WILDFIRE SUPPRESSION: PARAMETERS RELEVANT TO AERIAL FIREFIGHTING

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ABSTRAKT

Cílem tohoto článku je identifikovat parametry ovlivňující letecký požární zásah při hašení lesních požárů. Zaměřuje se na parametry související s vrtulníky provádějícími zásah, na samotný požár, techniku pilotáže a její omezení, meteorologické podmínky a možnosti zásobování hasební vodou. Článek zahrnuje stručný úvod týkající se leteckých požárních zásahů se zvláštní pozorností věnovanou vrtulníkům provádějícím hašení požáru z vrtulníkových Bambi vaků. Článek pokračuje určením parametrů, které hrají hlavní roli při ovlivňování hašení požárů, a pakliže jsou – definuje souvislosti mezi nimi. Pozornost je věnována především způsobu vedení protipožárního zásahu z vrtulníku, jak je ovlivňován samotný shoz hasební vody a jaká je účinnost zásahu v daných podmínkách. Dále je uvedena stručná diskuse, která má za cíl vyhodnotit závěry a shrnout komplexnost tématu.

KLÍČOVÁ SLOVA

Letecké hašení požárů • Hašení lesních požárů • Hašení požárů vrtulníkem • Ovlivňující parametry

ABSTRACT

This paper aims at identifying parameters influencing aerial firefighting attack to suppress wildfire. It focuses to parameters related to the helicopters performing the attack, to the wildfire itself, pilot techniques and its limitations, meteorological conditions, and water supply possibilities. It comprises of brief introduction on the aerial firefighting attacks with special attention paid to helicopters performing the fire suppression from helicopter buckets. The paper continues with identification of parameters performing major role in influencing wildfire suppression and if any – connections among them. The paper mostly focuses to the way the fire attack is conducted, how the water discharge is influenced and what is the efficiency in given conditions. Brief discussion is given next to retrieve conclusions and summarize the complexity of the topic.

KEYWORDS

Aerial Firefighting • Wildfire Suppression • Helicopter Firefighting • Influencing Parameters

1. INTRODUCTION

Wildfire occurrences have been influenced by climate change and human activity, leading to both regional variations and increasing fire intensity. Between 2012 and 2023, the number of wildfires globally varied significantly. Areas such as Canada and the Mediterranean have experienced record-breaking wildfire seasons in 2023, with unprecedented fire extents and emissions.

Aerial firefighting plays a critical role in containing wildfires, particularly in inaccessible or remote areas. The percentage of wildfires requiring aerial suppression varies by region, but it's a crucial part of strategies in highly forested and mountainous areas where ground forces have limited reach.

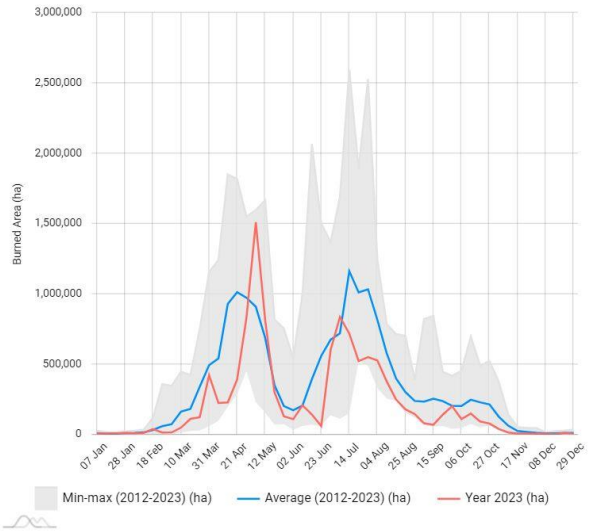

Figure 1*: Weekly burned areas in EU. Comparison of min-max percentage of burned area of years 2012 – 2023 (grey), its average (blue) and average of burned area in 2023. (Europa.eu, 2024)*

Global Wildfire Information System shows surge in total area burned in last year in EU countries (Figure 1) and in the Americas (Figure 2). The burned area is depicted by week and is showing the trend in different parts of the world. Thus provides a powerful tool for risk assessment and moreover for the location of sources – human, technique and the consideration of available natural sources.

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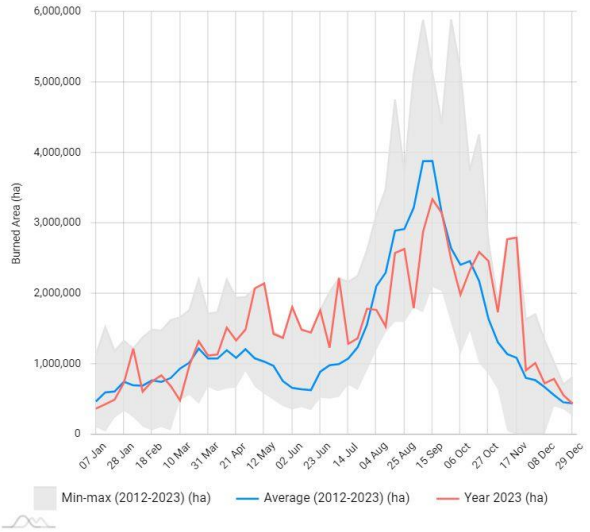

Figure 2*: Weekly burned areas in Americas. Comparison of min-max percentage of burned area of years 2012 – 2023 (grey), its average (blue) and average of burned area in 2023. (Europa.eu, 2024)*

2. OPERATIONAL PARAMETERS

Aerial firefighting is a complex and highly coordinated effort influenced by various environmental, technical, and safety parameters. Understanding and managing these parameters are crucial for successful wildfire suppression from the air.

2.1. Weather Conditions

Weather plays a pivotal role in aerial firefighting, as it can either assist or hinder efforts to contain a wildfire. The following weather-related factors are particularly relevant.

2.1.1. Wind Speed and Direction

Wind is the most significant weather factor in aerial firefighting. High winds can cause wildfires to spread more rapidly, making it harder to control. Additionally, wind affects the accuracy of water or fire-retardant drops.

Pilots need to adjust flight paths and drop points based on wind direction and strength to ensure that the payload lands on the targeted fire area. Crosswinds or shifting winds can blow the retardant away from the fire, reducing the effectiveness of drops.

Another wind-related condition is the aerodynamics impact on the helicopter. Headwind is preferred for takeoff, landing and hovering due to improved lift and control. Traveling to the fire site brings a lot of smoke and flying ash and hence may not be possible. Tailwinds on the other hand offer faster travel but less aerodynamic stability. The airflow over the helicopter is less predictable, making it harder to maintain precise control especially at lower speed. Generally, the water drop is conducted from the direction of downwind or crosswind – where there is no smoke and the visibility is clear. (FAA, 2019)

2.1.2. Visibility and smoke

Visibility is a critical safety and operational factor in aerial firefighting. Smoke from wildfires can obscure both the terrain and the fire itself, making it difficult for pilots to navigate and accurately deliver their payloads.

Thick smoke can make it impossible for pilots to see the fire and the surrounding landscape, increasing the risk of accidents, especially when flying at low altitudes.

Even minor miscalculations in drop zones due to low visibility can result in the water or retardant missing the intended target. In such cases, advanced technology like infrared cameras or GPS-based systems may be used to enhance drop accuracy despite poor visibility.

Hot air from the fire is less dense than cooler air, which can reduce the lift generated by the rotor blades, potentially requiring more power to maintain altitude.

Smoke contains ash, soot, and other fine particles that can be sucked into the engine. These particles can clog air filters, damage compressor blades, and reduce the efficiency of the combustion process. Pilots are advised to avoid prolonged exposure to smoke-filled environments.

2.1.3. Temperature and Humidity

High temperatures can dry out vegetation, making it more flammable, which increases the difficulty of suppressing the fire. In hotter conditions, aircraft may also face reduced lift capability, affecting flight performance.

Low humidity dries out fuels, increasing the fire's intensity and making aerial drops less effective. Conversely, higher humidity can help slow fire spread, offering more favorable conditions for aerial attacks. (Berčák et al., 2023)

2.2. Terrain and Vegetation

The geography of the wildfire area plays a crucial role in determining how aerial firefighting operations are carried out.

2.2.1. Topography

Steep or rugged terrain makes it difficult for ground crews to reach certain areas, which increases the reliance on aerial firefighting. However, uneven landscapes can create unique airflow patterns (e.g., updrafts, downdrafts), making it more challenging for aircraft to maneuver.

Fires on mountain slopes or canyons may require aerial teams to adjust their tactics, as fire moves differently on inclines—spreading uphill rapidly due to heat rising and slower downhill. Understanding this helps in targeting the head of the fire more effectively.

2.2.2. Vegetation Type and Density

The type of vegetation (e.g., grasslands, brush, dense forests) plays a major role in determining fire behavior and suppression strategies. Dense forest fires may require heavier drops of retardant to penetrate the canopy and reach the flames below, whereas grass fires might only need lighter water drops. Also, the helicopter speed (when water dropping) needs to be adjusted with respect to the vegetation type and density. Usually, the combination of speed of 30-45 KIAS and height of 100 ft above vegetation is used in case of localized forest fire. The speed of 60-70 KIAS and 45 ft would be more efficient for low-level widespread fire (field fire, low bushes fire). (Berčák et al. 2023, FAA 2019)

2.3. Flight Safety and Risk Management

Aerial firefighting is inherently dangerous due to the demanding conditions and need for precision at low altitudes. Ensuring flight safety is a top priority, and several parameters must be managed to reduce risk.

2.3.1. Aircraft Weight and Fuel Load

The payload of an aircraft (water load) directly affects flight performance. Heavier loads decrease aircraft agility, which is crucial when flying through complex terrain. Aircraft must balance the size of their load with the need for safe maneuvering in often volatile environments – e.g. Bell 412 of Czech Police carries Bambi bucker of 1,000 l and Sokol W-3A of Czech Air force usually carries Bambi bucket of 1,590 l.

Fuel management is also a key factor. Aircraft operating in remote areas must carefully plan for fuel availability and make decisions about how much fuel to carry without compromising their fire suppression payload.

2.3.2. Pilot Safety and Training

Pilots are among the most critical elements of an aerial firefighting operation. The challenging nature of wildfire zones requires highly trained pilots who can quickly adapt to changing conditions, such as unpredictable fire behavior or wind shifts.

Training also involves collecting water by 2 manners:

- Hover filling from natural water source - By lowering the bucket into the water. Once submerged, the bucket fills up automatically.
- Ground filling - can be filled on the ground using hoses from a nearby fire truck or hydrant. Or filling from a portable tank

Figure 3*: Sikorsky UH-60 Black Hawk when hover filling from river Labe. Deployed in 2022 for fire fighting in natural park Ceske Svycarsko. (Aktuálně.cz, 2022*)

Besides the need of perfectly coping with the aircraft, and with the aircraft in connection with Bambi bucket, there is also emphasis placed on how to work closely with ground crews and fire commanders to ensure coordination in strategy, as well as practicing emergency protocols to handle unforeseen issues like mechanical failures or sudden weather changes.

According to the best practice, all crew members trained for flights using the Bambi Bucket system must undergo special training once every 12 months, concluding with an examination in the form of a test. This specialized training and testing usually take place at the beginning of the year before the firefighting season starts.

2.3.3. Coordination with Ground Crews

Aerial firefighting is not done in isolation but rather in coordination with ground-based teams. Effective communication and synchronization are essential for success.

Ground crews provide crucial information to aerial teams regarding the location, behavior, and size of the fire. This information helps pilots decide where to drop water. At some situations, drones are deployed for the reconnaissance.

2.3.4. Joint Tactical Decisions

Aerial firefighting is often used to support ground crews by slowing down the fire or protecting specific areas (e.g., homes, critical infrastructure). Pilots must coordinate with ground teams to avoid duplicating efforts or targeting areas already being handled by firefighters on the ground.

Some literature also discusses the influence of cardinal directions and hence the impact of the position of the sun (also varying with the different year seasons).

3. EU PREPAREDNESS

The EU Civil Protection Mechanism is instrumental in ensuring that European countries can effectively collaborate and deploy aerial firefighting helicopters during major wildfire outbreaks, providing a faster and more coordinated firefighting response across borders. The EU Civil Protection Mechanism was established to enhance cooperation in disaster preparedness, prevention, and response. The mechanism enables the European Union (EU) and its member states to pool resources and collaborate effectively during emergencies, such as natural disasters (e.g., wildfires, floods, earthquakes), pandemics, or technological hazards.

Through the mechanism, member countries can request assistance in the form of equipment, personnel, and expertise. The system also facilitates joint disaster preparedness through shared training exercises and the creation of a European response capacity known as the "rescEU" reserve, which includes helicopters, airplanes, and other emergency assets.

The mechanism facilitates training and joint exercises for helicopter pilots and ground crews, ensuring that firefighting units across different countries operate under similar protocols and safety standards. This standardization ensures seamless cooperation when helicopters from various countries are working together.

Also, when a country activates the mechanism, the cost of deploying aerial firefighting helicopters is shared among EU member states. This financial support allows for a more robust and sustained firefighting effort. From 2027 there shall be permanent rescEU fleet – firefighting planes and helicopters financed 100 % by the EU distributed among designated member states. (European Civil Protection and Humanitarian Aid Operations, 2024)

Figure 4*: Photo of a helicopter carrying Bambi bucket for fire-fighting purposes. (European Civil Protection and Humanitarian Aid Operations, 2024)*

4. DISCUSSION

Aerial firefighting from helicopters is a complex and demanding operation due to the unique challenges it presents. The primary complexity arises from the need to operate in difficult terrain, often in remote, mountainous, or heavily forested areas that are not easily accessible by ground crews. Helicopters are invaluable in these situations because of their ability to hover, maneuver in tight spaces, and reach areas where fixed-wing aircraft cannot operate. However, this also requires highly skilled pilots who can navigate hazardous conditions, including low visibility due to smoke, strong winds, and rapidly changing fire behavior.

Another layer of complexity comes from the limited water or fire-retardant capacity of helicopters. They typically carry smaller amounts of water - between 1,000 to 3,000 liters - compared to fixed-wing aircraft, meaning they must make multiple trips between water sources and the fire. This can be time-consuming and requires efficient coordination with ground crews to ensure that drops are made in the right locations at the right time. Additionally, helicopters have limited fuel ranges, meaning they need to refuel frequently, further complicating the logistics of aerial firefighting.

Weather conditions, such as wind speed and temperature, further complicate helicopter operations. Wind can affect the accuracy of water drops, and extreme heat can reduce the helicopter's lift capacity, making it more difficult to carry water or equipment. Pilots must constantly adjust to these conditions, making real-time decisions that affect both the safety and effectiveness of the mission.

5. CONCLUSIONS

The conclusion is that while helicopters are critical for fighting wildfires in difficult-to-reach areas, the complexity of their operations is influenced by terrain, weather, limited payload capacity, and the need for precise coordination with ground teams. Despite these challenges, helicopters remain an essential tool for wildfire suppression, particularly when used in conjunction with other firefighting resources.

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