Helicopter Safety Analysis in South Africa: a preliminary study

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IHSS 2009
September 30, 2009
Plan

- Helicopter safety background
- South Africa Operations
- Accidents analysis
  - HFACS
  - Categorical analysis
- Conclusions
Helicopter Safety Motivation

• 2005 New Zealand CAA moves to outlining target safety outcomes:
  • Valuation based upon cost of statistical life, damage to property etc.
  • Highlights helicopter accidents as an area of concern
  • Problem with understanding true causes of helicopter accidents
  • 2007 analysis conducted with UK and NZ helicopter accidents (IHSS 2007, RAeS Journal forthcoming)
  • Interest in studies with similar countries to see where NZ CAA could improve.
Research Questions

What are causes of helicopter accidents?

- What types of helicopter are prone to accidents?
- How much is due to technical failure, human error and mixed failure?
- Which components of a helicopter are most prone to failure?
- What are the types of human error committed during helicopter accidents?
- What are the prevailing phases of flight when helicopters are involved in accidents?
- What are the most common nature of flights involved with helicopter accidents?
- Is there any association between the items above?
Helicopter Safety Background (1)

- South Africa
  - 1.2 million sq. Km land mass
  - 47 million people
  - 9 provinces
  - Wide variation in terrain
  - Major cities
  - Sparsely populated areas
  - 2% of world fleet helicopters
Helicopter Safety Background (2)

- Game operations
  - 5% of SA is national parks, game reserves
  - Helicopters most effective to track, capture and dart animals over large distances
  - Common method is to use a plastic “boma”
    - enclosure disguised as local habitat
    - efficient for capturing large numbers of animals with minimal risk to animal
Figure 33.1 A plastic capture boma based on the Oelofse method. A = capture funnel, B = capture area, C = holding area, D = loading funnel, and E = loading ramp. (Based on the Oelofse method.)
Features of game operations

Extra demands upon the pilot:

- fly at low altitude;
- carry out rapid manoeuvres;
- simultaneously focus upon the target and helicopter without losing situational awareness of other hazards or operating out of the helicopter’s performance envelope;
- Rapid decision making under pressure;
- Rapid communication with ground staff, veterinary personnel onboard or other helicopters in the operation.
- These operations demand higher levels of pilot attention and skill which are reflected in additional flight hour training and licence rating for game capture.
Helicopter Safety Analysis

- Accidents analyses:
  - Technical failures
  - Human factors

- Data coverage
  - 192 detailed final accident reports from 1998-2008
  - Variation in quality of reports
  - Permission from SA CAA to use
Helicopter Engine/Weight Classes

  - Heavy Twin Turbine (HTT) > 2730 kg in weight
  - Heavy Single Piston (HSP) > 2730 kg in weight
  - Light Multi Turbine (LMT) < 2730 kg in weight
  - Light Single Turbine (LST) ditto
  - Light Single Piston (LSP) ditto
  - 206 and other Single Turbine ditto
  - Gyroplane and balloon
## Helicopter Operations Categories

**Introduction of game**

<table>
<thead>
<tr>
<th>Public</th>
<th>Private</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambulance /Search and Rescue</td>
<td>Game</td>
</tr>
<tr>
<td>Passenger</td>
<td>Business</td>
</tr>
<tr>
<td>Police Support</td>
<td>Freight</td>
</tr>
<tr>
<td></td>
<td>Private</td>
</tr>
<tr>
<td></td>
<td>Survey</td>
</tr>
<tr>
<td></td>
<td>Training or Private Training</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
</tr>
</tbody>
</table>
# Helicopter Phases of Flight Categories

<table>
<thead>
<tr>
<th>Phase of Flight</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Takeoff</strong></td>
<td>i.e. Takeoff/Climb/Initial Climb</td>
</tr>
<tr>
<td><strong>Landing</strong></td>
<td>i.e. Landing/Approach/Descent</td>
</tr>
<tr>
<td><strong>Taxi &amp; Hover</strong></td>
<td>i.e. Taxi/Hover/Parked</td>
</tr>
<tr>
<td><strong>En Route</strong></td>
<td>i.e. En Route/Cruise/Circuit/ Manoeuvring/ Game Manoeuvring. Game Manoeuvring includes operations at low altitude and other distinct manoeuvres.</td>
</tr>
</tbody>
</table>
Causes of Accidents

- **Operational Failure (Human Error)**
  - Accidents caused by pilot error & external factors, e.g. bad weather
- **Airworthiness Failure (Engine)**
  - Accidents caused by the failure of a properly maintained engine part
- **Airworthiness Failure (Non-Engine)**
  - Accidents caused by the failure of a properly maintained component part (non-engine parts)
- **Maintenance Failure**
  - Accidents caused by improper or inadequate maintenance
- **Mixed Failure**
  - Accidents contributed by both human error and mechanical failure (airworthiness failure or maintenance failure)
Data Processing

- **Data was grouped in different ways:**
  - Cause of accidents
    - i.e. airworthiness failure, operational failure, etc…
  - Helicopter types
  - Type of operation,
  - Phase of flight
  - Failure parts (only applicable for airworthiness failure accidents)
  - Operational failure - HFACS categories
## Data Processing - Engine Component

<table>
<thead>
<tr>
<th>Rotorcraft Component Group</th>
<th>Typical Components Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Parts (excluding carburettor)</td>
<td>propeller, engine cylinder, compressor, piston, turbocharger, engine cowling, turbine wheel</td>
</tr>
<tr>
<td>Carburettor</td>
<td>Carburettor</td>
</tr>
<tr>
<td>Main Rotor Blade</td>
<td>Main Rotor Blade</td>
</tr>
<tr>
<td>Tail Rotor Blade</td>
<td>Tail Rotor Blade</td>
</tr>
<tr>
<td>Gearbox/Transmission</td>
<td>gearbox, connecting rod, drive belt, drive shaft, swash plate assembly (main rotor), pitch change assembly (tail rotor)</td>
</tr>
<tr>
<td>Control System</td>
<td>collective control, cyclic control, control rod, computer system, trim control</td>
</tr>
<tr>
<td>Electrical System</td>
<td>Battery, electrical wiring/ cables</td>
</tr>
<tr>
<td>Indication System</td>
<td>fuel indicator, altitude indicator, chip detection magneto, sensors</td>
</tr>
<tr>
<td>Cooling System</td>
<td>cooling pipe, cooling fan</td>
</tr>
<tr>
<td>Hydraulic System</td>
<td>hydraulic pump, pipeline</td>
</tr>
<tr>
<td>Fuel System</td>
<td>fuel, fuel control unit (FCU), fuel tank, auxiliary fuel tank, fuel boost pump</td>
</tr>
<tr>
<td>Lubrication System</td>
<td>lubricating oil, oil feed-back line</td>
</tr>
<tr>
<td>Structure</td>
<td>tail boom, cockpit structure, bolts/ bearings, landing gear/ skid, horizontal/ vertical stabiliser</td>
</tr>
<tr>
<td>Other parts/ Unknown</td>
<td>cargo string, cargo hook, unknown components</td>
</tr>
</tbody>
</table>
HFACS Framework

• EHEST HFACS Manual (2008) via UK CAA
Annual accident numbers

- Completeness of data
Annual accident rates - I

Lacking flight hours data:
• Two approaches chosen
• NZ CAA Hours for similarity (%age fleet)
• If flight hours same
Annual accident rates II

Lacking flight hours data:
- If accident rate is comparable
- Flight hours 20% less for same accident rate

[Graph showing annual accident rates for South Africa and New Zealand from 1998/3 to 2006/3]
• Similar proportion of operational errors to global studies
Accident causes by rotorcraft type

- LSP dominate with 60%
- Turbines ~ 36%
Accidents by cause and rotorcraft type

- Single Turbine Light
- Twin Turbine All
- Single Piston Light
- Gyroplane and Balloon

Categories:
- UNKNOWN
- MIXED
- OPERATIONAL-EXTERNAL
- OPERATIONAL-ERROR
- MAINTENANCE
- AIRWORTHINESS-OTHER
- AIRWORTHINESS-ENGINE
Accidents by operation type

<table>
<thead>
<tr>
<th>OPERATION TYPE</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUBLIC AMBULANCE</td>
<td>2</td>
<td>1.04</td>
</tr>
<tr>
<td>PUBLIC PASSENGER</td>
<td>18</td>
<td>9.38</td>
</tr>
<tr>
<td>PUBLIC POLICE SUPPORT</td>
<td>6</td>
<td>3.13</td>
</tr>
<tr>
<td>NON PUBLIC GAME</td>
<td>38</td>
<td>19.79</td>
</tr>
<tr>
<td>NON PUBLIC BUSINESS</td>
<td>17</td>
<td>8.85</td>
</tr>
<tr>
<td>NON PUBLIC FREIGHT</td>
<td>5</td>
<td>2.60</td>
</tr>
<tr>
<td>NON PUBLIC PRIVATE</td>
<td>78</td>
<td>40.63</td>
</tr>
<tr>
<td>NON PUBLIC SURVEY</td>
<td>5</td>
<td>2.60</td>
</tr>
<tr>
<td>NON PUBLIC TRAINING</td>
<td>23</td>
<td>11.98</td>
</tr>
<tr>
<td>Total</td>
<td>192</td>
<td>100</td>
</tr>
</tbody>
</table>

- Non-public transport dominant ~86%
- Private; Game; Training ~ 73%
• Private; Game - LSP dominant
Phase of flight in each rotorcraft type

- Unsurprising that route operations are major phase for LSP
• Also unsurprising that operational errors dominant for the route phase.
Type of operation vs. accident cause

- Public Ambulance
- Public Passenger
- Public Police Support
- Non Public Game
- Non Public Business
- Non Public Freight
- Non Public Private
- Non Public Survey
- Non Public Training

Legend:
- Unknown
- Mixed
- Operational-External
- Operational-Error
- Maintenance
- Airworthiness-Other
- Airworthiness-Engine
Accidents by nature of flight

- Single Turbine Light
- Twin Turbine Heavy
- Twin Turbine Light
- Single Piston Light
- Gyroplane and Balloon

Legend:
- NON PUBLIC TRAINING
- NON PUBLIC SURVEY
- NON PUBLIC PRIVATE
- NON PUBLIC FREIGHT
- NON PUBLIC BUSINESS
- NON PUBLIC GAME
- PUBLIC POLICE SUPPORT
- PUBLIC PASSENGER
- PUBLIC AMBULANCE
HFACS analysis

<table>
<thead>
<tr>
<th>HFACS CATEGORY</th>
<th>FREQUENCY</th>
<th>PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skill</td>
<td>80.0</td>
<td>62.5</td>
</tr>
<tr>
<td>Decision</td>
<td>55.0</td>
<td>43.0</td>
</tr>
<tr>
<td>Misperception</td>
<td>10.0</td>
<td>7.8</td>
</tr>
<tr>
<td>Violation</td>
<td>23.0</td>
<td>18.0</td>
</tr>
<tr>
<td><strong>Total unsafe acts</strong></td>
<td><strong>168.0</strong></td>
<td><strong>131.3</strong></td>
</tr>
<tr>
<td>Preconditions</td>
<td>81.0</td>
<td>63.3</td>
</tr>
<tr>
<td>Supervisory</td>
<td>9.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Organisational</td>
<td>5.0</td>
<td>3.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>263.0</strong></td>
<td><strong>205.5</strong></td>
</tr>
</tbody>
</table>
HFACS causes over the data period

Graph showing the trends of HFACS causes over time from 1998 to 2006. The causes are differentiated by color and line style:
- **ERROR-SKILL** (Blue line)
- **ERROR-DECISION** (Red line)
- **ERROR-PERCEPTUAL** (Green line)
- **VIOLATION** (Purple line)

Additionally, 2 per. Mov. Avg. lines are shown for **ERROR-SKILL** and **ERROR-DECISION**.
HFACS categories by type of rotorcraft

Light Single Piston

Light Single Turbine

- VIOLATION
- MISPERCEPTION
- DECISION
- SKILL
Unsafe acts by type of operation

- Public Passenger
- Non Public Game
- Non Public Private
- Non Public Training

Categories:
- Total Violation
- Misperception
- Total Decision
- Total Skill
Unsafe acts by phase of flight

- Hover/Ground
- Takeoff
- Landing
- Route

Legend:
- Violation
- Misperception
- Decision
- Skill

Graph shows the percentage distribution of unsafe acts across different phases of flight.
Accidents by pilot experience

- Pilot inexperience, ~ 25% of accidents
- Spike at 3000 hours
Accidents by pilot experience II
Percentage of technical components failure

- Engine Parts: 41%
- Control System: 17%
- Main or Tail Rotor: 12%
- Fuel Systems: 18%
Categorical analysis

<table>
<thead>
<tr>
<th>Variables</th>
<th>Chi-Squared Goodness of Fit Statistic $X^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Game &amp; Channelized Attention</td>
<td>8.11</td>
</tr>
<tr>
<td>Training &amp; Inadequate Supervision</td>
<td>16.67</td>
</tr>
<tr>
<td>Private &amp; Attention Errors</td>
<td>30.95</td>
</tr>
<tr>
<td>Private &amp; Choice Errors</td>
<td>10.94</td>
</tr>
<tr>
<td>Private &amp; Technique Errors</td>
<td>15.48</td>
</tr>
<tr>
<td>Private &amp; Perception Errors</td>
<td>7.16</td>
</tr>
<tr>
<td>Route &amp; Operational Error</td>
<td>8.546</td>
</tr>
</tbody>
</table>

- **Important significant associations at 1% level**
Final conclusions

• Note preliminary nature of the study
• Data issues - flight hours
• Similar results in many respects to other countries, e.g. private, training
• Game operations unique
• More data on organisation factors
• Opportunity for IHST to perform thorough analysis
Thank you!

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