Analysis of 2004 German General Aviation Aircraft Accidents According to the HFACS Model

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Introduction: The number of aircraft accidents remains on a constant level since the late 1990s. Routine analysis in detail of the causative factors is not carried out in Germany. The analysis of flight mishaps has been demonstrated to be an important basis for flight safety. The Human Factors Analysis and Classification System (HFACS) model is best suitable for aircraft accident analysis. The aim of this study was to classify aircraft accidents in the General Aviation (GA) of Germany according to the HFACS model and to figure out the underlying causes.

Material and Methods: The analysis was performed with the HFACS model and on the basis of the regularly published reports of the German state department for aircraft accident analysis (BFU) including accidents (but not incidents) of GA aircraft flown by German pilots in Germany and in other countries. The underlying reasons were classified as follows: pilot errors, organizational factors, ergonomic factors, aeromedical problems, and crew resource management. Additionally, the phase of the flight was classified.

Results: Two hundred thirty-nine GA aircraft accidents were registered in 2004 in Germany. Eighty-seven (36%) were reported in the class up to 2 tons, six (3%) in the class of 2.0 to 5.7 tons, 28 (12%) for Touring Motor Gliders (TMG), and 118 (49%) for gliders. Of these accidents, 54 (35 crewmembers and 19 passengers) aircraft occupants survived slightly injured, 35 (23 crewmembers and 12 passengers) were seriously injured, and 34 (21 crewmembers and 13 passengers) were killed. Data for uninjured aircraft occupants were not available. Most accidents happened on summer weekends during approach and landing (53%) due to pilot errors (84%).

Conclusions: Our data mainly seem to be in concordance with previously published data on GA. An improvement of flight safety can be achieved only with a detailed analysis of the accident data. Therefore, more data on aircraft accidents in Germany are needed, for example, by adapting the German aircraft accident report form. Pilots should train in approaches and landings to conduct a higher level of proficiency.

Introduction

In General Aviation (GA) as well as in other aviation areas, human error and aircraft mishaps (incidents and accidents) have a strong correlation. Previous investigations revealed that human error causes or contributes to more than half of all aviation mishaps each year and is associated with up to 75% of all accidents.[1,2]

For nearly all countries, the number of aircraft accidents has remained at a constant level since the early 1990s (Fig. 1). Each year approximately 250 to 300 accidents occur in Germany; among these 30 to 50 fatalities have resulted.[3,4] However, understanding and preventing pilot error remains the foremost challenge in aviation safety.[5]

Although a systematic accident investigation and analysis is routinely performed in Germany for scheduled air service (eg, airline aviation) by the federal state department for aircraft accident analysis (*Bundesstelle fuer Flugunfalluntersuchung*, BFU), a detailed investigation of causing factors is not carried out for nonscheduled air service (GA, privately owned business, or nonscheduled commercial aviation). In these, a detailed investigation is performed for fatal accidents only. For all

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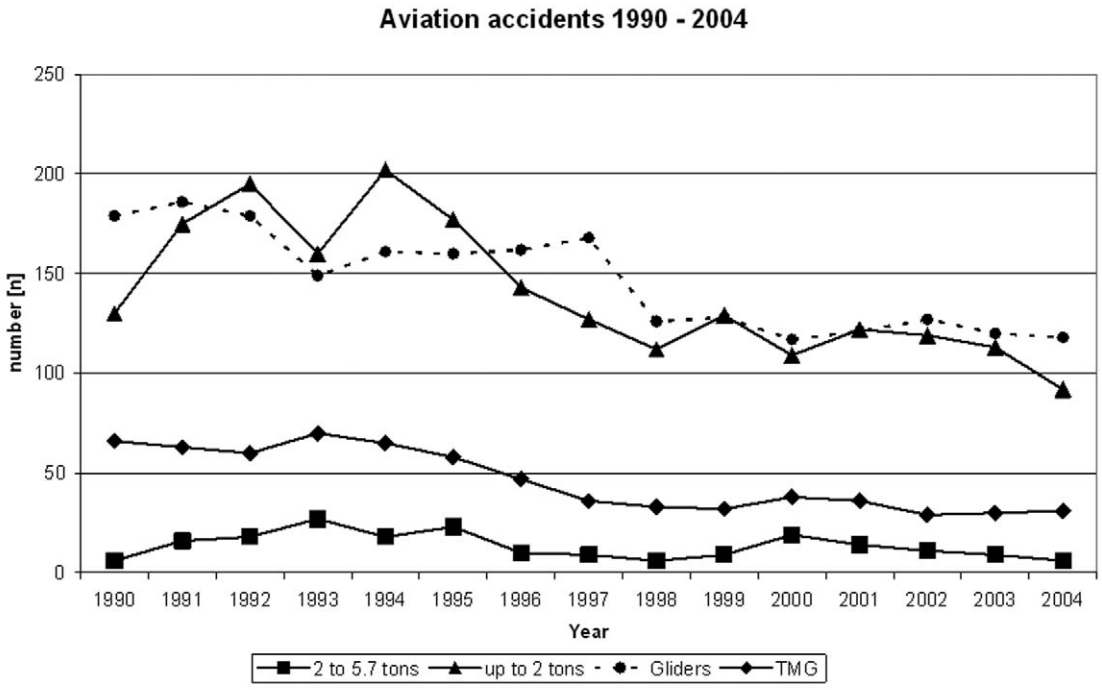
Fig. 1. Number of aircraft accidents between the years 1990 and 2004 depending on the Maximum Take-off Mass (MTOM) and aircraft category, respectively.



nonfatal accidents, simply brief reports (publicly accessible via the Internet) were published each year without a detailed analysis.[3]

To improve safety and to reduce the number of incidents, a detailed analysis of flight circumstances is an important basis and essential to identify the underlying factors leading to accidents. The Human Factors Analysis and Classification System (HFACS) is a general human error framework originally developed as a tool for investigating and analyzing the human causes of aviation accidents.[6,7] In previous investigations, the HFACS framework was demonstrated to be a viable tool for use within civil aviation.[7]

The aim of this study was to classify aircraft accidents (fatal and nonfatal) in GA caused by German pilots with German aircrafts in Germany or other countries according to the HFACS model and to figure out the contributing and causative factors for the year 2004. Besides pilot characteristics, crash circumstances also were analyzed.

Materials and Methods

Study design

A retrospective review of safety data published by the *Bundesstelle fuer Flugunfalluntersuchung* in the monthly published aircraft accident bulletin was carried out for accidents that occurred between January 1 and December 31, 2004, caused by German pilots within and outside Germany involving German GA aircrafts. These brief reports were published regularly via the internet and were retrieved on the publicly accessible BFU homepage.[3] In this investigation, only accidents but not incidents were analyzed by two subject matter experts independently.

Definitions

Definitions of "accident" and "incident" were retrieved from the FAR part 830.2[8]: Aircraft accident means an occurrence associated with the operation of an aircraft that takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage. Incident means an occurrence other than an accident, associated with the operation of an aircraft, that affects or could affect the safety of operations.

Serious injury means any injury that (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burns affecting more than 5% of the body surface. Slightly injured means all injuries other than serious injuries.

Accident characteristics

For each aircraft group (single- and multi-engine less than 2 tons, 2 to 5.7 tons, touring motor gliders/TMG, and gliders), the analysis was performed regarding the phase of flight (take-off/departure, in-flight/cruise, and approach/landing). Gliders with a supplemental engine were analyzed in the glider class.

Type of flight

Each accident was assigned to one of the following categories: private flights/scenic flights, training or check

Fig. 2. Proportion in percentage of accidents depending on the phase of flight.

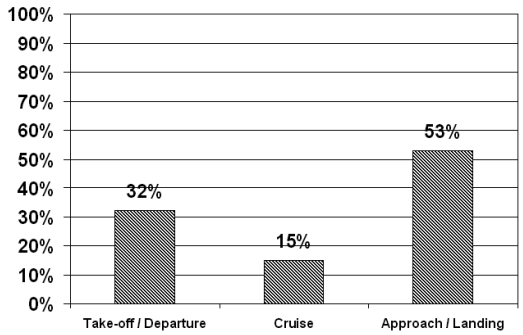


Fig. 3. Primary (most important) causes for aircraft mishaps categorized with the HFACS model. Data in percentages do not add up to 100% because accidents were classified into more than one category to get an overview of all contributing factors for an accident.

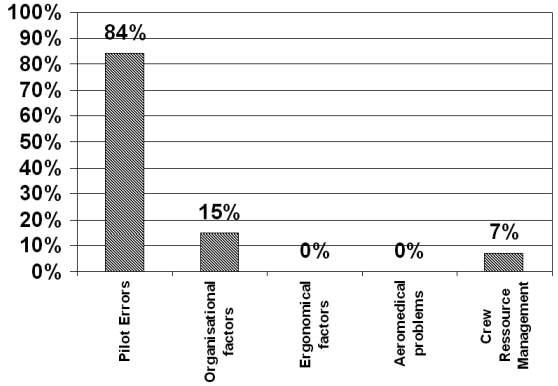
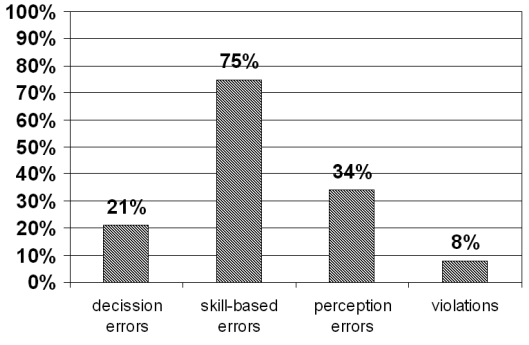


Fig. 4. Results of the detailed analysis of pilot errors. Data in percentages do not add up to 100% because accidents were classified into more than one category to get an overview of all contributing factors for an accident.



flights, glider towing, commercial flights, acrobatic flights, demonstration flights, transfer flights, and test flights.

Season

A descriptive data analysis was performed to analyze accidents depending on the season. Analysis was performed for the summer period (March to October) and winter periods (January to February and November to December), respectively.

Injury patterns

To analyze injuries of persons involved in aircraft accidents, the total number of persons inside the aircraft was recorded. Occupants were assigned to aircraft crew and passengers. The severity of the injuries was classified as fatal, severely injured, or slightly injured.

HFACS analysis

The HFACS framework was used to determine human error associated with aircrew-related general aviation accidents that occurred during the analyzed period.[6] The underlying reasons of the mishaps were classified according to the HFACS model and categorized as pilot errors, organizational factors, ergonomic factors, aeromedical problems, and crew resource management problems (ie, primary or most important causes). Pilot error was further divided into decision errors, skill-based errors (proficiency), perception errors, and violations.

Accidents were classified into more than one category, if appropriate, to get an overview of all contributing factors of an accident.

Statistical data analysis

Statistical analysis was performed with STATISTICA (StatSoft GmbH, Germany). The chi-squared test was used to prove significance for dichotomized parameters. $P < .05$ was considered statistically significant.

Results

Data acquisition

Published data from the *Bundesstelle fuer Flugunfalluntersuchung* in Germany was retrospectively analyzed for the period between January 1 and December 31, 2004 to perform this study. A total of 239 reports for GA accidents of German pilots and airplanes within and outside Germany were identified in the database and analyzed further.

Descriptive accident data

In 2004, 196 (82%) accidents occurred within Germany and 43 (18%) outside Germany. Altogether 118 (49.5%) mishaps were reported in the glider class, 87 (36%) for the aircrafts up to 2 tons maximum take-off mass (MTOM), 28 (12%) in the TMG class, and six (2.5%) in the class with an MTOM of 2.0 to 5.7 tons (Fig. 1). Regarding the phase of flight, most accidents happened during approach and landing (n = 125; 53%). During takeoff and departure (n = 76; 32%) as well as during cruise (n = 35; 15%), fewer accidents were reported (Fig. 2).

Type of flight

Accidents occurred most often in private flights or scenic flights (n=173; 72%) and less often in training or check flights (n = 41; 17%), glider towing (n = 10; 4%), commercial or acrobatic flights (each n = 6; 3%), as well as demonstration, transfer, and test flights (each n = 1; 0.4%).

Time-related analysis

The number of mishaps showed a strong relationship to the season: during the flying season from April to September 2004, (i.e., 6 months), 208 (87%) aircraft accidents were reported. Only 31 (13%) were registered during the winter, from October to March.

The mean number of accidents (mean, 27 accidents per day) on weekdays (n = 135 for the period Monday to Friday, i.e., 5 days) was less than the mean number of accidents (mean, 56 accidents per day) on weekends (n = 104 for Saturday and Sunday, i.e., 2 days).

Injury severity

In these 239 accidents, 21 pilots were killed, 23 severely injured, and 35 slightly injured. In six accidents, 13 passengers died, and in seven accidents 12 passengers were severely injured. For most of the 15 accidents, 19 passengers survived slightly injured. Only six other persons were involved in aircraft accidents: two were killed, one severely injured, and three of them slightly injured.

HFACS analysis

Pilot errors (n = 201; 84%) were most often reported as underlying factors leading to the mishap, mainly during the preparation of approach and landing (Fig. 3). Aircrafts were reported to overshoot the runway, landed too hard, or diverted off the runway during landing, for example, because of strong crosswind. Pilot error was additionally subdivided into the categories skill-based errors (i.e., proficiency, n = 179; 75%), perception errors (n = 81; 34%), decision errors (n = 51; 21%), and violations (n = 18; 8%) (Fig. 4).

In-cruise flight accidents were mainly caused by technical problems in the class up to 2 tons and due to in-air crashes in the glider class.

Organizational factors as causes for the mishaps were raised to 15% (n = 35) of all reports analyzed. Several problems occurred in the organization of the aero clubs. Some accidents happened because of insufficient maintenance of the aircraft, missing aircraft parts, or rechecking correct branch connections in the ailerons of the gliders, which were assembled the first part of the day. Other accidents happened in solo flights of student pilots.

Accidents related to problems in crew resource management (CRM) were reported less often (n = 16; 7%). The problems occurred during instruction flights because of a wrong or missing intervention of the flight instructor in critical situations.

Aeromedical issues were not reported in Germany for 2004 in association with aircraft accidents (n = 0).

Ergonomic factors could not be analyzed because of missing data and the unavailability of the aircrafts that were involved in the accidents.

Discussion

In GA as well as in other aviation areas, human error, aircraft incidents, and aircraft accidents have a strong relationship. Previous investigations revealed that human error causes or contributes to considerably more than half of all aviation mishaps each year and is associated with approximately 75% of all accidents.[1,2]

Although a systematic accident investigation and analysis is performed for scheduled air service (commercial and airline aviation), for GA and non-scheduled air service (e.g., Business Aviation), a detailed investigation of underlying factors is not carried out, except for fatal accidents.

We performed a retrospective analysis of the published reports of the German state department for aircraft accident analysis (BFU) for the year 2004. Unfortunately, most reports gave no detailed information about the accident circumstances or performance analysis and showed only the categorized underlying problems (pilot errors, organizational factors, ergonomics, aeromedical issues, and crew resource management).

In this investigation, 239 accidents were identified and analyzed in the mentioned period. Most accidents were reported for gliders and smaller aircrafts with less than two tons maximum takeoff weight. Mishaps for TMG and larger aircraft (2–5.7 tons) were reported less often, probably because of the smaller number of flight activities. Concerning the phase of the flight, we found that approach and landing (53%) had the strongest relationship to aircraft mishaps. In our investigation, landing accidents had the highest proportion.

Additionally, the number of mishaps showed a strong relationship to the season: 87% of all accidents were reported from April to September. Sokol et al. reported for the Czech Republic that most civil aviation accidents occurred during April to September, without giving any specific data.[9]

HFACS analysis

The Human Factors Analysis and Classification System (HFACS) is a general human error framework originally developed as a tool for investigating and analyzing the human causes of aviation accidents.[6,7] HFACS is based on Reasons´ model of failures and addresses human error at all levels of the system, including the condition of aircrew and organizational factors.[7,10,11] In previous investigations the HFACS framework has been shown to be a viable tool in civil aviation.[7]

Throughout the world, human error causes or contributes to considerably more than half of all aviation mishaps.[1] We found pilot errors (84%) to be reported most often as the underlying problem leading to accidents, mainly during approach and landing. Other authors reported a similar incidence of pilot errors causing aircraft mishaps. Within published literature the factor of human error still accounts for approximately 75% of all accidents.[2]

In this study, skill-based errors (75%) and perception errors (34%) were most involved in accidents compared with decision errors and violations. In accordance with our data, Gaur reported skill-based errors as well, followed by decision errors, to be the most common in civil

aircraft accidents in India.[12] Li and co-workers found that pilot error was a probable cause in 85% of the GA and 74% of the commuter/air taxi crashes and stated a similar frequency to that in our study.[5]

Organizational factors (15%) and crew resource management problems (7%) were found in our investigation to have only a minor relevance for GA accidents. Gaur found that a fairly large number (52%) of aircraft accidents had organizational influences contributing to the accident.[12] The reason for this discrepancy remains unclear, but it might be attributable to different data recording methods in our countries.[5]

Aeromedical issues were not reported for 2004 in Germany in association with aircraft accidents and therefore seem to have only minor relevance or might be underreported. Accidents due to ergonomic problems were not able to be classified because there was no access to the crashed aircrafts, and detailed information was not provided by the BFU reports.

To improve safety and to reduce the number of accidents, the analysis of flight circumstances is an important basis and essential to identify the causing factors leading to the mishaps. We found pilot errors—mainly due to bad pilot proficiency (75%)—as well as accidents during approach and landing to have the highest importance for GA in Germany.

In general, our data seem to be in concordance with previously published data and larger studies concerning aircraft accidents and HFACS in GA in the United States.

Limitations

This investigation was not able to be carried out exactly as required by HFACS. We used and analyzed data from previously published accident reports from the official BFU homepage, but not the handwritten primary reports of the BFU personnel. An analysis according to HFACS requires the analysis of primary unpublished data. Unfortunately these detailed data (hand-written reports) are not available for Germany.

Mishaps due to ergonomic problems were not able to be classified because there was no access to the crashed aircrafts, and detailed information was not provided by the published reports.

Conclusions

Our data mainly seem to be in concordance with previously published data on GA. An improvement of flight safety can be achieved with a detailed analysis of the accident data. Therefore, acquiring more data regarding aircraft accidents in Germany is necessary, for example, by adapting the German aircraft accident reporting form. HFACS is a valuable tool to analyze aviation accidents. Most accidents occurred with light GA aircrafts on summer weekends, especially during approaches and landings.

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