INCIDENT

Aircraft Type and Registration:	HS 748 Series 2A, G-BVOU
No & Type of Engines:	2 Rolls-Royce Dart 534-2 turboprop engines
Year of Manufacture:	1973
Date & Time (UTC):	15 February 2005 at 1323 hrs
Location:	Belfast (Aldergrove) Airport, Northern Ireland
Type of Flight:	Public Transport (Cargo)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Both left main wheel tyres deflated
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	8,500 hours (of which 4,000 were on type) Last 90 days - 180 hours Last 28 days - 60 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and extensive enquiries by the AAIB

Reported circumstances

The aircraft commander, who held the post of Deputy Chief Training Captain of the operator, reported that the aircraft had landed in calm conditions with good visibility. He was occupying the right-hand seat with the left-hand seat occupied by the handling pilot who, according to the commander, had completed his LPC/OPC to a very good standard on the previous leg.

The commander stated that the landing in question appeared normal in every respect, and he observed no excessive or heavy braking at any stage. Upon exiting the runway onto the taxiway, however, steering became difficult and the aircraft could only just be manoeuvred off the runway. ATC reported that the aircraft was moving slowly and when asked if assistance was required, the crew stated that the left engine had stopped. On leaving the aircraft the commander noted that both tyres on the left main landing gear were flat.

Photographs of the aircraft taken by the airport authorities after the incident indicate that both tyres on the left side had deflated, and their treads and carcass structures had completely worn through locally to 'flat spots'. The left propeller was in a coarse pitch position, at or approaching the feathered setting.

The aircraft technical log was annotated 'Left-hand fire indication on landing; both (undecipherable word) fired'. Subsequent maintenance actions included the replacement of both fire bottles. Analysis of further entries in the technical log show that no significant internal damage had occurred in the left engine and subsequent ground running was carried out successfully. No problems were reported with wheel braking after the aircraft returned to service.

Subsequent operating problems and component changes

The aircraft subsequently experienced a series of engine flame-outs during landing, as well as occurrences of RPM hunting in flight. A micro-switch within the control console, operated by the flight fine pitch-stop (FFPS) lever and intended to cancel the auto-coarsening function once the pitch stops were withdrawn during landing, was noted as being slightly damaged. It was suspected of incorrect operation and was replaced. The plug to the solenoid in the left propeller control unit (PCU) was also replaced and ultimately the PCU was changed.

Relevant aircraft features

Propeller control and interlocking

The landing procedure on the HS 748 requires the FFPS lever to be moved upwards and aft to the 'stops-removed' position soon after touch down. This can only be done if the throttles are both in the fully aft position. Operation of the FFPS lever causes micro-switches to function, resulting in an electrical signal being supplied to each PCU. Consequent operation of a solenoid valve in the PCU allows hydraulic pressure to pass, via a dedicated 'third' oil line in each propeller hub, causing each FFPS to be extracted. This allows each propeller to reduce in pitch to an angle below the FFPS setting, towards a figure ultimately limited by the ground fine pitch stop (GFPS).

Circuitry in the aircraft forms an auto-coarsen facility which operates if the FFPS fails to function. Auto-coarsening takes place if the propeller pitch becomes significantly below the FFPS setting in flight. The system utilises the feathering pump and causes the propeller pitch to increase until the operation is cancelled by action of a hub-switch; pitch will then decrease until the cycle is repeated. Movement of the FFPS withdrawal lever to the aft position during the landing, in addition to its primary function, operates micro-switches in the auto-coarsening circuits. These microswitches inhibit the auto-coarsening function permitting the pitch of each propeller to decrease below the FFPS setting.

It is possible on the 748 to remove the FFPS regardless of whether or not the main landing gear oleos are compressed.

At high runway speeds, early in the landing run, FFPS removal increases drag and assists retardation. It also reduces lift as a result of affecting airflow over the wing immediately aft of each propeller. FFPS removal, in allowing the propeller to fine off below the FFPS pitch angle, permits engine/propeller rpm to rise if the throttles are subsequently moved forward, thus safeguarding the turbine against rapid over-temperature and failure.

Engagement of the flying control gust-lock lever, positioned on the control console, normally takes place as speed reduces. The lever is mechanically interconnected with the FFPS lever, preventing the latter moving away from the 'Stops-Out' position once the gust locks are engaged. Locks engagement is achieved by upwards, aft and downward movement of the telescopic lock lever.

A theoretical evaluation of the functioning of the PCU was carried out by the manufacturer using archived data together with experience of development engineers involved with the unit during its development process and previous service use. It was determined that normal control of the delivery pressure from the oil pump within the unit was achieved by axial movement of a sleeve allowing progressive exposure of bleed ports to take place. A ball valve incorporated in the system had been designed to operate in conditions of very low oil temperature when the normal regulating system was not able to bleed sufficient flow rate to prevent excessively high pressure levels being produced by the pump.

Braking system

The 748 is equipped with 'Maxaret' anti-skid units. These detect changes of wheel rotational speed and release brake pressure to prevent locking of the relevant wheel. They do not, however, prevent locking should a stationary wheel come into ground contact with the brake already applied.

Engine nacelles

Examination of a similar aircraft, in the company of an HS 748 engineering specialist, indicated that small amounts of a grease, used to lubricate universal joints on the drive shaft between the engine and the accessory gearbox, tend to be centrifuged away from the joint by shaft rotation. This material then frequently coats adjacent areas in the region of the combustion system. These surfaces are cooled by the normal ventilation airflow through the engine nacelle. If, however, during a landing, the aircraft is brought to a halt and the throttles remain in the fully aft position with low engine and propeller rpm, normal ventilation through the nacelle reportedly becomes greatly reduced and in extreme cases a flow reversal can take place. Without normal nacelle ventilation flow, temperature in the region of the deposited grease becomes much higher than normal and combustion of the deposits can take place. The high temperature characteristics of the materials in this area are such that no fire damage normally results from the brief period of combustion required to destroy the grease deposit. The fire detection loop, however, passes directly above the position at which the grease deposit usually occurs and is thus easily activated.

Recorded data

Considerable difficulty was experienced in decoding the flight data recorder (FDR), and the limited set of parameters recorded were of no value in this investigation. In addition, the recorded data was of poor quality and the pitch attitude, one of the required parameters, had not been recorded. The engineering organisation that supports the operator has been advised of these observations and has initiated actions to resolve the issues.

The cockpit voice recorder, however, indicated that operations were normal during touch-down and initial deceleration. Verbal reference can be heard to the propeller pitch stop withdrawal and the application of the gust-lock lever, both normal procedures during the landing run of an HS 748. Subsequently a crew member exclaims that an engine has stopped and it appears that attempts are being made to taxi the aircraft. During crew discussions about the difficulty of taxiing the aircraft the audio fire warning is heard followed by the commander questioning the handling pilot as to the point of origin of the smoke.

Component testing

No fault could be reproduced in the micro-switch removed from the auto-coarsen circuit. The problems with the engine, however, ceased after the micro-switch had been changed.

Rig testing of the PCU initially revealed no functional problems with that unit. A strip examination was then carried out which revealed no internal defects. Following re-assembly, however, a functional problem was experienced during a rig test. This was initially attributed to pre-existing damage to the ball of a pressure relief valve within the unit, which acted as a peak pressure governor to the oil pump. Subsequent microscopic examination of the ball and assessment of its operating mode by the component manufacturer did not, however, substantiate the theory advanced for the effect of a sticking ball on the functioning of the propeller.

Although the reason for the incorrect functioning of the PCU during the subsequent rig test was not established, its behaviour was consistent with the possibility that a solid contaminant in the rig oil supply had become lodged in one of the ports in the sleeve of the pressure relief valve. Such an obstruction, if capable of temporarily jamming the sleeve, could leave it in an open port condition allowing excessive spilling of oil and loss of system pressure, the phenomenon noted during the rig test. Since the test was carried out after strip examination and re-assembly of the PCU, it is considered unlikely that any contamination of the engine/PCU oil supply present during flight operation would have remained present in the region of the pressure controlling sleeve at the time of the rig test. It is also not clear how a loss of system oil pressure could lead to an unexpected increase in blade pitch angle during the landing.

Further information

Information supplied by the propeller manufacturer revealed that occasional service problems had been experienced in the past with corrosion of contacts in the PCU socket into which the airframe cable connector is plugged. Although the airframe plug was changed during part of the diagnostic process, the part of the connection within the PCU remained present with potential for retaining problems of bad contact until the PCU was changed.

Analysis

The precise sequence of events during this landing is not clear. The anti-skid units normally prevent wheel locking, unless there is a system defect or brake pressure is being applied by a crew member as the aircraft or relevant wheel touches down. Since each wheel brake is safeguarded by an individual anti-skid unit, the damage inflicted to both left tyres, together with the absence of corresponding damage on the right units, cannot readily be accounted for by a system failure.

No mechanical reason for the stoppage of the left engine is evident from the technical log entries covering rectification during the operating period immediately after the flight in question.

The problem of occasional left engine flame-out on landing and periodic rpm fluctuation in flight continued, however, until the left auto-coarsen system micro-switch was replaced. Thereafter, the problems appear to have ceased. Although testing of the removed micro-switch failed to reproduce a failure condition, it should be recognised that such testing does not necessarily fully reproduce the varying temperature and vibration levels experienced in service. Such electrical components are often susceptible to 'dormant' faults, which can be exploited by vibration and temperature changes.

If the micro-switch was not operating correctly as the aircraft landed, auto coarsening of the left propeller could commence once the throttles were fully retarded, the airspeed had decayed and the pitch stop withdrawal lever had been operated. Progressively increased airflow would then be briefly created by the left propeller with an increase in propeller thrust and local lift. When the FFPS was selected 'out' the right propeller alone would fully enter the ground-fine range, significantly reducing local airflow and hence reducing both thrust and lift, but solely on that side of the aircraft. Thus if the FFPS selection was made during the flare, fractionally before the aircraft touched down, considerable and unexpected lift asymmetry would occur. If not immediately identified and successfully counteracted with lateral control this could have caused the left wheels to remain clear of the ground during the round-out whilst the right wheels made positive ground contact. Thus the aircraft may have alighted initially on the right wheels only, without this situation being entirely evident to the crew.

Depending on any float, and the precise points at which the FFPS lever was withdrawn and wheel braking was initiated, the possibility exists that brake pressure was applied to the left units whilst the corresponding wheels unexpectedly remained clear of the runway. Such a sequence would explain the locking and subsequent flattening of both tyres on the left and the undamaged state of those on the right. Although sliding contact of the locked wheels with the runway would produce considerable retardation, this is unlikely to have been more effective than a rolling wheel with firm braking and correctly operating Maxaret units on the right hand side. Thus with appropriate modulation of pressure on the right brake pedal, directional control could have remained effective. The low sampling rate of the FDR heading parameter would mask any rapidly corrected short period heading change brought about by asymmetric retardation resulting from any difference between the performance of the locked and rolling wheels.

Under these circumstances, the left engine would have suffered progressive reduction of rpm as the blade pitch increased and the airspeed decayed; with the fuel flow remaining at or below the idle figure it is possible that reduced compressor delivery pressure and flow rate would have lead to flame out. Although the hub switch would have normally limited auto-coarsening of the blades once a pitch figure slightly above the FFPS setting was reached, with reducing air-speed, coupled with engine flame-out, the propeller rpm would have decayed. The centrifugal twisting moment (CTM), normally tending to drive the blades towards fine pitch, would have progressively reduced, permitting any residual hydraulic pressure to drive the blades, without the usual CTM restraint, towards the high pitch position.

The engine fire warning that took place is consistent with the effect of a sudden loss of nacelle ventilation on the ground occurring as a result of engine stoppage, immediately after the engines had been operating at approach power. In such circumstances, the area contaminated with grease could be expected to reach a higher temperature than would occur during a normal shut-down following a period of low power operation during taxiing with consequent nacelle ventilation present. Although implementation of the in-flight engine fire drill involves propeller feathering, the bottles alone can be discharged in isolation, an appropriate action on the ground if the fire warning occurred some time after it had been identified that the engine had flamed-out. The fact that the engine flamed out during the landing run appears to have been a consequence of the increasing propeller blade pitch without a corresponding rise in fuel-flow, further suggesting that the final coarse propeller pitch setting was achieved before the fire warning and subsequent crew actions took place.

Conclusion

An intermittent defect in a micro-switch in the control console could account for the engine flame-out and the eventual coarse pitch position of the left propeller. This defect is broadly consistent with the reported events, the recorded data, the final position of the propeller blades and the damage known to have occurred to the tyres. The limited data available, however, together with the lengthy and progressive nature of trouble-shooting and component replacement carried out, make it unclear as to the precise sequence of events and any potential aircraft defect which led to the incident.