Statens haverikommission
Swedish Accident Investigation Authority

Final Report RL 2017:04e

Accident at Ängsö, Västmanland County, on 22 January 2016 involving the aeroplane SE-LVR of the model Diamond DA42, operated by Airways Flygutbildning Svenska AB.

Reference no. L-06/16

21 March 2017

SHK investigates accidents and incidents from a safety perspective. Its investigations are aimed at preventing a similar event from occurring again, or limiting the effects of such an event. However, it is not the purpose of SHK investigations to apportion blame or liability, whether criminal, civil or administrative.

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Cover image three – Photo: Anders Sjödén/Swedish Armed Forces.

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Appendicies: Calculation of altitude trajectories, engine power and attitude. (Swedish only).

General points of departure and limitations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to, as far as possible; determine both the sequence of events and the cause of the events, along with the damage and effects in general. An investigation shall provide the basis for decisions which are aimed at preventing similar events from happening in the future, or to limit the effects of such an event. At the same time the investigation provides a basis for an assessment of the operations performed by the public emergency services in connection with the event and, if there is a need for them, improvements to the emergency services.

SHK accident investigations thus aim to answer three questions: *What happened? Why did this happen? How can a similar event be avoided in future?*

SHK does not have any supervisory remit, nor is it charged with apportioning blame or liability with respect to damages. This means that issues concerning liability are neither investigated nor described in association with its investigations. Questions of blame, liability and damages are dealt with by the judicial system or, for example, by insurance companies.

Furthermore, SHK's remit does not include, aside from that part of the investigation that concerns the rescue operation, an investigation into how people transported to hospital have been treated there. Nor is there any investigation of the actions of society in the form of social care or crisis management subsequent to the event.

Investigations of aviation occurrences are governed primarily by Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation and the Swedish Accident Investigation Act (1990:712). Investigations are conducted in accordance with Annex 13 to the Chicago Convention.

The investigation

The Swedish Accident Investigation Authority was informed on 22 January 2016 that an accident involving an aeroplane with the registration SE-LVR had occurred at Ängsö, Västmanland County, that same day at 19:07.

The accident has been investigated by the Swedish Accident Investigation Authority, which is represented by Mikael Karanikas, Chair, Stefan Christensen, investigator in charge, Johan Nikolaou, operational investigator, Ola Olsson, technical investigator and Jens Hjortensjö, behavioural sciences investigator until 23 September 2016.

The Swedish Accident Investigation Authority has been represented by Kristoffer Danèl, technical expert, and Lena Bergön, expert in fire and rescue services.

Johannes Woldrich from VERSA[1] has participated as an accredited representtative of Austria.

Thomas Karge from BFU[2] has participated as an accredited representative of Germany.

Hans Hermansson has participated as an advisor for the Swedish Transport Agency.

The following organisations have been notified: The European Commission, EASA[3], the Swedish Transport Agency, VERSA, BFU and SHT[4].

Investigation material

Interviews have been conducted with the instructor, the student, the passenger and representatives of the operator and the Swedish Transport Agency.

The following external examinations have been undertaken in conjunction with the investigation:

- The emergency locator transmitter (ELT) has been examined by Bromma Air Maintenance (BAM).
- The memory card from the autopilot has been examined by Honeywell in the United States.
- The aeroplane's FADEC units (see section 1.6.4) have been examined by Technify Motors GmbH in Germany.

A meeting with the interested parties was held on 25 October 2016. At the meeting the Swedish Accident Investigation Authority presented the facts discovered during the investigation that were available at the time.

[1] VERSA (Bundesanstalt für Verkehr - Luftfahrt) – the Austrian air accident investigation authority.
[2] BFU (Bundesstelle für Flugunfalluntersuchung) – the German air accident investigation authority
[3] EASA – European Aviation Safety Agency
[4] SHT (Statens Havarikommisjon for Transport) – the Norwegian air accident investigation authority.

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Aircraft:	
Registration, type	SE-LVR, Diamond
Model	DA42
Class, airworthiness	Normal, Certificate of Airworthiness and valid Airworthiness Review Certificate (ARC)[5]
Serial number	42 127
Operator	Airways flygutbildning Svenska AB
Time of the occurrence	19:07 on 22 January 2016 Note: all times are given in Swedish standard time (UTC[6] + 1 hour)
Location	(Position 59°32N, 016°51E, 4 metres above mean sea level)
Type of flight	Flight training
Weather	Wind approximately southerly, 05 knots, visibility 10–15 km, clouds 6–8/8 with base at 300 - 400 feet, temperature/dew point -7/-8°C, QNH[7] 1027 hPa
Persons on board:	3
Crew	2
Passengers	1
Injuries to persons	3 seriously injured
Damage to the aircraft	Destroyed
Other damage	Damage to vegetation
The instructor:	
Age, licence	53, CPL[8]
Total flying hours	7,500 hours, of which 1,500 hours on the type
Flying hours – last 90 days	130 hours, of which 105 hours on the type
Number of landings – last 90 days	175
The student:	
Age, licence	25, CPL(FAA[9])
Total flying hours	945 hours, of which 200 hours on the type
Flying hours – last 90 days	3 hours
Number of landings – last 90 days	20

[5] ARC – Airworthiness Review Certificate
[6] UTC – Coordinated Universal Time
[7] QNH – Atmospheric pressure at mean sea level.
[8] CPL – Commercial Pilot Licence.
[9] FAA – Federal Aviation Administration.

SUMMARY

A training flight in an aeroplane of the model Diamond DA42 was to be undertaken at Västerås Airport. On board were an instructor and a student in the front seats, with one further student in the back seat. During the training exercise – the plan for which included approaches and flying on one engine – the instructor should demonstrate a manoeuvre called “deep stall”. It was dark during the flight, which was undertaken partly under instrument meteorological conditions, with overcast clouds with base of 300–400 feet and tops of approx. 2,000 feet, with icing conditions forecasted in clouds.

According to the instructor, the exercise was conducted in the following manner: The aeroplane was brought into a steep climb with an attitude of approx. 25–30º at the same time as an approx. 30º bank to the right was set. During the deceleration, both engines were set to full power and when the aeroplane was approaching stall speed, the stick was pulled fully back. However, the students gave evidence when interviewed that the pitch attitude during the climb was at least 50º (nose up). This information also supports the analyses conducted by the Swedish Accident Investigation Authority (SHK) on data recorded by units in the aeroplane.

At the top of this manoeuvre, the aeroplane rolled over to the left and entered a spin from an altitude of approx. 4,500 feet. The instructor attempted – e.g. by varying the engine power – to exit the spin. However, the aeroplane continued to spin and, following a sequence of events lasting just over 30 seconds, crashed into woodland close to Ängsjö Church. According to the data registered on units on board and the radar data that have been obtained, the rate of descent in the initial phase is determined to have been approx. 52 m/s (approx. 10 200 ft/min), which then gradually decreased to approx. 19 m/s (approx. 3 700 ft/min) prior to impact.

During the impact phase into the woods, a tree trunk entered the fuselage, causing the student in the back seat to be thrown out of the aeroplane. With the rate of descent and the rotation decreasing and with parts of the aeroplane remaining in the surrounding trees, the wrecked aeroplane finally impacted in the woodland and was totally destroyed. The two people in the front seats survived, but were seriously injured. The student in the back seat, who also suffered serious injuries, came to his senses standing in front of the aeroplane wreckage.

Both SHK and the type certificate holder, Diamond, have made the assessment that the manoeuvre performed can be classified as a type of aerobatic flying that is not permitted in accordance with the aeroplane’s approved flight manual.

According to the applicable regulations, the flight training organization shall have a well-thought-out and functional quality and safety system for the identification and minimisation of potential hazards in its operations. This system is scrutinised during the Swedish Transport Agency’s initial inspection and oversight inspections.

However, these inspections do not encompass any detailed inspection of practical realisation – or levels of risk – with respect to the aspects of practical flight training that may be associated with increased levels of risk. The applicable regulations also contain no guidance pertaining to the practical execution of such exercises.

All in all, SHK is of the opinion that it must be possible to guarantee students at flying schools the same level of flight safety as afforded to passengers on commercial flights. This accident shows that both regulations and supervision are deficient with respect to the identification of areas of risk and hazardous circumstances in conjunction with flight training.

The accident was caused by the following factors:

- The high risk factor of the exercise.
- Deficient planning of the training exercise with respect to the options for managing hazardous situations.
- Lack of guidance from the authorities concerned regarding practical implementation of certain exercises within flight training.

Safety recommendations

EASA is recommended to:

- Identify exercises in flight training that might entail an increased risk factor and to issue guidance material (GM) for the practical execution of these. *(RL 2017:04 R1)*

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Circumstances

A training flight was to be undertaken from Västerås Airport using an aeroplane of the model Diamond DA42 (see Figure 1). There were three people on board: an instructor, one student pilot and one further student pilot in the back seat, who was accompanying as an observer.

The training exercise in question was part of a training programme the purpose of which was to convert the students' CPL/FAA commercial pilot licences into the equivalent European licences. The training programme was put together by the flight school and was largely consistent with the syllabus stipulated for IR/ME[10] training.

Some of the exercises that were to be included in the training flight had been practised first in the simulator earlier that day. The intention was to conduct two flights, with the students switching between flying the aeroplane and accompanying as an observer in the back seat while their colleague was flying.

Figure 1. The aeroplane in question, SE-LVR. Photo: Carl von Rosen Johansson.

Preparations prior to the flight were undertaken in accordance with the school's normal procedures, which include the drawing up of operational flight plans. The ATC[11] flight plan was handed in and the airspace for the exercises had been blocked in a sector outside of Västerås up to 5,000 feet.

The aeroplane had no technical remarks and the information obtained indicates that there were no other known problems prior to the flights. The first flight was undertaken in the morning with one of the students in the left seat and the instructor in the right front seat. The weather during the flights was completely overcast with a cloud base of

[10] IR/ME – Instrument rating/multi-engine.
[11] ATC – Air traffic control.

approx. 300–400 feet, visibility of 10–15 km with some higher cloud layers. It was daylight during the first flight.

1.1.2 Sequence of events

Certain agreed exercises, e.g. approaches and practice flying on one engine, were undertaken during the first flight. The instructor then took control of the aeroplane in order to demonstrate an element called "deep stall". According to the instructor, a high nose-up attitude was adopted during this demonstration at the same time as a c. 30° bank was set. Both engines were then set to full power during the deceleration. When the aeroplane was approaching stall speed, the stick was fully pulled back.

During the first flight, the bank was set to the right during this exercise. At the top of the manoeuvre, the aeroplane stalled to the left. The aeroplane was recovered from the stall and it was possible to resume normal flight. The training flight was completed and the aeroplane returned to Västerås Airport to allow the students to switch places. The next training flight was undertaken in darkness and partly under IMC[12]. The flight was undertaken in accordance with the radar trace that is shown in Figure 2. The stall exercise in question was initiated at approx. 4,500 feet by initiating a steep climb. The instructor chose to bank to the left on this occasion.

At the top of the manoeuvre, the aeroplane rolled over to the left and then entered a spin. The instructor attempted – e.g. by varying the engine power – to exit the spin. However, the movement became uncontrolled and the aeroplane continued to spin with a high rate of descent.

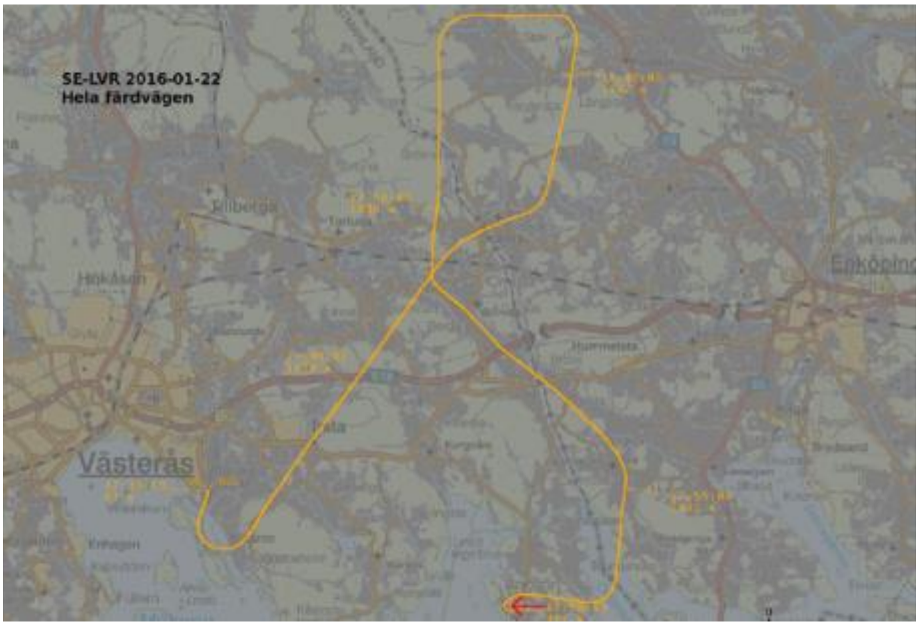


Figure 2. Map of the area with a radar track showing the aeroplane's flightpath. Source: Swedish Armed Forces.

[12] IMC – instrument meteorological conditions.

With reference to the altitude information from the radar track and data from recording equipment on board, it can be established that the average rate of descent during the spin was approx. 50 m/s (approx. 9,800 ft/min). This indicates an approximate time for the sequence of events during the uncontrolled spin – from the top of the demonstrated manoeuvre to the impact in the woods – of just over half a minute (see also Section 1.11.2).

1.1.3 The impact

At approx. 2,000 feet, the aeroplane entered the underlying cloud layer and a number of seconds later, impacted into an area of woodland. During the initial sequence of events, the aircraft hit the surrounding trees while rotating. Parts of the wings were found in the trees at the accident site at a height of up to approx. 10 metres. The aeroplane then twisted itself round a Scots pine that penetrated the fuselage and which the plane then rotated around on its way towards the final point of impact. At the impact, the remaining parts of the aeroplane were completely destroyed (see Figure 3), but no fire broke out.

Figure 3. The wrecked aircraft. Photo: Mälardalens Brand- och Räddningsförbund.

The two pilots sitting in the front seats remained on board and suffered serious injuries when the aeroplane hit the ground. The third person on board – who was sitting in the right back seat – had been thrown out of the aeroplane during some part of the sequence of events involving the tree penetrating the fuselage. The root end of the pine that the aeroplane had hit during the crash remained by the seat where the third person had been sitting.

The accident occurred at position 59°32N, 016°51E, 4 metres above mean sea level.

1.1.4 Interviews with those on board

The flight instructor

The instructor's memory of events on the day of the accident is poor. He remembers that they undertook certain exercises, e.g. steep turns and holding patterns. He could not recall whether any ice had formed on the wings while passing through the clouds, but stated that the climb check-list contains a point at which the wings should be checked.

With regard to the exercise that was to be demonstrated – "deep stall" – he only remembers that the plane quickly went into rotation and that there were no response from the flight controls, at the same time as he probably had made a short "power on and off" in order to see whether there was any change.

He could not recall if any stall warning had been activated during the event, but stated that the stall warning had been activated during earlier exercises of the same kind.

The instructor has no memory of the subsequent sequence of events; instead he only remembers being dragged out from the wreckage by the rescue staff.

The instructor also stated that he had undertaken the exercise previously and that the result then was that the aeroplane stalled over the wing. He had no specific training in aerobatic flying, but had practised spins in a single-engine aeroplane during his own basic training.

The instructor has later expressed the opinion that the movement on top of the manoeuvre - that the stick was pulled fully backwards - not was carried out in a harsh way, but had been a "soft and gentle backward movement of the stick" in order to obtain a stall of the aircraft.

The student in the front seat

The student had been sitting in the back seat while the exercise in question was demonstrated during the previous flight. Once the students had switched places and the second flight session was commenced, the instructor asked whether the student had practised any "deep stall" before. The student had practised this before, but only in single-engine aeroplanes approved for aerobatic flying.

However, the student thought that it was fun to experience this. During the previous flight, he had experienced a sensation like that of a rollercoaster and thought that the manoeuvre gave an "aerobatic sensation". According to information from the interview, the exercise was now initiated with the instructor bringing the nose up to an attitude of approx. 40–50° with a bank to the left and power on the engines.

He did not know exactly what had happened after that, but remembers that the aeroplane "rolled over" and went into a full spin to the left. The attitude was difficult to assess, by the student's memory was that the nose had been under the horizon. The instructor had decreased and increased power during the sequence of events. The student called "power to idle". The student in the back seat called out: "opposite rudder". He was not able to recall whether the instructor had pushed the stick forward during the sequence of events.

The student stated that the aeroplane stopped rotating for a second or so before beginning to rotate again with full force. When the aeroplane then entered the clouds at approx. 2,000 feet, he remembers having thought: "Now we're finished". The student then remembers a crashing sound, but has no memory of the impact itself. He woke up sitting trapped in the cockpit and saw then that his colleague was standing outside of the wreckage.

The student in the back seat

After his flight, the student switched to an observer's position in the right back seat when it was his colleague's turn to fly. "Deep stall" was to be demonstrated following some standard exercises. The student stated that the instructor raised the nose of the aeroplane to approx. 50°. He perceived the attitude to be so steep that there was a sensation that they "stood straight up".

At the top of the manoeuvre, the aeroplane twisted around and went into a spin to the left. The student understood that they were in a flat spin with the nose in a limited nose-down attitude. He also remembers having called "opposite rudder" to the pilots in the front seats. However, it was not possible to see with certainty from the back seat which flight control movements that were made. He remembers that the instructor altered the power on the engines and that the aeroplane temporarily stopped rotating for a short time.

His memory of the impact is confined to the sound from the trees and branches the aeroplane passed through. The student then remembers that he found himself standing outside of the wreckage. He made verbal contact with the other student and also, after some time had passed, with the instructor, both of whom were seated in the front section of the wrecked aeroplane.

1.2 Injuries to persons

1.2.1 General

	Crew	Passengers	Total on board	Others
Fatal	-	-	-	-
Serious	2	1	3	-
Minor	-	-	0	Not applicable
None	-	-	0	Not applicable
Total	2	1	3	-

1.2.2 Injuries to those on board

The instructor suffered serious but not life-threatening injuries. These injuries consisted of several fractures to the sternum, spinous processes, hip and one foot. The instructor also suffered lung injuries and cuts. These injuries required a long convalescent period in hospital following the accident.

The student in the front seat suffered serious but not life-threatening injuries and was able to evacuate the aeroplane himself. The student hit the left side of his face, broke both feet and ankles and suffered lung injuries. These injuries required a long convalescent period in hospital following the accident.

The passenger in the back seat suffered serious but not life-threatening injuries in the form of a fractured nose, fractured lumbar vertebrae and injuries to the lungs.

1.3 Damage to the aircraft

Destroyed.

1.4 Other damage

Damage to surrounding trees and vegetation at the accident site.

1.4.1 Environmental impact

Minor oil and fuel spills. The accident site was decontaminated by the fire and rescue service following the accident.

1.5 The crew

The instructor

The instructor was 53 years old and had a valid CPL with the applicable operational and medical eligibility. At the time of the exercise in question the instructor was PF[13].

Flying hours				
Last	24 hours	7 days	90 days	Total
All types	3.5	no data	130	7,500
Type in question	2	no data	105	1,500

Number of landings, type in question – last 90 days: 175.
Type rating conducted on 2007.
Latest PC[14] conducted on 22 April 2015.

The student

The student was 25 years old and had a valid FAA CPL with the applicable operational and medical eligibility. At the time of the exercise in question the student was PM[15].

Flying hours				
Last	24 hours	7 days	90 days	Total
All types	3	3	3	945
Type in question	3	3	3	200

Number of landings, type in question – last 90 days: 20.
Type rating on the type for conversion was ongoing.
Last PC: Not applicable

1.5.2 The pilots' duty times

The instructor had been on duty for four working days in the past seven days. The day in question contained two simulator exercises and two flights in aeroplane.

The student had taken part in training for five of the past seven days. The day in question contained one simulator exercise, a flight as observer and a flight as an active pilot (the flight during which the accident took place).

13 PF (pilot flying) – the pilot who is manoeuvring the aircraft.
14 PC – proficiency check.
15 PM (pilot monitoring) – pilot who is assisting the PF.

1.6 The aircraft

1.6.1 General

The Diamond DA42 (Twin Star) is a light twin-engine aeroplane that is powered by two four-cylinder diesel engines equipped with variable-pitch clockwise-rotating propellers. The aeroplane is used primarily within private flying and flying schools for training pilots on twin-engine aeroplanes.

The aeroplane is largely constructed of glass fibre/carbon fibre composite and has four seats. The DA42 was certified in Europe in 2004 in accordance with the construction standard JAR-23, which was the applicable standard in Europe at the time the certification process began. The EASA later introduced the currently applicable construction standard CS-23 for new constructions.

Type certificate holder	Diamond Aircraft Industries GmbH
Model	DA42
Serial number	42 127
Year of manufacture	2006
Gross mass (kg)	Max. takeoff/landing mass 1,785 actual 1,682
Centre of gravity	Within limits.
Total operating time (hours)	3,904
Operating time since last periodic inspection (hours)	2
Number of cycles	N/A
Type of fuel loaded prior to the occurrence	Jet A-1

Engine		
Type certificate holder	Technify Motors GmbH	
Type	CD-135	
Number of engines	2	
Engine	No. 1	No. 2
Serial number	02-02-02996	02-02-02995
Total operating time (hours)	1,504	1,504
Operating time since last periodic inspection (hours)	2	2
Operating time since last overhaul	N/A	N/A

Propeller		
Type certificate holder	MT-Propeller Entwicklung GmbH	
Type	MTV-6-A-C-F	
Propeller	No. 1	No. 2
Serial number	06747	06133
Total operating time (hours)	Unknown	Unknown

Operating time since overhaul (hours)	1,469	1,390
Time between overhaul (hours/cycles)	2,400	2,400

No deferred remarks

The aircraft had a Certificate of Airworthiness and a valid ARC.

1.6.2 Performance

General

The aeroplane has a modern aerodynamic design and wings with a laminar profile. The drag is significantly lower than that of older, traditionally constructed aeroplanes in the light twin-engine class. This makes it possible to use engines with a comparatively low effect.

The aeroplane is constructed mainly from carbon-fibre material. All of the seats have Kevlar reinforcement and are equipped with shock-absorbent elements (crash elements) consisting of stiff plastic foam with carbon-fibre reinforcements. The elements compress in the event of high vertical forces and the intention is to protect those on board from injury.

The model is approved for flying under icing conditions and is equipped with a de-icing system that applies a thin film of de-icing fluid to critical parts of the aeroplane.

Mass and balance

SE-LVR had a maximum structural takeoff mass of 1,785 kg. There is also a limitation on the maximum zero fuel mass, which is 1,650 kg.

The actual takeoff mass for the first flight was 1,682 kg and the centre of gravity was 2.45 metres aft of the reference plane, which means that the aeroplane's centre of gravity was centred in the permitted area.

Limitations

The DA42 is approved for flying in the normal category in accordance with the applicable certification rules in JAR-23. This means that the aeroplane is approved for the following:

- All normal flight manoeuvres,
- Stalls (with the exception of dynamic stalls)[16],
- Lazy eights, chandelles[17] and steep turns and similar manoeuvres in which the angle of bank is not more than 60°.

[16] A dynamic stall is the result of a rapid and substantial change of the wing's angle of attack.
[17] Lazy eights and chandelles consist of combined climbing and turning manoeuvres.

According to the flight manual, all other forms of aerobatic flying are prohibited, including spins or manoeuvres in which the angle of bank is more than 60°. Stalls with asymmetric power or with one engine inoperative and intentional manoeuvres resulting in negative g-forces are also not permitted.

The flight manual's emergency procedures section describes actions to take in order to recover from an unintentional spin. These are essentially consistent with the actions described in Section 1.17.5.

Stall characteristics

The aeroplane has been tested in accordance with the requirements in JAR-23/CS-23. Stall tests in the certification category that encompasses the DA42 consist of tests using various configurations (flaps/landing gear) with engine power from idle up to 75% during level flight and 30° of bank.

Approach to stall with a 1 knot/second deceleration and up to 5 knots/second deceleration is tested as part of the flight tests. No spin tests have been conducted and nor are these a requirement for this category of aeroplane. The manufacturer has also stated that possible tendencies to spin have been evaluated during all stall tests, however with negative results.

As mentioned previously, the wings on the DA42 have a laminar profile. The wings are constructed so that the thickest part of the wing is at roughly the middle of each wing and the curve is similar on the over- and underside. In brief, this means that the part of the air flow closest to the wing, the so called boundary layer, is laminar and not turbulent.

However, a disadvantage of the aircraft is that the wings are sensitive to disruptions. Damage, dirt (e.g. insect remains on the leading edge), water, ice or frost can have a detrimental impact on the profile that changes the aeroplane's normal performance. For example, stalls and spins can occur at higher speeds and in different flight attitudes and configurations than those that would otherwise be expected.

Spin characteristics

At the request of SHK, Diamond Aircraft has commented on some of the aeroplane's characteristics. Because the certification requirements do not include any spin tests, no such flight tests have been performed. The conditions under which the manufacturer deem there to be the greatest risk of the aeroplane entering a spin are:

- Tail-heavy aeroplane,
- 75% power[18],
- flaps up,

[18] 75% is the maximum allowed power when testing stalls.

- wings level or in a turn, and
- maximum rudder deflection when the stall occurs.

The above applies to the DA42 NG model. However, the manufacturer has explained that this likely also applies to the model in question, DA42, with a proviso that the models differ in terms of mass and balance. It is also pointed out that the aeroplane will display an increased tendency to yaw when the engine power is being increased and the speed is decreasing.

The engines on this model of aeroplane are clockwise rotating, which means that the propeller blades move down on the right-hand side. If the aeroplane has a high angle of attack, the down-moving blades will have more thrust that those that are ascending, which results in a turning moment to the left. This phenomenon is normally called the P-factor.

If a yaw to the left arises, a nose-raising gyroscopic moment will arise because the rotating parts of the propeller have a mass moment of inertia. Combined with the P-factor, this results in a nose-raising moment and a yaw moment that may contribute to the aeroplane entering a spin in conjunction with a stall at high engine power.

It is for this reason that the standard method for recovering from a spin has reducing the power as its first point. Increasing power during a left spin with clockwise-rotating engines can aggravate a spin or make recovery impossible. At the request of SHK, the type certificate holder has stated that they do not intend to conduct any flight tests as a result of the accident (see Section 1.17.7).

1.6.3 *The type certificate holder's assessment of the manoeuvre*

The manufacturer has submitted the following comments regarding the specific exercise that was conducted:

- Abrupt change of attitude, abnormal attitude or abnormal changes to the aeroplane's speed are considered to be aerobatic flying.
- A pitch attitude of 40–50° is considered to be abnormal.
- An entry into a stall with a high attitude or large deceleration is to be considered a dynamic stall and is thus not permitted in accordance with the aeroplane's AFM[19]

The information provided by both students indicates that the aeroplane's attitude during the entry into the manoeuvre was a least 50°. The calculations that SHK has had conducted also show that the attitude was probably in excess of 50° (see Section 1.17.3).

[19] AFM – Aeroplane Flight Manual.

The TC-holder believes finally that the expression dynamic stall best describes the maneuver was carried out during the event.

1.6.4 Examination of the FADECs

It was possible to recover the engines’ FADEC (Full Authority Digital Engine Control) units in conjunction with the examination of the wreckage. Both units had minor damages to the casings, but were generally in a good condition. The FADEC is a unit that, among other functions, translates the pilot’s control of power and other engine parameters into mechanical changes to engine values. Each FADEC unit also has a memory function that stores certain information. The following parameters are recorded in this memory unit:

- The engine RPM
- The engine power
- Air pressure
- Coolant temperature
- Air temperature
- Oil temperature
- Oil pressure
- Fuel pressure
- Oil temperature in the gearbox
- Electrical voltage to the FADEC

Once the units had been removed from the wreckage, they were transported to the engine manufacturer’s laboratory in Hamburg (see Figure 4). In the presence of representatives of SHK, the units were connected and the memory function could be evaluated. The damage that occurred during the accident had not affected the units’ recording functions. All parameters could be read out for analysis.

Figure 4. Examination of the FADEC units in Hamburg.

The parameters that were of the most interest to the ongoing investigation were the engine values for evaluating the engine power during parts of the sequence of events and the barometric air pressure for conversion to values that indicate the aeroplane's altitude (see Figure 5).

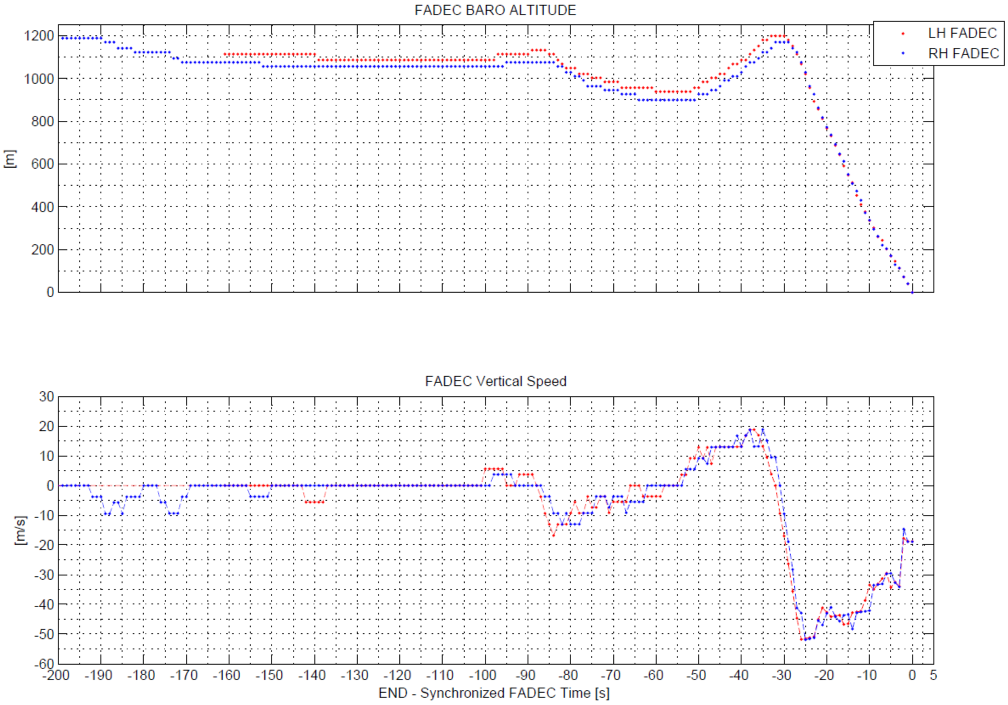


Figure 5. Graphic showing data from the FADECs pertaining to altitude and rate of descent.

All recorded values are presented in tabular form, but some of the values have been translated into graphical form using a special program. Parameters pertaining to engine data are presented in diagrammatic form in Figures 6 and 7.

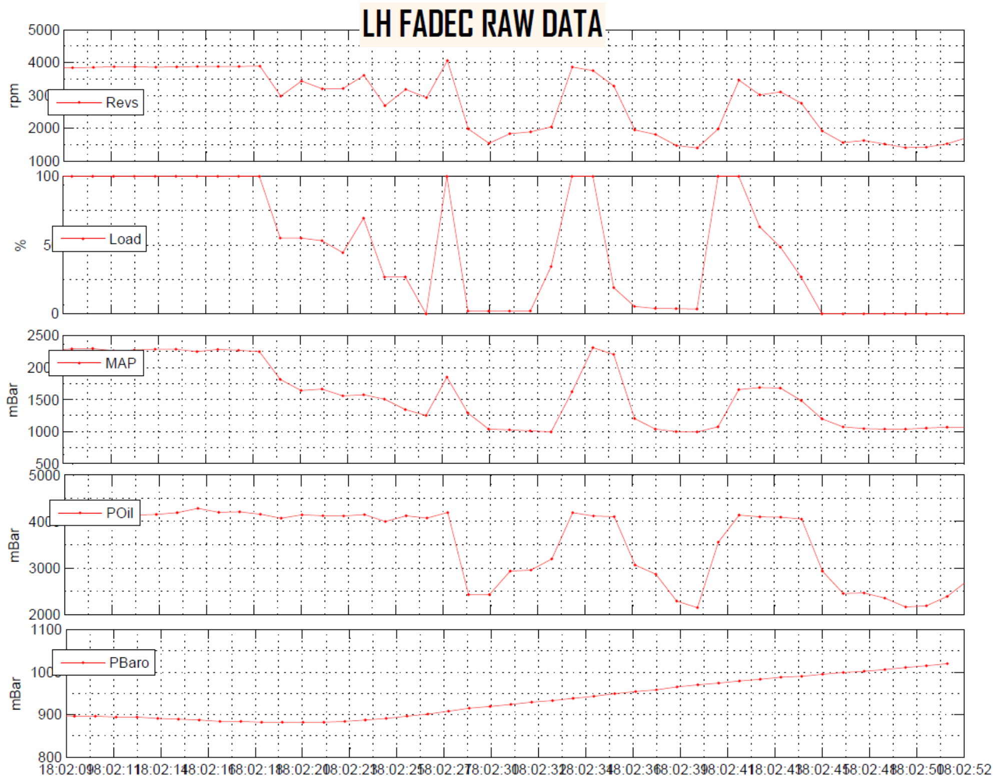


Figure 6. Graphic showing engine data covering the last 60 seconds from the FADEC on the left engine.

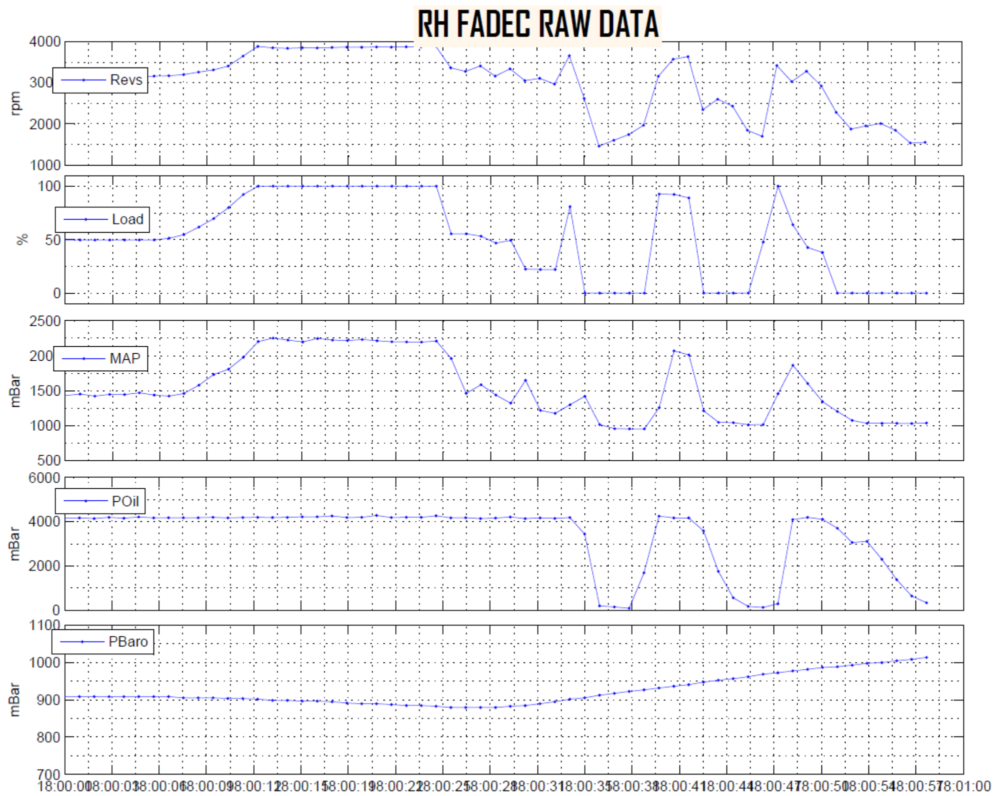


Figure 7. Graphic showing engine data covering the last 60 seconds from the FADEC on the right engine.

The values that were read from the FADEC data and were analysed in more detail are described in Section 1.17.

1.7 Meteorological information

According to an analysis from the Swedish Meteorological and Hydrological Institute (SMHI) covering the area around Ängsö Church at 19:07. Wind approximately southerly, 05 knots, visibility 10–15 km, clouds 6–8/8 with base at 300 - 400 feet, temperature/dew point -7/-8°C, QNH 1027 hPa

Several cloud layers were present, with a first overside at approx. 2,000 feet. Further layers were present above at varying levels. Icing conditions forecasted in clouds.

It was dark during the flight.

1.8 Aids to navigation

Not pertinent.

1.9 Communications

The communication between the aeroplane and air traffic control in Västerås has been obtained by SHK, but has not provided any information that has been used in the investigation.

1.10 Aerodrome information

Västerås Airport had status in accordance with AIP[20] Sweden.

1.11 Flight recorders

1.11.1 FDR/CVR

There was no flight data recorder or cockpit voice recorder nor is there any requirement for these in this type of aircraft.

1.11.2 Garmin 1000

The aeroplane was equipped with the Garmin G1000 multifunction system. The memory card for this system was removed from the wreckage by SHK for analysis. However, the card is not of the type that stores information, which is why it has not been possible to use it in the investigation.

1.11.3 The autopilot's memory unit

The DA42 is equipped with an autopilot of the KCM 100 type. This unit was removed from the wreckage and sent to Honeywell in the United States for examination and analysis. No data of relevance to the flight in question could be found in the unit.

[20] AIP – Aeronautical Information Publication.

1.11.4 Radar images of the sequence of events

SHK has used radar images from Swedish military and civilian stations in order to obtain a trajectory of the sequence of events. The image in Figure 8 below has been obtained from the Swedish Armed Forces and shows the final 60 seconds of the flight in question.

This information is based on radar images with a 5 second sampling time between each pulse. It is therefore not possible to establish the exact time – or altitude – at which the demonstrated manoeuvre "topped" and the aeroplane entered the uncontrolled spin.

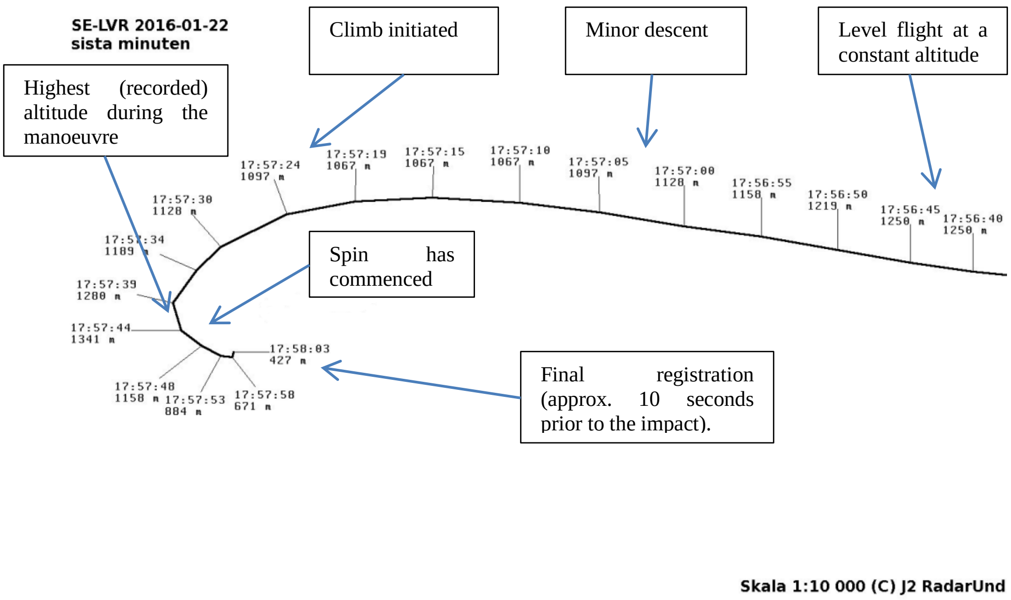


Figure 8. Graphic based on radar data from the Swedish Armed Forces.

The graphic in Figure 8 can be interpreted as indicating that the aeroplane has largely remained at a constant altitude and has then initiated a minor descent. A climb has then started in order to accomplish the previously described manoeuvre involving the stall demonstration manoeuvre.

Somewhere around the recorded altitude of 1,341 metres (approx. 4,500 feet), the spin has then commenced. The time from this point until the impact in the woods can be estimated at just over 30 seconds, which means an average rate of descent during the sequence of events as approx. 50 m/s (approx. 9,800 ft/min).

1.12 Accident site and aircraft wreckage

1.12.1 Accident site

The accident site was located at Ängsö, approx. 20 km south-east of Västerås. Ängsö is an island in Lake Mälaren and is part of Ängsö Nature Reserve.

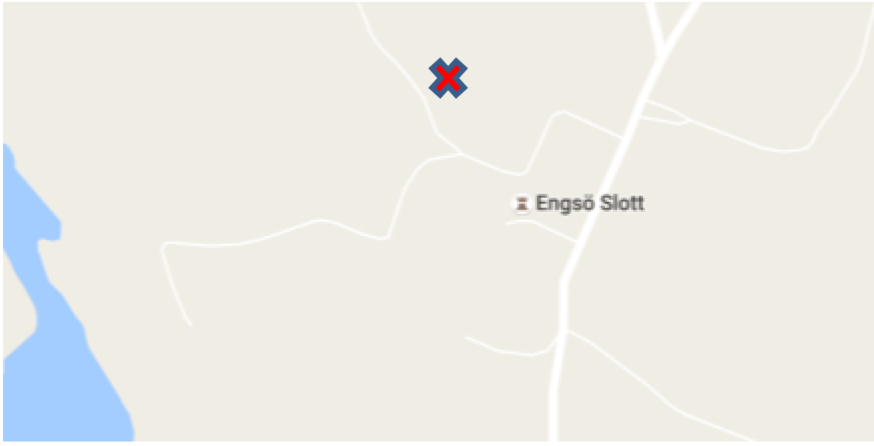


Figure 9. Map of the area with the accident site marked. Source: Google.

The accident occurred in an area of woodland approx. 300 metres north-east of Ängsö Castle (see Figure 9). The woodland consists of mixture of trees of varied size. The site of the impact consisted largely of a small open area surrounded by tall trees of various species.

Figure 10. The accident site in the woods.

1.12.2 *Aircraft wreckage*

The aeroplane went down in the woods while rotating to the left. Many large pieces of the aeroplane were found in the surrounding trees at heights of up to 10 metres (see Figures 11 and 12). The aeroplane began breaking up when it made contact with the trees. There were a large number of pieces of wreckage spread out on the ground underneath, probably originating from the rotational impacts.

Figures 11 and 12. Parts of the aeroplane, sections of the fuselage and left winglet.

During the initial stage of the impact phase, the aeroplane has also hit a Scots pine in such a way that the trunk penetrated the fuselage (see Figure 13). The aeroplane has then – probably while rotating more slowly – slid down the tree trunk. During the final impact, the tree trunk has broken close to the roots and was found in the place where the right back seat had been.

Figure 13. The wrecked aircraft.

SHK conducted an initial examination and documentation at the crash site. The wreckage was located in a limited area at the accident site. What remained of the aeroplane had hit the ground largely horizontally, probably with very limited forward movement. The aeroplane was completely destroyed.

Fuselage and wings

The remains of the fuselage were broken up into a large number of pieces. The rear section with stabilisers and elevator has twisted out and was found mainly at the left side of the wreckage, but also partly in the surrounding trees. The fuselage behind the cabin was largely destroyed by the Scots pine that the aeroplane slid down during the final stage of the sequence of events.

Both wings were found alongside the fuselage, but had come off their attachments. The wings were bent into various angles and broken in a large number of places. Part of the left wing – the outermost part that is angled upwards (winglet) – was found in a tree at a height of approx. 10 metres. A certain quantity of aviation fuel remained in the wing tanks and it was possible for decontamination personnel to pump this out.

Engines and propellers

The engines, with attachments and components, were found largely in their positions on each wing. The units were found in a correctly oriented state and showed major damage. Parts of the propellers were found spread out around the accident site. The propeller pieces that could be recovered demonstrated a pattern of damage that indicates they were rotating at the time of the impact.

The cabin

The majority of the aeroplane's cabin was destroyed during the accident. The front part was considerably broken and crushed. However, the pilots' seats were relatively intact and remained for the most part in their attachments. The instrument panel – which was partly undamaged – had, together with the frame and pedal gear, been pushed in towards the front seats, which is what caused the serious injuries to the crew. The aeroplane's nose section was completely destroyed.

The rear part of the cabin had been cracked at the join between the front and rear parts of the cabin section. The left back seat was crushed against the front seat. The root end of the Scots pine that had penetrated the aeroplane was found in the place where the passenger in the back seat had been sitting – the right back seat. Cabling to, for example, the emergency transmitter was severed or damaged.

Flight controls

Those parts of the aeroplane's flight control systems that could be identified were examined to the extent practicable at the accident site. The examination showed no signs of damage that could have occurred prior to the crash or the impact with the trees.

1.13 Medical information

Nothing has emerged that points to the pilots' mental or physical condition having been impaired prior to or during the flight.

All three of those on board had valid medical certificates. Medical examinations had been conducted on them in May 2015, January 2016 and November 2015, respectively.

The health of the student and the passenger had, according to themselves, not deteriorated following their latest medical examinations; they were healthy, physically active and had slept normally on the day prior to the accident.

At the time of the interview, the instructor had some gaps in his memory of the accident and the period preceding it. However, nothing has emerged to indicate that his state of health had deteriorated since his last medical examination or that he had slept poorly on the day prior to the accident.

1.14 Fire

No fire broke out.

1.15 Survival aspects

The aeroplane rate of descent decreased gradually during the sequence of events, from approx. 52 m/s (approx. 10 200 ft/min) to approx. 19 m/s (approx. 3 700 ft/min) at the time of the impact, which probably contributed to the accident becoming survivable. The tree trunk that penetrated the fuselage decreased the speed further and hence reduced the force of the impact.

Figure 14. The Scots pine trunk in the right back seat.

The two people in the aeroplane's front seats remained in the aeroplane at impact. SHK has not found it to be meaningful to attempt to calculate the forces of impact due to the special circumstances in the final stage of the sequence of events. The forward speed was probably close to zero, but the vertical forces, combined with the nose-down attitude that has been established at the time of the impact, resulted in the nose section – with the instrument panel and pedal gear – largely being forced into the cabin and causing severe injuries to the crew.

Aside from the parts of the nose section that were crushed, the front cabin section of the aeroplane survived relatively well. The front seats were relatively intact and remained attached. The forces of impact were, however, relatively great, which is indicated by the safety belts having separated from their respective attachments to the fuselage.

1.16 The search and rescue operation

Provisions concerning fire and rescue services are found primarily in the Civil Protection Act (2003:778) and the Civil Protection Ordinance (2003:789).

According to Chapter 1, Section 2, first paragraph of the Civil Protection Act, fire and rescue services denotes those rescue operations that central government or the municipalities are to be responsible for in the event of accidents and the imminent threat of accidents that aim to prevent and limit harm to human beings and damage to property and the environment. Central government is responsible for mountain rescue services, air rescue services, sea rescue services, environmental rescue services at sea, rescue services in the event of emissions of radioactive substances and searching for missing persons in some cases. In other cases, each municipality is responsible for fire and rescue services (Chapter 3, Section 7 of the Civil Protection Act).

At 19:04, the air traffic control tower in Västerås informed the Joint Rescue Coordination Centre (JRCC) that the aeroplane has disappeared from radar. During this call, a telephone call was received from one accident survivor of those on board the aeroplane who reported that they had crashed in the woods and that everyone had survived the accident. The caller did not know their position, which is why the operator at the JRCC asked whether he was able to see the coordinates on his mobile phone. The signals from the aeroplane's emergency transmitter (ELT)[21] could be heard clearly in the background of this call.

In the minutes that followed, a helicopter was called out at the same time as it was established that the signals from the ELT could not be

[21] ELT – emergency locator transmitter.

detected by any station. However, the WGS[22] coordinates given by the crash victim appeared to lead to a position out in Lake Mälaren, which is why the JRCC asked the accident survivor for new coordinates at 19:14.

With the aid of radar images from Stockholm Air Traffic Control Centre (ATCC), it was possible to restrict the search area to the area south-east of Västerås. The direction had initially been given incorrectly as to the south-west. The new coordinates from the accident survivor's mobile phone, combined with information from the radar, led to the crash site being confirmed as Ängsö at 19:28. At this point, a rescue helicopter, Lifeguard 001, was directed towards the presumed accident site. Because of the poor weather, neither the air ambulance helicopter nor the police helicopter could take off.

At 19:48, the JRCC called the accident survivor and informed him that the helicopter would arrive in approximately five minutes and that land-based rescue services were also on their way to the site. At this time the student in the left hand front seat had managed to get out from the aeroplane wreckage.

Having located the aeroplane wreckage and selected a safe landing site, the rescue helicopter was able to land at 20:04. The land-based rescue services arrived at the accident site at 20:08.

Once the flight instructor, who still was trapped, had been taken out of the wreckage, and all the injured transported to hospital, an environmental rescue operation also was conducted, with the site being cleared of approx. 100 litres of aviation fuel. The rescue services operation was terminated at 22:20.

The ELT of the type Artex ME406 was activated during the occurrence and deactivated by the rescue services.

1.16.1 Use of seat belts

All those on board were wearing seat belts during the flight. The investigation conducted by SHK shows that all the belts were intact following the accident. However, the attachments to the front belts had torn free at the points where they attach to the fuselage (see Section 1.15).

1.17 Tests and research

1.17.1 Calculation of altitude

The pressure altitude during the final stages of the flight can be calculated using the air pressure data from each engine's FADEC. Combined with the radar data that was recorded, a trajectory can be

[22] WGS (World Geodetic System) is a global reference system for determining position by means of coordinates.

established that demonstrates with a high degree of probability the aeroplane's vertical movements during the sequence of events, see Figure 15.

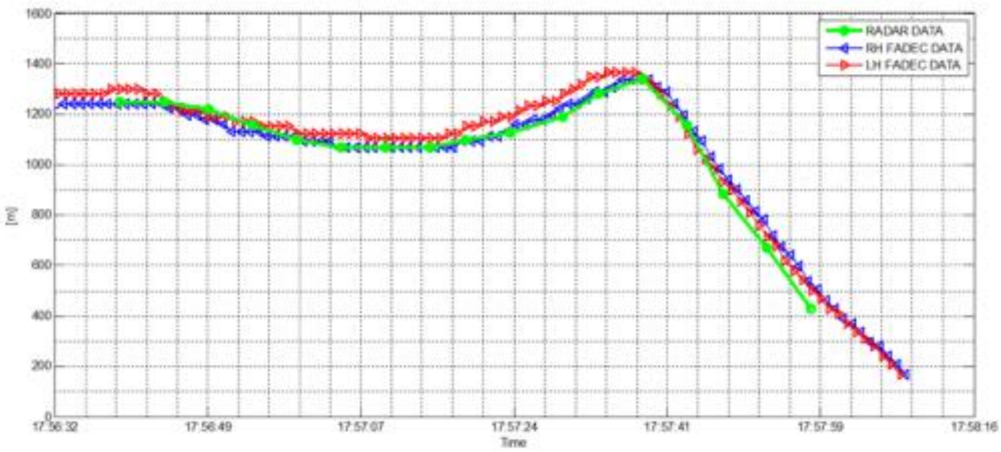


Figure 15. Combined data from radar and right and left FADEC respectively.

As earlier stated, see the graphic in Figure 5, the rate of descent was approx. 52 m/s (approx. 10,236 ft/min) during the initial phase of the spin. The diagram also shows that there was a gradual reduction in the rate of descent, which can be estimated at 19 m/s (approx. 3 700 ft/min) at the time of the impact with the first trees. For details of these calculations, please refer to Appendix 1 to the report.

1.17.2 Calculation of engine power

According to data from the FADECs, the engine power varied during the just over 30-second-long sequence of events. The parameters that have been analysed can be seen in the graphic in Figures 6 and 7.

Three episodes where the engine was throttled to high power have been recorded during the sequence of events. Each of these had a duration of approx. 3 seconds, after which sequences of approx. 7 seconds of low power are recorded. The power increases were synchronous, i.e. no difference between the left and right engines has been established. For details of these calculations, please refer to Appendix 1 to the report.

1.17.3 Calculation of the aeroplane's attitude

The aeroplane's attitude at different phases of the sequence of events has been calculated on the basis of the aeroplane's performance from the AFM, its actual mass, centre of gravity and configuration and data in accordance to point 1.17.1 above. Because some assumptions have had to be made, these calculations cannot be claimed to be totally exact. Nevertheless, the basic values that are available can be regarded as entirely reliable, which is why the calculated values for the aeroplane's attitude are probably very close to those that actually occurred in reality.

The rate of climb during the final climb prior to the manoeuvre can be estimated at approx. 9 m/s, with a nose-up attitude of approx. 16°. The rate of climb during the entry into the “deep stall” manoeuvre can be estimated at approx. 18 m/s, with a nose-up attitude of approx. 52°. For details of these calculations, please refer to Appendix 1 to the report.

1.17.4 Examination of the ELT

Because the ELT signals were not detected by any stations, SHK decided to have the ELT unit examined by a maintenance organisation. The examination showed that the unit functioned but that the outgoing signals to the antenna were weak, which was probably caused by the battery being weak at the time of the test.

1.17.5 General information about stalls and spins

An aeroplane’s – or a wing’s – lift is produced by the air that is forced downwards when the wing meets the surrounding stream of air at a certain speed and angle of attack. If the speed decreases, the angle of attack must increase in order to maintain the lift. The wing’s drag also increases when the angle of attack is higher. When a certain critical angle of attack is achieved, the lift decreases and the lift capacity of the wing ceases and the wing stalls.

Practising stalls during training normally involves reducing the aeroplane’s speed until it reaches a critical speed window at which a stall can occur. Depending on a range of factors such as bank, configuration, mass, centre of gravity, etc., a stall can result in the aeroplane displaying various patterns of movement when the stall occurs. In the most common form – stall straight forward – the result is usually a drop of the nose together with an increased rate of descent. Depending on the type of aeroplane, vibrations or buffeting may occur.

The intention of these exercises is to teach student pilots to recognise and identify the signs when the aeroplane is stalling or approaching a stall and how to safely recover from these potentially dangerous situations.

Stalls can also occur in other ways. A dynamic stall occurs if a rapid change in the aeroplane’s attitude is initiated or a high angle of attack arises in some other way. The rapid loss of lift in the event of such a manoeuvre usually results in a full stall in which the nose of the aeroplane abruptly turns downwards. Exactly how a specific type of aeroplane behaves in the event of such a manoeuvre is dependent on a range of factors and is normally tested when the type is undergoing certification. The DA42 is not approved for any type of dynamic stall and has not therefore undergone any flight tests with respect to this.

If the aeroplane is given a tendency to yaw during the stall – pilot induced or caused by external yaw forces – an asymmetrical loss of the wings' lift can occur. In such a situation, where the inner wing has lost the majority of its lift at the same time as the drag has increased, the aeroplane is turned along its own longitudinal axis and the stalling aeroplane begins rotating. This spinning movement takes place with completely or partly stalled wings, with an attitude and speed of rotation that can vary significantly between different aeroplane types. In the event of a low nose, the rate of descent is often high, while a higher nose (flat spin) normally results in a lower rate of descent.

The method generally used to recover from a spin, as recommended in the EASA's certification specifications CS-23, is:

- Power to idle
- Neutral ailerons
- Opposite rudder
- Stick forward – until the rotation ceases
- Resume normal flight

The Swedish expression "vikning" is used to describe the moment when the nose of the aircraft drops in a stall, but has no equivalent in the English reference literature where the term full stall, with an uncontrolled downward pitching motion, is used as an expression for this moment.

A dynamic stall, where the attitude abruptly is changed to high angles of attack, can result in a deep stall, where an aircraft with highly placed stabilizer for example could end up in a situation where the stabilizer is "shaded" and therefore loses most of its lift.

1.17.6 Aerobatic flying

According to the Swedish Aviation Agency's regulations (LFS 2007:45) concerning aerobatic flying, aerobatic flying denotes intentional manoeuvres that involve a sudden change in the aircraft's attitude or a sudden change in its speed; manoeuvres with a bank of 60° or more or a pitch of 30° or more are always aerobatic flying.

These regulations also define the term "limited aerobatic flying". This term also encompasses manoeuvres such as stalls and full stalls. Exercises in this category may be performed during training and with instructors who do not have specific training in aerobatic flying.

The following apply to both categories of aerobatic flying:

- the aeroplane must be approved for the manoeuvre that is to be performed,
- the flights may only be undertaken in daylight,
- all manoeuvres must be completed at least 1,500 feet above land or cloud tops, and

- if there are accompanying passengers, information about the intended manoeuvres must be provided to them prior to the flight.

1.17.7 Test flights for investigation purposes

At the request of SHK, the type certificate holder, Diamond Aircraft, has stated that they do not intend to conduct any flight tests in order to attempt to recreate the sequence of events during the accident.

SHK has also considered the possibility of conducting such flight tests, but dismissed it, partly because of the obvious high risks entailed and partly because this would involve flying outside of the aeroplane's approved flight envelope.

1.18 Organisational and management information

1.18.1 General

Airways Flygutbildning Svenska AB was at the time an approved training organisation (ATO) that held a valid training permit issued by the Swedish Transport Agency with the number SE-ATO-012. The most recent oversight inspection was conducted in the fourth quarter of 2015.

The flight school had permission to undertake the flight training operations that were conducted during the flight in question. The school mainly provides practical flight training. The training course that was being run on this occasion, conversion of American FAA certificates to European EASA certificates, does not have a syllabus that has been approved by the EASA with respect to its content and scope. The programme for this training course has therefore been put together by the school itself – with the approved training plan for IR/ME training used as a basis – and contains elements that include 15-hours' flight training and two skill tests.

On its programme, the school had several training courses for both private and commercial pilot licences, as well as other specially focused advanced training courses. According to information obtained, training that leads to a commercial pilot licence forms the bulk of the school's operations. Practical training is provided principally using three single-engine aeroplanes of model DA40 and the twin-engine aeroplane, DA42, that was involved in the accident.

Airways Flygutbildning has approximately 25-years' experience of providing flight training and there are a number of instructors associated with the company, some of whom are permanent employees and some who work at the school on a temporary basis. The school's owner – also the school's head of training – also works as an instructor in flight operations. The company has been operating from Västerås Airport since 2012.

1.18.2 The school's training programmes

According to the school's own marketing, the goal of the commercial pilot training course is for students to be ready for conversion to large aircraft following completion of the training. The school's representatives have stated in interviews that the goal of the school's commercial pilot training course is for students to be able apply for jobs as a first officer within commercial aviation.

The DA42 aeroplane type is commonly used for flight training with multi-engine aeroplanes. This type has duplicate controls for manoeuvring from both the left and the right pilot seats. A substantial proportion of the training programme on twin-engine training consists of one engine operations, approaches and stalls and approach to stall.

The current EASA regulations (Part-FCL) stipulate that this part of the training for IR/ME shall encompass recognition of – and recovery from – situations involving incipient and full stalls.

Description of the exercise stall

After the accident the Head of Training at the school has provided SHK with a description of the exercise: *Stall / recovery procedures used at AW – TM (Training Manual) IR/ME,* where the exercise is described as:

> *Deep stall / clean configuration: Moderate to full power, nose up approx. 30°, bank approx. 30°.*
>
> *Action: Reduce power during deep stall (vikning), follow the a/c with neutral rudders and when nose under the horizon adjust power, wings level and nose up.*

The exercise is described in such a way that the student shall be able to perform it. However, as mentioned previously, the DA42 is not approved for any type of dynamic stall. Any detailed description of the exercise – or how to perform it – has not been present in the school's manuals.

The normal execution of this manoeuvre - according to the school - is only 15-20 ° nose-up attitude and 20 ° banking where after the air-plane stalls and a controlled recovery can be performed. The reason that the flight school has chosen to call the exercise "deep stall" is that foreign students are not familiar with the Swedish expression "vikning".

According to information from representatives of the school, exercises containing full stall have always been part of the school's training programmes. The school uses these exercises to teach students to recognise and recover from abnormal situations and thus fulfil the training plan for exercises such as stalls and full stalls. According to the school cannot the described manoeuvre in any way be compared to a dynamic stall. If stall, turning or wing drop occurs shall, according to the school, the exercise be discontinued.

Description of the exercise $VMC_{(A)}$

The following exercise in the section *stall / stall recovery procedures* in the manual is described as following:

> *Demo VMCA clean configuration up to vikning/roll.*
>
> *Action: Power off, follow the a/c below horizon increase power when VMCA+, wings level, pick up blue line speed with full power on active engine.*

$VMC_{(A)}$ is the lowest speed at which the aeroplane can be controlled in flight by means of flight controls during one engine operation. However, according to the AFM, the aeroplane is not approved for stalls with asymmetric power or with one engine inoperative.

1.18.3 UPRT

EASA has tightened up the requirements with regard to training programmes within the area of prevention of abnormal flight situations – and recovery of control in the event of such – known as upset prevention and recovery training (UPRT). These requirements are described in the regulations in ED Decision[23] 2015/001/R, with an account of the expanded training programmes set out in ORO.FC.220 and 230, which apply as of 4 May 2016.

However, the requirements only encompass operators and pertain to training in simulators. Work to produce implementation regulations for UPRT as a part of basic training of pilots is currently taking place within the EASA and is expected to be completed in 2018. UPRT is not to take place at ATOs until these regulations have been adopted by the European Commission.

1.18.4 Regulations

Flight operations that are to be undertaken with the EU are governed by the common aviation provisions contained within Regulation (EC) No 216/2008 of the European Parliament and of the Council on common rules in the field of civil aviation and establishing a European Aviation Safety Agency. Compliance with these provisions is supervised at the EU level by the European Aviation Safety Agency (EASA), which also supervises the member states' national aviation organisation and supervisory authorities.

Training operations of the type conducted at the school in question are regulated by Commission Regulation (EU) No 1178/2011, Annex VII, Part-ORA, Subpart ATO. This sets out the requirements that an approved training organisation must fulfil in order to receive permis-

[23] ED Decision (Executive Director Decision) – EASA decision.

sion to conduct flight training. These requirements pertain to areas including finance, personnel, training manuals, operations manuals, premises, aeroplanes equipped with duel controls, etc. The requirements also stipulate that the organisation in question draw up a management system, encompassing both a safety management system (SMS) and compliance monitoring system (CMS).

The national supervisory authority for aviation, i.e. the Swedish Transport Agency in Sweden, has to approve the planned operations and also supervise them while operational.

At the request of SHK, the EASA has stated that flight training operations are not considered commercial air transport (CAT), i.e. transport of passengers, goods or mail for remuneration, but that one of the goals of a flight school should be to achieve the same level of flight safety as applies to operators who operate in accordance with the provisions for CAT.

According to Article 18 (c) of Regulation (EC) No 216/2008 of the European Parliament and of the Council on common rules in the field of civil aviation, the EASA is to issue, when necessary, instructions concerning acceptable means of compliance with the regulation's requirements and guidance material for the application of these. However, no guidance material has been produced for the practical implementation of flight training at approved training organisations.

In conjunction with the investigation or the accident that occurred, SHK sent a letter to the EASA that contained some of the factual information gathered during the investigation.

Aside from pointing out the responsibility the training organisation in question has with respect to the identification and prevention of hazardous elements in its operations, the EASA's response also contained the following points of view and questions:

- Deep stall is not defined in Regulation (EU) No 1178/2011 as the exercise has no relevance to commercial pilot training.
- How has the element called "deep stall" been approved in the training course in question?
- Has the training organisation been aware of the limitations in the aeroplane's flight envelope as per its AFM?
- Has the training organisation been aware of the certification requirements for this class of aeroplane as per CS-23?
- How has the continuous supervision of operations been conducted with respect to aviation safety and evaluation of risk?

1.18.5 Approval of the school's operations

The company is inspected prior to the commencement of operations. This initial inspection is conducted by the Swedish Transport Agency in accordance with the requirements stipulated in Commission Regulation (EU) No 1178/2011, Annex VII, Part-ORA, Subpart ATO. A PI is also among the inspectors who participate in the initial inspection.

The organisation's safety and quality systems (SMS and CMS) is also scrutinised during the initial inspection. According to the applicable regulations, the operator's SMS has to show how it assesses and manages the potential aviation safety risks that may arise in its operations.

The intention of the CMS is to ensure that the operator has a plan for its systematic safety management that involves operations being continually monitored and discrepancies and risks being captured. The system shall supervise all operations and also rectify any safety deficiencies that are identified.

The school's training manual, containing the syllabus for the various training courses provided, is also scrutinised during the initial inspection. The applicable regulations stipulate *which elements* are to be included in various types of flight training. However, there are no regulations that describe *how* these elements are to be practised.

The practical implementation, i.e. how the flight lessons are conducted, is therefore not subject to scrutiny during the initial inspection, instead it is presumed that this can be dealt with by the school's SMS and CMS. The exercise that was being practised when the accident occurred was not described in the school's training manual. The manual does also not state the conditions, e.g. in terms of entry altitude and meteorological minima, under which stall exercises may be conducted.

Following the initial inspection, a consultation takes place with the participating inspectors from the Swedish Transport Agency during which the overall impression of the flight school is assessed with respect to the potential approval of the organisation. At this point, the organisation is also assigned a risk level that forms the basis of future operational supervision.

1.18.6 Operational supervision

According to the regulations in Commission Regulation (EU) No 1178/2011, Annex VI, Part-ARA, Subpart ATO, the national supervisory authority shall conduct regular supervision of flight training operations. In Sweden, this supervision takes the form of regular oversight inspections, VK1 and VK2, conducted by the Swedish Transport Agency. The major inspection, VK1, involves a review of the entire company's operations. The inspections are conducted every 12–24 months, depending on the level of risk established for the organisation. The smaller inspection, VK2, is an intermediate, less extensive inspection that is normally conducted every 12 months.

The oversight inspections are conducted in accordance with check-list laid down in Part-ARA. The main aim is to monitor the organisation's compliance with both regulations and the procedures and systems the organisation describes in its own manuals. The implementation of VK1 includes a practical element in which the Swedish Transport Agency's inspector – normally a PI (Principal Inspector) – goes along as an observer on at least one training flight.

According to information from the Swedish Transport Agency, only minor remarks and discrepancies have been noted during the oversight inspections conducted at the school, primarily with respect to the management system's SMS and CMS. However, the exercise in question involving "deep stall" was not included in the training syllabus that was subject to the Swedish Transport Agency's scrutiny.

1.18.7 Action taken

SHK-Swedish Transport Agency

Following this accident, SHK has sent an official letter to the Swedish Transport Agency regarding the observations made in conjunction with the accident, as well as information that the exercise during which the accident occurred is still included in the school's training programmes.

The Swedish Transport Agency has also submitted a response to the recommendation issued in report RL 2016:05, accident involving SE-GIC at Malmö/Sturup Airport, in which the Swedish Transport Agency was recommended to:

During the certifying process and operational controls of air training organisations to tighten its supervision concerning the identification of training elements that might entail increased flight safety risks. (RL 2016:05 R3).

In its response to SHK, the Swedish Transport Agency has also included actions that pertain to the accident involving SE-LVR and has made it known that the following action will be taken:

The following new questions will be asked of the operator during oversight inspections:

- In what way does the organisation ensure that the limitations stated in the flight manual are not exceeded during flight, especially in exercises that include abnormal situations?

- What risks have the flight school established with regard to exercises involving abnormal situations?
- What action has the flight school taken in order to minimise the risk of flight exercises that involve practising abnormal situations?

However, the Swedish Transport Agency has not announced that any action will be taken against the flight school as a consequence of the manoeuvre in question still being included in the training courses.

SHK-EASA

SHK has also posed certain questions to the EASA as a result of the observations made in conjunction with the investigation of the accident.

The EASA has also submitted a response to the recommendation issued in report RL 2016:05, accident involving SE-GIC at Malmö/Sturup Airport, which recommended that the EASA:

Identify exercises in flight training that might entail an increased risk factor and to issue guidance material (GM) for the practical execution of these. (RL 2016:05 R1).

In its response to SHK, the EASA has stated that issuing guidance material is not appropriate as the levels of risk vary depending on the type of operations. According to the EASA, these risks have to be evaluated and minimised by the individual operators themselves, taking into account the type of operations and the types of aeroplane being used for flight training. However, with reference to the serious accidents that have now occurred, SHK is of the opinion that the EASA’s response is not satisfactory. Please refer to Section 2.8

Airways Flygutbildning

Following the accident, the flight training organization has decided that the exercise in question will no longer be conducted in darkness and under IMC.

The school also claimes that the flight maneuvers executed at the accident deviated from how the school has described the exercise. Performing the maneuver was done with a too high nose-up attitude and moreover in darkness and partly IMC.

According to the school, the accident was caused by that the instructor during the accident flight exaggerated the flight control movements, with e.g. high nose-up attitude, as a result of the darkness and limited visual references, and that this resulted in that he did not observe that the aircraft rapidly was approaching a hazardous situation.

2. ANALYSIS

2.1 Circumstances

2.1.1 The exercise

The exercise – “deep stall” – that was to be conducted was not described in the school’s syllabus for IR/ME training. After the accident the school has described the exercise in the section: *Stall / stall recovery procedures used at AW.* SHK considers that this description founded the base for the exercise at the occasion.

More detailed descriptions of how the stall and stall recovery training should be carried out according to the EASA syllabus does not exist. The lack of detailed instructions means that it is up to the individual flight school to decide how the exercise should be performed. The only limiting factors are the aircraft operating envelope, the instructor's training and experience and results from the flight school's risk assessments.

2.1.2 The aeroplane

The Diamond DA42 is certified in accordance with the provisions in JAR-23/CS-23. These regulations include testing of the aeroplane’s characteristics and behaviour in the event of a stall. However, the tests conducted do not encompass the form of advanced and dynamic stall exercises that have been conducted at the school.

The results of the type certificate holder’s flight tests constitute the basis of the limitations that are described in the aeroplane flight manual (AFM) for this model and approved in conjunction with the certification. With the support of a statement from the type certificate holder, SHK can conclude that the exercises conducted by the school are very close to the limits in the aeroplane’s approved flight envelope as there is a risk that the aeroplane will enter a dynamic stall if the execution of the exercise contains fast and abrupt change of the wing’s angle of attack.

The risk to enter situations with uncontrolled stall or spin also increases with the very steep (30 ° - 50 °) nose-up attitudes that has been applied in the exercises. According to the school's own manuals, the exercise should be discontinued if stall, turn or wing drop should occur during the manoeuvre. In SHK's view, however, these instructions are of minor importance as the aircraft - when any of the above occurs – at that point already has been maneuvered into a potentially hazardous situation.

This assessment also applies to the exercise that, according to the school’s training programme, is conducted in conjunction with demonstration of $VMC_{(A)}$ up to “vikning”/roll. At these occasions however, the aircraft is already operated outside the approved operations envelope, as DA42 is not permitted to stall with asymmetric engine power.

2.1.3 *The flight instructor*

The instructor had no specific training in aerobatic flying. His experience of exercises involving, for example, spins was limited to the demonstrations and exercises he undertook on single-engine aeroplanes in conjunction with basic training.

SHK has assessed the manoeuvre performed to be aerobatic flying. A manoeuvre with an attitude of approx. 50°, a bank of 30°, full power on both engines and a conclusion in which the stick is fully pulled back cannot reasonably be regarded as the type of stall indicated in the section of LFS 2007:45 concerning limited aerobatic flying.

With reference to the degree of aerobatic flying that was involved in the exercise in question, the instructor cannot in all respects be said to be qualified to perform – or to teach – manoeuvres of this type. Dealing with and mastering all the situations that may arise when performing manoeuvres that are as advanced as the “deep stall” demonstration in question requires – aside from an aeroplane approved for the manoeuvre – that the person who is to perform it have both training and experience.

The instructor on this flight had no experience of the consequences – a spin – that can, under some circumstances, arise when an aeroplane is intentionally forced into a dynamic stall with high attitude and simultaneous banking. The accident may serve as an example of shortcomings in terms of the ability to assess a manoeuvre’s level of risk.

2.1.4 *Preparations*

The prevailing conditions on the day in question were good for flight training under instrument meteorological conditions, with low cloud base in the area around Västerås. No operational or technical problems were known prior to the planned training flight. According to what emerged during the interviews, no specific briefing with the students concerning the demonstration of “deep stall” planned by the instructor had taken place prior to the first flight, aside from instructor having asked the students if they had experienced a “deep stall” previously.

The students expected that the training flight would include standard exercises including holding pattern procedures and instrument approaches. The students were therefore not – at least during the first flight – specifically prepared for the manoeuvre that was performed.

During training flights of this type, the instructor is always the commander. The format of the flight and the exercises that were to be performed must – aside from the educational content – be planned by this person in such a way that flight safety can be maintained throughout all phases of the flight.

However, as mentioned above, the instructor has only minimal experience of exercises involving spins and had only limited knowledge of how to safely recover from such a situation. In addition, neither of the students had any specific training in aerobatic flying. Their experience of stalls and spins was limited to the demonstrated exercises during basic training conducted in single-engine aeroplanes approved for aerobatic flying.

None of those on board during the flight in question can thus be regarded as having been very familiar with performing and dealing with manoeuvres of the type that came to be included in the exercise, especially with respect to hazardous secondary effects.

2.1.5 The prevailing weather

As mentioned previously, the weather can be regarded as having been suitable for the standard exercises, including instrument approaches, that were planned for the training flight. The prevailing weather conditions cannot be deemed to be anything other than strongly unsuitable for the demonstration of such advanced exercises as full stalls.

The vertical layer of relatively clear air that was available – calculated from the top of the manoeuvre at approx. 4,500 feet, down to the cloud top at c. 2,000 feet – was thus only 2,500 feet. According to the applicable regulations in LFS 2007:45, all aerobatic manoeuvres must be completed at least 1,500 feet above the ground or cloud tops. In the present case, the margin was 1 000 feet, which cannot be regarded as a safe margin for performing such an advanced and hazardous manoeuvre.

In addition to the tight vertical margin, it was also dark at the time and that the air was misty, with visibility of 10–15 km. The lack of moonlight due to the scattered cloud layers above meant that it was almost completely dark at the time of the exercise. The underlying cloud cover also meant that there were minimal opportunities to use visual references from lights on the horizon.

All in all, it can be concluded that the manoeuvre in question was performed with a limited vertical margin in the dark and almost under instrument meteorological conditions (IMC). Regardless of the spin that occurred, SHK is of the opinion that the manoeuvre would probably not have been performed had there been an accurate risk assessment.

2.1.6 Flight training

Dealing with unexpected and unplanned situations during flight is a normal element of flight training and must to be part of a flight instructor's mental preparations prior to every flight lesson. Student pilots make mistakes and can sometimes deal with situations that arise in a way that is unexpected, at the same time as one of the manoeuvres demonstrated by the instructor can have an unforeseen outcome. However, this can be regarded as constituting normal aspects of a flight training course and depends on the instructor always being prepared for unplanned situations.

Consequently, it is of the utmost importance that an instructor always has an alternative plan of action and preparedness to act in the event that an exercise or demonstration does not proceed as planned. In the case of the accident in question, nothing has emerged to indicate that the instructor was prepared for – or had knowledge of – the aerodynamic phenomena that can be the result of the hazardous manoeuvre that was performed.

Learning to know your aeroplane and being able to master it under varying conditions forms the core of all flight training courses. This training course also includes practising simulated emergency situations – e.g. stalls – in which flight sometimes takes place at the margins of the aeroplane's approved envelope. Practising such situations must always take place under safe conditions with good margins in case a student is unable to recover from a situation or an exercise is unsuccessful.

The investigation of this accident has shown that the school in question has regularly conducted exercises of the type that caused the accident. These exercises have been conducted as a recurring element of commercial pilot training with students that are sometimes unprepared and in conditions that have entailed an increased risk factor. Practising stalls is an important element of the training plan for prospective commercial pilots, however not the type of stall performed at the school in question.

2.2 The occurrence

2.2.1 The beginning

When the instructor was to demonstrate the deep stall manoeuvre, this was probably under the assurance that everything would go well. The exercise had been conducted previously without other consequences than that the aeroplane had stalled. The instructor was, at least on the basis of what emerged during the interviews, not prepared for a circumstance in which anything else hazardous could occur. An analysis of the operational circumstances in which the manoeuvre was to be performed on the evening in question can be summarised as follows:

- No one on board the aeroplane was trained in aerobatic flying.
- No one on board the aeroplane had any notable experience of spins or of recommended techniques for recovering from these situations.
- The instructor was not completely aware of the aeroplane's operational limitations as per the AFM.
- The flight was not planned in accordance with the regulations in LFS 2007:45 pertaining to aerobatic flying.

The entry into the manoeuvre probably fulfilled the criteria to be defined as a dynamic stall. The aeroplane was brought rapidly into a steep climb in which the nose-up attitude was at least 50°, at the same time as a bank was set. With this attitude – and full power on the engines – the stick was finally pulled fully back when the aeroplane was tending to stall.

It is SHK's belief that this manoeuvre was not only aerobatic, it was almost a textbook example of a high-risk manoeuvre with respect to the risk of entering a spin. It has not been possible to establish why the aeroplane actually entered a spin on this occasion, when it had previously only entered a full stall. There are, however, several possible reasons:

For example, on this occasion the manoeuvre may have been performed steeper and more abruptly. A small – potentially corrective – rudder deflection may also have caused a lateral movement at the same time as the aeroplane's mechanical tendency to yaw (see Section 1.6.3) probably amplified the lateral movement and thus initiated the spin. However, any analysis of the reason why aeroplane entered a spin is only theoretical as this has not been tested in accordance with the certification requirements laid down for this category of aeroplane.

It may also be a possibility that there was some ice coating on the aeroplane's wings and stabiliser following the climb through clouds. Coating of any type degrades the aeroplane's performance and can, for example, have a detrimental impact on the aeroplane's stall characteristics.

The school has presented a perception that the accident was a result of that the instructor exaggerated the flight control movements with e.g. too high nose-up attitude. The prevailing darkness and limited visual references would have meant that the instructor in this situation had difficulties to assess the situation and its potential hazards.

SHK can however conclude that the instructor earlier in the day had performed the manoeuvre in question – which according to the interviews was performed with the same steep nose-up attitude - with the other student. At this session the student had experienced a "roller – coast feeling" and that the manoeuvre was "aerobatic". The exercise was performed during good weather and light conditions. This indicates that the high nose-up attitude during the second flight not deviated from the instructor's normal execution of the exercise.

2.2.2 The spin

When the aeroplane "rolled over" at the top of the manoeuvre, it very quickly entered a spin to the left. According to information from the interviews, the movement was perceived as a flat spin with the nose somewhat under the horizon and a high speed of rotation. SHK cannot verify or analyse the perceived flight situation in more detail as no spin tests have been performed with the DA42 and there is therefore a lack of reference material to use for comparison.

Nevertheless, it can be established that the rate of descent during the initial phase of the sequence of events was approx. 52 m/s (approx. 10 200 ft/min), which is why those on board probably perceived this part of the sequence of events to be not just surprising, but also dramatic and frightening.

It has not been possible to establish what flight control movements were then performed during the sequence of events. However, neither of the students could remember the stick having been pushed forward at any time. The rudder pedals were not visible from the students' positions, but given that the student in the back seat called "opposite rudder", it is probable that he had noticed at this stage that the instructor had not set opposite (right) rudder. The student in the front remembers that he called "power to idle" – but not when this took place.

All in all, this paints a picture that indicates the actions taken and the flight control movements performed were not the result of a rational and conscious thought process, instead they demonstrate a pattern of behaviour characterised by confusion. The correct primary actions required to recover from a spin – power to idle, opposite rudder, stick forward – were probably never performed during the sequence of events.

Instead, the instructor attempted to correct the spin by increasing engine power on three occasions. This probably resulted in the initiation of some raising of the nose, but had no positive impact on the spin. It has not been possible to determine the reason why the speed of rotation decreased for a short time, but the possibility that an isolated rudder deflection to the right – potentially in conjunction with a reduction in power – may have temporarily reduced the rotation cannot be excluded.

2.2.3 *The impact*

As mentioned previously, the spin was initiated with the aeroplane in a nose-down attitude. Section 1.6.8 contains a description of how increased engine power during a spin acts to raise the nose. This is amplified in the event of a left spin and clockwise-rotating propellers – as is the case on the DA42. The three cyclical power increases performed during the sequence of events therefore resulted in the aeroplane’s nose being gradually raised.

This raising of the nose resulted in a gradual reduction in the rate of descent over the course of the just over 30-second-long sequence of events. When the aeroplane hit the tops of the first trees, the rate of descent had decreased to approx. 19 m/s (approx. 3 700 ft/min) – which contributed greatly to the accident becoming survivable by the three people on board.

The rotation decreased and rate of descent was further reduced when the aeroplane hit the trees. The aeroplane’s wing tips hit the surrounding trees, further reducing the energy of the movement. At this point, the aeroplane also hit a Scots pine that was broken in such a way that the trunk penetrated the fuselage. In the final stage of the sequence of events – when the aeroplane twisted itself around the trunk – the passenger in the back seat was thrown out of the aeroplane. With a significantly reduced rate of descent and rotation, the remains of the aeroplane hit the ground with a slight nose-down attitude and minimal forward speed (see Figure 16).

Figure 16. The wrecked aircraft.

Because of the special circumstances, it has not been possible to calculate the vertical impact forces. However, it is clearly the case that the collision with the trees, especially the rotation around the penetrating tree trunk, significantly reduced the aeroplane's vertical speed.

2.3 Survival aspects

The passenger who was sitting in the back seat was thrown out during the sequence of events, probably at the time the tree penetrated the aeroplane. It can only be regarded as improbably lucky that he survived the collision with the tree, a fall from a height of perhaps 10 metres and then avoided being hit by the aeroplane – which probably had rotating propellers during this sequence of events. The passenger had no memory of the sequence of events involved in the crash, but came to his senses standing in front of the wrecked aeroplane with injuries that were less serious than those of his trapped colleagues.

The root end of the penetrating Scots pine occupied almost the entire space where the right back seat had been (see Figure 14). It can be concluded that the passenger's chances of survival would have been almost non-existent had he remained in his seat when the impact took place. The two people in the front seats remained in the aeroplane as it came down and were to some extent jammed tight in the front of the aeroplane between the seats and the instrument panel.

The reason why this part of the aeroplane was not totally destroyed can probably be attributed to the shock-absorbent elements that absorbed a large proportion of the vertical impact forces that arose during the impact. However, the safety belts' attachments had not coped with these forces; instead they were found to have come loose from their attachments to the fuselage.

According to the type certificate holder, these attachments are designed and constructed in accordance with current regulations. SHK is of the opinion that these regulations could be reviewed in order to investigate the feasibility of making the requirements concerning the attachment of safety belts on this type of aeroplane more stringent.

The wiring from the aircraft ELT- unit to the antenna was destroyed on impact. Although signals from the unit were heard after the impact, the signals without antenna were too weak to be received over longer distances. With a different sequence of events - with its occupants incapacitated - could the absence of ELT signals have implied a serious setback in the search for the accident site.

The overall impression of why this serious accident became survivable for those on board can be expressed as a combination of fortunate circumstances and the robust construction of the aeroplane's cabin section with shock-absorbent elements at the seats' attachment points.

2.4 The search and rescue operation

Because of the prevailing circumstances, the wrong position initially having been given, ELT signals that were not registered and the weather conditions, it may be considered reasonable that it took one hour from the alarm being raised until the first rescue team arrived at the accident site. The reason why the wrong position was given initially is probably that the system used to give the position (WGS) had different options for stating coordinates.

A misunderstanding in terms of – or failure to state – which WGS option was used to determine the position, i.e. degrees or decimals, may involve a significant geographic displacement of the position of the accident site. It is therefore important that the emergency operator is certain about which option the person raising the alarm is using. This should also take into account the fact that a survivor from a plane crash is probably in shock or injured and thus cannot always be expected to provide accurate information.

The signals from the ELT that was activated by the forces involved in the impact have not been detected by any receiving stations. The examination of the unit that SHK had performed has shown that the transmissions from the unit were weak as a result of a weak battery. The reason why no signals could be detected by any receiver units was probably that both the cabling and the antenna were damaged by the forces involved in the impact.

2.5 The school’s quality and safety systems (SMS and CMS)

As mentioned previously, the performed exercise – and also the demonstration of $VMC_{(A)}$ – were performed on the outer limits of the approved flight envelope of the aircraft. The occurrence clearly shows the risk of accidentally ending up outside the aircraft's approved operating envelope and in a dangerous situation that cannot safely be recovered.

This way of operating in the border zone to what can be described as hazardous conditions, where an inadvertent rudder movement or an external disturbance in some circumstances may be enough for the aircraft to enter a spin, indicates according to SHK’s opinion, deficiencies in the operator's risk assessment of the operations at the flight school.

It may be regarded as a serious failing in a training organisation’s SMS that said organisation does not have the ability to assess which exercises or manoeuvres that are close to - or outside - the aeroplane’s approved flight envelope and therefore not might be approved or could imply increased risk to flight safety.

In practice, this has come to mean that the level of aviation safety at the school demonstrated failings, which has ultimately led to the accident that has now occurred. The basic premise of the SMS as a safety barrier is that potential risks and safety failings in the organisation are identified. Operations at the school must therefore be characterised at all levels by the awareness of safety necessary in order to guarantee the highest possible level of aviation safety.

When safety failings are established during operation, the control function CMS must identify and rectify the discrepancies and failings with respect to the SMS that may arise in the organisation. SHK contends that there could hardly have been a stronger warning signal than an accident of the type that now occurred. However, the only action on the part of the school that has been noted following the accident is that the exercise in question is no longer conducted in darkness and under IMC.

SHK is of the opinion that the accident that occurred – in which three people nearly lost their lives – should reasonably have resulted in the exercise in question being removed from the school's training programmes as it is close to the aeroplane's operational envelope limitations and not complies with the EASA's training programme. The fact that this has not taken place is demonstrative of failings in the school's own systematic safety management.

According to the EASA, student pilots are to be guaranteed the same level of aviation safety as passengers in the commercial air transport (CAT) category. It can be concluded that operations at the school in question have not been capable of living up to this objective.

2.6 Full stall ("vikning") as part of commercial pilot training

Aside from the obvious aviation safety risks associated with demonstrating the exercise called "deep stall" in the way the flight school did, it can also be questioned whether the exercise was at all appropriate in conjunction with commercial pilot training.

According to the majority of flight schools, the goal of commercial pilot training – or, as in this case, conversion of licences– is to train and prepare the students for their future careers as pilots in the commercial air transport category.

Full stall is a manoeuvre that is not in any way included in the normal operation of a commercial airliner. This manoeuvre constitutes an exercise drawn up by the school and can be characterised as a deviation from the stall practice that is normally included in this training course. A pilot who is, for example, undergoing type training on an aeroplane in order to use it privately may possibly benefit from practising – or trying – full stalls during their practical training in the aeroplane. However, it is hard to see how this exercise is necessary for prospective commercial pilots.

Nevertheless, SHK has no opinions concerning whether flight schools choose to offer similar exercises in some form of supplementary course. If this is the case, however, these exercises must be conducted under safe conditions, with specially trained personnel and in aeroplanes that are approved for aerobatic flying.

The prevention of – and recovery from – abnormal flight (UPRT, see Section 1.18.3) constitutes a supplement to the pilot training that was introduced for operators. However, there are no applicable regulations pertaining to the type of training that is conducted at the school in question. It is SHK's opinion that the implementation of the exercise in question indicates that the school has, to some extent, anticipated the new training rules that now apply to operators and has applied these as part of the training course.

All in all, SHK believes that the exercise element "deep stall" performed at the school is, for the following reasons, highly inappropriate as part of the school's training programme for commercial pilot training:

- the exercise is associated with an obviously increased risk to aviation safety,
- the element is performed by instructors who are not trained in aerobatic flying (stalls and spins),
- the exercise is performed using an aeroplane that is not approved for aerobatic manoeuvres or dynamic stall, and
- the exercise is conducted on the initiative of the school itself and, in its present format, is not part of the requirements for commercial pilot training.

2.7 Supervision

2.7.1 EASA

Training student pilots in a manner that is appropriate for a career in commercial aviation is dependent on aviation safety being given the highest priority throughout all phases of this training. SHK's understanding is that the exercises currently being conducted at some flight schools do not comply fully with this requirement.

Basic training of commercial pilots is not to focus on producing individuals who are the quickest and most effective at dealing with the loss of an engine at the lowest height or recovering from a full stall in the best way. Instead it is to focus on training individuals whose judgement – and deeply conditioned aviation safety culture – enables them to deal with a demanding future within commercial aviation.

The EU has established the common aviation agency EASA in order to meet the demands for high aviation safety within the Union. This work cannot simply be targeted at the existing commercial aviation sector, but must also take aim at the training of those individuals who will be administering and improving common aviation safety in the future. Within the scope of this, the EASA can play an important role in improving the safety of training activities within the EU's member states.

SHK has investigated two total losses that occurred during training on light twin-engine aeroplanes at Swedish flight schools, the accident described in this report and an accident at Malmö/Sturup Airport on 27 June 2015. Both of these accidents have resulted in serious injuries. Furthermore, they both share the common trait that they were caused by factors that included failings in *the application* of the content of some of the syllabuses' training elements.

Commission Regulation (EU) No 1178/2011 lays down requirements for minimum levels in terms of what has to be practised in different categories of flight training. However, the EASA has not drawn up any guidance material for flight schools concerning how these exercises are to be implemented in practice or what limitations should be applied when practising certain elements. SHK believes that guidance material of this type could contribute to improving the safety of approved training organisation's operations. This also applies to the conversion of commercial pilot licences.

2.7.2 The Swedish Transport Agency's supervision

The Swedish Transport Agency is responsible for applying the European aviation regulations in Sweden and has to guarantee that the highest possible level of aviation safety is maintained by the operators that are encompassed by its supervision. During the initial inspection that is conducted at organisations such as the one in question, the school's potential to conduct flight training in an appropriate and safe manner is scrutinised.

Because the regulations concerning approval of training organisations for civil aviation (ORA) do not contain any instructions concerning the practical realisation of flight lessons, it is understandable that the exercises involving full stall were not directly addressed in conjunct-tion with the school being granted approval.

The exercises called "deep stall" have – as far as SHK has been able to ascertain – not been discussed during the regular oversight inspec-tions that have been carried out.

Nevertheless it is part of The Swedish Transport Agency's response-bilities during continuous supervision to identify and assess exercises with a level of risk that for many reasons do not meet the requirements for a reasonable level of flight safety. According to SHK, the presence of guidance material would facilitate supervision related to certain parts of flight training.

The principal aim of exercises containing stall and approach to stall is for a student pilot to learn to identify and correct flight situations in which the aeroplane is, for example, approaching critical airspeed. Aside from the fact that aerobatic flying of the type in question is dangerous, it hardly increases the student’s ability to safely deal with a situation involving a stall.

Performing stalls with high attitude, full engine power and while banking in a twin-engine trainer that is not approved for aerobatic manoeuvres constitutes a sharply increased risk factor. If a training organisation is unable to identify such risks itself in its systematic flight safety management work, the Swedish Transport Agency must have methods of capturing and preventing these during the regular supervisions that are carried out.

2.8 Overall assessment

SHK believes that it must be possible to guarantee students at flying schools the same level of aviation safety as afforded to passengers on commercial flights. This opinion is shared by the EASA. However, the two accidents resulting in serious injuries that have occurred during commercial pilot training in Sweden in the past two years show that there are deficiencies in the current systems that need to be remedied in order to achieve this.

On the one hand, the EU legislative framework leaves too much scope for the flight schools to determine the content and thus the level of risk of the individual exercises and on the other, the Swedish Transport Agency’s permit issuing and supervision do not have a sufficient ability to identify hazardous elements and subsequently implement appropriate supervisory measures. At the same time, questions are raised as to whether smaller operators are able to create, maintain and develop safety management systems (SMS/CMS) that are reliably and fully functional.

The response SHK has obtained from the EASA regarding recommendations in report RL 2016:05 cannot be regarded as addressing the deficiencies reported. SHK is of the opinion that the EASA has too great trust in the individual flight schools’ quality and safety management systems and their ability to identify and deal with risks. Risk assessment is not an exact science and the assessment of the level of risk of any one exercise may vary depending on the assessor. It can also be difficult – before an accident occurs – to contend that the exercise is too hazardous to be conducted.

The fact that an exercise has been conducted previously without consequences or incidents is often accepted as evidence that it is safe. This is not necessarily the case, which this investigation clearly demonstrates. Accordingly, there are grounds from a safety perspective to set out a framework for how training exercises are to be conducted, i.e. indicate in an overall plan what risk levels are acceptable and may not be exceeded.

In contrast to the EASA, SHK does not believe that the basic risk evaluation in exercise plans should be allowed to vary between different flight training organizations. However, the individual exercises may – during implementation and within this framework – need to be adapted on the basis of factors including the current weather conditions, the aeroplane's performance and how experienced the instructor and students are. The guidance material would thus not replace the flying schools' own safety management systems, instead it would set limitations for what activities are undertaken.

In the light of this, SHK is still of the opinion that guidance material would make it easier for, above all, smaller flying schools to conduct accurate risk assessments and draw up a syllabus that does not contain unacceptably high risks to the students. The EASA has not addressed these matters in any more detail in its response to the previous recommendation. SHK is therefore directing a renewed recommendation to EASA with the same content as in the previous report.

The Swedish Transport Agency's initial approval and supervision has not been capable of identifying hazardous exercises, either during the initial inspection or during continuous supervisions. As far as SHK is aware, no direct supervisory measures have been implemented as a result of the accident either. Although this can be explained partly by the lack of guidance from the EASA and possibly an all too great trust in the flight school's own ability to identify and deal with risks in its operations.

The actions that have been reported by the Swedish Transport Agency as a consequence of the recommendation in report RL 2016:05 indicate that there is a plan to reinforce the supervision in this area and SHK can conclude that these actions are a step in the right direction towards improved aviation safety.

3. CONCLUSIONS

3.1 Findings

a) The flight instructor was formally qualified to carry out the training flight.
b) The aeroplane had a Certificate of Airworthiness and valid Airworthiness Review Certificate.
c) According to the type certificate holder, the manoeuvre performed was not permitted in accordance with the aeroplane's AFM.
d) The DA42 is not certified – or flight tested – for dynamic stalls or spins.
e) The instructor had no specific training in aerobatic flying.
f) The manoeuvre – both that which was performed and that described in the school's training programme – has been assessed by SHK to be aerobatic flying.
g) The sink rate during the initial phase of the sequence of events was approx. 52 m/s (approx. 10 200 ft/min).
h) The correct actions to recover from a spin was not taken during the sequence of events that resulted in the accident.
i) An increase in engine power was recorded on three occasions during the sequence of events that resulted in the accident.
j) The safety belts in the front seats did not cope with the forces involved in the impact.
k) There is no formal syllabus for the conversion of commercial pilot licences.
l) There is no guidance material for the practical implementation of flight lessons.
m) The manoeuvre performed is not part of the EASA syllabus for commercial pilot training.
n) A risk assessment of individual elements of flight training is not included in the Swedish Transport Agency's initial inspections and continual supervision.
o) According to the regulations issued by EASA, assessment of safety and risk is to be dealt with by the organisation's SMS and CMS.
p) Signals from the ELT could not be detected due to damaged cabling leading to the antenna.
q) The first unit from the rescue services reached the accident site one hour after the accident.

3.2 Causes

The accident was caused by the following factors:

- The high risk factor of the exercise.
- Deficient planning of the training exercise with respect to the options for managing hazardous situations.
- Lack of guidance from the authorities concerned regarding practical implementation of certain exercises within flight training.

4. SAFETY RECOMMENDATIONS

The EASA is recommended to:

- Identify exercises in flight training that might entail an increased risk factor and to issue guidance material (GM) for the practical execution of these. (*RL 2017:04 R1)*

The Swedish Accident Investigation Authority respectfully requests to receive, by **21 June 2017** at the latest, information regarding action taken in response to the safety recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Mikael Karanikas Stefan Christensen

Appendices - Calculation of altitude trajectories, engine power and attitude. (Swedish only).

Uppdrag för statens haverikommission

Beräkning och analys av höjdkurvor, motoreffekt samt attityd i samband med olycka med flygplanet SE-LVR den 22 januari 2016 utanför Västerås.

Kristoffer Danèl

2016-11-26

Beräkning och analyser har huvudsakligen baserats på data från ombordburna enheter på flygplanet, erhållna radardata samt uppgifter från flygplanets godkända AFM.

Beräkning av höjdkurvor

En av de registrerade parametrarna i FADEC är barometertryck. I det aktuella fallet antas det att det registrerade barometertrycket motsvarar det statiska omgivningstrycket. Lufttrycket varierar med höjden dels p.g.a. av att mängden luft som finns ovanför minskar (hydrostatisk variation) och dels på att temperaturen varierar med höjden (termodynamisk variation) . Det finns ekvationer som väl beskriver dessa variationer, så kallade ekvationer för standardatmosfär. I standardatmosfären varierar temperaturen linjärt med höjden inom den så kallade troposfären, dvs. upp till 11000 meters höjd över medelvattenståndet och kan uttryckas med:

$$a = \frac{dT}{dh} = 0.0065 \;\; [{}^{K}/_{m}] \qquad (1)$$

det hydrostatiska sambandet i differentialform för trycket är :

$$dp = \; -\rho g_0 dh \qquad (2)$$

där dp är den infinitesimala förändringen av lufttrycket, ρ är luftens densitet , g_0 gravitationskonstanten (9,81 8 [m/s^2]) och dh är den infinitesimala förändringen av höjden. Termodynamiskt samband mellan lufttryck, temperatur och densitet beskrivs väl inom det aktuella temperaturområdet av den allmänna gaslagen:

$$p = \; \rho RT \qquad (3)$$

där R är den specifika gaskonstanten som för luft antar värdet 287 [J/(kg K)].

för att kunna beräkna aktuell höjdskillnad mellan två olika avlästa tryck , delas (2) med (3):

$$\frac{dp}{p} = \frac{-\rho g_0 dh}{\rho RT} = -\frac{g_0}{RT} dh \qquad (4)$$

enl (1) är $h = \frac{dT}{a}$ vilket sätts in i (4),

$$\frac{dp}{p} = \frac{-\rho g_0 dh}{\rho RT} = -\frac{g_0}{aR}\frac{dT}{T} \qquad (5)$$

och integreras :

$$\int_{p_1}^{p} \frac{dp}{p} = -\frac{g_0}{aR}\int_{T_1}^{T} \frac{dT}{T} \longrightarrow \frac{p}{p_1} = \left(\frac{T}{T_1}\right)^{-\frac{g_0}{aR}} \qquad (6)$$

efter algebraisk manipulation av utrycken ovan fås slutligen det sökta utrycket:

$$\underline{h - h_1 = \frac{\left(\left(\frac{p}{p_1}\right)^{-\left(\frac{aRT_1}{g}\right)} - T_1\right)}{a}} \qquad (7)$$

Vid uträknandet har h_1 ansatts till nedslagsplatsens höjd , vilket inledningsvis inte var känt och därför sattes till 0 [m]. Temperaturen , T_1 på denna höjd sattes till 278.15 [K] vilket motsvarar 5 [°C].

När radardata med höjdinformation blev tillgängligt korrigerades dessa höjder.

När väl höjdvariationen med avseende på tid har beräknats kan vertikalhastigheten beräknas med $V_z = \frac{dh}{dt}$. (8)

Beräkning av motoreffekt och dragkraft

Flygplanets två FADEC-enheter registrerar även parametern "Load" vilket enklast kan beskrivas som det procentuella motoreffektuttaget av maximal tillgänglig motoreffekt. Den maximala tillgängliga motoreffekten beräknas i realtid och kan avvika från den nominellt uppgivna maximala effekten hos motorn, ($P_{NomMax} = 123.5$ [kW]). Den effekt en förbränningsmotor utvecklar beror på hur mycket bränsle som förbränns per tidsenhet och hur effektiv förbränningen är. De parametrar som registreras av FADEC, och som ger bäst information av aktuellt effekttuttag är: Motorvarvtalet (RPM), ingastrycket (MAP), insugsluftens temperatur (TAir), bränsleinsprutningstryck (PRail) samt duration för bränslespridarnas öppnande (valve duty cycle). I analysen gjordes endast en kvalitativ jämförelse mellan nyss nämnda parametrar och parametern Load. Jämförelserna gjordes mellan tillstånd vid tidigare flygningar och den aktuella flygningen. Baserat på dessa jämförelser bedöms det att i det aktuella fallet kan parametern Load approximeras som procentuell last i förhållande till nominell last.

Via propellern omvandlas motorns axeleffekt till dragkraft. Denna omvandling kan ske olika effektivt. Propellerns effektivitetsmått eller propellerverkningsgraden representeras av symbolen och kan beräknas enligt: $\eta_{prop} = \frac{T_a V_\infty}{P_{axel}}$, (9)

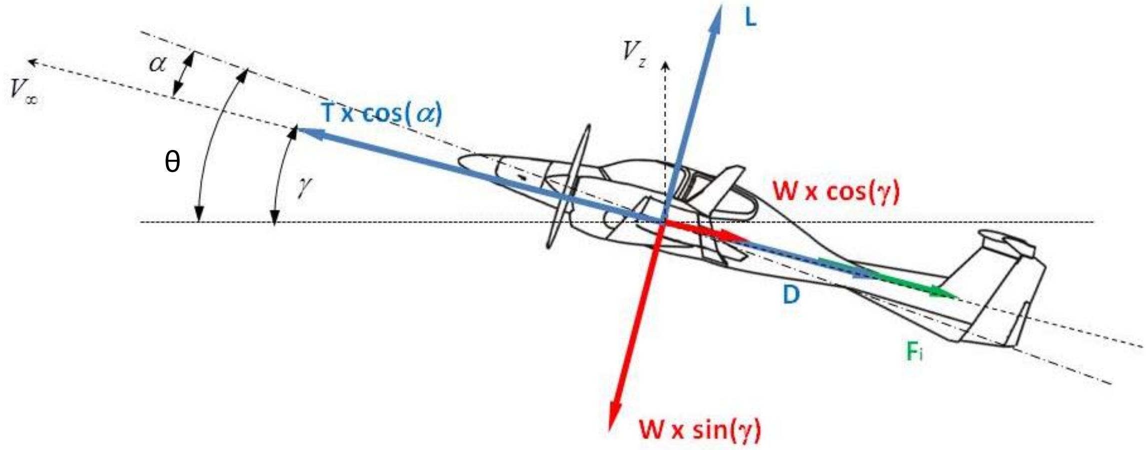
där T_a är aktuell dragkraft som propellern genererar, V_∞ är luftens friströmshastighet och P_{axel} är motorns aktuella axeleffekt. Dragkraften kommer i varje ögonblick att vara samma som luftmotståndet, kraft komposanten från flygplanets trajektoria gentemot horisontalplanet samt flygplanets acceleration i längdled. Enligt definition är effekt lika med dragkraft multiplicerat med framåtfart vilket benämns framdrivningseffekt. För att erhålla dragkraften blir utrycket således:

$$T_a = \frac{\eta_{prop} P_{axel}}{V_\infty} = \frac{\eta_{prop}\, Load\; P_{NomMax}}{V_\infty} \quad (10)$$

Propellerverkningsgraden varierar bland annat med varvtal , propellerbladsvinkel och framåtfart, där data vanligtvis återfinns presenterade av propellertillverkaren i så kallade "propeller performance chart". Dessa uppgifter fanns dock inte tillgängliga vid den aktuella analysen. Propellerverkningsgraden har istället uppskattats med ett iterativt förfarande med prestandadata från AFM som grund.

Beräkning av flygplanets attityd

En del i uppdraget var att beräkna flygplanets attityd vid den den konstanta stigningen samt under manöverns sista skede innan stallen inträffade. Figuren nedan visar vilka krafter som verkar på flygplanet under stigning.



Flygplanets attityd representeras av grekiska bokstaven θ. Det som är givet är flygplanets massa, motoreffekt samt stigfart. I det första fallet antas att flygplanet stiger med konstant framåtfart, dvs. termen **F_i** är 0. Detta antagande är rimligt då stigfarten V_z är konstant under denna fas. θ är summan av anfallsvinkel α och γ, vinkeln mellan horisontalplanet och flygplanets trajektoria.

Sambandet för γ är : $\gamma = asin\left(\frac{V_z}{V_\infty}\right)$ (11)

Flygplanets massa tilldelas bokstaven **W** (flygplanets massa multiplicerat med jordaccelerationen)

Flygplanets framåtfart kan erhållas genom kraftbalans av ekvation (10) och flygplanets samlade motstånd **D**, och kraftkomposanten från flygplanets aktuella massa och vinkeln γ , som tillsammans med utrycket för stigeffekt bildar ett ekvationssystem.

Ett flygplans motstånd **D** kan delas upp i ett sk nollmotstånd, bestående av friktion och tryckmotstånd från luftströmmen kring flygplanet, och ett lyftkraftsberoende motstånd så kallat inducerat motstånd. Det inducerade motståndet beror på flygplanets anfallsvinkel som i sin tur bland annat beror på flygplanets massa och framåtfart. Detta motstånd är ett mått på hur effektivt vingen (flygplanet) arbetar för att generera lyftkraft. Denna effektivitet beror på vingförhållndet, AR, och en konstant kallad Oswalds effektivetetetstal, e . Mer om detta kan läsas i [1]. För att underlätta jämförelser mellan olika flygfall delas lyftkraft och motstånd med det dynamisk trycket, q, och en referensyta, som i det aktuella fallet är flygplanets vingarea enligt AFM. På så sätt kan man enklare nyttja olika prestandadata, bl.a. från AFM, för analysen.

Följande ekvationer kan nu defineras :

$$q = \frac{1}{2}\rho V_\infty^2 \qquad (12)$$

$$D = D_0 + D_i \qquad (13)$$

$$CD = \frac{D}{qS} \qquad (14)$$

$$CD_i = \frac{C_L{}^2}{\pi e\ AR} \qquad (15)$$

$$CL = \frac{L}{qS} \qquad (16)$$

Effektbalans ger att:

$$V_z W = (TV_\infty - DV_\infty) \qquad (17)$$

--> $V_z W = V_\infty \left(T - \left(CD_0 + \frac{C_L{}^2}{\pi e\ AR}\right)\right)\frac{1}{2}\ \rho V_\infty^2 \leftrightarrow V_\infty = \sqrt[3]{\frac{2V_z W}{\rho\left(T - \left(CD_0 + \frac{C_L{}^2}{\pi e\ AR}\right)\right)}}$ (18)

De okända paramtrarna är CD_0, CL, e och η_{prop}

Från AFM fås att med flygmassan 1999 kg och på 600 meters höjd och 5°C,har flygplanet följande framåtfart vid oaccellererad flygning.

Tabell 1 Prestanda enl AFM

Effektuttag [%]	Framåtfart [knop]
92	164
75	148
60	131
45	106

Dessutom framgår i AFM att stallfarten vid flygmassan 1999 kg är 70 knop.

Lyftkraften är konstant i fallen ovan men CL kommer att variera. CL varierar med anfallsvinkel och denna varitaion kan approximeras med vingprofilens anfallsvinkelvariation. Enligt AFM är DA-42 vingprofil en modiferad Wortman FX 63-137 (Wortmann FX 63-137/20 - W4). Underlaget på profildata som användes för analysen har hämtats från [2].

Baserat på tabell 1, kan en approximativ motståndspolar erhållas, dvs. CL(CD), och via ett iterativt förfarande samt ansättning av e och η_{prop} , till e = 0.7och η_{prop} = 0.83 samt underlaget från [2], erhålles aproximativa värden för V_∞ och α för den aktella flygmassan och luftdensiteten.

$$\left.\begin{array}{l} V_\infty \approx 49\ [m\ /s] \\ \alpha \approx 4\ [°] \end{array}\right\}$$

Ekvation (11) och anfallsvinkeln ger flygplanets attitydvinkel $\theta \approx 14°$

För att beräkna attitydvinkeln vid stall nyttjas värdena för CL och α vid stall :

$CL_{stall} = 1.63$, $\alpha_{stall} \approx 14°$.

Med insättning av den aktuella flygmassan och densiteten, erhålls framåtfarten V_∞ . V_z har beräknats från FADEC data, och med samma tillvägagångssätt som tidigare beräknas γ och slutligen θ.

$$\left.\begin{aligned} \alpha &\approx 14° \\ V_{stall} &\approx 29\ [m/s] \\ \gamma &= 38° \end{aligned}\right\} \text{-->}\ \theta = 52°$$

Flygplanets attityd under manöverns sista skede innan stallen inträffade kan således beräknas till 52°.

Referenser

[1] H. Schlichting, Aerodynamics of the Airplane, McGraw Hill, 1979.

[2] S. S. Michael och B. D. McGranahan, ”Wind Tunnel Aerodynamic of six airfoils for use on smallwind turbines,” National Renewable Energy Laboratory, Golden, Colorado, 2003.