Aircraft Type and Registration:	Aero Vodochody L-39ZO Albatros, G-OTAF
No & Type of Engines:	1 Ivchenko AI-25TL turbofan engine
Year of Manufacture:	1982
Date & Time (UTC):	2 August 2003 at 1421 hrs
Location:	Field three miles south of Duxford Airfield, Cambridgeshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Nose gear collapsed, minor damage to wings and nose
Commander's Licence:	Private Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	1,574 hours (of which 50 were on type) Last 90 days - 8 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot plus post-accident engine testing and further enquiries

Description of the aircraft

The Aero Vodochody L-39ZO Albatros aircraft is a two-seat tandem military jet trainer manufactured in the former Czechoslovakia. The aircraft has a maximum take-off weight of 5,600 kg and a maximum operating speed of Mach 0.80/490 KIAS. It is equipped with two ejection seats and is powered by an Ivchenko AI-25TL twin shaft bypass turbofan engine.

History of the flight

The pilot had already completed one uneventful flight during the morning. The accident occurred on his second flight whilst rejoining the circuit at Duxford. The weather was CAVOK (no cloud below 5,000 feet, visibility of 10 km or more and no significant weather) and the surface wind was light.

The pilot intended to carry out a 'run and break', flying parallel to the runway slightly offset to the north before turning crosswind to join downwind for a landing on Runway 24. The fuel level indicated 450 kg and the minimum recommended downwind fuel state is 300 kg. When it entered the circuit the aircraft was at 220 KIAS with a power setting of 85% RPM. As the pilot began to turn crosswind he retarded the throttle to IDLE and extended the speed brakes. After the airspeed had reduced through 180 KIAS he lowered the landing gear and advanced the throttle to a position that would normally result in about 90% RPM - the normal power setting for maintaining the appropriate speed with the gear down. At this point the speed was at approximately 175 KIAS so the pilot decided to leave the speed brakes extended until the aircraft had slowed to the maximum speed for flap extension of 165 KIAS.

The pilot then reported noticing a "change in the usual sound" of the engine. At this time the aircraft was descending through 850 feet agl (circuit height was 1,000 feet agl) so he instinctively applied full throttle. The engine did not accelerate and the pilot reported that it became apparent to him that the engine had failed or flamed out. He made a MAYDAY call to Duxford ATC and advised them of the problem. The pilot's attention was focused outside the aircraft and therefore he was neither sure if any captions had illuminated on the caution warning panel nor was he aware of the engine instrument indications.

The pilot selected the throttle to IDLE to initiate an engine re-light attempt but then he decided against trying to re-start the engine because the aircraft's height was low and he did not think there would be sufficient time to complete the procedure. He then realised that his two remaining options were a forced landing or an ejection. He decided to eject and grasped the ejection handle with both hands and depressed the firing trigger. Before pulling the handle he hesitated and re-considered his decision to eject because the aircraft was now descending rapidly and was very low. The pilot estimated that the aircraft was by then outside the safe ejection envelope and so he decided against ejecting. The aircraft then entered a light pre-stall buffet. The pilot released the ejector seat handle, applied forward pressure to the control stick to prevent a stall, and then committed himself to a forced landing.

He located a recently harvested wheat field and flew towards it. The aircraft touched down firmly but not heavily in the field and then while still travelling at high speed, it passed through a large hedge and came to rest in a second field consisting of standing wheat. At some point during the landing run the nose gear collapsed but the aircraft remained structurally intact. After it stopped the pilot turned off all the electrical services, opened the canopy, unbuckled his harness and vacated the aircraft unassisted. There was no fire so he returned to the aircraft and inserted the ejector seat safety pins.

The Duxford Airport fire service arrived on the scene within approximately 10 minutes followed shortly by paramedics and the police.

A photographer filmed the aircraft on video seconds after the MAYDAY was heard being declared on the radio. In the video the aircraft can be seen to porpoise nose up and down while descending rapidly, before disappearing from view behind a hill in a level pitch attitude. The landing gear appears to be extended and there is no visible plume of vapour or smoke trailing from the aircraft.

History of the aircraft

G-OTAF was delivered to the Libyan Air Force in 1982 where it accumulated 521 flying hours. In 1989 the aircraft was sold to the British Aerial Museum. Prior to the aircraft's ferry flight to the UK in April 1991, it was fitted with a replacement engine that had accumulated 217 hours. The history of the engine prior to this point is not known but the engine was manufactured in 1982 and installed by the aircraft manufacturer's engineers. Between April 1991 and April 1996 the aircraft logged 19 hours flight time which included the ferry time. In 1996 the aircraft had a CAA test flight and received it's Permit to Fly on 26 April 1996. In 2002 it was sold to the present owner and was being operated on the UK register with a Permit to Fly current at the time of the accident. The most recent maintenance was a 100 hour/annual inspection that was completed on 7 May 2003. At the time of the accident the aircraft and engine had accumulated 806 hours and 528 hours respectively.

Aircraft examination

The maintenance organisation at Duxford towed the aircraft to a nearby farm to carry out an initial examination. The nose gear had collapsed and there was minor damage to the nose and wing leading edges. The open canopy had detached from the aircraft, the speedbrakes were extended, the flaps were retracted and the landing gear doors were down. The Ram Air Turbine (RAT) was retracted.

Some of the circuit breaker switches on the right side of the cockpit, including 'fuel pump' and 'ignition', were found in the OFF position, but it was also noted that the seat harness buckle could reach the circuit breaker panel. The circuit breakers were switched ON and with electrical power applied, no fault or trip was encountered. The four circuit breaker switches in the nose cone of the aircraft were also found in the OFF position, two of these were redundant, but one controlled the engine fire extinguisher and another controlled the RAT. The Exhaust Gas Temperature (EGT) 730°C warning light did not illuminate when electrical power was applied. Had this warning light triggered in flight, the event would have been stored in the EGT control system until it was reset on the ground by pushing a reset button behind the rear ejection seat.

Powerplant examination

It was determined that approximately 450 kg of fuel remained in the tanks. The jet pipe was dry and there were no indications of fuel leakage from the aircraft. Although the air intake had internal debris from the hedge, the engine did not appear to have sustained any damage during the landing; therefore, the aircraft was prepared for an engine test. Two successful engine test runs were carried out. During the second run 'slam' checks were performed whereby the throttle was rapidly retarded from 80% RPM to IDLE and then after some period back to high power. The engine continued to operate but it was noted that when the throttle was 'slammed' to IDLE the RPM momentarily dipped to 53.5% before recovering to a stable 55%. The pilot carrying out the test considered this to be normal. The aircraft was then inspected for indications of contamination in the fuel system. No faults or contamination were found in the filters or the fuel control valve. After these engine tests the aircraft's wings were removed and it was transported back to Duxford Aerodrome for a more detailed examination.

The aircraft owner employed an L-39 consultant engineer to investigate the cause of the engine failure and a copy of the engineer's findings was sent to the AAIB. The engineer had considerable experience of the L-39, having maintained the type whilst serving in the German Air Force. He carried out a number of inspections and tests and concluded that an electrical fault was an unlikely cause of the engine failure. His significant findings from the engine examination related firstly to the Inlet Directing Body (IDB) of the high pressure compressor and secondly to the fuel consumption setting.

Inlet Directing Body

The Inlet Directing Body (IDB) of the High Pressure Compressor (HPC) helps to maintain stable airflow between the Low Pressure Compressor (LPC) and HPC by varying the angle of its blades between -5° and -15° depending upon RPM. At idle RPM the IDB is set to -15° and the blade angle increases with increasing RPM up to -5° at between 74% and 77% RPM. The IDB position is controlled by the fuel control unit via a hydraulic actuator which moves the blades and a connecting pointer which indicates the blade angle. Normally it is possible to move the blades by hand using the pointer but on G-OTAF the pointer could not be moved. The hydraulic actuator was disconnected to measure the torque required to move the pointer. However, the pointer could not be moved with the torque wrench and the torque applied exceeded the scale of 2.2 kpm (kilopon-meter or kilogram[force]-metres). It was the consultant engineer's opinion that the hydraulic actuator would not have been able to overcome the torque and therefore the IDB on G-OTAF was stuck at -15° at all engine RPM speeds.

Fuel consumption setting

The fuel consumption setting on the Fuel Control Unit (FCU) determines the minimum fuel flow at idle RPM and should be set to ensure that the engine does not flame out when the throttle is brought back to IDLE at any airspeed or altitude within the aircraft's flight envelope. During the engine test runs the RPM dipped to 53.5% before recovering to 55% during the throttle 'slam' checks. It was the consultant engineer's opinion that this dip in RPM was caused by a low fuel consumption setting. The adjustment screws for setting the fuel consumption setting on the FCU were found in their factory sealed condition. In the engineer's experience the fuel consumption setting on the L-39 was usually adjusted approximately every four years to maintain the idle setting at the nominal 56% RPM. However, the maintenance manual states that a momentary dip of up to 3% below the nominal RPM of 56% is permissible during a throttle 'slam' check to IDLE.

Bleed air valves

The consultant engineer also raised concerns about the operation of the bleed air valves. The engine has two bleed air valves which are designed to prevent the high pressure compressor from surging at low rotational speeds. The bleed air valve at the third compressor stage opens below 86% to 90% RPM and the bleed air valve at the fifth compressor stage opens below 74% to 78% RPM. At the time of the engineer's inspection, the wings were removed from the aircraft and therefore it was not in a condition for the engine to be test run.

In July 2004 the maintenance organisation rigged the aircraft up for another engine run to test the operation of the bleed air valves. The operation of the bleed air valves is tested by slowly increasing the power and checking for a slight increase in the high-pressure compressor RPM when the low-pressure compressor RPM is in the regions of 74% to 78% and 86% to 90%. The maintenance organisation reported that the engine passed this test satisfactorily. During this engine test they also ran the engine up to full power. A maximum RPM indication of 106% was obtained which is within the specified range of 106.8 ±1%. Additional throttle 'slam' checks were also carried out and the engine operated normally. This was despite the fact that the IDB blades were still seized. A borescope inspection was carried out but due to the location of the IDB it was not possible to determine whether there was any internal blockage preventing IDB movement.

Throttle lever examination

The throttle lever has a thumb actuated latch that when depressed permits the lever to move aft of the IDLE stop and into the fuel shutoff region. Inadvertent application of this latch while slamming the lever back to IDLE could result in an inadvertent engine shutdown. However, normal positioning of a hand around the throttle grip with one's thumb close to the airbrake switch on the side would make it extremely difficult to accidentally depress the latch. Multiple hard throttle slams were performed to check that the IDLE stop gate had not worn down and on no occasion did the throttle move aft of the IDLE stop. It is conceivable that a pilot might deliberately, albeit subconsciously, depress the latch while reducing the throttle to IDLE and thereby inadvertently shut the engine down. The German Air Force had two incidents whereby a low-time student pilot inadvertently shut down the engine in this manner. The aircraft manufacturer provides an optional modification that requires the throttle to be retarded to IDLE before the latch becomes effective.

Fuel pump

Fuel is delivered to the engine via an electric fuel boost pump and an engine-driven high pressure pump. The circuit breaker switch for the fuel boost pump was found in the OFF position. No electrical cause for the circuit breaker to have tripped could be found and the boost pump operated normally during the engine test. Had the switch been knocked to the OFF position in flight, the loss of fuel pressure could have contributed to a surge following a rapid throttle increase. The boost pump de-activation would also have much reduced the chances of an engine re-light. However, if the fuel pressure had dropped below the acceptable level the 'Master Caution' and 'Don't Start' captions would have illuminated. The pilot did not recall seeing either caption illuminate.

Ram air turbine

The ram air turbine (RAT) provides backup electrical power in the event of an engine shutdown or flame-out. It should extend automatically when main generator power is lost and should retract automatically when the nose gear 'squat' switch actuates on touchdown. The RAT was found retracted and the lack of dirt or grass inside the RAT indicated that the RAT was probably retracted prior to nose gear touch down. The circuit breaker switch in the nose of the aircraft labelled 'Seat Blocking Emergency Source' also controlled the RAT. This switch was found in the OFF position and had this switch been off in flight, it would have prevented RAT extension. According to the maintenance organisation there was some confusion over what the 'Seat Blocking Emergency

Source' switch did and that some pilots thought it should be turned off for single seat operation. The maintenance manual did not explain this switch's effect on the ejection system but a wiring diagram clearly showed that turning it off would deactivate the RAT and therefore the switch should be on for flight. The pilot stated that before flight, he would normally turn on all four circuit breaker switches in the nose cone, including the 'Seat Blocking Emergency Source'. All four switches were found in the OFF position and therefore it is possible that he forgot to turn them on. However, the pilot believes that damage to the nose cone structure may have knocked them off.

Maintenance procedures

The aircraft was maintained in accordance with technical manuals that had been produced in English by the aircraft manufacturer. The manuals did not specify a torque check of the IDB mechanism. However, the engine manufacturer issued a service bulletin on 7 February 1980 that called for a torque check of the IDB mechanism (Service Bulletin Ivchenko Progress 225000521); it was issued in response to an incident where the IDB blades had seized resulting in failure of the actuating pointer (the incident did not result in an engine failure). The service bulletin specified an IDB torque limit for a new or overhauled engine of 0.8 kpm and a torque limit of 1.1 kpm for an engine in service. This torque check was to be carried out at regular intervals. However, the service bulletin was only issued in Russian and Spanish. When the AAIB contacted the engine manufacturer, a representative stated that no English version of the service bulletin existed.

The aircraft was also maintained in accordance with its CAA Airworthiness Approval Note (AAN) No 24967 issued in April 1996. The AAN stated that the engine's time between overhauls (TBO) was 750 hours with a service life of 4,000 hours. This limit was stated in a letter to the aircraft owner from the aircraft manufacturer (MP/544/96). Since the engine had only accumulated 528 hours its TBO was not yet due at the time of the accident. No calendar time limit was specified in the AAN or in the letter from the manufacturer. The engine manufacturer and aircraft manufacturer have stated to the AAIB that the engine has a six-year calendar limit of operation and storage between overhauls and that this limit is clearly stated in the engine logbook. The engine's original Russian logbook was not available and had been replaced by a CAP (Civil Aviation Publication) 391 standard logbook which did not contain any overhaul limit information. The maintenance manual did not specify a six-year calendar limit for engine operation but it did include a six-year storage limit that required the engine to be overhauled if it had been stored for six years. There was no record in the logbooks of the engine having been overhauled since its installation on G-OTAF in 1991. In addition, the engine manufacturer did not have any record of the engine having been overhauled at their facility since its manufacture in 1982.

Discussion

From the evidence available it is possible that the engine began to surge when the throttle was rapidly retarded from 85% RPM to IDLE and this surge produced the unusual sound that the pilot reported hearing after he advanced the throttle. In large turbofan engines, surges usually produce loud 'bangs' but this does not necessarily occur in small, military, turbofan engines.

When the engine is operating normally, as the throttle is retarded to IDLE the bleed air valves open and the IDB blades rotate to -15°. The combination of these events helps to stabilise the airflow during the engine slowdown. In G-OTAF it appeared that the IDB was stuck at -15° and therefore could not rotate to compensate for the change in airflow. It is possible that this led to a surge and subsequent sub-idle compressor stall which was only recoverable by shutting down the engine and restarting it. Alternatively, a surge could have led to a flame-out of the engine, but a flame-out usually results in unburned fuel being exhausted from the engine. The jet pipe was found to be dry and the video footage of the aircraft's final moments did not show a fuel vapour trail. Therefore, a sub-idle stall is more probable than a flame-out.

The engine operated normally when test run on the ground despite the IDB blades being seized. The engine produced full power and did not surge or flame out when the throttle was slammed closed. However, the aircraft was flying at 175 KIAS when the engine failed to respond and this airspeed would have a different effect on the engine when compared to a ground run. It could be that the function of the IDB becomes more critical at higher airspeeds, particularly when coupled with a rapid throttle closure.

The engine manufacturer and G-OTAF's maintenance organisation did not believe that a seized IDB could lead to an engine surge. However, two independent propulsion experts considered that the seized IDB could, in some circumstances, lead to an engine surge.

The idle RPM was on the low side of the RPM tolerance. According to the consultant engineer, he would have adjusted the fuel consumption setting to increase the IDLE RPM and reduce the RPM undershoot during the throttle 'slam' check. It is possible that a low fuel consumption setting could have contributed to a surge or flame-out, but according to the maintenance manual, the IDLE RPM was within tolerance and therefore no adjustment was required. There is a procedure for checking the fuel consumption setting during a ground run but this was not carried out.

An electrical cause of the engine failure was also examined by the consultant engineer but no direct fault was found. The open ignition and fuel pump circuit breaker switches in the cockpit could not be explained but could have been struck by the seat's harness as the pilot vacated the aircraft. If these switches had been knocked during flight, an engine re-light could have been prevented.

An inadvertent engine shutdown by the pilot was considered but the throttle lever latch operated normally, the IDLE stop gate was intact, and accidental operation of the latch appeared to be very difficult. It is possible that the pilot subconsciously depressed the latch during the throttle slam, but his subsequent reapplication of throttle would have resulted in unburned fuel being exhausted from the engine. However, the video footage of the aircraft's final moments did not show a fuel vapour trail and so this explanation seems unlikely.

The aircraft and engine manufacturers had issued a service bulletin in 1980 calling for a torque check of the IDB mechanism. No such check had been carried out on G-OTAF because the maintenance organisation did not have a copy of the service bulletin and were not aware of its existence. In addition, no English version of the bulletin was available. The aircraft manufacturer no longer produces L-39 type aircraft and no longer provides service bulletins to new owners. The inadequate dissemination of this service bulletin and the lack of a version in English may have been a contributory factor to this accident, if the loss of thrust was indeed caused by the seized IDB.

The CAA has stated that it is the operator's responsibility for monitoring service information and that this responsibility is embodied in condition No 3 of the Permit to Fly which states: "The aircraft shall be maintained by an Approved Organisation (BCAR A8-20) in accordance with a recognised maintenance programme/schedule based on the manufacturer's and/or the previous military authority's published maintenance requirements." It may be implied in this statement, but the CAA should emphasise to operators of Permit to Fly aircraft that it is the operator's responsibility to obtain all relevant service information and if necessary translate the information from a foreign language into a language they understand.

It is not known what caused the seizure of the IDB blades - only an engine teardown would reveal this. It is possible that the blades were damaged on impact or by material ingested from the hedge. Alternatively, the age of the engine may have been a factor; it had only accumulated 528 hours but it was manufactured in 1982. There is no record of the engine having been overhauled since it was installed in G-OTAF in 1991. The engine logbooks prior to this date were missing but the engine manufacturer had no record of overhauling the engine since its manufacture. Since the engine TBO was 750 hours and no calendar limit was specified in the AAN, there was no regulatory requirement for the engine to be overhauled despite its age. However, the engine manufacturer and aircraft manufacturer have stated that the engine should be overhauled after six years of operation. The engine had been highly under-utilised as is common with privately owned aircraft when compared to military operated aircraft. Under-usage helps promote corrosion and the accumulation of dirt and dust. Dirt, dust, corrosion, or a combination of these factors may have contributed to the seizure of the bearings of the IDB blades. The maintenance organisation disputes the necessity to overhaul the engine every six years and pointed out that L-39 aircraft operated in the U.S.A. were not bound by an engine calendar limit. The AAIB believes that in light of this accident and given the engine overhaul requirements by the engine manufacturer, the Civil Aviation Authority should consider mandating a calendar limitation between overhauls for Ivchenko AI-25TL engines.

Conclusion

The AAIB could not determine the cause of the engine failure but the IDB blades were found seized and this could have been a contributory factor. The IDB mechanism seizure could have been avoided had the service bulletin been carried out or had the engine been overhauled. Therefore, the AAIB issued the following safety recommendations:

Safety Recommendation 2004-91

It is recommended that the UK Civil Aviation Authority considers mandating a calendar time limitation between overhauls for Ivchenko AI-25TL engines.

Safety Recommendation 2004-92

It is recommended that the UK Civil Aviation Authority takes appropriate action to inform owners, operators and maintainers of L-39 type aircraft of the need to check that the Inlet Directing Body (of the high pressure compressor) operates correctly in accordance with Service Bulletin Ivchenko Progress 225000521.

Safety Recommendation 2004-93

It is recommended that the UK Civil Aviation Authority emphasises to operators of Permit to Fly aircraft that it is their responsibility to ensure that they possess all published service information and that they regularly check for new service information published by the manufacturer.

Safety Recommendation 2004-94

It is recommended that the UK Civil Aviation Authority emphasises to operators of Permit to Fly aircraft that in situations where service information is only available in a foreign language, it is the operator's responsibility to obtain, if necessary, a translation of the service information into a language that the operator understands.