Mooney M20J, G-BIWP

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Aircraft Type and Registration:	Mooney M20J, G-BIWP
No & Type of Engines:	1 Lycoming IO-360-13B6D piston engine
Year of Manufacture:	1981
Date & Time (UTC):	29 April 1999 at 0740 hrs
Location:	Near Selby, Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 2 - Passengers - 2
Injuries:	Crew - Fatal - Passengers - Fatal
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	437 hours (of which 205 hours were on type)
	Last 90 days - 8 hours
	Last 28 days - None
Information Source:	AAIB Field Investigation

History of the flight

The aircraft was owned by a syndicate of four pilots, two of whom were planning a day trip from Sherburn-in-Elmet, Yorkshire, to Texel, Holland. Two passengers were to accompany them. The pilot in command had arranged for the aircraft to be refuelled at Sherburn two days prior to the flight. He requested that the tanks be filled to an internal tank level indicator giving 50 gall/US of fuel on board, some 14 gall/US less than full. On the morning of the flight he filed a flight plan by telephone with Manchester ATC which was then activated on the aircraft's departure from Sherburn by the airport duty manager.

On the morning of the accident four people wearing lifejackets were seen around the aircraft. The aircraft was later observed to taxi out towards Runway 11, stop to carry out power checks, and backtrack the runway prior to departure. Several people saw and heard the aircraft depart and they described the take off and initial climb as normal. Two witnesses later saw the aircraft flying in an easterly direction one mile to the west of Selby, just under the cloudbase, which they estimated to be at 600 to 800 feet. At about this time the pilot in command, who was sitting in the right hand seat making the RT communications, made contact with Church Fenton Approach and received a clearance to climb to FL 55. The clearance was acknowledged and the flight proceeded under a radar advisory service climbing up to 2,000 feet before being handed over to Humberside ATC. The handover proceeded without incident and there was no report of any problem during the aircraft's initial transmission to Humberside.

During this time the aircraft noise was heard by two people working inside a shed, about one mile to the west of the accident site, who described the sound as that of an engine in trouble. Two other people also heard the aircraft further to the east, close to the accident site. They described the engine as running, but cutting out some four or five times, followed later by the sound of an impact.

The aircraft was seen by several witnesses to be descending out of the cloud in a steep nose down attitude and turning slowly to the right. The aircraft then impacted with the ground. A number of people heard the impact and some described seeing a column of smoke rising almost immediately. The first people on the scene were unable to offer any assistance because of an intense fire and small explosions. Several people telephoned the emergency services and they arrived at the scene within a few minutes.

Meteorological conditions

It could not be determined what forecast the pilots had obtained before the flight. The forecast for the destination was good, with CAVOK and north easterly winds at 12 kt. The weather at Sherburn on departure was described as overcast at 700 to 800 feet with an easterly wind of 10 kt. The cloudbase at the accident site, 30 minutes after the accident, was reported by the police helicopter as 500 feet and other witness observations at the time of the accident correspond with this. Other pilot reports from the area gave the cloud tops as being 1,800 to 2,000 feet.

Radar data

Recorded radar returns were obtained from Great Dunn Fell and Claxby Radars which were plotted on a map to show the track of the aircraft. This data also provided a vertical profile for the flight together with a computed groundspeed (see Figure 1). From this it can be seen that there was a significant reduction in groundspeed followed by a loss of climb rate indicative of a power loss or reduction. The first radar contact was at a point where the aircraft would have entered the cloud layer and the final contact was approximately over the accident site.

Pilot experience

The pilot in command, who was sitting in the right hand seat, first obtained his licence in 1991. The next year he completed an IMC rating and maintained this rating until the date of the accident. He first started flying G-BIWP in 1994, his most recent flight was six weeks prior to the accident. The pilot flying, seated in the left seat, had 295 hours of experience, 65 hours of which were on type. He obtained an IMC rating in 1992 and had maintained the validity until two months prior to the accident. He had one hour of flight time in the 28 days prior to the accident.

Pathology

There was no evidence of any medical factor having an influence on this accident. All four persons suffered fatal injuries at the time of the impact.

Engineering investigation

The aircraft had struck the ground on a southerly heading and had come to an immediate halt. The aileron mass balance horns, located on the outboard tips of the ailerons, had made clean holes in the ground. These were both inclined at 42° to the horizontal, which thus gave the impact angle of the aircraft. The extensive disruption to the aircraft structure indicated a moderate impact speed. The rear fuselage had suffered compressive buckling and the empenage had whipped round to the left at impact such that the left stabiliser tip had contacted the ground. This suggested that there might have been some degree of aircraft rotation to the right.

The intense post-impact fire had largely destroyed the cabin area, including the instrument panel, the inboard wing sections (including the fuel tank locations), and the rear of the engine accessory gearbox. The engine itself had become buried in a 1 metre deep crater that had subsequently filled up with water, due to the high water table. The bulk of the engine had thus been protected from the effects of the fire. It was considered that the most probable cause of the fire was electrical.

The aircraft was fitted with a three bladed propeller. One blade was virtually undamaged, another was bent aft underneath the engine, and the third had broken off, in bending overload, close to the root. The separated portion was eventually recovered from the bottom of the crater. The blades displayed virtually no leading edge damage or rotational scuffing, indicating a low power, low RPM condition at impact. The blades appeared to be at their fine pitch setting, which was consistent with a low power condition.

It was established that the aircraft was complete at impact, and that the flaps and landing gear were retracted. The wreckage was all contained in the impact area.

Detailed examination of the wreckage

General

The post impact fire had been so severe that none of the cockpit instrumentation was available for detailed examination. However, it was possible to identify the propeller RPM, mixture and throttle control knobs. These were found in their fully forward positions, ie maximum RPM, mixture fully rich and throttle open. The last mentioned disagreed with the position of the throttle butterfly in the fuel injector, which was found in the closed position when it was subsequently examined. There was no evidence of a pre-impact disconnect of the throttle cable, thus the disagreement was most probably due to the severe disruption that occurred in the impact. The cowl flap operating lever was found pushed fully forward, ie flaps closed. It would be normal for the cowl flaps to be at least partially open when the aircraft was climbing, in order to keep the cylinder head temperatures within limits. The lever extends aft into the cockpit a considerable distance; thus in the event of it being in this position at impact, it is most likely to be deflected downwards due to being struck by debris or occupants, as opposed to being pushed in. This would also be true for the throttle control, and thus could provide a more reliable indicator than the throttle butterfly position, as noted above.

The flying controls were examined, with no evidence of a pre-impact disconnect being found. The horizontal stabiliser trim screwjack was found with eleven threads exposed. Reference to a similar aircraft revealed that 14 exposed threads corresponded to full nose up trim, with 3 threads at full nose down. Eight exposed threads gave approximately neutral trim.

Engine and fuel system

The engine, which had achieved approximately 1,870 operating hours, was examined at a UK overhaul agency for Lycoming engines. There was no evidence of a pre-impact mechanical failure having occurred. No faults were found in the fuel injector, boost pump or engine driven pump, although the presence of oil on the 'air' side of the diaphragm suggested that some wear may have occurred in the valve guides, thus allowing oil to be entrained into the induction system. The vacuum pump and all accessory gear drives appeared intact. The 'dual drive' magneto had burned and thus could not be tested.

The most significant finding was that both inlet valve cam lobes on the camshaft were severely worn, with approximately 0.140 inches removed from the cam "peaks". This would have reduced inlet valve lift by the same amount, with an associated reduction in the fuel/air charge entering the cylinders. The overall effect would be an unquantifiable reduction in the power output of the engine. The overhaul agent stated that worn inlet valve cams were occasionally seen on engines returned to the workshop, although usually only one of the two cams would be affected. It is noteworthy that engines so affected were invariably in the workshop for reasons other than symptoms of reduced power.

The problem of cam wear has been addressed by the Lycoming house magazine, 'Flyer', and is usually associated with aircraft that are flown relatively infrequently. After a period of inactivity, the oil drains away from the camshaft, which is located at the top of the engine. The cam lobes then become susceptible to corrosion pitting, with wear resulting from the metal to metal contact that occurs between the cams and cam-followers during the start sequence, before oil reaches this area of the engine. The inlet valve operating cams are more likely to be affected as each cam operates the inlet valves of two (opposing) cylinders, and thus are worked harder than the exhaust valve cams, which operate only one valve each.

The inboard portions of the wings, which contained the fuel tanks, were destroyed in the post crash fire, and as a consequence it was not possible to recover and identify all the fuel lines between the tanks and the fuel selector. All the components downstream of the selector were available however, and although some of the pipe unions were found to be only finger tight, this could be attributable to the severe distortion that occurred to some of the pipework during the impact. The fuel selector was found selected to the left tank. The fuel strainer was found to be free of debris and no blockages were found in the fuel lines between the selector and the injector. The injector, fuel boost pump, engine driven pump and flow divider (which distributes fuel to the individual cylinders) were all examined, with no defects being found.

Autopilot

The aircraft was fitted at the time of manufacture with a King KFC 200 Autopilot system. This was most often used by the pilots in a heading and attitude mode. It also had an altitude hold facility and the capability of interfacing with the GPS and other navigation systems in the NAV mode. In the attitude mode the autopilot maintains an attitude selected by the pilot by means of a switch on the autopilot control panel. While in use the autopilot will trim out any control forces after a few seconds so that the aircraft would be in trim following autopilot disengagement.

In addition to the mode control panel, the autopilot components comprise pitch and roll servo motors, a pitch trim servo motor and the autopilot computer. The pitch servo is located in the rear fuselage and essentially consists of an electric motor driving a cable drum attached to the elevator.

Engaging the autopilot operates a solenoid, which engages the servo motor to the cable drum. Out-of-trim forces, generated as a result of moving the elevator, take the form of tension in the cables, which register as a torque on the cable drum axis. This triggers one of two torque switches, depending on whether the tension is in the elevator 'up' or 'down' side of the cable drum. The electrical contact so made is detected by the autopilot computer, which then signals the pitch trim servo motor to operate the trim screwjack until the cable tension is eliminated and the torque switch 'unmakes'.

The autopilot can be used to make the aircraft climb or descend by operating the vertical trim switch in the UP or DOWN directions which in turn drives the flight director V-bar; the pitch servo then moves the elevator until the aircraft adopts the selected attitude.

The pitch and roll servos, together with the computer and the pitch trim servo were subjected to bench tests. The roll servo functioned satisfactorily; however a defect was confirmed on the pitch servo in that the 'nose down' torque switch made only intermittent contact. This in turn would have resulted in intermittent nose down trim screwjack operation and, in consequence, out of trim forces which would have been contained by the servo and thus not apparent to the pilot until the autopilot was disconnected. However the intermittent nature of the defect probably meant that a severely out-of-trim condition would reduce with time.

The autopilot computer chassis (ie the box that contained the logic boards) had been blackened in the fire, and this probably accounted for the failure of the unit to function on test. Satisfactory results were obtained when the boards were mounted into a serviceable chassis.

The aircraft

It was not possible to determine the actual load of the aircraft prior to departure. It was estimated that with the four persons on board, the fuel, the aircraft equipment, and known baggage the aircraft would have been at about the maximum weight with the trim at the aft limit.

The manufacturer quotes an indicated stall speed of 61 kt at maximum weight. The stall warning consisted of a warning horn only. The system was evaluated as operating correctly, giving a warning 10 kt before the stall, during a flight test carried out on 24 August 1998. The same horn was used for the gear warning, designed to give an intermittent tone at any time the throttle was retarded below approximately 1,500 RPM with the landing gear not down. The autopilot disconnect also had an audible warning giving a series of similar but not identical tones.

A similar aircraft was flight tested to evaluate the relationship between power and airspeed during the climb with the autopilot engaged. Deceleration times from 110 kt to 80 kt at various power settings in climbing flight were recorded and the resulting calibrated trim positions and altitude changes noted. It was found that from a full power climb a substantial power reduction would stop the climb within 200 feet and cause a decay in airspeed over some 20 to 30 seconds to a speed approaching the stall. The trim also drove to an aft position and it was felt that if taken to the full stall a figure approaching 11 turns of the trim screwjack would be achieved.

The trim was then manually set to 11 turns of the screwjack and the aircraft flown without autopilot to determine the control forces required. It was found that unusually strong forces were required to fly the aircraft in this trim position and it was felt that this position would not have been attained using a manual trim input under normal flight conditions.

Analysis

Power loss

The final minute of recorded radar returns to show a decrease in the rate of climb to level flight and a steady reduction of airspeed. This is consistent with a partial or total loss of engine power. From the flight evaluations in a similar aircraft the timing more closely matches a partial loss of power and the witnesses' descriptions of the engine cutting in and out are consistent with this. The cause of the power loss was not established although the worn condition of the inlet valve cams was such that the fuel/air charge entering the engine would have been significantly reduced, with a consequent reduction in maximum engine power. Notwithstanding the fact that the aircraft had successfully climbed to around 2,400 feet, it is possible that a marked rise in cylinder head temperature could have resulted from closed cowl flaps. This would have caused a reduction in the volumetric efficiency, together with a further loss of power. If the cumulative power loss was sufficient to prevent the climb being sustained, it is possible that the pilot operated the engine controls in an attempt to identify/rectify the problem, thus accounting for the ear witness reports. Alternatively, it may be that the engine problems were unrelated to the cam lobe condition. In view of the lack of mechanical failure, and the positive statements that could be made about components such as the engine driven pump, the cause could have been associated with the fuel supply to the engine, such as air entrainment in a loose fuel pipe union. Such a problem may only have become apparent following switching off the fuel boost pump.

In a single engine aircraft there is always the possibility that an engine failure may occur and consideration should be given to the likelihood of achieving a successful forced landing. An engine failure whilst flying above cloud implies that part of the descent must be carried out in IMC. On this occasion the aircraft would have needed to be established in a gliding attitude and descended through the cloud. The highest obstacle within five miles of the track was 870 feet amsl but generally the terrain was less than 100 feet amsl so there was a reasonable chance of a successful descent through cloud. With the reported cloudbase at 500 feet agl in the area the time available for field selection would have been very short and the pilot committed to landing almost straight away. Neither of the pilots had achieved much flight time in the six weeks prior to the accident and therefore could not be considered to be in good current flying practice. The power loss therefore occurred in circumstances which meant that completing a successful forced landing would have been difficult.

In this accident recognition and response to the engine failure seems to have been a problem. The commander gave no indication of any problem on first contact with Humberside ATC. Listening to the reply from Humberside may have distracted one or both of the pilots leading to their not noticing changes in the sound of the engine. The sound of the engine power reduction may have been partially disguised by the constant speed propeller attempting to maintain the rpm. Also the type of headsets worn by the pilots would have been effective in suppressing external noise. With the autopilot maintaining a constant attitude the normal pitch down following a loss of power would have been masked from the pilots' attention.

Stalling

The evaluation of the trim forces during the flight test led to the conclusion that the autopilot was engaged up to the time of the loss of control and possibly until the time of the impact. Some of the usual cues of an impending stall would have been disguised by the autopilot; notably a nose high attitude and sloppy controls. It is probable that the first indication noticed by the pilots was the stall warning horn, but even this may not have been immediately recognised because of its similarity with other warnings that they were accustomed to hearing. This familiarity could have led them to misidentify or not respond to the stall warning. It should also be noted that with the pilots wearing noise suppressing headsets and there being no associated warning light the horn may not have been obvious.

The aircraft had climbed through the cloud and was in VMC above a cloud layer. With the instrument part of the flight now behind them the pilots may have taken the opportunity to look around and complete any outstanding checks. At about this time the engine suffered a loss of power. The autopilot would maintain the aircraft in a constant attitude and the power loss would therefore lead to a reduction in airspeed and rate of climb. The autopilot would continue to trim the aircraft resulting in an aft trim position. If disconnected at a stalled or near stalled condition a considerable force would then be required to push the control column forward, thus lowering the aircraft's nose for the recovery. If the autopilot were not disconnected at the stall the pitch input would continue to be held throughout the stall and subsequent spin thus making recovery almost impossible.

Once the aircraft had entered the incipient spin stage the pilot would have had limited visual reference because of the cloud layer beneath the aircraft and could have become disorientated. On entering cloud the disorientation would be complete and a recovery unlikely. There was insufficient height available to recover below the cloud.

Autopilot

The pre-flight checklists on Private category aircraft are not subjected to CAA scrutiny as in the case of an Operation Manual for public transport operations. The checklist used for this and similar aircraft called for only a cursory check of the autopilot, as opposed to full functional checks on Public Transport category aircraft. Had a full autopilot check been carried out on G-BIWP, the pitch servo defect would almost certainly been found. Although the defect probably did not contribute to the accident, if the pilots had detected it they may have elected not to use the autopilot.

A number of light aircraft in the UK are fitted with autopilot systems. A handbook would normally be supplied with the aircraft describing the autopilot functions and controls. It would be unusual for a pilot to receive specific training in the use of an autopilot, other than an introduction to the switch controls. In practice a number of pilots teach themselves how to use an autopilot. Thus some pilots using these systems do not well understand the potential problems when a malfunction of the aircraft or the autopilot occurs. In this case it appears that the autopilot contributed to disguising the loss of power and the impending stall from the pilots. It is also likely that the resulting aft trim position would have impeded an attempted recovery.

An autopilot is a useful tool for a pilot trained in its use but without appropriate training it can be misleading. Given the number of pilots using aircraft that are fitted with autopilots there would appear to be a need for training in their proper use. It is therefore recommended that the CAA, as part of its safety promotion programme, should bring to the attention of all private pilots likely to operate aircraft that are fitted with autopilots the need for adequate training in their use.

Safety recommendation

Recommendation No 99-48

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