ACCIDENT

Aircraft Type and Registration:	DH82A Tiger Moth, G-ADGT
No & Type of Engines:	1 De Havilland Gipsy Major 1F piston engine
Category:	1.3
Year of Manufacture:	1935
Date & Time (UTC):	14 September 2005 at 1120 hrs
Location:	Oxford Airfield, Oxfordshire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Partially collapsed undercarriage and damage to propeller
Commander's Licence:	Air Transport Pilot's License
Commander's Age:	66 years
Commander's Flying Experience:	20,050 hours (of which 500 were on type) Last 90 days - 116 hours Last 28 days - 49 hours
Information Source:	AAIB enquires and Aircraft Accident Report Form submitted by the pilot

Synopsis

Shortly after taking off the engine suffered a reduction in power, as a result of a sticking exhaust valve, that required the pilot to undertake a forced landing within the airfield perimeter. The aircraft landed heavily, which resulted in the collapse of the left main landing gear and the propeller blades striking the ground.

History of the flight

On the day of the accident the wind was reported as 230º/10 to 15 kt and the pilot, who was a flying instructor, planned to carry out a series of flights, with a student, covering Exercises 1 to 6 and 9 of the JAR-PPL syllabus. Following two uneventful flights of 30 minutes duration each, the pilot then experienced difficulty in starting the hot engine for the third detail of the day. In accordance with the operators normal procedure, the magnetos were switched off and the engine was turned backwards through 12 revolutions in order to purge the cylinders through the exhaust ports. The engine started and power checks were carried out prior to the aircraft taxing to the threshold of Runway 27, where it held for a short period whilst awaiting clearance to take off. The engine performance and aircraft's initial acceleration were normal and once airborne the engine

speed was reduced from 2,150 rpm to 2,050 rpm for a 'standard' climb. At a height of about 150 ft, the engine speed decreased by about 450 rpm and it started to run roughly; the engine did not respond to the throttle being moved to the full power position.

With a rough running engine and insufficient power to climb the pilot was left with the option of either landing ahead or turning approximately 90º to the left to land in the airfield helicopter landing area. The first option entailed negotiating a hedge, a dual carriageway and a footpath, whereas the second option required the aircraft to turn sufficiently to the left to miss some houses and aerials sited on the airfield. The pilot selected the second option and successfully remained clear of the obstacles, before touching down heavily on the left wheel with the aircraft banked to the left. The aircraft was then seen to bounce several times before the left Main Landing Gear (MLG) collapsed, causing the propeller to strike the ground. The aircraft ground looped 180º to the left before it came to rest in the helicopter landing area.

Damage to aircraft

The left MLG lower casting and locating bolt had failed during the landing, which allowed the left wing to drop and the propeller blades to strike the ground. The outer portion of both wooden blades broke off approximately four inches in from the blade tips. The repair organisation, who recovered the aircraft, considered that the casting and locating bolt had failed due to a high side load imparted into the left MLG as it made contact with the relatively soft turf.

Engine description

The DH Gipsy Major engine is an air cooled in-line inverted four cylinder carburetted piston engine. The original Gipsy Major 1 series engines were equipped with aluminium bronze[1] alloy cast cylinder heads and had a compression ratio of 5.25:1. Later models were equipped with bronze cylinder heads, with a higher compression ratio of 6:1 and were fitted with 'Stellite' valve seats to resist corrosion resulting from operating on leaded fuels. Later Marks of the Gipsy Major were fitted with aluminium cylinder heads and had a compression ratio of 5.25:1 for operating on unleaded fuels and a compression ration of 6:1 for use on the higher octane leaded fuels.

Engineering investigation

On the first engine ground run, undertaken by the company maintenance organisation following the accident, the engine started normally and the power checks were found to be satisfactory with no excessive magneto drop. However, when the engine was hand swung during the next engine start it was evident that there was no compression in one of the cylinders. It was suspected that a valve had stuck open and, therefore, the cylinder heads were removed and sent to a specialist overhaul facility who established that a heavy build up of carbonised deposits had caused the No 2 and No 3 exhaust valves to stick in the valve guides. It has been suggested that the sticking valves was probably a result of operating engines, fitted with bronze cylinder heads, on Avgas 100LL.

Research

In the past, there were many different grades of aviation fuel in general use ranging from 80/87 octane to 115/145 octane, and it is widely assumed that the Gipsy engine series were initially designed to run on an 80/87 octane fuel. However, whilst 80/87 grade appeared to have been used for much of its service life, the Gipsy Major 1

Footnote

[1] Bronze: Alloys of copper and tin and/or aluminium.

series handbook states that when the engine first entered service it was designed to run on '*good grade automobile fuel'*, or non-leaded grade 73 fuel. With decreasing demand, the different grades were rationalised down to one, 100/130, which was a leaded fuel designated as Avgas 100; however, an additional grade was subsequently introduced for engines that were designed for operating on fuels with a lower lead content. This grade was designated Avgas 100LL, where LL stands for low lead. Avgas 100 is only available in a few locations around the world and, for practical purposes, is now considered to be obsolete.

It is known that since, at least, the early 1950s grade 80/87 and 100LL have had the same calorific value and nominally burn at the same temperature. Both fuels now contain Tetra Ethyl Lead (TEL), which is used to increase the performance of the fuel, particularly when operating in high compression or turbo/supercharged engines. The difference between these fuels is that grade 80/87 has a lead content of 0.14 g Pb/l, which corresponds to a mix of 0.6 ml TEL/Imperial gallon, whereas 100LL has a lead content of 0.56 g Pb/l, or 2.4 ml TEL/Imperial gallon. This lead content is within the maximum limit of 4 ml TEL/Imperial gallon specified in the Gipsy Major engine operating handbook. However, engine oils have a limited capacity to dissolve lead and its by-products and there is a risk that, once the oil is 'lead saturated', solid deposits form which can, for example, obstruct oil-ways. Also, TEL degrades within the combustion process to form lead oxide, and this can remain as a solid at temperatures up to 1,000ºC. In order to prevent the formation of such solid material, ethylene dibromide is added to the fuel which reacts with lead oxide to form lead bromide. This is a gas at 200ºC to 250ºC. However, the chemical process to convert lead oxide to lead bromide requires a reasonably high combustion temperature which, if not achieved, will allow lead oxide to form on spark plugs and valve guides, a condition commonly referred to as 'lead fouling'. This fouling can occur in engines that have been subjected to long, low power descents, or have taxied for some distance and where, consequently, the cylinder temperatures are relatively low.

Originally Gipsy Major engines were fitted with cylinder heads made from an aluminium bronze alloy[1]; however later Marks were fitted with aluminium alloy cylinder heads. One disadvantage of the bronze head is that lead reacts with the copper in the alloy, and may cause considerable corrosion, particularly around the exhaust port. This reaction will occur with 80/87 and 100LL grade fuels, which both contain TEL. Whilst this reaction will ultimately result in a loss of performance, it will not normally cause valves to stick in their guides. Another disadvantage is that, in comparison with the aluminium alloy cylinder heads, bronze heads conduct heat less well; indeed for a number of flight conditions, the Cylinder Head Temperate (CHT) operational limits quoted in the Gipsy Major (1 series) handbook, are 40ºC higher for the bronze head in comparison with the aluminium alloy head. Incorrect setting of the carburettor, leaks in the induction system and deterioration of the engine cooling baffles could all cause the engine to run excessively hot, with the risk of carbonising oil on the valve stems. The maintenance manual for the engine states that the inlet and exhaust valve stem to guide clearance should be between '*0.003 and 0.004¾*' inch; however the experience of an engine overhaul organisation is that exhaust valve guides that have been reamed out to give a minimum of 0.0045 inch clearance between the guide and valve stem are less likely to stick than those with lower clearances. The engine fitted to the accident aircraft had operated for approximately 154 hours since being overhauled, when the valve stem to guide clearance was measured at '*0.004 3/10*' inch.

Whilst the cylinder heads on the Gipsy Major engine have a stud to which a cylinder head temperature transducer could be attached, very few aircraft, including G-ADGT, have this modification fitted and therefore a pilot has no way of determining whether the engine is running hot or cold. Instead, an assessment of cylinder compressions during the starting sequence, and subtle changes in engine performance, are generally used to give some warning of an emerging problem.

Discussion

At 150 ft, with a rough running engine and insufficient power to climb, the pilot's options were somewhat limited and the decision to attempt a landing in the helicopter landing area with an 8/13 kt cross wind was probably the best option available. It is likely that it was the combination of the drift from the crosswind and a touchdown made on the left wheel that resulted in the left MLG lower casting and locating bolt failing when the wheel touched the ground.

The Gipsy Major engine was not designed to be run on modern fuels and, in comparison to modern aircraft engines, requires more careful handling. Consequently, if an engine is not maintained or handled appropriately, then the cylinder heads could either reach temperatures sufficient to cause the oil on the exhaust valve stems to carbonise, or run at temperatures low enough to precipitate 'lead fouling', thereby increasing the risk, in both cases, of a reduction in the clearance between the valve stem and guide with the possibility of the valves sticking. Operation of the engine with the cylinder head temperatures in an appropriate range, correct setting of the carburettor, regular oil changes, ensuring that the induction system and cooling baffles remain in a good condition and opening the exhaust valve guides out to give a minimum of 0.0045 inch valve stem-to-guide clearance, are all measures that may help to reduce the occurrence of sticking exhaust valves.

ACCIDENT

Aircraft Type and Registration:	DH82A Tiger Moth, G-TIGA
No & Type of Engines:	1 De Havilland Gipsy Major I piston engine
Category:	1.3
Year of Manufacture:	1955
Date & Time (UTC):	17 August 2005 at 1610 hrs
Location:	Nottingham Airport, Nottinghamshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Undercarriage strut and underside of starboard wing damaged
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	72 years
Commander's Flying Experience:	5,224 hours (of which 1,650 were on type) Last 90 days - 8 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was practising visual circuits at Nottingham Airport. Runway 21 was in use, and the pilot was using the central grass portion of the airfield, which was bounded by two runways and a taxiway, for takeoff and landing. This area was specially prepared for use by aircraft such as the Tiger Moth, and the pilot had already completed one 'touch and go' landing on it during the accident flight. On the second approach, the aircraft landed normally but, as power was applied, the aircraft drifted to the right to the extent that it struck a runway marker board on the edge of the grass area. The aircraft structure limited forward visibility, consequently the pilot was initially looking to the left. As the tail was raised during the 'touch and go' he transferred his vision to the right, and it was only at this stage that he became aware of the proximity of the marker board shortly before it struck the lower right mainplane. The pilot immediately closed the throttle and landed on a grass area straight ahead, before taxiing back to the aircraft hangar and shutting down. The weather was good at the time, with a southerly surface wind which the pilot considered caused the aircraft to drift to the right.