SHORT COMMUNICATION

Gyroplane Accidents 1985–2005: Epidemiological Analysis and Pilot Factors in 223 Events

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Introduction: Gyroplanes (autogyros) are regarded as a relatively safe and stable type of general-aviation aircraft. The U.S. Federal Aviation Administration categorizes them as sport pilot/light sport aircraft, and reports of gyroplane accidents are included in a publicly available database. We hypothesized that issues related to pilot experience and aircraft maintenance would affect the severity of accidents as indicated by aircraft damage and fatalities. ***Methods:*** A search of the National Transportation Safety Board database for the period 1985–2005 yielded 223 reports of gyroplane accidents. Information from those reports was compiled and cross-referenced with pilot performance breakdowns and contextual information. The data was then analyzed using the Human Factors Analysis and Classification System. ***Results:*** There was a strong effect of pilot experience on crash outcomes; compared to more experienced pilots, crashes involving pilots with less than 40 flight hours in the same make/model gyroplane were five times more likely to involve loss of control, twice as likely to destroy the aircraft, and four times more likely to involve fatalities. On the other hand, crashes involving pilots with more than 40 make/model hours were more likely to be related to perception-based performance breakdown. Maintenance issues were not found to play a significant role in this sample of crashes. ***Conclusion:*** The results support the hypothesis that pilot experience is a significant predictor of accident fatality in gyroplanes. Training that is adapted to the experience level of pilots as implemented in new FAA regulations for sport pilot and light sport aircraft (2004) may help to reduce the frequency and seriousness of gyroplane accidents.

Keywords: perceptual error, sports, general aviation, flight experience.

IN RESPONSE TO the stall-induced crash of a bomber plane designed for the Spanish military, Juan de la Cierva invented the autogiro in 1919. He designed it to be stall-proof and, introducing the first articulated rotor, it was the first successful rotorcraft in the world. In the United States, these aircraft were called autogyros until the Federal Aviation Administration (FAA) designated them as gyroplanes (1).

Research into accidents in aviation is concentrated on military and commercial aviation. This leaves a fissure in our collective knowledge of aviation accident phenomena, namely in general aviation. While this gap has begun to be filled in recent years, trends in gyroplane aviation remain largely unexplored. The FAA implemented the new sport pilot and light sport aircraft regulations in 2004, creating new certification classes for pilots and aircraft. The FAA intends to make recreational aviation safer with these new regulations, and these changes will undoubtedly affect all areas of general aviation. To fully understand the ramifications such a change in policy can impose on gyroplane aviation, trends before and after the new policy require analysis. To provide a starting point for such research, this study provides an epidemiology of gyroplane accidents from 1985 to 2005 and attempts to establish relationships between the relevant variables. These results provide a benchmark for research conducted after 2004 and perhaps should have been provided prior to the implementation of new regulations.

The Popular Rotorcraft Association conducted a study in 2002 on gyroplane accidents between 1999 and 2002, providing descriptive statistics of 44 accidents (6). They state, "Instructor availability is spread so thinly across the U.S. that normal completion of pilot training or transition is difficult. The result is that enthused students often may not complete the necessary training or experience to be safe pilots." Hasselquist and Baker published a study in 1999 on homebuilt aircraft accidents from 1993 (2). Their study is methodologically similar to this one and applies to amateur-built aircraft, a category to which many gyroplanes belong. Their conclusions emphasize the problems of maintenance and subsequent mechanical failures, a result also found in other parts of sports aviation such as ultralight flights (5). In light of these trends, this study contains epidemiological information, including the most severe accident factors. These are analyzed operationally across variables such as accident type and accident circumstances. "Most severe accident factors" then are those which have the most impact on such accident variables as fatality and aircraft damage.

Previous research on homebuilt aircraft in general and ultralights in specific indicates that the most severe accident factor was pilot experience, having a significant effect on the fatality rate and types of accident involved (2,5). The same research points to aircraft maintenance

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and assembly as significant factors. With such trends emerging in previous research, this project hypothesized that pilot experience, based on flight hours and certification, and aircraft maintenance issues, based on mechanical or nonmechanical types of accidents, are significant factors in fatality and aircraft damage for gyroplane aviation.

METHODS

The data used for this study was extracted from the National Transportation Safety Board (NTSB) online database and includes all accident reports dated from 1985 to 2005 in the "Gyroplane" category (4). NTSB accident reports provide data on pilot, weather, and aircraft; probable cause reports provide an analysis of the accident by a NTSB examiner and include cause(s) and contributing factor(s) of the accident. Queries on the database filtered results by date and aircraft category. The query showed NTSB accident reports on "Gyroplane" category aircraft dated 1 January 1985 to 31 December 2005.

This study analyzes categorical data, manifested in numbers of observations (counts) in different categories, and presents relations between data sets using Pearson's Chi-square (χ^2) method and the standard odds ratio (Ω) (3). The data were analyzed by means of SPSS 12.0 software. Of the 25 variables gathered for this sample of accidents, only the values of pilot age and flight hours were numerical, so that the statistical analysis was largely concerned with categorical data. The assessment consists of total aeronautical experience (flight hours) and make/model-specific flight hours. These data were split into two groups: those with less than 40 (< 40) flying hours and those with 40 or more (40+) flying hours. The grouping was made based on the frequently occurring "private" pilot certificate in the sample ($N = 102$; 45.7% of total) that requires 40 flight hours as a minimum and on previous research that used the same distinction (2,5).

The contextual information provided in the probable cause reports was used to identify active and latent failures. The former result from a direct action by the pilot, while the latter commonly occur before flight and have repercussions that lead to active failures. The framework used here for categorizing these errors is the Human Factors Analysis and Classification System (HFACS) (7). For this study, the HFACS categories "violation" and "error" are treated as one, since it is impossible to tell from an accident report if a violation is routine or exceptional. Wiegmann and Shappell, who created the HFACS framework, also combine these categories in a similar study (8).

RESULTS

A total of 223 accidents have been reported in the United States between 1985 and 2005. There were 92 (41.3%) of them that resulted in at least 1 fatality. The number of accidents per year has two low points across time: the first is between 1980 and 1984 with one accident in 1980 and none between 1981 and 1984. Starting in 1985, the number of accidents per year is around 12. In 1995, there is a second low point with only three accidents. The 2 yr following each had five accidents. In 1998, the level returned to around 13 accidents per year. Homebuilt gyroplanes make up the bulk of the sample ($N = 194$; 87.0%), and most are certified as either Experimental (Special) ($N = 156$; 70.0%) or a mix of Experimental and another category ($N = 5$; 2.0%). The aircraft involved were either substantially damaged ($N = 146$; 65.5%) or destroyed ($N = 75$; 33.6%). One aircraft (0.4%) sustained no damage, and one (0.4%) had only minor damage reported. **Table I** provides an overview of the following results.

Of the 223 pilots, only 206 (92.4%) are reported with specific information on experience. Most pilots had a private pilot certification ($N = 102$; 45.7%), while others were certified as either a student ($N = 41$; 18.4%), commercial ($N = 29$; 13.0%), airline transport ($N = 25$; 11.2%), or U.S. military ($N = 1$; 0.4%). Some pilots ($N = 25$; 11.2%) did not possess any FAA certification. Make/model flight hours ranged from 0 to 4000 with a mean of 100.3, and total flight hours ranged from 0 to 30,000 with a mean of 2395 h. Most of the pilots, however, had not yet accumulated 40 make/model flight hours ($N = 131$, 58.7%). Pilots with less than 40 total flight hours comprised 12.1% ($N = 27$) of the sample, while 179 of the pilots (80.3) had at least 40 h.

The pilots with less than 40 make/model flight hours were over four times as likely to be involved in fatal accidents as pilots with at least 40 make/model hours ($\chi^2 = 21.09$; $P < 0.001$; df = 1; $\Omega = 4.56$). The 40-h cutoff for total flight hours, on the other hand, was not significantly related to fatal accidents ($\chi^2 = 3.43$; $P = 0.64$; df = 1). Instead, they were both significantly more likely to lead to the destruction of the aircraft ($\chi^2 = 9.69$; $P < 0.005$;

TABLE I. SIGNIFICANT ACCIDENT FACTORS IN 223 GYROPLANE ACCIDENTS.

		Significant Accident Factors				
Variable		***N* Fatal Cases**	***N* Non-Fatal Cases**	χ^2	**df**	**p**
Make/Model Flight Hours	Less than 40	67	64	21.09	1	< 0.001
	40 or more	14	61			
Certification	Not Certified	15	10	4.08	1	< 0.05
	Certified	77	121			
Accident Cause	Mechanical	12	33	4.95	1	< 0.05
	Non-Mechanical	80	98			

df = 1; Ω = 2.87) (χ^2 = 5.60; $P < 0.05$; df = 1; Ω = 2.63). Along the same lines, pilots with no certification were also significantly more likely to be involved with fatality (χ^2 = 4.08; $P < 0.05$; df = 1; Ω = 2.34) and aircraft destruction (χ^2 = 4.26; $P < 0.05$; df = 1; Ω = 2.35).

Up to two latent failures were identified in each accident. The most common first latent failures fall into 3 categories, namely physical/mental limitations (N = 51; 22.9%), technological environment (N = 47; 21.1%), and physical environment (N = 39; 17.5%). Most accident reports (N = 160; 71.7%) show only 1 latent failure or none at all. Accidents associated with first latent failures falling in the physical/mental limitation category as opposed to other categories were more likely to have a fatal end (χ^2 = 15.00; $P < 0.001$; df = 1; Ω = 3.66). Accidents associated with latent failures in the physical/mental limitation category were significantly linked to destroyed aircraft (χ^2 = 5.34; $P < 0.05$; df = 1; Ω = 2.12).

Active breakdowns in pilot performance were reported in 163 accidents (73.1%) in total. Such accidents can be associated with multiple errors. The majority of these errors belong to skill-based errors, which comprises 172 errors. There were 137 (61.4%) accidents associated with skill-based errors, 32 (14.3%) with decision-based errors, 19 (8.5%) with perception-based errors, and 10 accidents (4.5%) associated with violations.

In this sample 7 types of causes are reported, of which the most prevalent is loss of control (117; 52.5%), followed by engine failure (N = 27; 12.1%) and rotor strike on the same aircraft (N = 27; 12.1%). Other types are structural failure (N = 18; 8.1), collision with nonaircraft objects (N = 15; 6.7%), rotor strike on other objects (N = 15; 6.7%), and collision with other aircraft (N = 3; 1.3%). One accident's cause was unknown (0.4%) because the aircraft's wreckage was not found until years after the accident. Accident reports categorized as loss of control had no reported mechanical factors. The relationship between the nature of accident causes (mechanical vs. nonmechanical) and accident fatality is significant (χ^2 = 4.95; $P < 0.05$; df = 1; Ω = 2.24). That is, accidents associated with at least one fatality were 2.24 times more likely to have been nonmechanical in nature than mechanical.

In addition, two accident circumstances particular to gyroplane flight were significant, namely rotor strike on the same aircraft and oscillation occurrence. Rotor strike is a significant predictor of fatality in this sample (χ^2 = 24.46; $P < 0.001$; df = 1; Ω = 10.65), and of aircraft destruction (χ^2 = 11.84; $P < 0.005$; df = 1; Ω = 4.05). Oscillation was likewise significantly tied to fatality (χ^2 = 27.88; $P < 0.001$; df = 1; Ω = 36.36) and aircraft destruction (χ^2 = 18.81; $P < 0.001$; df = 1; Ω = 7.80).

DISCUSSION

It is concluded that mechanical accident types are significantly less likely to have caused fatalities than nonmechanical ones. This, along with the extensive relationship between pilot behavior and both fatality and aircraft damage, contradicts the proffered hypothesis that mechanical issues are significant accident factors for gyroplanes.

The data support the hypothesis that pilot experience is a significant accident factor. Three coinciding trends are prevalent in this sample, indicated by frequencies. Over half of the accidents fall into the "loss of control" category, the most prevalent category of latent failures is "physical/mental limitation," and most of the breakdowns in pilot performance are skill-based. These trends coincide insofar as all three are indicative of pilot behavior. Similarly, the most severe accident trends, discriminated based on their statistical relationships with accident fatality and/or aircraft destruction, are also pilot-related. Pilot experience shares a statistical tie with fatality and destruction in this sample, as pilots with less than 40 make/model flight hours were significantly more likely to be involved with a fatality and destroy their aircraft than more experienced pilots. It is supposed that pilots do not typically fly with less than 40 h because that is the cutoff for having a private pilot license, but this trend applies to make/model flight hours, not to total hours. Instead, the majority of pilots had less than 40 make/model hours at the time of their accidents.

In sum, pilot experience and certification are significant predictors of accident fatality and aircraft damage in gyroplane aviation. Gyroplane maintenance issues, however, are not. It is these findings that should be central in assessing the consequences of the FAA's sport pilot and light sport aircraft regulations. In either case, it is hoped that more effective accident prevention measures may ensue.

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