

Investigation Report

3X181-0/06
April 2010

Identification

Kind of occurrence: Accident
Date: 29 November 2006
Location: Mattsies
Type of aircraft: Fixed wing
Manufacturer/Model: Grob Aerospace / G 180A
Injuries to persons: Pilot fatally injured
Damage to aircraft: Aircraft destroyed
Other damage: Crop damage
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This investigation was conducted in accordance with the Federal German Law Relating to the Investigation into Accidents and Incidents Associated with the Operation of Civil Aircraft (*Flugunfall-Untersuchungs-Gesetz - FIUUG*) of 26 August 1998.

The sole objective of the investigation is to prevent future accidents and incidents. The investigation does not seek to ascertain blame or apportion legal liability for any claims that may arise.

The present document is the translation of the German Investigation Report. Although efforts were made to translate it as accurate as possible, discrepancies may occur. In this case the German version is authentic.

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Abbreviations

AC	Advisory Circular	Rundschreiben der FAA
ACJ	Advisory Circular Joint	Rundschreiben der JAA
AFM	Airplane Flight Manual	Flughandbuch
AMC	Acceptable Means of Compliance	Empfohlene Nachweisführung
A/E	Area of responsibility: Avionics/Electrics	Verantwortungsbereich Avionik / Elektrik
CAS	Calibrated Air Speed	Kalibrierte Fluggeschwindigkeit
CFK	Carbon Fibre Composite	Kohlefaserverstärkter Kunststoff
CVE	Compliance Verification Engineer	Musterprüfingenieur
CVR	Cockpit Voice Recorder	Tonaufzeichnungsgerät
CRI	Certification Review Items	Zulassungsdokumentation
DO	Design Organisation	Entwicklungsbetrieb
DOA	Design Organisation Approval	Entwicklungsbetriebs-Genehmigung
DoC	Declaration of Compliance	Übereinstimmungserklärung
DOH	Design Organisation Handbook	Entwicklungsbetriebs-Handbuch
DOK	Area of responsibility: Documentation	Verantwortungsbereich Dokumentation
EAS	Equivalent Air Speed	Äquivalente Fluggeschwindigkeit
EASA	European Aviation Safety Agency	Europäische Agentur für Flugsicherheit
ESS	Design Assurance System	Entwicklungssicherungssystem
FADEC	Fuel Authority Digital Engine Control	Digitaler Kraftstoffregler
FAR	Federal Aviation Regulations	Amerikanische Zulassungsvorschrift
FDR	Flight Data Recorder	Flugdatenschreiber
FLU	Area of responsibility: Flight Test	Verantwortungsbereich Flugerprobung
FP	Area of responsibility: Flight Physics	Verantwortungsbereich Flugphysik
FPA	Manufacturing and inspection Procedure	Fertigungs- und Prüfanweisung
GFK	Glas Fiber Composite	Glasfaserverstärkter Kunststoff
GM	Guidance Material	Zulassungsrichtlinien
HL	Horizontal Stabilizer	Höhenleitwerk
HoD	Head of Design	Entwicklungsleiter
HoDO	Head of Design Organisation	Leiter des Entwicklungsbetriebes

HOoA	Head of Office of Airworthiness	Leiter der Musterprüfleitstelle
HR	Elevator	Höhenruder
JAA	Joint Aviation Authorities	ehem. Europäische Zulassungsbehörde
JAR	Joint Airworthiness Requirements	Europäische Zulassungsvorschriften
LA	Area of responsibility: Loads	Verantwortungsbereich Lastannahmen
KCAS	Knots Calibrated Airspeed	Kalibrierte Fluggeschwindigkeit in kt
KEAS	Knots Equivalent Air Speed	Äquivalente Fluggeschwindigkeit in kt
KO	Area of responsibility: Design	Verantwortungsbereich Konstruktion
MFD	Multifunction Display	Bildschirm mit Multifunktionsanzeige
MOC	Means of Compliance	Art der Nachweisführung
MP	Area of responsibility: Certification	Verantwortungsbereich Musterprüfung
MPI	Compliance Verification Engineer	Musterprüfingenieur
MPL	Office of Airworthiness	Musterprüfleitstelle
NVM	Non-Volatile Memory	Nichtflüchtiger Speicher
OoA	Office of Airworthiness	Musterprüfleitstelle
PFD	Primary Flight Display	Hauptbildschirm für die Anzeige von Flugdaten
P0	Production Organisation	Herstellungsbetrieb
POA	Production Organisation Approval	Herstellbetriebs-Genehmigung
POH	Production Organisation Handbook	Herstellbetriebshandbuch
QA	Quality Assurance	Qualitätssicherung
QM	Quality Management	Qualitätsmanagement
QS	Quality System	Qualitätssystem
S/F	Area of responsibility: Statics & Strength	Verantwortungsbereich Statik & Festigkeit
SoC	Statement of Conformity	Konformitätsbescheinigung
SW	Area of responsibility: Software	Verantwortungsbereich Software
SYS	Area of responsibility: Non electrical Systems	Verantwortungsbereich nicht-elektrische Systeme
TC	Type Certification/Type Certificate	Musterzulassung/Musterzulassungsschein
TCDS	Type Certificate Data Sheet	Kennblatt
TRI	Area of responsibility: Engine	Verantwortungsbereich Triebwerk
VA	Procedure	Verfahrensanweisung

Synopsis

At 13:34¹ hrs on 29 November 2006 the German Federal Bureau of Aircraft Accident Investigation (BFU) was informed by the Search and Rescue service (SAR) of an accident to a Grob G 180A aircraft in Mattsies. Three members of BFU staff arrived at the accident site at about 21:00 hrs and began an investigation. Their arrival was preceded by an external expert for field investigation.

The aircraft had taken off from the Grob company airfield of Mindelheim-Mattsies at 13:12 hrs with the intention of demonstrating the aircraft' performance with a fly-past to a group of visitors on the ground at the invitation of the aircraft manufacturer.

After the G 180A had flown east around the village of Tussenhausen and turned to line up for the fly-past towards Mindelheim-Mattsies airfield, parts of the stabilizer detached. The aircraft rapidly lost height and at 13:15 hrs crashed into a meadow about 1,500 m south-east of the airfield.

The pilot was fatally injured and the aircraft destroyed in the crash. The cause of the accident was that the horizontal stabilizer broke up in flight due to aerodynamic flutter, with the result that the aircraft could no longer be controlled.

Due to the absence of flight data and the limited investigation options, it was not possible to conclusively determine the factors that led to the flutter.

Remark:

Following the insolvency of the design and manufacturing organisations -- and the associated termination of the G180A project -- the breadth and depth of the investigation into this accident was adjusted commensurate with the situation.

¹ Unless otherwise specified, all times are indicated in local time

1. Factual Information

1.1 History of the flight

The Grob G 180A aircraft was a prototype being operated for the Type Certification flight test programme and had landed at Memmingen airfield on 27 November 2006; it had been parked there until 29 November 2009 because the company airfield at Mindelheim-Mattsies was closed due to bad weather. The Type Certification flight test programme resumed during the flight to Mindelheim-Mattsies on 29 November. During a flight lasting about 60 minutes, the pilot conducted a number of manoeuvres and system tests before landing on the company airfield at about 11:40 hrs. The aircraft was parked on the ramp and prepared for the next flight.

At about 12:50 hrs the prototype was accepted by another company test pilot whose task was to demonstrate the aircraft in the air to a group of visitors on the ground. The plan was for the pilot to make a standard demonstration flight. This was to consist of a fly-past with landing gear retracted to demonstrate the aircraft in different flight attitudes to the observers on the company airfield. This was to be followed by a wide-radius left turn, followed by an approach and landing.

The test pilot who had conducted the flight that morning from Memmingen to Mindelheim-Mattsies was observing from the roof of a hangar on the works premises and had radio contact with the pilot in the aircraft. The pilot in the aircraft on Runway 33 reported to the observer that he was ready for departure and the planned demonstration flight.

The Grob G 180A took off at 13:12 hrs in a northerly direction. Shortly after take-off, the aircraft disappeared from the view of the airfield observer; witnesses stated that the aircraft had entered clouds. The aircraft reappeared descending into view at an increased bank angle in the right crosswind leg. The aircraft then continued in a slight descent, repeatedly entering and leaving clouds.

In the period from 13:13:28 hrs to 13:13:43 hrs the aircraft was detected as a radar reflection by the German Air Traffic Service, as being east of the villages of Zaisertshofen and Tussenhausen at Flight Level (FL) 25 (see diagram 1).

Witnesses observed how the Grob G 180A made a right turn east around the village of Tussenhausen towards Mindelheim-Mattsies airfield. Parts were seen to detach from the airframe as it flew between Tussenhausen and Mattsies. At 13:15 hrs, the aircraft impacted at a high rate of descent into a meadow between Tussenhausen and the airfield.

The aircraft was destroyed in the accident and the pilot fatally injured.

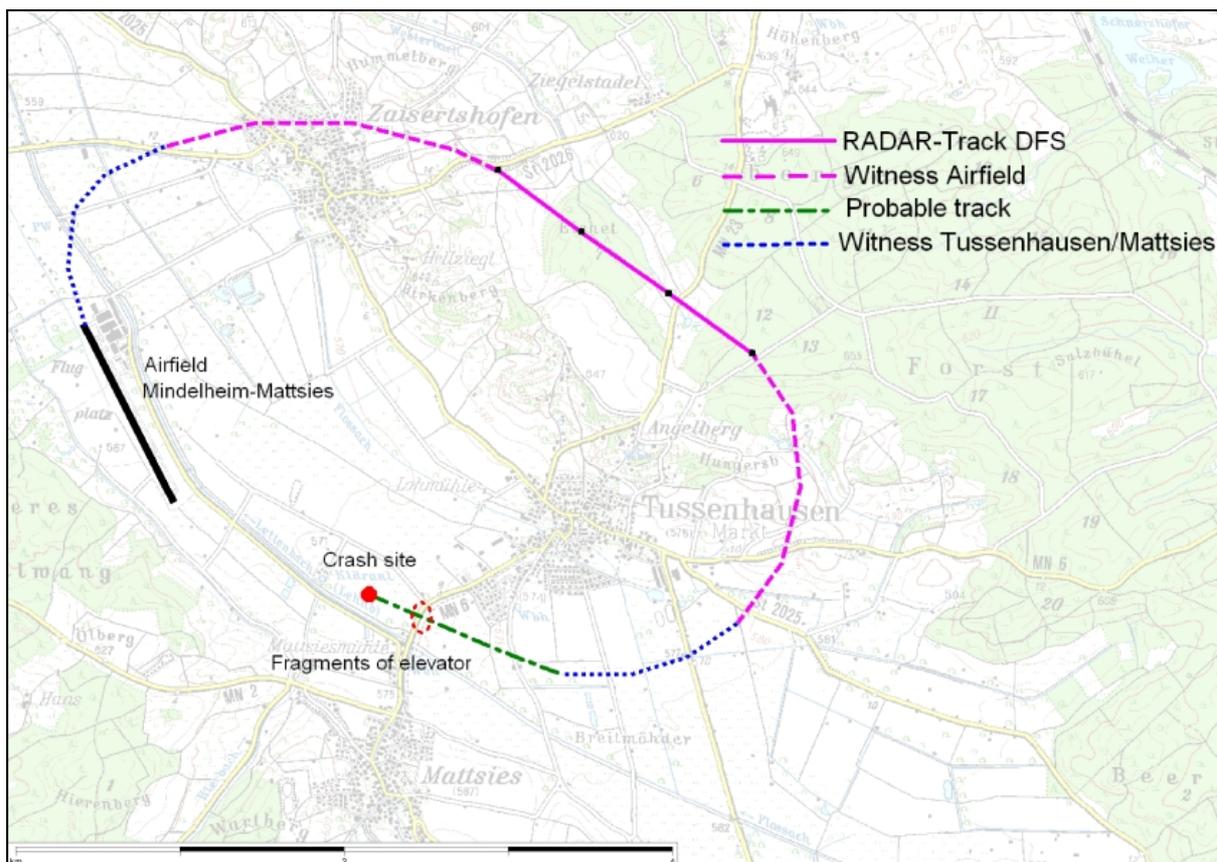


Diagram 1: Reconstructed flight track

Source: Bavarian State Cartographic Survey (Map), BFU (Flight Track)

1.2 Injuries to persons

Injuries	Crew	Passengers	Total	Other
Fatal	1			
Serious				
Minor				
None				
Total	1			

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

Following the accident, about 750 tons of contaminated soil was removed from an area of about 1,500 m² and replaced with non-contaminated soil.

1.5 Personnel information

The 45 year-old pilot was employed as the chief test pilot by the aircraft manufacturer. He was in possession of a Commercial Pilot's Licence (CPL(A)) issued in accordance with JAR-FCL rules. His licence had a number of ratings including that for Class 2 Test Flying. He was in possession of a Class 1 Medical Certificate valid to 22 January 2006, the Class 2 being valid to 22 July 2007. His total flight time was 7,800 hours, of which 257 were on the aircraft type in question.

He had trained in the French Air Force and had flown as a pilot, flying instructor and flight systems test pilot on a number of tactical aircraft. In 1999 he completed a course at the National Test Pilot School in the USA, qualifying as a test pilot.

Prior to joining Grob Aerospace GmbH in mid-2005 as a test pilot for the G 180A flight test programme, he had flown as Type Certification test pilot for single- and twin-engined aircraft on behalf of aircraft manufacturers in Germany, Austria and the USA.

1.6 Aircraft information

Type

The G 180A is a twin-engined aircraft whose structure consists of carbon fibre reinforced plastic (CFK). The low-winged aircraft has two FADEC-controlled jet engines mounted on the rear fuselage, and a cruciform tailplane. The aircraft was to be fitted with a glass cockpit and was designed for the following speeds and Mach numbers:

Design Cruising Speed:	$v_C = 270$ KEAS	$M_C = 0.7$
Design Diving Speed:	$v_D = 338$ KEAS	$M_D = 0.77$
Design Manoeuvring Speed:	$v_A = 180$ KEAS	$M_A = 0.5$
Maximum Operating Limit Speed (to 8,000 ft)	$v_{MO} = 260$ KCAS	
Maximum Operating Limit Speed (above 8,000 ft)	$v_{MO} = 272$ KCAS	$M_{MO} = 0.7$

The aircraft manufacturer planned to achieve Type Certification through the European Aviation Safety Agency (EASA) in the third quarter of 2007, and through the Federal Aviation Administration (FAA) in the fourth quarter of 2007.

The aircraft was conceived as a business jet and designed in accordance with Certification Specifications EASA CS-23 and FAA Part 23 for operation by a single pilot with nine passengers, or two pilots with eight passengers.

Prototypes

The accident aircraft was the second prototype (P2) and was built as part of the G 180A Type Certification programme. The first prototype made its first flight on 20 July 2005, since then this aircraft had flown 248 hours. The first prototype (P1) had neither a full glass cockpit nor a pressurized cabin, but these systems were installed in the second prototype. The intention had been to install further systems during the course of subsequent testing. The further intention had been to build a third prototype, which would then be identical with series-production aircraft in all essential aspects.

Aircraft manufacturer:	Grob Aerospace
Type:	G 180A
MSN:	90002
First flight:	29 September 2006
Max. take-off weight:	6,300 kg
Total flight time, airframe:	31 hr / 43 flights
Engines:	Williams FJ 44-3A

The prototype aircraft were not equipped to carry passengers.

Operation of the ailerons, elevator and rudder was by carbon fibre pushrods inside the fuselage, with the operating force transmitted to the control surfaces by shafts. The elevator trim tab was operated by an electric motor inside the fuselage. The motor was coupled to actuators within the stabiliser, in turn linked to the trim tabs by pushrods.

The aircraft was equipped with an integrated Honeywell Apex avionics system, the main components of which were: two Primary Flight Displays (PFDs); a Multi-Function Display (MFD); two PFD Controllers; a Flight Controller; an MF Controller; a Multi-Mode Digital Radio (MMDR); two Mode S Transponders; an Air Data Attitude Heading Reference System (ADHRS); a Magnetometer; an Audio Panel; two Modular Avionic Units (MAUs) and a Radar altimeter. These components were located in the cockpit, the front and rear avionics compartments. The autopilot servos had not been installed, and the autopilot was therefore non-operational.

In addition, the following instruments were fitted: an Integrated-Instrument (horizon, airspeed indicator, altimeter); one DME; one NAV/COM/GPS Garmin GNS 430; one Electronic Horizontal Situation Indicator (EHSI); a UHF System; and accelerometer (G-meter).

On 26 September 2006 the German Civil Aviation Authority (Luftfahrt-Bundesamt, LBA) issued a Permit to Fly for flights forming part of the Flight Test Certification programme, including positioning and demonstration flights. The Permit to Fly was only valid in conjunction with Flight Instruction 90002/1 and Flight Clearance Note No. 90002/3. The Flight Clearance Note permitted flights at sea level at speeds up to 297 kt. Speeds above the V_{MO} were only permitted for flight-testing. The maximum permissible load factor with flaps retracted was +3.1 g and -1.24 g. The Airplane Flight Manual (AFM) for P2 gave the V_{MO} up to an altitude of 8,000 ft as 260 kt CAS. Between 8,000 ft and 28,440 ft the V_{MO} was 272 kt CAS.

Horizontal stabiliser design and construction

The stabiliser was constructed primarily of carbon fibre (CF) reinforced plastic. The stabiliser outer extremities were manufactured of glass fibre reinforced plastic (GRP) and incorporated mass balances.

Stabiliser section	NACA 64010 modified
Stabiliser surface area	7.107 m ²
Stabiliser span	6.48 m
Stabiliser chord	Root: 1.65 m, Tip: 0.54 m
Stabiliser sweep-back 25 %-line	20.84°
Elevator-reference surface	1.595 m ²
Elevator chord	0.26 m
Elevator deflection	+30°, -22°
Elevator trim tab surface area	0.182 m ²
Elevator trim tab length	1.38 m
Elevator trim tab chord	0.13 m
Elevator trim tab deflection	+10°, -30°



Diagram 2: Prototype P1 of the Grob G 180A

Photo: ILA-Berlin

1.7 Meteorological information

The general aviation weather forecast (AFWA/GAFOR) valid for 29 November 2006 from 12:00 to 18:00 UTC for Southern Germany stated:

Weather Situation:

Baden-Württemberg and Hessen will be under a cold front with light rain under which there will be widespread haze and low cloud, moving slowly eastwards. The QNH was 1,030 hPa.

Wind aloft:

3,000 ft 310/10kt

Freezing level:

Between 6,000 ft in the West, and 8,000 ft in the East.

Visual Flight Rule forecast:

Area 72: M5, M5, M5

(M5 = horizontal visibility 5 –< 8 km, cloud base above mean sea level 500 –< 1,000 ft)

Witnesses said that at the time of the accident, the weather in the vicinity of the accident was:

Clouds: 8/8 at about 1,000 ft AGL

Wind: about 300° / 2-3 kt

Horizontal visibility at surface level: about 10 km

Temperature: about 4 °C

1.8 Aids to navigation

None

1.9 Communications

The pilot in the aircraft was in radio communication with the pilot observing from the ground. Communications were not recorded.

1.10 Aerodrome information

The company airfield at Mindelheim-Mattsies has a 1,149 m x 20 m asphalt runway in the directions 15/33. The airfield elevation is 1,857 ft above mean sea level.

1.11 Flight recorders

1.11.1 Flight Data Recorder und Cockpit Voice Recorder

The prototype P2 had no Flight Data Recorder (FDR) or Cockpit Voice Recorder (CVR) on board. The installation of crash-resistant recording equipment was not required either by the aviation regulations or the National Aviation Authorities.

1.11.2 Data logging

The aircraft was fitted with a number of sensors and data recording systems for use in the flight test programme. There was no telemetry equipment on board the P2 prototype for transmission of data to a ground station.

The data logging system units were installed in two 19-inch racks. The Honeywell Rack had two computers. These were to gather data for a number of parameters including testing the autopilot, and were non-operational during the accident flight.

The second rack consisted of three components:

- Video system

The video system consisted of a VHS recorder and a hard disc DVD recorder. Neither of these was in operation during the accident flight.

- ASCB-Logger

The ASCB logger was installed in a 19-inch housing. The computer had two hard discs arranged piggyback. The 3.5-inch hard disc recorded all data from the ASCB bus. These also served as a FIFO buffer for the downstream tape recorder. Data on the hard disc was the same as that on the tape deck.

- KAM 500

The KAM 500 Logger was installed on its own 19-inch rack. A selected quantity of calibrated ASCB data was transferred via a configuration file to the KAM 500 data logger, where it was stored on a 4GB CF card. In addition, this card stored data from other sensors (e.g. data from the nose-boom, control surface deflection and control forces). This data could be accessed by the pilot via a supplementary display in the cockpit.

The storage medium with the data relevant to investigation of this accident was identified as magnetic tape type HP AIT-1 70GB; it was badly damaged and soiled.

1.11.3 Radar data

On the downwind leg the air traffic control radar service detected four targets flying towards the airfield.

The ground speed was measured as 245 kt +/- 10 kt. From this radar data the airspeed was calculated to be 240 kt with a tolerance of +/- 10 kt.

1.12 Wreckage and impact information

The accident site was about 1,500 m south-east of the threshold to Runway 33 of the company airfield at Mindelheim-Mattsies. The accident site is about 572 m above mean sea level.

The aircraft first made contact with the ground wings level and penetrated about 1 metre into the ground. From this point, wreckage was strewn over a path about 200 metres long and 120 metres wide. Surface marks left by wreckage and their scatter pattern indicated that the aircraft heading was about 280°.

The aircraft was destroyed by the impact. Most of the fragments were less than 10 cm x 10 cm. Aggregate components such as the landing gear and avionics were fragmented.



Diagram 3: Accident site

Photo: BFU

The wings made distinctive marks in the ground at the point of initial impact, where the residue of the main spar was found. Traces of fire were found in and around the impact crater. In this area, some of the carbon fibre components were reduced to ashes.

Due to the degree of destruction, it was not possible to determine the position of the flaps or landing gear at the time of the accident.

Parts of the elevator, the lower shell from the left stabilizer, and the leading edges from both stabilizers, were found about 400 metres prior to the point of initial impact. These components were found in a field scattered within an area about 100 m x 50 m. Small carbon fibre fragments were found south-east of this field several hundred metres away.

Part of the left elevator horn with mass balance was found between the two main areas of wreckage.



Diagram 4: Parts of the horizontal stabiliser found prior to the main point of impact

Photo: BFU

Examination of the stabiliser

All identifiable stabiliser components were separated from the remaining wreckage and rearranged in their original positions (see appendix). Examination of the stabiliser and elevators revealed the following:

1. The pattern of damage to the residual components provided no indication of Foreign Object Damage (FOD).
2. The total damage pattern pointed towards a rapid structural failure at different positions.
3. There was noticeable symmetrical similarity in the damage to the left and right stabilisers.
4. A continual fracture was found on the left stabiliser, running in the direction of flight via the leading edge, stabiliser and elevator (near the third elevator bearing).
5. Symmetrical fractures were found in the stabiliser leading edges, both left and right.
6. There were symmetrical cracks left and right above the main spars in the stabiliser upper shells.
7. Both elevator horns bore clear traces of their supplementary weights (lead shot in resin); the mass balances were absent.



Diagram 5: Parts of the left stabiliser

Photo: BFU



Diagram 6: Parts of the right stabiliser

Photo: BFU

1.13 Medical and pathological information

A post-mortem examination was conducted of the pilot's body. The pilot died as a result of the aircraft impact with the ground. The examination found no other reason for pilot incapacity.

A chemical and toxicological examination of samples produced no evidence of the misuse of alcohol, drugs, medication, or the exposure to fuel or carbon monoxide.

1.14 Fire

Fire broke out when the aircraft hit the ground. The fire was limited to an area less than 10 metres in diameter around the point of impact. Individual parts scattered more widely around the point of impact showed traces of fire arising from explosion or deflagration.

1.15 Survival aspects

In view of the high-energy impact, the accident was not survivable.

1.15.1 Rescue system

A rescue system had been incorporated for the test-flying programme; in an emergency, the pilot's seat was to shift towards the door. The test pilot had a parachute, which was subsequently found unopened.

1.15.2 Emergency Location Transmitter

The aircraft was equipped with an Emergency Location Transmitter (ELT) for frequencies 406 MHz, 243 MHz and 121.5 MHz. This was installed in the rear fuselage.

The RCC Münster subsequently reported that, at 18:23 hrs on 29 November 2006, one single emergency transmission was detected by a satellite on frequency 406.025 MHz. No further emergency transmissions were detected on frequencies 121.5 MHz, 243.0 MHz or 406.025 MHz.

An examination of the ELT unit revealed fractured internal connections between the transmitter and the antenna socket. In addition, the connector to the 406.025MHz antenna had sheared off.

1.16 Tests and research

None

1.17 Organisational and management information

1.17.1 Company

The Grob G 180A aircraft was designed and built as a prototype by Grob Aerospace GmbH. The factory was located in Tussenhausen-Mattsies with facilities for design and manufacture, where the company also had its own airfield. Since 1971 the company had designed and built a range of composite fibre structure aircraft (sailplanes, self-launching motor gliders, training aircraft and others for special purposes e.g. Strato high-altitude reconnaissance).

Grob Aerospace GmbH was a subsidiary of Grob Aerospace AG in Zurich, Switzerland, with the sales office for the Grob G 180A aircraft.

1.17.2 Design organisation

Grob Aerospace GmbH was certificated by the European Aviation Safety Agency (EASA) as a design organisation in accordance with EASA Part 21, Section A, sub-part J. The approval encompassed the design of aircraft in accordance with CS-23, sailplanes, motor gliders and piston-engined aircraft.

The Design Organization Handbook (DOH) defined the basic structure of the organisation, responsibilities, the scope of technical development and the essential procedures and operational sequences in the design organisation. At the time of the accident, Version 5.2 of the DOH was valid; Version 6.0 was finished and was undergoing the approval process. A number of witnesses stated that Version 6.0 was then in use. For this reason, any further references to the DOH in this report will refer to Version 6.0, unless otherwise stated.

The company consisted of design, compliance verification, quality management, quality assurance, and production / maintenance. The production / maintenance and quality assurance roles were the responsibilities of the Grob Factory.

In particular, this included the production and maintenance of prototypes and assemblies, plus the provision of advice as to the preparation of construction drawings, data and documents suitable for production purposes. Queries and departures from the existing construction were to be reported to the design organisation (DOH 4.3.4.2). As stated in the handbook, the production organisation was required to verify that the manufactured parts/components/products, complied with the construction drawings, data and documents as supplied by the design organisation (DOH 4.3.2.4).

The relationship between the design organisation and the production organisation was described more closely in procedure QS-VA-1. Chapter 3.4.1 and gave the division of responsibility as follows:

Design organisation responsibilities

For reasons of flexibility, during this phase small changes can be made by hand to drawings / parts lists. The changes to drawings will be marked in colour and countersigned as correct by the responsible CVE (Compliance Verification Engineer). However, before this drawing is issued as the 'master version', all the handwritten changes must be incorporated in the master drawing. This task is the responsibility of the respective CVE.

Production organisation responsibilities

The fabrication of components and products will take place solely upon the basis of drawings / parts lists that have been examined and released as correct. Finished components / sub-assemblies are to be marked accordingly and after approval will, if necessary, be re-identified by the production department. All defects / deviations from the design objectives are to be documented and reported at once to the design organisation. The responsibility for this rests with the production manager.

Implementation of the current status of construction drawings / data / documentation into the working documents and check plans is the responsibility of Quality Assurance (QA). The QA record must contain the sequence of operations / check plan, drawing number, drawing issue with date, and parts list. It is the responsibility of QA to keep these plans up to date. QA authenticates that the product conforms to the design specification. The authentication is given in the form of a Conformity Statement. The responsibility for this rests with the head of quality assurance.

The design organisation has nine areas of responsibility: design (KO), flight testing (FLU), design loads (LA), stress analysis (S/F), flight physics (FP), avionics / electrics (A/E), non-electrical systems (SYS), engines (TRI) and software (SW).

The demonstration of compliance reports provided by the design organisation are checked by named Compliance Verification Engineers (CVEs) and are released via the Office of Airworthiness (MPL) after three authorised counter-signatures (DOH 7.3). The same procedure is adopted for reports by sub-contractors forming part of the design organisation Design Assurance System (ESS) (DOH 7.5.2). In both cases, the CVE were responsible for checking the correctness of calculations. This included checking the numerical values used and indicating this with a 'tick'. The computer programs were to be checked using comparative calculations and comparative evaluations (DOH 4.3.1.5 b).

1.17.3 Technical personnel

For the verification of sufficient qualification of their technical personnel the design organisation was required to define and put in writing the technical and personal requirements. The respective employee was required to fulfil these job requirements (DOH 10.3). The heads of department were responsible for ensuring that their subordinates were properly trained, and were required to keep written training records (DOH 10.4 and 10.4.1). In addition, employees were instructed to notify their supervisor immediately of any shortfall in knowledge or abilities (DOH 10.1).

The flight physics (FP) department was responsible for demonstrating flutter safety compliance (DOH 4.3.2.4). A sub-contractor undertook the static vibration tests and calculations. This sub-contractor was incorporated in the design organisation design assurance system (DOH Appendix CI-1).

A number of witnesses stated the design organisation was unable to demonstrate flutter compliance as required by the Design Organisation Handbook, because the design organisation lacked the necessary technical skills. The author of the demonstration of compliance was the departmental head of flight physics (FP), who was also Head of Office of Airworthiness (HOoA). There was no written training record for the CVE. Nor was there a written report from the individual concerned to his supervisor. However, witnesses stated that this shortcoming was well known to all those concerned.

1.17.4 Flight operations

The aviation regulation did not require official permission or supervision for operation of the aircraft. The aircraft could be operated within the generally valid legal framework for non-commercial operations.

Flight-testing

From the organisational point of view, flight-testing formed a part of the design organisation. The head of the flight test department (FLU) was responsible for the test-flying programme.

The CVE and quality assurance personnel in the production organisation were responsible for ensuring pre-flight readiness of the aircraft. Overall responsibility rested with the head of flight-testing, who reported to the office of airworthiness (MPL).

Operation of the test aircraft was internally regulated by written flight procedures, flight clearance notes and flight test cards.

The written flight procedures formed part of the Permit to Fly. These procedures described the flight limitations and type of flight operations, named the pilots who were permitted to fly the aircraft, plus the key technical details.

The Flight Clearance Note contained further operating limitations and procedures for flight-testing. Flight Clearance Note FCN 90002/3 dated 14 November 2006 referred to the Provisional Flutter Analysis, (DT-G 180A-000010, Rev. 1) setting a maximum speed of 297 KCAS.

The tasks to be undertaken on each test flight were given to the test pilot in the form of flight test cards.

Demonstration flights

Demonstration flights were allowed under the terms of the Permit to Fly (VVZ) with the task stated in a flight instruction card. Flight instruction card No. 90002/1 stated that

- Only crew members could be on board during demonstration flights,
- Demonstration flights must be conducted only within the demonstrated flight envelope,
- The demonstration flight routine must be approved by the Head of Office of Airworthiness.

Further demonstration flight limitations were set out in the Flight Display Policy. This document was issued by the senior management of Grob Aerospace AG (Switzerland) on 23 November 2006. Amongst other things, the document set out the following instructions:

8.2 Flight Limitations

[...]

f) Weather requirements for flight displays

- *Visibility:* 8 km
- *Cloud Base:* 3 000 feet AGL
- *Wind:* 10 kt X-Wind Component
- *Separation from cloud:* 1 km
- *VMC day only*
- *Only between:* Sunrise + 1 hour and Sunset – 1 hour
- *Not into the sun*

For reduced flight displays when the minimum weather conditions are less than required for normal displays, the minimum requirement will be as follows:

- *Visibility:* 5 km or above
- *Clouds:* 1 500 feet AGL
- *Wind:* 10 kt X-Wind Component
- *Separation from Cloud:* 1 km horizontal and 500 ft vertically
- *VMC day only*
- *Only between:* Sunrise + 1 Hour and Sunset – 1 hour
- *Not into the sun*

8.4 Flight Display Profiles

b) For reduced flight display (see paragraph F above)

[...]

- *Performance take-off 20 deg flap*
- *Performance climb to 1 000 ft AGL*
- *High Speed fly by max 200 KIAS*
- *Slow Speed fly by gear and flap extended (see paragraph C)*
- *Performance landing (only on dry runway)*
- *Taxi-in and shut down*

The Flight Display Policy did not require a written pre-flight authorisation.

Conformity with the limitations or instructions issued for demonstration flights was not monitored with respect to conduct of the display flight, nor the technical aspects. Flight data recorded was not evaluated.

Prior to the accident, no demonstration flights had been conducted with the P2 prototype. The P1 prototype had made four demonstration flights with a similar profile as that in the accident. These were evaluated and showed that the speed over the accident site during these flights was between 260 kt and 272 kt. The maximum speed reached in the vicinity of the airfield was between 273 kt and 296 kt on each occasion.

1.18 Additional information

Flutter

Paragraph 629 ('Flutter') of EASA Certification Specifications CS-23 requires that the aircraft must not suffer from flutter in any part of the permitted speed-load factor range. CS-23.629 (c) requires a calculated demonstration of compliance for the absence of flutter for all speeds up to $1,2 v_D$. AMC 23.629 refers to FAA AC 23.629-1A, which has since been supplanted by Version 1B and gives guidance on the interpretation of damping graph curves (see appendix).

Horizontal stabiliser

The span of the horizontal stabiliser on P1 was 5.59 m. In P2 this was increased to 6.48 m to improve the control characteristics. This and other changes from the P1 configuration required a re-evaluation of the flutter characteristics, even though flight tests had been successfully conducted on P1 at speeds up to v_D . Prior to the first flight of P2 a sub-contractor for aeroelastic tests was entrusted with a reappraisal of the flight characteristics. At the time of the accident, flutter tests had not been conducted in flight with aircraft P2.

The characteristic natural vibration value was measured in a static vibration test using the classic phase-resonance method. The induced unsteady air forces and the aeroelastic behaviour / flutter behaviour were calculated on the basis of the measured natural vibration. The calculation was made using a program developed by the sub-contractor. This produced a graph curve for each of the individual natural vibration forms showing the relationship between damping and airspeed. FAA Advisory Circular AC 23.629-1B says that in order to ensure absence of flutter, the zero crossover point damping should be at least 1.2 times the planned maximum speed for each possible natural vibration form.

Static vibration tests with the P2 revealed that the vibration characteristics of the horizontal stabiliser were found to be critical and could only allow the aircraft to fly at speeds up to 135 kt. The calculation was then changed to increase the weight of the mass balances in the elevator horns from approx. 1 kg to approx. 4.5 kg each. The damping curves of the modified tailplane had their zero crossover points at 313 kt (580 km/h) and 324 kt (600 km/h) respectively (see appendices). The sub-contractor issued a flutter safety certificate for resumption of flight-testing up to a speed of 297 kt (550 km/h) EAS (see appendix). Based on this flutter safety certificate, an engineer of the design organisation wrote a Certificate of Compliance Flutter Analysis DT-G180-000010 that was countersigned by a compliance verification engineer, which then formed the basis for the MPL (office of airworthiness) approval. At this time, the design organisation was not in possession of the damping graph curves.

Following verbal agreement between the design organisation and the production organisation, the latter added the necessary additional mass balance. Witnesses said this was done in the form of lead shot with resin bonded into the elevator horns. A hole was cut in the elevator horn rib through which a glass-fibre crosspiece was bonded inside the horn. The void was completely filled with a mixture of lead shot and resin. The hole in the rib was then closed up with a glass fibre plate. The elevator weights and residual moments were determined and recorded in the construction documentation of the aircraft. Incorporation

of the additional weights was not included in the design organisation construction drawings. There was no commensurate standard procedure in the production organisation.

After incorporation of the lead shot the weights were as follows:

- left elevator: 14.9 kg with approx. 4.5 kg mass balance
- right elevator: 14.6 kg with approx. 4.5 kg mass balance

The stress calculation for the horizontal stabiliser (Doc SC-G 180A-552000) used the following mass values:

- left and right elevator, 10 kg each including 4 kg mass balance

After the accident a team of experts made an analysis of the flutter calculations based on the results of the static vibration tests; they identified two critical cases:

- symmetrical elevator rotation against the control column, coupled with bending vibration of the horizontal stabiliser.
- anti-symmetrical elevator torsion, coupled with anti-symmetrical vibration of the horizontal stabiliser

Analysis showed that above a speed representing 83% of the damping curve zero crossover point, the damping curve associated with the worst flutter condition could occur. The probability for this was approximately 0, but increased to 1 with approach to the speed at the zero crossover point. The range between 83 % and 100 % of the speed at the zero crossover point (in this case 261 kt (483 km/h) to 313 kt (580 km/h)) was identified as a critical speed range.

Further, the damage pattern to the P2 horizontal stabiliser matched that resulting from loads determined by modal analysis of the horizontal stabiliser bending vibration, especially in that area joining the elevator horns to the elevators.

1.19 Useful or effective investigation techniques

1.19.1 Data reconstruction from damaged data storage medium

The determination of flight data such as flight speeds was of relevance to the accident investigation. The aircraft was not equipped with a flight data recorder. However, it was equipped with a system to record data measured for the flight test programme. This data was recorded on several data carriers. These were badly damaged to varying degrees by the impact. A magnetic tape was identified as being probably the only readable source.

The magnetic tape was very severely damaged, but in an effort to recover useful data was entrusted to a company in Germany that specialised in the recovery of data from damaged storage media. Some of the data was reconstructed, but the data recovered related only to a time when the aircraft was still on the ground.

A further attempt was made to recover data with the assistance of Sony, Recording Media division, Sony Corporation (Sony) in Japan. Sony was the manufacturer of the tape recorder and developed the technology employed in the recovered magnetic tape.

The following sections of damaged magnetic tape were used in the reconstruction attempts, which were observed by a BFU investigator in the tape recorder manufacturer's laboratory:

- 1.37 m section of the original initial input feed
- Approx. 228.5 m, final section
- Nine tape fragments
- Magnetic tape with data from an earlier flight

By changing the playback parameters, the manufacturer was able to reconstruct more data than that which had been read from the original input feed (see diagram 9).



Diagram 7: Parts of the damaged magnetic tape

Photo: BFU

In addition, an attempt was made to extract data from the fragments (diagram 7). The fragments were carefully flattened and spliced with an undamaged tape, followed by an attempt to extract further data.

The damage was so severe, that it was not possible to extract data.

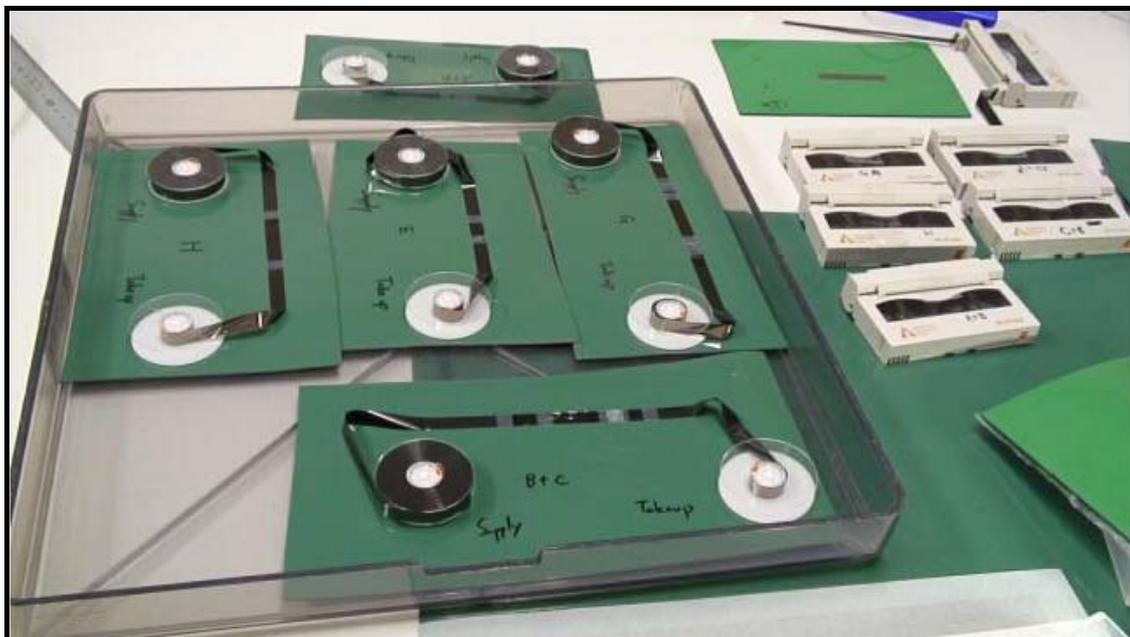


Diagram 8: Cassettes with prepared sections of magnetic tape

Source: BFU

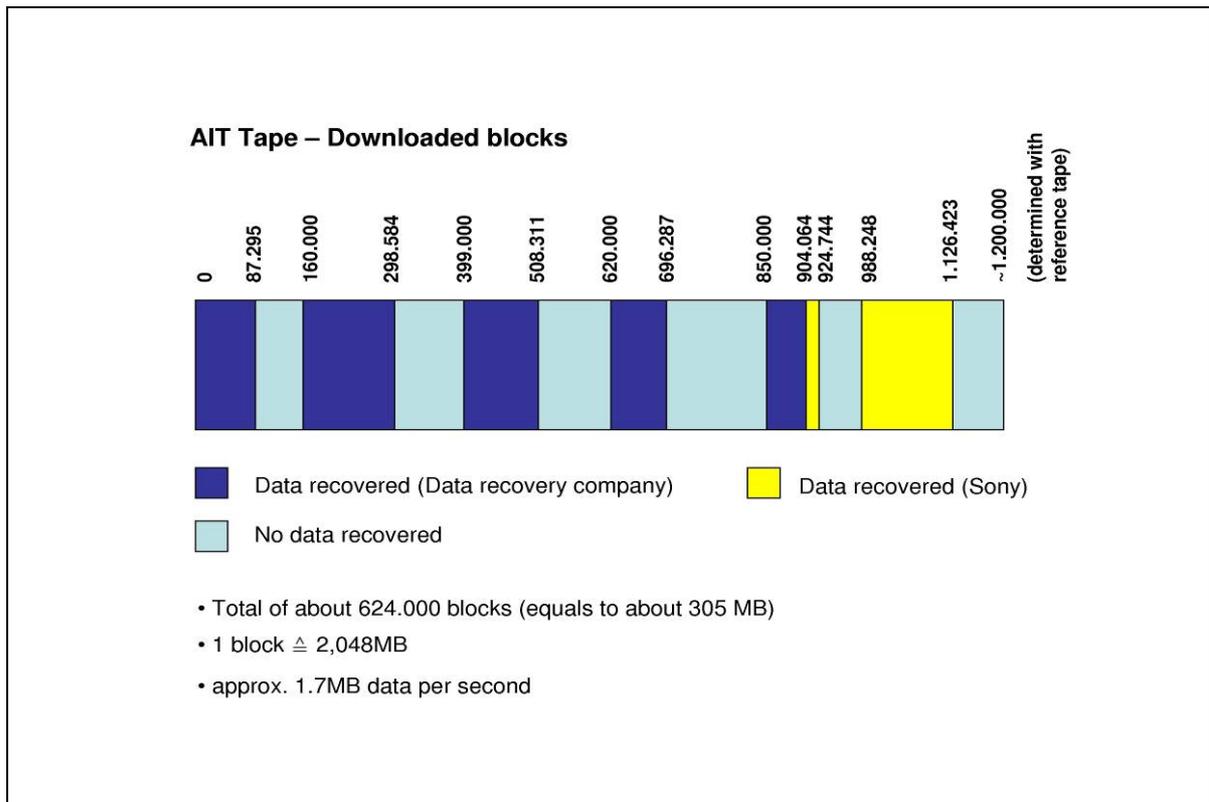


Diagram 9: Reconstructed data blocks (Magnetic tape original input feed)

Source: BFU

It was found that further data could be read out by changing the playback parameters. The reconstructed data are from the accident flight recording, but prior to take-off. The actual flight phase data was on the fragmented sections and was unreadable due to impact damage.

1.19.2 Evaluation of the engine controls

Each of the two Williams engines FJ44-3A had its own Type EMC 50 Full Authority Digital Engine Controls (FADEC).

Both FADECs were recovered from the wreck with the intention of obtaining engine power data and any possible fault errors from non-volatile storage media.



Diagram 10: The FADECs from the two engines

Photo: BFU

The two FADECs were examined and read out by their manufacturer Goodrich Engine Control Systems (GECS) under observation of the National Transportation Safety Board (NTSB). The read-out process was agreed between the BFU and engine manufacturer.

The FADEC unit was so designed that the engine power output and data are not continually stored, but logged only if there is a fault, or on passing an operating limit. In addition, one so-called 'trend point' is stored per flight. The FADEC unit could also store further data such as coordinates, height and speed. However, this required that the FADEC unit would receive the data via ARINC 429.

Both FADECs were read out. There were no coordinates on the ARINC-bus. The year given as 2130 was implausible. The time set in the system was not synchronised with the actual time.

The data gave no indication of faulty operation or that the engines had exceeded their operating limits.

1.19.3 Other non-volatile storage media

In an effort to obtain further data and information that would describe the sequence of events and aircraft system functions, the investigators combined with the aircraft manufacturer to identify all non-volatile storage media and to recover these from the wreck.

The following data storage media were found and examined:

- CF-Card from KAM 500 Logger

The storage card forming part of the data logging system was discovered in damaged condition. During examination, it was determined that none of the storage chips on the board were readable. As a result of the impact, the storage unit was incomplete.

- Hand-held GPS Garmin 296

The pilot had a hand-held Garmin GPSmap 296 with him, which was found in the wreck in a damaged condition. The non-volatile storage medium that would have recorded the flight path, had sheared off the board during the accident, and could not be found.

2. Analysis

General

At the time of the accident the aircraft was subject to tests towards obtaining Certificates of Compliance to meet the airworthiness construction requirements of EASA CS-23 and FAA Part 23. As a consequence, at the time of the accident the final operating limitations, power- and airworthiness characteristics – and the safety reserves required for certification – were as yet undefined or without demonstrated compliance.

The deciding factor for airworthiness of the prototype and safety reserves was the qualification and experience of the test pilot, plus the working procedures and processes within the design and production organisations.

During the test programme, calculations previously made of speed threshold limitations were demonstrated by test flights. Based on these figures, the German National Aviation Authority (Luftfahrt-Bundesamt) had issued a provisional permit to fly for test flights leading to type certification, also positioning and demonstration flights.

The purpose of the flight during which the accident occurred, was solely to demonstrate the aircraft to a group of visitors on the ground at Mindelheim-Mattsies airfield. There was no intention to demonstrate flight performance or operating limitations associated with type certification. In order to reduce the risk of accidents, the aircraft manufacturer had issued a flight display policy which also included operational terms and conditions.

In view of the company's subsequent insolvency, the analysis of some of the facts and aspects – in particular as these relate to the design, production and quality assurance procedures – was reduced to the minimum. The same goes for the design analysis of the G 180A horizontal stabiliser.

2.1 Flight operational aspects

2.1.1 Sequence of flight and flight speeds

The flight in question was a demonstration flight and not a test flight; it therefore fell under the company's flight display policy. Given the weather situation at the time, the reduced flight display applied. This internal company rule specified a maximum speed of 200 kt and a performance climb to no more than 1,000 ft AGL.

In addition there was a general legal limit of 250 kt for flights below FL100.

The Airplane Flight Manual (AFM) gave the V_{MO} as 260 kt. The flight clearance note permitted speeds of up to 297 kt for test flights.

During the accident flight the aircraft exceeded the speed limitation of 200 kt set down in the flight display policy. The radar trace shows that when the aircraft was downwind with respect to the runway it flew at a speed of 240 kt. Because the intention had been of a fly-past, it can be assumed that the aircraft subsequently accelerated.

During previous demonstration flights with the P1 prototype, the aircraft had reached a maximum speed of 270 kt in this phase of the flight.

The BFU assumes that at the onset of the events leading to the accident (flutter), the aircraft was flying at a speed of at least 240 kt but probably not greater than 270 kt. In the absence of objective measured data (flight data recorder, telemetry, GPS) it is not impossible that the aircraft flew at a higher speed.

2.1.2 Loss of control

The loss of the elevator and parts of the horizontal stabiliser resulted in nose down rotation about the lateral axis that could not be corrected by the pilot.

There was no evidence of engine failure, or failure of other aircraft systems that would have put the aircraft in an attitude that was uncontrollable by the test pilot.

2.2 Pilot's qualification and experience

The pilot was appropriately trained for his role as test pilot in the company. The design organisation handbook stated that he was the chief test pilot and deputy head of the flight test department and was accepted in this role by the certification and supervisory authority. He was in possession of the necessary licenses.

He was qualified for his role as test pilot by previous military experience and subsequent employment as a civil test pilot. From the beginning, he had been involved with the design and development of the G180 in which he made the first flight, and was therefore very familiar with the aircraft.

He was not in possession of a Class 1 medical certificate which was a formal requirement for the flight in question; however, he was in possession of a Class 2 medical certificate and there is no reason to believe he was unfit to fly.

2.3 The aircraft

At the time of the accident the Grob G180A P2 prototype had not reached the target performance figures; hence the target V_D speed 338 kt for final certification and operation was not applicable to operation of this aircraft.

2.3.1 Proof of mid-air break-up

The aircraft impacted with the ground at high speed and at a relatively shallow angle. The aircraft longitudinal axis was directed downwards and the wings were level. The wreckage scatter trace indicated the flight direction as 280°.

The largest parts of the horizontal stabiliser such as elevator and skin were located on the ground several hundred metres prior to the point of impact, either directly on or near to the track left by the wreckage and confirmed by witnesses. They had separated from the aircraft in flight. It was not possible to determine the exact time or place at which this happened. However, separation must have occurred before the aircraft had flown over the point at which these components were subsequently found.

The smallest parts such as carbon fibre fragments were subsequently found as much as one kilometre east of the accident location. They were probably thrown back into the air on impact and blown east by the wind.

The loss of the elevator meant that the aircraft could no longer be controlled in pitch. The reduction in horizontal stabiliser surface area and the loss of skin shells caused a further reduction of tailplane downforces, so that the aircraft pitched nose down.

2.3.2 Horizontal stabiliser break-up

The break-up in flight of the horizontal stabiliser took less than one second. This was indicated by the fact that this part of the wreckage was distributed over a fairly small area 100m x 50 m.

The left elevator horn with mass balance was subsequently found on the ground between the horizontal stabiliser wreckage and the main point of impact. After the elevator horn separated from the stabiliser it continued on a longer trajectory than the other stabiliser components, because it had a better ratio of mass to coefficient of drag and therefore did not decelerate so quickly in the air. The elevator horn was found about 300 metres from the other horizontal stabiliser components, which supports the assumption that these components detached from the aircraft at the same moment.

Both the distribution of wreckage around the main point of impact and that of the horizontal stabiliser (diagrams 3, 4, 5, 6) are evidence for a rapid break-up of the structure at several points.

2.3.3 Elevator flutter

The investigation team and involved experts determined that the findings on the horizontal stabiliser and the wreckage pattern allowed for only one conclusion that the horizontal stabiliser had suffered an in-flight break up due to aerodynamic flutter.

The results of the flutter evaluation prior to flight-testing (appendix), the calculated damping curves and the Flutter Analysis Evaluation AC 23.629-1B in conjunction with Certification Specification CS-23, resulted in a speed of 313 kt at which the probability of flutter was 100%. Information before the BFU indicates the aircraft did not reach this speed.

The speed at which there might have been the onset of flutter – established by calculation in accordance with AC 23.629 (probability >0%) – was about 261 kt. It is probable that the aircraft reached or exceeded this speed during this flight.

To the best of BFU knowledge, during this flight the aircraft reached speeds between 240 kt and 270 kt, and therefore infers it is improbable that flutter was due to excessive speed.

The possibility cannot be excluded, that the bond holding the retrofit elevator mass balance had previously failed. In this case, the critical speed range would have shifted towards lower speeds.

There is doubt as to whether the addition of mass balance lead shot and resin was the optimum solution for this aircraft.

The retro-fitted additional mass balance was not adequately allowed for in the strength calculation (Doc SC-G 180A-552000). The BFU did not investigate the possibility of prior damage. If there had been prior damage, this would likewise have lowered the critical speed range.

The heavier mass balance should have been incorporated in the stress analysis calculations.

Flutter is a phenomenon resulting from the random combination of several natural vibration forms, and can be triggered by a minor aerodynamic disturbance such as turbulence or a control input.

2.3.4 Data recording

With the exception of the radar trace, no data were recorded that would show accident investigators the flight profile, performance or systems behaviour, because the aircraft was not fitted with a flight data

recorder. In particular, a record of the flight speeds attained would have been highly relevant to subsequent analysis of the flutter characteristics.

Similarly, a cockpit voice recorder would have picked up cockpit sounds and radio communications and would have been useful to investigators.

Alternatively, telemetric data transfer to ground stations is a standard flight test procedure and would have provided valuable information.

2.3.5 Rescue system

Given the degree of destruction, it was not possible to determine whether the pilot had triggered the rescue system. It is highly probably that, given the rapidity with which the horizontal stabiliser broke up in flight, he had no time to activate the system.

The pilot's packed rescue parachute was found in the wreck, proving that it had not been opened.

2.3.6 Emergency Locator Transmitter (ELT)

The emergency locator transmitter could not transmit an emergency signal because an internal connector to the antenna cable and an external cable between the emergency transmitter and the antenna were damaged by the impact.

The BFU is of the opinion that the design of the 406 MHz emergency transmitter is unsuitable for aircraft. Even though a functioning emergency locator transmitter would not have given the pilot any chance of survival, the accident revealed the design shortcomings of this emergency transmitter system.

2.4 Specific conditions at the time of the accident

2.4.1 Weather situation

Information available about the weather in the vicinity of the airfield indicates that visual flight conditions existed below the cloud base, which was between 2,900 ft MSL und 3,000 ft MSL.

The radar trace record shows that the aircraft flew near the cloud base from time to time. It was not possible to determine whether visual flight conditions existed at this altitude and time.

After the aircraft entered the base leg prior to the intended approach to the airfield, it was clear of clouds. The weather therefore had no direct influence upon the sequence of accident events.

2.4.2 Demonstration flight

The purpose of the flight was to demonstrate the aircraft and its performance to a group of visitors and potential customers. The flight route and profile should have been conducted in line with the company's flight display policy: 'Reduced Flight Display'.

The maximum speed for a reduced flight display was 200 kt, but this was exceeded at 240 kt by about 20%. Also, the cloud base was less than the 1,500 ft required under section 8.2f of the company's flight Display Policy. It is probable that the required 500 ft vertical separation from clouds was not maintained.

In line with the weather minima specified by the flight display policy, the flight should not have been undertaken under these conditions. However, the non-observance of these flight operation limitations was not the cause of the accident.

2.5 Defences

2.5.1 Certification and construction regulations

The project was to design and build a jet aircraft with a carbon fibre structure capable of transporting up to nine passengers at a cruise speed of $V_c = 270$ kt (0.7 Mach) and bring this to series production. To this end, the design and production organisations had to employ numerous new technologies.

Essentially, the design and construction regulations EASA CS-23 and FAA Part 23 were suitable as the basis for type certification. However, in view of the special requirements arising from the fact that this was a new type of project and the detailed specification of the aircraft, many items were subject to detailed Certification Review Items (CRI) and special conditions

2.5.2 Procedures

Comprehensive procedures were laid down for development and production and described in the respective handbooks. These descriptions were sound and practicable.

However, investigation showed that the procedures laid down were not always implemented. The reasons were inadequate communications and the general set-up within the company.

Following the company insolvency, the development and production organisations no longer exist in their original form, so the underlying reasons for these shortcomings were not examined further.

2.5.3 Demonstration of flutter strength compliance

According to Certification Specification CS-23.629 (c) the calculated demonstration of compliance for the absence of flutter at all speeds up to $1,2 V_D$ is required for type certification. This is demonstrated by undertaking static vibration testing on a single aircraft and measuring the values; these are then used as the basis for the flutter calculation. The use of mathematical factor 1.2 in the calculations provides a safety margin for technical measuring errors, mathematical imprecision, series production tolerance and possible deterioration with age.

The flutter compliance certificate issued by the sub-contractor for speeds up to 297 kt (550 km/h) used a mathematical safety factor of only 1.05. The reduction of this safety factor was plausible, because the tolerances required in series production and service life were not relevant to this prototype. Whether the reduction from 1.2 to 1.05 was appropriate was not subject of the investigation.

The BFU is of the opinion that the accident occurred at a speed below 270 kt; in other words, a flutter flight test for a maximum speed of 293 kt would have had no validity in this speed range.

The following conditions could have resulted in a reduction in flutter strength (at the speeds in the critical range):

- Prior damage to the elevator horn in the vicinity between the horn and elevator.
- Failure of the bond between the mass balance and the adjacent structure.

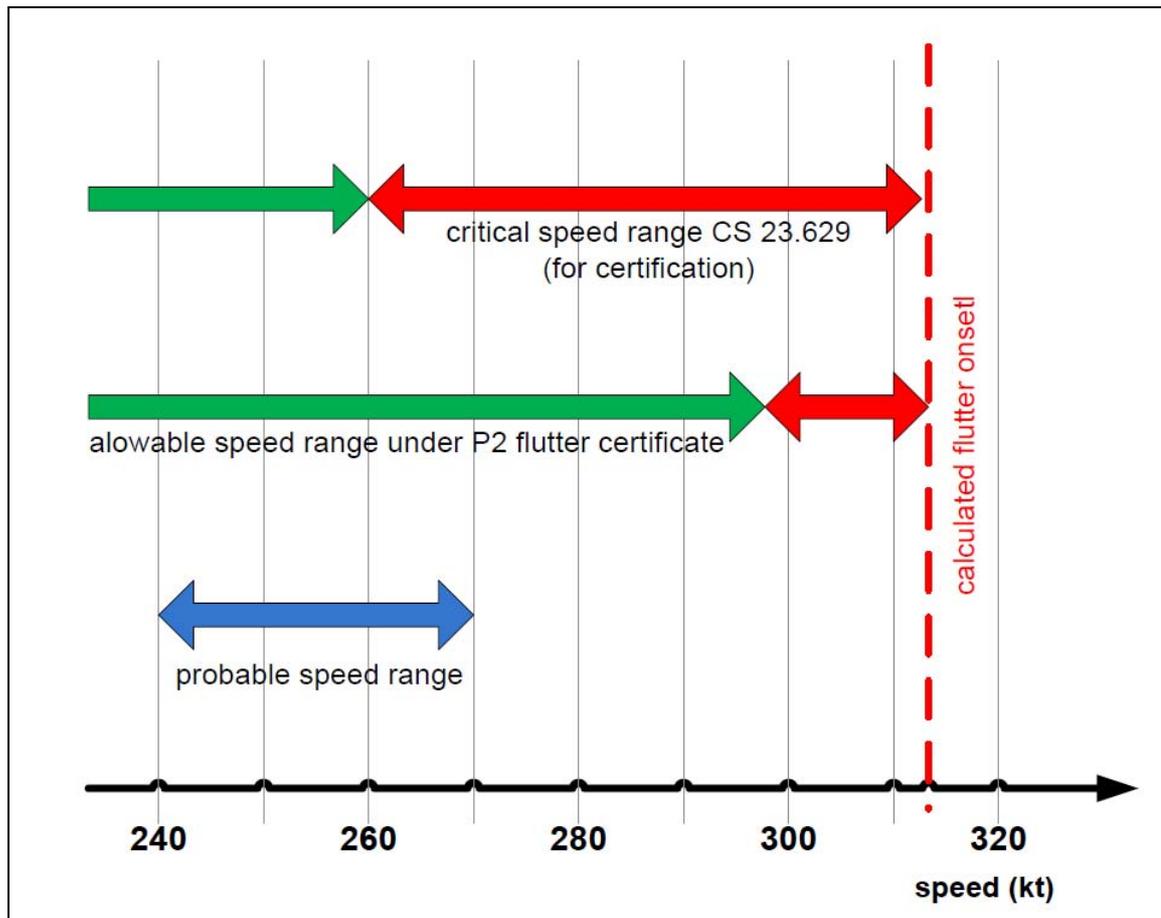


Diagram 11: Overview of flutter onset speeds

Source: BFU

2.5.4 Flight operations procedures

The company had recognised the need to have binding rules for the conduct of demonstration flights. The flight display policy laid down rules which also took the airspace structure and the actual weather conditions into account.

Even though the Flight Display Policy only came in force three days prior to the accident, it was known to the pilot; its contents had been discussed several times prior to the accident.

The BFU is of the opinion that the pilot was competent to conduct the flight under the weather conditions then pertaining. He was motivated to demonstrate the aircraft in flight to observers and accepted the associated risk of the reduced cloud base. Apparently, the company flight display policy was a lesser consideration in the decision to fly.

2.5.5 Quality assurance

The design and production organisations also incorporated quality management. Non-compliance with company procedures was not recognised or remedied by the quality assurance mechanisms. During the investigation this shortcoming was recognised with respect to technical matters and flight operations.

2.6 Organisational framework

The company was certified as a design organisation and thus fulfilled the formal requirements for the design of the aircraft.

The use of the sub-contractor to provide a demonstration of flutter compliance was clearly and plainly stated in the Design Organisation Handbook (DOH). The DOH stated that the CVE was responsible for checking the correctness and accuracy of the flutter calculations including the numerical values. Likewise, the CVE was responsible for checking computer programs using comparative calculations and evaluation of test results. The BFU is of the opinion that the CVE did not discharge these responsibilities nor was it possible for him to do so. He was unable to undertake this assessment, because he did not have the requisite knowledge, nor the necessary documentation. However, a plausibility check of the results would have been possible and necessary and could have been made by evaluation of the diagrams (appendices 3 and 4). The issue of a flight clearance note based solely on the numerical values received by fax was inadequate.

Because the results of the flutter calculations are usually conveyed as speed values without diagrams, there was no way to make a sound assessment. Hence, it was not possible to check or arrive at a properly qualified appraisal of the calculated results. This brought with it the risk, that the speed thresholds given in the flight clearance note might be faulty.

The company's quality management did not recognise or rectify this risk.

3. Conclusions

3.1 Findings

- The pilot was adequately licensed and qualified to conduct the flight. He was familiar with the aircraft.
- There is no evidence to suggest that the pilot was medically incapacitated in a way that could have caused the accident.
- At the time of the accident the aircraft was subject to tests towards obtaining certificates of compliance to meet the airworthiness construction requirements of EASA CS-23 and FAA Part 23. These tests were incomplete. The final operating limitations, power- and airworthiness-characteristics – and the planned safety reserves – were without demonstrated compliance.
- The aircraft had a permit to fly issued by the German Civil Aviation Authority (LBA) for the purposes of test flying to obtain Type Certification, also for positioning and demonstration flights.
- In accordance with Flight Instruction 90002/1 and Flight Clearance Note No. 90002/3, flights were allowed at speeds up to 297 kt at mean sea level.
- Under the weather situation then pertaining and, in accordance with the company flight display policy the demonstration flight should have been conducted under the reduced flight display rules, which would have limited the speed to 200 kt.
- The aircraft probably flew at a speed of between 240 kt and 270 kt.

- The critical speed range within the meaning of the type certification demonstration of flutter compliance certificate, was between 261 kt and 313 kt. However, there was no obligation to apply the suggested safety factor (AC 23.629).
- In accordance with the flutter compliance certificate and flight clearance note, the aircraft was cleared to fly at speeds up to 297 kt.
- The speed probably flown was less than the maximum stated in the flutter compliance certificate, but may have reached a critical area with respect to the requirements for type certification.
- The horizontal stabiliser broke up in flight as a result of aerodynamic flutter.
- The calculated flutter compliance certificate was plausible.
- The design organisation did not check or monitor the sub-contractor providing the flutter compliance certificate.
- It was not possible to exclude a reduction in the critical speed (possible onset of flutter) arising from any in-flight failure of the bond securing the retro-fit mass balance.
- It was not possible to exclude a reduction in the critical speed (possible onset of flutter) arising from prior structural damage in the area between elevator horn and the elevator surface, due to inadequate-dimensioning or stress analysis of the structure.
- Due to the high degree of wreck destruction, it was not possible to determine the position of the wing flaps or landing gear on impact. However, the planned fly-past would have required the flaps and landing gear to be retracted.
- There was no evidence of in-flight fire or explosion. All traces of fire in the wreck were caused on impact.
- Post-accident examination of the emergency location transmitter indicated that it had no influence upon the search time required, but points to a shortcoming in the design and construction of this system.

3.2 Causes

The accident happened because the horizontal stabiliser broke up in flight as a result of flutter, following which the aircraft was no longer controllable.

The circumstances that led to the onset of flutter could not be fully ascertained due to the absence of flight data and limited investigation possibilities.

4. Safety recommendations

The BFU has issued the following safety recommendations:

Recommendation No. 12/2010

If the project be continued, the owners of the construction drawings, documentation and certificates of compliance required for Type Certification of the Grob G 180A aircraft should thoroughly scrutinise the design, construction and technical arrangements of the horizontal stabilizer with respect to aerodynamic efficacy, strength and absence of flutter, and redesign as necessary.

Recommendation No. 13/2010

The Federal German Civil Aviation Authority (LBA) should require that aircraft with a maximum take off weight (MTOW) of more than 5 700 kg and having a Permit to Fly for the purposes of test flying, should require installation of a Flight Data Recorder (FDR) and a Cockpit Voice Recorder (CVR); in place of which an uninterrupted telemetric flight data link would be acceptable.

Recommendation No.: 14/2010

The European Aviation Safety Agency (EASA) should ensure that aircraft with a maximum take off weight (MTOW) of more than 5,700 kg will be fitted with a Flight Data Recorder (FDR) and a Cockpit Voice Recorder (CVR) during the entire flight test programme leading to Type Certification and during demonstration flights.

In lieu of which, the uninterrupted transmission of flight data via telemetry is acceptable.

Recommendation No. 15/2010

The European Aviation Safety Agency (EASA) and other National Civil Aviation Authorities should check and monitor the integration of sub-contractors in design organisations engaged in the design and construction of aircraft as described in EASA Part 21, 21A.239, and regulate as necessary.

Recommendation No.: 18/2009

The International Civil Aviation Organisation (ICAO) should require in Appendix 6, Parts II and III, or in Appendix 10 part III, that 406-MHz Emergency Locator Transmitters (ELT) for aircraft should have a supplementary internal antenna; or that the external antenna is, if possible, so designed as to ensure continued transmission of the emergency signal after an aircraft accident.

Recommendation No.: 19/2009

The European Aviation Safety Agency (EASA) and the Federal Aviation Administration (FAA) should ensure that new installations or retro-fitted 406 MHz Emergency Locator Transmitters (ELT) used in aircraft are all designed and built with a supplementary internal antenna, or with an external antenna that will, if possible, ensure continued transmission after an aircraft accident.

Braunschweig, 15 April 2010

For German Federal Bureau of Aircraft Accident Investigation

Johann Reuss

Investigator-in-Charge

The following persons took part in this investigation:

Thomas Kostrzewa (Airframes and Structures)

Philipp Lampert (Data Recovery)

Andreas Wilke (Flight Operations)

5. Appendices

Appendix 1: Three-view drawing of the Grob G180A

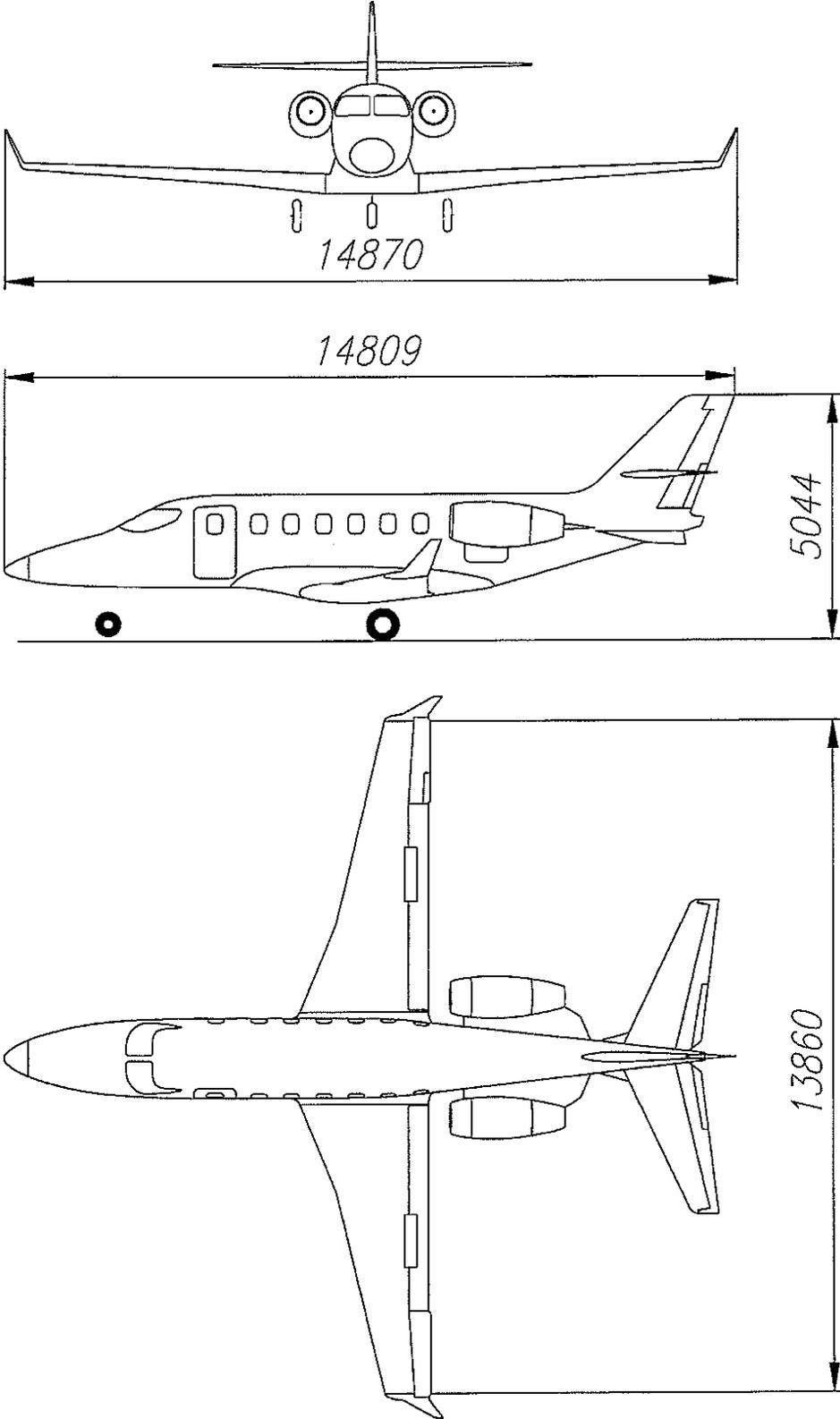
Appendix 2: Extract from AC 23.629-1B

Appendix 3: Damping curve: Symmetric Normal Mode 0 m

Appendix 4: Damping curve: Asymmetric Normal Mode 0 m

Appendix 5: Flutter compliance certificate

Three-view drawing



Extract from AC 23.629-1B

(9) Flutter Analysis Evaluation. The resulting output of flutter analysis consists of a number of theoretical damping values (g) with associated airspeeds and flutter frequencies.

(10) Various cross plots of these values among themselves and versus varied input parameters allow a study of trends. Common plots are: damping versus equivalent airspeed (V-g plots), control surface balance versus flutter speed, modal frequency versus flutter speed, altitude versus flutter speed, etc. Normally only the critical items will be extensively compared.

(11) Of particular importance is evaluating the crossing of a damping velocity (V-g) curve toward the unstable region, through the zero damping line. The typical critical V-g curve will first become increasingly stable with increasing speed, then the damping will decrease and finally cross the zero damping line as in curves 3 and 4 in Figure 1-1. Figure 1-1 shows some typical characteristics.

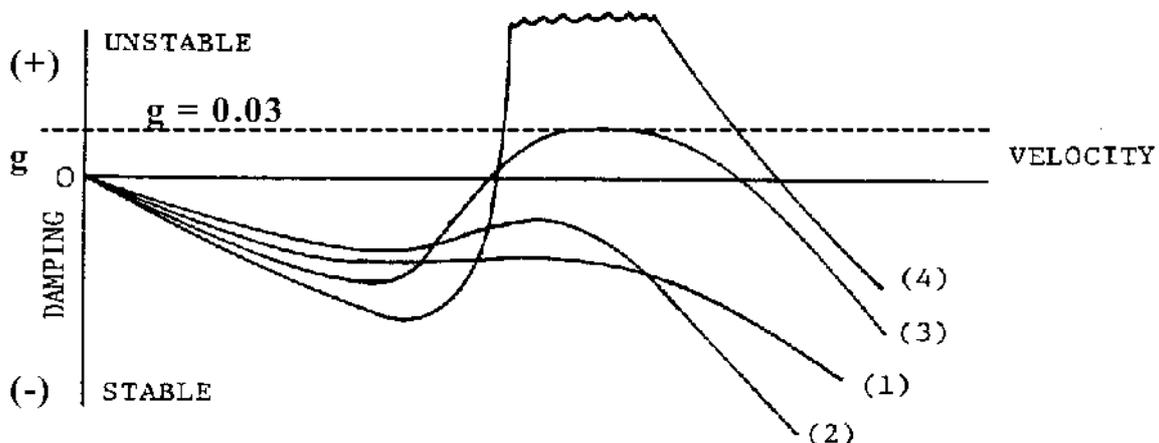


Figure 1-1. Flutter Analysis Evaluation

(12) Curves 1 and 2 show slight trends toward instability, but do not approach actual instability.

(13) Curve 3 crosses the stability axis but, depending on the inherent structural damping, may or may not actually become unstable. Curve 4 is obviously unstable and probably violent, since its slope is steep as it passes through the zero damping line. In actual flight it may be a few miles an hour or so between completely stable and extremely unstable explosive flutter. Flight tests are not advisable when this type of plot is observed inside or at the boundary of the flight envelope.

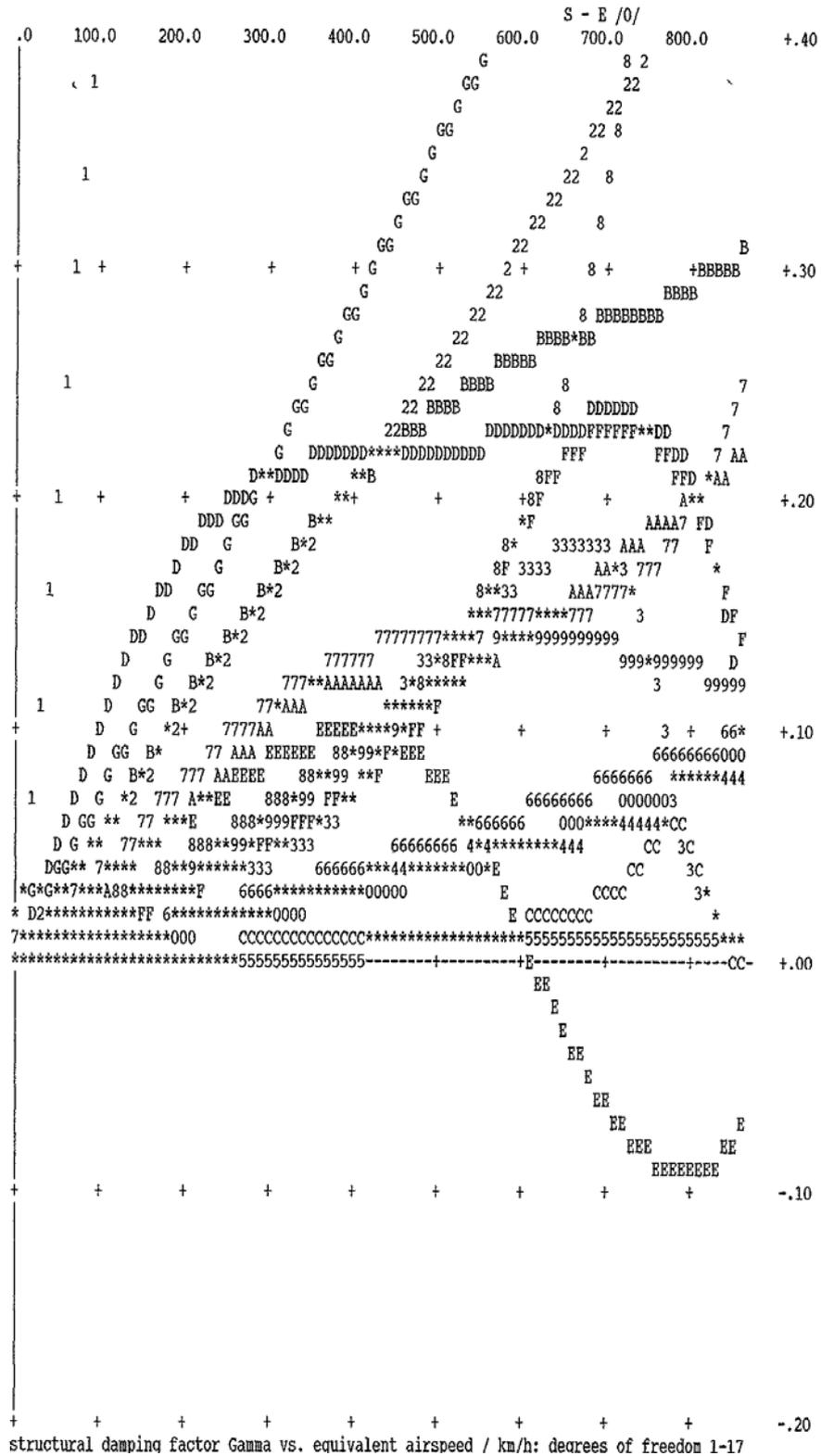
(14) Much can be learned from V-g and V-f plots. Absolute values should be viewed with some reserve as there is no perfect one-to-one correspondence of the analytical parameters and flight parameters. Equally important is the rate of approach to instability (slope of curve).

(15) The general practice is to use a damping value of $g = +0.03$ (as the inherent structural damping) in the V-g plots. In Figure 1, an assumed value for the inherent structural damping value of $g = +0.03$ would be a positive value. However, this value should be used with caution if the slope of the curve is steep (damping decreases very rapidly with an increase in airspeed) between $g = 0$ and $+0.03$. In cases where the slope is steep (generally this would be a decrease in damping of 50 percent for a 5-10 knot airspeed increase), it is suggested that the $g = 0$ airspeed be at least $1.2 V_D$. Freedom from flutter should be shown to $1.2V_D/1.2M_D$.

(16) For damping curves such as (3), which peak out below $1.2 V_D$, the predicted damping should be no more unstable than $g = +0.02$ unless justification is provided by other acceptable means.

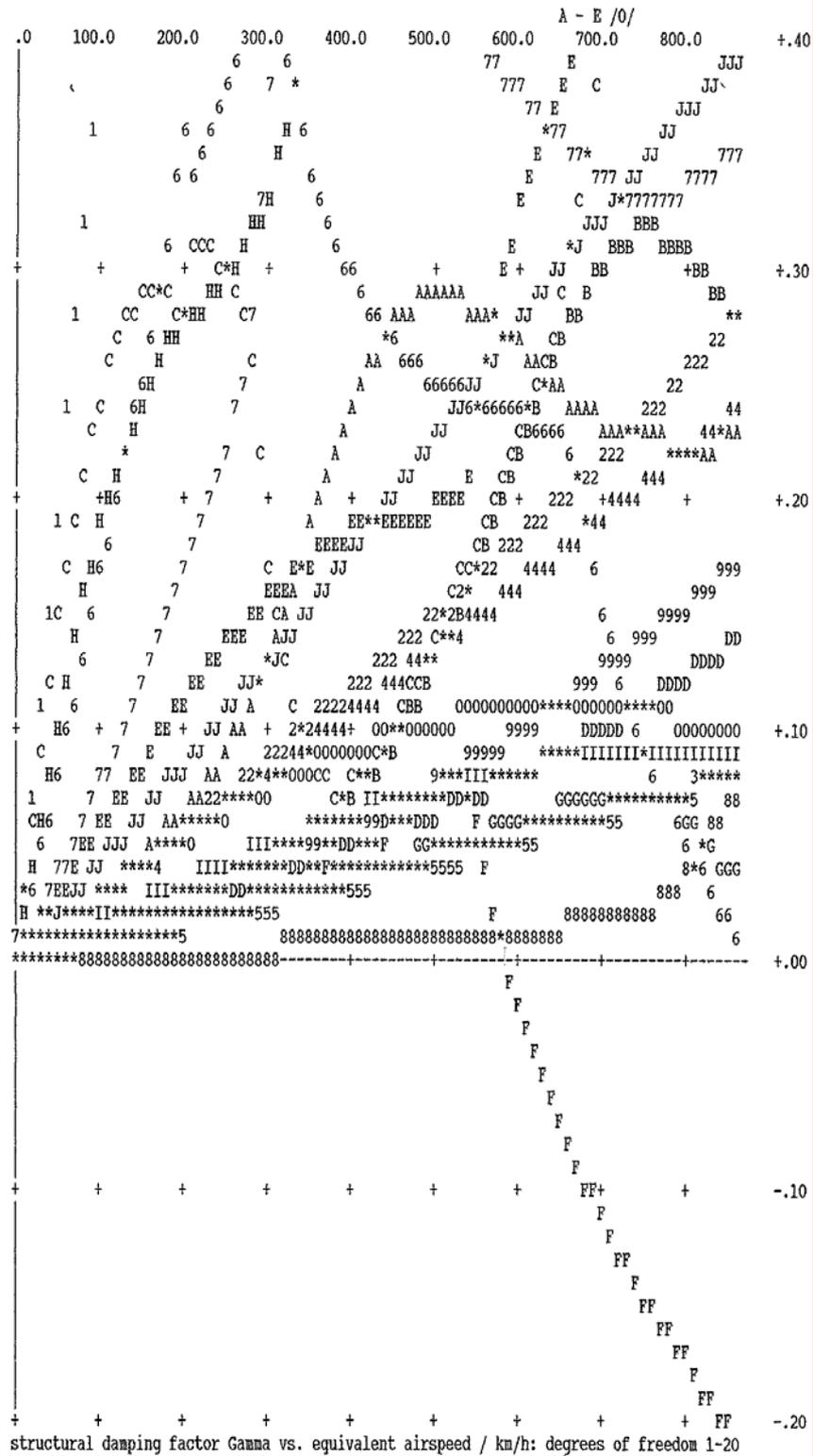
Damping curve: Symmetric Normal Mode 0 m

E = Curve of the elevator vibration against control column



Damping curve: Asymmetric Normal Mode 0 m

F = Curve of elevator tip vibration against trim tab.



Demonstration of Flutter Compliance Certificate

Flutter Assessment prior to commencement of flight testing,
G 180A powered aircraft

The natural vibration frequencies of the G 180A were determined by static testing (27-30 August 2006). Based on the measured characteristic values of these natural frequencies, the flutter stability of the G 180 was investigated by calculation at speeds up to 818 km/h and altitudes up to 12,500 m.

There are no objections to the commencement of flight-testing up to a speed of

$$V = 550 \text{ km/h EAS} = 710 \text{ km/h TAS (flaps retracted)}$$

and up to an altitude of 5,000 m. In the altitude range 5,000 m to 12,500 m the maximum true and equivalent airspeed is

710 km/h TAS = 363 km/h EAS at 8,000 m
710 km/h TAS = 313 km/h EAS at 10,000 m
710 km/h TAS = 257 km/h EAS at 12,500 m

provided that the following tolerances for control surface masses and the static moments including the mass balances (MB) stated are within the ranges:

Ailerons including trim tab (single control surface)

Mass:	12.5	-	14.0	kg	⇐ with MB
Static moment:	50	-	75	Ncm	⇐ with MB

The MB of from 4.5 – 8.5 kg is installed within aileron span range 20 – 90%

Aileron trim tab (single trim tab)

Mass:	0.70	-	0.90	kg	⇐ no MB
Static Moment:	33.0	-	38.0	Ncm	⇐ no MB

Elevator including trim tab (single control surface)

Mass:	12.3	-	15.0	kg	⇐ with MB
Static Moment:	145	-	175	Ncm	⇐ with MB

The elevator tip incorporates a mass balance of 4.5 kg with a lever arm of 205 mm

Elevator trim tab (single control surface)

Mass:	1.2	-	1.5	kg	⇐ no MB
Static moment:	70	-	85	Ncm	⇐ no MB

Rudder including trim tab:

Mass:	13.3	-	18.2	kg	⇐ with MB
Static Moment:	(-560)	-	(-150)	Ncm	⇐ with MB

The rudder horn incorporates a MB of from 4.5 to 7.10 kg with a lever arm of 195 to 175 mm.

Rudder trim tab:

Mass :	1.25	-	1.55	kg	⇐ no MB
Static moment: 75	-	100	Ncm	⇐ no MB	

23 October 2006