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Helicopter Pilots Encountering Fog: An Analysis of 109 Accidents from 1992 to 2016

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Abstract: Helicopters have the ability to make maneuvers or precautionary off-airport landings to avoid flights into instrument meteorological conditions (IMC) such as fog. Flight accidents in which fog was encountered as well as inadvertent and intentional flights into fog were examined to understand their occurrence. A 25-year period in the United States using the National Transportation Safety Board online database was used to collect 109 accident reports of which 73 (67%) were fatal. Pilots flying intentionally into IMC were more likely to be a part of a fatal accident than those who did so inadvertently. Those pilots who were reported as being under pressure when encountering fog conditions were also more likely to be in an accident. The findings confirm a high prevalence and an added danger to intentional flights into IMC. In addition, decision-making under pressure when encountering IMC conditions is now linked to a higher proportion of fatalities, emphasizing that helicopter pilots should be made aware of these specific decision-making circumstances in their operations.

Keywords: general aviation; helicopter; HEMS; instrument flight rules; accident analysis

1. Introduction

Helicopters, similar to other small aircraft in U.S. general aviation, mostly operate in Class G airspace, which defines the weather minimums for an aviation operation. Instrument Flight Rules (IFR) apply when flights are conducted below a minimum cloud ceiling of 1000 feet and visibility of three statute miles. However, helicopters may also operate in Class G airspace under visual flight rules (VFR) when the weather is clear of clouds with only a half-mile visibility during the day time and with one mile visibility clear of clouds during the night. The Federal Aviation Administration only added this visibility requirement in 2014. They increased weather minimums for general aviation, commercial and air ambulance helicopter operations to mitigate, among others, fatal accidents occurring when flying into IMC [1]. These rules already existed as advisories prior to this time. IFR and VFR differ for helicopters compared to fixed-wing aircraft and for the purposes of this study, it suffices to state that helicopters generally have lower visibility and cloud base requirements than fixed-wing aircraft. Fog is an instrument meteorological condition (IMC) that requires IFR, and helicopters flying under visual flight rules (VFR) are expected to avoid or leave such conditions immediately.

Weather has been identified as an important factor in accidents both for air carriers and general aviation (GA) but particularly affect the latter [2]. Simulations on fixed-wing flights into inadvertent instrument meteorological conditions (IMC) have shown decision-making biases that are affected by social pressures as well as experience with instrument flight rules or IFR [3–6]. Helicopter, as opposed to fixed-wing flight, procedures received less attention with the exception of emergency medical service (HEMS) operations. Studies of helicopter accidents show that both GA and HEMS

operations that encountered unplanned instrument meteorological conditions should be considered especially dangerous in combination with unfavorable light conditions [7,8].

In a simulation task for fixed-wing pilots, overconfidence was reported in personal ability and inaccurate diagnoses of visibility conditions when flying under visual flight rules into IMC [4]. An GA accident analysis study that excluded helicopters confirmed that most flights under visual flight rules (VFR) going into IMC accidents involve intentional flights into adverse weather by the pilot [5]. They also reported situation assessment, risk perception and social pressure as the main underlying causes. In contrast, in a simulation study of fixed-wing pilots flying into deteriorating weather it was concluded that social influence was the least important factor affecting their decision [9]. The role of inadvertent versus intentional flights into IMC of helicopters is unclear but the specific ability of helicopters to make off-airport landings as well as the overall paucity of general aviation helicopters equipped to fly under IFR suggest that the findings are likely different from fixed-wing operations.

A simulation specific for helicopter flights into IMC showed that short training sessions produce significant performance improvements, and that situations with impaired visibility had a strong negative effect on pilot performance that was more pronounced than situations with low airspeeds and low altitudes [3]. In this study it is maintained that, "Because helicopter operations by nature are largely conducted in VFR environments, many helicopter pilots, even those with instrument training, have relatively little instrument flight time in actual IMC" [3] (p. 236).

A study of aviation accidents in Australia concerning visual flight into IMC conditions found that pilots were more likely to be in a fatal accident when they had more than 500 total flight hours, chose to continue into IMC, did not undertake proper preflight planning, only had night VFR rating and were involved in private operations [10]. Although this study was not exclusively concerned with helicopters, the results provide a useful benchmark for our study of helicopters encountering fog.

In this study, accident reports mention fog when describing the situation of the accident. The presence or the danger of this specific IMC condition is examined for factors significantly associated with fatality. IMC weather conditions take many forms and include any circumstance in which the minimum visibility and cloud ceiling requirement of the specific airspace class have not been met. In the case of helicopters, it also includes so-called brown-outs and white-outs caused by sand or snow, respectively, when they are stirred up due to the downwash of the rotor-system. Only accidents that mentioned "fog" were selected, highlighting the problem of visibility as opposed to other complicating factors such as wind gusts or snow. The decision to enter IMC conditions in situations where fog was reported is made central to the discussion.

2. Methods

A total of 133 accidents from the 25-year period from 1992–2016 were extracted from the US National Transportation and Safety Board (NTSB) online database [11]. The year 2016 was used as a cut-off point to avoid the presence of preliminary reports for more recent accidents. Accident reports in the 1990s and before often have less information available for a statistical comparison. In the majority of the cases from the 1990s, the weather report and information about whether the pilot reviewed such a report was missing. We extended our dataset into the 1990s to allow for statistical analyses and observe possible trends over time.

Accidents were identified using the search term "fog." Although 133 accidents were identified using the term, 24 of the accidents were removed from analyses because the term was only used: in reference to a training manual (N = 7), to describe weather conditions outside the area of the accident (N = 9), describing a flight different from the accident in question (N = 5), or there were conflicting reports about the presence of fog, and it could not be determined which report was the most reliable (N = 3).

In addition to the factors and circumstances listed by the NTSB investigators, we retrieved from the narrative statements the investigators' impression of whether or not the pilot was under pressure (external or self-induced) to attempt the flight in question. We are particularly interested in examining

the pilots' awareness of the adverse weather conditions and the extent to which this was related to whether the flight resulted in fatalities, however the earlier accident reports did not allow a detailed examination on the awareness of weather reports. Instead, we compared the number of fatal accidents in which the investigator determined that the flight into IMC was intentional, versus inadvertent. The significance of differences in the proportion of fatal and nonfatal accidents in the dataset were determined using Pearson's Chi-Square analysis. Relations were considered significant if p-values were below 0.05.

3. Results

The use of the term "fog" in accident reports appears 24 times between 1992–1995, 19 times between 1996–1999, 25 times between 2000–2003, 18 times between 2004–2007, 7 times between 2008–2011, and 16 times between 2012–2016, with no reports in 2007 (see Figure 1). Out of the 109 accidents in this study 73 (67%) were fatal with a total of 163 fatalities. For an overview of some of the main results see Table 1.

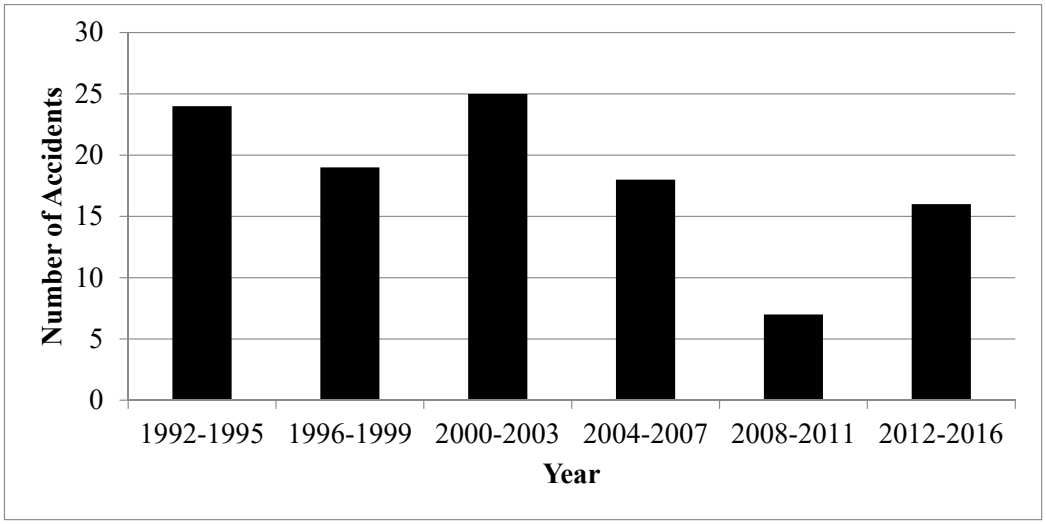

Figure 1. Number of Accidents between 1992 and 2016.

Table 1. Distribution of fatal and non-fatal accidents for helicopters encountering fog.

Comparison	Fatal	Non-Fatal	Statistical Analysis
≤500 Total flight hours	2	10	(1, N = 109) $p > 0.05$ (F)
>500 Total flight hours	34	63	
Instrument rated	51	23	χ^2 (1, N = 109) = 0.39, $p > 0.05$
Not instrument rated	22	13	
Intentional into IMC	32	9	χ^2 (1, N = 55) = 3.98, $p < 0.05$
Inadvertent in IMC	7	7	
Flight into adverse weather	12	10	χ^2 (1, N = 109) = 1.92, $p > 0.05$
No flight into adverse weather	61	26	
Pressure reported	26	6	χ^2 (1, N = 109) = 4.17, $p < 0.05$
No pressure reported	47	30	
Pressure (excl. HEMS)	9	0	(1, N = 86) $p < 0.05$ (F)
No pressure (excl. HEMS)	47	30	
Part 91	55	21	χ^2 (1, N = 108) = 3.75, $p < 0.05$
Other FAR	21	15	

Note: (F) indicates that a Fisher's Exact Test was used to account for expected cell frequencies below 5.

3.1. Geographic Location

Fog-related accidents occurred in 28 different states. The accidents occurred most frequently in California (N = 19) with seven accidents occurring in Alaska, Louisiana, Oregon, and Texas each. Only three accidents, of which two were fatal, reported that the locations were particularly prone to fog, one fatal in the state of New York and Texas, and one non-fatal in Alaska. The overall numbers per state are too low to allow for a more fine-grained statistical analysis.

3.2. Pilot Characteristics and Behaviors

The average age of the pilots was 47.77 years, the youngest being 23 and the oldest 81. They had an average total number of 6266.94 flight hours, with a low of 81 h and a high of 22,911 h. Those with more than 500 total flight hours were not significantly more often associated with fatal accidents ($p > 0.05$) than those with equal or less than 500 h (see Table 1).

Pilots were instrument-rated in 74 cases, of which 13 only had an instrument-rating for fixed-wing aircraft. Those without an instrument-rating were not significantly more often part of a fatal accident ($p > 0.05$). Instrument-rated pilots were also not significantly more often part of an accident in IMC conditions, χ^2 (1, N = 106) = 0.65, $p \geq 0.05$.

We found a significantly higher number of fatal accidents occurring when it was determined that the pilot intentionally flew into IMC (32 out of 41) compared to inadvertent flights into IMC (7 out of 14), χ^2 (1, N = 55) = 3.98, $p < 0.05$. Interestingly, we did not find evidence of a similar pattern when we examined the proportion of times the investigators determined that "flight into adverse weather" was a circumstance or factor in the resulting accident. The number of fatal accidents when "flight into adverse weather" was listed as a circumstance or factor (12 out of 73) was not significantly different from the number of nonfatal accidents with this term listed as a circumstance or factor (10 out of 36), $p > 0.05$.

Investigators indicated in their reports that pilots were under pressure and in the case of HEMS flights, this pressure was assumed when flights were en route to deliver or pick-up a patient. These accidents yielded a significantly higher number of fatal accidents when the pilot was under pressure (26 out of 32) compared to when the pilot was not reported to be under pressure (47 out of 77), χ^2 (1, N = 109) = 4.17, $p < 0.05$. This result remained significant when HEMS flights were eliminated from the analysis with 9 out of 56 fatal accidents reporting pressure while none reported such pressure for the remaining 30 non-fatal accidents. To account for the fact that the expected cell frequencies were not all greater than or equal to five, we conducted a Fisher's Exact (1, N = 86), $p < 0.05$.

Of the 73 fatal accidents, toxicology analyses revealed inappropriate amounts of drugs and/or alcohol for three pilots. The prescription drugs included doxylamine, hydrocodone, dihydrocodeine, acetaminophen, and hydromorphone. None of the nonfatal accidents reported issues with drugs or alcohol.

3.3. Type of Operation

All broad phases of flight were present in the dataset with the most occurring in the cruise (N = 51), maneuvering (N = 10), and takeoff (N = 11) phases. Those taking off in fog were mostly (8 out of 11) IFR equipped helicopters with IFR-rated pilots. Flights most frequently took place in IMC (N = 85), with VMC (N = 21), and three unknown occurring less frequently.

The selected accidents occurred in Part 91 General Aviation (N = 76), Part 133 Rotorcraft External Load (N = 2), Part 135 Air Taxi & Commuter (N = 36), Part 137 Agricultural (N = 3), one Public Use, and one unknown (see Figure 2). There were more fatal accidents for flights operated under Part 91 (55 out of 76) but this was not significantly higher than for those flying under other Federal Aviation Regulations (FAR) ($p = 0.053$).

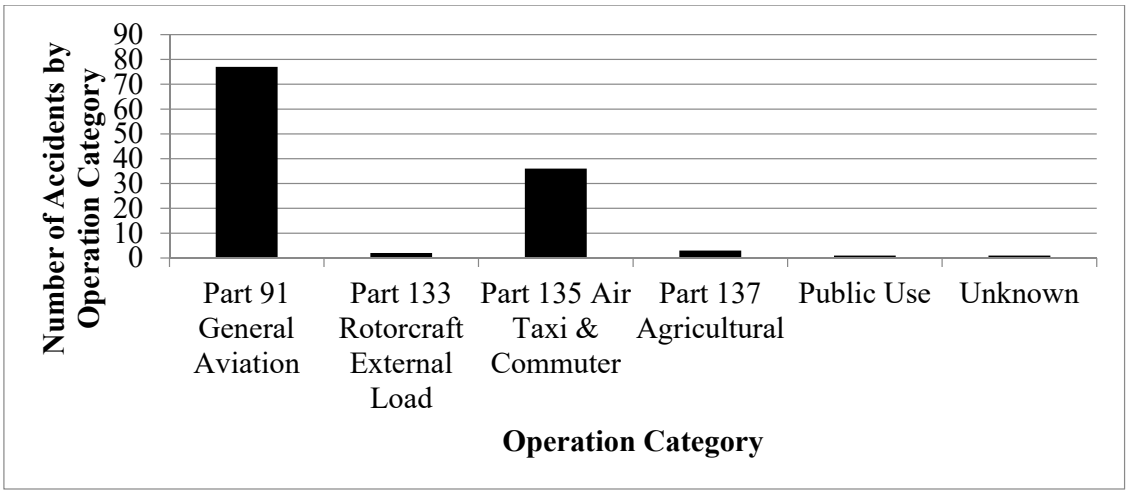

Figure 2. Number of Accidents by Operation Category.

The reports do not consistently mention if flights were conducted under VFR or IFR (see Table 2). There were a few cases where special VFR or temporary IFR are noted; these are situations where the pilot requests an exemption for flying in conditions that would otherwise require an IFR flight plan.

Table 2. Flight rules reported for fog-related helicopter accidents.

Flight Rules	Fatal	Non-Fatal
VFR	38	23
Special VFR	0	2
IFR	3	1
Temporary IFR	4	2
Not reported	28	8

4. Discussion and Conclusions

The high proportion of fatal accidents (67%) in the dataset of fog-related accidents confirms the specific danger of instrument meteorological conditions (IMC) for helicopters. Fog removes the visual spatial orientation necessary to operate the aircraft. Although an instrument-rating makes helicopter pilots familiar with flights using the cockpit instruments only, few helicopters are designed to allow for such IFR flights. Those pilots with an instrument-rating were part of a fatal accident in a similar proportion as non-rated pilots despite the performance improvements suggested in simulations [2].

4.1. Geographical Location

Fog-related accidents were found in a wide range of locations. The specific geographical location may be prone to fog but this was only reported in three cases. There was a relatively high total number of fog-related accidents reported for Alaska and its environment is generally considered more challenging although not specifically for fog [12].

4.2. Pilot Characteristics and Behaviors

Total flight experience, as was reported in a previous study, was not significantly related to more fatalities. Although an instrument-rating makes helicopter pilots familiar with flights using the cockpit instruments only, few helicopters in general aviation are designed to allow for such IFR flights. Those pilots with an instrument-rating were part of a fatal accident in a similar proportion as non-rated pilots despite the performance improvements suggested in simulations [3].

Similar to findings on accidents with fixed-wing aircraft, accidents with helicopters encountering fog had a significantly higher percentage of intentional flights versus inadvertent flights into IMC [5].

These findings confirm a higher prevalence but also add the increased danger of intentional flights into IMC as they were significantly more often involved in fatal accidents.

This study also found that social pressure that was underscored in findings from simulations [5] is also attested in accidents and reported as "under pressure" by NTSB investigators. This pressure is again linked to a higher proportion of fatal accidents.

4.3. Operations

Flights conducted under Part 91 General Aviation were most often reported in the dataset. This confirms the on-going concern in the literature that general aviation accidents have a disproportionate presence in the accident statistics and require particular attention. This may take the form of additional regulations such as the 2014 initiative by the Federal Aviation Administration (FAA) [1] or it could be part of pilots' initial flight training. Despite the higher accident rates reported for HEMS, these flights were not associated more strongly with fatalities when it comes to fog-related accidents.

4.4. Flight Training Recommendations

Helicopter training commonly includes procedures from operation manuals and flight school practices [13]. Pilots are taught to avoid IMC conditions when flying VFR but the circumstances that exacerbate the dangers of flying into IMC are not necessarily known or specified in manuals or flight school curricula. The implications for helicopter training are, therefore, three-fold. First, pilots with an IFR-rating should be cautioned that their training should not encourage VFR flights into IMC, despite their seeming familiarity with the situation. Second, pilots should be made aware that flights into IMC are among the most dangerous in helicopter operations [7,8] and that entering such a situation intentionally further adds to the danger of a fatal accident. Flight training does not include practice flights into IMC that could give students the experience of spatial disorientation, but flight simulators could play a useful role in exposing students to such an experience. Finally, social pressure during decision-making when encountering IMC conditions is a reported danger but again not a common part of initial flight training. Other than using flight simulators, active practice of maneuvers to avoid or exit IMC may condition pilots to follow the correct protocols when encountering IMC for the first time. Social pressure is likely less effective when a pilot is familiar and comfortable with their next course of action.

4.5. Limitations

Data from helicopter aviation accidents rarely contain the decision-making process on the part of the pilot and in fatal accidents much information about the pilot's understanding of the circumstances is often lost. Similarly, "being under pressure" may have been underreported even if it is already striking that pilots have mentioned this as part of the problem. These limitations at least partly hinder our interpretation of the causes of the accidents and frustrate the development of appropriate advice on future regulatory or other types of actions. For instance, it is unclear if pilots prior to their flight were aware or were taking into account the risks of entering into IMC conditions. Furthermore, it is often unclear in fatal accidents what measures were taken to exit IMC conditions and what role external pressures played. A meteorological analysis of individual accidents using surface and upper level sounding charts may provide more detail about the circumstances in which pilots made their decision, particularly in case of fatal accidents [14]. In the absence of such detailed information, it can be surmised that when helicopters fly into fog they generally violated advice or regulations to avoid IMC conditions and entered a situation where accidents are often fatal.

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