm to the south of Wellesbourne Mountford, as the pilot was about to contact the airfield, there was an increase in the level of vibration: the pilot felt a 'thump' and the helicopter yawed to the right. This was rapidly followed by a burning smell in the cockpit. The low rotor RPM warning horn then sounded and the pilot noticed that the rotor RPM needle indicated below the green arc and the engine RPM needle indicated above it. The pilot responded by fully lowering the collective control, applying full right yaw pedal and raising the nose of the helicopter to reduce the speed to the recommended autorotative speed of 65 mph. He also closed the throttle slightly, although it was never fully closed. As the low rotor RPM warning horn ceased the pilot was able to make a 'MAYDAY' transmission informing Wellesbourne of the helicopter's position and the engine failure. Wellesbourne replied, but the pilot did not recall the content of the call.

By now the helicopter was 1,000 feet overhead a rough grass field with steeply sloping ground to the left. The pilot manoeuvred the helicopter to the right through 180° to remain over the field and to turn into wind. He maintained full down collective control and full right yaw pedal throughout. At approximately 50 feet agl he flared the helicopter, raised the collective control to cushion the touchdown and centralised the yaw pedals. The helicopter touched down gently with no forward speed. After touchdown the pilot made a radio call to Wellesbourne informing them that the helicopter had landed safety.

The pilot's wife and child disembarked from the helicopter whilst the pilot completed the shutdown checks. As they exited they saw a small fire burning under the gearbox fairing. The pilot was made aware of this and quickly pulled the fuel cut off lever. He then successfully extinguished the fire using the aircraft's fire extinguisher. With the cowling open it could be seen that the upper pulley of gearbox drive belt was glowing red-hot and the belt was continuing to smoulder. The fire services were called and arrived about ten minutes later. By this time the pulley had begun to cool, but a fire tender remained in attendance until there was no further risk of fire. The pilot has since reported that at about this time he could see oil coming from the bottom of the helicopter.

Engineering investigation

Damage to the helicopter included twisting and bending of the tail rotor drive shaft due to severe shaft 'whirling'. The shaft had impacted and caused serious damage to the top of the tail boom. It had also distorted the laminates of the flexible (Thomas) coupling at the tail rotor gearbox input before shearing the input shear pin. The input drive shaft at the Main Rotor Gear Box, (MRGB) had fractured and its belt drive pulley, now at an unusual angle, had moved 1-2" rearwards. This had caused major damage to a Thomas coupling at the forward end of the tail rotor drive shaft. Although the nut securing the belt drive pulley was still wire-locked, it had lost its torque load. The drive belt between the engine and MRGB pulleys was displaced rearwards and damaged on its aft edge, and the belt tensioner was damaged. There had also been a small fire in the area, apparently fed by MRGB oil. Subsequently, only about ¼ pint of blackened oil could be drained from the MRGB. The MRGB chip detector was blackened with an oily sludge, but no chips were apparent. At the rear bearing, where the shaft fracture had occurred, the bolts on the bearing cover had lost torque and the gasket showed evidence of a small oil leak. The lower skins in the area were covered in a film of oil. The bearing, a self-aligning double row barrel roller bearing, had broken up and, with some of the rollers jammed sideways, the bearing had seized. This had caused the shaft, turning in the inner race, to

generate considerable heat. It was also apparent that the fractured shaft had been very hot, possibly causing a loss of torque.

The MRGB was stripped and examined, and a specialist report was prepared. Chips were found on the magnetic probe of the gearbox rotor speed sensor and the rear bearing had been extensively worn resulting in a break-up of the bearing cage due to fatigue. Temperatures in excess of 650º C had occurred at the inner race. The similar, forward bearing however, was undamaged. During the examination it was noted that lubrication of the rear bearing was more restricted than for the forward bearing. Although the gearbox is splash lubricated, the rear bearing is remote from the splash zone and is lubricated instead by the unpressurised flow of oil through a small oilway in the gearbox casing. There was, however, no evidence that this oilway had been restricted.

The report concluded that wear had taken place between the rear bank of barrel rollers in the aft bearing due to a breakdown in lubrication. The wear also caused the bearing cage to fail, leading to seizure of the bearing. During this process sufficient heat was generated to locally soften the case hardening on the pinion shaft, lowering its resistance to fatigue. Slackness in the shaft at this time probably resulted in multiple fatigue cracks in the shaft, finally causing the softened and cracked shaft to fracture in torsion.

Aircraft history

The helicopter, serial number 771, had its last annual inspection on 12 November 2002, at which time it had accumulated 415.2 flying hours. On 20 March 2003, at 428.3 hours, new main rotor blades were fitted. On 15 May 2003, at 435.7 hours, a 50 hour inspection was completed, and the requirements of Enstrom Service Setter SL 152 (belt adjustment and idler pulley alignment check), amongst other work, was carried out. By the time of the accident about 10 hours additional time (total time 445.7 hours) had been accumulated. The gearbox, which had been fitted since new, has an overhaul life of 1,200 hours.

The aircraft, built in 1990, had been imported from Japan. First registered in the UK as G-SCOX in 1998 it was re-registered to the current owners as G-BXXW in 2000.

MRGB chip detector history

The AAIB was advised by the Enstrom agent that the helicopter had a history of MRGB chip detector warning light indications, and that after the accident the chip detector had been found to be wired using an 'automotive type' crimp which was fitted over the wire insulation. The wiring had been dismantled by the agent and the parts made available to AAIB. The pilot advised that he had fitted the crimp because the chip detector wiring had broken while he was checking the chip detector. He had obtained the parts from a local electrical spares outlet, and bared the conductor and bent over the wires before crimping them. He had also obtained a new chip detector and supplied this to the agent for fitting when the new rotor blades were fitted. He assumed they would check the wiring when the new chip detector was installed. There was however, at that time, no requirement to test the wiring. Only a visual check of the chip detector was required and a check of the associated warning light functionality using the cockpit 'press to test' facility. After this accident Enstrom introduced a Maintenance Manual change for F-28 & 280FX series helicopters, to include a continuity check of chip detector wiring.

Analysis

The investigation showed that the rear bearing of the MRGB seized as a result of inadequate lubrication. The blackened condition of the limited amount of oil recovered supported this conclusion. With reduced lubrication, the rear bearing will be more adversely affected than the forward bearing due to its more restricted lubrication. Seizure of the bearing resulted in fracture of the pinion shaft, loss of tail rotor drive and damage to the boom and transmission.

The reason for the reduction of lubrication appears to be a reduced level of oil in the MRGB. It was difficult to ascertain when this occurred. The only possible pre-existing oil leak was that found at the gasket of the rear bearing cover. This, however, would have been a weep or drip rather than a rapid leak. The subsequent fracture of the pinion shaft would have allowed a large oil leak to occur, and the pilot reported seeing such a leak after landing. The quantity of oil involved in this leak cannot be determined, but it is considered to have occurred after the bearing seizure. As stated by the pilot, it is quite difficult to observe the oil level using the sight glass, even using a torch. If the oil level were very low, it is possible that a meniscus of oil might be trapped in the sight glass, giving an appearance of an almost normal oil level.

The possibility that the oil level was not low must also be considered. In such a case even quite contaminated oil would continue to cool and lubricate, and although the lubrication of the rear bearing is more restricted, it has been adequate in day to day operations of the type. Therefore some other factor would be required to explain the bearing distress, such as a pre-existing bearing defect or a blockage in its lubrication path. Both these possibilities have been considered and no evidence has been found for either, although the possibility of a transient blockage cannot be entirely dismissed.

It is not possible, therefore, on the basis of all the evidence, including the pilot's report, to determine conclusively the reason for the reduced lubrication. The impending bearing failure however, did generate chips and conductive debris, and the chip detector was sufficiently contaminated to provide electrical continuity. Subsequently, no cockpit warning was generated because of the defective crimp in the chip detector wiring.