38th European Rotorcraft Forum (ERF) 2012

Paper 123

HELICOPTER SAFETY RELATED RESEARCH AT NLR: A MULTI-DISCIPLINARY TASK

Jos STEVENS (Jos.Stevens@nlr.nl)

Yuk Shan CHEUNG

Leo de HAIJ

Udo DEES

Gerrit KOOL

National Aerospace Laboratory NLR, The Netherlands (www.nlr.nl)

ABSTRACT

Each year helicopters are involved in too many unnecessary (avoidable) accidents. Consequently, various international initiatives, such as the International Helicopter Safety Team (IHST) and the European Helicopter Safety Team (EHEST), have been set up to help reverse this (relatively constant) safety trend. The IHST and EHEST objective is to achieve 80 percent fewer helicopter accidents by the year 2016, as compared to 2006 levels. EHEST brings together helicopter and component manufacturers, operators, regulators, helicopter and pilots associations, research institutes, accident investigation boards and some military operators from across Europe. In total the initiative counts around 50 organisations and 130 participants, of which around 70 are actively involved in the analysis and implementation work. EHEST addresses the broad spectrum of helicopter operations across Europe, from Commercial Air Transport to General Aviation, and flight training activities.

In the Netherlands, there is approximately one civil helicopter accident per year, which sometimes results in fatalities. The National Aerospace Laboratory (NLR) is the key centre of expertise for aerospace technology in the Netherlands. NLR, as participant in EHEST, has mapped the causes of helicopter (un)safety. The point has now been reached however to devise and implement recommendations, such as technical solutions that make flying safer. In order to improve and promote helicopter safety in the Netherlands, NLR has initiated the so-called annual Dutch helicopter safety days.

To enable measuring and ensuring helicopter safety, one needs a quantification of risk levels that residents living near heliports will be subjected to. In the case of fixed wing aircraft those risks have been accurately quantified. Until now, this risk could not be accurately quantified for helicopters. NLR has developed a model that quantifies the third-party risk resulting from civilian helicopter operations. The model was based on an extensive database of accidents worldwide, which NLR has built up over many years. Only data representative of the Dutch situation were included in the model. Helicopter accidents in mountainous or desert terrain, for example, were excluded.

NLR's Air Transport Safety Institute has over 25 years of experience in accident investigation and air transport safety research and consultancy. The team consists of highly experienced safety experts, covering the whole aviation sector, ranging from academics to safety oversight inspectors, from commercial airline pilots to certified instrument procedure designers. Moreover advanced safety models and a unique database containing world-wide accident information and exposure data (weather, traffic, etc.) are available.

NLR also analyses aviation incidents and accidents, which are rarely attributable to a single cause. Very often, there is a combination of a mechanical defect and human error. It is therefore very important that experts from a variety of fields analyse the incident from the point of view of aircraft construction, avionics, air traffic control, and risk calculation. The NLR unifies this knowledge under its roofs and it is for this reason that so much safety-related research comes together at the NLR.

1. INTRODUCTION

The historic and current worldwide helicopter accident rate is (too) high. In 2005 the International Helicopter Safety Team (IHST) (Ref. 1) was launched with the objective to reduce the helicopter accident rate by 80% worldwide by 2016. The European Helicopter Safety Team (EHEST) contributes to this effort, bringing together some 130 participants from around 50 organisations, including helicopter and component manufacturers, operators, regulators, helicopter and pilots associations, research institutes, accident investigation boards and some military operators.

In the Netherlands, there is on average approximately one helicopter accident per year, and the trend is not improving. The Dutch National Aerospace Laboratory (NLR) joined EHEST right from the beginning, as aviation safety is one of its mainstays. But also other helicopter safety related work and research is performed at the NLR in a multi-disciplinary character. In this paper the NLR is briefly introduced in chapter 2, whereas other chapters concentrate on various aspects of other safety work: chapter 3 is dedicated to the EHEST work, chapter 4 to the third party risk model (quantification of risk levels that residents living near heliports are subjected to), chapter 5 to safety consultancy work and chapter 6 to accident investigations. The paper ends with some concluding remarks.

2. THE NLR

The National Aerospace Laboratory (NLR) is the main knowledge enterprise for aerospace technology in the Netherlands. NLR carries out commissions for government and corporations, both nationally and internationally, and for civil and military aviation. The overarching objective is to render aviation safer and more sustainable and efficient. In this way, NLR has been making essential contributions to the competitive and innovative capacities of Dutch government and industry for more than 90 years.

A staff of 650 employees develops new technologies, combining disciplines such as aircraft engineering, electrical engineering, mathematics, physics, information science, and psychology. They use state-of-the-art facilities such as wind tunnels and interconnected aircraft and air-traffic control radar and tower simulators.

NLR is targeting the entire lifecycle of aircraft: from research, via design, servicing and maintenance to modernisation in both civil and military aviation. But also accident investigations form an important part of this business.

3. EHEST WORK

The European Helicopter Safety Team (EHEST) brings together helicopter manufacturers, operators, authorities, helicopter and pilot associations, research institutes, universities, accident investigation boards and some military operators from across Europe (totalling around 130 participants from 50 organisations, from which around 70 are actively involved in the analysis and implementation work). EHEST addresses the broad spectrum of helicopter operations across Europe, from Commercial Air Transport to General Aviation, and also includes flight training activities.

The process adopted by EHEST is data driven: recommendations are developed on the basis of occurrence analyses. The scope of analysis are accidents (definition ICAO Annex 13) reported by the accident investigation boards, with date of occurrence starting from the year 2000 onwards and state of occurrence located in one of the EASA Member States. EHEST is committed to ensuring that the analysis carried out in Europe will be compatible with the work of the IHST, so that results can be aggregated at worldwide level. So far the countries covered by the analysis teams account for more than 90% of the helicopters registered in Europe.

NLR joined the EHEST initiative right form the very beginning. NLR plays an active role in various layers of the organisation:

- In the EHEST strategic / decision making body
- In the European Helicopter Safety Analysis Team (EHSAT) accident analyses
- In the European Helicopter Safety Implementation Team (EHSIT) and various of its specialist teams

Within EHSAT NLR has analysed helicopter incidents and accidents that happened in The Netherlands in the years 2000 through 2008. This involved 15 cases (7 related to Civil Air Transport, 3 to General Aviation, 2 to Aerial Work, and 3 to State Flight/Police). With such a low number of occurrences it is difficult to achieve any significant statistical results, but a few facts are notable:

- The highest ranking factors that played a role in the accident, the so-called Standard Problem Statements (SPS's), are Safety Management and Pilot Judgment & Actions (each about 25%)
- By far the highest ranking suggestion for a safety enhancement, the so-called Intervention Recommendation (IR), is related to Operations (75%); this is rather trivial, given the large percentage of 'professional' operations in the Netherlands

Solely looking at helicopters that are registered in The Netherlands, there is approximately one civil helicopter accident per year in The Netherlands, which sometimes results in fatalities. As is the case in the rest of Europe and the world, the trend is not improving, as can be seen in Fig. 1.

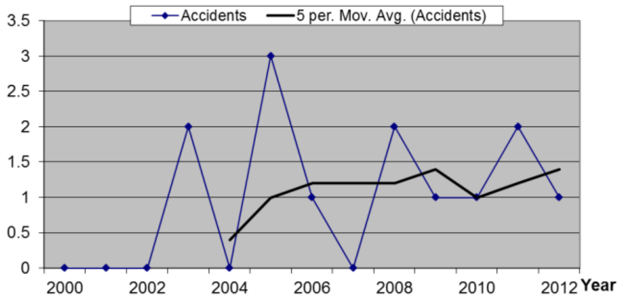

Fig.1 Absolute number of civil helicopter accidents in the Netherlands (Dutch-registered only)

Even when taking into account the increasing number of helicopters registered in The Netherlands, and therefore the increasing number of Flight Hours (FHs), the trend is still not good (see Fig. 2).

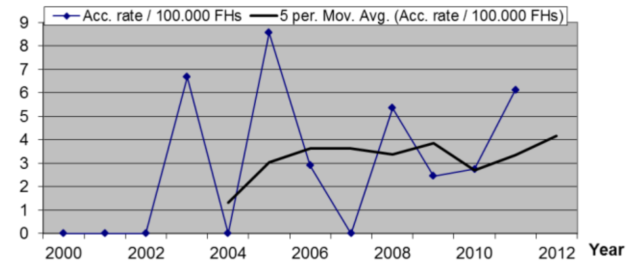

Fig.2 Relative number of civil helicopter accidents per 100.000 FHs in the Netherlands (Dutch-registered only)

Possible solutions to achieve improvements include strengthening the 'safety culture', improving training programmes and introducing new technologies. But also communication with stakeholders (helicopter users, regulators, accident investigators, etc.) is a critical aspect in these efforts.

Given these results NLR decided to organize (on a yearly basis) Dutch Helicopter Safety days, with the aim of improving helicopter flight safety in The Netherlands. The first one was organized in 2010. During the course of the day, presentations were given by a range of experts. This was followed by a panel discussion, in which the participants discussed a range of key issues. Some 75 visitors attended each of the events in order to exchange knowledge and experiences and therefore collectively improve helicopter safety levels. A broad cross-section of people who are professionally or privately involved with helicopters attended, including pilots, instructors, owners, leasers, maintenance personnel, regulators, 'operations & safety' managers and (accident) investigators. A good sign, because cooperation is essential for real progress in helicopter safety. Some of the possible solutions put forward for improving safety included intensifying the 'culture of safety', improving training, and introducing new technologies. By hosting this safety day, NLR provides a platform for stakeholders to share their knowledge and experiences, and thus improve helicopter safety together. Other countries have followed this initiative, like France and Belgium.

4. THIRD PARTY RISK MODEL FOR CIVIL HELICOPTERS

The presence of an airport or heliport causes a convergence of air traffic movements over the surrounding area (Fig. 3). In addition, it is known that the probability of an accident is relatively high during the take-off and landing phase of the flight. The involuntary exposure to this risk of air traffic accidents for the population in the vicinity is termed as third party risk. In the Netherlands, models for quantifying third party risk have been developed by NLR. The assessment of third party risk due to air traffic is a part of the Dutch environmental policy and risk calculations have been made for a number of airports.

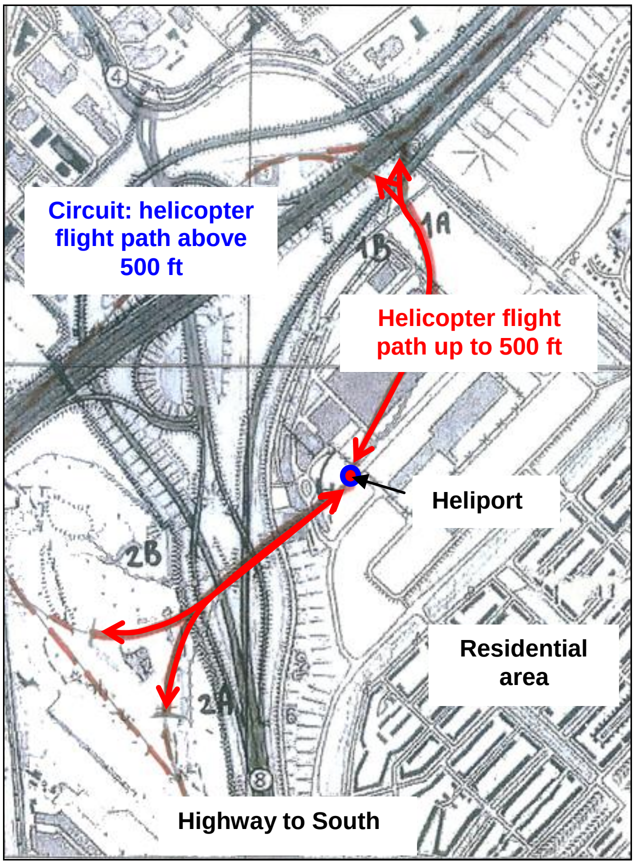

Fig.3 Layout of generic ground-level heliport

The latest addition to the third party risk model is the methodology to calculate the risk due to helicopter accidents near helicopter landing sites, specifically that of ground-level heliports and helicopter traffic on airports. It provides decision-makers an objective tool to relate traffic density to allowable risk levels in the vicinity of the heliport. The model set-up is generic and can only differentiate between helicopters with different engine types: single engine piston, single engine turbine and multi-engine turbine.

The helicopter third party risk model is based on the framework of the risk model for the civil fixed-wing aircraft. The risk model comprises three model components which answer the following questions regarding the risk of an inhabitant living in the vicinity of an airport or a heliport (third party risk):

- What is the chance that a helicopter accident occurs in the vicinity of an airport or heliport? (accident probability model)
- What is the likelihood of an accident occurring on a given location around the airport or the heliport (accident location model), given that a helicopter accident occurred in the airport / heliport surrounding? (accident location model)
- What is the consequence of a helicopter accident, given that the helicopter accident occurred in the airport/heliport surrounding? (accident consequence model)

For data selection of the model components, the following definition of a helicopter accident was taken into account (based on ICAO Annex 13):

Every contact with the ground outside the runway or the take-off and landing site, in which:

1. *a person is fatally or non-fatally injured as a result of:*
   a) *being in the helicopter (helicopter occupants, crew and passenger);*
   b) *being outside the helicopter (third party) and having direct contact with any part of the helicopter, including parts which have become detached from the helicopter (injuries self-inflicted or inflicted by other persons are excluded); or*
2. *the helicopter sustains damage, or*
3. *the external objects sustain damage.*

4.1. Accident probability model

The frequency of the occurrence of a helicopter third party accident is described in the parameters of the accident probability model. In the derivation of accident probabilities, both accidents and exposure data are necessary. Considering the operation, regulations (JAR-OPS 3) and helicopter usage, only the data of nineteen West European countries including Scandinavia and Switzerland were selected. Furthermore only accidents that occurred within a limited distance from the heliport are representative for the initial and final parts of the helicopter flight. Excluded are accidents during operations like testing, air shows and aerial work, and accidents due to sabotage. In addition, only accidents are selected which are representative for the Dutch situation. The helicopter accident data are obtained from the NLR Air Safety Database, which includes the data from Airclaims, ICAO ADREP and NTSB.

Besides accident data, exposure data are also required. Unlike the scheduled, commercial fixed-wing aircraft operations, a central reporting of helicopter operations does not exist in most countries. The number of helicopter flights published by authorities in their statistics or safety studies is mostly based on estimates. For this reason, the HeliCAS data was used to convert flying hours into number of flights. It is noteworthy that only the exposure data of turbine helicopters can be estimated from the HeliCAS data set. To derive the accident probabilities for piston engine helicopters the use of Lawrence Livermore National Laboratory statistics was made.

The resulting accident probabilities in the risk model differ for helicopter types based on engine types (single engine piston, single engine turbine and multi-engine turbine) and flight phases (departure and arrival). The single engine piston helicopters are further differentiated for two operation types: training and instruction purpose, and others (non-training).

4.2. Accident location model

The accident location model is based on the distribution of accident data obtained for which the distances to the helicopter take-off and landing point are included. By applying data-fitting a one-dimensional statistical distribution function is derived based on the distances. This distribution function is translated into a two-dimensional probability distribution function that is tailored to the sector traffic input used in this model.

Helicopters are capable of operating from a take-off and landing site (almost) in all directions due to their unique flying capability. Therefore the traffic to and from the heliport is defined in sectors with the take-off and landing point situated in the centre of the circle. For each sector the contribution to the location probability is determined by the proportion of helicopter movements assigned to that sector.

4.3. Accident consequence model

The accident consequence model takes into account the accident consequences in terms of affected area and fatal injuries. The area affected by an aircraft accident is defined as consequence area, whereas the chance on a fatal injury inside the consequence area is defined as lethality.

The consequence area is a model parameter and is a result of statistical analysis of crash area data points. By statistical analyses, an empirically determined correlation between consequence area and helicopter Maximum Take-Off Weight (MTOW) is obtained for helicopters with an MTOW up to 12 tonnes.

Lethality is defined as the probability of receiving fatal injuries when residing in the consequence area of a crash. The third party consists of people that are inadvertently exposed to the risk of a helicopter accident and are not involved in its operation. In the risk model, the lethality is determined by the relation: the ratio of the total number of fatalities and the number of persons present in the crash area.

In official accident reports, the number of fatally or non-fatally injured persons on the ground is given as factual information. However, hardly any information is reported on the number of persons that were present inside the helicopter crash area. This number is obtained by using the reported number of injured and non-injured persons, and by making assumptions of the number of persons in objects like buildings or cars involved in the accident.

4.4. Results

Fig. 4 shows a typical result of the third party risk model for civil helicopters, based on the generic heliport shown in Fig. 3.

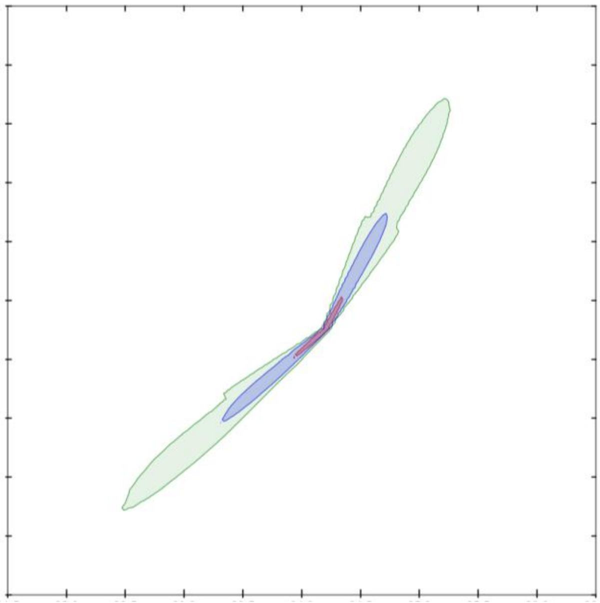

Fig.4 Individual risk contours of a ground-level heliport: $1{\cdot}10^{-5}$/year (red), $1{\cdot}10^{-6}$/year (blue) and $1{\cdot}10^{-7}$/year (green)

5. HELICOPTER SAFETY CONSULTANCY

The NLR Air Transport Safety Institute (NLR-ATSI) is the research and consultancy organisation of the National Aerospace Laboratory NLR. The institute develops and applies world-class knowledge and tools to help sustain and improve air transport safety. The mission of the institute is to support stakeholders in air transport to understand and resolve the safety implications of the growing demand for efficient and sustainable air transport.

Helicopter safety related research performed by the institute focuses on flight operational safety assessments and safety data analysis. Last year NLR-ATSI performed several exemplary studies in these domains.

5.1. Safety on a high level – HEMS operations from hospital rooftop helipads

For the DEGAS (Dutch Expert Group Aviation Safety) advice to the Dutch Minister of Transport NLR-ATSI performed an analysis of accidents with medical helicopter flights. Compared to fixed wing operations, HEMS flights have shown a poor safety performance during the last 20 years worldwide. In the Netherlands concerns had been raised regarding the safety of HEMS operations from hospital rooftop helipads and during darkness. An analysis of the influence of the operations from hospital rooftop helipads and lighting conditions on the risk of HEMS operations was conducted. In particular the take-off and landing operation on hospital rooftop helipads compared to ground based helipads and unprepared sites was analysed as well as the influence of light conditions on these operations.

From an analysis of 225 HEMS related accidents the following conclusions were drawn:

- Take-offs and landings on unprepared sites are associated with a higher risk than operations on helipads. An analysis of HEMS accidents that occurred in the USA indicate an increase in risk by a factor 2.7
- HEMS accidents at rooftop helipads are rare and only account for 4.4% of all analysed HEMS accidents that occurred worldwide
- From HEMS accidents that occurred in the USA it is estimated that the risk of operations on rooftop helipads is the same as for operations on level ground helipads
- HEMS accidents that occurred in the USA show that for take-offs and landings at unprepared sites the risk is about 2.7 times higher in darkness than in daylight conditions. For operations at helipads there is no significant difference in risk between operations in daylight and darkness

Further to these findings NLR-ATSI analysed their applicability to the situation in the Netherlands, based on which DEGAS formulated in their advice to the Dutch Minister of Transport not to prohibit the use of hospital rooftop helipads as home base location for HEMS operations during night.

5.2. Flight Operational Safety Assessment for helicopter approach procedure at Meiringen Air Base

On request of Swiss Air Navigation Services provider Skyguide, the Swiss Air Rescue Service REGA and the Swiss Air Force NLR-ATSI performed a Flight Operational Safety Assessment (FOSA) of a helicopter approach procedure at Meiringen Air Base. The challenging terrain environment did not permit to build a standard approach. The so-called PinS (Point in Space) Copter Meiringen 245 procedure, designed by Skyguide, is a Helicopter Approach through Fog (HAF) procedure, a RNAV (GNSS) approach procedure to be used by REGA and the Swiss Air Force as a cloud breaking procedure to descent though a layer of stratus clouds. The helicopter enters the HAF procedure in VMC above the cloud layer and inside the control region of Meiringen AB. The descent is then made under IFR (single pilot), with lateral guidance through the helicopter EFIS/FMS and indicated barometric altitude, towards a point in space (PinS). When arriving at the PinS and VMC is restored, the IFR procedure is cancelled and the helicopter proceeds VFR to Interlaken hospital. When at the PinS VMC is not reached an IFR missed approach procedure is carried out.

In order to ensure sufficient obstacle clearance throughout the procedure a number of non-standard features had to be introduced:

- The descent gradient of the final approach segment exceeds the recommended (10%) and maximum (13.2%) specified values in the PANS-OPS
- A 15 degrees turn is constructed in the final approach segment, where standard only a straight-in segment is allowed
- The missed approach segment after passing the PinS is constructed as an approach segment, with an associated 0.3 NM RNP instead of a 1 NM RNP which is normally associated with a missed approach segment
- The approach segment after the PinS is a climbing segment
- The approach segment after the PinS contains a 57 degrees turn

For the FOSA a hazard assessment has been performed, which addresses those flight operational hazards that are introduced by the operation of the procedure. In addition to the hazards analysis safety criteria have been defined, specifying the acceptable level of safety of the procedure.

It was found that none of the hazards show a risk level that exceeds the specified acceptable level of safety (based on ICAO PBN manual and CS-25). It was therefore concluded that the risk of all identified hazards was acceptable.

5.3. Flight Operational Safety Assessment of offshore platform operations after realisation of a nearby wind turbine field

On request of the Dutch Government NLR-ATSI has performed a FOSA of the Airborne Radar Approach (ARA) to and Departure from the Q01-HELM-A offshore platform after realisation of the Helmveld wind turbine field. EASA document AMC 20-26 and FOSA guidance material of Eurocontrol is used as guidance material, as the execution of a FOSA for these approach and departure procedures was not obligatory.

The FOSA executed consisted of the following steps:

- Description of the operation and the circumstances for which the FOSA will be executed (system definition);
- Determination of the safety criteria relevant for the operation under investigation; the safety criterion used is the one formulated in ICAO's Performance Based Manual: "The risk of a collision, with the ground, obstacles or other aircraft, should be smaller than 10^{-7}". The hazard classification table known from CS-25 is adjusted to this criterion;
- Execution of a hazard analysis (identification of hazards; determination of the severity and likelihood);
- Comparison of the risks related to the identified hazards and the safety criteria determined;
- Investigation of possible mitigating measures for those hazards with a too high risk.

The result of the FOSA was the identification of 4 hazards with an unacceptable high level of risk. To reduce the level of risk related to these hazards mitigating measures were suggested of which the most important one was an adjustment of the size of the Helmveld wind turbine field.

6. HELICOPTER ACCIDENT INVESTIGATION

NLR also analyses aviation incidents and accidents. In most cases there is not a single cause, but a combination of mechanical defects and/or human error. Therefore experts from various expertises analyse the incident or accident in detail. A recent example is the failure analysis of an APU driven gear in a Boeing Apache AH-64D helicopter accessory gearbox.

6.1. Problem description

In October 2010 a failure occurred in the accessory gearbox (AGB) of an AH-64D helicopter of the Royal Netherlands Air Force. The gear that is connected to the auxiliary power unit APU drive shaft was found to be severely damaged, and NLR was requested to provide assistance in the investigation into the root cause of this failure (Ref. 2).

6.2. Transmission – general

The transmission of the Apache helicopter takes input power from the two T700 engines, reduces the speed of rotation, and transfers the power to the main rotor shaft, accessory gearbox, and tail rotor assembly. The turbine output shafts from the T700 engines rotate at 20,900 rpm. This is reduced in the gearbox so that the main rotor turns at about 300 rpm. This is a total gear reduction of about 70:1 (Ref. 3).

6.3. Failed gearbox

The investigated accessory gearbox is integrated with the main transmission (Fig. 5). The incident occurred during the power-on phase of a 250 hours inspection.

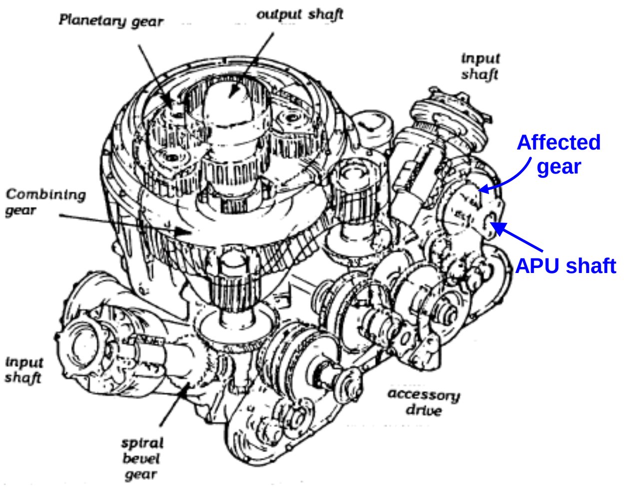

Fig.5 Cutaway view of the AH-64D transmission housing with the affected gear and shaft indicated in blue

After 15 minutes of APU run time a loud rumble was noticed and a number of warnings on the flight deck occurred. Finally the APU stopped after approximately one second and a severely deformed spline that connects the APU shaft to the accessory gearbox (Fig. 6) was found. This spline was torqued by about 35°.

Fig.6 Deformed spline

In addition, the freewheel in the AGB could be rotated in both directions. During normal operation this freewheel can only be rotated in clockwise direction. The gear (denoted as “gear 1”) that directly connects to the APU through the deformed spline was found to be severely damaged (Fig. 7). A significant part of the gear had separated, and the teeth on the gear part that was still attached to the shaft were all missing. Those on the separated part looked quite intact. The adjacent gear was moderately damaged.

The main transmission has been in service for 1,747 flight hours. A history check of the drive system has indicated that an overtorque of 123 % had occurred in March, 2010. The reported overtorque likely did not affect gear 1, since in-flight the freewheel disengages the APU drive shaft and the gear loading is very low.

6.4. Failure analysis results and conclusion

After detailed observations with an optical stereomicroscope (up to a magnification of 40×) and two scanning Electron Microscopes it was concluded that the gear has failed in fatigue. Micro- and macro-features were observed on the fracture surfaces. A 75 mm long fatigue crack developed and grew before final failure (Fig. 7).

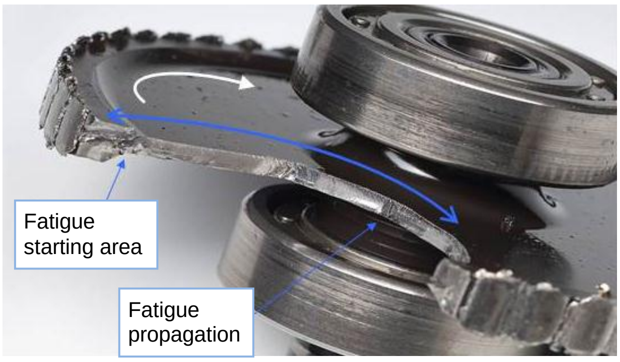

Fig.7 Gear 1 fracture surface; the blue arrow marks the area with fatigue indications and the white arrow indicates the direction of rotation (note missing teeth)

The presence of small cracks at some of the root fillets of the separated gear part suggests ‘natural fatigue’, although it cannot be excluded that these cracks have developed under high fluctuating loads induced during the failure process.

The failed gear driven by the APU is regarded as a non-flight critical part, since in-flight the freewheel disengages the APU drive shaft and the gear loading is very low. Remedial actions were limited to extra inspections for the ‘high time’ transmissions.

7. CONCLUDING REMARKS

The National Aerospace Laboratory (NLR) is the main knowledge enterprise for aerospace technology in the Netherlands. NLR carries out commissions for government and corporations, both nationally and internationally, and for civil and military aviation. The overarching objective is to render aviation safer and more sustainable and efficient. In this way, NLR has been making essential contributions to the competitive and innovative capacities of Dutch government and industry for more than 90 years.

In the Netherlands, there is approximately one civil helicopter accident per year, which sometimes results in fatalities. In order to improve and promote helicopter safety in the Netherlands, NLR plays an active role in the international helicopter safety initiative and has also initiated the so-called annual Dutch helicopter safety days.

To assess the risk of helicopter accidents for the population in the vicinity of inland heliports a so-called third party risk model was developed. The model is more generic than aimed for due to a lack of basic data over a significant time period. An improvement can only be obtained with the availability of more and improved accident and exposure data.

NLR’s Air Transport Safety Institute develops and applies world-class knowledge and tools to help sustain and improve air transport safety. Helicopter safety related research focuses on flight operational safety assessments and safety data analysis. Advanced safety models and a unique database containing world-wide accident information and exposure data (weather, traffic, etc.) are available.

NLR also analyses aviation incidents and accidents, which are rarely attributable to a single cause. Very often, there is a combination of mechanical defects and human error. Experts from a variety of disciplines analyse the accident or incident from the point of view of aircraft construction, avionics, air traffic control, and risk calculation.

NLR unifies multi-disciplinary knowledge under its roofs and it is for this reason that so much safety-related research comes together at the NLR.

REFERENCES

1. http://www.ihst.org/
2. Kool, G., Hattenberg, T., Faber, J., Bos, M., ‘Fractographic investigation of a failed gear in the accessory gearbox of an AH-64D helicopter of the Royal Netherlands Air Force’, NLR-CR-2010-507, Amsterdam, October 2010
3. Chait, R., Lyons, J., Long, D., ‘Critical Technology Events in the Development of the Apache Helicopter’, Project Hindsight Revisited, Center for Technology and National Security Policy, National Defense University, February 2006 (http://www.ndu.edu/CTNSP/)

ACRONYMS

ADREP	Accident/Incident Data Reporting
AGB	Accessory gear Box
AMC	Applicable Means of Compliance
APU	Auxiliary Power Unit
ARA	Airborne Radar Approach
ATSI	Air Transport Safety Institute
CS	Certification Standard
DEGAS	Dutch Expert Group Aviation Safety
EASA	European Aviation Safety Agency
EFIS	Electronic Flight Instrument System
EHEST	European Helicopter Safety Team
EHSAT	European Helicopter Safety Analysis Team
EHSIT	European Helicopter Safety Implementation Team
FH	Flight Hour
FMS	Flight Management System
FOSA	Flight Operational Safety Assessment
GNSS	Global Navigation Satellite System
HAF	Helicopter Approach through Fog
HeliCAS	Helicopter Analytical System
HEMS	Helicopter Emergency Medical Services
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IHST	International Helicopter Safety Team
IR	Intervention Recommendation
JAR-OPS	Joint Aviation Requirements - Operations

MTOW	Maximum Take-Off Weight
NLR	National Aerospace Laboratory
NTSB	National Transportation Safety Board
PANS-OPS	Procedures for Air Navigation Services - Aircraft Operations
PBN	Performance Based Navigation
PinS	Point in Space
RNAV	Area Navigation
RNP	Required Navigation Precision
SPS	Standard Problem Statement
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions