Dedicated to innovation in aerospace

POWER FAILURES IN SINGLE ENGINE HELICOPTERS: Establishment of the case for/against enhancing certification requirements on pilot intervention times

Jos Stevens, NLR

Jos.Stevens@nlr.nl

7th EASA Rotorcraft Symposium, Cologne, 4-5 Dec. 2013

The reason why

- **Entry into autorotative flight following loss of power in single-engine helicopters is time-critical event requiring immediate recognition and response**

- **Safe entry into autorotative flight dependent on**
  - allowable (available) response time
  - actual pilot response time

- **Normal certification practice assumes time delays of**
  - 1 second in cruise
  - 0.3 seconds for other flight phases

- **EASA’s future rulemaking: increasing pilot intervention times following power failure on single-engine helicopters**

Contents

- Study objective
- Literature study
- Safety impact analysis
- Computer simulations
- Technological solutions
- Regulatory Impact Assessment
- Outcome of RIA
- Conclusions

Picture: Nicole Garmston
***Source:* Sunday Herald Sun**

Study objective

- **Support EASA's future rulemaking on increased pilot intervention times following power failure on single-engine helicopters**

- **Specific objective of study is**
  - *"the establishment of the case for/against enhancing certification requirements in the area of pilot intervention time following power failure in single-engine helicopters"*

- NLR & ECORYS **performed Regulatory Impact Assessment**

Literature study -1-

- **Goal to identify**
  - range of pilot response times (allowable and actual) for single-engine helicopter loss of power events
  - existing or emerging technologies that could increase time available to successfully enter autorotation

- **Response times**
  - depend on rotorcraft type and characteristics (rotor inertia, weight, etc.), but even more on flight phase
  - allowable (available) response time
    - 0.3 seconds in hover
    - 3 to 5 seconds in forward flight (MTOM > 4300 kg)
  - actual response times (90th percentile)
    - 2 to 3 seconds (twin-engine helicopters only)

Literature study -2-

- **Identify technologies**
  - increasing allowable response time
    - active technologies
      - additional power source
      - tip jets
      - flywheel
    - passive technologies
      - additional blade inertia
      - increased rotor RPM
  - decreasing actual response time
    - additional cues (visual, aural, etc.): not beneficial
    - advance warnings: may reduce times by 0.5 to 1.4s
    - automated system performing corrective action

Safety impact analysis

- **Quantification of the maximum safety benefit**
- **NLR dataset of 886 single engine h/c accidents (EASA member states, years 2000-2011)**
- **151 accidents related to engine failure**
  - for 99 accidents a successful autorotation was deemed possible, but landing was unsuccessful
  - max. 22 of these (caused by "late response to start autorotation") could have been avoided, saving 13 lives
  - increasing time available to 2 seconds (for all flight phases) could have avoided 18 of these 22 (80%), saving 10 lives

Computer simulations -1-

- **Three NLR computer simulation codes used**
  - ‘EMPRESS’ for steady state flight performance
  - ‘EUROPA’ for engine failure simulations
  - ‘SPEAR’ to asses impact of technologies on design/mass

- **About 30 single engine helicopter types**
  - MTOW 450 to 3000 kg
  - piston and turbine engine

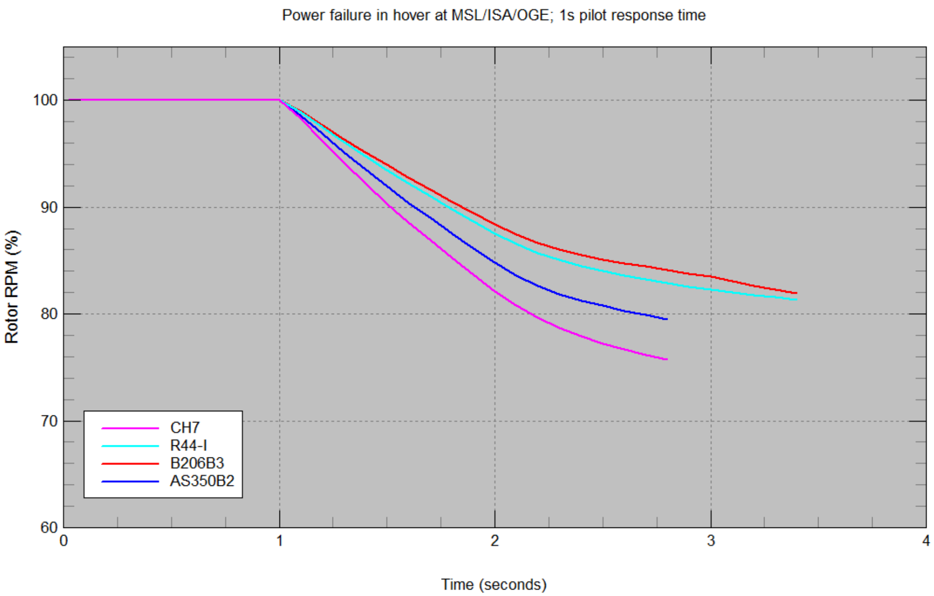
- **Four selected for computer analysis**
  - HeliSport CH-7 Kompress (450 kg)
  - Robinson R44 Raven I (1089 kg)
  - Bell 206B-3 JetRanger III (1452 kg)
  - Aerospatiale AS350B2 Ecureuil (2250 kg)

Computer simulations -2-

- **Instantaneous engine failure**

- **Variation of pilot response times after engine failure**
  - ranging from 0.5s to 4s

- **Variation of flight conditions**
  - air speed
  - level flight
  - climbing flight



- **In hover, minimum allowable rotor rpm reached**
  - CH7 after 0.5 s (min. allowed RPM 90%)
  - R44-I after 0.75 s (min. allowed RPM 90%)
  - B206B3 after 0.8 s (min. allowed RPM 90%)
  - AS350B2 after 1.2 s (min. allowed RPM 82%)

Computer simulations -3-

- **Likelihood of recovery after complete power failure**
  - current situation (no changes)

		AS350B2	B206B3	R44-I	CH7
Recovery after 0.5s pilot response time	hover OGE	likely	probable	probable	probable
	bucket speed	likely	likely	likely	likely
	cruise speed	likely	probable	probable	probable
Recovery after 1s pilot response time	hover OGE	probable	unlikely	unlikely	unlikely
	bucket speed	likely	likely	likely	probable
	cruise speed	likely	probable	likely	unlikely
	climb VBROC	probable	unlikely	unlikely	unlikely
Recovery after 2s pilot response time	hover OGE	unlikely	unlikely	unlikely	unlikely
	bucket speed	likely	probable	probable	probable
	cruise speed	unlikely	unlikely	unlikely	unlikely
	climb VBROC	unlikely	unlikely	unlikely	unlikely

Technological solutions -1-

- **Available response time to recover after complete power failure very limited**
- **For 3 out of 4 investigated helicopter types available response times ‘meet’ certification requirements**
- **Actual pilot response times longer than available times**
- **Technological solutions can improve available times**
- **Three types investigated**
  - adding emergency power source
  - increasing rotating system inertia
  - automatic lowering of collective control

Technological solutions -2-

- **Mass impact of installing solutions allowing 2 second pilot response time in hover**

	AS350B2	B206B3	R44-I	CH7
Max. take-off mass	2250 kg	1452 kg	1089 kg	450 kg
Installed MCP	466 kW	236 kW	175 kW	73.5 kW
Additional power required to keep rotor rpm above minimum allowable	120 kW	120 kW	90 kW	39 kW
Total delta mass at equal payload and range	95 kg	110 kg	81 kg	50 kg
Increase in rotor inertia required to keep rotor rpm above minimum allowable	100 %	150 %	150 %	200 %
Total delta mass at equal payload and range	94 kg	120 kg	70 kg	41 kg

Regulatory Impact Assessment -1-

- **RIA aims at establishing which option would best achieve rulemaking objective while simultaneously minimising potential negative impacts**

- **Four options considered**
  - Option 0 – “Do nothing scenario”
  - Option 1 – Mandatory certification of new single-engine h/c’s with allowable response time increased to 2 seconds for all flight phases (1A extra inertia, 1B extra power)
  - ~~Option 2: - Mandatory certification of new single-engine h/c’s with allowable response time increased to above 2 seconds for all flight phases~~
  - Option 3: Additional non-mandatory information to manufacturers w.r.t. safety benefit gains by increasing allowable response times (up to 2 seconds)

Regulatory Impact Assessment -2-

- **Items considered for RIA**

Assessment criteria	Weight
Safety	3
Economics	2
Social (e.g. employment in Industry)	2
Environment	2
Proportionality issues (proportional throughout Industry)	2
Regulatory harmonisation	1

- **Impact assessed through Multi-Criteria Analysis, either quantitatively or qualitatively**

- **Using standardised rating scale for assessment of effects (range -5 to +5)**

Outcome of RIA -1-

- **Summary of impacts**

Impact assessment area	Weighted score option 1A	Weighted score option 1B	Weighted score option 3
Safety	6	6	3
Economic	-3.5	-4.5	-1.5
Social	-2	-2	1
Environment	-2	-2	-1
Proportionality	0	0	0
Regulatory	0	0	0
Total impact	**-1.5**	**-2.5**	**1.5**

- **Option 3 ("non-mandatory request to manufacturers") produces positive case overall**

Outcome of RIA -2-

- **Safety impact**
  - cost savings due to prevented accidents/fatalities/injuries

- **Economic impact (expenditures)**
  - one-off costs (development, certification, production)
  - recurring costs (fuel, training, maintenance, airworthiness)
  - others (selling price, market impact)

	Option 1	Option 3*
Safety benefit / year	€ 3.9 million	€ 0.47 million
Additional fuel cost / year	€ 6.7 million	€ 0.80 million

* assuming 12% market penetration

- **Safety benefit and fuel cost figures unbalanced**

Conclusions

- **Certification practice not in line with human performance**
- **Study proposes to use 2 second time delay for all flight phases (in line with Def Stan 00-970)**
- **Technologies can help, but with mass and cost impact**
- **Safety and economic cost figures unbalanced (safety benefit €3.9M/year, extra fuel costs €6.7M/year)**
- **Very few accidents attributed to failure to enter autorotation (~2 accidents/year & 1 fatality/year)**

→ **<u>Recommend</u> manufacturers to increase allowable response time to 2 seconds**

NLR

Dedicated to innovation in aerospace

Questions?

www.nlr.nl - info@nlr.nl