ACCIDENT

Aircraft Type and Registration:	DA40D, G-CCLB
No & Type of Engines:	1 Thielert TAE 125-01 piston engine
Year of Manufacture:	2004
Date & Time (UTC):	20 October 2005 at 1430 hrs
Location:	Rochester Airport, Kent
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Nose gear, propeller and engine shock loaded
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	6,692 hours (of which 420 were on type) Last 90 days - 125 hours Last 28 days - 31 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft, which was operated by a flight training school based at a grass airfield, was being manoeuvred into wind prior to pre-takeoff power checks when the nose landing gear wheel separated from the nose leg. The engineering examination revealed that a failure had occurred in the nose wheel swivel/castoring pivot by a fatigue cracking mechanism and that the initiation of the cracks was due to the pivot material being below the minimum specified strength. This resulted from a failure in the manufacturing process to heat treat the pivot material correctly, an error which had not been identified by post-manufacturing quality checks. The aircraft operator found cracks in a similar area on another of their aircraft of the same type and of similar age and usage. The aircraft manufacturer has issued a Mandatory Service Bulletin, which the Austrian Civil Aviation Authority has made mandatory by an Airworthiness Directive, detailing inspections for cracking of the nose wheel swivel/castoring pivot. The aircraft manufacturer is also exploring the possibilities of strengthening the area of the nose wheel swivel/castoring pivot and simplifying the manufacturing process.

History of the flight

The purpose of the intended flight was for an existing PPL (A) holder to be converted to the aircraft type. He had carried out the pre-flight checks according to the checklist, with the instructor advising, with no faults or problems being found. After starting the engine and allowing time for it to warm up, the pilot taxied the aircraft onto the taxiway and then along it for approximately 800 m, to a 'mown' turning area which was used as an engine run-up area. Upon entering the turning area the aircraft was gently turned to the right prior to making a sharp turn to the left in order to face into wind for the engine power checks. With the aircraft taxiing very slowly, as the sharp left turn commenced, the nose pitched down and pieces of propeller blades, earth and grass rained down onto the aircraft. Upon exiting the aircraft it was found that the castoring nose landing gear wheel had separated from the nose leg, allowing the propeller to strike the ground. Examination of the aircraft's track on the grass surface did not show any evidence of ruts or depressions that may have contributed to the accident.

Engineering examination

General

The manufacture of the nose landing gear (NLG) strut, Figure 1, is sub-contracted by the aircraft manufacturer to a metal fabrication organisation. This organisation manufactures the NLG from two different types of steel, 1.3477.4 sheet steel and SAE 4130 steel for the main structure, which includes the pivot. Post manufacture, a hardness test is carried out with the intention of ensuring that the assembly has been correctly heat treated and has achieved the required combination of strength and toughness. The NLG struts are not individually serial numbered, and only feature a manufacturer's batch number, printed on a label attached to the inside of a section of the leg. Once the NLG is mounted on an aircraft it is difficult to access and view this label.

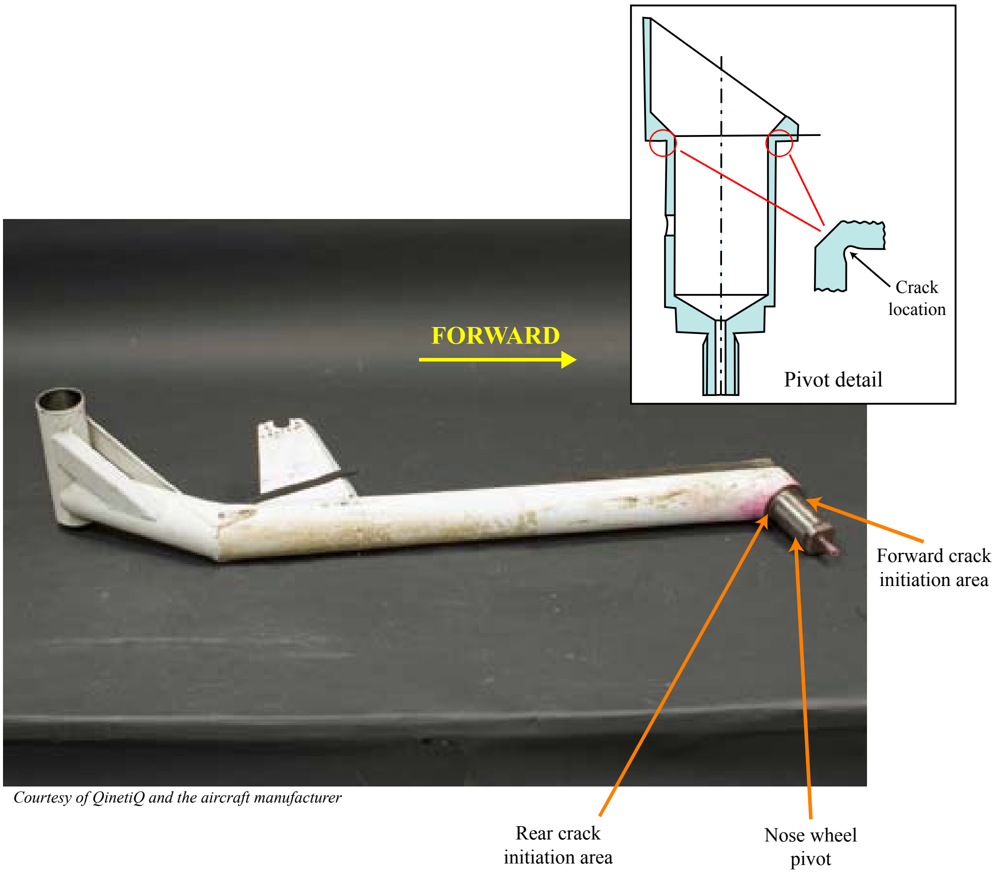


Figure 1

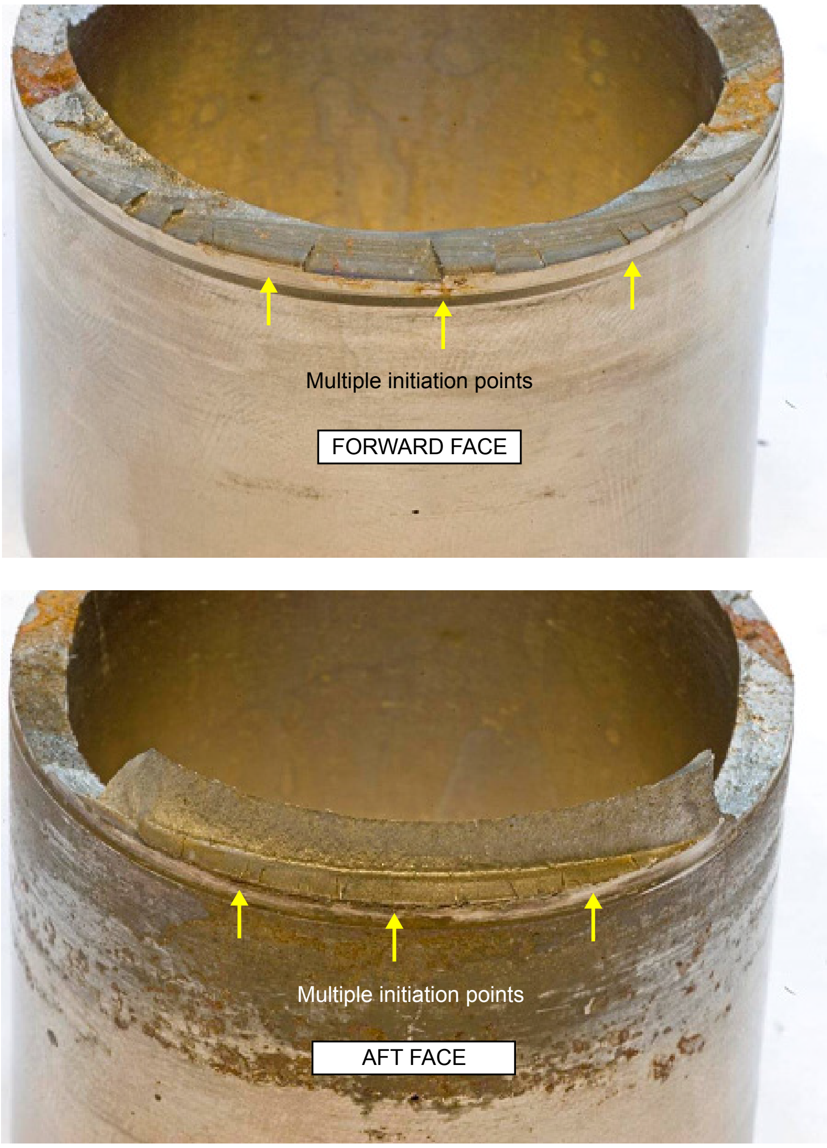
Initial examination

Initial visual examination of the failure area by a local aircraft engineer revealed what appeared to be a region of long term 'staining' on the failure surface, which indicated to him that there may have been a crack present for a period of time prior to the failure. This led the engineer to inspect the NLG of the other DA40D operated by the flight training school, G-CCUS ('US), where he found evidence of a crack in the same area where the failure had occurred on G-CCLB ('LB).

Metallurgical examination

The NLGs from both aircraft were sent to AAIB for a detailed examination, which was carried out in conjunction with the Materials Centre at Qinetiq, Farnborough. The results of this showed that fatigue cracking had occurred at the top of both nose wheel swivel/castoring pivots in an undercut/ radius adjacent to an abutment shoulder, Figure 1. In both cases the fatigue cracks had initiated at multiple points in the radius at the forward and rear sides of the pivots, Figures 2 and 3. The cracks in the pivot from 'LB had propagated around the majority of the circumference before the final overload failure occurred. The cracks in the pivot from 'US were very similar to those found on 'LB, albeit at an earlier stage of development and, as such, would almost certainly have eventually propagated to final failure in a similar manner.

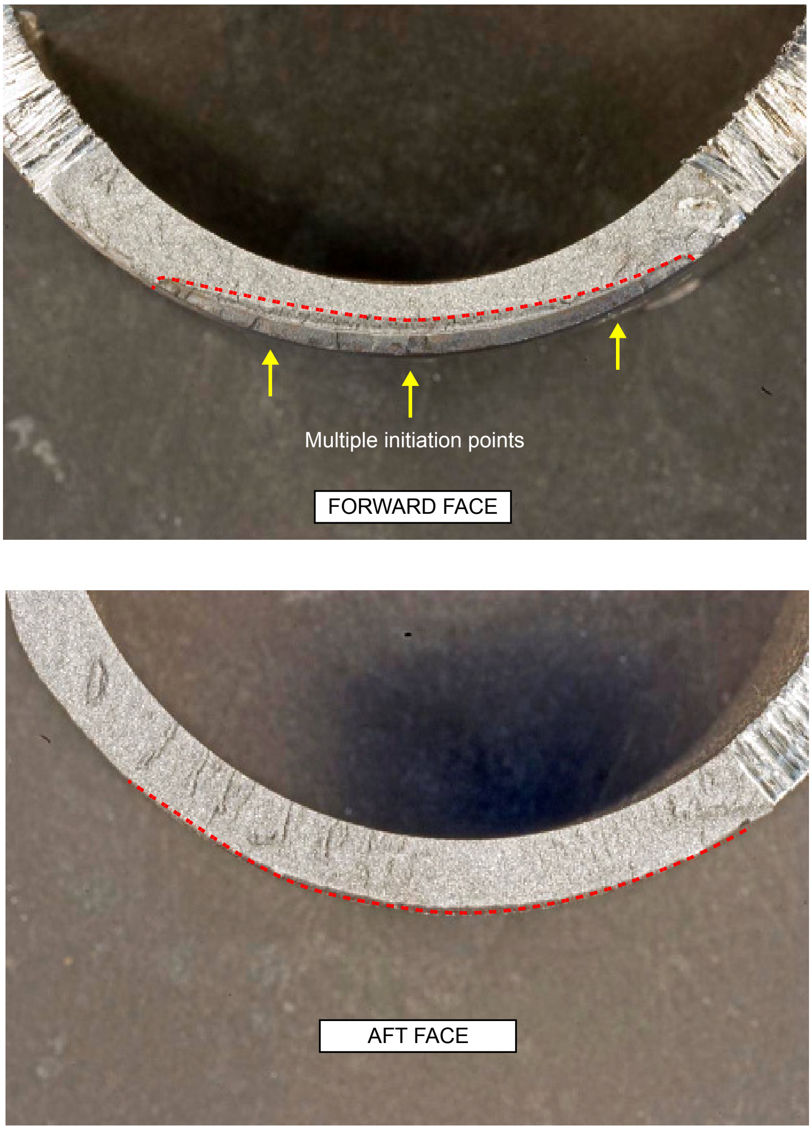
The fracture surfaces of the pivots were examined in the scanning electron microscope (SEM) to confirm that crack growth was by a fatigue mechanism. Detailed examination of the fracture surfaces showed evidence of corrosion which had removed a large area of the fine fatigue striation detail. However, the fracture topography was typical of the propagation of a fatigue crack in steel. The area of the overload failure of the pivot from 'LB showed evidence of ductile dimples typical of an overload failure. There was no evidence of any material defects or machining abuse which could have influenced the initiation of fatigue cracks, although there was evidence of corrosion on



Courtesy of QinetiQ

Figure 2

Forward and aft face of the fractures pivot from G-CCLB



Courtesy of QinetiQ

Figure 3

Forward and aft face of the fractures pivot from G-CCUS

the outer surfaces of the pivots, especially on their aft facing surfaces. This, however, did not appear to have influenced the initiation of the fatigue cracking as there was no evidence of corrosion pits at the fatigue crack initiation points.

Micro samples were taken from both pivots and these were visually examined and subjected to hardness tests using a Vickers hardness testing machine. The average hardness of the pivot from 'LB was found to be 232 HV10, equivalent to a minimum ultimate tensile strength (UTS) of 734 MPa, and that of the pivot from 'US was 236 HV10, equivalent to a minimum UTS of 746 MPa. The specified minimum hardness on the aircraft manufacturer's drawing for the pivot is 320 HV, ie, a required minimum UTS of 1080 MPa, and thus both pivots were below the specified minimum strength required. A material composition check was carried out on both pivots, which showed that they had been manufactured from Society of Automotive Engineers (SAE) 4130 low alloy steel, the correct material as specified in the aircraft manufacturer's drawing. It was noted that the manganese and sulphur levels of their composition appeared to be slightly higher than those specified in SAE Aerospace Material Specifications (AMS) 6374 for this material, but this was not considered to have influenced the initiation or propagation of the fatigue cracking.

Additional information

The manufacturer has established that the heat treatment process applied to NLG struts was only appropriate for the 1.3477.1 sheet steel and not for 4130 steel. In addition, the post manufacture hardness checks were only being carried out on the sheet steel section of the struts, which generally gave the correct result, and not on the parts made from 4130 steel, which would have given incorrect results. Since this accident occurred, hardness tests on three additional NLGs held in the manufacturer's stock, found that the swivel/castoring pivots were also below the specified hardness by a similar amount as the ones fitted to 'LB and 'US.

The types of steel used in the construction of this NLG strut are usually supplied in their softest condition, to allow easier machining and fabrication (welding, for example). Following manufacture, a specified heat treatment may be carried out to give the required combination of toughness and strength. These are low alloy steels that can achieve varying levels of strength depending on the tempering temperature. After quenching from a relatively high temperature, at low tempering temperatures, the steel remains strong but with low toughness, ie, it becomes more brittle. At higher tempering temperatures the toughness increases with a resultant drop in strength.

Aircraft usage information

Both 'LB and 'US had been operated since new by a flight training school located on a grass airfield. The airframe hours and number of flights for both aircraft, at the time of the accident were obtained and are presented below in Table 1. The airframe hours data is considered reliable, whereas the number of landings, which includes 'touch and go's,' is a best estimate figure in each case.

Crack growth

No fine detail was observed on the fracture surfaces from 'LB so an estimate of the time/cycles for crack propagation, from initiation to failure, could not be determined. However, as both aircraft were operating from the same airfield by the same training school, were being used in similar ways and had similar strength nose wheel swivel/castoring pivots, it could be assumed that the difference in landings, flights or airframe hours between the two would give an approximate indication of the time required for an initial crack to propagate to failure. The usage data showed that 'LB had carried out 308 landings, 152 flights and 117 airframe hours more than 'US.

However, when detected, the cracks in the pivot from 'US were considerably less well developed than to those associated with 'LB. If it is assumed that landing and taxiing loads are primarily responsible for crack propagation, then the minimum time/cycles for an incipient crack to propagate to failure would be around 308 landings/152 flights. It should be noted that these figures are only an estimate for crack growth and assume that the pivot material characteristics are identical, the fatigue cracks in both aircraft would initiate after the same time in service and that both would experience identical loading spectra. In reality this is unlikely to be the case.

Analysis

The region between the cylindrical section of the pivot and its abutment shoulder at its upper end is an area where fatigue cracking might be expected to develop as

G-CCLB	Total airframe hours:	634
	Total number of flights:	794
	Estimated total number of landings:	1,659
G-CCUS	Total airframe hours:	517
	Total number of flights:	642
	Estimated total number of landings:	1,351

Table 1

this is an area where stress concentrations are likely to occur due to the fairly abrupt change in cross-section. In order to minimise such concentrations, an undercut/radius is incorporated. Although the radius is the most likely region for a fatigue crack to develop, both the failure of the nose wheel swivel/castoring pivot from 'LB and the cracking found in the pivot from 'US should not have occurred. In both cases, the material checks identified that the pivots were of a much lower strength than that specified, and this would seem to account for the shorter than expected service life. The reduced strength of the pivots was not considered to have been due to the slightly higher levels of manganese found in their composition, but more likely to have followed from the inappropriate heat treatment with respect to the SAE 4130 steel. In this case, it is likely that the heat treatment carried out resulted in a situation which possibly allowed the stress levels induced by normal in-service loading to be above the material's fatigue limit, ie, at a level which would be likely to precipitate fatigue cracking.

Safety action taken

On 11 November 2005 the aircraft manufacturer issued a Mandatory Service Bulletin (SB) DAI MSB40-046 which requires that a visual inspection of the upper shoulder radius of the nose landing gear swivel/castoring pivot, using a x10 magnifying glass, be carried out to look for evidence of cracks. (A dye penetrant inspection method can be used were there is doubt). This inspection is to be carried out on:

A. Airplanes operated on grass surface within the next 25 hours of operation, not later than 31 Dec 2005, and every 100 hours inspection thereafter.

B. Airplanes operated on paved surface within the next 100 hours of operation and every 200 hours inspection thereafter.

On 15 November 2005, the Austrian Civil Aviation Administration (Austro Control) issued Airworthiness Directive A-2005-005 which made the aircraft manufacturer's SB mandatory with effect from 23 November 2005.

Proposed further safety action

The aircraft manufacturer is exploring the possibility of increasing the strength of the nose landing gear wheel swivel/castoring pivot with a view to modifying or removing the requirement for the heat treatment process during manufacturing.