Yak-52, G-YAKW

AAIB Bulletin No: 10/2003	Ref: EW/C2003/01/01	Category: 1.3
Aircraft Type and Registration:	Yak-52, G-YAKW	
No & Type of Engines:	1 Ivchenko Vedeneyev M-14P piston engine	
Year of Manufacture:	1985	
Date & Time (UTC):	5 January 2003 at 1125 hrs	
Location:	2 miles north-east of Towcester, Northamptonshire	
Type of Flight:	Private	
Persons on Board:	Crew -1	Passengers - 1
Injuries:	Crew - 1 (Fatal)	Passengers - 1 (Fatal)
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	48 years	
Commander's Flying Experience:	1,715 hours (of which 119 were on type)	
	Last 90 days - 2 hours	
	Last 28 days - 1 hour	
Information Source:	AAIB Field Investigation	

Synopsis

After a series of aerobatic manoeuvres the aircraft completed a stall turn and entered a vertical dive from which it did not recover. Examination of the wreckage revealed the presence of a short-handled flat bladed screwdriver that had jammed the elevator control such that the elevator control surface could not be moved beyond neutral in the nose-up direction.

History of flight

The pilot was a member of a syndicate who operated the aircraft from a private farm strip at Cuddesdon, Oxfordshire. On the morning of the accident he arrived at the farm strip with his brother who was to fly in the rear seat as a passenger. His brother was also a qualified pilot although less experienced. The aircraft, which was started with the help of another syndicate member, then departed Cuddesdon and flew to Turweston Airfield to refuel. The pilot and passenger re-entered the cockpit when the refuelling was complete. Both were seen to be wearing flying suits, parachutes and helmets. They then departed Turweston, from Runway 27, at 1110 hrs and flew to the north-east. The pilot informed the air ground radio operator that they were intending to carry out aerobatics to the north-east of the airfield for approximately 30 minutes before returning to Turweston to refuel again. The weather in the area was fine with no cloud, a light north-westerly wind and a temperature of +1°C.

Five minutes later the aircraft was observed flying aerobatics two miles to the north-east of Towcester. After flying a sequence of manoeuvres lasting approximately 10 minutes the aircraft was seen to enter a vertical climb and execute a stall turn. The aircraft completed the manoeuvre and began a vertical descent, from which there was no apparent sign of recovery. It impacted the ground directly beneath power lines without disrupting the electrical supply. There was no fire and the rescue services arrived at the scene 15 minutes later. Both pilot and passenger were fatally injured.

Witness evidence

A number of witnesses saw the aircraft prior to the accident although no one observed the actual impact. Most witnesses described the aircraft as carrying out vertical and horizontal aerobatic manoeuvres at altitudes that were not unusual or alarmingly low. By calculation from witness information it could be determined that the highest point of the final manoeuvre was approximately 3,000 feet agl. The final descent before impact was seen to be stable with the possibility of three slow rotations occurring before the descent was obscured by trees.

Pathological information

There was no evidence in the pilot of any alcohol, drugs or toxicological factors which may have caused or contributed to the cause of the accident.

Accident site

The aircraft impacted soft ground directly beneath power lines coming to rest with the forward end of the propeller still attached to the engine some five feet below the surface. Rotating slowly in an anti-clockwise direction during its descent it had severed the ground cable, running centrally between the tops of the pylons, but had passed between the remaining three phase cables spaced either side. The aircraft impacted the ground with its wings transverse to the cables in a right wing low, vertical (90˚) attitude at a speed estimated to be approximately 190 kt. The aft cockpit ASI, damaged in the impact and recovered from the wreckage, indicated 350 km/h (190 kt).

Following the impact the right wing folded at its mid span in the direction of the rotation. The left aileron, which had detached due to rotational forces, was found adjacent to the left wing. The aft fuselage, substantially intact, had folded over the top of the aircraft coming to rest 37˚ from the vertical. The rotational energy of the aircraft caused the tail to twist as it folded, allowing the tip of the right horizontal stabiliser to strike the ground. The tail then fractured, under torsion, from the main fuselage coming to rest approximately 10 metres from the main wreckage.

A tip of the propeller, found some distance from the main wreckage, exhibited slash marks consistent with having been in contact with the ground electricity cable. This and the fact that the aft cockpit RPM indicator indicated 83% RPM indicated that the engine was most probably under power just prior to and during impact.

Both occupants had been wearing five point harnesses, helmets and parachutes. The harnesses were still locked in position after the impact. It was not possible to ascertain if the canopy had been opened prior to the impact as this was severely disrupted and fragmented.

Aircraft Information

The aircraft is a low wing monoplane, with a tandem cockpit, powered by a single nine-cylinder air-cooled radial engine. It is of a metal construction, except for the fabric covered flying control surfaces, is fully aerobatic and has normal 'g' limits of +7 g to -5 g.

Originally designed in Russia in the 1970s as a military trainer to replace the Yakovlev 18, the Yakovlev 52 is the two-seat version of the single seat Yakovlev 50. Production of the aircraft was carried out in Romania, under licence up to 1991. In 1998 the design was resurrected as the Yak-52W and Yak-52TW, which are still in production.

The flying controls are all conventional with control effected from either the front or back seat by control column and rudder pedals. The rudder is controlled by cables that run from the rudder pedals, through the aft fuselage, to the rudder surface. The ailerons are controlled from the control column by push-rods that run through the wing via bell-cranks to each surface. Elevator control is via a push rod that links the forward and aft control columns. The push rod then connects, via a bell crank transfer assembly below the aft seat, to cables that run through the aft fuselage to a mass balanced quadrant. The quadrant in the aft section of the aircraft is connected to the elevator surface. For full control of the elevator in the nose-up direction the quadrant has to pass through an aperture cut in the top of the aft fuselage.

The structure of the Yak-52 fuselage is made up of a series of frames with longitudinal stringers running between them. The external fuselage skin is riveted to these frames and stringers. The aircraft, designed for military use, is fitted with a minimum of internal trim and does not incorporate any bulkheads. This means that the majority of the internal faces of the external fuselage skin are visible throughout the aircraft and that the internal fuselage is completely open from the forward firewall to the aft face at the base of the tail. Thus all the control cables, push-rods, bellcranks and quadrants are exposed and not protected in anyway from the ingress of foreign objects. The aft fuselage is segregated from the cockpit by an electrical equipment rack and the back of the rear seat, with open spaces around them. It is possible, with some difficulty, to view almost all of the rear fuselage structure and control runs in the aft fuselage over the top of the electrical equipment on the rack. However, areas immediately behind the frames and the rear most section of the aft fuselage are not visible from the aft cockpit. An access panel situated on the left of the rear fuselage enables access to the compass flux compensator, it also affords access to inspect this aft fuselage area using a torch and mirror.

Normal servicing, refuelling and the checking of engine oil levels requires the use of a tool to open various access panels. These panels are secured by quick release fasteners, which require a flat bladed screwdriver to open them. Most pilots of the Yak-52 carry with them a means to open the panels, either a screwdriver, a multi-tool or a 'Swiss Army' knife incorporating a screwdriver blade.

Detailed wreckage examination

The aircraft was recovered to the AAIB at Farnborough for a detailed examination. During an inspection of the aft fuselage section it was discovered that the elevators, although free to move in the nose-down direction, would not move beyond neutral when moved in the up direction. Examination of the aperture at the base of the tail on the top of the fuselage revealed a restriction that was preventing the aft elevator quadrant assembly from passing through the aperture (see Figure 1).

Figure 1: View from above the aperture and inside the aft fuselage

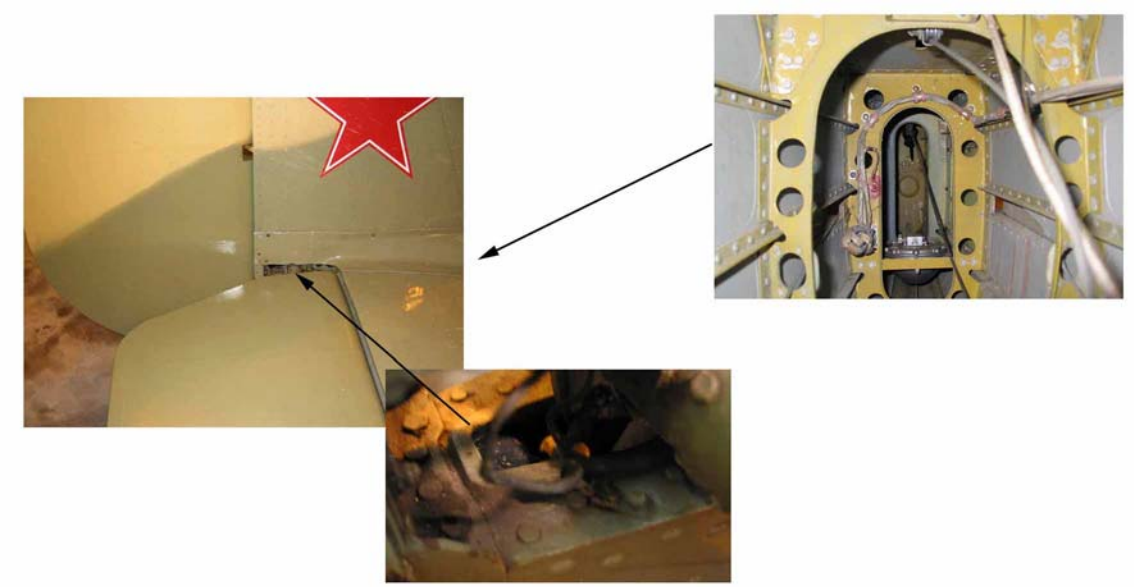

Figure 1
(view from above the aperture and inside the aft fuselage)

The restriction was discovered to be a small short-handled flat-bladed screwdriver, which had become impaled on the swaged end of the lower elevator cable at its attachment to the aft quadrant assembly (see Figure 2).

Figure 2: Screwdriver, as discovered, jammed on the aft elevator quadrant

Figure 2
(screwdriver, as discovered, jammed on the aft elevator quadrant)

The aircraft was manufactured in Romania in April 1985 and entered service with the Russian DOSAAF (military sport association) until February 1992. In June 1993, following a recent major

overhaul, it was imported to the UK with a Lithuanian Certificate of Airworthiness (C of A) and registered as LY-AKW.

In May 2002 the UK CAA issued directive DIR/05/2002/LY prompted by the Lithuania CAA that changed its policy with regard to the C of A issued on the Yak-52. The Lithuanian CAA determined that the Yak-52 did not meet the full requirements applicable to civil aircraft certification that would allow a full standard C of A. As a result a standard C of A from Lithuania would no longer be issued but would be replaced by a special C of A restricting operations to Lithuanian airspace.

The UK CAA decided that it would no longer honour the Lithuania C of A for the Yak-52 as this would be in contravention to article 118(1) of the Air Navigation Order. This left Yak-52 owners with the option to either ground the aircraft, apply for an exemption to the CAA or to obtain a permit to fly on the UK register.

The owners of G-YAKW decided to apply to the CAA for an exemption to the directive to allow the aircraft to continue to fly under the Lithuanian C of A. The exemption, granted and issued initially for a one month period, was subsequently extended until October 2002.

In December 2002 the aircraft was issued with a UK Permit to Fly and was placed on the UK register as G-YAKW.

The aircraft flew seven times between December 2002 and the date of the accident. One flight was the Permit to Fly air test, which involved spinning. Another, carried out on 26 December 2002, was a full aerobatics sortie, flown by the same pilot as on the accident flight. The remaining flights were ferry flights from maintenance and a formation flight, which did not involve aerobatics.

Maintenance

In September 2002 the aircraft, then LY-AKW, entered scheduled maintenance at a specialist maintenance facility for a 50 hour inspection and annual check. It returned to the same organisation in November 2002 to be converted from the Lithuanian register to the UK register.

A trainee mechanic at the maintenance organisation, upon hearing that a loose article had been discovered in G-YAKW, came forward and declared that he had lost a short-handled flat-bladed screwdriver matching the description of the item found in the aircraft. The trainee had started work at the maintenance organisation in September 2002 and had not worked on LY-AKW during its 50 hour inspection. However, he did work on the aircraft in November 2002. He does not recall ever using the screwdriver on the aircraft and only remembers using it to open a tin of paint away from the aircraft. Indeed the trainee was never given or accomplished a task that would warrant the use of such a screwdriver. This type of screwdriver is only used on tasks in difficult and restricted areas. The maintenance organisation also claims that screwdrivers of this type are seldom used during normal maintenance carried out on the aircraft. Subsequent testing of the screwdriver removed from the wreckage, however, revealed DNA matching that of the pilot. This indicated that he had touched it at some time prior to the accident.

The trainee's personal tools were located in two separate tool boxes at the back of the maintenance hangar. The tool boxes were never locked and were left open during the day but closed at night. The trainee had been made fully aware of the dangers of loose articles in aircraft and was reminded of this on many occasions by the more senior technicians and licensed aircraft engineers (LAE). The borrowing of tools did take place at the organisation and the policy was for the owner to be asked before hand, but if the owner was not present, items could be borrowed without his knowledge. The owner however remained responsible for his own personal tools including ensuring that they were all present and correct. There was no formal tool control at the maintenance organisation.

The maintenance organisation was approved under BCAR A8-20 as an E4 organisation. This allowed the organisation to furnish reports to the CAA for issue of Permits to Fly. It did not hold a maintenance approval (M5) under the same regulation. BCAR A8-20, however, only covers ex-military aircraft over an AUW of 2,730 kg. The Yak-52 is less than 2,730 kg and as a result there

was no need for the organisation to be approved to A8-20 to maintain the aircraft. Despite this, any work carried out on the Yak-52 must still be signed by a suitable LAE approved to BCAR A3-7.

The flight release certificate necessary for a Permit to Fly states: '*I hereby certify that the aircraft defined hereon has been inspected and is fit for flight provided that it is properly loaded*'. The release certificate for G-YAKW was signed by an approved LAE to BCAR A3-7 on 29 November 2002.

Loose articles

The aircraft records for G-YAKW showed the work carried out during the September 2002 and November 2002 maintenance periods. In the records was a separate sheet, which provided a checklist of items to be completed prior to delivery of the aircraft to the customer. Items on the list included: *'All ground equipment and loose items in aircraft....'* and *'No FOD in cockpit, check also under seats and seat bases'*. A sheet had been completed and signed for the September 2002 maintenance but no sheet was found for the November 2002 maintenance.

Loose article checking was carried out at the maintenance organisation. The onus was placed on the person who carried out the task to ensure that all tools, materials and any other foreign items were removed from the aircraft following accomplishment of the task. The area would then be checked by the LAE prior to signing the task on the work sheets. Before a panel was closed, the area would be checked at least twice and in some cases three times, for loose articles prior to closure. However none of these actions were formally recorded in the work sheets.

The maintenance schedule used for G-YAKW was translated from the original Romanian document. The document included a section entitled *'Preliminary Preparation'* which detailed the activities to be carried out prior to any scheduled maintenance. Under section 1.1.25 titled *'Check the rear part of the fuselage'* is a requirement to: *'- Check the absence of alien objects within the fuselage by the trap door'*.

The 'trap door' is a panel to the left of the aft fuselage, used to access a flux compensator. On approximately 80% of the occasions when this panel has been opened and an inspection carried out by the maintenance organisation several loose articles have been retrieved. The items found included: coins, sunglasses, pens, maps, fuel drain tools, keys, stones, batteries and in one case a five foot section of a broom handle. The panel on G-YAKW had been opened during the September 2002 maintenance check, but as the November 2002 check was not scheduled maintenance there had been no need to open the panel and it was not disturbed during the check. The panel had not been opened since the application of the 'G-YAKW' decal on the side of the fuselage in November 2002.

The pilots in the Yak-52 syndicate were very aware of the dangers posed by loose articles within the aircraft. They followed the advice recommended by a UK based company specialising in Yak-52 type conversions. This included a visual search, the wearing of flying suits with sealed pockets, slapping the underside of the fuselage and listening for vibrations, checking passengers and accounting for any tools that may have been used. Post accident investigation however, proved that it is possible for loose articles to be present at the rear of the fuselage and not be heard even with the most vigorous slapping of the underside of the fuselage. A handle at the rear end of the fuselage prevents slapping in that region further reducing the ability to detect loose articles.

Pilots who flew G-YAKW after its maintenance in November 2002, all accounted for the tools that they carried for normal servicing of the aircraft. Furthermore, the 'Swiss-Army' knife, used by the pilot for routine servicing, was found on his person after the accident.

Regulations

CAA General Aviation Safety Sense leaflet 19 entitled *'Aerobatics'* gives advice to pilots on loose article checks. In addition CAA Airworthiness notice (AWN) 12 appendix 7 entitled *'Foreign Objects and Loose Articles - Danger of Jamming'* contains pertinent information on the dangers of loose articles and the possibility of jamming of the flight controls. The notice states:

'As the presence of foreign objects can cause jamming or restriction of engine and flight control systems, organisations involved in the manufacture, operation and maintenance of aircraft, should establish standard practices to address foreign object and loose article control.'

As a further expansion for maintenance personnel CAA Civil Aircraft Airworthiness Inspection Procedures (CAAIP) leaflet 2-6 entitled *'Cleanliness of aircraft'* details the importance of keeping the aircraft clean.

Other occurrences

Loose articles causing a jam in the elevator bell crank assembly of a Yak-52 have been recorded on at least two other occasions.

In the first case a pilot who was carrying out aerobatics had just completed a zero 'g' manoeuvre followed by a dive. He attempted to recover only to find that the control column would not move beyond neutral in the elevator up direction. Fortunately he was able to achieve enough up elevator to recover from the dive, albeit only 300 feet agl. He then flew cautiously to an airfield for a difficult, but successful, landing. Subsequent investigation revealed that a pair of 'vicegrips', which had been used to maintain the aircraft two months before, had become lodged between the aft elevator quadrant and the structure. The 'vicegrips' had found their way into the rear section of the aircraft through the aperture at the top of the aft fuselage.

The second case concerns a fatal accident in Russia where a camera lens, lost on the previous flight, became jammed in the elevator transfer mechanism, located under the rear seat.

Additional anecdotal evidence from other Yak-52 pilots suggests that fatal accidents, directly attributable to loose articles becoming jammed in the elevator controls, have occurred in Lithuania, Russia and China. Full details on these accidents however could not be found.

Analysis

The primary cause of the accident was a loose article, in the form of a screwdriver, jamming the aft elevator quadrant and preventing the elevator from being moved beyond neutral in the up direction. The elevator only became jammed during the stall turn aerobatic manoeuvre. If it had become jammed prior to the stall turn the aircraft would not have entered the climb required to begin the manoeuvre. It is probable that whilst the aircraft was in the climb towards the apex of the stall turn the screwdriver rested on the aft most section of the fuselage. When the elevator was moved towards the neutral position the quadrant 'scooped up' the screwdriver preventing the elevator from moving beyond neutral. This prevented the aircraft from pulling out of its dive.

Aircraft design

Although the loose article jamming in the elevator was the primary cause, there were other causal factors which lead to the screwdriver finding it's way to the rear of the aircraft. One of these factors is the design of the aircraft. The Yak-52 was designed as a military trainer and is therefore stripped of most of the ancillary trim and bulkheads normally found on civilian aircraft. This means that with an open design, the flying controls are exposed and vulnerable to loose articles in both the cockpit and the rear fuselage. Also the fully open architecture from front to rear means that it is easy for items loose in the cockpit to find their way to the rear of the aircraft. This is borne out by articles found in the rear fuselage area during maintenance. Additionally the rearmost vertical fuselage bulkhead is just to the rear of the elevator control quadrant opening such that any loose article lodging on the rear bulkhead during vertical manoeuvres is adjacent to and conveniently 'offered up' to the quadrant for scooping into the narrow upper fuselage opening.

The design of the aircraft makes it difficult to check for loose articles. An item in the rear section of the fuselage can remain hidden unseen in the darkness behind the structural frames. The method of slapping the bottom of the fuselage, taught to most Yak-52 pilots and used by the syndicate that operated G-YAKW, is effective in identifying items only in the mid section of the aft fuselage. An item in the rear most section however, would remain undetected due to a handle preventing the direct

slapping of the fuselage in this area. The only effective method of checking the aft area is to remove the access panel on the left side of the fuselage and use a mirror and torch to inspect the area. This method is however quite impractical during pre-flight checking. The fact that most loose articles found during maintenance are in this rear most area shows that they are difficult to locate without direct inspection. Furthermore, this is not the first accident to involve a loose article becoming jammed in the elevator controls.

Tool control

The loose article found in G-YAKW was a short-handled flat-bladed screwdriver. Although the most likely source of the screwdriver was during maintenance in November 2002, what is not known and could not be established is how the screwdriver found its way into the aircraft. Screwdrivers of this type are used by pilots to carry out normal routine servicing on the aircraft. All the other pilots who flew the aircraft from November 2002 however were able to account for their tools used for this purpose, and the 'Swiss Army' knife normally used by the pilot involved in the accident was recovered. DNA testing however, showed that the pilot had come into contact with the screwdriver at some point prior to the accident but it could not be established when or how this occurred.

A maintenance trainee at the maintenance organisation admitted to losing a screwdriver whose description matched that of the item found. He also stated that he had not used, or been asked to carry out a task requiring, a screwdriver of that type on any aircraft nor had he ever used the lost screwdriver except to open a tin of paint. As his tools were in open toolboxes it is possible for the tool to have been borrowed and used on G-YAKW without his knowledge. The maintenance organisation carry out loose article checking of aircraft during and following maintenance but, as already discussed above the design of the aircraft can make this difficult. As the rear access panel had not been opened during the November 2002 check, a full loose article check of the area could not have been carried out. Loose article inspections are not recorded in the maintenance records therefore it was not possible to determine what inspections had been undertaken.

During the investigation it was discovered that, although tool control is recommended by the CAA in AWN 12 appendix 7 and CAAIP leaflet 2-6, the maintenance organisation did not have a specific tool control system and put the onus on the individuals. An effective tool control system can prevent tools from being missed following maintenance. However, it must be pointed out that if tools are borrowed without the owner's knowledge, then tool control relating to the task will not be effective. Systems should be in place where each tool can be accounted for make missing tools more easily identified allowing for remedial action to be carried out to locate missing items.

The following two safety recommendations are made as a result of this investigation:

Safety Recommendation 2003-71

The CAA should require the Yak-52, and aircraft of a similar design operating on the UK register, to have fitted a method of preventing loose articles migrating to a position where they could interfere with the operation or jam the flight controls.

(The maintenance organisation has already implemented the installation of a ceconite bulkhead, with a clear view panel, in the rear of all relevant aircraft. This bulkhead is being installed, on an opportunity basis, when aircraft are subject to routine maintenance by the organisation.)

Safety Recommendation 2003-72

The CAA should publicise the circumstances of this accident in order to bring to the attention of Licenced Engineers (LAE) and maintenance organisations the need for them to have in place an effective tool system that reduces the likelihood of tools being left in aircraft after maintenance.