Piper PA-38-112 Tomahawk, G-BGZW

AAIB Bulletin No: 9/97 Ref: EW/G96/08/29Category: 1.3

Aircraft Type and Registration:	Piper PA-38-112 Tomahawk, G-BGZW
No & Type of Engines:	1 Lycoming O-235-L2C piston engine
Year of Manufacture:	1979
Date & Time (UTC):	26 August 1996 at 0846 hrs
Location:	3 nm Southwest of Nantwich Farm, Cheshire
Type of Flight:	Private
Persons on Board:	Crew - 1 - Passengers - 1
Injuries:	Crew - None - Passengers - None
Nature of Damage:	Minor damage to right wing
Commander's Licence:	Private Pilot's Licence
Commander's Age:	25 years
Commander's Flying Experience:	62 hours (all on type) Last 90 days - Nil Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot and AAIB inquiries and strip examination of available engine parts

Flight History

The planned flight was from Welshpool to Manchester. The weatherwas good, with the 2,000 feet wind from 190°M at 8 kt,in-flight visibility of 15 km and broken cloud at 2,000 feet.

The flight was uneventful until, when nearing Manchester at analtitude of 2,000 feet, the sound of the engine changed dramaticallyand it lost power. The pilot trimmed to the glide speed, checkedfor the cause of the problem and attempted two engine restarts,without success. He then made a Mayday RT call to ManchesterApproach, which was acknowledged, and selected an area for a forcedlanding. This was a grass-covered field adjacent to farm buildings. The approach was over trees and the initial touchdown, with fullflap lowered and the stall warning horn just beginning to sound,was one third of the way into the field, followed by a singlebounce. During the subsequent ground roll the pilot kept theaircraft in a nose-high attitude for as long as possible to protectthe

nose landing gear from damage. As the aircraft slowed, thepilot steered it to the right to avoid a dense hedge and it passedthrough a single strand wire fence before coming to rest.

The pilot and passenger, each of whom was wearing a four-pointharness, were unhurt. The pilot radioed this information to ManchesterApproach, and both occupants evacuated the aircraft without difficulty. Damage was confined to deformation of the right wing leadingedge near the tip. The pilot, who had commenced training forhis Private Pilot's Licence only some 8 months before theaccident and had relatively low flying experience, attributedthe success of the forced landing to the high standard of trainingthat he had received.

A partial engine strip by the aircraft operator showed that therehad been a failure of the engine accessory drive train.

Engine Description

The accessory drive geartrain is driven by an accessory gear mountedon the aft end of the crankshaft (Fig 1). The gear is locatedon the crankshaft by an integral flange that registers in a counterboredrecess in the crankshaft end and is retained by a 5/16 inchdiameter bolt screwed into a threaded hole in the crankshaft. Bolt retention is by a lock washer with an outer tab locatingin a slot in the gearwheel and an inner tab bent against the bolthead after the bolt has been torque-tightened. A shouldered dowelfitted into the crankshaft has a 1/4 inchdiameter section that protrudes from the seating face and locatesin a hole in the gear flange. A similar accessory drive geardesign is used on all Lycoming reciprocating engines.

The engine manufacturer has stated that the design intention isfor the rotational loads on the accessory gear to be reacted bytorsional friction loads between the gear and the crankshaft generatedby the clamping effect of the retaining bolt. The dowel is providedto ensure the correct rotational orientation of the gear on thecrankshaft, and is not intended to transmit torque. The bolthas a right-hand thread and the crankshaft rotates clockwise asviewed from the rear and thus, in the event of a loss of torsionalrestraint between the gear and the crankshaft, geartrain loadswill tend to unscrew the bolt. The manufacturer considered thatloosening of the gear on the crankshaft had nearly always beencaused by a torsional overload on the gear or by inadequate clampingloads applied by the bolt.

Procedures for installing the crankshaft gear were recommendedin Avco Lycoming Service Instruction (SI) No 1179D, issuedon 29673. It noted that instances had been foundof damage in the area of the crankshaft gear and attributed theseto improper assembly technique or reuse of worn or damaged partsduring overhaul. It noted that the eventual failure of any ofthese parts would result in complete engine stoppage. The proceduresincluded checks of the crankshaft recess, the crankshaft bolthole threads, the dowel and the gear, and reassembly with a newbolt and locking washer. They also specified modification ofthe gear to allow inspection after installation by cutting three0.25 inch radius scallops in the rim of the flange. Compliancewas recommended at overhaul.

The SI was superseded by Textron Lycoming Service Bulletin (SB) No 475'Crankshaft Gear Modification and Assembly Procedures', originallyissued on 311086. The SB expanded the proceduresand required machining of the gear to enlarge the rim scallopsto 0.75 inch radius and to counterbore the central part ofthe mounting face. Compliance was required during overhaul, aftera propeller strike, or whenever crankshaft gear removal was required. It was categorised by the engine manufacturer as mandatory, butwas not mandated by the FAA or the CAA. A supplement (No 1)requiring assembly with the bolt threads clean and dry was issuedon 24588. The SB was re-

issued as No 475A on16790, with the addition of a caution against thereworking of crankshaft threads except by Lycoming.

An FAA Airworthiness Directive, AD 911422, wasissued on 19891 making SB 475A mandatory at eachoverhaul, after a propeller strike or sudden stoppage or whenevergeartrain repair was required. Compliance with the FAA AD byUK operators was mandated by CAA Airworthiness Notice No 36. The SB was reissued, as Textron Lycoming Mandatory Service BulletinNo 475B, on 23493, with additional cautions andexpanded text related to ensuring correct assembly. The contentsof this SB were incorporated in a revision of the Overhaul Manualissued in June 1993.

Aircraft Examination

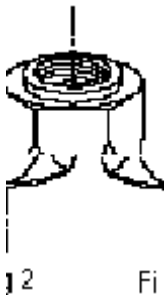
The aircraft operator made an Occurrence Report of the accidentto the CAA but did not report it to the AAIB. A partial enginestrip by the operator the day after the accident reportedly foundthat the accessory gear retaining bolt had partially unscrewedby several turns and the dowel had fractured. The bolt lockingwasher was found in situ, with the bolt lock tang bent at an approximately60° angle and the centre hole grossly elongated. The operatorlost the bolt, the locking washer and the fractured-off part ofthe dowel before AAIB obtained the engine for strip examination.

AAIB examination of the available parts showed that the dowelhad fractured flush with the gear/crankshaft mating surface.Clear signs of bending fatigue cracking over approximately 75%of the dowel fracture surface were found, with the remaining partof the fracture exhibiting fast fracture features. The positionof the crack origin was consistent with the fatigue having beencaused by the effects of torque transmission from the crankshaftto the geartrain via the dowel because of inadequate gearclamping.

The gear appeared to be to the SI 1179D standard, with small0.25 inch radius scallops and no mounting face counterbore. The mating faces of the gear and the crankshaft were generallycoated with an oil varnish-like deposit, possibly suggesting inadequateclamping. Light fretting type polishing of the gear mating facenear its outer diameter and heavy wear of the outer rim of thegear flange from contact with the crankshaft counterbore registerindicated that there had been significant relative movement betweenthe gear and the crankshaft for an extended period.

In the course of the engine strip it was noted that all eightnuts securing the connecting rod big end bolts had been installedincorrectly, with the raised lip on one end of the nut, ratherthan the flat face at

the other end, bearing against the big end cap surface. It was reported to be possible for the lip to yield in service if the nut were installed upside down, resulting in loss of bolt preload. Avco Lycoming Service Instruction (SI) No 1106D, issued 9-672, includes a Caution: "The connecting rod bolt cannot be tightened correctly if the nut is installed upside down. The raised edge, or lip on the end face of the nut must be on the free end of the bolt; the flat face must be in contact with the rod. See figure. . . . . " (as Fig 2). The SI also notes that the connecting rod bolt will loosen if under-torqued.



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Engine History

Maintenance records indicated that the aircraft and engine hadbeen maintained in accordance with the CAA Light Aircraft MaintenanceSchedule CAA/LAMS/FW1978. They indicated that the engine (SerialNo L1642315) had been removed from another aircrafton 2586 as time expired. It had been overhauled and,in June 1988, released untested, according to a Log Book entry,although the Job Card Certificate of Release to Service was notsigned until 4690. Thus at the time of completionof the overhaul, the detailed accessory gear installation procedures,including the requirement for enlarged flange scallops, had beenclassified as mandatory by the engine manufacturer but not bythe FAA or the CAA.

The engine had been installed in GBGZW on 261092. At the time of the accident it had accumulated 2,667 hourssince overhaul. This had reportedly been the last occasion onwhich the accessory drivetrain had been disturbed. No evidencewas found to indicate that a propeller strike or accessory geartrainproblem had occurred since the overhaul.

Previous Cases

No similar previous cases were found listed on the CAA accidentand incident database and only one previous UK case was identified,to an RAF aircraft during take off. Information from the enginemanufacturer listed 40 known cases of accessory gear dowelfailure between 1974 and the time of the accident. Some of thesecases had been discovered during maintenance but at least 33 ofthem had occurred in flight and had been associated with looseningof the gear and consequent engine power loss, generally total. The manufacturer believed that there had been no cases affectingengines with the AD incorporated.

Service Bulletin Status

The CAA Light Aircraft Maintenance Schedule notes (Section 3,para 2.4) that "Modifications relating to the aircraft,engine, propellers and equipment recommended by the manufacturersmay be carried out at the discretion of the owner/operator unlessthe particular modification has been classified mandatory by theCAA in accordance with Airworthiness Notice No. 36." It was believed that this was intended to mean that the modificationmust be carried out if classified as mandatory by the CAA butwas otherwise optional, irrespective of the manufacturer's classification. While the engine manufacture recommended the measures of SB 475in 1973 and categorised as mandatory the similar measures of SB 475Ain 1986, there was no requirement for them to be incorporatedon UK registered aircraft until 1991 when an FAA AD was issued. There was therefore no airworthiness authority requirement forthe measures to have been incorporated on GBGZW at the timeof its accident.

Recommendations

The evidence indicated that the possibility of accessory gearloosening, with resultant engine stoppage, had come to the enginemanufacturer's attention many years before GBGZW's accident. This had led the manufacturer, over 25 years previously,to recommend measures aimed at preventing recurrence of the failureand, 10 years previously, to categorise them as mandatory. It is likely that the manufacturer, with a wide range of serviceexperience and research information available, would be in a muchbetter position than an aircraft owner/operator to judge the effectivenessof a modification in preventing a particular failure. However,the CAA specified that the incorporation of manufacturer recommendedor mandated measures should be at the discretion of owners/operators.

In the case of the accessory gear measures, there would seem littledoubt that they represented a substantial improvement and wouldimpose no major penalty on owners/operators. The damage to GBGZWwas fortunately minor, but forced landings do on occasion endcatastrophically. The following recommendation has therefore beenmade:

Recommendation 9736

It is recommended that the FAA and the CAA review their proceduresfor classifying airworthiness improvement measures published byaircraft or equipment manufacturers when they are recommendedor categorised as mandatory by the manufacturer. Considerationof the improvement measures should take account of the manufacturer'sknown service experience. It is proposed that the CAA shouldrequire that such measures are incorporated on UK registered aircraftor publish its reasons for leaving them as optional to assistowner/operators in exercising their discretion.

Similar AAIB Recommendations were made in 1994 (No 94-30, AAIBReport 6/94) and 1997 (No 97-6, AAIB Bulletin 3/97 and No 97-11,AAIB Bulletin 5/97).