BAe ATP, G-MANP

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Aircraft Type and Registration:	BAe ATP, G-MANP
No & Type of Engines:	2 Pratt & Whitney Canada PW-126 turboprop engines
Year of Manufacture:	1990
Date & Time (UTC):	9 May 1998 at 1705 hrs
Location:	Jersey Airport, Channel Islands
Type of Flight:	Public Transport
Persons on Board:	Crew - 4 - Passengers - 46
Injuries:	Crew - None - Passengers - Minor/None
Nature of Damage:	Engine, propeller, wing and fuselage damaged
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	33 years
Commander's Flying Experience:	3,570 hours (of which 460 were on type)
	Last 90 days - 177 hours
	Last 28 days - 59 hours
Information Source:	AAIB Field Investigation

History of flight

The aircraft was parked on Stand 9 at Jersey Airport. Clearance to start engines was given at 1656 hrs. The normal procedure when there is headset contact with the ground crewman was for the commander to start the No 2 engine prior to pushback and then to start the No 1 engine during pushback.

The No 2 engine was started and pushback requested at 1659 hrs. There was a slight delay but, at 1702 hrs, the aircraft was cleared to pushback. It was facing north on the stand and the pushback started to position it on the taxiway facing west. The No 1 engine started about 11/2 minutes later, as the aircraft heading passed through about 305°. It had stabilised by the time the aircraft was aligned with the taxiway. Shortly after this the aircraft began to push the tug, the towbar failed, the aircraft moved forward and the right propeller struck the tug.

A series of 'bumps' was heard on the Cockpit Voice Recorder (CVR) area microphone channel; these were similar to the sound made by a nosewheel running over raised centreline lighting. These increased in frequency until, 11 seconds after they had started, a loud 'crack' was heard followed 5 seconds later by a crashing impact. During this sequence a noise was heard which sounded similar to that made when a live headset is dropped.

The Tower controller saw the collision and immediately informed the Airport Fire Service (AFS). He declared a Ground Incident at about 1705 hrs. The commander's first action was to shutdown both engines and close the LP cocks. The crew were aware at this stage that the aircraft had rolled forward and the right propeller had struck the tug. After liaising with the No 1 cabin attendant, the commander briefed the passengers and told them that they would be disembarking as soon as possible. The crew then completed the shutdown check.

The commander told the cabin crew to select the doors to manual and told the passengers that they would be leaving the aircraft via the forward passenger door and airstairs. Shortly afterwards, the first officer drew his attention to a small amount of smoke which was evident on the flight deck. This was about 11/2 minutes after the impact and the commander decided to start the evacuation immediately and, on the PA, told the passengers to evacuate the aircraft via the forward steps. He then told the cabin crew to arm the rear door, deploy the chute and start evacuating passengers through that door as well. Despite the fact that there were several elderly and some infirm passengers, and some who attempted to take their cabin baggage with them, the cabin crew managed to evacuate the aircraft in an orderly and timely manner. They then checked that the cabin was clear before leaving the aircraft. The flight deck crew made the aircraft safe and power was switched off about 21/2 minutes after the impact.

The commander left the aircraft to assist the evacuation but went back on board when he saw that AFS personnel were already in attendance, as were two cabin attendants from an aircraft parked nearby. They had witnessed the collision and, regardless of their own safety, had gone immediately to the scene to render whatever assistance they could.

The AFS arrived at 1708 hrs and laid a foam blanket over the area of the No 2 engine and tug. They noted that the front passenger door was open and the steps were deploying. Shortly afterwards passengers started to disembark; the rear door then opened and a full evacuation started. The AFS together with the aircraft crew and passenger handling personnel completed a head count and marshalled the passengers away from the scene. At 1812 hrs, AFS personnel boarded the aircraft to ensure that all the passengers had been evacuated, to secure the aircraft and to confirm with the commander that all aircraft power supplies had been shutdown.

Ground handling crew

The ground handling party consisted of a headset operator, a tug driver and a third man. The headset operator is in charge of the pushback and is in communication with the flight crew. The third man removes the ground power and ensures that the area, into which the aircraft is pushed, is clear of obstructions and vehicles. They gave the following accounts of the accident.

Headset operator

He reported that the pushback appeared normal until the aircraft was being straightened on the taxiway centreline. It seemed to him that the "tug was struggling to straighten up due to strain". Before he was able to alert the flightdeck crew, the towbar snapped, the aircraft "shot forward about twenty feet" and the right propeller struck the left side of the tug cab. His headset came off as he ran to one side to get out of the way. There was debris flying all around and he saw the tug driver run around the back of the tug. He was physically uninjured but was taken to the hospital and treated for shock.

Tug driver

He pushed the aircraft straight back from the stand and then started to turn it to the left onto the taxiway centreline. He felt a resistance to the pushback "as if the aircraft was pulling power". He felt the front of the tug lift, which caused him to lose the ability to steer it. The aircraft seemed to push forward and the tug jack-knifed. The aircraft moved towards the tug and the right propeller struck the left side of the cab ripping off the door. The driver did not remember how he escaped from the vehicle. Although physically uninjured the driver later stated that he was suffering from post-traumatic stress.

Third man

As the aircraft straightened up on the taxiway centreline he noticed that the tug was out to its right. The tug then stopped and the aircraft started to move forward. He shouted a warning to the headset operator and ran towards the terminal building. He saw the right propeller strike the tug and stop. He saw the tug driver leave the tug and the headset operator run from the area.

Witness account

The station engineer of another airline had a clear and unobstructed view of the incident. Initially his attention was drawn by the engine noise of the ATP on Stand 9 that sounded louder than normal. He watched what appeared to be a standard pushback procedure except for the louder engine noise. He heard the No 1 engine came up to speed about halfway round the turn onto the taxiway centreline. He was momentarily distracted but when he looked again, the tug was at about 45° to the centreline facing away from the aircraft which suddenly moved forward and struck the tug.

Flight crew account

The flight crew were not aware that anything abnormal had occurred until shortly before the propeller hit the tug. They were aware of "graunching" noises prior to the impact but thought they were typical of those heard during pushback with certain tug/aircraft combinations. It did not cause them any concern.

When apprised of the FDR data, which indicated higher than normal power on all four starts on the day of the accident, both crew members appeared genuinely surprised and could offer no explanation. Both thought that, if nothing else, the higher engine noise level would have been immediately obvious. They could not recall any of the starts that day being other than normal.

Flight data recorder (FDR)

The FDR data indicated that the No 2 engine stabilised at 15% torque after start and remained at that level until the impact with the tug. The No 1 engine stabilised at 10% after start and remained at that level until it was shutdown after the impact. Normally the torque is set at 7 to 8% after start by positioning the rollover levers at or about a white Minimum Torque mark. Although the rollover lever position and torque gauge indication are important, the engine noise is often the first indicator to the crew that the torque is too high. The thrusts associated with 10% and 15% torque are 300 kg (662 lbf) and 713 kg (1,571 lbf) respectively.

Examination of the three previous starts that day, all by the same crew, showed similar higher than normal torque levels on both engines. The first and second starts were associated with pushback from Manchester and Jersey and on the third the aircraft was taxied off the stand at Cardiff.

Available FDR data related to engine starts before the day of the accident was analysed. The torque levels recorded after start were consistently between 7 and 8% on both engines.

As part of the investigation, an ATP aircraft was recorded on videotape during pushback from Stand 9. The commander was asked to apply 10% and 15% torque to the No 1 and No 2 engines respectively after the tug had been disconnected, and then to release the brakes. The louder than normal engine noise was very noticeable and the speed at which the aircraft moved forward from stationary was indicative of a significant amount of power being developed.

Damage

Aircraft

The ATP propeller blades are made from forged aluminium spars covered with a fibreglass shell, filled with polyurethane foam. The right hand propeller had struck the rear left hand side of the tug cab, severely damaging the six blades and the engine nacelle. The fuselage had suffered multiple debris strikes and the outer skin and a cabin window had been penetrated, although debris had not penetrated the cabin. The wing trailing edge, aft of the rear spar, had also been damaged. Witness marks on the right nose wheel door on the aircraft and paint damage on the left hand front mudguard on the tractor indicated that there had been contact between the two items. See photograph at Appendix 1.

Tug

The tug was equipped with a robustly constructed steel framed cab, the top left hand rear corner of which had been struck by the aircraft's propeller. The corner of the cab had penetrated the engine air intake below the propeller hub and, although the propeller blades had been badly damaged and the cab had lost the left hand door, the cab structure was only moderately distorted.

The right hand front tyre of the tug had been deflated during the accident by a split in the inner tube, which was most probably the result of excessive load carried during the accident sequence. The tyre had scrape marks on the outer wall, consistent with the tyre being dragged laterally across an abrasive surface. Similar marks were present, but to a lesser degree, on the inside wall of the left hand front tyre.

Towbar

The towbar had originally been manufactured for heavier DC9 aircraft; but had been fitted with a shear pin that allowed its use with the lighter ATP aircraft. A modified towing eye constructed from heavy rectangular section material had also been fitted to overcome problems of bending which had occurred on the original towing eye made from 1 inch diameter round bar material. The 30 mm x 50 mm section that formed the end of the towing eye was fillet welded to a flange plate bolted to the towbar. This weld had failed in 'shear out' around the fillet weld on the bar side of the fillet. The fracture had occurred progressively by a very low cycle, high stress fatigue mechanism. It was estimated that 12.5 to 13.5 cycles of stress had occurred from crack initiation to final fracture. This number of cycles corresponds well with the series of 'bumps' recorded by the CVR. A conservative estimate based on the area of sheared weld gave a failure load in the region of 30 tons.

The middle section of the towbar contained a witness mark that matched the right hand end of the front bumper on the tug; this showed that at some stage the towbar had jammed against the front bumper, at right angles to the tug. The towbar sheer pin had not failed in the accident and was subsequently tested to failure in tension at a load of 55.4 kN (12,454 lbf). The aircraft manufacturer requires the towbar shear pin to release at a pull of 10,930 lbf, approximately 14% less than that achieved.

Other information

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Aircraft parking area

The ATP had been parked nose-in to Stand 9; a survey of the stand showed that, at the time of the accident, the aircraft was being pushed up a slope with a 1° gradient. The aircraft taxiway, onto which aircraft was being manoeuvred, was at right angles to, and at a distance of 60 m from, the initial aircraft position, although part of this distance would have been used to enable the tug to clear the stand equipment before manoeuvring could start (the length of an ATP is 26 m).

The coefficient of friction of the surface of the stand was measured by three traverses of a towed surface friction tester, and was determined to have an average value of 0.98. The measurements had been carried out on a dry surface rather than in the more usual wet conditions which would have given a more pessimistic figure, normally used for performance calculations. The figures obtained were correspondingly high, so the friction tester manufacturer was consulted, and verified the validity of the results.

Aircraft information

The power levers carry a subsidiary rollover lever, connected such that the main power lever is used to control the engine in flight and the rollover lever can only be used for ground power control. The main lever controls the engine power between the flight idle position and the take-off/maximum contingency position. The rollover lever controls engine power between the flight idle position and full reverse.

The engine mounted components that control engine torque are the Mechanical Fuel Control (MFC) and the Engine Electronic Control (EEC). The MFC provided essential fuel metering from the fuel pump into the engine and houses a centrifugal governor to maintain propeller speed control. Rotary valves on the side of the MFC are connected by rod and cable assemblies to the power and condition levers on the flight deck.

The EEC works in conjunction with the MFC to control engine fuel flow for all operating conditions. It modulates the MFC's fuel metering in accordance with certain power management functions, compensating for ambient conditions and providing some engine power indications. It also provides opposite engine up trim in the event of engine failure occurring during take off. The EEC monitors some engine parameters, which are compared with reference data stored within its memory. Engine control commands are generated by the EEC and transmitted to the stepper motor inside the MFC to adjust the fuel flow to match the power lever angle selected and therefore to control engine RPM.

The engine control system adjustment had been upset by engine and engine mounting distortion during the accident, and on-aircraft checks of the throttle-to-MFC rigging were not possible. The FDR data was supplied to the aircraft and engine manufacturer in an attempt to predict a fuel scheduling failure mode before the MFC or EEC were tested. No such failure mode was identified. The FDR data showed the engine performing as the manufacturer would have predicted. A rig test was carried out on the MFC and the EEC and did not reveal any discrepancy.

Tug characteristics and serviceability

The tug had an overall weight of 5,790 kg, with 1,170 kg (1.15 tons) supported by the front axle; the wheelbase was 2,057 mm (6' 9"), and the towbar attachment on the front was at a height of 600 mm - the same height as the aircraft towbar attachment. The maximum thrust from the tug would have been dependant on the coefficient of friction; under the circumstances which applied at the time of the accident the maximum thrust available would have been 4,347 kg.

The tug was examined by the Driver and Vehicle Standards organisation in St Helier and was found to be in a generally poor condition; with a braking efficiency of 42.9% on the service system and 23.3% on the hand brake. It was not possible to lock the wheels during the rolling drum brake test. The suspension securing pins of the tug were not wholly located in the spring hangers of the vehicle. The accelerator cable and linkages were inspected to investigate the possibility of the throttle sticking; no such fault was found.

The faults that are listed above were considered to be indicative of lack of maintenance, but not related to the accident. They were therefore considered to be road worthiness matters and have been taken up by the Employment and Social Security Department under the Health and Safety at Work (Jersey) Law, 1989.

Aircraft rolling resistance

Stiction breakout and rolling resistance forces for the ATP were not available from the aircraft manufacturer, but rolling resistance forces for a Jetstream 41 were supplied. These were factored for the ATP using a ratio of maximum all up weights. Additional forces resisting the tug were the thrust from the aircraft engines and the slope up which the aircraft was being pushed. The total rolling resistance to motion of the aircraft when it was aligned with the towbar and the tug was calculated to have been 2,551 kg. A larger thrust would have been necessary to breakout from the stiction forces if the aircraft were stationary, although this force was unquantified.

Airline action

On 18 May 1998, the company issued a Fleet Instruction. This modified the pushback procedure and required that no engine should be started during the push back ie the right engine is started before push back and the left engine after the tug has been disconnected. It reminded crews that they should check that engine torque is at a minimum after each engine start. It also reminded them that full attention should be given to the push back controller and to activity around the aircraft.

Analysis

Witness marks on the aircraft, tug and the tow bar confirmed eye witness reports that jack-knifing had occurred, with the aircraft rotating the tug to the right until the towbar lay along the front bumper, at right angles to the tug. The towbar eye end was therefore overstressed in bending rather than tension or compression. In this condition the shear pin was not loaded. The leverage produced by this configuration caused the towbar weld to fail after a small number of high stress cycles, leaving the aircraft free to accelerate past the tug, striking it with the No 2 engine and propeller.

Jack-knifing could only occur if the component of the towbar force across the front wheels of the tug exceeded the frictional force available from the front wheels. This force would be the product of the coefficient of friction, and the reaction force between the ground and the wheels ie the front wheel loading, less the weight reduction derived from the torque effect from the driving wheels.

The weight on the front wheels of the tug was 1,170 kg (almost a quarter of that on the rear wheels), and a tug thrust of 3,962 kg would have lifted the front wheels when the aircraft was coupled to the front towing eye. This force would only have provided a moderate acceleration and, had the aircraft been attached to the rear of the tug, would have had little effect on its stability.

If the aircraft, towbar and tug were not aligned on a single heading the position would become more complex. The manufacturer's figures show that an increasing angle between the aircraft and the towbar will reduce the force required because the aircraft linear motion will reduce as it is rotated by the increasing nosewheel angle. However, an increasing angle between the towbar and the tug will require a greater thrust from the tug to move the aircraft as only a component of the thrust will be applied to the aircraft, the remaining component being resisted by a frictional force across the front wheels of the tug.

The complete geometry of the aircraft, tug and towbar at the moment of jack-knifing are not known, although most witnesses agree that the aircraft/towbar angle was around 30°, and that the aircraft had come to a halt. Whatever the other factors; the resistance to motion caused by the stiction forces; the uphill slope; the excessive engine thrust; and the geometry of the combination, were such that the aircraft and tug were susceptible to the addition of a modest amount of extra thrust from the tug, which finally lifted the tug's front wheels, allowing the aircraft to accelerate past the tug causing it to jack-knife.

Neither an analysis of the FDR data carried out by the aircraft and engine manufacturers, nor a rig test of the power plant components explained the excessive torques recorded by the FDR during the four starts on the day of the accident. The FDR data is derived from the same source as the analogue torque gauges on the flight deck therefore, in the absence of any malfunction, the same torque values should have been recorded as were displayed on the gauges.

The balance of evidence indicates that the engines were at a higher torque than normal and that this was the initiating event in the accident. The reason why the crew had set, and more importantly not noticed, the higher than normal torque after all four starts that day could not been satisfactorily explained.

Safety recommendation 99-8

It is recommended that Jersey Authorities require the ground handling organisations at Jersey International Airport to review the characteristics of their aircraft towing tugs to ensure that there is a sufficient safety factor available when used for push back operations with the aircraft attached to the front towing pintle.