ACCIDENT

Aircraft Type and Registration:	Rotorway Executive 162F, G-JONG
No & Type of Engines:	1 Rotorway RI 162F piston engine
Year of Manufacture:	2004
Date & Time (UTC):	14 June 2009 at 1845 hrs
Location:	1.5 miles east of Bullington Cross on A303, Hampshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Tail boom severed, damage to main rotors, landing gear and body panels
Commander's Licence:	Private Pilot's Licence (Helicopters)
Commander's Age:	52 years
Commander's Flying Experience:	1,471 hours (of which 43 were on type) Last 90 days - 19 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, an AAIB strip examination of the engine and subsequent metallurgical examination of engine components

Synopsis

The helicopter was in flight when the engine stopped suddenly and without any warning. During the subsequent forced landing onto soft ground, the helicopter pitched forward, the main rotor blades struck the ground, and it rolled on to its right side.

It was established that the cast alumimium gear which drives the camshaft within the engine was of poor manufactured quality, resulting in the failure of several gear teeth. This led to the de-synchronisation of the camshaft with the crankshaft, allowing the connecting rods to hit the camshaft, breaking it into four sections.

History of the flight

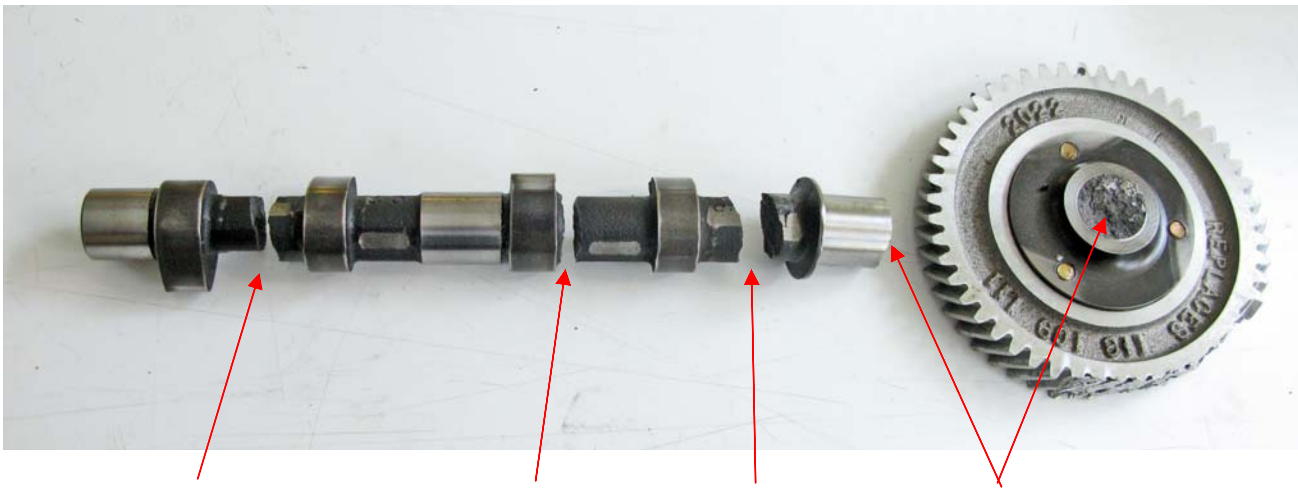
After completing a daily inspection 'A' check, during which nothing abnormal was found, the pilot made an uneventful short flight from his home base at Barton Ashes to Popham, where the helicopter was refuelled to full tanks. He subsequently conducted an uneventful local flight before landing back at Popham, where again the helicopter was shut down. At approximately 1930 hrs, after carrying out a normal pre-flight inspection and an uneventful engine start, run-up, and hover checks, the aircraft departed Popham for the return flight to Barton Ashes.

Whilst in the cruise at an altitude of 1,800 ft, 5 nm west of Popham, with the engine running apparently well and displaying normal indications, it stopped suddenly and without warning. The pilot immediately entered autorotation, reduced airspeed to 65 mph, and selected a field for landing which had no standing crop. A landing flare was initiated approximately 30 ft above the ground at an airspeed by this stage reduced to around 30 mph and a straight and level run-on touch-down was executed. After sliding straight for approximately 2-3 skid lengths, the helicopter pitched forward and the main rotor struck the surface, causing the helicopter to skew rapidly to the left and roll onto its right side.

The pilot was restrained by his seat harness throughout the impact sequence. After releasing it, he fell into the right side of cockpit, the aircraft having come to rest on its right side. He was, however, able to extricate himself and, after retrieving his spectacles, climb out through the left side cockpit door, turning off the switches on the overhead panel as he did so. There was no fire, although fuel was leaking from the tank filler caps.

Engine examination

Preliminary examination of the engine by Rotorway's UK agent, established that it would not turn freely and that, within the little movement of the crankshaft available, no corresponding movement of the valve gear could be detected. Subsequently, a bulk disassembly of the engine under the AAIB supervision established that the aluminium camshaft drive gear teeth were stripped over a segment comprising almost a quarter of its circumference. The camshaft had fractured at three separate locations along its length internal to the crankcase, and also at a fourth location, externally, in the accessory case, immediately behind the drive gear attachment flange. Figure 1 shows the fractured camshaft and partially stripped gear, with the camshaft fractures identified and numbered one to four for reference.



4 3 2 1

Figure 1

Camshaft fractures and gear failure

Fragments of broken gear teeth and shards of ground-up tooth material were scattered within the accessory case. The rest of the engine was undamaged and in good condition, and no evidence was found of any abnormality or failure except for minor secondary damage directly attributable to the camshaft fracture. Clean oil was present in liberal quantities internally throughout the engine, all bearings were in good condition, all valves and cam followers operated freely and the (steel) camshaft drive pinion was in good condition.

The camshaft, drive gear, and tooth fragments were taken to a specialist metallurgical laboratory where the fracture faces were subject to detailed visual and scanning electron microscopy. No evidence of fatigue cracking or any other mode of progressive failure was found either on the camshaft or the failed gear.[1] The aluminium gear was evidently a cast component that had been turned to final dimensions and then machined to produce the required tooth profiles. The quality of the casting was found to be exceptionally poor, exhibiting a very porous and open structure. Extensive voids and flaking were visible in several areas on the surface of the gear, both on the face of the gear rim and on the flanks and roots of some of the teeth.

Extensive porosity was also evident in the microstructure of two of the tooth fractures, indicating that these teeth were extremely weak and vulnerable to fracture. Also the drive flanks exhibited gross voiding and flaking, Figures 2 and 3 respectively. Despite these material defects, no evidence was found in the gear generally, of fatigue cracking or any other form of progressive failure, nor specifically in the tooth fractures that exhibited porosity and surface void defects. In summary, metallurgical examination of the camshaft and gear failed to identify any evidence of pre-existing or progressive fracture, but the poor quality of the casting would have weakened the teeth and pre-disposed them to fracture.

Upon completion of the metallurgical examination, the fractured camshaft was physically restored with adhesive permitting it to be relocated in its bearings in one half of the crankcase. This was in order to facilitate correlation of witness marks on the camshaft with the physical form and proximity of the crankshaft and connecting rods. This work was supplemented by 3-D CAD modelling of the crankshaft, camshaft, and connecting rods, which permitted an analysis of these marks, in terms of the rotational synchronisation between the camshaft and crankshaft/connecting rods, and the positions of gear tooth damage. The objective of this was to sequence the various camshaft and gear tooth failures.

Failure sequence analysis

Numerous bruise marks were evident on the camshaft at various locations along its length, consistent with it being struck by the connecting rods. The following was noted:

- Bruises were present that bridged fracture Nos 2 and 4, ie, these bruises were produced coincident with, or before, the associated fracture became physically separated.

- Bruises at positions on the camshaft beyond fracture No 2 (relative to the drive gear end) were at positions displaced slightly from their correct positions for an intact camshaft, and

Footnote

[1] Fatigue cracking in cast iron materials of the kind used for the camshaft does not always leave visable evidence, and the possibility that a fatigue crack at one or other of the camshaft fracture sites had precipitated the chain of failure could not be positively excluded on the metallurgical evidence alone.

Figure 2

Tooth fracture face, displaying extensive voiding (evidenced as bead-like features) where metal has solidified upon encountering a void

Figure 3

Flank of fractured tooth (separated piece re-positioned, showing porosity at the surface

were therefore produced after fracture No 2 had separated.

- One of the bruises that bridged fracture No 2 also produced significant smearing of the fracture edges, consistent with the strike that produced it having caused this fracture. The other bruises at this location, therefore, were produced prior to fracture.

The evidence above indicated clearly that fracture Nos 3 and 4 were secondary failures, occurring after fracture No 2, and that fracture No 2, at least, was caused directly by a connecting rod strike. Since a connecting rod strike will not occur whilst the camshaft and crankshaft are correctly synchronised, it follows that fracture Nos 2, 3 and 4 were all produced after synchronisation was lost, and that the primary failure was either the fracture at position No 1, or drive gear tooth failure(s).

Analysis of the various connecting rod strikes on and around fracture No 2 showed that several strikes at this location, including strikes on opposing sides of the camshaft, corresponded with positions of the gear where teeth were intact, ie, at positions where the gears

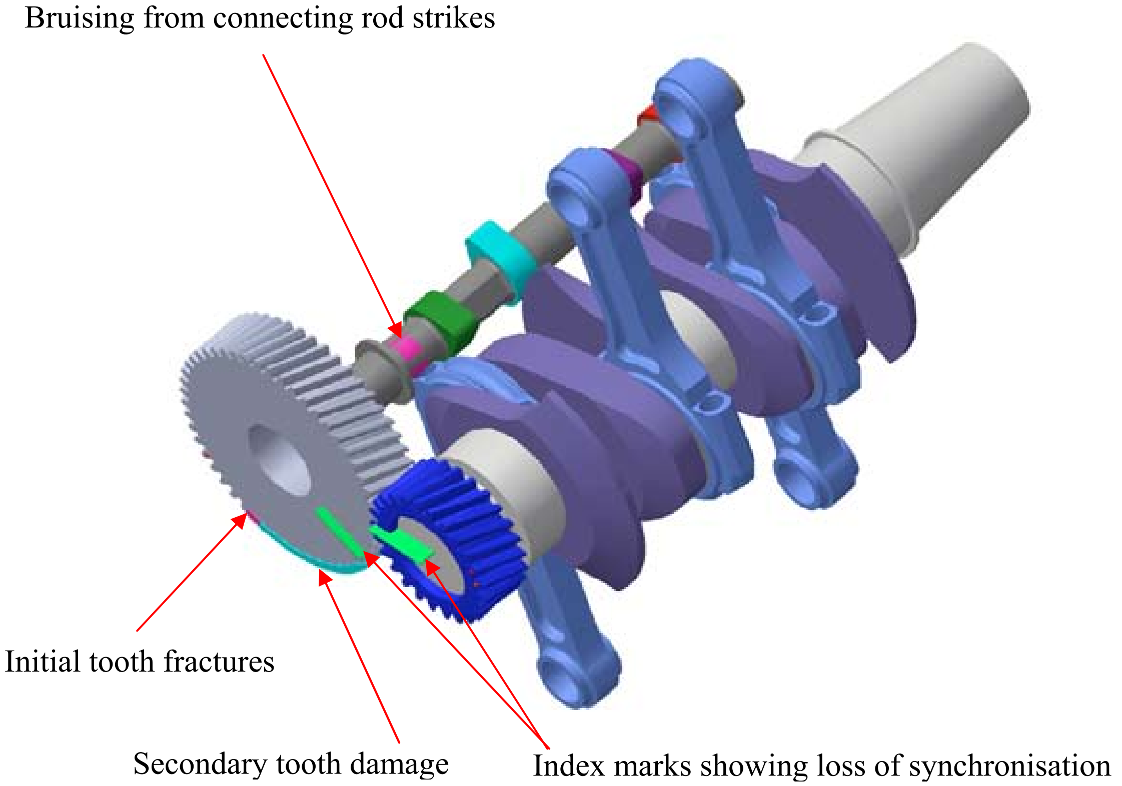


Figure 4

Typical example of connecting rod strike on the camshaft and associated loss of synchronisation

were in a viable state of mesh, albeit not synchronised. Figure 4 shows an example of once such contact. Given that a mechanical drive must have been present in the time interval between these strikes, in order for the cam lobes to have been turned against the reaction load imposed by the valve springs, it follows that all connecting rod strikes occurred before fracture No 1 occurred. Therefore, the initiating event must have been a gear tooth fracture.

As no evidence of fatigue, or any other mode of progressive fracture, was found at the initial tooth failure sites, it is considered most likely that the tooth failed spontaneously under normal in-service loading as result of an inherent weakness caused by material defects in the casting.

Safety action

Premature failures of the camshaft drive gear have occurred previously and are the subject of Mandatory Compliance Bulletin M-14, issued by the helicopter kit manufacturer on 2 January 1997, which states:

> *'In a few instances the cam gear in the engine has had teeth break off, causing engine failure. This gear, made of aluminium, has failed for various reasons: improper valve adjustments, sticky valves or excessive backlash between the cam gear and crankshaft gear.'*

The remedial action specified in this Bulletin was to reduce the service life of the gear from 500 hrs to 250 hrs. In this case, the gear failed at less than

100 hrs, apparently as a result of a manufacturing defect.

In addition, the manufacturer issued a Service Letter on 16 June 2005 which stated, in part, the following:

> *'Starting with engine number 6353, built in 1999, both of the timing gears have been made of steel. At approximately the same time, the steel gears were supplied for parts requests for compliance to the bulletins. With the experience of service, Rotorway International has raised the replacement time of the steel timing gears from 250 hours to 400 hours. Rotorway will continue to evaluate the serviceability of the timing gears for further increases in service life.'*

The UK agent for the kit manufacturer has advised that, since steel timing gears became available in 1999, there are very few Rotorway Exec, Exec 90 and Exec 162F helicopters flying with the aluminium gear fitted and that, as the remaining items achieve their 250 hour life, they will all be removed from service.