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REPORT ON THE ACCIDENT AT BROKSKAR, TROMS COUNTY, NORWAY 17 MAY 1999, INVOLVING EUROCOPTER (AEROSPATIALE) SA 365N DAUPHIN 2, LN-OLT OPERATED BY LUFTTRANSPORT AS

SUBMITTED
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REPORT ON THE ACCIDENT AT BROKSKAR, TROMS COUNTY, NORWAY 17 MAY 1999, INVOLVING EUROCOPTER (AEROSPATIALE) SA 365N DAUPHIN 2, LN-OLT OPERATED BY LUFTTRANSPORT AS

Aircraft type:	Eurocopter SA 365N Dauphin 2
Registration:	LN-OLT
Owner:	Lufttransport AS, Postboks 2500, 9002 Tromsø
Operator:	Same as owner
Crew:	3, commander, HEMS crew-member and medical doctor
Accident site:	At an altitude of 800 ft at Brokskar over Straumsfjorden, Troms County, Norway, N 69 31 00, E 018 31 00
Time of accident:	17 May 1999, at 1406 hrs

All times given in this report are local times (UTC+2 hours), unless otherwise stated.

NOTIFICATION

The company's flight operations manager gave notification of the accident to the Tromsø police district at approx. time 1600 on the same day. AIBN did not receive any information about the accident on the actual day other than in an enquiry from a journalist. Following a local press briefing on 18 May, with text and pictures of the helicopter flight, the company's flight operations manager made contact and gave AIBN an oral report. After the degree of seriousness of the accident had been established, an accident report was sent to AIBN.

SUMMARY

During an ambulance mission from Tromsø to Senja the helicopter flew into an area of strong turbulence and at the same time encountered a wind vortex with horizontal axis. This resulted in a large pitch down attitude and both sides of the helicopter's horizontal stabiliser ruptured. The Commander's control reaction to achieve a normal flight attitude, plus the effect of the Stability and Control Augmentation System (SCAS), resulted in a severe rotor flapping. The flapping resulted in contact between the main rotor blades and the helicopter fuselage. The flight continued towards its destination with the crew unaware of the extent of the damage, except that the trim attitude was more

nose-down than normal. The landing at the destination of Sifjord, Senja, was uneventful, but the return flight was cancelled.

Most of the stabiliser and both vertical fins were later recovered on the shore of Kvaløya. Following extensive technical investigations, AIBN has been unable to prove any structural weakness of the horizontal stabiliser prior to the accident. However, AIBN cannot rule out the possibility that the structure had been weakened prior to the accident. AIBN has identified weaknesses in the design and certification requirements in FAR 29, in that they do not take into consideration all aspects of the additional vertical fins, nor the effects of "dynamic stall" which can yield higher loads than expected. AIBN's investigations have revealed that the wind conditions in the area were not extreme and that they probably were within the certification requirements. AIBN's investigations have also shown that this type of helicopter can have upsets and extreme flight attitudes during flight in strong turbulence/wind vortices.

AIBN has forwarded 8 (eight) safety recommendations relating to the Aircraft Flight Manual, Aircraft Maintenance Manual, requirements on the training of maintenance personnel, implementation of Service Bulletin and stabiliser design.

1 FACTUAL INFORMATION

1.1 History of the flight

1.1.1 On 17 May at time 1349 the commander on duty and HEMS crew at the company's air-ambulance base at the Regional hospital in Tromsø (RIT) received an emergency call for a high-speed emergency ambulance mission to Sifjord in the southwest of Senja. The crewman obtained a local weather report from Sifjord and also examined TAF, METAR and IGA forecasts.

1.1.2 The helicopter, an SA 365N Dauphin 2, LN-OLT, was ready for operations in the hangar at the RIT helipad. The helicopter was already fuelled with the standard 600 kg of fuel. The crewman towed the helicopter out of the hangar to the start-up position on the helipad. While towing the helicopter, the crewman received a message on his radio telephone (ICOM – an internal radio for communication with AMK centres and ambulances) that the contingency status had changed from "emergency" to "standard".

1.1.3 The start-up was normal with the HEMS crewman outside the helicopter until both engines were started. He then boarded the helicopter, taking the co-pilot's seat on the left. The medical doctor arrived from the hospital entrance and got into the cabin in the front seat, which is his usual place. He turned the seat 180º in order to face forward during the flight.

1.1.4 The commander received clearance from the control tower of Langnes airport, Tromsø (ENTC), to lift off and the helicopter took off from the RIT helipad at time 1359. The commander was instructed to keep the aircraft at a maximum height of 500 ft until the Rya reporting point and to cross the centre line south of runway 01 beyond 6 NM, due to incoming traffic to Tromsø. At this point, the weather was overcast, with clouds at 1,000 and 2,000 ft. The wind was south-westerly, approx. 20 kt.

1.1.5 After passing the Rya reporting point, LN-OLT climbed from 500 ft to 800-900 ft. So far, the flight had been completely routine. Turbulence was light to moderate. The flight continued on course 250º on the south side of the Straumsfjord, at a distance of between 200 and 400 m from the shore. The indicated airspeed was approximately 150 kt. The commander subsequently told AIBN that he had been flying on the south side of the fjord in order to maintain visual contact with the next fjord, Malangen. He was aware that this area was more prone to turbulence than the north side of the fjord due to its proximity to high mountains, but in light of the weather information he was not expecting any extreme turbulence.

1.1.6 At time 1406 at a cruising level of 800 ft, between Vollstad and Brokskar (see map, Appendix 3), the level of turbulence increased. Suddenly and without warning, the helicopter's nose pitched sharply downward and, probably at the same moment, the horizontal stabiliser ruptured and broke away on both sides, approx. 25 to 30 cm from the tail boom.

1.1.7 It is unclear how large the pitch down angle was. The crewman estimated that the nose went down approx. 45º. The commander considered that the pitch down was 25º at a maximum, while the doctor felt that the helicopter was forced down and at the same time rolled first to the left and then to the right. The two crew-members sitting in the cockpit, had no clear perception of any helicopter rolling motion.

1.1.8 The commander immediately corrected the nose down pitching by applying rearward cyclic control in order to lift the nose. During this manoeuvre the blade mounting bolts contacted the top of the main gearbox cowling, and a bracket on the main gearbox' lower mounting (crossbeam) was overloaded suffering a small crack. The helicopter then encountered a rising air current, which forced the commander to reduce collective pitch to avoid entering the clouds. The whole incident from pitch down to stable horizontal flying was estimated to have lasted only a few seconds.

1.1.9 After the incident, the commander reduced the speed to below 135 kt in accordance with the procedure described in the Aircraft Flight Manual for flying in turbulence. The speed was kept below 135 kt for the remainder of the flight. The commander did not observe any eddies on the water, which might indicate heavy turbulence.

1.1.10 After the aircraft had passed Ansnes, the strong turbulence ceased and the remainder of the flight continued in moderate turbulence. The commander felt that LN-OLT was flying with a slight nose-down attitude at speeds between 120 and 135 knots, but not to such an extent making him concerned. He assumed that this was due to the trim having locked in the forward position. For the remainder of the flight, the crew was not aware of vibrations or abnormal noise.

1.1.11 When the descent to Sifjord started, the commander felt that the helicopter was not behaving as expected; he had to apply more rearward cyclic control than normal. He did not have any other control problems with the helicopter. Flaring, hovering and landing proceeded normally.

1.1.12 The landing time was 1443 on a road outside the senior citizen's home in Sifjord where the patient was due to be picked up. When the crewman exited from the helicopter to check that the ground was clear before the engines were stopped, he was surprised to discover that large sections of both horizontal stabilisers and vertical fins were missing. Due to this, he asked the commander to shut down the engines and stop the rotor. The helicopter was no longer airworthy and was later transported by truck back to the technical base in Tromsø. The patient was treated locally.

1.1.13 The subsequent investigations revealed that the stabiliser broke off downwards. Sections of it fell into Straumsfjord and were later recovered on the shore of the island Kvaløy.

1.2 Injuries to persons

INJURIES	CREW	PASSENGERS	OTHERS
FATAL			
SERIOUS			
MINOR/NONE	3	0	0

1.3 Damage to aircraft

Both horizontal stabilisers and vertical fins were separated from the aircraft. In addition, the main rotor blades (MRB) had made contact with the MGB cowling, which meant that the main gearbox (MGB) and drive train had to be checked for sudden stoppage. The engine and main gearbox cowlings were damaged (ref. § 1.12.2).

1.4 Other damage

None.

1.5 Personnel information

1.5.1 Commander

1.5.1.1 The Commander, a man aged 48, held a Canadian commercial helicopter and aeroplane pilot licence (CPL-H/A), a US commercial helicopter pilot’s licence (CPL-H), instrument rating (IR) and Norwegian CPL-H. He received his basic training in Canada where he worked as a pilot before coming to Norway in 1984 (where he converted his foreign licences to the Norwegian CPL-H).

1.5.1.2 The Commander was rated on: Bell 206, Bell 205, Bell 214, Bell 212, HU 369, SA 315B, AS350B/B1/B2 and SA 365N. He had been employed in the company since 1 April 1984.

1.5.1.3 The Commander had approximately three years’ experience of air-ambulance flying, mainly from Tromsø in the Bell 212 and SA 365N. The previous operations proficiency check flight in an SA 365N took place on 5 February 1998. CPL-H was first issued on 18 December 1984, valid until 26 June 2006, and was last renewed with LPT-2 in SA 365N 1 March 1999.

1.5.1.4 The Commander was a very experienced helicopter pilot. His flight experience includes expeditions to Spitsbergen, both from land and ship. During his employment with the company, he had flown both in Europe and in the Far East. His total flying time was 8,201 hours, of which 6,120 were in helicopters.

1.5.1.5 The commander's total flying experience was:

FLYING EXPERIENCE	ALL TYPES	ON TYPE
LAST 24 HOURS	2:10	2:10
LAST 3 DAYS	4:25	4:25
LAST 30 DAYS	35:50	23:40
LAST 90 DAYS	72:35	Not specified
TOTAL	8,201	6,120 in helicopters

1.5.1.6 The commander had been at work for 7 hours during the previous 24 hours, 15 hours during the previous two days, and 20 hours during the previous 3 days prior to the accident. The crew had carried out one ambulance mission before the flight that resulted in the accident. At the enquiry, the commander stated that he had been well rested before flying.

1.5.2 <u>The HEMS crew-member</u>

1.5.2.1 The HEMS crew-member had served in this position on the S-61N and Bell 212 with Helikopter Service AS from 1 June 1980 until 31 December 1983. On 1 January 1984 he joined Lufttransport AS as a crew-member on the Puma helicopter. On 1 January 1987 he became HEMS ambulance helicopter crew-member for the same company. He had been working in that position until the accident.

1.5.2.2 The HEMS crew-member was well acquainted with the Troms region and had a varied background, as a diver, fireman and HEMS crewman at Tromsø airport. He previously also held a private pilot's aeroplane licence.

1.5.2.3 At the enquiry, the crewman stated that he felt healthy and rested when the flight began.

1.5.3 <u>The medical doctor</u>

The medical doctor had approximately four years experience of air ambulance duty on helicopters of the type SA 365N and aircraft of the type Beach 200 belonging to the RIT base.

1.5.4 <u>The crew's rest time prior to the accident</u>

There was nothing unusual in the crew's rest period before the flight.

1.6 Aircraft information

1.6.1 <u>Helicopter data</u>

Manufacturer:	Eurocopter
Type/model:	SA 365N Dauphin 2

Year of manufacture:	1985
Serial number (S/N):	6140
Helicopter's total flying time:	12,351:38 hours
Stabiliser's flying time:	1,124 hours

(The stabiliser has no Serial Number (S/N) and may be difficult to trace)

Last 500-hour inspection:	20 June 1998 at TT 12,042:17
Last 100-hour inspection:	11 May 1999 at TT 12,340:11
Engines:	2 Turbomeca Arriel 1C
Engines' serial numbers:	LH 2253/RH 2159
Time since engines last overhauled:	LH 514:48/RH 2,800:00 hrs.

1.6.2 Stabiliser design, materials and certification

1.6.2.1 Design

1.6.2.1.1 The horizontal stabiliser on the SA 365N consists of one section mounted through the tail boom and bolted onto the fuselage, forming identical halves on each side of the helicopter (Ref. Appendix 2). The purpose of the stabiliser is to stabilise the helicopter longitudinally (around the lateral axis), thereby stabilising the fuselage in a more or less horizontal attitude at cruising speed. A vertical fin is attached to the tip of each stabiliser side. These vertical fins work together with the vertical tail fin to stabilise the helicopter around the vertical axis (the weathervane effect).

1.6.2.1.2 The two vertical fins are tall and protrude well under the tail boom of the helicopter. This means they are prone to contact with the ground during landing in hilly terrain, marshes or in deep snow. A side-effect of the stabiliser mounted vertical fins is that they give increased lift on the tail surface ("end plate effect"), in addition to causing torsional loading on the stabiliser in turbulence.

1.6.2.1.3 The stabiliser's surfaces have a NACA 5412 lift profile and are mounted in such a way that they provide negative lift (downwards). A vertical rail (Gurney flap) is mounted on the trailing edge of the profile and works as a lift augmentor (flap).

1.6.2.1.4 The stabiliser is made up of a main spar and an auxiliary spar, which, with the skin plates, make up a torsion box to absorb the aerodynamic bending, tension and torsion loading. The skin consists of 4 layers of carbon fibre fabric from the attachment area close to the tail boom. Approx. 30 cm out from the tail boom the 4-layer area ends and continues as 3 layers of carbon fibre fabric. (Ref. Figure 1, page 19).

1.6.2.1.5 Eurocopter has stated that the stabiliser's design and certification was based on FAR 29 Amendment 16, with special reference to § 305, 341 and 413.

1.6.2.2 Materials

The stabiliser is constructed of carbon composite materials (ref. § 1.18.1).

The two fabric types used in the construction are:

- DHS 217 325 unidirectional fabric
- DHS 217 332 bi-directional fabric (G803/M10)

1.6.2.3 Certification

1.6.2.3.1 Reference loads

Loads are defined in the document for 365N1 civil certification "Structural general design load calculation condition" at a maximum mass of 4,100 kg. (Ref. document 365A05 2002). FAR 29 §305, 341 and 413 are covered.

1.6.2.3.2 General conditions

The maximum aerodynamic load on the horizontal stabiliser is achieved at Maximum Continuous Power (MCP) at V_D with Cn = 0.7.

$V_D = (1.11 \times V_{NE}) = 100$ m/s

V_D = Vdive = absolute maximum speed

V_{NE} = Vnever exceed = maximum operating speed

Cn = Normal load coefficient = tail surface's lift coefficient

The aerodynamic load is uniformly distributed spanwise and the resulting load is localised at 25% chord.

The following applies for each side of the stabiliser (LH and RH side):

Surface	S = 0.71 m^2
Length	L = 1.26 m
Chord	C = 0.561 m

The loads are distributed symmetrically on both stabiliser surfaces.

$F_Z = ½ \rho S V^2 Cn = 0.5 \times 1.225 \times 0.71 \times 100^2 \times 0.7 = 3\,044$ N "limit load"

at V_D = Vdive = 195 kt = 100 m/s

Fz = Normal load on each stabiliser surface (lift)

1.6.2.3.3 Vertical gust load at high speed

The general balancing of the aircraft is not accomplished with local loads. These loads are evaluated separately for local analysis (Part strength and fixation).

According to the regulations of FAR 29.341, the resulting load on the horizontal stabiliser is the total of the balance load and gust load at speed V_H and max. Gust = 30 ft/s.

V_H is the speed in horizontal flight with Maximum Continuous Power.

Load conditions:

Gust speed: U = 30 ft/s = 9.15 m/s

Flight speed: V_H = 162 kt = 274 ft/s = 83.3 m/s

Gust load, general: $\Delta L = ½ \cdot \rho \cdot V^{2 \cdot} S \cdot a \cdot U/V$

where a = lift slope = Cn/rad

Gust load EC: $Lhe = ½ \rho Kgt\ U\ V_H\ (\delta cz/\delta i)\ S$

Gust attenuation coefficient: Kgt = 0.7 (0.55 required in FAR 29 § 413)

Gust factor: $\delta cz/\delta i = 4.35$

$U/V_H < 0.176 = tg\ 10^o$ (delta angle of attack, due to vertical gust)

Gust load: Lhe = 0.5 x 1.225 x 0.7 x 9.15 x 83.3 x 4.35 x 0.71 = 1 010 N

Balance load: Fe = 0.5 x 1.225 x 0.71 x 83.3^2 x 0.7 = 2 112 N

Resulting load at V_H = 162 kt (= 83.3 m/s) and U = 30 ft/s (= 9.15 m/s):

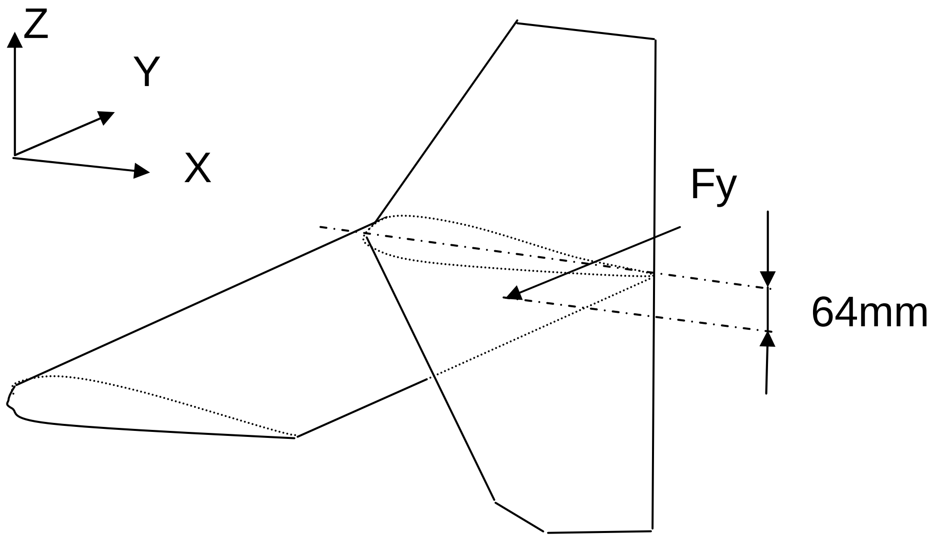
Fzr "limit load" = Lhe + Fe = 3 122 N at V_H and max. Gust.

Fzr "ultimate load" = 3 122 N x 1.5 = 4 683 N (FAR 29 Safety Factor = 1.5)

The Maximum Design Load is dictated by max. Gust at V_H.

1.6.2.3.4 Lateral loading on vertical fins

Lateral loading on the fins (lateral gust condition) is described in EC document 365A052002 "AS 365N1 structural general design load condition".



1.6.2.3.5 Eurocopter position:

"The principal goal of the test (DEL1045) was to reach the allowable moment at the h.s. critical section. The fact to have obtained this moment by a pure vertical load was a conservative manner to perform the test as it induced a greater share load at the critical section. The effect of the lateral fins is taken into account in the analytical calculation.
The dimensioning load case for the h.s. is the maximum bending moment due to the forward speed associated with the vertical gust. In these conditions loads applied at the lateral fins acted as a pure moment applied at the h.s. extremity. This moment is very low due to the position of its surface geometrical centre to the h.s. chord (64mm)."

1.6.2.3.6 Static test

A static load test has been performed by Eurocopter on a stabiliser of the same type (document ref. 365A06 0218).

Rupture moment Mr = 553 mdaN (metre deca-Newton). The static test includes the lateral aerodynamic load applied on the lateral vertical fin as per document 365A06-0218.

1.6.2.3.7 Fatigue test

A fatigue test was demonstrated on a stabiliser possibly weakened by soft areas (document ref. 365A05 2011). The fatigue test was performed on the same stabiliser that was used for the static test (document ref. 365A06 0449). “Low cycle fatigue spectrum” fatigue on a stabiliser has been demonstrated at 40,600 flying hours. (DEL 1093, doc. 365 06 1093).

A limiting average fatigue moment at the stabiliser’s root was demonstrated.

1.6.2.3.8 Measurements during flight test - registrations

Measurements were carried out during test flying using an SA 366G 6003 helicopter (Sud Aviation type 366G, S/N 6003. SA 365N is the former designation of the AS 365N, with AS standing for Aerospatiale).

All the results are part of "flight test results document" H/EV No 14.684. The "flapping moment" as a function of speed emerged from these tests. Throughout the entire acceleration phase, the maximum moment at the stabiliser's root was measured at ± 45 mdaN.

1.6.2.3.9 Static substantiation

Static substantiation of the stabiliser was carried out in accordance with document 365A05 1402.

The safety margin was calculated using the following formula:

$$M = [(Mr\ \sigma_{mr} / \sigma_{mp}\ K_{v+t})/Mu - 1]$$

With:

$Mu = 295$ mdaN	ultimate bending moment (312 x 0.63 x 1.5)
$Mr = 553$ mdaN	rupture test moment
$\sigma_{mp} = 123{,}2$ hbar	average rupture stress value
$\sigma_{mr} = 115$ hbar	minimum allowable reception value (statistic approach)
$K_{v+1} = 0.8$	aging and temperature reduction factor

The safety margin includes the strength of the tested stabiliser and loss of strength as a result of ageing and the temperature factor.

For the "unidirectional fabric" main component of the stabiliser's longeron, the safety margin has been calculated to M = 40%.

1.6.3 Maintenance

The helicopter had been maintained in accordance with the maintenance system. No deficiencies were found in relation to the helicopter's maintenance program.

The "coin tapping" method was used, where the engineers involved tap lightly on the skin surface of the actual structure with a standardised tapping tool. Being alert for changes in sounds, they expect to detect areas of delamination.

This method is simple, but demanding on the person carrying it out. Tests have shown that some engineers will find delamination using this method, while others will not detect the same areas of damage (Ref. AIBN report 02/1998, LN-OBP).

1.6.4 Mass and balance:

1.6.4.1 Mass

Mass calculation for this flight:

Empty mass:	2,910 kg
Mass of crew:	170 ”
Mass of passenger:	85 ”
Fuel:	600 ”
Actual take-off mass	3,765 kg

Maximum permissible take-off mass was 4,000 kg.

1.6.4.2 Balance

The helicopter was within the balance limits.

1.6.5 Fuel

The helicopter had the company standard quantity of 600 kg of Jet A-1 fuel on take-off.

1.6.6 Limitations when flying in turbulence

SA 365N Flight Manual, section 4.1, 8.3 Flying in Turbulence states:

“Fly at best-range cruising speed”, which for this type is 135 KIAS.

This is a recommendation, not a limitation. It has been listed with regard to comfort, not to prevent damage to the helicopter. There is no limiting airspeed for flying in turbulence listed in Flight Manual, section 3, Limitations.

1.7 Meteorological information

1.7.1 Report from the Weather Bureau for Northern Norway

"WEATHER SITUATION FOR TROMSØ – RYA – SIFJORD MONDAY 17. MAY 1999 1200Z

General description:

The maximum average wind (10 min) at Hekkingen lighthouse north of Senja was southerly (strong breeze) in the period 06Z-12Z and southerly 27 kt (strong breeze) from 12Z to 18Z.

The equivalent figures for Tromsø were southerly 19 kt (fresh breeze) from 06Z-12Z and southerly 29 kt (moderate gale) from 12Z to 18Z.

These values show the wind at ground level. Both Hekkingen lighthouse and Tromsø are exposed to this wind direction. Using subjective evaluation, the wind at 1,000 – 5,000 ft was 5-10 knots above the ground values in this case.

A warm front was crossing the area during the period. The front caused some precipitation (19 mm in Tromsø from 06Z to 18Z) and there was a warning of moderate icing. As a front passes over, the wind usually briefly increases by 5-10 kt.

At time 1200Z, the wind gauge on Kjølen (a mountain northwest of Tromsø, 790 m above sea level) indicated a wind from 183°, average wind speed was 41 kt, gusting up to 48 kt.

The terrain in the south is dominated by the mountains on the Malang peninsula, with peaks from 800-1,170 m and clefts and valleys in the direction northwest-southeast with hills of 200-300 m. This has contributed towards locally stronger winds and turbulence.

Conclusion

Using a subjective evaluation, the aircraft may have had an average southerly 40-50kt wind speed for a short time and the meteorologist on duty estimated that there was moderate turbulence in the area. It is possible that there could have been heavy turbulence locally in the period in question.

Attachments:

It has not been possible to produce increases and winds at altitude for the period in question, but the following have been attached:

1.	*Analysis 17May 1999 1200Z*
2.	*Extract from Nordenkartet 1200Z*
3.	*Extract from Nordenkartet 1800Z*
4.	*Relevant METARs from Tromsø/Langnes airport*
5.	*Main warning 0700 local time*
6.	*Gale warning issued 0925Z*
7.	*Ice message issued 1230 (No Ice message prior to this)*
8a. and 8b.	*IGA forecasts valid 06-18 and 11-21.*

No turbulence Sigmet was issued during the period in question. A Sigmet is issued when there is a risk of severe turbulence. A criterion for this is 55 kt at 5,000 ft. The risk of turbulence is also evaluated in relation to the wind direction at the different airports.

The attachments from the Weather Bureau have not been included in this report.

1.7.2 TAF Tromsø airport (ENTC) at time 0900-1800 UTC

Wind: 200° 20 kt. Visibility: More than 10 km. Scattered clouds at 1,000 ft. Broken clouds at 2,000 ft. Temporary visibility of 5,000 metres in rain and mist. Scattered clouds at 500 ft and broken clouds at 1,000 ft.

1.7.3 METAR Tromsø airport (ENTC) at time 1050 UTC

Wind 170° 15 kt. Visibility: More than 10 km. Weather: rain and mist. Clouds: Few clouds at 1,500 ft, scattered clouds at 2,000 ft and broken clouds at 3,000 ft. Temperature 4 °C. Dewpoint: 4 °C. QNH: 1017 hPa.

1.7.4 Weather warning (IGA forecast) for Nordland, the Troms coast and the fjord district at time 1100-2100 UTC

Up to 2,000 ft: Wind SSW 15-30 kt. Visibility: more than 10 km, 3-8 km in rain and mist. Clouds: scattered clouds at 1,500 ft, overcast at 2,500 ft, intermittent scattered clouds at 800 ft and overcast at 1,500 when there is rain and mist. Turbulence: Light to moderate, later locally moderate.

1.7.5 Weather conditions at take-off from RIT Helipad (at time 1359)

Wind: 200° 20 kt. Visibility: More than 10 km. Clouds: Few clouds at 1,000 ft, partly overcast at 2,000 ft. Temperature 4 °C. Dewpoint: 4 °C. QNH: 1017 hPa.

1.7.6 Witness observations

Representatives from the helicopter company have told AIBN that strong winds were gradually increasing in the Tromsø area on 17 May 1999.

1.7.7 Commander's observations

The Commander pointed out that there was no notification of particularly strong winds in the area or any particularly turbulent conditions. Nor were there any notable wind squalls on Straumsfjord. Regarding this last point, others have reported that the wind direction that day was such that you would not have seen any effects on the water.

1.8 Aids to navigation

Normal.

1.9 Communications

Normal.

1.10 Aerodrome information

The RIT helipad is located at the regional hospital in Tromsø, 1.3 NM east of Langnes airport at Tromsø.

1.11 Flight recorders

Not mandatory and not installed.

1.12 The accident site and damage to the helicopter

1.12.1 The accident site

The helicopter was at a height of 800 ft on the southern part of Straumsfjord, approx. 200 – 400 m from the shoreline and the same distance from Brokskar, when the horizontal stabiliser ruptured (Ref. Appendices 3 and 6-1).

1.12.2 Damage to the helicopter

1.12.2.1 The following damage was discovered on the helicopter

The stabiliser, which was still attached to the helicopter:

- A break on the RH stabiliser approx. 30 cm beyond of the right-hand mounting bolt (Image 2).
- A break on the LH stabiliser approx. 25 cm beyond the left-hand mounting bolt (Image 1).
- The upper part of the skin on the LH stabiliser between the crack and the vertical fin remained attached to the helicopter during landing.

Recovered parts of the stabiliser and vertical fins:

- The RH vertical fin separated from the horizontal stabiliser and tore off the skin along the entire length from the middle and backwards on the outer side (Image 7). All the torn-off parts of the stabiliser remained attached to the vertical fin. The left-hand vertical fin was slightly damaged with 10-20 cm of the horizontal stabiliser still attached to the fin (Image 12).

Top cowlings:

- MGB top cowlings, contact damage (scratches) in the left back corner after contact with sleeve bolt/nuts (Image 4).
- Engine top fairing, 40 cm contact damage (scratches) after contact with sleeve nuts and 10 cm damage behind this, scratches caused by contact with MRB bolts (mounting bolts).

Tail fin:

- At the "2 o'clock" position on the right side of the fan opening, 10 cm-long dent approx. 3 mm deep, 7 – 8 mm wide (Image 3).
- A small dent on both sides in the middle below the fan.

Loran Antenna:

- Bent back and to the left (Image 2).

Main gearbox bottom suspension:

- One laminated elastomer stop had a small crack

All detached parts from the helicopter (with the exception of the lower part of the left stabiliser) were recovered on the shore of the island of Kvaløya. The location where the parts were found was in conformity with the location of the incident, taking into account the wind and current conditions.

1.13 Medical and pathological information

No medical examinations of the crew were performed.

1.14 Fire

There was no fire.

1.15 Survival aspects

In the extreme flight attitudes the helicopter adopted following the loss of the horizontal stabiliser, the main rotor blades made contact with the fuselage. This resulted in damage to the fuselage and rotor system. More damage of the same nature would have caused rotor blades/tail fin contact and possibly loss of control.

1.16 Tests and research

1.16.1 Examination of the stabilisers

1.16.1.1 During the preliminary examination of the remains of the stabiliser on LN-OLT, S/N 6140 (STAB 1), Lufttransport AS revealed that it had another horizontal stabiliser which had been removed from another helicopter, LN-OPD, S/N 6067 (STAB 2) due to "soft areas". STAB 2 was 15 years old and had logged 5,000 flying hours. The removal of this stabiliser was due to the discovery of a soft spot in the left lower side, approx. 20-30 cm from the attachment to the tail boom, and stretching of approx. 10 x 20 cm (Ref. Appendices 1-4). This type of soft spot has also been reported by other operators of the same helicopter type.

1.16.1.2 Following an agreement between Lufttransport, Eurocopter and AIBN, this stabiliser was used as a reference object. The stabiliser became the subject of both non-destructive testing and destructive testing in the case of static loads.

1.16.1.3 Further details about technical investigations and analyses will therefore refer to two stabilisers, STAB 1 and STAB 2.

1.16.2 Examination of STAB 1, DET NORSKE VERITAS (DNV, Ref. Appendix 4)

1.16.2.1 The remains of STAB 1 consisted of 6 parts and were initially examined by DNV. The lowermost skin plate on the left hand side was not recovered and was therefore not subject for examination. The examination was supported by a comparison with Eurocopter’s production specifications.

1.16.2.2 The number of layers of fibre fabric in the skin plates conformed to the specifications, 3 and 4 layers respectively. The transition from 3 to 4 layers was sharp and 21.5 cm from the attachment points (in accordance with the specifications), right inside the break areas. On both break sides, characteristic load breaks were indicated, caused by downward loading.

1.16.2.3 Areas with cracks through the gelcoat/paint were found on both the top and lower side. None of the cracks had spread into the laminate.

1.16.2.4 Internal areas of laminate were examined without irregularities being found.

1.16.2.5 The stabiliser has two longitudinal support beams/spars, a main spar located at the thickest part of the profile and a smaller one approximately 19 cm behind the main spar. These were examined and confirmed as being in accordance with the design specifications.

1.16.2.6 Some areas of the spar's surface had micro-cracks, probably caused during the rupture sequence.

1.16.2.7 The main spar had a crack that stretched from the skin's rupture location and 15-20 cm beyond. The length of the crack was the same on both sides of the skin (on the top and bottom) and on both sides of the stabiliser.

1.16.2.8 The break indications on the skin gave the impression that the rib failed before the skin gave way. Never-the-less, it is not possible to conclude with any certainty which of the elements failed first, the rib or the lowermost (curved) skin.

1.16.3 <u>Examination of STAB 1, Eurocopter. Ref. Appendix 9</u>

1.16.3.1 General

Following the investigations at DNV, the remains of the stabiliser from LN-OLT (STAB 1) were sent to Eurocopter France, Marseille. Eurocopter conducted a preliminary examination on the basis of the following assumptions with regard to fault mechanisms:

1. Production faults.
2. Abnormal aerodynamic load (overload) during flying/inadequate margins in the permitted operational boundaries (flight envelope boundaries).
3. Damage to the tail surface by a foreign body during flight, which resulted in a rupture first on one side and then on the other, due to aerodynamic load caused by the helicopter pitching nose down.
4. Previous damage, which had weakened the structure.

1.16.3.2 Findings

- There was no sign of any pre-existing delamination in the construction before the rupture damage.
- No deviation from the construction specifications was found, neither in material nor dimension values. The transitions between skin and buttresses (beams, ribs) were examined specifically.
- It was established that the breaks had occurred during a downward movement. The damage appears to be greater on the left-hand side than on the right.

1.16.3.2.1 Eurocopter confirmed that these investigation results correlated with the results from the investigations carried out by DNV. In view of this, Eurocopter believes that assumptions 1 and 3 (§ 1.16.3.1) can be disregarded. Eurocopter also revealed that it would conduct further investigations based on assumptions 2 and 4 (§ 1.16.6)

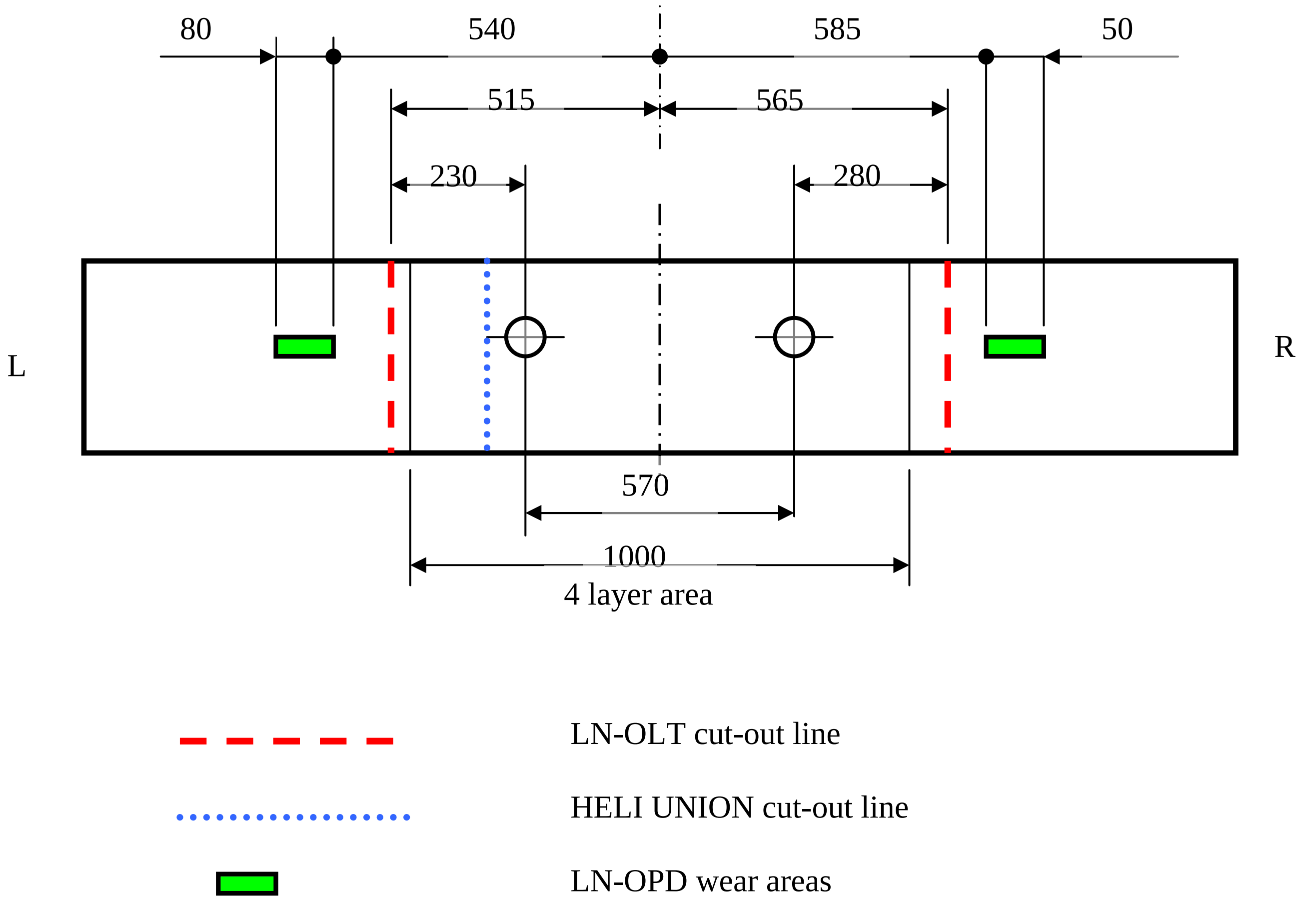
1.16.3.2.2 Both Lufttransport and other operators, have raised concerns about the constant cracking of the paintwork on the underside of the tail surfaces. Eurocopter will look more closely into this phenomenon during further investigations.

1.16.3.3 Later investigations have revealed the following in relation to STAB 1

Traces of wear were found on the inside of the right-hand lower skin plate. The wear was caused by chafing between the skin and the carbon fibre tube housing of the cable for the navigation light, which is installed at the far end of each stabiliser surface. The left, lower skin plate was not examined, as it was never recovered.

The aforementioned wear on the skin plate was also found in the examination of STAB 2 (LN-OPD), on both the left and right sides. This wear eventually caused the skin plate to become perforated. (§ 1.16.6).

Figure 1: HORIZONTAL STABILIZER SCHEMA
TOP VIEW – NO SCALE



1.16.4 <u>Examination of STAB 2, Det Norske Veritas (DNV)</u>

1.16.4.1 The examination revealed that the soft spot had a thinner cross-section than the surrounding area.

1.16.4.2 Measurements revealed differences in the total thickness of the skin on STAB 1 and STAB 2 in the region of 0.4-0.7 millimetres.

1.16.5 <u>Examination of STAB 2, Luftforsvarets Forsyningskommando (LFK)</u>

1.16.5.1 The examinations were concentrated on the previously mentioned soft area on the underside of the left half.

1.16.5.2 The examinations did not reveal any information of significance, apart from the fact that radiographic testing made it possible to define the delamination (soft area, see photos, Appendix 1-4).

1.16.6 <u>Examination of STAB 2, Eurocopter</u>

1.16.6.1 In these investigations, STAB 2 was used for stiffness measurements, static load tests (ultimate load test) and examination of mechanical characteristics of the material in areas where ruptures had occurred during these tests.

1.16.6.2 It was discovered that areas on the inside of both lower halves of the stabiliser had suffered wear from the screening tube of the electric cable leading to the navigation light, to such an extent that the skin gradually became perforated.

1.16.6.3 Eurocopter has performed a static load test on STAB 2, documented in Eurocopter report 365A.06.1175. The test was conducted with the tail surface mounted in a jig. Clamps were mounted round the profile, 0.63 from the tail surface’s attachment to the left and right side. The clamps imposed forces on the tail surface’s sides by means of hydraulic jacks that were attached with the clamps. During the loading test, downward bending was measured and failure reaction in the structure was observed.

1.16.6.4 The results of the static test showed that a failure in the carbon fibre structure occurred at:

- 410 mdaN on the right half, which gives a safety margin of 39% in relation to ultimate
- 378 mdaN on the left half (where the soft spot is detected), which gives a margin of 28%.

in relation to the ultimate design load (Ref. § 1.6.2.3.3).

The lower margin on the left-hand side is due to the fact that:

- the right side is subject to less loading in flight and therefore had less fatigue damage
- the damage on left side was larger than on the other side.

The test also revealed that the first local instability occurred at:

- 0.4 times the limit load on the right half
- 0.75 times the limit load on the left side

This indicated a certain reduced strength of the horizontal stabiliser due to wear and aging.

1.16.6.5 DNV detected a substantial difference in the thickness of the laminate between STAB 1 and STAB 2 (§ 1.16.4.2) Eurocopter's investigations established that this was mainly due to a difference in the paint thickness on each stabiliser surface, namely 4 layers for STAB 1 and 15 layers for STAB 2. After the paint layers on parts of the stabiliser surfaces had been removed, the laminate was measured at 1.3 millimetres on STAB 1 and 1.2 millimetres on STAB 2.

1.16.7 <u>Examination of the Laminated Elastomer Stops. Ref. Appendix 5</u>

1.16.7.1 The base of the main gearbox is attached to the fuselage by means of two elastic stop brackets. These are designed as laminated blocks consisting of layers of metal and rubber (laminated elastomer stops). The stop brackets are meant to absorb the torsional moment and lateral and longitudinal loads, which enables the gearbox to move within certain limits, and to absorb the vibrations from the main rotor.

1.16.7.2 The front laminated stop was found to be cracked during the technical examination of the helicopter after the accident. The crack went through both the metal and rubber plates. DNV and Eurocopter have concluded that the stop bracket had cracked as a result of regular material overloading caused by extreme side loads (bending). These side loads were caused by the rotor through the main gearbox when the main rotor blades made contact with the fuselage.

The conclusion from the examination of the bracket is as follows:

"The visual and macro-graphic rupture investigation shows that the crack started to develop because of overloading associated with lateral bending forces. These forces also resulted in side buckling.

No indication was found of previous crack development or other geometrical faults during the break analysis.

No significant irregularities were found in the material during the metallographic examination."

1.17 Organisational and management information

1.17.1 Lufttransport AS was founded as an independent company in 1955, but was at the time of the accident a subsidiary of Helikopter Service AS. The helicopter company is approved by the CAAN in accordance with JAR-OPS-3 and holds a licence and operating permits (VFR and IFR) for sightseeing flights, parachute drops, photography and advertising flights and patrol flights. The company has also a contract with Rikstrygdeverket (National Insurance Administration) for air ambulance flights from several bases in Norway, including the Regional Hospital at Tromsø (RIT). The company's head office is located in Tromsø. Operations are distributed over several bases across the country. This means the company has experience in flying over varying topographical conditions and in different climatic conditions, including flying in heavy turbulence. At the time of the accident the company had 117 employees and operated 10 fixed-wing aircraft, mainly of the type Beach 200, and 3 helicopters of the type SA 365N.

1.17.2 <u>The company's SOP 2-4-4 WIND LIMITATIONS states the following</u>

> *"The PIC must evaluate if flying can take place under the prevailing and expected wind conditions, with respect to wind speed, squalls and turbulence. This evaluation depends upon the topographical conditions."*

1.18 Additional information

1.18.1 <u>Fibre-reinforced polymer composites (reinforced thermosetting plastic)</u>

1.18.1.1 Fibre-reinforced polymer composites have been used in the aviation industry for many years. Many aeroplane and helicopter manufacturers are using composites in both primary and secondary constructions. Fuselage parts, pipes, rotor blades, propellers, wing panels and covers are examples of polymer composite constructions.

1.18.1.2 The advantage of this type of construction is that it produces good chemical and physical properties, which include low weight, together with a high level of rigidity and strength in the fibre direction. At the same time, dimension stability, temperature and chemical resistance are achieved. The constructions are often flexible and relatively easy to produce.

1.18.1.3 Fibre-reinforced polymer composites consist mainly of reinforcing materials (e.g. glass fibre and carbon fibre) and matrix materials (e.g. epoxy, polyurethane, polyamide and hardeners). Carbon fibre is the predominant reinforcement material in the aviation industry.

1.18.1.4 The material can be supplied as fabric with different weave patterns depending on what it will be used for. Industrial fabric is often pre-impregnated with matrix materials. The fabric is laid one layer over another on a template. The construction is then placed in an autoclave. Here the air is forced out and under pressure and temperature the carbon fibres and matrix materials are combined into one homogenous unit. This construction method (briefly) is used in the manufacture of the horizontal stabiliser of the helicopter type in question.

1.18.1.5 Eurocopter France uses reinforced polymer composites extensively. Among the places in which composite materials are used in the helicopter, which is the subject of this report, are the tail section, the horizontal stabiliser, the rotor blades and parts of secondary structure.

1.18.1.6 Experience has shown that composite materials have been weakened after being subjected to impact loading. This damage may be invisible and further inspection may not be performed.

1.18.1.7 It is time-consuming to check composite construction for delamination and other damage. Ultrasound can be used to check for delamination of composite materials, but the method is not widely used in practical flight maintenance where the coin tapping method continues to be used. (Ref. § 1.6.3).

1.18.1.8 Eurocopter has told AIBN that loss of the left stabiliser section has occurred previously on the same type of helicopter during flight. In these cases, Eurocopter reports that the stabilisers had been damaged beforehand.

1.18.1.9 The SA/AS 365N/N2 helicopter is used extensively for air ambulance services. In Norway this type of operation often requires landing away from prepared landing sites in terrain or snow covered ground. This may result in the vertical fins being subjected to loads in the form of bending and twisting which can produce "invisible" damage in the composite structure.

1.18.2 <u>SA 365N Stability and Control Augmentation System (SCAS)</u>

1.18.2.1 The SA 365N is equipped with an AP 155 auto-stabilising system. In principle, this is a 3-axis (pitch, roll and yaw) Stability and Control Augmentation System (SCAS), whereby each axis is controlled by two identical channels which function in a “fail-passive” configuration. SCAS functions as a stabilising system (Stability Augmentation System, SAS) where the rotor is activated by serial actuators with limited authority and which superimpose the pilot’s control movements. It also maintains position and course in relation to reference values that the pilot controls by means of the cyclic and collective controls (Automatic Stability Equipment, ASE). Both functions are usually in use concurrently.

1.18.2.2 The system includes a fly-through control, which enables the pilot to modify the steering and position references via a “beep trim” button on the control stick (cyclic beep trim). Both the SAS and ASE functions are in use during manual flying. The SAS/ASE system has limited authority, using series actuators to activate the Flight Control System (FCS) and modifying control signals to the control system independently of the pilot’s controls. In this way, the helicopter is stabilised in turbulent air. The aircraft is also equipped with a CDV 85 Coupler, which allows coupling between a Flight Director (FD) computer and the SCAS. This enables the traditional autopilot function, which automatically maintains course, altitude, VS, IAS etc. The Flight Director Coupler function was not in use at the time of the accident.

1.18.3 <u>Accident involving an SA 365N belonging to the Iceland Coast Guard</u>

1.18.3.1 General

On 25 May 2001 helicopter TF-SIF flew into a wind vortex over a cliff on the west coast of Iceland (Ref. report M-02901/AIG-07 from the Icelandic Aviation Accident Commission). The helicopter pitched up sharply and then down, to such an extent that the pilot was looking straight down at the ground. During these movements, and as a result of the pilot's control movements to bring the helicopter under control again, damage occurred as a result of the main rotor coming into contact with the tail fin and top of the motor cowling. The damage to the fuselage (cowling) was in the same area as on LN-OLT. However, the horizontal stabiliser was not lost and on LN-OLT the main rotor blades did not hit the tail fin.

1.18.3.2 Sequence of events

Excerpt from the Icelandic report:

"History of the flight:

The weather was good and according to the Commander, there were no indications that turbulence might be expected. The helicopter flew south over Hraunsfjordur, then southeast over lake Hraunsfjardarvatn and lake Baularvallavatn. Then a slight right turn south was made over the hills at the western slopes of the valley. The land rises slightly towards Urdarmuli, a rather steep hill at the south end of the slopes, which is about 1 000 feet above sea level. The helicopter was climbing slightly, according to the Commander, and height above ground was maintained between 30 and 50 feet. A slight tailwind was observed after the turn and indicated airspeed was kept at approximately 120 knots. As the helicopter reached the southern ridge, without a warning, the helicopter pitched up and the Commander applied forward cyclic as an immediate reaction. The rotor speed went up and the helicopter pitched rapidly forward so the Commander immediately applied rearward cyclic. The helicopter levelled off with a slight left roll. The crew, however, noticed rotor vibration after the incident and a landing site was selected on a grass field adjacent to the nearest main road that is about 60 feet above sea level. There an uneventful landing into the southwesterly wind was made about two minutes after the incident. After landing, damages to the tail section and main rotor blades were discovered."

TIF-SIF had a cockpit voice recorder (CVR) installed. The report on the CVR data stated the following:

"From the average of about 355 RPM [rotor speed], the speed exceeded 380 RPM in 4 seconds, high RPM warning sounded within a second and 17 beeps were recorded, lasting about 2 seconds. The RPM started to drop immediately after reaching its peak and dropped to about 335 RPM in 3 seconds when a thud was recorded. Low RPM warning sounded just over a second later but lasted only for two beeps. The RPM had started to increase again immediately after reaching the minimum when the thud was recorded. The main rotor speed stabilized at about 355 RPM just over 2 seconds after reaching the minimum. The whole upset lasted about 9 seconds according to the CVR data."

1.18.4 Previous incidents involving loss of horizontal stabiliser on SA/AS 365

1.18.4.1 General

Eurocopter has delivered more than 500 helicopters with this type of stabiliser, which have logged totally more than 2,000,000 flight hours. Three failures have been reported to EC.

1.18.4.2 AS 365N2, Gabon 1994

A helicopter belonging to Heli-Union lost the left stabiliser while flying at 2,000 ft and 175 KIAS. According to Eurocopter, the stabiliser had been weakened previously after a mechanic had hit it with a ladder (Ref. Figure 1).

1.18.4.3 SA 365N, Norway 1995

A helicopter belonging to Airlift lost the left stabiliser after taking off from a landing site out in the country. According to Eurocopter, the structure had been weakened by the left vertical fin coming into contact with the ground during landing. This meant that the vertical load was transferred to the left horizontal stabiliser, which was left with a permanently weakened structure.

1.18.5 Previous incident involving loss of horizontal stabiliser on SA 365C1, UK 1977

The SA 365C1 is the forerunner of the SA/AS 365N series and therefore a different type of helicopter, even though it has much in common with the SA/AS 365N. The helicopter was flying at a cruising speed of 110 KIAS. The helicopter suddenly pitched 30º nose down. The Commander immediately pulled the cyclic stick towards him and reduced collective. This enabled him to regain controlled flight at 80 KIAS and he continued at this speed until reaching the destination, 30 minutes away. When the Commander was hovering before landing, eyewitnesses saw the left stabiliser fall off. After landing, it was discovered that the left stabiliser had failed in the tubular steel spar. This spar attaches the stabiliser to the tail boom. The failure was caused by a fatigue crack in the tube construction.

1.18.6 Previous incidents involving contact between the main rotor blades and the fuselage

The accident involving the coastguard helicopter (TF-SIF) is the most serious case of contact between the main rotor blades and the fuselage of which AIBN is aware (§ 1.18.3). In conjunction with the investigation into the accident, information was received from the US Coast Guard regarding previous cases of contact between the main rotor blades and the fuselage. All the incidents referred to occurred during landing and manoeuvring on the ground. AIBN is not aware of cases involving contact during manoeuvring in the air other than TF-SIF and LN-OLT. In conjunction with the investigation into TF-SIF, reference was made to a Service Bulletin (SB), SA 365N no. 67.03, which increases the clearance between main rotors and fuselage.

1.18.7 Service Bulletin SA 365N, no. 67.03

LN-OLT had not implemented Service Bulletin SA 365N, no. 67.03. This SB reduces the flapping of the rotor plane and thereby the danger of contact between the rotor blades and the fuselage. The SB was optional.

1.18.8 Flight attitudes without the horizontal stabiliser

1.18.8.1 Eurocopter has made the following description in report E/TA No. 800/00 CG "Flight attitudes without the horizontal stabilizer, dated 7 December, 2000":

"Calculations carried out using the simulation model have enabled assessment of the level flight attitudes in the event of loss of the horizontal stabilizer. The appended diagram shows the result of this study. It is evident from this that in the case of the incident, the attitude in level flight at 120 knots (configuration at the end of the flight) should have been in the order of 5° nose-down (compared with 1,5 to 2° nose-down with the horizontal stabilizer), and the stick should have been 15% further to the rear than usual."

1.18.8.2 In a report OTEA no. 246/04, dated 12 July 2004, Eurocopter has summarised the results from a later simulation of the loss of the horizontal stabiliser on a Dauphin N:

"The simulation was started in 150 kt level flight, 800 ft PA, ISA condition, with a weight of 3 565 kg and a 3.90 m C.G. position."

"A longitudinal stick input of approximately 60% backwards is used, with minor adjustment of the collective pitch. This allows stopping the nose-down pitch motion at an approximately -22º pitch attitude that is close to the Commander estimation of the extreme pitch attitude (-25º)."

"The maximum flapping that is encountered corresponds to a 14º longitudinal component and a 2º coning angle downwards. Taking into account the 4.5º precone angle, this leads to an aft blade flapping angle of 11.5º downwards with respect to the plane normal to the mast. This is consistent with a contact on the upper cowling without touching the tailboom."

The simulation results show that the helicopter will continue in level flight with a nose-down pith attitude of -9º after the loss of the horizontal stabiliser.

1.18.8.3 It has been reported from incidents with other helicopter types that the fuselage will pitch down 10º-30º if the tail surface fails during flight. A British AS 332L offshore helicopter lost the horizontal stabiliser at a cruising speed of approx. 130 kt and pitched down 10º (AAIB Bulletin 8/98). Similarly with a British SA 365C1 helicopter (§ 1.18.5), which pitched down an estimated (by the pilot) 30º when the left half-stabiliser fell off at a cruising speed of 110 kt.

1.18.8.4 There have been several reported cases of contact between the main rotor blades and the fuselage when the helicopter makes a sudden positional change with SAS/ASE activated at the same time as the pilot tries to correct with cyclic (§ 1.18.6).

1.18.9 Expert assessments

In addition to DNV's and Eurocopter's testing and calculations, AIBN has collected assessments from several external aeronautical experts. §§ 1.18.9.1-1.18.9.4 including expert assessments made in response to the request from AIBN.

1.18.9.1 Professor Helge Nørstrud, NTNU (Norwegian University of Science and Technology)

Professor Helge Nørstrud has made an assessment of the possible aerodynamic loads on the stabiliser in conditions of extreme turbulence, in which he writes (Nørstrud, H. et al.; ”Simulation of wind-induced vortex flow and effect on a helicopter structural failure”, paper at the NATO/RTO Symposium on ”Vortex Flow at High Angle of Attack”, Loen, Norway 7-11 May 2001):

"A report issued by Eurocopter says that the rupture of the stabilizer can be explained by aerodynamic calculations with a sudden entry into a vertical gust of 17.6 m/s (58 ft/s), which is twice the value in the JAR 29 Amendment 16 requirements. As shown in Figure 6, this value could well be exceeded for farfield winds of 80 knots. Furthermore, static failure tests have shown that a root moment of 5,330mN per half-stabilizer will also lead to a failure. If we assume a uniform loading over the stabilizer, this would yield (for t = -5s) a vertical downward loading of 8,460 N or a static lift coefficient corresponding to 2.1 for the specified flight conditions (with a head wind of 20 m/s) and given stabilizer geometry. Hence, a dynamic stall of the stabilizer at about t = -5s can occur, partly due to rotor reaction of headwind.

CONCLUSION

The primary conclusion from the present study is that the numerical simulation of steady-state wind conditions reveals strong vortex flow patterns in two areas of the flight path, with one coinciding with the location of the sudden nose-down movement of the subject helicopter (Figure 11) and also the recovery of the stabilizer in the fjord.

This wind flow structure will further introduce strong transient flow conditions on the flight vehicle and on the horizontal stabilizer including the two vertical fins. This highly three-dimensional wind induced flow could be the cause for the structural failure of the stabilizer, however, no aerodynamic proof can be put forward."

1.18.9.2 Aeronautical engineer Åge Røed, formerly with SAAB, now a consultant

Åge Røed has produced an assessment for AIBN, in which he writes:

".....when the helicopter flies into downdraft (turbulence), further "static" load increases are obtained. These loads are more difficult to determine than the primary static loads due to the difficulty of determining the magnitude of the downdraughts, the dynamic effects of the vertical wind changes and the pilot or autopilot reactions to these disturbances. Investigations of wing failures have shown that wings may fail at speeds where they should have stalled before they failed. However, due to dynamic lift increase the wings still failed. The dynamic lift increases probably doubled the maximum static values. Thus, the designer is faced with a very difficult problem when trying to determine the maximum load a lifting surface will be subjected to. He must ask himself: Which downdraught and which dynamic lift should I design for? Should I try to find the most severe and sudden vertical wind changes on earth or should I try to standardise vertical gusts in order to avoid making the helicopter too heavy? If I standardise do I have to stipulate flight restriction in turbulence? How do I do that and how do I inform the pilots/operators and make the restrictions easy to implement?

In the case of helicopters flying in heavy turbulence, large whiplash loads may be obtained if the on/off loading of the stabilizer is very fast. In the case of the Eurocopter LN-OLT, the whiplash loads could be aggravated by the vertical fins mounted on the stabilizer tips. These fins increase stabilizer efficiency (end plate effects) but they also move the stabilizer lift resultant outboard. This in combination with the weight of the fins might give large shear and bending loads on the stabilizer in whiplash cases."

....

"If the helicopter with a large nose down attitude flies into a sudden headwind increased loads on the stabilizer could become sufficiently large to exceed the maximum design loads, especially if the maximum lift effects are taken into consideration. Mr. Nørstruds investigation shows that the maximum static lift of the stabilizer can be close to 2. This could increase to 4 with dynamic effects. In the present case the speed of the helicopter was 150 kts = 77.2 m/s. With a dynamic maximum lift coefficient of 4 and a stabilizer half area of 0.72 m^2, the maximum download on each side will be equal to ca 1,100 kg (10,791 N) at stall. Is this sufficient to tear off the stabilizer?

According to Eurocopter the limit design load, taking into consideration effects of gusts, is approximately equal to 320 kg per side. This seems to be very low considering the possible loads that may be obtained in severe turbulence. Even if a dynamic lift coefficient of 3 is assumed, giving a load of 550 kg per side, a safety factor of more than 550/320 = 1.72 would be required to prevent failure. Furthermore, the stabilizer could easily be weakened in short time if the loads in turbulence often exceed the limit loads."

1.18.9.3 Aeronautical engineer Dudley Collard, formerly with Airbus, now a consultant

Dudley Collard has produced a "Report on the in-flight loss of the stabilizer LN-OLT" for AIBN, dated 5 June 2000, in which he writes:

"JAR Strength requirements and compliance with these requirements

(see FAX E/ST.SV No 1137/00 from J-P. Oliva, Eurocopter to A. Skaalerud, AIBN, dated 02/05/00).

JAR 29.307 (a) Compliance .... must be shown for each critical loading condition. EC has assumed:

1.1 Maximum steady aerodynamic load to be that due to trim at V_D (100 m/s = 194 kt) at n = 1. From wind tunnel tests on a comparable model with and without stabilizer, $C_{N\ trim}$ = 0.7 downwards. This gives F_Z = 3,044 N limit load.

- *the aircraft is supposed at zero sideslip so that loads introduced by the fins are negligible.*

- *downwash from the rotor gives higher download on the LHS (Left Hand Stabilizer) than on the RHS. In the determination of limit loads the two downloads are assumed equal.*

- *the effect of load factor, n, on local stabilizer angle of attack is negligible.*

- *wind tunnel data from a complete aircraft wind tunnel model can be directly applied to flight. No allowance has been made for aircraft flexibility.*

1.2 Gust velocity to be 30 ft/sec (9.15 m/sec) as par JAR 29-341. Maximum speed in level flight at rated power and r.p.m., V_H = 300 km/hr = 162 kt.

- *the critical loading condition is associated with a vertical gust giving $\Delta\alpha_{STAB} = \Delta\alpha = \arctan V_{GUST}/V_H = 6.3°$.*

- *stabilizer normal coefficient for trim is as in 1-1: $C_N = 0.7$.*

- *Steady state load + gust load is F_Z = 1,010 + 2,117 = 3,122 N limit load.*

1.3 Ultimate bending moments at the stabilizer root are based on the 1-2 gust case, M_{ULT} = 1.5 x 312.2 x 0.63 = 295 mdaN, assuming uniform spanwise loading (see fig. 1 for approximate stabilizer geometry).

Static tests performed, with the load applied at mid span ($y-y_{fuselage}$ = 0.63 m), as accepted by JAR 29.339, gave a rupture bending moment of, M_{RUP} = 553 mdaN.

- *The load was applied at 0.25 chord, close to the position of the front spar.*

EC has taken margins to allow for material strength variation.........

With these coefficients (........) = 1.4.

On this evidence the stabilizer strength more than meets the JAR 29 requirements.

1.4 JAR 29.307 (b)(4) demands flight stress measurement tests. These were carried out on the SA 366G 6003 helicopter. Maximum measured stabilizer root bending moment was $-45 < M_R <$ mdaN, well below M_{ULT} and M_{RUP}, but seemingly not consistent with, say, $M_{VH} = 0.63 \times F_{ZVH}$ = 0.63 x 211.2 = 133 mdaN."

(ECs comments: The load measured on the lateral fin was 45 daN corresponding to a maximum moment on the horizontal stabiliser equal to: My = 45 x 0.3 = 13.5 mdaN.)

"DISCUSSION

From paragraph 1) it would appear that structural margins, as shown by test, cover all flight cases. Since the LN-OLT stabilizer has only 1,124 flight hours the values (margins) of 1-3 are probably conservative.

In flight loads, combining forward speed, gust and entry into high wind gradients, are probably higher than normally estimated, but if the stabilizer failed as per test, compared to normal flight at n = 1, V = 150 kt, the ratio of failure moment to *that due to normal flight is (with margin for strength variations and ageing/temperature = 1) = 4.8*

This large factor must be eroded somehow.

EC is going to carry out new aerodynamic loading calculations including CFD Norway estimates of wind gradients. At the present time EC Aerodynamics (Catherine Guyomard) has estimated that rupture could occur on encountering a sharp edge gust of V = 59 ft/sec at V = 150 kt assuming rupture at only M_{RUP} = 385 mdaN.

It is very likely that with the new conditions loads will increase, but it must be re-emphasised that flight conditions were not considered extreme, and that (margins for strength variations and ageing/temperature) are probably close to unity.

<u>Vertical loads under test conditions</u>

Tests of stabilizer No. 2 (LN-OPD) showed an ultimate load downwards on the RHS, similar to that found during certification testing. EC (Patrica Guerard) stated that onset of skin buckling occurred at 94.5 mdaN upwards and 150 mdaN downwards. Limit mean fatigue moments during certification testing was +- 88 mdaN, associated with a 176 mdaN static moment.

The load in all the above testing was applied at 25% chord.

<u>Loads under design conditions and in flight</u>

Design vertical loads are assumed to be uniformly distributed spanwise along the stabilizer and act normal to it at approximately 25% chord. Bending moments are resisted by skins which take 80% of the load and by the sparcaps, with the leading edge and the central spar closing a substantial torsion box.

The tail boom attachments placed just aft of the front spar carry loads to and from the fuselage.

As far as bending moments at the spanwise station of the step in skin thickness are concerned, the test with a concentrated load at 50% span represents adequately the uniform load assumed in flight.

It is not clear whether local skin buckling coefficients are sufficiently well represented, but the distance from the test load to the step being approximately twice the distance between the spars, they are probably reasonable.

Vertical loads not mentioned either as design conditions or as JAR requirements are those introduced dynamically from the flexible fuselage to the stabilizer, taking into account the inertia effects of the stabilizer and fin. Side loads on the fins will introduce end loads that were not represented on the test rig.

The NOTAT from Helge Nørstrud to AIBN, ”Ulykke med helikopter LN-OLT.... 17 MAI 1999”, gives pressure distribution on a wing profile NACA 4412 with Gurney flap. Two things are apparent:

- Below the stall angle and at constant angle of attack the flap increases the circulation round the profile without modifying the position of the centre of pressure.

- For the 2% flap there is a large loss of lift at the stall. This loss of lift is probably associated with a significant aftward excursion of the centre of pressure, away from x/c = 0.25, which introduces torsional loads round the stabilizer front spar. Resistance to such loads must vary considerably between pre- and post- buckled states of the skin.

It is not known if theoretical estimates of torsionnal loads and their effects, under stalled stabilizer flight conditions, have been made. If so, JAR requirements could perhaps have been met by structural analysis, as laid down in JAR 29.307 (a).

During the meeting (at EC) the subject of temperature effects and of a "soft spot" on the LHS of the LN-OPD stabilizer were discussed. Taking into account normal ambient temperatures encountered in Lufttransport operation, the strength of the RHS of the LN-OPD stabilizer after 5 000 flight hours and there is no apparent "soft spot" on the LN-OLT stabilizer, these effects are not considered important in the present investigation.

<u>Conclusions</u>

The design requirements selected by EC as "critical loading conditions" (JAR 29.307 (a)) appear reasonable <u>except</u>:

- *No torsional or compressive end loads were introduced in the testing.*

However, the large margins obtained from the static tests as conducted were considered sufficient to cover these sorts of additional loads.

EC mentioned (Patrica Guerard) that no structural analysis had been carried out on the complete stabilizer in the post-buckling phase.

Estimated steady flight trim loads at V = 150 kt are close to those at the onset of buckling. Any additional loading, end load or particularly torsional load, can lead to deformations not covered by the tests.

- *No torsional (around x/c = 0.25) or end loads were introduced on the fatigue rig.*

Since the normal flight trim load is close to buckling onset load flight in turbulence could lead to continual twisting and bending of the stabilizer. This could be the cause of the paint cracking noted above.

Whether or not this induces fatigue damage locally at the step is an open question. The residual strength of the RHS of LN-OPD, after 5,000 flight hours would suggest not.

What seems clear is that any significant loading that leads to torsion while the "plates" or skin are buckled must erode the margins found by simple tests in flexion.

The author visualises the following as the most likely sequence of events leading to failure:

1. *The helicopter encountered unexpected wind gradients and turbulence at a normal cruise speed of V = 150 kt. This led to:*

2. *Loading on the stabilizer sufficient to cause plate buckling of the skin, sufficient to significantly reduce the stabilizers resistance to torsional loads. (AIBN, ref. also "soft spots").*

3. *Stalling of the LHS (probably before the RHS due to higher downwash on the LHS) caused the aerodynamic centre to move away from x/c = 0.25.*

4. *The resulting loads twisted the stabilizer, thus reducing α_{mean} so that it unstalled.*

5. *2) and3) acted cyclically to produce failure of the bottom of the central spar in shear and in compression, and the bottom of the front spar in compression (as per the EC laboratory report).*

6. *The RHS failed concurrently or perhaps very shortly afterwards as local α was increased at the beginning of pitchdown.*

Knowledge of the post stalled pitching moments of the Gurney flap equipped stabilizer at flight Reynolds number, and measurements of the torsional stiffness of the stabilizer as it progressively buckles, would help to confirm or to disprove the validity of the above."

1.18.9.4 Eurocopter

1.18.9.4.1 Eurocopter has made calculations and carried out simulations at the request of AIBN, based on the conditions at the accident site:

".......Following the loss of the horizontal stabilizer from the helicopter LN-OLT in level flight at 150 knots, a preliminary study was carried out with the aim of assessing the gust which would explain the failure of the horizontal stabilizer in these flight conditions (weight, center-of-gravity, speed, etc.). It appeared that the failure loads could only be explained by very strong gust (50 feet/second), in conjunction with penalizing calculation assumptions (load applied at two-thirds of the horizontal stabilizer, sudden entry of the horizontal stabilizer into the gust, a 60/40 load distribution ratio over the two half-stabilizers, etc).

Furthermore, a numerical simulation of the air flows within the area of accident was carried out with winds from 5 different directions. These simulations (Numerical wind simulation around Straumsfjorden - CFD Norway AS - CFDn Report 229: 1999) show that there is a particularly disturbed region close to Ansnes; the most severe case was obtained with a wind direction of 200º (South-South-West). The results of these simulations were supplied in the form of reduced wind speed *components over the flight path taken by the aircraft, at 3 altitudes (600 feet, 800 feet and 1,000 feet). Diagram 1 shows the variation in speeds (non-dimensioned) with respect to time.*

The purpose of this study was to assess the effect of this "disturbed" environment on the horizontal stabilizer loads, in order to determine whether the force of the gust, which would explain the failure, is less. Simulations were therefore carried out within an irregular wind speed on the flight path, and the variation of the horizontal stabilizer load was analyzed. Two types of simulation were carried out; the first simulation, with no action by the pilot, led to quite significant altitude variations, which seems unrealistic. Nevertheless, the horizontal stabilizer load variations are low. The second simulation, which in this case seems more likely, consists in holding the aircraft altitude and attitude constant. In this case, the horizontal stabilizer load variations also remain very low compared with the variations that would explain the failure of the horizontal stabilizer. Diagram 2 shows the variation in the main parameters in the latter case. We can note that the horizontal stabilizer does not vary more than 10%, which is very low for a 50-knot wind.

The effect of this horizontal stabilizer load variation on the force of the gust, which would explain the failure, is therefore negligible: for a load increase of 10%, the gust that would lead to the failure is reduced by only 7% in the most penalizing assumptions.

The conclusions of the previous study therefore remain valid: the gust which would explain the failure loads is very strong".

1.18.9.4.2 In Annex 1 to the aforementioned report, Eurocopter has made calculations of the possible loads that might explain an overloading of the stabiliser.

"The aim of this note is to assess the loads that could have been encountered during this incident, and the vertical gust that could have produced loads likely to lead to failure of the horizontal stabilizer. An assessment is then made of the consequences of the missing horizontal stabilizer on the behaviour of the aircraft in flight.

In-flight loads with gust (FAR substantiation type calculation):

The method of calculation used is the same as that used to assess the design loads at the dive limit speed (V_D) (critical case: minimum weight, forward-center-of-gravity).

The loads applied to the horizontal stabilizer in flight conditions when the incident occured were assessed using the simulation model in the most unfavourable weight/center-of-gravity case (weight at the end of the flight).

The result is a vertical load of 345 daN over the whole horizontal stabilizer at 150 knots (M = 3,565 kg, forward center-of-gravity). If we add the load due to a FAR 29-type gust (30 feet/second), these loads increase at most to 531 daN.

Gust that would explain the failure:

Static failure tests have shown a root moment of 553 mdaN per half-stabilizer. We have considered an allowance of 30% (aging, defects, etc.) for the assessment of the gust that could have caused the failure. Furthermore, we have studied two assumptions concerning the point of aerodynamic load application on the horizontal stabilizer (point of application located at the center of the stabilizer, and then at two-thirds of the stabilizer).

In addition, we assume a lift distribution ratio of 60%/40% over the two half-stabilizers in equilibrium, and a ratio of 55%/45% of the effect due to the gust. For both assumptions, the following table shows the load values leading to the failure of the "aged" horizontal stabilizer, and the gust that would create this load.

<u>Load applied at the center of the stabilizer</u>

Load leading to the failure	*614 daN*
Gust that would explain the failure	*83 ft/s*

<u>Load applied at 2/3 of the stabilizer</u>

Load leading to the failure	*455 daN*
Gust that would explain the failure	*50 ft/s*

These calculations were carried out on the assumption that the helicopter does not react instantaneously to the gust (no attitude variation).

Effectively, this calculation is conservative because the helicopter would tend to pitch-up heavily following a gust of this strength (attitude +8º to +12º), which would amount to reducing the effect of the gust on the local pitch variation on the horizontal stabilizer. It is also assumed that the horizontal stabilizer does not stall, and that the gust occurs suddenly, which is pessimistic. It should be noted that if this type of gust was encountered, it would cause a variation of 20º on the horizontal stabilizer incidence, which normally would lead to stalling of the stabilizer, unless unstationnary stalling effects are taken into account.

Flight attitudes without the horizontal stabilizer:

Calculations carried out using the simulation model have enabled assessment of the level flight attitudes in the event of loss of the horizontal stabilizer. The append diagram shows the results of this study. It is evident from this that in the case of the incident, the attitude in level flight at 120 knots (configuration at the end of the flight) should have been in the order of 5º nose-down (compared with 1.5º to 2º nose-down with the horizontal stabilizer), and the stick should have been 15º further to the rear than usual."

1.19 Useful or effective investigation techniques

1.19.1 Numerical wind simulation

1.19.1.1 In this investigation, a numerical wind simulation was carried out by CFD Norway AS, around Straumsfjorden. CFDN Report 229:1999 “Numerical wind simulation around Straumsfjorden". (Ref. Appendix 6).

A conclusion from the report states:

“The current investigation simulates the wind distribution over a part of Straumsfjord with five different wind directions.

The results obtained show clear formation of eddy currents generated from the mountains on the south side of Straums fjord for specific wind directions, namely south or southwesterly winds.

The investigation also shows areas that are significantly affected by the above-mentioned eddy currents (winds) and the area outside Brokskar is one such area.

For this reason, the simulated wind data will serve as an important basis for the investigation of the accident involving LN-OLT on 17 May 1999."

1.19.1.2 The simulation indicates that a southerly wind direction creates a wind vortex at Brokskar. The wind vortex rotates counter-clockwise from 90º to the right in relation to the flight direction.

1.19.1.3 The simulation supports the assumption about stronger winds and turbulence in the area than predicted by the weather service.

1.19.1.4 The simulation supports the assumption that the helicopter flew into a wind vortex at Brokskar, which resulted in a powerful pitch-down attitude in the order of -25º.

2 ANALYSIS

2.1 Design of the stabiliser

2.1.1 The stabiliser on the SA 365N helicopter series is characterised by

- Relatively large stabiliser fins mounted at the far end of each half-stabiliser. These give the helicopter increased directional stability, as well as increased aerodynamic loading on the horizontal stabiliser (end plate effect)
- Certification (FAR 29), which is not specific regarding the end plate effect
- Rupture margins (FAR 29), which are not specific regarding dynamic stall
- Designed with sharp transition from 4-layer to 3-layer fibre skin

- Possibility of chafing on the lower skin from the internal tube leading to reduced buckling resistance/torsional stiffness

2.1.2 The composite stabiliser on the SA 365N may be more susceptible to damage due to external effects of operations caused by the vertical fins contacting the ground. This helicopter type is used for air ambulance flying which involves landing in uneven terrain and on snow-covered ground. This increases the danger of the tail fins coming into contact with the ground. In addition, the composite stabiliser may be subjected to hidden/invisible damage during maintenance work in the hangar.

2.1.3 The stabiliser surfaces failed in the transition from 4-layer to 3-layer fibre skin. The transition of the skin thickness produces stress concentrations. Both half-stabilisers failed in the transition from 4-layer to 3-layer fibre skin. A more gradual de-escalation of the material thickness would have reduced the stress concentration.

2.2 Evaluation of the stabiliser's condition before rupture

2.2.1 Examination of the damaged stabiliser, at the premises of both DNV and Eurocopter, has not revealed any fault in the composite structure that could be attributed to earlier damage. Examination of the stabiliser from LN-OPD (STAB 2), which was used for the static and dynamic testing, showed major internal wear from the electric cable screening (§ 1.16.6). Because the bottom left skin plate on STAB 1 was never found, it was not possible to compare the results of the examination of STAB 2 with LN-OLT's stabiliser (STAB 1). It can therefore not be proved or disproved that the failures on both sides of the stabiliser were associated with earlier damage to the stabiliser. A weakened lower surface will increase the buckling tendency when load increases.

2.2.2 It was discovered that areas on the inside of both the lower halves of the stabiliser were prone to wear from the electric cable screening tube to the navigation light to such an extent that the skin gradually became perforated. Eurocopter maintains that this wear, together with the blistering of the skin during loading, is the cause of the soft spot and the paint cracks that have been discovered on many helicopters of this type. EC has issued a Service Bulletin (SB 55.00.04, dated 7 October 2002) regarding this deficiency.

2.2.3 Eurocopter's investigation indicate that despite the fact that skin wear on the bottom left underside was clear on the test stabiliser (STAB 2) and in one area weakened stiffness, the half-stabiliser still had a 28% safety margin against rupture during the static test (torsional load not taken into consideration). Eurocopter's claim is based on EC's view that the rupture of this stabiliser was caused by aerodynamic overloading due to EC's interpretation of the wind situation at the accident location. In EC's view there is nothing that points to the stabiliser having been subjected to earlier damage. On the other hand, not all parts of the stabiliser of LN-OLT (STAB 1) were recovered. Therefore AIBN can not rule out this possibility. A weakened stabiliser would give a lower margin against rupture (buckling caused by torsional load).

2.3 Maintenance and operational considerations

2.3.1 Understanding the properties of composite material compared with conventional metal constructions is of paramount importance from a safety perspective. The damage mechanisms can vary enormously. A conventional metal construction is left with permanent deformation damage in the case of overloading, whereas the composite construction springs back to its original form more easily and may conceal internal damage.

2.3.2 AIBN questions the manufacturer-approved fault localisation method to find delamination of composite materials. A method called “coin tapping” is used, which involves engineers tapping lightly on the skin surface of the actual structure with a standardised tool. By listening for changes in sounds, they are supposed to detect areas of delamination. This method requires extensive knowledge and experience in working with this type of material. Evaluations have shown that some engineers will find delamination using this method, while others will not find the same areas of damage (ref. AIBN report 02/1998, LN-OBP).

2.3.3 This helicopter type has large, low mounted vertical fins on the end of each side of the stabiliser. These fins protrude so far under the tail boom that they can easily make contact with the ground during operations in the field. This may leave the stabiliser surface with permanent, non-visible damage, and thereby reducing its strength.

2.3.4 The SA/AS 365N series helicopter is used for air ambulance flying and other flying that involves landing in uneven terrain and on snow-covered ground, which increases the danger of the tail fins coming into contact with the ground. In addition, the stabiliser may be subjected to damage during maintenance work in the hangar.

2.4 Flying in turbulence and selection of flight path

2.4.1 The Commander stated that he had deliberately planned the helicopter’s flight path along the south side of Straumsfjord. He considered that the degree of turbulence would not be an obstacle. However, he was aware that the proximity to the mountains and the southerly wind direction could produce turbulence. With this in mind, he was on the lookout for eddies on the water, which might indicate heavy turbulence or vortices in the area. He did not see any and the flight continued along the south side of the fjord. There were showers in the area, reducing visibility to such an extent that he wanted to be on the south side to ensure visual contact from Ansnes across Malangen.

2.4.2 With a ground wind speed of approx. 20 kt, it was not unlikely that there could be more than light turbulence at an altitude of 800 ft near 1,000-metre peaks. On the other hand, the Commander had flown extensively in this area and the weather forecast did not predict any particularly strong winds in the area.

2.4.3 The meteorologist subsequently stated that there were strong southerly winds (40-50 kt) and that strong turbulence was expected to develop in the area in which the helicopter was flying. However, no such information was made available to the Commander. His estimation of flying conditions was based on the available TAF 09-18 (200/20 kt) and METAR (170/16) from ENTC, the wind conditions at the RITO Helipad (200/20 kt) and the IGA forecast (S-SW 15-30 kt up to 2,000ft). The Commander was not expecting winds in excess of 30 kt and selected the southern flight path because visibility was a more crucial factor than turbulence. He did not have any indication of strong turbulence that would be so extreme that he would not be in a position to control it in the usual way by reducing speed.

2.4.4 Another factor is whether the available meteorological information was adequate to enable him to judge the weather and wind situation along the selected flight path. In retrospect, it can be concluded that the wind force from the south over the mountains towards the Straumsfjord may have reached 50 kt and that topography such as that around Brokskar could produce strong turbulence. If this had been made clear in advance, the Commander probably would have kept to the speed recommended by the manufacturer for turbulent conditions.

2.4.5 AIBN considers that the Commander made a qualified overall assessment and selected the flight path he believed to be the best VFR route. AIBN also considers that many pilots would have selected the same route, given the prevailing conditions. Turbulence in mountainous areas is a known phenomenon and the normal procedure is to follow the Flight Manual recommendation (not limitation) to reduce speed by approx. 20 KIAS when encountering heavy turbulence. It is standard Flight Manual procedure to reduce speed when encountering heavy turbulence.

2.4.6 In this case, the Commander did not experience heavy turbulence until after the helicopter had pitched nose down. He then reduced the speed from 150 KIAS down to below 135 KIAS, in accordance with Flight Manual, section 4.1, 8.3 “Fly at best-range cruising speed”. On the basis of this explanation, AIBN considers that the Commander followed standard procedures and the Flight Manual’s guidelines. This illustrates AIBN’s view that the information in the Flight Manual is inadequate with regard to flying in heavy turbulence. In view of incidents of upset in turbulence and loss of stabiliser with this type of helicopter (TF-SIF, LN-OLT), AIBN believes that the Flight Manual should contain a warning against flying at speeds in excess of 135 KIAS if there is a possibility of encountering winds above 30 kt or if turbulence is expected.

2.4.7 The present AS 365 N Flight Manual refers to flight in turbulence in section 4 Normal procedures. The information under section 4, 8.3 is not a limitation but a recommendation and will not prevent crews from entering strong turbulence at a higher speed. This accident illustrates the danger of entering turbulence at high cruise speed and in AIBN's view there should be a speed limitation in the Flight Manual section 3 Limitations.

2.5 Manual versus autopilot operation

2.5.1 During this flight the Commander was flying manually with the SAS and ASE functions activated as normal. The FD/Coupler was not activated. When flying in light and moderate turbulence, the SAS/ASE system has sufficient control authority to stabilise aircraft oscillations, and hence relieves the pilot from constantly having to monitor the flight attitude. That was also the case in this flight up to the time of the incident. The Commander registered turbulence, but it was well within what he had experienced previously and well within the oscillations that the SAS/ASE system could handle.

2.5.2 When the helicopter encountered a wind vortex and adopted a nose down attitude, the SAS/ASE system reacted by full extension of the series actuators. When the helicopter’s pitch down exceeded the ASE system’s authority, the helicopter’s rotation continued downwards to an angle of approx. 25º. After a normal reaction time, the Commander pushed back the cyclic stick forcefully to level off the helicopter. The combined effects of full ASE, the Commander pulling back the stick forcefully and the helicopter’s mass inertia, caused a reduction in the clearance between the rotor plane and the fuselage and the rotor made contact with the fuselage. A contributory cause of the rotor coming to contact with the fuselage is that the clearance between the main rotor blades and the fuselage is relatively small on this helicopter type. An example of this is the accident involving the Icelandic Coast Guard helicopter (§ 1.18.3). There have also been several cases in the US Coast Guard (§ 1.18.6).

2.6 Discussion on the similarity between the accidents involving LN-OLT and TF-SIF

2.6.1 AIBN considers the circumstances involving LN-OLT and TF-SIF to be similar (§ 1.18.3). The difference is that LN-OLT was flying at 150 KIAS, while TF-SIF was flying at 120 KIAS. 120 KIAS is below the maximum recommended speed for flying in turbulence, prescribed in the Aircraft Flight Manual (135 KIAS) and this may explain why the stabiliser of TF-SIF did not break. At 120 KIAS the helicopter was, however, subjected to a severe upset. This indicates that the control and stability properties of this helicopter are such that it may be more prone to be affected in turbulence (upset due to wind vortices) than other helicopter types. This, despite the fact that this helicopter type is equipped with an auto-stabilising system.

2.6.2 The AS 365N was initially certified without stability augmentation system due to a large and very effective horizontal stabiliser. As a consequence, this helicopter may become somewhat uncomfortable (strong response to turbulence) in rough weather conditions. The incident involving TF-SIF supports the AIBN view that it is possible to encounter this type of manoeuvring situation as a result of turbulence of a particular character (wind vortices). The question is whether this type of stabiliser can withstand such extreme angles of attack at 150 KIAS.

2.6.3 The two accidents (LN-OLT and TF-SIF) also illustrate the good manoeuvrability and recovery characteristics of this helicopter type in upset conditions.

2.7 Comparison with previous losses of horizontal stabiliser from the SA/AS 365 helicopter

2.7.1 <u>AS 365N2, Gabon 1994</u>

Ref. § 1.18.4.1 Eurocopter believes that the stabiliser had been weakened prior to the accident. The incident confirms that it is possible for the structure to be subjected to damage that will weaken the structure.

2.7.2 <u>SA 365N, Norway 1995</u>

Ref. § 1.18.4.2 Eurocopter believes that, in this case too, the structure was damaged by external effects.

2.7.3 <u>SA 365C1, UK 1977</u>

2.7.3.1 The left stabiliser surface failed at normal cruising speed and the helicopter pitched down to a reported value of approx. -30º. When the helicopter established hover before landing, the left stabiliser surface fell off.

2.7.3.2 The design of the horizontal stabiliser on SA 365C1 is different from AS 365N and the causes of damage cannot be compared. However, it is interesting to note the helicopter's reaction as a result of the loss of the left half-stabiliser. It is important to note that at 110 KIAS, the helicopter pitched as much as 30º nose down as a result of the loss of one half-stabiliser.

2.7.3.3 In comparison, LN-OLT was flying at 150 KIAS and lost most of both half-stabilisers. It is therefore possible that the helicopter could pitch down 20-30º as a result of a loss of both half-stabilisers.

2.8 Possible causal factors of the stabiliser rupture

2.8.1 General

2.8.1.1 In addition to Eurocopter's testing and calculations, AIBN has collected assessments from several external aeronautical experts. One of many damage theories is the possibility of overloading as a result of wind and turbulence conditions that exceeded the certification requirements in FAR/JAR 29. It is AIBN's opinion that, if this is correct, it may be concluded that the Norwegian approval for the type is questionable. The forecast and reported wind conditions in Tromsø at the time in question were not, in AIBN's estimation, so extreme that overloading of the helicopters structure could be expected. This means the recurrence of similar accidents involving the same type of ambulance helicopter in Norway may be expected.

2.8.1.2 Helicopters have been flying in Norway for many years without any reported connection between wind/turbulence and accidents. Particularly in offshore flying there have been reports of several cases of severe turbulence in which pilots have been concerned about the helicopters continued airworthiness, but where thorough technical examinations have not revealed any damage in the structure or drive system. Another factor is that there have not been any reports of similar cases involving other helicopter types, whereas this type has lost the left side of the stabiliser three times (and on this occasion also the right side).

2.8.1.3 AIBN believes that it is significant that this helicopter type has had one case of abnormal/extreme flight attitude as a result of upset in turbulence (wind vortices), and one case where sections of the horizontal stabiliser broke off, during somewhat similar flight conditions. The helicopter's responses and pilots corrective actions during the upsets were very similar.

2.8.2 The possibility of overloading as a result of wind conditions alone

2.8.2.1 Expert assessments

2.8.2.1.1 Professor Helge Nørstrud (§ 1.18.9.1)

> *"....This wind flow structure will further introduce strong transient flow conditions on the flight vehicle and on the horizontal stabilizer including the two vertical fins. This highly three-dimensional wind induced flow could be the cause for the structural failure of the stabilizer, however, no aerodynamic proof can be put forward...."*

2.8.2.1.2 Aviation engineer Åge Røed (§ 1.18.9.2)

> *"....If the helicopter with a large nose down attitude flies into a sudden headwind increase, the loads on the stabilizer could become sufficiently large to exceed the maximum design loads, especially if the maximum lift effects are taken into consideration...."*

"....Furthermore, the stabilizer could easily be weakened in short time if the loads in turbulence often exceed the limit loads...."

2.8.2.1.3 *Aviation engineer Dudley Collard (§ 1.18.9.3)*

"....The author visualises the following as the most likely sequence of events leading to failure:

1. *The helicopter encountered unexpected wind gradients and turbulence at a normal cruise speed of V = 150 kt. This led to:*
2. *Loading on the stabilizer sufficient to cause plate buckling of the skin, sufficient to significantly reduce the stabilizer's resistance to torsional loads.*
3. *Stalling of the LHS (probably before the RHS due to higher downwash on the LHS) caused the aerodynamic centre to move away from x/c = 0.25.*
4. *The resulting loads twisted the stabilizer, thus reducing α_{mean} so that it unstalled.*
5. *2) and 3) acted cyclically to produce failure of the bottom of the central spar in shear and in compression, and the bottom of the front spar in compression (as per the EC laboratory report).*
6. *The RHS failed concurrently or perhaps very shortly afterwards as local α was increased at the beginning of pitchdown...."*

2.8.2.1.4 Eurocopter (§ 1.18.9.4)

"....Gust that would explain the failure:

Static failure tests have shown a root moment of 553 mdaN per half-stabilizer. We have considered an allowance of 30% (aging, defects, etc.) for the assessment of the gust that could have caused the failure.

Furthermore, we have studied two assumptions concerning the point of aerodynamic load application on the horizontal stabilizer (point of application located at the center of the stabilizer, and then at two-thirds of the stabilizer). In addition, we assume a lift distribution ratio of 60%/40% over the two half-stabilizers in equilibrium, and a ratio of 55%/45% of the effect due to the gust. For both assumptions, the following table shows the load values leading to the failure of the "aged" horizontal stabilizer, and the gust that would create this load.

<u>Load applied at the center of the stabilizer</u>

Load leading to the failure	*614 daN*
Gust that would explain the failur	*83 ft/s*

<u>Load applied at 2/3 of the stabilizer</u>

Load leading to the failure	*455 daN*
Gust that would explain the failure	*50 ft/s*

These calculations were carried out on the assumption that the helicopter does not react instantaneously to the gust (no attitude variation)...."

2.8.2.2 AIBN's calculations

2.8.2.2.1 On the basis of the above assessments and information, AIBN has made the following calculations:

Conditions:

Speed	150 KIAS (77 m/s)
Static stall C_L with 2% Gurney flap	1.9
Dynamic stall C_L with 2% Gurney flap	3.0

Static $F_Z = ½ \rho S V^2 C_L = 0.5 \times 1.225 \times 0.71 \times 77^2 \times 1.9 = 4{,}899$ N

Dynamic $F_Z = ½ \rho S V^2 C_L = 0.5 \times 1.225 \times 0.71 \times 77^2 \times 3.0 = 7{,}735$ N

2.8.2.2.2 In static testing, Eurocopter found that the tested stabiliser failed at moment M_{RUP} = 5,530 mN. When "ageing" is taken into consideration, this is reduced to 70% and gives M_{RUP} = 5,530 x 0.7 = 3,870 mN. (Ref. § 1.6.2.3.6).

This produces a rupture force of F_Z = M/d = 3,870/ 0.63 = 6,140 N which is lower than F_Z = 7,735 N with a dynamic $C_{L.}$ (Ref. § 2.8.2.2.1).

2.8.2.2.3 It is possible to exceed the maximum static rupture load by taking into account dynamic stall $C_{L.}$ All the above experts, including Eurocopter, cite this factor as a possibility without quantifying it. The graph of "C_L vs α" for NACA 4412 with 2% Gurney flap shows this (Ref. Appendix 7). The actual profile is NACA 5412 with 2% Gurney flap, which has a corresponding "C_L vs α".

2.8.2.2.4 From this, AIBN can conclude that it may be theoretically possible to overload the actual stabiliser in extreme situations, but that not such extreme wind conditions were present in the area in question at the time of the accident. In order to produce vertical gusts of magnitudes of 50-80 ft/s, the general wind velocity in the region would have to have been in the order of 80 kt. The estimate from the weather bureau was a maximum of 50 kt in the region.

2.8.3 <u>Possible consequences if the stabiliser was overloaded as a result of turbulence</u>

2.8.3.1 As shown in the above calculations, it may be possible under certain wind conditions to overload the horizontal stabiliser on this helicopter type. The assumptions are that the helicopter is exposed to strong vertical gusts and that this causes dynamic stall, which may result in C_L up to 3.0. This is, however, outside the FAR 29 certification criteria.

2.8.3.2 During the investigation, AIBN has received confirmation from Eurocopter that the calculation models for aerodynamic loading on the horizontal stabiliser in accordance with FAR 29 are very simple. The load is assumed to work as a point load, located on the chord's 25% line at a distance of b/2 from the attachment (at a point located at 50% of the half-stabiliser's span).

2.8.3.3 Furthermore, dynamic stall was not taken into consideration, which may result in C_L up to 3.0.

2.8.3.4 This type of stabiliser is combined with a vertical stabiliser fin mounted on the far end of each half. This design gives an end plate effect, which increases the Aspect Ratio (AR) and the maximum C_L that can be achieved, both static and dynamic. The resultant lift and the moment at the attachment increases. This means the lifting force and the moment load are higher than that specified in the FAR 29 calculation model.

2.8.3.5 Another effect is that aerodynamic loads on the fins subject the stabiliser to mechanical torsional loads, which increase the total load on the horizontal stabiliser.

2.8.3.6 In the same way, the mass of the fins and dynamic oscillations on the stabiliser and fins produce increased loads on the stabiliser in turbulence and sharp changes in the helicopter's attitude.

2.8.3.7 In his analysis of possible causes of the stabiliser failure, Mr. Dudley Collard has indicated that buckling was not taken into consideration in the calculation of strength (§ 1.18.9.3). A torsional box (the stabiliser) with a possible weakened lower skin is even more prone to buckling.

2.8.3.8 On the basis of the above assessments, AIBN concludes that the design and certification criteria (FAR 29) for the special stabiliser construction on the AS 365N helicopter may be inadequate. It has been deduced that during normal flight it may be possible to overload the stabiliser in severe turbulence and in wind conditions that are normally inside the limitations of other helicopter types.

2.8.4 The possibility of rupture as a result of turbulence, combined with a possible weakened structure

2.8.4.1 On the basis of Eurocopter's testing of STAB 2 and investigation of the remaining parts of STAB 1, nothing indicates that the stabiliser on LN-OLT having been seriously weakened prior to the accident. However, the technical evidence is not strong enough for AIBN to rule out this possibility. Eurocopter's testing of STAB 2 and investigation of the remaining parts of STAB 1, have shown that the structure was weakened in relation to a new structure. However, it is Eurocopter's conclusion that the stabiliser's left half had a 28% margin, while the right half had a 39% margin in relation to the design requirements (§ 1.16.6.4).

2.8.4.2 In its calculations to establish the failure of the stabiliser as a result of overloading in wind conditions in excess of the FAR 29 certification criteria, EC assumes 30% reduction of strength as a result of ageing and/or temperature effects. AIBN considers it possible that a reduced strength may be greater. Experience has shown that it is possible that a composite structure can be left with internal damage without this being clearly visible on the skin surface.

2.8.4.3 AIBN also considers as negligible the likelihood of wind conditions having been so extreme that the gust strength exceeded the certification value of 30 ft/sec. Both wind simulations from CFDn and statements from Eurocopter and other experts indicate that the wind force must be up to 80 kt in the area in question, in order to produce vertical speeds of 50-80 ft/sec. The meteorology service estimates that the wind force in the area could have reached a maximum of 50 kt, which is well inside the FAR 29 design requirements.

2.8.4.4 A third factor that may indicate a possible weakened structure is that, for a sound structure to be overloaded it must be subjected to a vertical wind speed of 82 ft/sec by an instantaneous gust (step input). This is not physically possible in reality, as the helicopter's stability properties will rotate it in the wind direction (weathervane effect). This means that the angle of attack and loading on the stabiliser will be reduced correspondingly. This has also been indicated by Eurocopter (§ 1.18.9.4).

2.8.5 <u>AIBN's assessment of calculations and analyses in §§s 2.8.1 – 2.8.4</u>

On the basis of the aforementioned calculations and analyses, AIBN considers that the most likely sequence of events was that the helicopter encountered a strong horizontal wind vortex. This resulted in a sudden increase in the stabiliser's aerodynamic load. The load exceeded the left half-stabiliser's strength and it was torn off. This increased the load on the right half, which also became overloaded and tore off.

2.8.5.1 Likely sequence of events

2.8.5.1.1 Helicopter SA 365N, LN-OLT was flying a VFR route from Tromsø to Senja. The flight path was on the south side of Straumsfjord alongside the mountains. The pilot was controlling the helicopter manually with SCAS, which was activated as normal.

2.8.5.1.2 At a cruising altitude of approx. 800 ft when passing Brokskar and a speed of 150 KIAS, the helicopter suddenly encountered strong turbulence. CFDN Report 229:1999 (simulation of wind conditions in the named area) documents severe wind shear (turbulence) in this area, with winds from 180-200º, generated from the mountains on the western side of Brokskar (Ref. Appendix 6-1 and 6-2).

2.8.5.1.3 The above simulation indicates a strong horizontal wind vortex out of Brokskar. The simulation demonstrates that this vortex was rotating with a counter-clockwise movement (viewed from the right of the helicopter). The helicopter flew first into the downward air-flow and was pitched down to an angle estimated by the Commander at 25º. This placed the horizontal tail surface, which has the main task of stabilising the helicopter, at an angle to the relative wind and exposed to a sudden increase in angle of attack and increased relative wind. The result was a sudden and powerful increase in the downward lift of the stabiliser.

2.8.5.1.4 Aerodynamic theory has documented that a sudden change in the angle of attack may result in a larger stall angle of attack than normal (dynamic stall versus normal stall). This means that the resulting downward lifting force on the horizontal stabiliser may have exceeded the actual structure strength, with the result that the stabiliser became overloaded and ruptured. This theory applies, regardless of whether the stabiliser had been weakened beforehand or not.

2.8.5.1.5 The helicopter's ASE (SCAS) will try to counteract the sudden attitude change by simultaneously pitching the main rotor rearward with maximum authority (the series actuators are fully extended). After normal reaction time, the pilot pulled back the cyclic stick to level off the helicopter. This left the main rotor tilted rearward even more, as the ASE correction and the pilot's correction were applied. The result was that the main rotor tilted back so much that it made contact with the fuselage on the MGB top cowling and the engine top fairing, but not so much as to contact the tailboom lower fin fairing (Ref. report from EC, § 1.18.8.2). This sequence of events was also confirmed by the report from the Icelandic Aviation Accident Commission after the serious air incident involving the Icelandic Coast Guard's TF-SIF. Apart from the horizontal stabiliser and the fin damage, the other damage was similar (§§ 1.18.3 and 2.6).

2.8.5.1.6 The helicopter then flew into an upward vortex flow, which resulted in the helicopter climbing. The rising airflow was so strong that the Commander had to reduce collective to prevent the helicopter from climbing into the clouds.

2.8.5.1.7 For the remainder of the flight the helicopter was flying with reduced longitudinal static stability, which left the helicopter with a somewhat nose-down attitude. The helicopter's longitudinal stability was then based on the main rotor's attitude, which was tilted rearward more than normal. The impact of this was that the pilot had to trim the helicopter with the cyclic stick more rearward than normal (Ref. report from EC, § 1.18.8.2).

2.8.5.1.8 The commander stated that he thought the helicopter's abnormal flight attitude after the incident was due to "stuck trim". It is worth pointing out that stuck trim cannot cause the helicopter to adopt such an attitude, as the trim system trims the position of the cyclic stick. The pilot continued to fly with the trim system activated, despite the fact that it is possible to disengage cyclic trim.

2.8.5.1.9 AIBN has not been able to establish with certainty the sequence of events during the pitch down movement. One possible scenario is that the wind vortex caused the pitching down to 25º and that the following aerodynamic forces caused the rupture.

2.8.5.1.10 The other scenario is that the stabiliser was directly overloaded in turbulence to such an extent that it was torn off. If the horizontal stabiliser is lost, the helicopter will pitch down to 22º (Ref. report from EC, § 1.18.8.2). The same pitch down has occurred when the horizontal stabiliser was lost on AS 332L and SA 365C1 helicopters (§ 1.18.8.3).

2.8.5.1.11 The fact remains that the horizontal stabiliser failed in turbulence. The main question is what caused the failure. The accident involving the Icelandic helicopter (§§ 1.18.3 and 2.6) showed that the consequence of encountering a powerful horizontal wind vortex may be a severe upset.

2.8.5.1.12 Further, the AS 365N series helicopters are extensively used in air ambulance and offshore missions, often in severe turbulent atmospheric conditions. For these reasons, the horizontal stabiliser must have the strength to withstand high dynamic loads.

2.9 The crew's handling of the accident

2.9.1 AIBN has no comments on the crew's actions and considers their assessments and actions to be as expected. AIBN considers this type of emergency to be outside standard emergency training syllabus.

2.9.2 The Commander misinterpreted the abnormal flight attitude as a fault in the trim system. However, AIBN finds it reasonable that the Commander did not connect this with the loss of the horizontal stabiliser. His ambulance flying had given him experience of flight in severe turbulence and he was not concerned about the helicopter's airworthiness. After the accident he felt he had full control of the aircraft and he continued to his destination.

2.9.3 In retrospect, it could be questioned whether the Commander should have made a precautionary landing to check the helicopter after the extreme flight attitude to which it was subjected. AIBN sees no reason to criticise the Commander for his decision to continue the flight on the basis of the available information. However, AIBN believes that this accident and the other similar incidents and accidents involving the same helicopter type should result in more information in the Aircraft Flight Manual. This may include an emergency procedure for flying after the adoption of abnormal and extreme flight attitudes in turbulence and following suspected loss of the horizontal stabiliser. In addition, pilots of this helicopter type should be given instruction and training in the helicopter type's control response and flight characteristics (upsets) as a result of turbulence.

2.9.4 AIBN finds that this helicopter type is prone to damage in turbulence. Both LN-OLT and TF-SIF (Iceland) were left with damage in their structure, as well as possible damage to the main rotor blades. The contact between the rotor blades (bolts) and the fuselage could easily have caused more large-scale damage, which could have resulted in loss of control.

2.10 Service Bulletin SA 365N, no. 67.03 and its significance to the extent of the damage

2.10.1 The operator of LN-OLT had not implemented Service Bulletin SA 365N, no. 67.03. This SB reduces the rotor plane's flapping angle and reduces the danger of contact between the rotor blades and fuselage.

2.10.2 Neither had the operator of TF-SIF implemented the SB no. 67.03, which was left with even greater damage than LN-OLT.

2.10.3 The US Coast Guard has implemented this SB to reduce the number of incidents involving contact between the rotor blades and the fuselage.

2.10.4 Based on this and other accidents, AIBN considers that this SB should be mandatory on the Norwegian SA/AS 365N series of helicopters.

3 CONCLUSIONS

3.1 Investigation results

3.1.1 <u>The crew</u>

a. The Commander held valid certificates.

b. The Commander was experienced and had undergone the required training.

c. The crewman held valid papers required for service as an HEMS crew-member.

d. The crewman was experienced in helicopter operations.

e. The working and rest periods for the crew were within limits.

3.1.2 Flight conditions

a. The forecast wind for the area was 15-30 kt at 2,000 ft.

b. The actual wind in the area was fresh, south-south-westerly. The surface wind was approx. 20 kt and the wind at altitude was estimated to be 40-50 kt. The turbulence varied in intensity and was estimated by the meteorologist to be moderate.

c. Visibility varied, but satisfied the VFR conditions. It was overcast with few clouds at 1,000 ft and overcast at 2,000 ft.

3.1.3 Operational conditions

a. The Commander estimated that the level of turbulence would not present a restriction to flight at a cruising speed of 150 KIAS.

b. The Commander followed the Aircraft Flight Manual recommended procedure by reducing to below the “best range speed” (135 KIAS) after having encountered strong turbulence.

c. The Aircraft Flight Manual, section 3 Limitations, does not include a limiting airspeed for flight in turbulence.

d. The Commander did not realise that they had lost the stabiliser and continued the flight to the destination.

e. The Commander misinterpreted the abnormal flight attitude as being caused by a fault in the trim system.

f. The pilots on the SA 365-series helicopters are not given any special instruction or training in the helicopter type’s control response and abnormal flight attitudes after upset in turbulence.

3.1.4 Aircraft information

a. The aircraft was registered according to regulations and had valid airworthiness certificates.

b. Maintenance had been carried out in accordance with current regulations.

c. The aircraft’s mass and centre of gravity were within the approved limitations.

d. LN-OLT did not have Service Bulletin SA 365N, no. 67.03 implemented.

e. No irregularities, damage or weaknesses were found that might explain the course of events and which are attributable to the aircraft’s condition before the accident. It still cannot be ruled out that the structure in the stabiliser had been weakened before the accident.

f. The FAR 29 certification requirements are not specific regarding the load substantiation of the effects of the vertical fins on the stabiliser's loads, caused by the end plate effects, twisting or buckling.

g. The FAR 29 requirements are not specific regarding the effects of the dynamic stall on the profile's maximum C_L.

h. This accident and the accident in Iceland confirm that this helicopter type can adopt extreme flight attitudes (upset) in extreme turbulence.

i. This helicopter type has lost the LH side of the stabiliser (and in this case also the RH side) in different flight conditions. This could indicate that the stabiliser is too weak in relation to the actual loads to which it may be exposed in normal operation.

j. This helicopter type has shown good recovery characteristics after upsets in turbulence.

3.1.5 Eurocopter's investigation results

a. There was no sign of any delamination in the structure that might have been present before the rupture damage occurred.

b. No deviations from the design specifications were found.

c. Traces of wear were found on the inside of the right-hand lower skin plate. The damage was caused by rubbing between the skin and cable screening tube for the navigation light (LH side lower skin was not recovered).

d. It was established that the ruptures had occurred during a downward movement and that the damage appeared to be greater on the left than on the right half-stabiliser.

e. Examination of STAB 2 revealed that areas on the inside of both lower half-stabilisers had wear damage similar to STAB 1.

f. The investigations revealed that this wear, together with the blistering of the skin during loading, are the cause of the soft spot and paint cracks that have been discovered on many helicopters of this type.

g. Eurocopter has pointed out that STAB 2, after 15 years and 5,000 flying hours, had a strength margin of 39% for the right half and 28% for the left half.

h. Eurocopter's investigations conclude that the stabiliser failed as a result of overloading in strong turbulence at a vertical gust of 50-80 ft/sec. The FAR 29 certification requirement for vertical gust is 30 ft/sec.

3.1.6 AIBN's conclusions

a. AIBN considers the stabiliser failed in actual wind conditions of 40-50 kt and that this is within the FAR 29 criteria.

b. AIBN considers that the FAR 29 design and certification requirements do not adequately cover the special design of the horizontal stabiliser on the SA/AS 365 - series helicopter types.

c. Eurocopter's investigations show that a stabiliser may become weakened with aging, but that the design continued to have a 28-39% margin towards static rupture. As not all the parts from the failed stabiliser were recovered, AIBN cannot rule out the possibility of a previously weakened structure.

d. AIBN considers the composite maintenance inspection procedure ("coin tapping") to be inadequate in the way it is practiced.

e. Eurocopter's investigations confirmed that the left side of one of the stabilisers, STAB 2, which was 15 years old and had logged 5,000 flying hours, was 11% weaker than the right side.

f. AIBN's assessment of the accident is that if the horizontal stabiliser failed as a result of wind vortices/turbulence in an estimated wind of 40-50 kt, without any sign of having been weakened earlier, consideration should be given as to whether this helicopter type is suitable for air ambulance and offshore flying in Norway.

g. AIBN considers that an ambulance helicopter flying in Norway must be able to sustain flying in weather conditions prevailing at the time of the accident without damage.

h. A weakened lower skin would have reduced torsional stiffness and made the stabiliser more prone to buckling. This has not been tested, nor was it a FAR 29 requirement.

4 SAFETY RECOMMENDATIONS

AIBN recommends that:

4.1 The Norwegian Civil Aviation Authority evaluates whether the text of the SA/AS 365 - series Aircraft Flight Manual should be revised to warn pilots against flying at speeds of over 135 KIAS in forecast wind of such a force as to indicate turbulence.
(SL recommendation no. 20/2005).

4.2 The Norwegian Civil Aviation Authority evaluates whether an airspeed limit for flight in turbulence should be included in the Aircraft Flight Manual section 3 Limitations.
(SL recommendation no. 21/2005).

4.3 The Norwegian Civil Aviation Authority evaluates whether the Aircraft Flight Manual should be revised to include a warning against landing in hilly terrain or snow-covered ground, which will increase the danger of the stabiliser fins touching the ground. The review of the Flight Manual should also consider a note that if such contact is suspected, the stabiliser must be checked by qualified personnel before any further flying takes place. (SL recommendation no. 22/2005).

4.4 The Norwegian Civil Aviation Authority evaluates whether the text of the Aircraft Maintenance Manual should be revised to warn engineers against the danger of the composite structures being subjected to damage that is not visible on the exterior, but which can weaken the structure. This also includes the possible need for extra investigation if there is any suspicion of the stabilisers having been overloaded during operational or technical activities. (SL recommendation no. 23/2005).

4.5 The Norwegian Civil Aviation Authority evaluates whether the inspection procedures for composite structures ("coin tapping"), and especially the training of engineers who will be carrying out such inspections, are satisfactory. (SL recommendation no. 24/2005).

4.6 The Norwegian Civil Aviation Authority evaluates whether Service Bulletin SA 365N, no. 67.03 (increased distance between rotor plane and fuselage) should be made mandatory for Norwegian helicopters of this type. (SL recommendation no. 25/2005).

4.7 The Norwegian Civil Aviation Authority in collaboration with Eurocopter evaluate whether the FAR 29 certification requirements adequately cover the design of the horizontal stabiliser on SA/AS 365 - series helicopters. (SL recommendation no. 26/2005).

4.8 The Norwegian Civil Aviation Authority in collaboration with Eurocopter evaluate the design with regard to the transition between 4-layer and 3-layer fabric and the strength of the stabiliser on SA/AS 365 - series helicopters. (SL recommendation no. 27/2005).

APPENDICES

Appendix 1-1 to 1-4	Photo images 1-14.
Appendix 2	SA 365N helicopter.
Appendix 3	Map of Troms area.
Appendix 4	Excerpt from “Examination of horizontal stabiliser from LN-OLT” (DNV).
Appendix 5	Excerpt from "Examination of a laminated stop bracket from a Eurocopter SA 365N helicopter reg. LN-OLT" (DNV).
Appendix 6-1	Excerpt from report 229:1999 “Numerical wind simulation around Straumsfjorden". CFD Norway AS.
Appendix 6-2	CFDN wind simulation from 200 deg.

Appendix 7	Excerpt from report on dynamic stall by Professor Helge Nørstrud.
Appendix 8	Excerpt from "Report by RNoAF Material Command" (RNoAF MC).
Appendix 9	Excerpt from report from Eurocopter.
Appendix 10	Excerpt from report by Mr. Dudley Collard.
Appendix 11	Comments from BEA, France

REFERENCES

1. Nørstrud, Helge. et al. Paper "Vortex Flow at High Angle of Attack", NATO/RTO Symposium, Loen, Norway, 7-11 May 2001.

ABBREVIATIONS

AIBN	Accident Investigation Board Norway
AMK	Acute Medical Communication centre
AR	Aspect Ratio (the ratio of the wing span to the wing chord)
AS	Aerospatiale (former name of Eurocopter)
ASE	Automatic Stabilisation Equipment
ATPL-H	Airline Transport Pilot Licence-Helicopter
BSL	Regulations for Civil Aviation (BSL)
C	Celsius
CPL-H	Commercial Pilot Licence Helicopter
CVR	Cockpit Voice Recorder
DNV	Det Norske Veritas
EC	Eurocopter
FCS	Flight Control System
FDC	Flight Director Coupler
Ft	Feet

HEMS	Helicopter Emergency Medical Services (JAR OPS 3)
IAS	Indicated Air Speed
ICOM	Inter Communication
IGA	IGA Forecast –General Aviation weather forecast
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
JAR-OPS	Joint Aviation Regulation – Operations
Kg	Kilo
KIAS	Knots Indicated Airspeed
Kt	Knots
LFK	Norwegian Air Force Material Command
LPT-2	Licence Proficiency Test 2 (practical test for extension of licence)
LV	Norwegian Civil Aviation Authority
METAR	Meteorological Aerodrome Report
M	Metres
MGB	Main Gearbox
MHz	Mega Hertz
MRB	Main Rotor Blade
NDT	Non Destructive Testing
NM	Nautical Mile
NTNU	Norwegian University of Science and Technology
OM	Operations Manual
QNH	Altimeter setting
RIT	Regional hospital In Tromsø
RPM	Revolutions Per Minute
SA	Sud Aviation (former name of Eurocopter/Aerospatiale)
SAS	Stability Augmentation System

SCAS	Stability and Control Augmentation System
SOP	Standard Operating Procedure
TAF	Terminal Aerodrome Forecast
TWR	Tower
UTC	Universal Time Coordinated (Greenwich Mean Time, universal time)
VFR	Visual Flight Rules
Z	Zulu time (another name for GMT/UTC)

ACCIDENT INVESTIGATION BOARD NORWAY (AIBN)

Lillestrøm, 25 May 2005

APPENDIX 1-1 IMAGE 1-4   LN-OLT

Image 1. Left Stabilizer

Image 2. Right Stabilizer

Image 3. Dent in Fin

Image 4. Blade Bolt-Cowling Contact

Image 5. Left Stabiliser-top skin

Image 6. Right Stabiliser top view

Image 7. Right Stabiliser

Image 8. Stabiliser top view

Image 9 Left Stabilizer-bottom view

Image 10 Stabilizer-bottom view

Image 11 Stabilizer-bottom view

Image 12 Left Stabilizer-top view

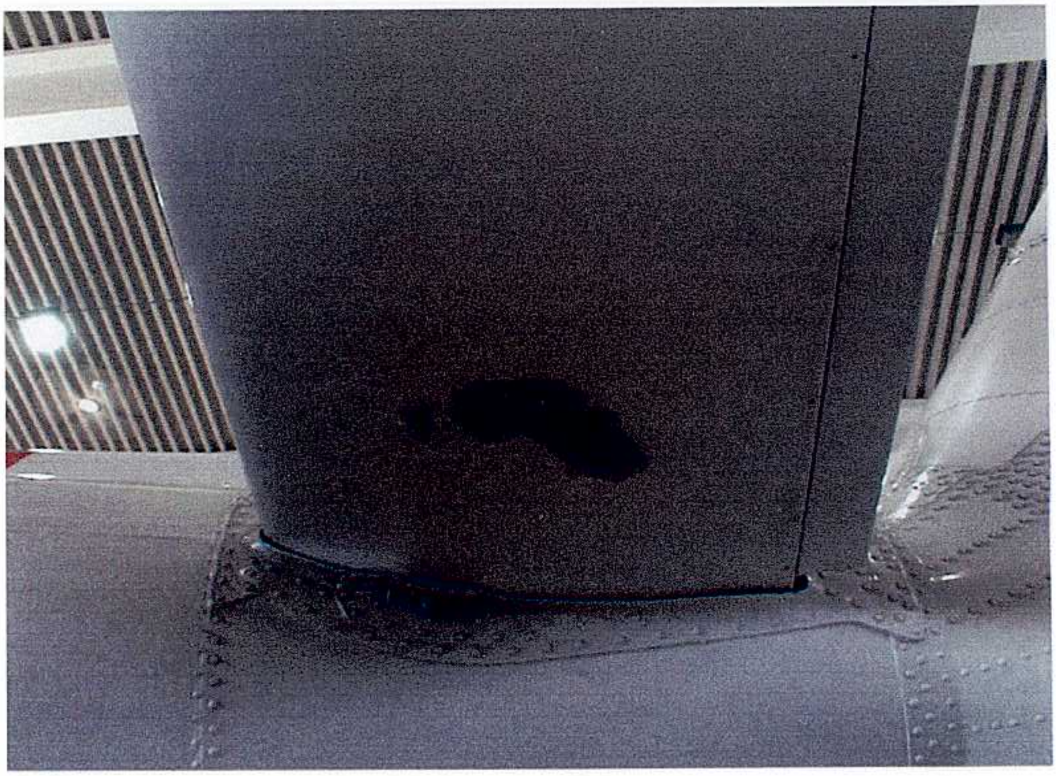


Image 13. Soft area Stabilizer 2

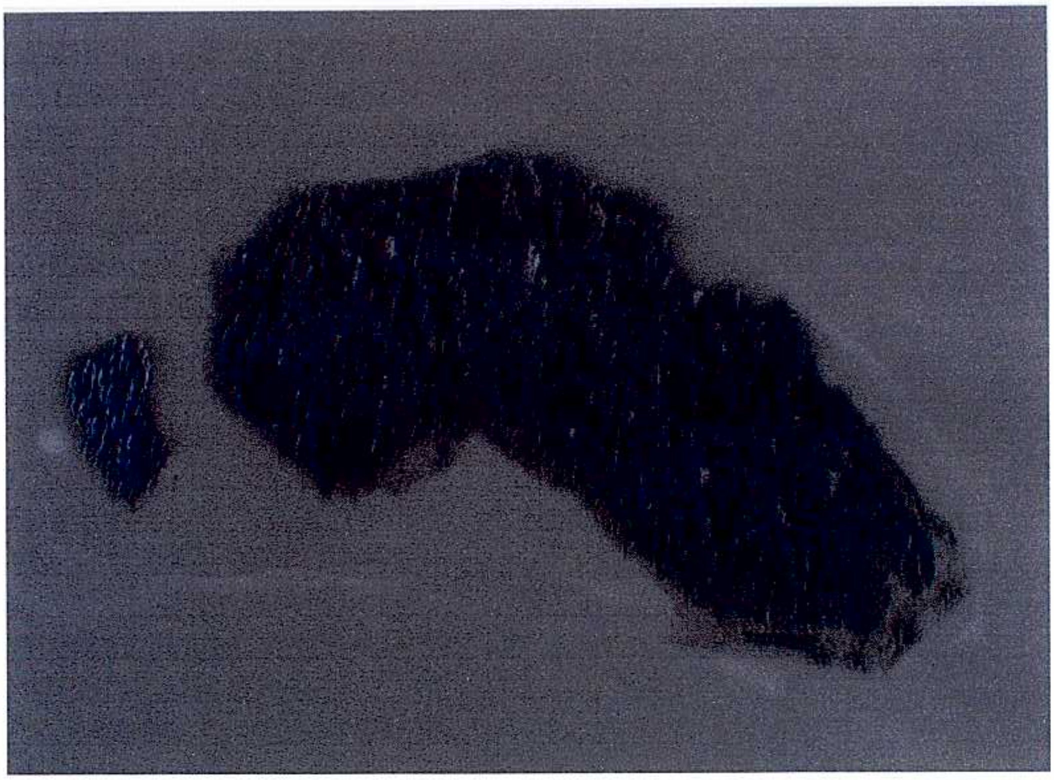
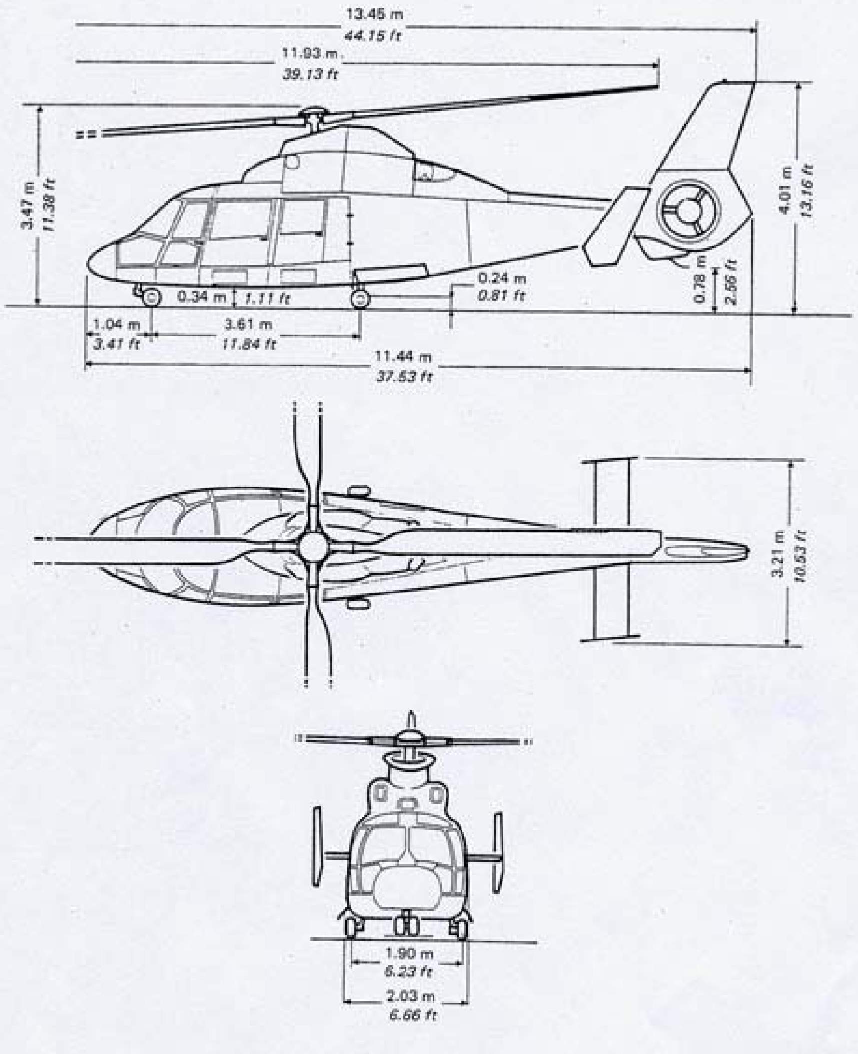


Image 14. Soft area Stabilizer 2

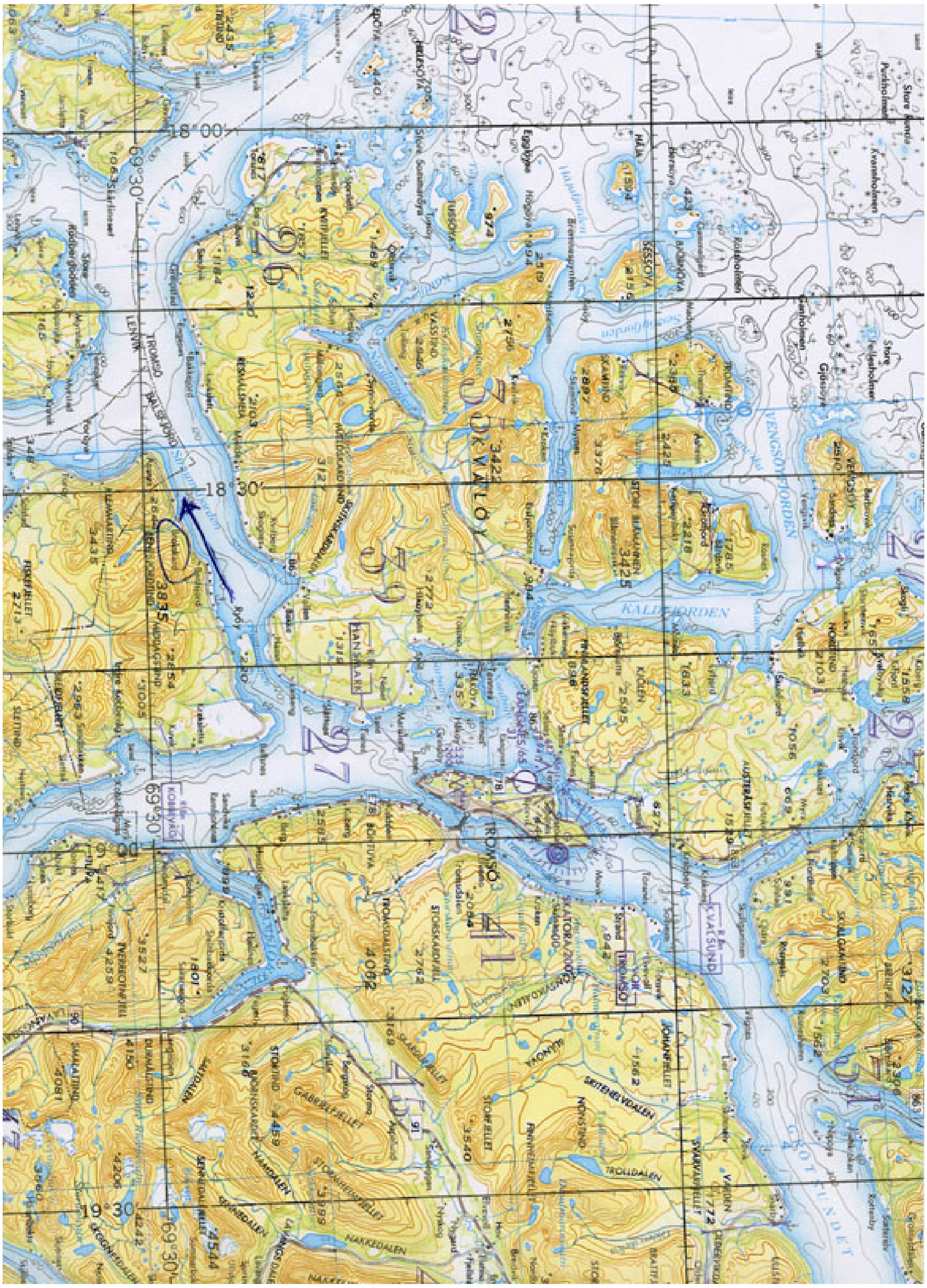
1.2 MAIN DIMENSIONS AND WEIGHTS



- MAXIMUM PERMISSIBLE WEIGHT .... 4000 kg*
- EMPTY WEIGHT, BASIC AIRCRAFT .... 2025 kg

** maximum permissible weight on take-off and landing depends on the altitude and temperature, it may be less than, but must never exceed, this value.*

APPENDIX 3 AREA MAP LN-OLT



Map over Troms area

DET NORSKE VERITAS

EXAMINATION OF HORIZONTAL STABILISER FROM LN-OLT

TECHNICAL REPORT

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Summary:

Two horizontal stabilizers were received from A/S LUFTTRANSPORT.

- Horizontal stabilizer 1.
  Damaged stabilizer from LN-OLT. SA 365 N. Received in 6 main parts.

- Horizontal stabilizer 2.
  The stabilizer was received from Tromsø. There were no visual damages to this stabilizer.
  Marked 365A13-3030-1905

Report No.: oes/99aaaar8	Subject Group:	
Report title: Examination of horizontal stabilizer from LN-OLT		
Work carried out by: Odd Sund		
Work verified by:		
Date of this revision:	Rev. No.: 01	Number of pages: 5

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5 PHOTOGRAPHIES 4

1 CONCLUSIVE SUMMARY

- The number of plies of reinforcement seems to be in accordance to the given specification. Both fracture surfaces and cross sections from flat and curved skin, and from stiffeners were examined. The laminate for Stabilizer 1 seems to be thinner than the laminate for Stabilizer 2.
- Areas with surface cracks were found for both curved and flat skin. All the examined cracks were found to go through the gelcoat/painting, but none of them had propagated into the laminate.
- Areas of the laminate surface inside the stabilizer were examined in a stereo microscope. No irregularity was found.
- Fracture surfaces indicate that the stabilizer was broken downwards on both sides.
- It is difficult to state whether the first fracture was a compressive fracture of the curved (lower) skin or a failure of one of the stiffeners.
- Thickness measurements of Stabilizer 2 indicate an area of thinner laminate, approximately 100mm in diameter.

2 INTRODUCTION

Two horizontal stabilizers were received from A/S LUFTTRANSPORT.

- Horizontal stabilizer 1.
  Damaged stabilizer from LN-OLT. SA 365 N. Received in 6 main parts.

- Horizontal stabilizer 2.
  The stabilizer was received from Tromsø. There were no visual damages to this stabilizer.
  Marked 365A13-3030-1905

3 VISUAL EXAMINATION

HORIZONTAL STABILIZER 1.

The stabilizer was broken on both sides approximately 30 cm out from the aircraft body. The upper flat skin for the left side was still attached to the aircraft after the incident. The curved skin from the left side was missing.

3.1 Fracture surfaces

LEFT SIDE

The fractures for the lower curved skin were characteristic bending fractures. See photography 1. From the bending fracture it was seen that the stabilizer was broken downwards. The upper flat skin had been cut off for transportation purposes.

RIGHT SIDE

Both fractures for the upper flat skin and the lower curved skin were characteristic bending fractures. From the bending fracture it is seen that the stabilizer was broken downwards.

The rib stiffener had a fracture that extended from the fracture of the skin and to a distance 15-20cm away from this. The fracture extension was the same on both sides of the skin fracture and both sides of the stabilizer. The bending fracture of the skin indicates that the rib failed before the total failure of the skin. Which failed first, the rib or the lower curved skin (compressive failure), was difficult to judge.

3.2 Laminates

UPPER, FLAT LAMINATE

The laminate thickness was measured to 1.3 mm for the laminate made of 3 plies of carbon fibre rowing, including approximately 0.3 mm gelcoat/paint. Some areas with visible cracks were found. Some of these cracks were examined in a stereo microscope by removing the gelcoat/painting. All the examined cracks were found to go through the gelcoat/painting, but none of them to had propagated into the laminate.

Some areas of the inside surface of the laminate were examined in a stereomicroscope. No irregularity was found and no signs of fatigue were found.

LOWER, CURVED LAMINATE

The laminate thickness was measured to 1.3 mm for the laminate made of 3 plies of carbon fibre rowing, and 1.6 mm for the 4 plies laminate, including approximately 0.3 mm gelcoat/paint. On the left part of the stabilizer an area with yellow primer was found. The fracture of the stabilizer went through the area with yellow primer. Also some cracks in the gelcoat/paint were found here. The cracks seemed to have an orientation from the centre of the yellow primer and radial away from the centre. See photography 2. The cracks were examined by removing the gelcoat/painting. No cracks were found to have propagated into the laminate. Under the cracks in the gelcoat, the laminate had a wet surface. The skin was cut to examine the cross section of this area. No irregularity was found for the cross section.

Some areas of the inside surface of the laminate were examined in a stereomicroscope. No irregularity was found and no signs of fatigue were found.

RIBS

The stabilizer had two ribs. The thickness of the large rib was 1.1 mm and the small rib 1.0 mm. The angle of the reinforcement for the ribs was measured to be from 35° to 50°compared to the longitudinal direction of the stabilizer. Some areas with less matrix material were found near the joint between the skin and the ribs. The wetting of the carbon fibres however, seemed also here to be satisfactory.

Some areas of the surface of the ribs were examined in a stereomicroscope. Some minor cracks were found. The cracks are most likely caused by the failure, but fatigue cracking may also be a possibility.

4 ULTRASONIC THICKNESS MEASUREMENTS

The thickness of Stabilizer 2 was measured using a 5 MHz ultrasonic probe. A sample from Stabilizer 1 was used to calibrate the apparatus.

An area approximately 100mm in diameter of Stabilizer with possible defect were marked. This part of the laminate is build up of 3 plies of reinforcement.

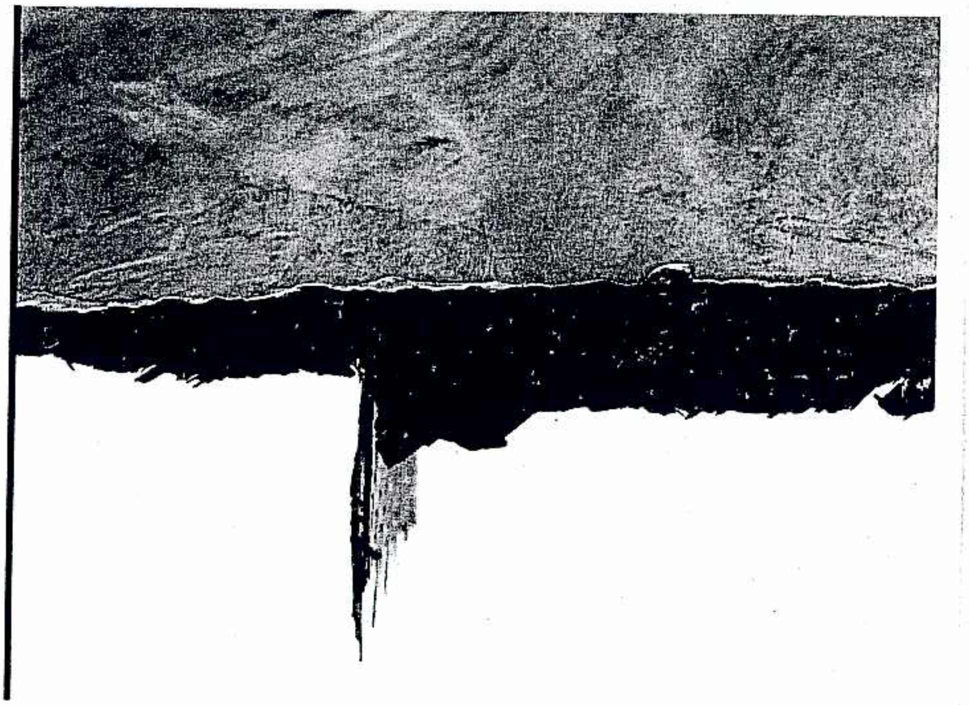
Thickness measurements

Thickness in mm of	Stabilizer 1	Stabilizer 2
Curved skin, 3 plies laminate	1.2	1.9
Curved skin, 4 plies laminate	1.7	2.1
Skin at large stiffener	3.1	4.0
Skin at small stiffener	1.5	2.2
Marked area of Stabilizer 2, (3 ply laminate)	--	1.6 - 1.7

The thickness measurements indicate a thinner laminate for the marked area of Stabilizer 2 than outside the marked area. Stabilizer 2 is thicker than Stabilizer 1.

Gelcoat thickness of Stabilizer 1 is approximately 0.3 mm. Gelcoat thickness for Stabilizer 2 is not known.

5 PHOTOGRAPHIES



Photography 1. Bending fracture of lower curved skin.

Photography 2. Area with yellow primer. Cracks marked with arrows. At arrow 2 the gelcoat was removed to examine the laminate.

- o0o -

DET NORSKE VERITAS

EXAMINATION OF A LAMINATED STOP BRACKET FROM A EUROCOPTER SA 365N HELICOPTER REGISTERED LN-OLT

DET NORSKE VERITAS

TECHNICAL REPORT

DNV

DET NORSKE VERITAS AS
Region Norge

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Date of first issue: 16 September 1999	Project No.: 53011433
Approved by: Einar Tore Moe, Head of Section	Organisational unit: RN530 - Materials Technology and Laboratories
Client: Havarikommisjonen for Sivil Luftfart	Client ref.: Arne Østby Wik

Summary:

A "Laminated Elastomer Stop", Part No. E1T 2611-31, Serial No. 3799, was received from the Norwegian Aircraft Accident Investigation Board (AAIB/N) for examination on 6 June 1999. The bracket in question, which had suffered deformation and cracking, had been serving the main gear box (MGB) attachment as one of the bottom suspension components.

The visual and macrofractographic examination carried out have stated that the crack formation of interest has been started due to regular material overload related to sideways bending forces also causing significant sidewall deformation.

No presence of former cracking or other geometric defects has been seen during the fractographic examination.

No significant material irregularities has been brought to light during the metallographic examination.

Report No.: 99-1298	Subject Group: E3	
Report title: Examination of a laminated stop bracket from a Eurocopter SA 365 N helicopter, reg. LN-OLT		
Work carried out by: Knut Strengelsrud		
Work verified by: Trude Helgesen		
Date of this revision:	Rev. No.: 01	Number of pages: 3

Indexing terms

HELICOPTER
BRACKET
CRACK
OVERLOAD

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CFD NORWAY AS

NUMERICAL WIND SIMULATION AROUND STRAUMSFJORDEN

1. INTRODUCTION

On May 17, 1999 a helicopter of type Aerospatiale SA 365 Dolphin 2, registration code LN-OLT, was flying over Straumsfjorden (south of Tromsø, Norway) in a westward direction, see figure 1. The flight altitude was 800 ft (=244 m) and the speed was 150 knots (=77 m/s). The wind was heavy (40-50 knots) and came from the south.

At an estimated position of $69^0 31' 60''$ N and $18^0 31' 26''$ E the helicopter experienced a sudden nose down pitch which was recovered by the pilot with the autopilot engaged. After a safe landing it was observed that the horizontal stabilazor was missing, see figure 2.

The present study simulates, by numerical techniques, the wind distribution over part of Straumsfjorden and around the surrounding mountains. This will yield wind data along the flight path of the helicopter at the estimated time for the subject pitch change which could coincide with the mishap of the stabilizor.

1.1 Meteorological conditions

The weather forecast on May 17, 1999 for the Tromsø area was southerly fresh breeze (Beaufort Wind Scale 5) in the morning turning to southwesterly strong breeze with some rain. From measurements and subjectiv assessment the mean wind speed which the helicopter could have encountered was estimated to 40-50 knots (Beaufort Wind Scale 9 - strong gale) with moderate turbulens.

The present study has selected five different wind directions for analysis, i.e. wind from 140^0, 160^0 180^0 (south), 200^0 and 220^0.

1.2 Topographical description

Figure 1 shows the asumed flight path of the helicopter with indicated location for the sudden pitch down occurance. This spot lies at the mouth of the river Brokskarselva which again forms a canyon between the two mountain peaks Bentsjordtinden (1168 m) and Blåruttind (806 m). These peaks lie about 4500 m apart and are situated 2000-3000 m south of the flight path. Hence, strong interactions from the adjacent topography on wind conditions outside Brokskar could be expected. This is also verified by the present analysis, see e.g. figures 3 to 7.

2. NUMERICAL WIND SIMULATION

2.1 Mehtod of analysis

The physical domain under study covers an area of 15 by 20 kilometers and a height of 2 km. This domain was transformed to a numerical space based on a digital representation of the topography. Hence, a number of computational cells were generated in which the non-viscous Euler equations for rotational flow were solved.

The numerical method applied, see also reference [1] and [2], is based on the time stepping finite volume technique and incorporates cell centered fluxes for spatial discretization. Time integration is performed by a three-stage Runge-Kutta method of second order accuracy.

The Euler equations describe the conservation of mass and momentum for the velocity components u, v and w in a cartesian coordinate system x, y and z. The variables are taken as the mean value within each computational cell. The solution is obtained by iteration and represents a steady state solution for the various flow fields, i.e. for each wind direction imposed.

2.2 Boundary condition

The upwind velocity profile which serves as the input wind velocity is given as

$$U(z) = U_{inf}\left(\frac{z}{z_{ref}}\right)^{0.28} \qquad (z \leq z_{ref})$$

where z [m] represents the height above ground and $z_{ref} = 400$ m. For $z > z_{ref}$: $U(z) = U_{inf}$ and this is depicted in figure 8.

3. RESULTS AND DISCUSSIONS

3.1 General wind patterns

3.1.1 Wind from 140°

Figures 9, 10 and 11 show the dimensionless wind components u, v and w respectively for the area around Straumsfjorden under concern, i.e.

$$u = \frac{u\ (x,y,z)}{U_{inf}}$$

$$v = \frac{v\ (x,y,z)}{U_{inf}}$$

50 kt 200° 400 m

$$w = \frac{w\ (x,y,z)}{U_{inf}}$$

where U_{inf} [m/s] is the reference wind speed at the height z = 400 m (see section 2.2). Positive value of u is in the direction of U_{inf} whereas a positive value of v is to the right of that vector. Negative value of w means downward wind motion.

Figure 12 depicts the distribution of u,v and w in a vertical plane along the given flight path and figure 13 shows similar information with wind vector representation. This latter figure shows that the main wind direction is westward along the fjord with a counterclockwise vortex (looking southward) generated by the Bentsjordtinden mountain.

3.1.2 Wind from 160°

Figures 14 to 18 show similar wind data for a wind direction of 160° which is almost normal to the flight direction. As figure 18 indicates, the wind does not have any large component along the fjord, but both mountain groups (Bentsjordtinden and Blåruttind) generate vortical flows in both clockwise and counterclockwise direction.

3.1.3 Wind from 180^0

This southerly wind induces flow in the fjord towards east with stronger vortical flows in the flight path plane, see figures 19 to 23. Note that vortex over Brokskar is counterclockwise.

3.1.4 Wind from 200^0

This condition (figures 24 to 28) is similar to the previous condition, but is signified by the fact that the vortical flows are more distingted (see also figure 6) and that the vortex over Brokskar has changed rotation.

3.1.5 Wind from 220^0

Figures 29 to 33 show that the vortical flow pattern induced by the wind is now absent and, hence, this wind condition does not represent the wind condition experienced on May 17, 1999.

3.2 Numerical wind values along flight path

The flight path for LN-OLT on the reference date is shown in figure 34 with a selected time axis for the flight speed of 150 knots. Furthermore, figures 35 to 39 shows the relative velocities V_{head}, V_{side} and $V_{vertical}$ for the five different wind directions. These velocities are made dimensionless based on the reference velocity U_{inf} [m/s] .

4. CONCLUDING REMARKS

The present study simulates the spatial wind distribution over part of Straumsfjorden area for five different wind directions.

The obtained results clearly points to the formation of vortical flows generated by the mountains located on the southern part of Straumsfjorden for specific wind directions, i.e. for southerly and southwesterly winds.

The study also reveals areas which are strongly influenced by the referenced vortical flows (winds) and the area outside Brokskar coinsides with such a zone.

Hence, the simulated wind data will serve as an important base for the ongoing investigation of the accident with the helicopter LN-OLT on May 17, 1999, see also reference [3] for related discussions.

REFERENCES

[1] Eidsvik, K.J. et al, «Turbulent separated flows over hills», Report to The Norwegian Civil Aviation Administration, ISBN No. 82-7482-022-3, December 1994.

[2] Pahlke, K., «Berechnung von Strömungsfeldern um Hubschrauberrotoren im Vorwärtsflug durch die Lösung der Euler-Gleichungen», DLR Forschungsbericht 1999-22.

[3] Vuillet, A., «Rotor and blade aerodynamic design», in Aerodynamics of Rotorcraft, AGARD-R-781, November 1990, pp.3-1 to 3-59.

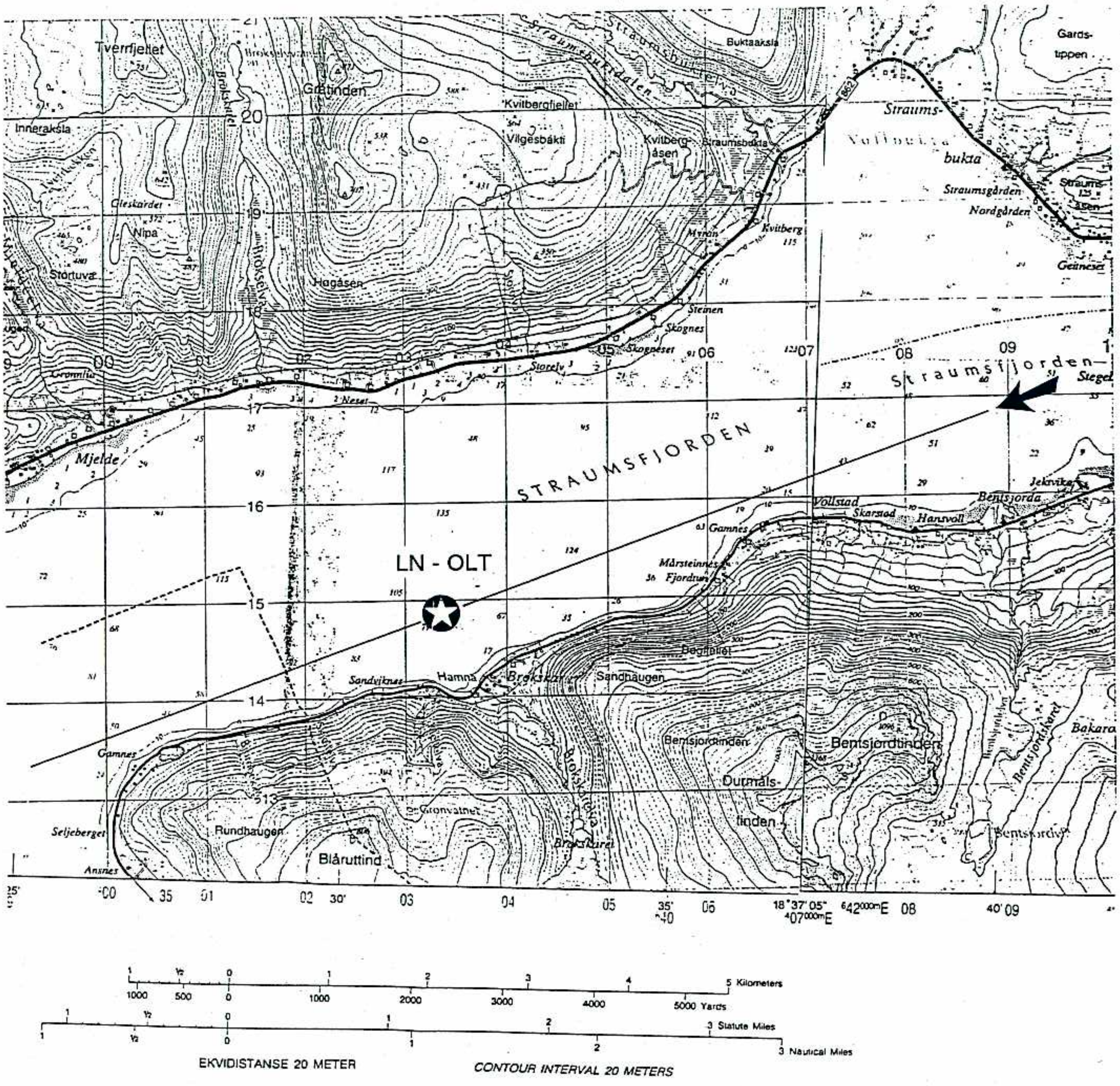
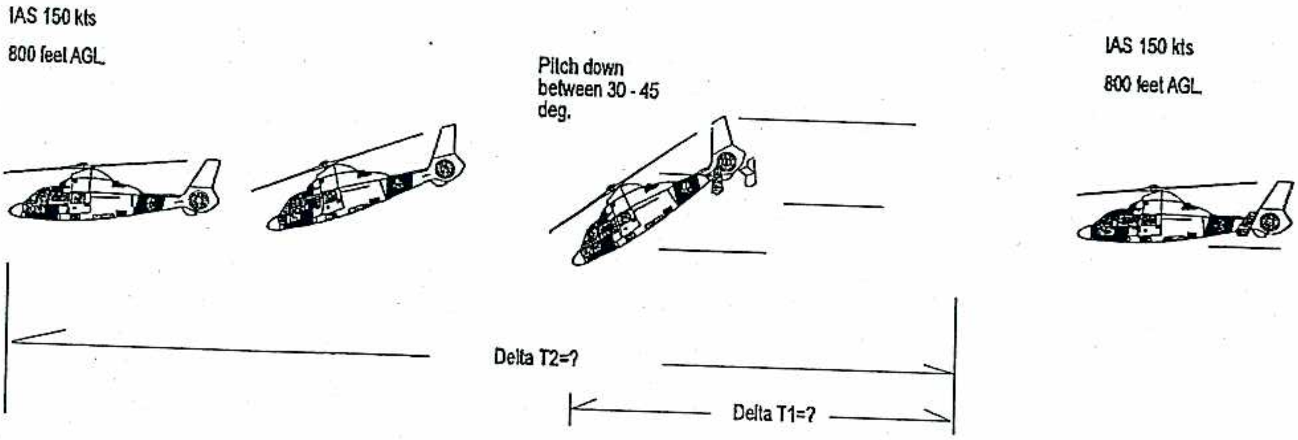


FIGURE 1 - Straumsfjorden area in Northern Norway (Troms county)

This pitch change was very fast.
Wath kind of forces can be expected during
such a movement?
The pilot was flying without the autopilot engaged,
and the counter-reaction as fast as you can expect by
a pilot flying in heavy turbulence.

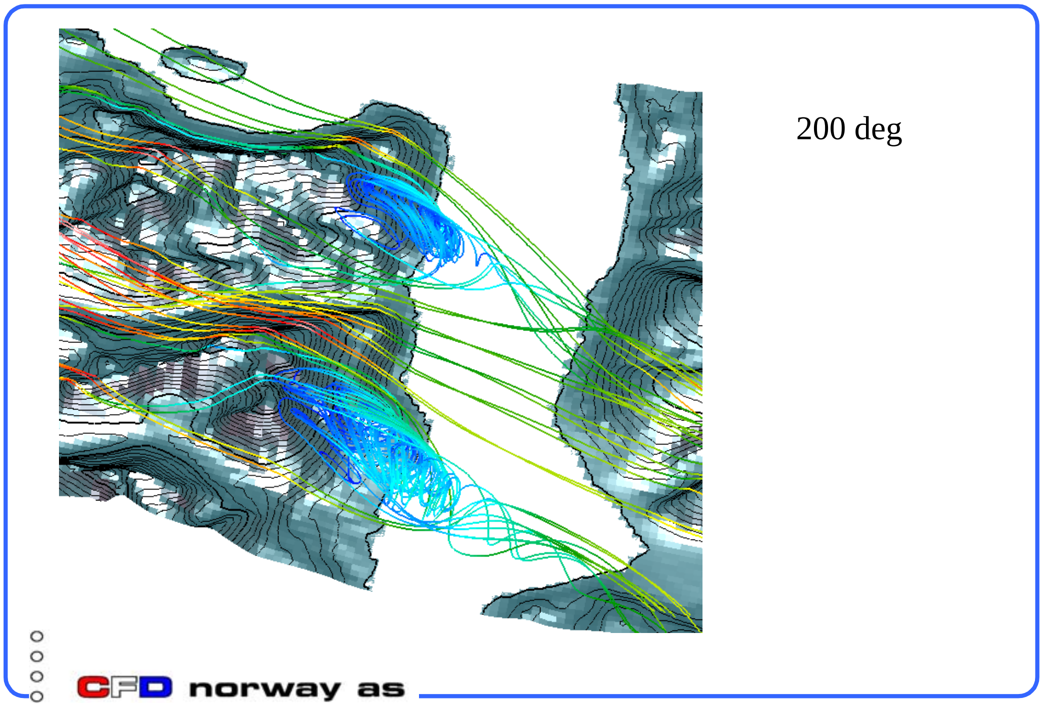


Delta T1 is time from movement start to max. pitch down.

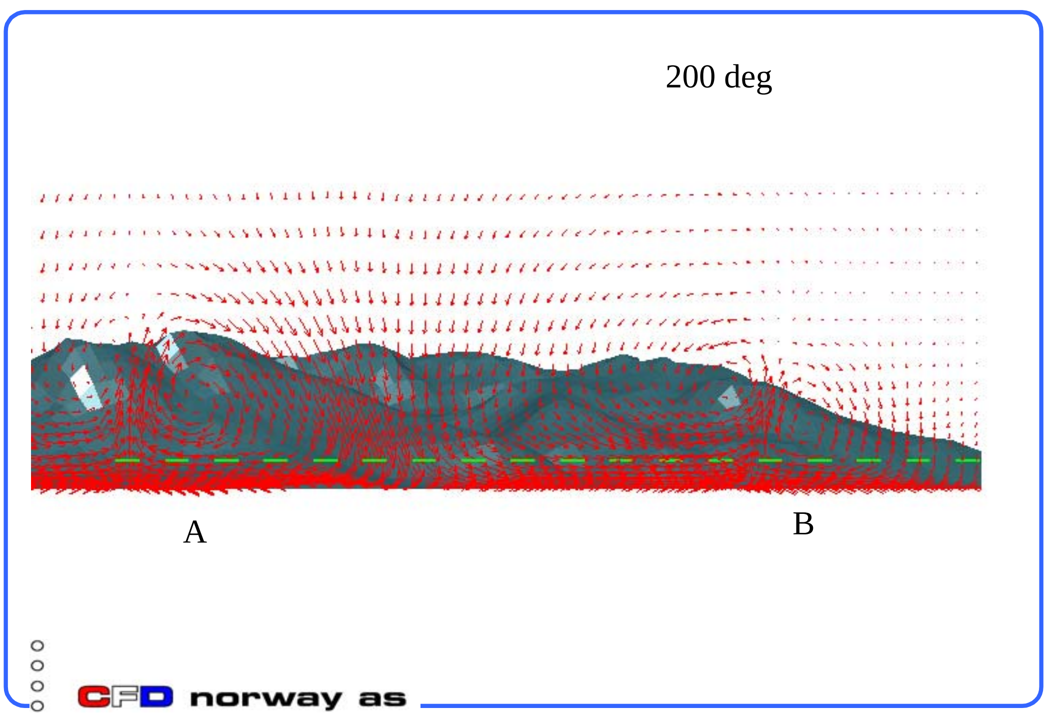
Delta T2 is time from movement start and back to initial attitude.

Question: Can such a movement of aircraft combined with
pilots counter-correction be the one reason for loss
of horizontal stabilaizor with both fins?

FIGURE 2 - Pitch change of helicopter LN-OLT at Brokskar



CFDN wind vortex simulation from 200 degrees



PROF. HELGE NØRSTRUD

REPORT ON DYNAMIC STALL

NOTAT

TIL: Arne Østby Wik, Havarikommisjonen for Sivil Luftfart

FRA: Helge Nørstrud, NTNU

DATO: 17. november 1999

ULYKKE MED HELIKOPTER LN-OLT - LITT OM DYNAMISK STALL

Med referanse til vårt møte den 27. Oktober 1999 sender jeg noen tanker omkring temaet dynamisk stall. Først vil jeg sitere Jim McCroskey som sier:

The term dynamic stall usually refers to unsteady separation and stall phenomena on airfoils that are forced to execute time-dependent motion, oscillatory or otherwise, or to cases where flow-field perturbations induce transitory stall.

The light dynamic stall shares some of the general features of classical static stall, such as loss of lift and significant increases in drag and nose-down pitching moment compared with the theoretical inviscid values, when the angle of attack exceeds a certain critical value. However, the unsteady stall behaviour is characterized by growing hysteresis in the airloads.

The initial breakdown of the flow in the deep-stall regime begins with the formation of a strong vortex-like disturbance in the leading-edge region. This vortex is shed from the boundary layer and moves downstream over the upper surface of the airfoil, producing values of C_L, C_M, and C_D that are far in exess of their static counterparts when the angle of attack is increasing; large amounts of hysteresis occur during the rest of the cycle.

Figur 1, som også er hentet fra McCroskey (Annual Review of Fluid Mechanics, Vol. 14, 1982) illustrerer forskjellen mellom lett og dyp dynamisk stall. I hvilken grad en kan forbinde dynamisk stall til helikopterulykken med LN-OLT er bakgrunnen for dette notat.

Undertegnede antar at den horisontale stabilasator på helikopteret SA 365 Dolphin har et profil av typen NACA 4412, se trykkfordelingskurvene for inkompressibel strømning som vist i figur 2. For et Reynoldstall på 3.06 10^6 , som er basert på helikopterhastigheten V=77 m/s og kordelengden c=0.6 m, vil den maksimal løftekoeffisient bli $C_{L,maks}$ = 1.51.

Stabilasatoren er imidlertid utstyrt med en Gurney flap i bakkanten, figur 3, og en slik konfigurasjon er blitt testet i NASA Ames 7-by 10 feet vindtunnel med resultat som også er vist i figuren. For en 0.04 % Gurney flap vil som vist den maksimale løftekoeffsient ha økt til omlag 1.7 (eller med 12 %).

Effekten av dynamisk stall er knyttet til den reduserte frekvens

$$k[-] = \pi\, c /(T\, V)$$

hvor sirkelfrekvensen $\omega = 2\pi f = 2\pi/T$. For de tidligere gitte verdier for c og V oppnås relasjonen k=k(T) hvor T[s] angir svingetiden, dvs.

T[s] = 80	f[1/s] = 0.013	k[-] = 0.0003
= 20	= 0.05	= 0.0012
= 1	= 1	= 0.0245
= 0.163	= 6.13	= 0.15
= 0.122	= 8.17	= 0.2
= 0.025	= 40.87	= 1.0

Hvorvidt det kan oppserveres en sammenheng mellom den reduserte frekvens og tidsforløpet av vindbelastningen , se figur 5, er ikke forsøkt pga. den automatiske stabilitetsstyring av helikopteret. Men en hysteresiseffekt kan fra figur 4 estimeres til å gi en faktor på 1.5 for økningen av løftekoeffisienten ut fra den statiske maksimalverdi. Dette fører til følgende antagelse:

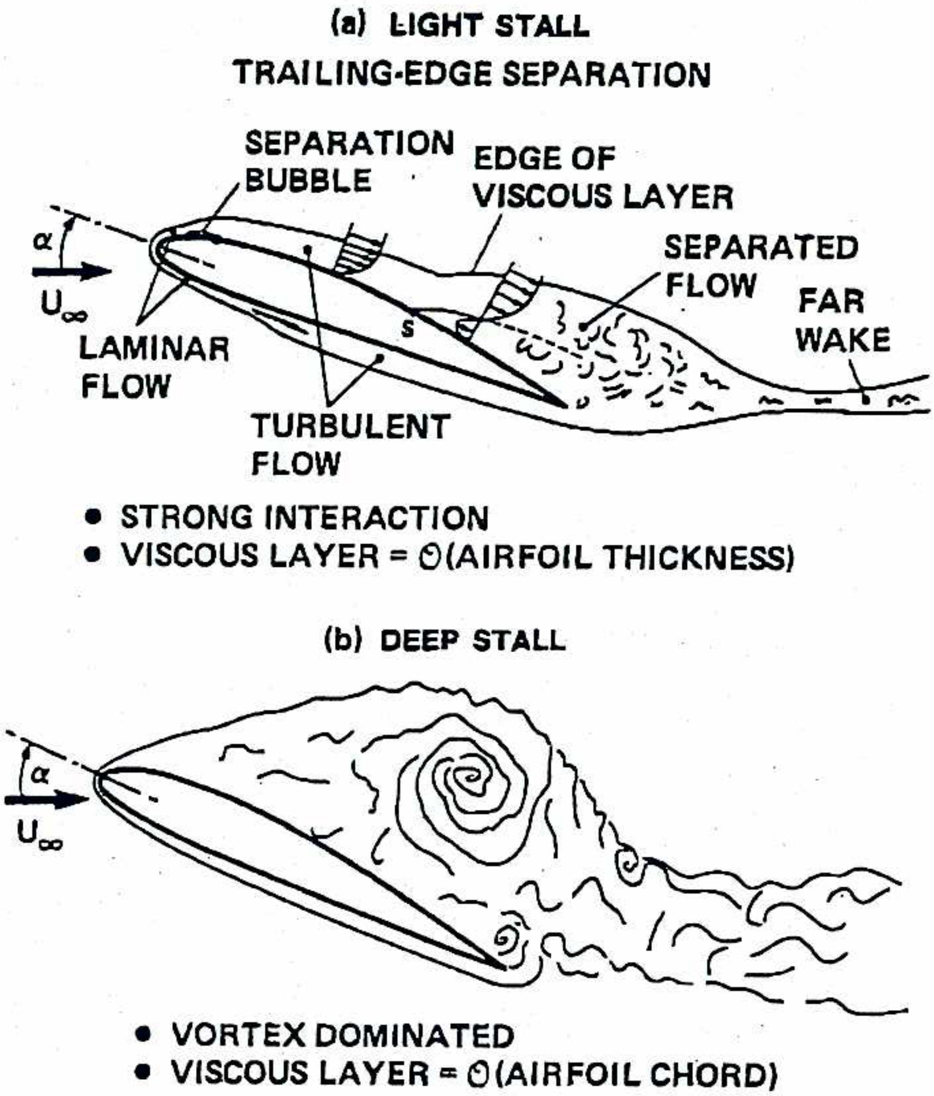
$$C_{L,\ maks,dyn.stall} = 1.7 * 1.5 = 2.25$$

Med referanse til side A2 i CFDn Report 229:1999 (Numerical wind simulation around Straumsfjorden) estimeres det aerodynamiske løft på stabilisatoren til

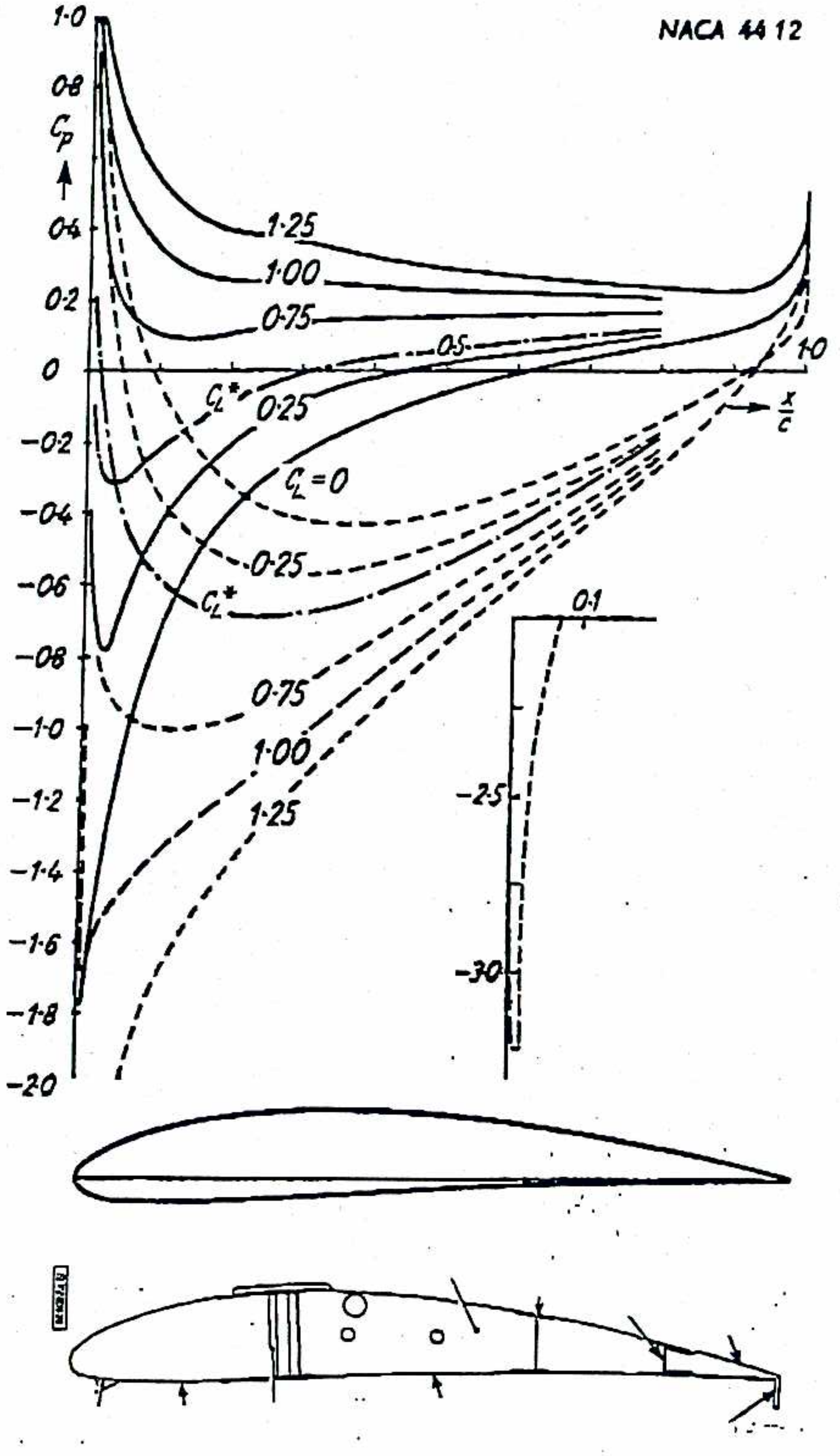
$$L = 7\,684 * 2.25 / 1.2 = 14\,408 \text{ N} \ \ (= 1469 \text{ kg})$$

Med en økning av hastigheten V som representerer den fristrømshastighet som stabilisatoren utsettes for, vil den reduserte frekvens k reduseres og effekten av dynamisk stall minskes. En økning av V vil imidlertid øke løftekraften L slik at en eventuell overbelastning oppstår.

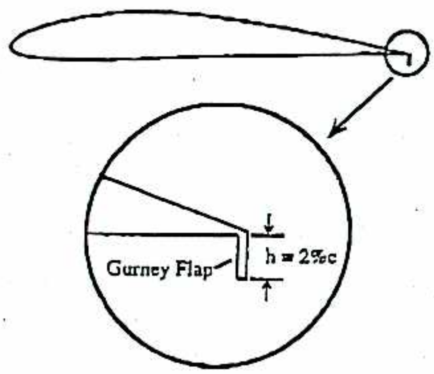
KONKLUSJON - Vindbelastningen på helikopteret ved Brokskar kan ha ført til at den automatiske stabilisering har innledet dynamisk stall for stabilisatoren som igjen kan ha ført til overbelastning. Antas f.eks. en maksimal løftekoeffisent på størrelse 3.0 vil løftekraften på stabilisatoren gi 1958 kg.



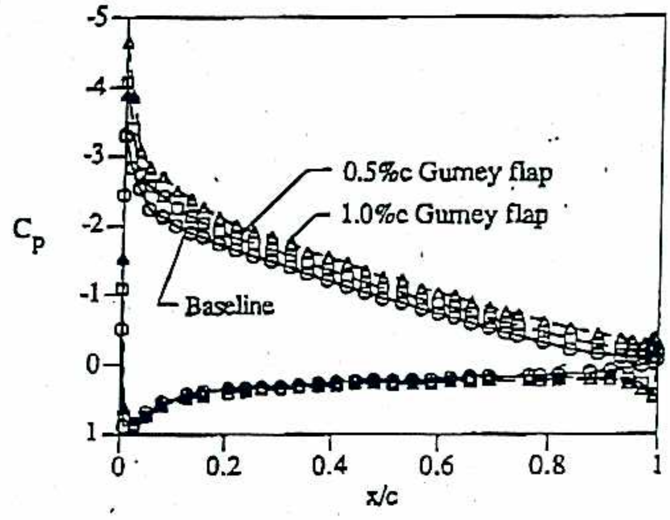
FIGUR 1 - Illustrasjon av dynamisk stall

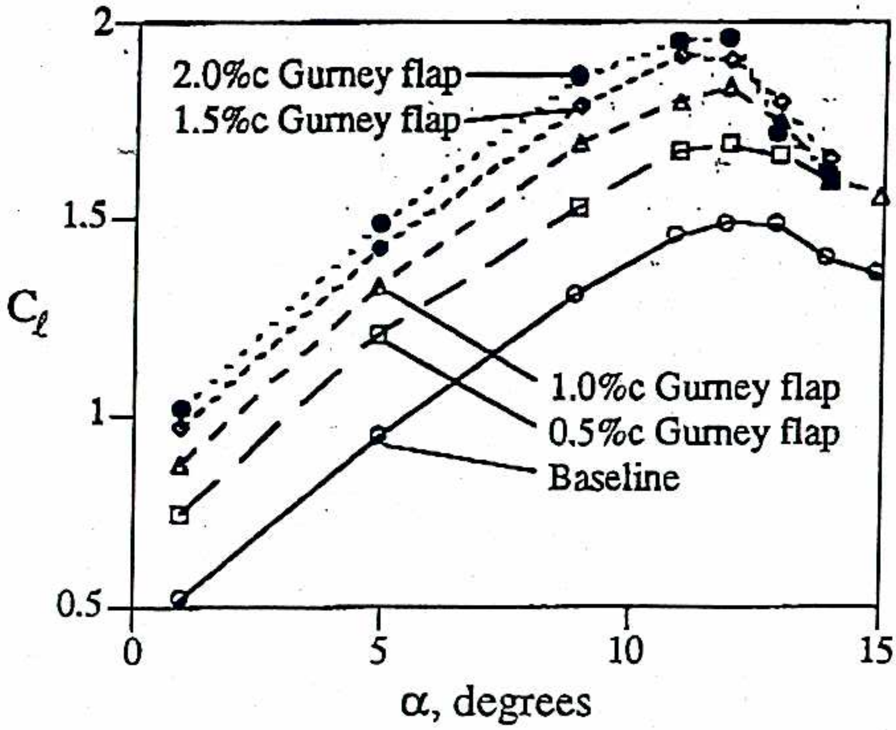


FIGUR 2 - Trykkfordeling over NACA 4412 vingeprofil

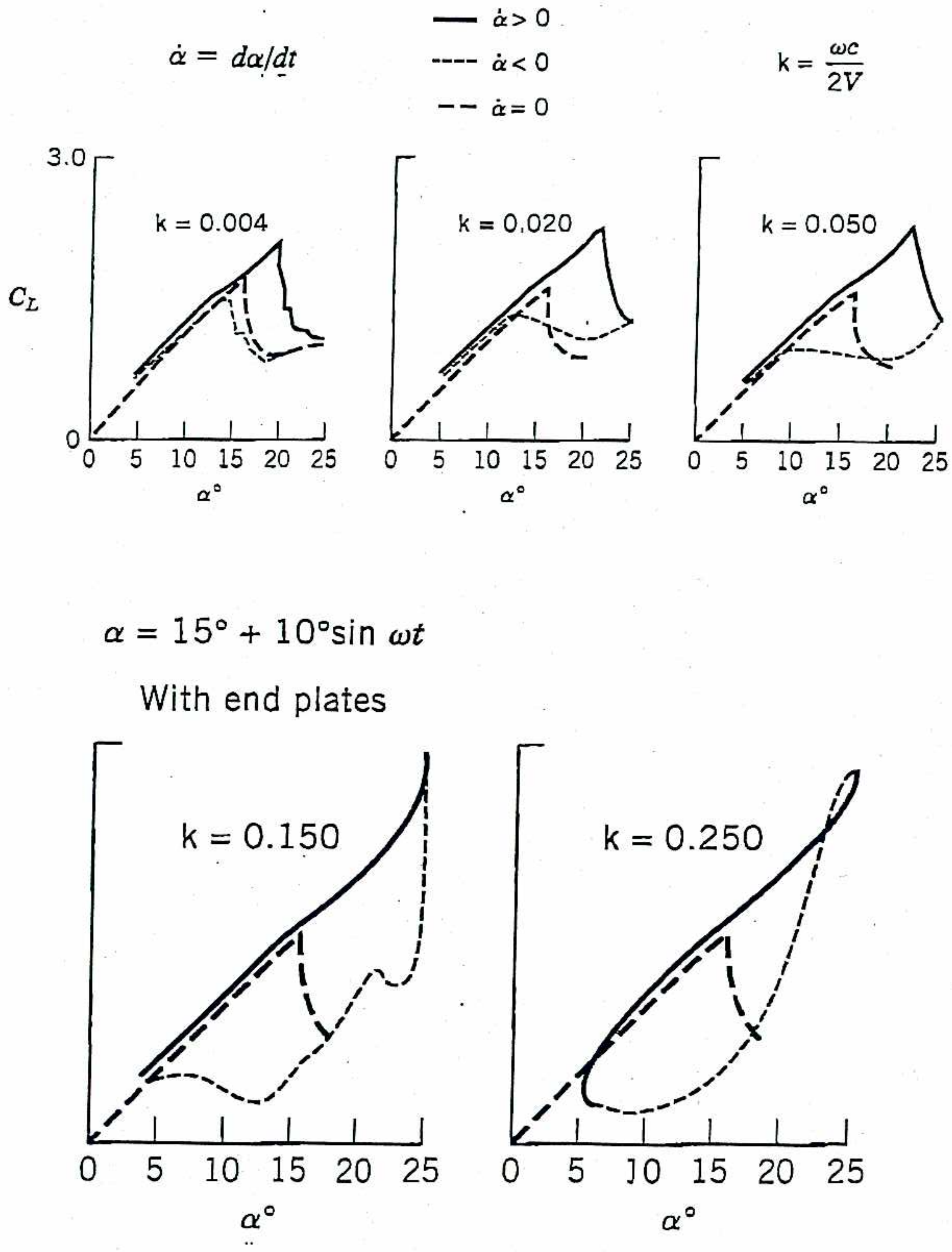


2% chord Gurney flap on a 4412 airfoil.

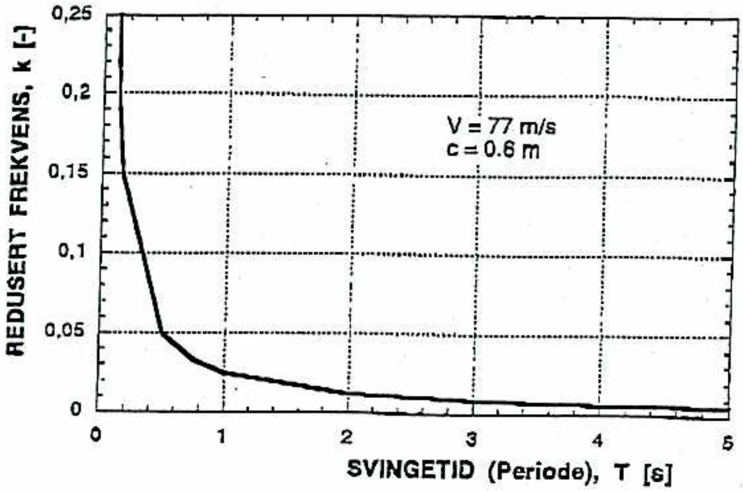


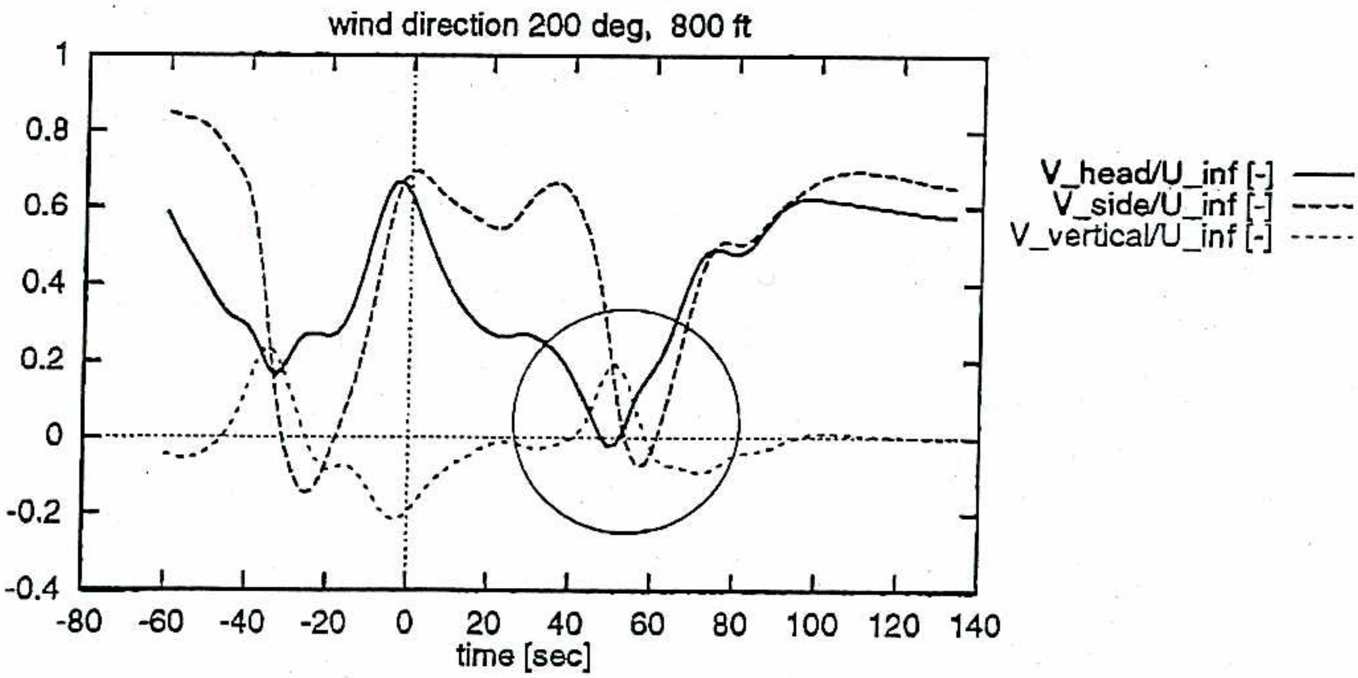


FIGUR 3 - Data for NACA 4412 vingeprofil m/ Gurney flap



FIGUR 4 - Hysteresis for NACA 0012 vingeprofil





FIGUR 5 - Vindkomponenter som funksjon av tid (200^{o},800 ft)

REPORT FROM RNOAF MATERIAL COMMAND

MATERIAL TESTING OF HORIZONTAL STABILIZER
P/N 365A13-3030-1905

Royal Norwegian Air Force
Materiel Command

Our date	Our reference	
1999-09-07	1999/	/LFK/VP
Previous date	Previous reference	

Action officer
VM Bent Kristian Slotnes, + 47 63808987

To Arne Østby Wik
Aircraft Accident Investigation
Board, Norway.

Copy to

Staff

Staff - info only

Material testing of Horizontal Stabiliser, P/N 365A13-3030-1905.

1 Background

During routine inspection a “softened” area was reported on the stabiliser fitted on helicopter LN-OPD. The stabiliser was dismounted on 4. of June 1999.

LFK NDT- workshop received 04.aug.99 Horizontal Stabiliser, to performing some Non Destructive Testing in a specific area at the mid-section.

2 Examination

Testing was conducted by use of following methods:

- A visual inspection on the inside of the stabiliser was performed using a videocamera (probe) connected to a video screen. Visual examination of the outer surface shows blue filler between the paint and the carbonfibre. The area seems to have a somewhat different surface texture/gloss.
- Eddy Current Testing gave no reliable indication of the material composition and thickness.
- Ultrasonic Testing was done by using a miniature t/r probe. This testing gave an indication of the material thickness and homogeneity. The thickness readings were written down on the stabiliser surface, and measured between 1.4 and 4.4 millimetre. The thickest area describes the tee of the reinforcement-spar inside the stabiliser.

  Probe used: MTD705 5,0/,150. Couplant Ultragel ZG. Equipment USN52R.
- Paint thickness measurements was performed, but turned out unreliable.
- Radiographic testing gave a well-definable indication in one area of about one square dm.

  Ref. enclosure A.

Mailing address	Telephone no	Fax no	Document file	No of enclosures
Postboks 10 2027 KJELLER NORWAY	0047 63 80 80 00	0047 63 80 89 61	W:\DATA\BENT\EXTSKRIV\Havarikommisjon Horizon. Stab.Doc	2

3 Conclusion

Thickness reduction or different material-composition could cause the indication detected by radiography.

By testing the indicated area with ultrasonic, some small thickness variations was observed. Ref. enclosure B. Thickness measurement could be uncorrected due to different sound velocity variations caused by the different layer-thickness in material-composition.

Enclosure

A Four attached radiographic films.

B Map of findings.

Bent Kristian Slotnes (ba)
Supervisor
Sivil

EUROCOPTER

REPORT FROM EUROCOPTER

SUMMARY OF THE INVESTIGATION INTO THE RUPTURE OF BOTH SIDES OF THE HORIZONTAL STABILIZER ON LUFTTRANSPORT 365N HELICOPTER LN-OLT (s/n 6140)

Circumstances of the incident:

In May 1999, during a flight with 365N helicopter LN-OLT in Norway, on an EMS mission, the aircraft flew over a fjord region and the pilot approached the ground to have better visibility. The helicopter was flying at a speed of 150 knots at an altitude of 800 feet when the pilot first encountered a zone of turbulence: the aircraft pitched down suddenly (at an angle of 30 to 45° according to the pilot's report). The pilot pulled back abruptly on the cyclic stick. The aircraft returned to a normal attitude and the pilot continued the flight after reducing the speed to 135 knots. A second zone of turbulence caused the aircraft to pitch down slightly; the pilot was able to correct this reaction quite easily. The rest of the flight and the landing were normal. According to the pilot's report, the turbulence was typical for the topography of the area flown over, with winds of 25 to 30 knots.

It was only when the pilot walked around the aircraft that he discovered that **both sides of the horizontal stabilizer were lost.**

Initial findings:

A thorough inspection in the workshop revealed contact between the blade attach beam pins and the engine cowling, and damage (cracks and distortion) to the MGB lateral suspension mechanical stops. The pieces of the horizontal stabilizer were recovered, to a great extent, because they were floating on the water. The horizontal stabilizer had logged 1,124 flying hours (it was replaced in 1997 following incorrect handling of the aircraft in the maintenance hangar, which, in addition to other damage, ruptured the horizontal stabilizer), and the aircraft had logged more than 11,000 flying hours.

Previous incidents:

We have received no reports of incidents concerning the loss of both sides of the horizontal stabilizer. However, we have recorded 2 cases concerning the loss of one side of the horizontal stabilizer.

- ✓ the first incident occurred with Heli-Union (rupture of the LH side of the horizontal stabilizer on 365N2 helicopter s/n 6412 in Gabon in 1994), but this was due to earlier damage: a mechanic on the ground hit the horizontal stabilizer with a stepladder.

- ✓ we have received a report from AIRLIFT who inform us that in 1995 the LH side of the horizontal stabilizer on AS365N helicopter s/n 6319 was lost during take-off, but that this was due to a landing during which the LH side fin hit a high spot on the ground (the customer did not report this incident to us at the time).

Although these 2 incidents were recorded in flight, they were subsequent to earlier damage and are therefore unrelated to the intrinsic strength of the horizontal stabilizer.

Eurocopter investigation:

Examination of the pieces of the horizontal stabilizer from helicopter LN-OLT has shown that the horizontal stabilizer is compliant as concerns dimensions, soundness, mechanical properties, etc.. A comparison between specimens taken from this horizontal stabilizer and the values measured on the qualification stabilizer show that the mechanical properties are comparable. The laboratory examination shows a static rupture. Incidentally, a study of the strength margins shows values which are 40% greater than FAR29 statutory requirements, after taking into account aging, the variation in material characteristics, fatigue and temperature (the certification values are confirmed by the additional temperature tests).

In parallel with this incident, the customer supplied us with a second horizontal stabilizer for examination, removed from 365N helicopter LN-OPD (s/n 6067): this horizontal stabilizer (having logged 5,000 flying hours, and more than 15 years old) had an area, flexible to the touch, in the lower section and on the LH side, between the forward and center spars, and beyond the center doubler fabric spanwise. This horizontal stabilizer was subjected to a static rupture test which showed a margin of 39% for the RH side, and 28% for the LH side.

The rupture can be explained by aerodynamic calculations, with a gust of 58 ft/s which is well above the values in FAR29 Amendment 16 (30 ft/s). These calculations are done using the speed reported by the pilot (150 knots) and on the assumption of sudden entry into the gust. This assumption is reinforced by a survey submitted by the AAIB/N based on a topographical and aerological simulation of the region where the horizontal stabilizer was found. This survey shows that the region is disturbed and generates significant wind variations (strength and direction).

Furthermore, the horizontal stabilizer sent by the customer, which had significant wear (perforation) on the skin, between the forward and center spars, and beyond the doubler fabric, indicated sustained friction with the position light electrical sheath. This wear, which was identified on the second horizontal stabilizer sent by LUFTTRANSPORT (LN-OPD), is the cause of the flexible area of the lower skin. It was not possible to determine whether or not there was wear on a skin panel of the horizontal stabilizer from aircraft LN-OLT because the skin panel in this area was not recovered.

In addition, the loads in this area, and in particular on the LH side, cause blistering of the structure. This phenomenon was demonstrated during the static test on the second horizontal stabilizer (LN-OPD).

The blistering alone, and in some cases, combined with wear of the skin, explains the recurring phenomenon of paint cracks detected by several customers.

Conclusion:

The examinations, tests and calculations show that:

- ✓ the horizontal stabilizer from aircraft LN-OLT complies with the specifications,
- ✓ the rupture of the stabilizer is the result of aerological conditions well in excess of its flight and certification envelope.

In fact, if we rule out damage prior to rupture of the horizontal stabilizer, it seems that the rupture of both sides of the horizontal stabilizer of aircraft LN-OLT is explained by a gust in excess of FAR29 requirements, associated with the high speed of the helicopter. According to a survey by the AAIB/N, this type of gust is generated by the aerological phenomenon associated with the topography of the region that was flown over. It is reminded that the Flight Manual recommends that speed must be reduced to 135 knots in turbulent atmosphere.

eurocopter

Marignane, dated December 07, 2000
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Subject: Operating Incident Report (RIU) DA 379:
Loss of Horizontal Stabilizer In Flight

This note describes the calculations carried out at the request of the Norwegian Authorities (AAIB), following the loss of the horizontal stabilizer from LuftTransport helicopter LN-OLT, and completes the studies carried out previously (ref. [1]).

Following the loss of the horizontal stabilizer from helicopter LN-OLT in level flight at 150 knots, a preliminary study (ref. [1]) was carried out with the aim of assessing the gust which would explain the failure of the horizontal stabilizer in these flight conditions (weight, center-of-gravity, speed, etc.). It appeared that the failure loads could only be explained by a very strong gust (50 feet/second), in conjunction with penalizing calculation assumptions (load applied at two-thirds of the horizontal stabilizer, sudden entry of the horizontal stabilizer into the gust, a 60/40 load distribution ratio over the two half-stabilizers, etc.).

Furthermore, a numerical simulation of the air flows within the area of accident was carried out with winds from 5 different directions. These simulations (ref. [2]) show that there is a particularly disturbed region close to Ansnes; the most severe case was obtained with a wind direction of 200° (South-South-West). The results of these simulations were supplied in the form of reduced wind speed components over the flight path taken by the aircraft, at 3 altitudes (600 feet, 800 feet and 1,000 feet). Diagram 1, issued from ref. [2], shows the variation in speeds (non-dimensioned) with respect to time.

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The purpose of this study was to assess the effect of this "disturbed" environment on the horizontal stabilizer loads, in order to determine whether the force of the gust, which would explain the failure, is less. Simulations were therefore carried out within an irregular wind speed on the flight path, and the variation of the horizontal stabilizer load was analyzed. Two types of simulation were carried out: the first simulation, with no action by the pilot, led to quite significant altitude variations, which seems unrealistic. Nonetheless, the horizontal stabilizer load variations are low. The second simulation, which in this case seems more likely, consists in holding the aircraft altitude and attitude constant. In this case, the horizontal stabilizer load variations also remain very low compared with the variations that would explain the failure of the horizontal stabilizer. Diagram 2 shows the variation in the main parameters in the latter case. We can note that the horizontal stabilizer load does not vary by more than 10%, which is very low for a 50-knot wind.

The effect of this horizontal stabilizer load variation on the force of the gust, which would explain the failure, is therefore negligible: for a load increase of 10%, the gust that would lead to the failure is reduced by only 7% in the most penalizing assumptions.

The conclusions of the previous study therefore remain valid: the gust which would explain the failure loads is very strong.

References:

[1] see annex 1

[2] "Numerical wind simulation around Straumsfjorden" - CFD Norway AS - CFDn Report 229 :1999

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ANNEX 1:

Subject: Operating Incident Report (RIU) DA 379:
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The aim of this note is to assess the loads that could have been encountered during this incident, and the vertical gust that could have produced loads likely to lead to the failure of the horizontal stabilizer. An assessment is then made of the consequences of the missing horizontal stabilizer on the behavior of the aircraft in flight.

In-flight loads with gust (FAR substantiation type calculation):

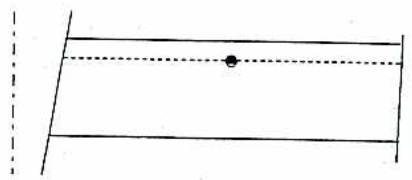
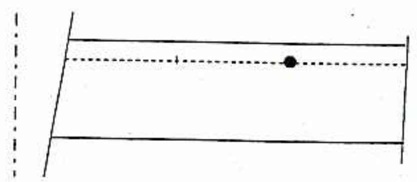
The method of calculation used is the same as that used to assess the design loads at the dive limit speed (VD) (critical case: minimum weight, forward center-of-gravity).

The loads applied to the horizontal stabilizer in the flight conditions when the incident occurred were assessed using the simulation model in the most unfavorable weight / center-of-gravity case (weight at the end of the flight). The result is a vertical load of 345 daN over the whole horizontal stabilizer at 150 knots (M = 3565 kg, forward center-of-gravity). If we add the load due to a FAR29-type gust (30 feet/second), these loads increase at most to 531 daN.

Gust that would explain the failure:

Static failure tests have shown a root moment of 533 m.daN per half-stabilizer. We have considered an allowance of 30% (aging, defects, etc.) for the assessment of the gust that could have caused the failure. Furthermore, we have studied two assumptions concerning the point of aerodynamic load application on the horizontal stabilizer (point of application located at the center of the stabilizer, and then at two-thirds of the stabilizer).

In addition, we assume a lift distribution ratio of 60% / 40% over the two half-stabilizers in equilibrium, and a ratio of 55% / 45% of the effect due to the gust. For both assumptions, the following table shows the load values leading to the failure of the "aged" horizontal stabilizer, and the gust that would create this load.

	 load applied to the center of the stabilizer	 load applied at 2/3 of the stabilizer
Load leading to the failure (daN)	614	455
Gust that would explain the failure	83 ft/s - 25.3 m/s	50 ft/s - 15.2 m/s

These calculations were carried out on the assumption that the helicopter does not react instantaneously to the gust (no attitude variation).

Effectively, this calculation is conservative because the helicopter would tend to pitch-up heavily following a gust of this strength (attitude +8 to +12°), which would amount to reducing the effect of the gust on the local pitch variation on the horizontal stabilizer. It is also assumed that the horizontal stabilizer does not stall, and that the gust occurs suddenly, which is pessimistic. It should be noted that if this type of gust was encountered, it would cause a variation of 20° on the horizontal stabilizer incidence, which normally would lead to stalling of the stabilizer, unless unstationnary stalling effects are taken into account.

Flight attitudes without the horizontal stabilizer:

Calculations carried out using the simulation model have enabled assessment of the level flight attitudes in the event of loss of the horizontal stabilizer. The appended diagram shows the results of this study. It is evident from this that in the case of the incident, the attitude in level flight at 120 knots (configuration at the end of the flight) should have been in the order of 5° nose-down (compared with 1.5 to 2° nose-down with the horizontal stabilizer), and the stick should have been 15% further to the rear than usual.

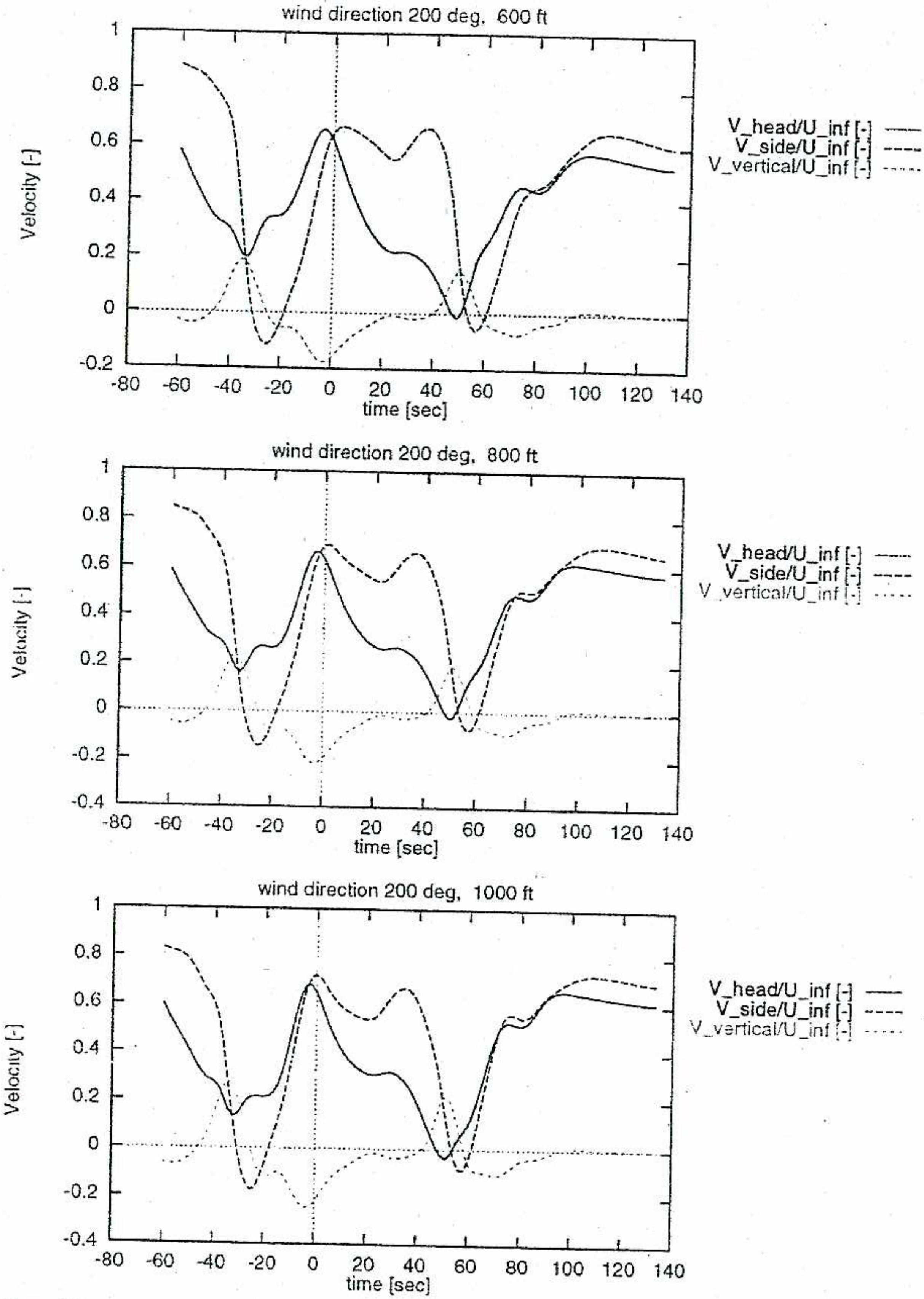


Figure 38. Relative velocity along the flight path for the heights 600, 800 and 1000 ft. Wind direction 200 deg.

Planche 1

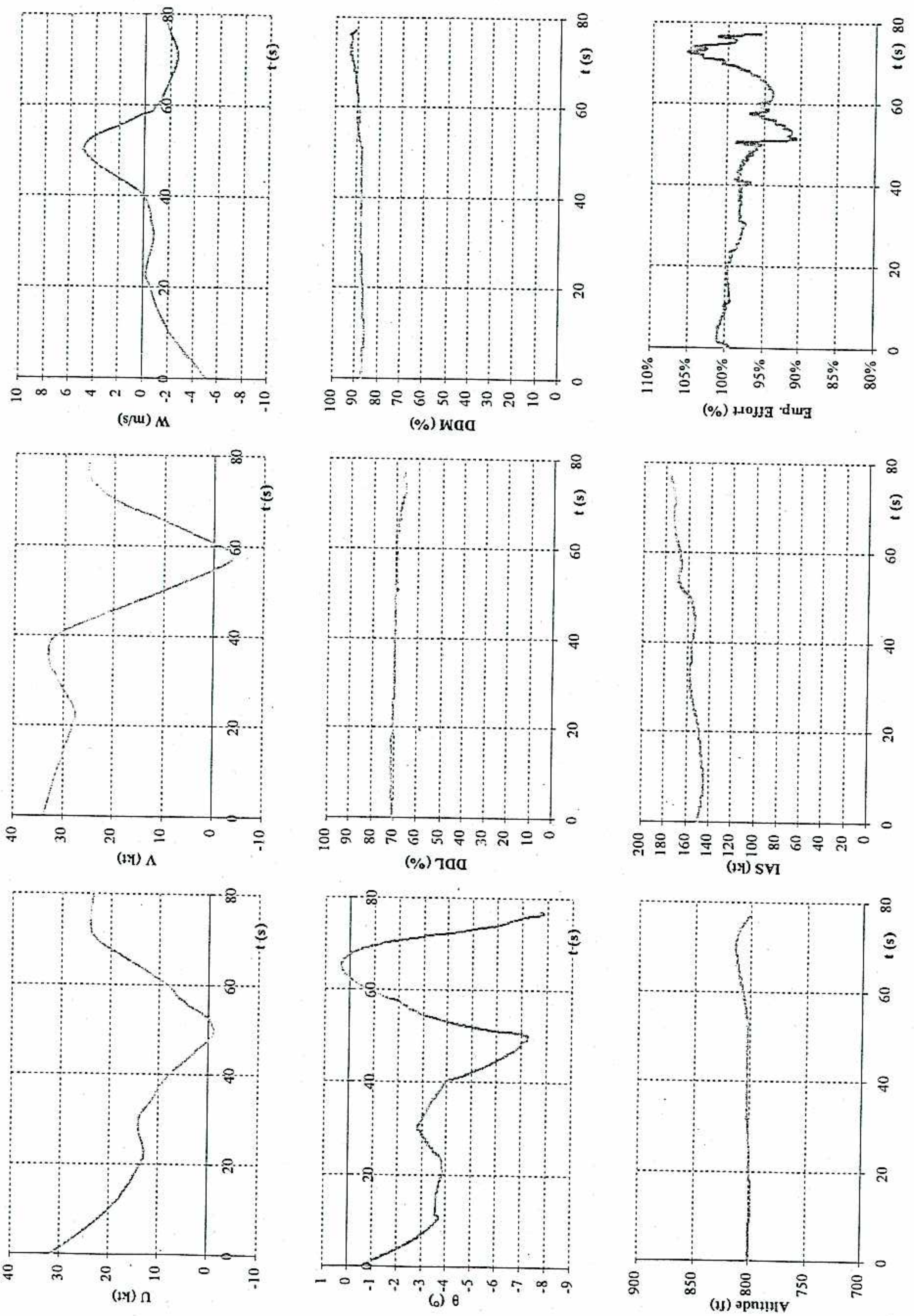


Planche 2

MR. DUDLEY COLLARD

REPORT FROM COLLARD

This lost of lift is probably associated with a significant aftwards excursion of the centre of pressure, away from $\frac{X}{c} = 0,25$, which introduces torsionnal loads round the stabiliser front spar.

Resistance to such loads must vary considerably between pre- and post. buckled states of the skin.

It is not known if theoretical estimates of torsionnal loads and their effects, under stalled stabiliser flight conditions, have been made. If so, JAR requirements could perhaps have been met by structural analysis, as laid down in JAR 29.307 (a).

During the meeting the subject of temperature effects and of a "soft spot" on the LHS of the LN.OPD stabiliser were discussed. Taking into account normal ambient air temperatures encountered in LUFTTRANSPORT operation, the strength of the RHS of the LN-OPD stabiliser after 5000 flight hours and there is no apparent "soft. spot" on the LN.OLT stabiliser, these effects are not considered important in the present investigation.

3-4 Consequence of stabiliser loss

Until this incident the SA 365 has never lost more than one side of its stabiliser. In the 1994 case this loss had a negligable effect on aircraft attitude.

In this incident total stabiliser loss resulted in a large pitch down which was countered by the automatic pilot and the pilot acting concurrently. The sum of these actions led to contact of the blade attachment pins with the MGB cowling and cracked and bent the MGB lateral suspension mechanical stop.

The pilot thought that the trim was stuck in the forward position and had to pull back the cyclic more than usual.

No discussion was made in the meeting about the effect of aircraft c.g., weight and airspeed on the possibility of increased impact between the rotor blade assembly and the fuselage, nor of the potential danger of heavier damage.

The pilot landed normally despite reduced available cyclic movement "stick back". Reduced manoeuvre margins may lead to difficulties in hovering and landing under other conditions of weight, c.g., and atmospheric conditions. These latter do not seem to have been noted for LN.OLT's landing at SIFJORD.

The subject of pilotability, not being of direct interest in the determination of the reasons for the incident, were not discussed during the meeting, except to say that the pilot had no signs of incipient turbulence that would make him reduce speed.

(4) Conclusions

The design requirements selected by EC as "critical loading conditions" (JAR 29.307 (a)) appear reasonable except-

- No torsional or compressive end loads were introduced in the testing.

However the large margins obtained from the static tests as conducted were considered sufficient to cover these sorts of additionnal loads. EC mentionned (Patrice GUÉRARD) that no structural analysis had been carried out on the complete stabiliser in the post-buckling phase.

Estimated steady flight trim loads at V=150Kt are close to those at the onset of buckling.

Any additionnal loading, end load or particularly torsional load can lead to deformations not covered by the tests

No torsional (around $x/c = 0{,}25$) or and loads were introduced on the fatigue rig. Since the normal flight trim load is close to buckling onset load flight in turbulence could lead to continual twisting and bending of the stabiliser. This could be the cause of the paint cracking noted above.

Whether or not this induces fatigue damage locally at the step is an open question. The residual strength of the RHS of LN. OPD, after 5000 flight hours would suggest not.

What seems clear is that any significant loading that leads to torsion while the "plates" or skin are buckled must erode the margins found by simple tests in flexion.

The author visualises the following as the most likely sequence of events leading to failure :-

1)- The helicopter encountered unexpected wind gradients and turbulence at a normal cruise speed of V = 150 Kt. This led to

2)- loading on the stabiliser sufficient to cause plate buckling of the skin, sufficient to significantly reduce the stabilisers resistance to torsional loads.

3) Stalling of the L.H. stabiliser (probably before the RHS. due to higher downwash on the L.H.S.) caused the aerodynamic centre to move away from $x/c \simeq 0{,}25$.

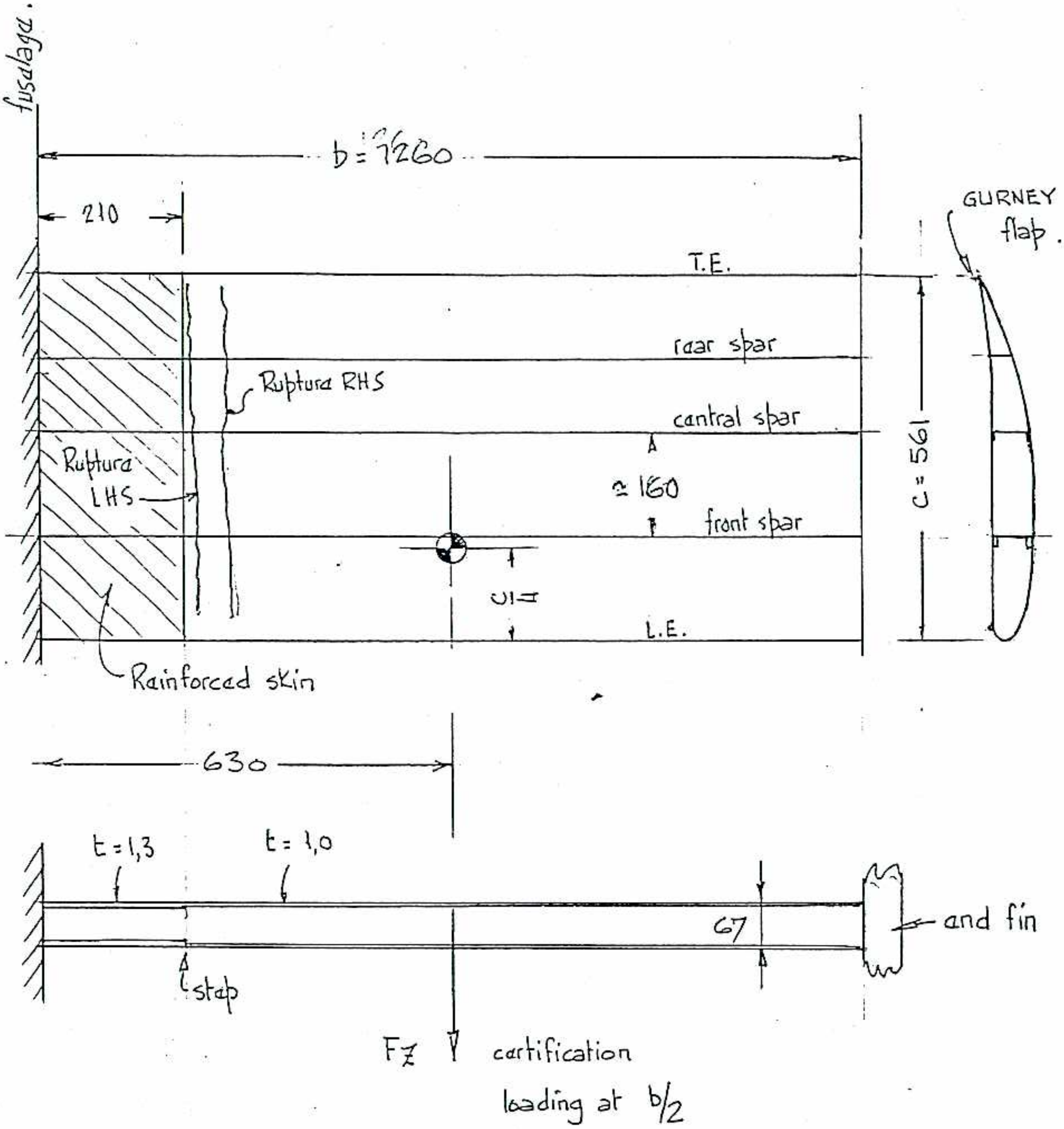
4) The resulting loads twisted the stabiliser, thus reducing α_{mean} so that it unstalled.

5) 2) & 3) acted cyclically to produce failure of the bottom of the central spar in shear and in compression, and the bottom of the front spar in compression (as per the EC laboratory report).

6) The R.H. stabiliser failed concurrently or perhaps very shortly afterward as local α was increased at the beginning of pitchdown.

Knowledge of the post stalled pitching moments of the GURNEY flap equipped stabiliser at flight Reynolds number, and measurements of the torsional stiffness of the stabiliser as it progressively buckles, would help to confirm or to disprove the validity of the above.

D. Collard. 4 June 2000.



LN. OLT ~ Approximate stabiliser geometry

figure 1

BEA

COMMENTS FROM BEA

Comments to the draft report on air accident over Straumsfjorden at Brokskar Troms, 17 may 1999, involving Lufttransport AS, Aérospatiale SA 365N Dauphin 2, LN-OLT

The report mentions some previous incidents which, as far as the BEA is concerned, are not relevant in the context of this event. Moreover, the report includes the statements of some experts mandated by the AAIBN. The expertise of these experts is not in question, though the lack of global information about the event and of factual elements to substantiate their studies make the result of these studies questionable. They draw slightly different conclusions as to the aerodynamic causes of the tail failure, but the AAIBN seems to credit M. Collard with the most appropriate explanation. In particular M. Collard questions the certification requirement laid down in the FAR 29 regulation, as in-flight conditions might prove to be more severe. In turn, the BEA doubts that M. Collard's conclusions are based on factual information. Furthermore the BEA would stress that the core principle of any certification process is to impose a set of requirements which cover most of the operating constraints, but do not encompass the entire scope of existing conditions. The BEA considers that the report fails to demonstrate any flaw in the certification of the SA 365N. Nevertheless, if the AAIBN wished to address a recommendation similar to recommendation 4.8, this should be understood as a way to improve the certification of all future generations of helicopters equipped with a horizontal stabilizer (whether or not fitted with vertical fins). In any case, such a recommendation should only be aimed at improving the FAR 29 certification process in general, and should be applicable to all types and makes of helicopters in this category.

The report does not come up with a definitive scenario, but we agree with most of the "likely sequence of events". However, a couple of issues raised some concern.

The report suggests that the operational capacities of the SA 365N are not appropriate for the severe operating conditions in the Nordic region, even though no supporting evidence is included in the factual section. This conclusion is based on an estimated wind during the incident that remained within the certification envelope prescribed by FAR 29. Though, by flying below the ridge of the fjord, the pilot might have encountered wind vortices of much greater energy than a laminar flow, that is to say some high-speed turbulent flows with a vertical component that cannot be inferred solely from the wind velocity. It is noteworthy that the AAIBN carried out a computer simulation of the wind conditions in the incident area. The results of this simulation indicate a strong vortex area coinciding with the location of the sudden nose-down movement of the helicopter. It should be born in mind that such a simulation of the steady-state wind condition can only give an indication of what might have been the situation during the incident. In the present case this situation was very close to the limits of the certification criteria required by FAR 29. Flying beyond the operational speed limitation, recommended in turbulence, the margin is reduced. The BEA regrets that the investigation did not call into question the crew's assessment of the meteorological situation and did not further examine its consequences on operations. Indeed, although there was no specific warning for turbulence in low altitude available to the crew, the latter were, however, familiar with the area. Experienced crew thus have their own references and can assess the local conditions quickly.

Furthermore, the crew's statement represents almost the sole source of information supporting the analysis. As there is no flight recorder to cross-check this data, the BEA is of the opinion that any scientific consideration solely based on this information should take into account the lack of accuracy and reliability of the data.

Another important concern with the report is the discussion about the composite material which is not supported by the facts. A composite material is not subject to fatigue, unless a significant defect has been found (insufficient curing, high porosity, etc.), or has been submitted to loads well beyond the limit load. Damage can always be detected when the proper maintenance is performed. All the examples given in the report actually demonstrate this fact, which stands in contradiction with the report's conclusions. No defect in the material was detected during its examination by the lab.