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Human Factors in Air Accidents of Military Helicopters of Czechoslovakia and the Czech Republic

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Abstract:

The article presents an analysis of air accidents involving military helicopters used in Czechoslovakia and the Czech Republic from their introduction in 1956 to the end of 2021. It focuses on the contribution of human factors of flight personnel to these air accidents. The aim of the article is, based on extensive analyses of the circumstances and causes of individual air accidents, to formulate the root causes of the factors that have threatened and still threaten the lives of not only pilots, but also other members of military helicopter flight crews while performing their profession. To conclude, recommendations are given to reduce, or in many cases even to eliminate, the effects of these factors on flight safety.

Keywords:

air accident, human factors, military helicopter, pilot, supervision

1 Introduction

The history of military helicopter aviation in the former Czechoslovakia goes back to 1956 with the introduction of the first Soviet Mil Mi-4 helicopters into the inventory of the then Czechoslovak People's Army (hereafter "CSLA" from "Československá lidová armáda" in Czech).

Over time, another 11 types of helicopters, mostly of Soviet manufacture, followed (listed chronologically according to the year of introduction into the CSLA inventory: Mil Mi-1, Mil Mi-8, Mil Mi-24, Mil Mi-2, Mil Mi-9, Mil Mi-17, Mil Mi-35 and Mil Mi-171Š). Czechoslovak Aero HC-2 "Heli Baby", Polish PZL W-3A Sokol, and American Enstrom 480B-G helicopters were also among those in service with the CSLA.

Over the last almost 66 years of military helicopter operation in Czechoslovakia and the Czech Republic, several hundred aviation emergencies have occurred. These

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reflected the technical capabilities of helicopters and the level of training and flight safety control of the time. The most serious aviation emergencies (in terms of impact on human health, property and the environment), known as air accidents, are the subject of this study.

The definition of the term “Air Accident” is currently contained in Order of the Minister of Defence No.13/2016 of the Journal [1] and it merges three formerly distinguished types of air accidents (disaster, crash and damage) into one common designation.

However, for better clarity and illustration of the principles in the root cause chains of emergency occurrences, the author uses the former division of air accidents according to the Všeob-P-10 Flight Safety Regulation [2], which was previously in force. In the Všeob-P-10 Flight Safety Regulation, air accidents were divided into: *disasters* (air accidents associated with loss of life of flight crews or other involved persons), *crashes* (air accidents associated with destruction of aviation equipment without loss of life of crew members or other involved persons) and *damage* (air accidents associated with repairable damage to aviation equipment without loss of life of crew members or other involved persons). The reason for this decision made by the author is that there is often a distinct difference in the chains of causes for different types of air accidents.

The main focus of this study is to identify the involvement of human factors in the occurrence of the air accidents under investigation and to identify their root causes.

“Human factors” [3] are defined in this context as “*...factors resulting from natural human characteristics (physical and mental) that affect human performance (both qualitatively and quantitatively).*” The official definition of human factors in aviation is provided in full by, for example, the Federal Aviation Administration (hereafter “FAA”) [4] or the International Civil Aviation Organization (hereafter “ICAO”) [5] on their websites or in referenced official documents.

2 Statistics of Air Accidents

For the purpose of this study, a total of 131 air accidents that could be reliably traced were analyzed, of which 19 were disasters, 31 were crashes and 81 were damages according to the previous classification. Information on the air accidents in question, mainly in the form of original investigation reports and supplementary expert opinions, was obtained by long-term collection of documents from military archives [6-8], aviation literature [9-13], and continuously supplemented by testimonies of surviving witnesses or eyewitnesses [14-15]. All this was done in order to achieve the maximum possible accuracy in the interpretation of historical data.

A total of 49 persons were killed in the aviation disasters, including 32 flight crew members and 17 passengers. The first aviation disaster of a military helicopter in Czechoslovakia was recorded in 1960. The last one so far took place in the Czech Republic in 1998. The aviation disaster associated with the greatest loss of life occurred on 12 September 1972 (a technical fault caused the rotor blade to break off in flight on a Mil Mi-4 helicopter causing 10 deaths). A total of 19 helicopters of various types (seven Mil Mi-4s, six Mil Mi-1s, one Mil Mi-17, one Mil Mi-2, and four Mil Mi-24s) were destroyed in aviation disasters.

A total of 31 helicopters of various types were destroyed in air crashes (ten Mil Mi-4s, thirteen Mil Mi-1s, one Mil Mi-17, one Mil Mi-2, three Mil Mi-24s, one PZL W-3A Sokol, one Mil Mi-8, and one Mil Mi-171Š). The first air crash of a military helicopter in Czechoslovakia was recorded in 1957. The last air crash so far occurred in the Czech Republic in 2019. The air crash with the largest number of people on board the helicopter took place on 8 January 1998 (technical failure resulted in transmission decoupling in flight on a Mil Mi-17 helicopter; all 21 occupants survived).

A total of 81 helicopters of various types (thirty Mil Mi-4s, thirty-three Mil Mi-1s, two Mil Mi-2s, five Mil Mi-24s, three PZL W-3As Sokol, five Mil Mi-8s, two Mil Mi-171Šs, and one Enstrom 480B-G) were damaged in the air damage. The first historically documented damage to a military helicopter in Czechoslovakia was recorded in 1956. The most recent damage, the investigation of which has been concluded to date, occurred in the Czech Republic in 2021.

The numerical distribution of the different types of aircraft accidents on a timeline, including references to important historical events affecting military helicopter operation and accidents in Czechoslovak and Czech history, is shown in Fig. 1.

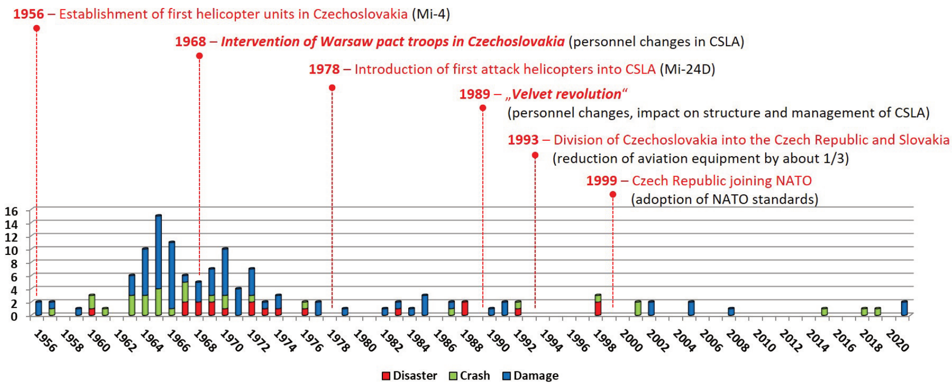

Fig. 1 Air accidents of military helicopters of Czechoslovakia and the Czech Republic in 1956-2021 on the timeline with marking and commentary of important dates [6-13]

3 Human Factors Models for Air Accident Analysis

In order to segregate the influence of human factors from the chain of causes of air accidents and to perform downstream analyses, it may be useful to take inspiration from one of the models called human factors models or a suitably selected combination of them. These are essentially well-designed graphical mind maps with a logical structure of the interrelationships between various elements of the environment and individual human characteristics that may affect human performance. Furthermore, when these elements are expressed in complex terminology, human factors models are highly effective tools that can save aviation accident investigators a great deal of time and effort. Examples of such tools include the PEAR (People, Environment, Actions, Resources) [15], PEART (People, Environment, Action, Resources, Time) [17], HFACS (Human Factors Analysis and Classification System) [18-19] models, which were used in the data analyses for this study – see Fig. 2.

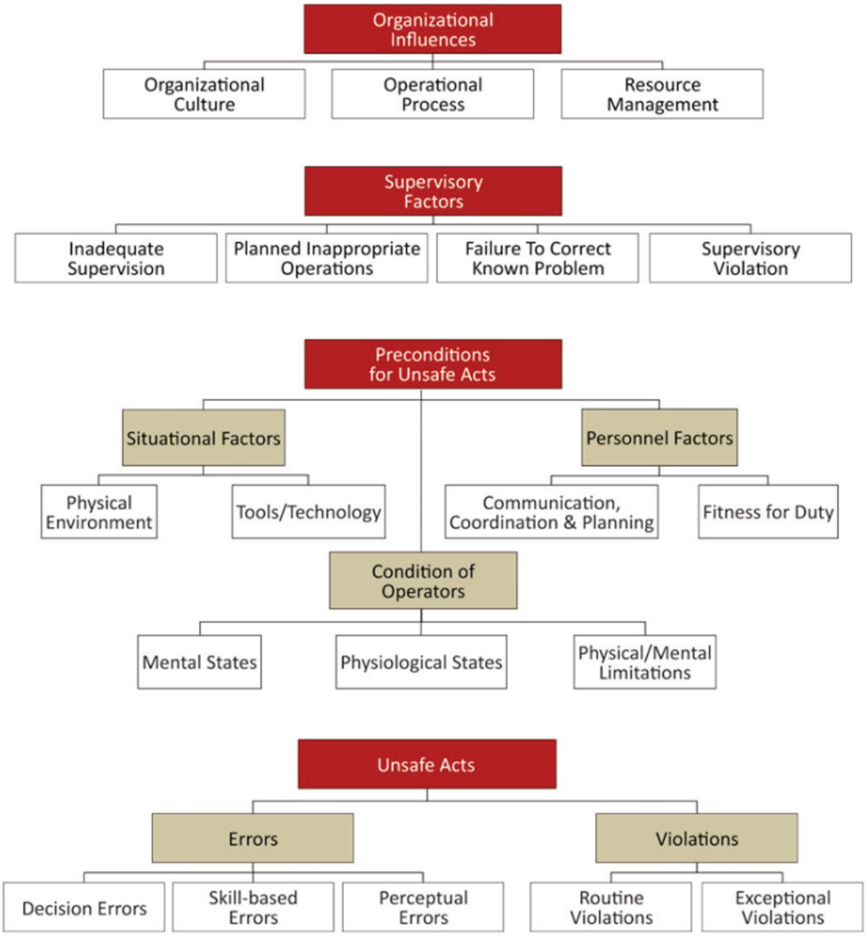

Fig. 2 Structure of the HFACS model [18]

4 Analysis of the Causes of Air Accidents

Subject to the analysis was a set of all 131 traceable accidents of military helicopters in the service of the former Czechoslovakia and the present Czech Republic that occurred from 1956 to the end of 2021.

Each air accident was analyzed under 26 criteria divided into 4 groups: timing details (date, time, day of the week, and season), data on the helicopter (type, version, tail code or serial number, type of on-board flight recorder, military unit affiliation), data on crew (name; rank and title; age; total flight hours: on both aircraft and helicopters, flight hours flown on all types of helicopters, flight hours flown on a given type of helicopter; pilot class rating; and service ranking) and data on air accident circumstances (main cause factor; main cause; stage of flight; conditions at the occurrence of the accident: flight mode, flight altitude, flight speed, weather conditions; injuries to crew members; and a brief description of the event).

All the information obtained was systematically entered in the Microsoft Excel spreadsheet in order to further analyze individual criteria using various filter functionalities.

The aim of the analysis was to track down any common features, differences and specific features interesting from the flight safety point of view. The information acquired was then divided into two groups: “still relevant” (as yet unresolved problems) and “no longer relevant” (now obsolete problems). The problems falling under “still relevant” were put in relation to each other and subjected to further analysis. The resulting logical links and rules were then formulated both in the text and in graphics.

4.1 Overview of Main Cause Factors and Main Causes

Fig. 3 shows the interpretation of numbers and percentage of individual main cause factors and main causes of the 131 air accidents analyzed. Each air accident is caused by a chain of causes, which most often consists of three to five elements (circumstances) acting simultaneously or consecutively, both type and course of which generate an undesirable outcome.

In the context of this study, the “main cause” is the part of the chain that was critical to the occurrence of the air accident or the part of the chain where the accident could still have been averted. The main causes can be divided into 4 groups collectively referred to as “main cause factors”, which include: technical factors, environmental factors, human factors (of flight and non-flight personnel), and not found [2]. To express the percentage of both main cause factors and main causes, the total number of 131 air accidents is regarded as the base (100 %).

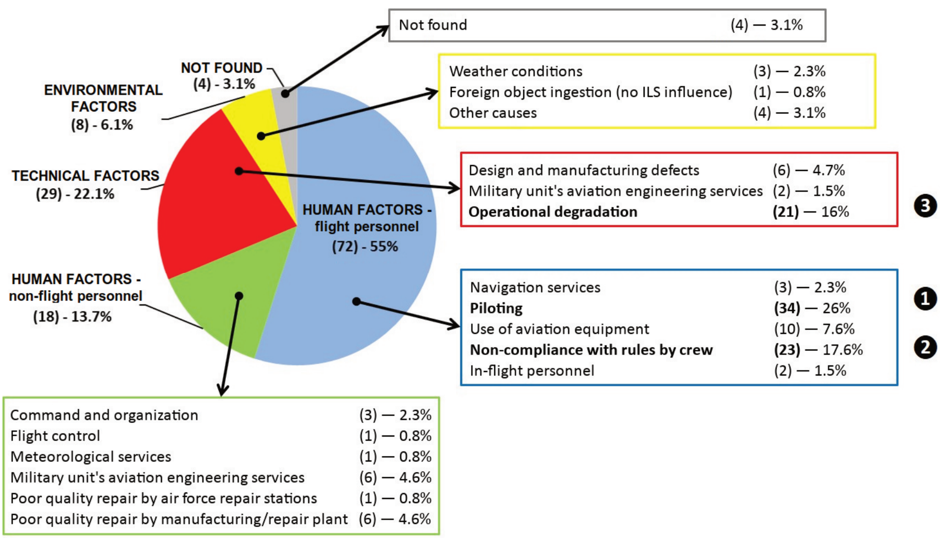

Fig. 3 Main cause factors and main causes of air accidents in military helicopters of Czechoslovakia and the Czech Republic between 1956 and 2021 (classified according to the Všeob-P-10 Flight Safety regulation [1]*)* [6-13]

The graphic presentation above shows the predominance of “human factors” with a share of as much as 68.7 % of the total (i.e. 90 out of the total of 131 occurrences). Within human factors, 80 % of incidents are attributed to “flight personnel” (i.e. 72

out of 90 occurrences) and 20 % to "non-flight personnel" (i.e. 18 out of 90 occurrences). Other main cause factors are represented only in smaller numbers.

Surprisingly, there is a relatively high number of events where the cause was due to "technical factors". They accounted for almost a quarter (22.1 %) of the total number of military helicopter accidents (i.e. 29 out of the total of 131 occurrences). This was generally due to the then lower level of knowledge in the design and operation of helicopters, in materials engineering and in the monitoring of the service life of components exposed to operational stresses. It is important to bear in mind that helicopters are not only considerably more complex technical systems than airplanes, but they are also much more recent in terms of development. Therefore, especially during the first approximately 20 years after their introduction into service (in the former Czechoslovakia in the 1960s and 1970s), they were largely technically and operationally undertested, which is illustrated in their relatively high failure rate.

Fig. 3 shows that "piloting" (26 %), "non-compliance with rules by crew" (flight indiscipline – 17.6 %) and "operational degradation" (16 %) predominate among the main causes ranking first through third. Other main causes are represented to a lesser extent and fortunately most of them can currently be considered "no longer relevant".

Most of the technical problems of aircraft technology evaluated in this study no longer exist as they were associated with aircraft technology that is not in operation anymore. In addition, the rules of command and organization, flight control, meteorological security and helicopter maintenance management have changed significantly and the problems identified in earlier times are no longer encountered. Although the environmental factors have not changed in relation to meteorological conditions, with the functionality of other systems and technical elements its influence is statistically proven to be minimal.

However, what have not substantially changed over the last 66 years are the main causes falling under "human factors – flight personnel" category. As it follows from the results of the analyses, they are among the causes of aviation accidents which are "still relevant" and, as such, will be given major attention in the following text. They mainly involve matters related to habits, flight indiscipline, flight training supervision, crew communication and information, and work overload, from which long-term fatigue logically ensues (see sections below).

4.2 Customs and "Customary Rights"

In order to better understand the historical development of the atmosphere, customs, "customary rights" and the overall way of thinking of members of helicopter units (especially flight crew members), it is desirable to give a short historical overview of important events in the commented context.

For a very long time, the safety of helicopter flights was (and to some extent it still is) governed by various customs, mostly unrecorded in regulations, which over time became so-called "customary rights". The concept of "customary right", of course, has no support in any applicable state legislation and is merely an argument for pursuing any course of action based on long experience. Nevertheless, some "customary rights" have merit and do, or did, compensate for some imperfections of military aviation regulations. Others, however, are highly counterproductive and potentially dangerous, as has been demonstrated by numerous aviation accidents.

How did custom and customary rights in helicopter units come about? To understand this phenomenon, one must go back deep into the history of military helicopter flying in the former Czechoslovakia. Apart from a few experiments with German-made Focke Achgelis Fa-223 Drache helicopters (later referred to as VR-3 in Czechoslovakia) in the second half of the 1940s, the history of Czechoslovak military helicopter flying began in 1956 with the delivery of the first Soviet-made Mil Mi-4 multi-purpose helicopters followed shortly thereafter by Mil Mi-1s.

The functional and combat potential of this type of combat equipment proved very effective during the Korean War (1950-1953). In order to continuously increase the combat capability of the armies of the Warsaw Pact countries, it was appropriate to follow this trend and introduce helicopters into the CSLA armament. The problem was that there was no previous experience with helicopters or helicopter flying, and the information provided by the former USSR (Union of Soviet Socialist Republics) was imperfect (adequate to the then level of knowledge). Moreover, there was nobody with a clear idea of how to use helicopters conceptually in Czechoslovakia, both in potential wartime offensive operations and air defense.

This was the reason why helicopters were deployed at several dozen then active military airfields, and served non-specifically for all purposes for which fixed-wing aircraft were not suitable: selected transport tasks, reconnaissance tasks, medical assistance, communications tasks, etc. As it was completely new, unknown and marginal CSLA aviation equipment at that time, it was not given any special attention at the command levels, neither from the technical nor organizational point of view. This fact was reflected in the regulatory base, flying organization, and above all in flight training supervision (control supervision, especially over the actual execution of flight operations).

It is also important to understand who the first pilots of military helicopters were. Some of them were former pilots of towed cargo gliders (in Czechoslovakia at that time referred to as the NK-4, NK-14 and NK-25), which were operated as a legacy of World War II and whose military use was later abandoned [14]. Others were pilots reassigned from fixed-wing aircraft, usually due to disciplinary infractions.

Not much was known at that time about helicopter flying and its many potentialities, especially in terms of piloting technique and environment. For many pilots in those days, the helicopter was a slow, lazy, low-flying, cumbersome and unaesthetic machine. So, they very often regarded their assignment as a gesture of humiliation.

It was only after some time that they realized the possibilities, the unique attractiveness and complexity of helicopter piloting technique, and found a deep personal and professional bond with it. However, in the absence of a sufficient regulatory base, with no procedures or recommendations of any kind for many activities, helicopter crews often had to improvise heavily. This was compounded by the fact that each airbase was located in a specific terrain and, in addition to having area-specific meteorological conditions, also performed different flight tasks.

Imagine highly creative and slightly irritated flight personnel confronted with specific, often very demanding flight tasks at low altitudes (usually up to about 200 m above ground level) and in difficult terrain, without a sufficient information portfolio to accomplish the task and survive, then one thing comes up: a very strong need for creative improvisation. Local improvisations later became “customs” and customs changed into “customary rights”. But not all of them were well thought out and applicable under all conditions.

Unless there was a more obvious problem with task performance, there was no need to make major changes to the regulations, and so the customs were reinforced and passed on to new generations of pilots.

4.3 Crew Communication

Crew communication in multi-crew helicopters is very different from that in other types of aircraft and takes place at different flight phases than, for example, in transport or tactical aircraft. This is largely due to the ergonomic constraints of the cockpit, the flight mission environment (especially when flying at low altitudes and in difficult terrain), and helicopter flight mode (especially when it comes to take-off and landing maneuvers).

Cockpit ergonomics usually restrict the helicopter pilot's vision rearward and downward, and often also to one side when two pilots are seated side by side in the cockpit. The helicopter captain (pilot) can only see perfectly forwards and to the side on which he is seated (usually the left). This can be a problem when, for example, a precision landing to a designated point with an accuracy of 1-2 meters (often less) is required. In such cases the role of other crew members, who verbally provide the pilot with information from hemispheres where he cannot see perfectly, is essential. Close to the ground, the role of the flight engineer or, in some types of helicopters, on-board gunners, is often indispensable, as they can monitor the area below and behind the helicopter by viewing it from the cargo bay doors or their gunnery stations. Good communication interplay, i.e. factual, timely, direct and clear communication in a prescribed or agreed way, is necessary for the effective transmission of important information in a timely manner. In exaggerated terms, for some types of flight tasks and some flight maneuvers, a helicopter needs multiple pairs of eyes to check all of its external hemispheres at the same time and to deliver important information to the helicopter captain.

Like many other aviation specializations, communication and its forms in aviation have undergone a historical evolution. The historical experience of air accidents of the last few decades has shown two major facts that affect flight safety.

The first fact is that one of the most important parts of crew communication is verifying that the information has been received and correctly understood by the recipient. This is usually done by verbal confirmation of the information, or at least the most important part of it, by the recipient.

The second fact is that professionalism in in-flight communication should not be affected by interpersonal relationships and conflicts between individual crew members (see, for example, the Mi-24D crash of 11 November 1987). Interpersonal disagreements should either be addressed and resolved immediately after they arise (if there is an urgent need) or suspended until after landing.

4.4 Flight Training Supervision

Supervision (i.e. control mechanisms) of the actual conduct of flight training was, until recently, carried out only on a limited scale in helicopter units. The reasons for this were several at different times.

The first one is that most of the flying takes place at ground altitudes (i.e. up to 200 m above ground level) and in rugged terrain where continuous radar monitoring was not, and for the most part still is not, technically possible. The second was – until recently – the absence of comprehensive systems of objective monitoring (flight operational quality assurance equipment: operational and emergency flight recorders), which allow individual flights to be reconstructed accurately enough from the recorded data (flight trajectories, pilot interventions in the controls, methods of operating the engine, etc.). The third reason was a certain indulgent attitude of some commanders towards exceeding the permitted limits of flight parameters by themselves and their subordinates (flight indiscipline). When misconduct was observed, some commanders preferred a non-conflicting deal with subordinates rather than a strict and potentially conflicting order. Regrettably, not all people are appreciative of such an approach in life. Some may interpret it as a sign of weakness and continue their flight indiscipline. All of this, of course, was long made possible by inadequate control mechanisms and low penalties laid down in military aviation regulations.

The lack of effective supervision of real flight operations has been evaluated as the top and most serious deficiency related to flight safety in helicopter units over the last 65 years, and it still needs to be addressed in the future. This is especially true with the future planned rearmament with the U.S.-made helicopter equipment, which, unlike older Soviet-made aviation equipment, no longer allows for long-term exceedances of permitted flight parameter limits (take-off weight, speed, overload in turns, etc.) for design reasons.

4.5 Flight Indiscipline

Flight indiscipline is the conscious and deliberate disregard of flight rules by the crew. There are 3 main types of flight indiscipline:

- indiscipline based on testing the performance limits of the helicopter,
- indiscipline based on testing the crew's performance limits,
- indiscipline based on the need to display one’s abilities or to accommodate somebody.

The first type of indiscipline in helicopter flying primarily involves failure to comply with maximum takeoff weight, airspeed, G-overload maneuvers, recommended engine modes, etc.

The second type of indiscipline includes, in particular, failure to follow the planned route of flight (for which adequate navigational preparation has been made), failure to observe safety flight altitudes, underrating of meteorological conditions and their possible sudden changes, arbitrary attempts to fly higher-level piloting maneuvers without adequate training or supervision by an instructor, flying in a state of severe physical or mental exhaustion, etc.

The third type of indiscipline has two forms. With the first one, the person to whom the display or accommodating gesture is intended is outside the helicopter (i.e. usually watching the action from the ground). With the second one, that person is aboard the helicopter as a passenger, subordinate, peer, or superior commander. Both of these alternatives are potentially fatal because they place the pilot in a state of undesirable over-motivation that temporarily affects his judgment, assessment of the situation and the level of subjectively acceptable risk.

The types of indiscipline based on testing the performance limits of the equipment and crew were often inspired in the last 30 years by the experience of foreign air forces that operated that particular aircraft (especially the Mil Mi-8 and Mil Mi-24 helicopters) in combat. Most notably, it was the experience of Soviet pilots from the 1979-1989 Afghanistan war that gave rise to a number of modified basic and advanced piloting techniques. These included special techniques for taking off and landing overloaded helicopters in the thin air of high altitudes (e.g. nose wheel takeoffs or takeoffs with a run close the ground after a short control hover), as well as dynamic combat turns at higher speeds with greater G-loading, which reduced the likelihood of being hit by enemy ground fire in the battlespace. Other sources of inspiration for various pilot experiments came from the international aviation days, in which representatives of the Czechoslovak and later Czech military aviation participated from the 1990s. Later, international military exercises with NATO armies were held, where the performance of different types of aviation equipment could be directly confronted. Some of the Western-made helicopters showed better maneuvering capabilities, which prompted a number of Czechoslovak and Czech pilots to try to emulate these maneuvers with their own older Soviet-made equipment.

As a result, this often resulted in long-term experimental and non-regulatory overloads on helicopter structures and engines, usually by trial and error (without adequate training by the manufacturer), which in many cases had serious consequences for the machine and crew (faster progression of operational degradation of the helicopter or an air accident).

With hindsight, in virtually all of these cases of indiscipline, the main cause was the lack of awareness of the flight crew of the true context and history of the development of these piloting techniques and their technical implications for the machine. The fact of the matter is as follows.

In Afghanistan, pilots did indeed fly beyond the permitted limits of the technical regulations of their helicopters because they were driven to do so by the flight and combat conditions of the environment in Afghanistan (high altitude, high air temperature, dust, specific combat tactics of the enemy in difficult mountainous terrain, etc.). However, after these deviations in helicopter use were identified by the Moscow Helicopter Plant ("Московский вертолётный завод – МВЗ" in Russian) as early as in 1980 [20], the technical lifetimes of the stressed elements were recalculated and the maintenance management system was changed so that losses due to technical causes through operational degradation did not exceed combat losses. Unfortunately, this never happened in Czechoslovakia or later in the Czech Republic.

At international aviation days in the 1990s, pilots of foreign Western military helicopters were indeed often able to perform more dynamic combat maneuvers than Soviet-made machines. There was a justification for this. It must be remembered that the design, engine performance, passive ballistic protection, and associated overall weight of these helicopters were often designed with a completely different philosophy and in many cases for different tactical uses that cannot be compared.

A specific phenomenon falling under the category of flight indiscipline is also the so-called "flying on the edge". The imaginary "edge" here means the actual maximum performance of the helicopter and the pilot at a given time and under given conditions. This is a very dangerous type of flying beyond the limits laid down in the regulations, which has only one, but very important drawback. No one in the world is able to estimate or calculate exactly where that "edge" is at any given moment. Neither the power of an aircraft engine nor the power of a human agent is constant over time. They have their own, sometimes considerable, deviations. The power output of an aircraft turbojet engine in modern military helicopters can fluctuate by several percent due to, for example, changes in air temperature, dust, operational degradation, fuel and lubricant quality, etc. The performance of the human agent (pilot) may also vary in both physical and mental terms, as manifested by varying speed and accuracy of responses to stimuli, motor accuracy, time and space estimation capabilities, etc. To ensure that the deviations of these two performances never collide, there is a safety margin given by the operating regulations which should ensure that the helicopter has a sufficient performance margin against all major human failures and foreseeable changes in environmental conditions. If a pilot's actions reduce or completely eliminate this safety margin, he is likely to reach a point where the real "edge" in helicopter performance will be revealed at the least opportune moment. Such situations tend to result in air accidents.

Of course, flying "on the edge" cannot be generalized, because there are differences here as well. The important thing is always: by how much the regulatory limit was exceeded, in which parameter it was exceeded and, last but not least, for how long. Of course, the highest risks are involved in large and frequent exceedances for long periods of time (seconds, minutes, hours). The consequences of this style of flying can be illustrated by the following few examples.

Exceeding the maximum permissible flight speeds poses a risk of destruction of the carrier rotor due to vibrations within hours (with the inevitable crash of the helicopter), as demonstrated by the experience gained in the former USSR. For instance, at high multiples of G, there is a risk of deformation or destruction of the airframe structural system (resulting in destruction of the helicopter in flight or changes in its aerodynamic properties or maneuverability). Exceeding the maximum permissible flight speeds poses a risk of destruction of the carrier rotor due to vibrations within hours (with the inevitable crash of the helicopter), as demonstrated by the experience gained in the former USSR. Exceeding the calculated maneuver dynamics can create a number of aerodynamic traps specific for each type of helicopter (for example, in the case of the Mil Mi-24 helicopter uncontrolled pitch-up [14], stalls due to insufficiently fast acceleration of engines in a dynamic maneuver, vortex rings, etc.).

In summary, flight indiscipline is primarily derived from pilots' ignorance, inexperience and lack of predictive thinking, which often results in overestimation of their skills and abilities. If a pilot is fully aware of the possible and probable consequences of his intention at a given moment, his natural instinct for self-preservation certainly prevents him from carrying out that intention.

4.6 Work Overload, Stress and Fatigue

Work overload, especially with non-flight work tasks, is the result of understaffing of military units. The understaffing is not intentional, of course, but rather a consequence of societal and political changes that have significantly altered the public's view of the role and function of the Army of the Czech Republic. For many reasons, the service in the Army is no longer an attractive occupation for the younger generation of people, which is why the number of applicants is currently limited and the qualitative selection from among them for stressful professions, such as aviation specialties, is becoming increasingly difficult. However, this is a problem not only in the Czech Republic, but in virtually all European countries that have adopted the professional military system and are members of NATO.

A natural consequence of work overload and other related life situations is stress, the collective compensation for which has almost completely disappeared at air bases. Before 1989 (Velvet Revolution), when the army was not yet understaffed, air bases had a very intensive social life accompanied by plenty of sporting activities. Members of the units spent a great deal of time together in the units, which gave them the opportunity to communicate and solve many pressing problems together. There were many informal social events that played their important role in mental hygiene as it was possible to discuss many professional and personal problems informally. There was ample opportunity to relieve work stress in team sports such as football, volleyball, group cycling, etc. The staff often lived close to their bases with their families knowing each other, which gave them the opportunity to solve or at least identify a lot of problems early on. These natural anti-stress mechanisms have practically disappeared. Because of their small numbers, the personnel in the units practically never all get together as most staff spend several hours commuting between home and work (at their air bases) these days. Team sports and informal social events with families are virtually non-existent for organizational reasons. Collective sports have given way to individual activities, which have significantly less effect in terms of stress relief. Communication with each other has been reduced to the minimum necessary.

The natural consequence of the stress and work overload described above is fatigue, not only physical but especially mental. Fatigue itself is a cause of error in various areas of human activity. When combined with another undesirable psychological condition (such as over-motivation, frustration or long-term psychological trauma), it is a dangerous precondition for the occurrence of an aviation incident or accident. The analyses of air accident cause in which the flight personnel human factors played a decisive role in the cause chain (72 out of the total number of 131 accidents analyzed, i.e. about 55 %) clearly show the conclusion that: "Most errors stem from LACK OF CONCENTRATION and PHYSICAL AND MENTAL DEBILITATION while, at the same time, quick ADAPTATION TO SIGNIFICANT CHANGES of conditions is needed". In other words, it has been shown that the greatest threat to helicopter flight personnel (as is the case with military fixed-wing aircraft pilots) is posed by their own mental states often combined with organic physical debilitation (fatigue) due to inappropriate lifestyle and inadequate mental hygiene in particular.

The principle of increased error rate of a member of flight personnel (most often a pilot in command) can be found in Chapter 5 of the article [21] (to avoid duplication of text).

4.7 Long-term Pilot Performance Curve – Dangerous Phases and Intervals

To understand the origin and progress of some mental states that, under certain conditions, can be threatening to pilots, it is necessary to look at the situation in a broader context. The mental state always reflects the reaction to a specific stimulus or life situation, both personal and professional. To get a better and clearer idea of the pilot's professional situation, a model "long-term pilot performance curve" can be used (Fig. 4) to show critical points of the pilot's professional career and also to explain their most common causes.

The first prerequisite for understanding the performance curve is the fact that there is often a vast difference between the "flying EXPERIENCE" and the "real flight PERFORMANCE" of a pilot. By no means are these synonyms. Flying experience is determined by the number of flight hours (the greater the number of hours flown, the greater the "flying experience"), while real flight performance is determined by the number of errors made by the pilot during the flight and it can be expressed as a percentage (100 % corresponds to pilot's error-free performance). As the shape of the performance curve suggests, the relationship between flying experience and flight performance generally changes over time. The professional life of a military helicopter pilot can be divided into about 4 stages.

The first and fourth stages of the presented model performance curve is the same for military helicopter pilots as for jet fighter pilots (please see Chapter 5 of the article [21]).

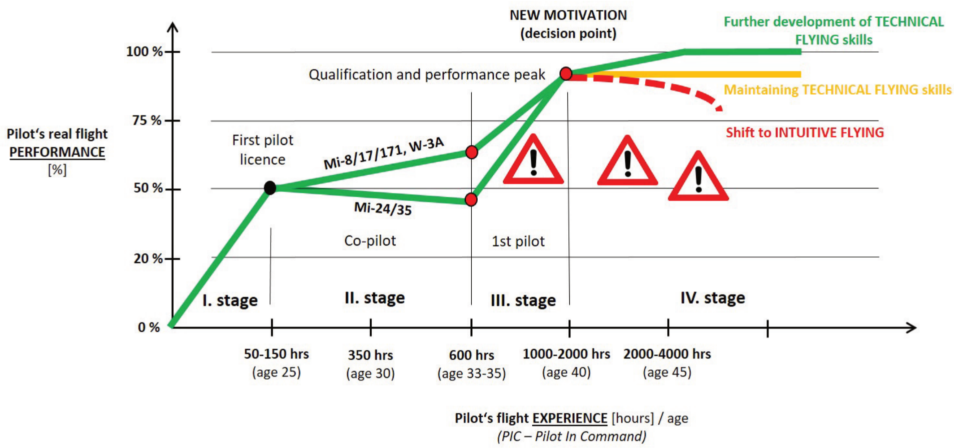

Fig. 4 Model curve of military helicopter pilots' long-term performance (valid for Mil Mi-171Š, Mil Mi-24, Mil Mi-35 and PZL W-3A Sokol helicopters)

The second stage, representing training on a specific type of helicopter at a military unit, can have two variants, which are determined by the ergonomic design of that type of helicopter. If the helicopter captain and the co-pilot are seated in separate sections and the co-pilot has only access to a very reduced selection of emergency controls (as is the case with the Mil Mi-24 or Mil Mi-35 helicopter), then the flight performance of the co-pilot stagnates or decreases over time despite his flight experience. If the helicopter captain and co-pilot are seated side by side in a common section and the co-pilot has full dual controls (as is the case with Mil Mi-8 /17/171Š and PZL W-3A Sokol helicopters), then his flight performance increases steadily with flight experience. Although this increase is slower compared to basic flight training because the co-pilot does not get to flying full control as often, the co-pilot's skills still continue to develop.

The third stage begins when the pilot starts training as a helicopter captain. This moment is delayed by 5-8 years compared to tactical pilots, which means that the helicopter pilot starts to rise to the peak of his professional career with a delay (at around 33-35 years of age). This opens the first of dangerous periods of his professional life. The pilot usually does not yet really know the limits of his mental or physical performance and often unreasonably rushes to the professional peak trying to make up for the time "lost" as a co-pilot. In this period, with overly strong motivation it is very easy to overestimate one‘s skills in hopes of gaining recognition or advancing in one‘s career quickly. There are usually two types of pilots: safety-oriented and mission-oriented.

Mission oriented-pilots in particular can develop a phenomenon that can be referred to as "personality cult". It is basically a self-destructive mental condition in which the pilot is unhealthily fixated on attaining his goals, loses the ability of objective self-reflection and, most importantly, loses the ability to communicate effectively with others. The biggest problem with this condition is the inability and unwillingness to communicate, because from then on, the pilot performs tasks originally designed for a team of several people completely on his own. Then it is not a question of *whether* a major error occurs, but *when* it occurs.

Most often, pilots of that age and at that stage of their professional life are threatened by ignoring their own limits and by their impatience related to performance and the associated career advancement. This problem has to be acknowledged and addressed, both through the pilot's subjective mental hygiene and from supervisor positions. The third stage usually ends with the pilot reaching his qualification peak around the age of 40. At that time, the pilot is at the height of professional competence and has completed everything a regular training can offer him. With experience comes balanced prudence and healthy fighting aggressiveness backed by self-confidence. But these are soon undermined, usually by the coming of a "mid-life crisis" of varying intensity. This is a period of taking stock of one's life so far and a "decision point" of a kind. During this period, the pilot's personal and professional life often changes, and the pilot decides what to do next. Very often, the order of his priorities changes, as, accordingly, does the distribution of his energy put into them.

The fourth stage starts after this "decision point" and usually has three possible scenarios:

- further improvement of TECHNICAL FLYING skills,
- maintaining TECHNICAL FLYING skills, or
- shifting to INTUITIVE FLYING.

A more detailed description of all three scenarios can be found in Chapter 5 of the article [21] (to avoid duplication of text).

5 Recommendations for Flight Safety

As follows from the above analysis, military helicopter crews have been subjected to a combination of factors that threaten their safety in the long term, which include, in particular, work overload (mainly non-flight work tasks), stress and the resulting fatigue. Fatigue often also results in undesirable psychological conditions, the origin of which can be found mostly in interpersonal relationships and communication in the workplace or in private life (family). If we add to this the lack of effective control mechanisms (supervision) of the pilots' real flight performance, an ideal environment for unconscious unintentional errors and conscious and deliberate flight indiscipline is created. Flight indiscipline in particular, the potential consequences of which are not sufficiently known or explained to pilots, can lead to a number of air incidents and accidents in the long term.

Therefore, in the author's opinion and factual findings, it would be beneficial to pay increased attention to these risk factors in the future. Specific recommendations to improve flight safety include:

- structural prevention of work overload at command levels (adjustment of the organizational structure and work planning with regard to available human resources),
- modification of the flight training curriculum so that the duration of the 2nd stage of the training (see Fig. 4) is shorter than the current 5-8 years (pilots should not be wasting the most productive years of their professional life in a position where they do not have the opportunity to develop their pilot skills, which often leads to premature professional burnout as well as to a decrease in work motivation, and consequently to over-motivation when training for the position of helicopter commander at a later age),
- promotion of proactive, educational and preventive flight safety activities (e.g. training courses on lifestyle, mental hygiene and techniques for physical and

mental recovery; and a clearer legislative decoupling of the criminal process of investigating air accidents and incidents from the causal one, ensuring that there is no connection between the two, i.e. the willingness of the actor in an incident to truthfully report the real cause of the incident should never be held against him).

6 Conclusion

The motivation of this study is to improve the level of flight safety of military helicopter units within the Czech Air Force.

A systematic study and analysis of 131 air accidents using sophisticated analytical methods for the determination of errors and violations of human factors (PEART method, HFACS method) showed several serious problems at the organizational level of the management of helicopter units, which would be beneficial to address in the future. Individual problems and their causes are discussed in sub-sections of chapter 4. Specific recommendations for flight safety are given in chapter 5.

The presented study proves that the used methods and system of analytical work are suitable for this field of interest in the future as well, and could also be applied to other specific types of military air forces (e.g. tactical specialization, transport specialization).

In the very end, the author would like to pay tribute to the work and memory of the flight crews killed in the above analyzed accidents, from whose experience, gained and paid dearly, we have today the opportunity to learn for the future of flying and flight safety.

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