APPLICATION OF THE KNOWLEDGE GAINED FROM THE ACCIDENTS INTO THE TRAINING PROCESS

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This article describes and analyzes the impact of the main meteorological factors of aviation accidents and incidents in various phases of a typical transport flight and the various operating rules. Specifically addresses the issue of comparison of selected theoretical and practical syllabus of both basic and ongoing flight training together with regulatory requirements of analyzed data on incidents. Identifies the reserves of assessed syllabus and proposes a methodology for their removal.

K e y w o r d s: aviation accident and incident, meteorological factors, phases of transport flight, operating rules, flight training, flight training syllabus.

1 INTRODUCTION

Aviation is developing day by day and therefore its growth also requires increasingly better-trained crew, especially pilots. Pilot profession is very interesting, but also difficult, because he must be carefully prepared in each domain, and one of them is the aviation meteorology.

After all unequivocal statistic results, air travel causes psychological problems for many people. A simple explanation is that aviation accidents attract a considerable publicity. Despite its relative rarity compared to other modes of transport accidents, because they have very vast consequences.

My ambition is to show what a danger can be bad weather during flight, i.e. during different phases typical for the flight, despite the fact that air travel is considered one of the safest modes of transport.

2 OBJECTIVES AND METHODOLOGY

In this thesis, I have identified a number of sub- and main objectives, each of these will briefly analyzed in this article:

1. Processing of information on the main causes of aviation accidents and incidents
2. Identifying and defining the main meteorological factors having the greatest effect possible on air transportation
3. Analysis of meteorological factors of aviation accidents and incidents in various phases of a typical transport flight
4. Analysis of meteorological factors of aviation accidents and incidents by categories of operating rules
5. Zoom-in of basic flight training of pilots and its syllabus
6. Analysis of theoretical and practical pilot training syllabus, due to the main meteorological factors and the possibility of coping
7. Identifying the reserves of assessed syllabus and designing the methodology for their removal

To obtain the necessary information, it had to be taken from various publications, i.e. Slovak, Czech and English.

On the evaluation and interpretation of the results, the article uses the method of analysing dangerous meteorological factors in several ways, such as according to transport phases of flight and type of flight operation rules. The results of the analysis are applied to the actual theoretical and practical syllabus of pilot training.

All informations obtained from the analysis are evaluated using graphs and tables. After finding potential weaknesses, a methodology for their removal or improvement can be proposed.

3 ANALYSIS

For the analysis, I acquire the needed information above all from the document Weather - Related Aviation Accident Study 2003-2007 and from the Syllabus of theoretical knowledge and flight instruction for the private pilot licence (aeroplane) PPL (A).

3.1 The main causes of aviation accidents & incidents

The first objective was to process the data on the main causes of aviation accidents and incidents in order to confirm the fact that **negative weather during different phases of flight** is really one of the main causes of these accidents. In addition to meteorological factors, other typical causes of the most serious, of 80 identified, are human error, technical cause and a terrorist attack. It is also necessary to distinguish an accident caused by weather or pilot, where to the accident contributed meteorological factor.

3.2 The main meteorological factors

The main weather factors that are most affecting aviation safety are: wind (1149), visibility or ceiling (402), high density altitude (102), turbulence (114), icing (64) and carburettor icing

conditions (86), precipitation (81), updraft and downdraft (81), thunderstorms (42), windshear (37), thermal lift (20), temperature extremes (13) and lightning (4), which occurred in different numbers.

***(...)** - number of meteorological factors

3.3 Analysis of meteorological factors of aviation accidents and incidents in individual phases of flight

Starting document for this analysis is the already mentioned Weather - Related Aviation Accident Study 2003-2007. This study is the subject of numerous researches. The result shows the aviation accidents in terms of meteorological factors, which was released in 2010. This study processes the National Transportation Safety Board NTSB. It's actually a Department of investigation of the causes of aviation accidents in the United States, which falls under the Federal Aviation Administration - FAA.

During this period, there were 8,657 aviation accidents, where the weather was the cause or a contributing factor in **1740** accidents, but meteorological factors occurred **2223** times, with one accident affected or caused by a number of factors.

The main phases of flight by transport studies include: standing, taxiing, take-off, climb, cruise, descent, approach and missed approach, landing, maneuvering of aircraft, hovering (typical for helicopters), emergency descent or landing and emergency landing after take-off (Fig.1).

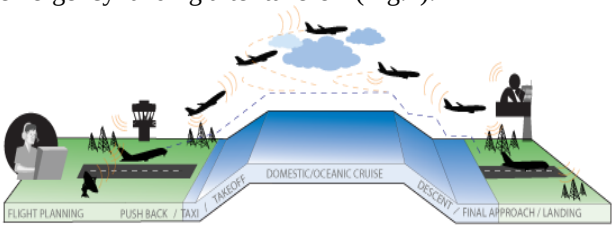

Fig. 1 Phase of transport flight

The analysis of meteorological factors of aviation accidents and incidents in various phases of flight indicates that the most dangerous and frequently occurring meteorological factor is **wind** and the least dangerous is **lightning** that occurred only a few times.

It can also be noted that the most dangerous phase of flight is **landing**. The overall ranking of the hazards and occurrence of meteorological elements and phenomena in various phases of transport flight is such:

1. Landing (743/wind)
2. Take-off (368/ wind)
3. Cruise (332/visibility)
4. Approach (263/visibility)
5. Maneuvering (186/visibility)
6. Missed approach (78/ wind)
7. Descent (73/turbulence)
8. Climb (46/visibility)
9. Taxi (38/wind)
10. Hover (26/wind)
11. Standing (22/wind)
12. Emergency descent/landing (21/wind)
13. Emergency landing (9/wind)
14. Unknown (4/wind)
15. Emergency landig after take-off (3/visibility)
16. Other (1/visibility)

***(../..)** - number of meteorological factors / most frequent factor in a particular phase of flight

From the results of the analysis can be calculated the **density of the time** to better illustrate the danger of eight most essential phases of flight traffic. First you need to determine how much % roughly represents the given phases of the total flight time of a particular flight.

Temporal density is obtained by dividing the number of aircraft accidents and duration of phases in %. For example, the density of the time to compute the take-off is calculated as: 368/0,02 = 18400 (Tab.1).

$$Temporal\ density = \frac{Aviation\ accidents\ (number)}{The\ duration\ of\ phase\ (\%)}$$

Tab. 1 Temporal density of transport flight phases

Phase of flight	The duration of phases in %	Number of aviation accidents	Temporal density
Standing	17	22	129
Taxi	3	38	1266
Take-off	2	368	18400
Climb	7	46	657
Cruise	61	332	544
Descent	7	73	1043
Approach	2	263	13150
Landing	1	743	74300

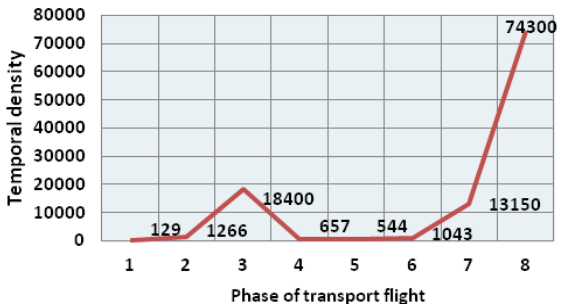

Fig. 2 Temporal density of transport flight phases

From the graph (Fig.2), it can be seen that the first two phases, i.e. **1** - standing on the apron and **2** -

taxiing due to unfavorable meteorological factors and their duration, are not dangerous phases. In contrast, the following third stage **3** - take-off, which is the second most dangerous maneuver. Phase number **4** - climb, falls back almost to the level of standing and taxiing. This is followed by phase **5** - cruise at the flight level, which, although one of the more dangerous phases in view of the weather, but with regard to its duration, an average of 3 to 3 and a half hours, this phase is very safe. The next phases as **6** - descent, **7** - approach and **8** - landing, are much shorter in duration than the cruise itself, and according to the order they follow each other, increases also the danger. The graph also shows that the landing is the most difficult and dangerous phase of flight, in all respects. It should be noted that a high time (temporal) density, for example during landing, may be beyond the skills of the crew, because everything is happening very quickly and it is necessary to do many things at once in a short time. Right here, often a fatal mistake is made.

3.4 Analysis of meteorological factors of aviation accidents and incidents by category of operating rules

Analysis of weather - related accidents can be processed not only by the different phases of flight, but also by category of operating rules, which include pilot qualifications. This operation is divided into four parts:

91 - General aviation operations
121 - Domestic, flag, supplemental air carrier operations
135 - Commuter and on-demand operations
137 - Agricultural aircraft operations

Results of analysis confirm that in part 91 had the highest number of weather - related accidents, accounting for 88%. Part 135 accounted for 5% of weather - related accidents, while parts 121 and 137 accounted for less than 4% each of accidents studied (Fig.3).

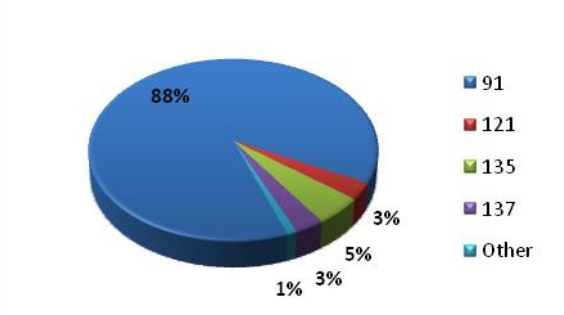

Fig. 3 Number of weather-related accidents by operation

Based on the results, it can also be said that the final ranking of hazards and occurrence of meteorological factors in different categories of operating rules is as follows:

1. General aviation operations (1960/wind)
2. Domestic, flag and supplemental air carrier operations (128/turbulence)
3. Commuter and on-demand operations (64/visibility)
4. Agricultural aircraft operations (48/wind)

***(../..)** - number of meteorological factors /most frequent factor in the particular operation

In terms of the presence of meteorological factors in all categories are the most dangerous **wind** and the least dangerous **lightning**, as well as during phases of flight.

3.4.1 Pilot qualifications

For this issue and article pilot qualifications and assessments, held by the pilot or pilots who may be a contributing factor to the accident, are relevant.

The experience of the pilot or pilots may also correlate to accident rates. Data analysis shows that private pilots who have accumulated a minimal number of flight hours without an instrument rating had the most number of weather-related accidents. The accident rate as a function of total flight time increases as the pilot accrues time, and subsequently declines.

The probability of having weather - related accident peaks for private pilots at approximately **175** to **225** hours of total flight time.

Accident probability for commercial pilots peaks at approximately **700** to **1200** hours total flight time (Fig.4).

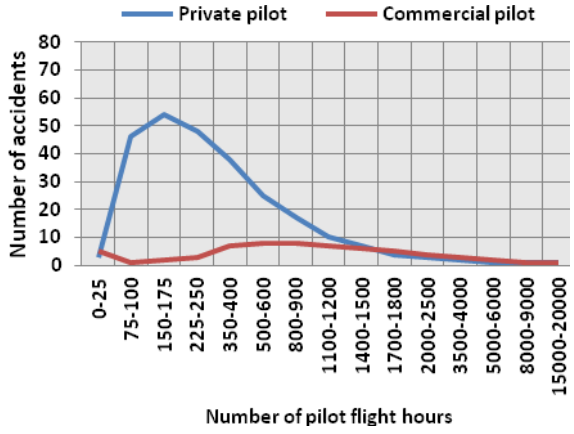

Fig. 4 Accident rate as a function of pilot flight time

3.4.2. Analysis of a selected aviation accident

This analysis confirms all the previously found information, i.e. the most dangerous phase - **landing**, the most dangerous weather - related factor - **wind**, the most dangerous category of operation - **general aviation**, the greatest number of accidents - **private pilots**.

Pilot qualification: the pilot in command of general aviation held a private pilot certificate without instrument rating with 74 hours of total flight time, 5 flight hours in make and model, and 7 flight hours in the past 90 days at the time of the accident. His experience was at the lower end of the scale.

Accident synopsis: the pilot, who was landing in gusty **crosswinds**, had already made one **landing** and was on the landing roll of his second when he encountered crosswinds that lifted the aircraft's left wing in the air. At the same time as the wing was being lifted, the aircraft started drifting toward the right side of the runway. As the pilot attempted to get the wing down using aileron deflection and tried to get the aircraft heading straight down the runway, it felt to him like the aircraft was going to cartwheel. He therefore decided to let the aircraft go off the side of the runway in the direction it was headed. After departing the runway, the aircraft encountered soft terrain, whereupon the nose gear dug in and the aircraft nosed over. According to the pilot, except for a minor nose wheel shimmy, there did not seem to be any problems with the aircraft's controls.

Probable cause: the probable cause of the accident was the pilot's inadequate compensation for wind conditions and his failure to maintain directional control during the landing roll. Factors include gusty crosswinds and soft terrain in the area where the aircraft departed the side of the runway.

3.5 Basic flight training

Another important step is to compare the selected curriculum = syllabus of basic and continued training with regulatory requirements with analyzed data on incidents from the previous section. Also identify the reserves of assessed syllabus and propose a methodology for their removal.

3.5.1 Syllabus PPL(A) - practical

Basic flight training PPL(A) - private pilot can be in terms of the JAR-FCL1, within 45 flight hours in general, divided into two phases: **Technique of pilotage (piloting)** and **Navigation.**

Tab. 2 Total overview of flights and hours

		Technique of pilotage	**Navigation**	**SUM**
Dual	Flights	97	17	114
	Hrs.	21:05	13:05	34:10
Solo	Flights	32	7	39
	Hrs.	5:10	5:40	10:50
SUM	Flights	129	24	**153**
	Hrs.	26:15	18:45	**45:00**

The basic and continuing syllabus for student-pilots and pilots are the basic documents which define the objectives, content and sequence of the whole training, safety and **weather conditions** for each exercise.

Syllabus of practical training PPL(A) shall include:

- procedures before flight, take-off weight determination, determining the center of gravity, inspection and maintenance of the aircraft before flight
- airport flights and circuit flights, procedures to prevent aircraft collisions
- operating an aircraft under visual references
- flights in critical low speeds, recognition and prevention of crash, collecting aircraft from full-out fall
- flights in critical high speed, pattern recognition and alignment of the aircraft from flight spiral
- normal take-offs and landings, **crosswind take-offs and landings**
- use of maximum performance of aircraft, landing on short runways
- instrument flight rules (in simulated conditions IFR), including full horizontal turn at 180 °
- overflights using comparative navigation (visual reference), navigation by calculation and navigation using navigation devices
- emergency procedures, including simulated engine errors
- flights from controlled aerodrome and control zone overflights with Air traffic services compliance procedures, procedures for communication A/G (air/ground) and prescribed phraseology

Practical training is focused from the various meteorological elements and phenomena, only on wind, especially the **elimination/bypassing of crosswind**. The exercises are devoted also because the wind is already proven as the most dangerous element under study that has caused many accidents.

The point of practice is to teach student to eliminate/bypass crosswind at:

- takeoff
- climb

- circling
- calculation of landing
- landing

Terms of exercises:
- flight implementation on the circuit during good visibility of the natural horizon and ground reference points
- number of flights: **6**
- hours: **0:35**
- altitude: 300 m - 1000 ft AGL

Weather conditions:
- ceiling: at least 500 m
- visibility: at least 5km

Guidelines: flight instructor shows a student way of bypassing/eliminating crosswinds on circuit with course method and the landing with course - crab method and sideslip method. Student repeats them on other flights till he is familiar with them. For other flights a paved area is available on which it is possible to make a landing.

Safety Rules:
- do not exceed the side wind component specified by the aircraft flight manual
- do not allow landing at girder, especially on the paved runway

3.5.2 Syllabus PLL(A) - theoretical

The greater part of the training in meteorology that the candidate has to pass is a theoretical training, because the weather is unpredictable, and as a pilot will behave in the situation depends, among other factors, on his preparation.

Theoretical syllabus PPL(A) shall include: air law, aircraft general knowledge, flight performance and planning, human performance and limitations, aviation **meteorology**, navigation and radionavigation, operational procedures, principles of flight and communication.

Minimum amount of theoretical instruction to obtain a private pilot license must be **80** hours, out of which about **8** are meteorology lessons.

Syllabus of theoretical knowledge for the private pilot licence PPL(A) on the subject **aviation meteorology** must include the following sections:
1. The atmosphere
2. Humidity and precipitation
3. Pressure, density and temperature
4. Pressure and wind
5. Cloud formation
6. Fog, mist and haze
7. Airmasses
8. Frontology
9. Ice accretion
10. Thunderstorms
11. Flight over mountainous areas
12. Climatology
13. Altimetry
14. The meteorological organisation
15. Weather analysis and forecasting
16. Meteorological broadcasts for aviation
17. Weather information for flight planning

Since the wind is still and by far the most risky, teaching *„Pressure and wind"* from the curriculum includes:
- high and low pressure areas
- motion of the atmosphere, pressure gradient
- vertical and horizontal motion
- convergence, divergence
- surface and geostrophic wind
- effect of wind gradient and windshear on take-off and landing
- relationship between isobars and wind, Buys Ballot's law
- turbulence and gustiness
- local winds, föhn, land and sea breezes

Training or normal transport flight can be also affected by other meteorological factors than wind, set out in section 3.2.

Example: on cloudiness depends forming of icing, storms, precipitation and reduced visibility are associated with it. The clouds can also be linked to turbulence. At the same time, cloud nature allows visually identify possible risk during flight = many times it happens that the different effects behave as **complex** and not as isolated elements.

3.6 Analysis of basic flight training syllabus due to dangerous meteorological factors

If we take into account the most dangerous phase of flight - **landing**, which also graduates of flying schools study to cope with, and the most dangerous meteorological factor - **wind**, what follows is, that landing with wind (mostly crosswind) is contained in the basic syllabus of flight training PPL(A).

3.6.1 Landing with crosswind

Landing is a maneuver of an aircraft from the agreed altitude of 15 or 25 meters to the runway to a complete standstill or release.

Crosswind is one of the meteorological situations that the pilot meets very often. Although for airport blueprints, wind figures as one of the key factors affecting the orientation of the runway, in real operation the wind breeze exactly on the axis rarely. Effect of crosswind is the greater, the lighter is the aircraft.

Maximum allowable amount of the side wind component should pilots possess by heart and are given and tested by the aircraft manufacturer. Sometimes only the maximum tested amount is indicated, which is not listed as an explicit limit. Then pilots need to rely on their own common sense and experience.

Landing with drift due to side wind component can cause damage to the landing gear or the wing of the aircraft, possibly create an accident.

If during landing the wind vector is not parallel to the centreline of the runway, it is necessary to eliminate its effect so that the vector of moving aircraft is parallel to the axis of the runway. For the bypassing of wind, there are **3 methods:**

1. course method (crab)
2. sideslip method
3. combination of course and sideslip methods

Course method (technique „crab“) is done by collapsing the aircraft upwind so that the longitudinal axis of the aircraft creates a certain angle with the actual flight route and the axis of the runway. It is used mostly in *„great transportation“*, because the planes have larger wingspan and during the sideslip method could be damaged.

Sideslip method is carried out by maneuvering the aircraft to slip with a tilt against the wind, so that the longitudinal axis is parallel to the aircraft flight route and actual runway axis. That, which technique is safer and more secure depends on the type of aircraft and pilot experience.

Fig. 5 Landing with a crosswind - course method

3.7 Summary of practical and theoretical training

Throughout the whole study, the most dangerous element was wind. The safest phenomena were lightning, which were encountered only a few times.

Most dangerous phase became clearly **landing**. Of the main phases, the safest is taxiing or standing at apron. The combination of wind and landing brings a combination of the most vulnerable. This means that during landing, when occurred wind (mainly crosswind) happened the **most major aviation accidents**.

By categories of operation rules, the most endangered is the part 91 - general aviation, particularly personal flights. The least threatened are the agricultural aircraft operations. Again, by merging the wind and general aviation, we get the most dangerous combination from the point of operation.

For each pilot are very important observation skills of current weather, analysis of meteorological elements and their interpretation in flight. Moreover, it is very important to know, understand the underlying meteorological documentation for flight and specialized aviation weather forecasting. In combination with the right decisions during the flight, the pilot becomes a specialist on weather conditions and over time a skilled expert.

Nowadays there are already many good flying schools that have instructors trained at a high level and who also know how to train pilots to the desired level. The **practical training** dedicates, from the meteorological elements and phenomena, attention only to crosswind elimination. Other elements are confined to **theoretical knowledge** and as a pilot will behave in this situation depend on his training but also on the aircraft equipment and the airport he wants to land at. The theoretical training prepares the pilot, at least in theory, to know how to react in the presence of this dangerous phenomenon, or he can at least *„try it out“* when it suddenly occurs during training.

4 CONCLUSION

In a particular case during flight, such as a sudden and unexpected change in weather conditions, the pilot is affected mainly by **flight experience** and also by the **level of preparedness** to deal with emergencies. The first reaction is fright, followed by, with an experienced pilot, prescribed implementation of procedures for a particular situation.

What I would **recommend** is to increase the practical learning of bypassing the crosswind by a few hours, because it‘s really the weather element that caused the most aviation accidents and incidents, and thus occurred the most times.

If it is taken from the perspective of theoretical training, there I would not make any major changes, as it includes everything that the pilot should know for his future work. At the same time, theoretical training is taught by established norms and laws and the pilot is getting pilot training in the meteorological part.

Further I would **recommend** including specific training during particular hazardous weather conditions in the simulated training, because it is not possible to send a pilot to such actual conditions. Although, for example, reduced visibility can be simulated, but this is just a small piece of various elements and phenomena, that may occur. Pilot may not encounter this situation for several years, and if he happens to come across such a dangerous situation, he can be very unsure, surprised and can make a fatal mistake, which could result in an aviation accident.

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