

جامعة ميدأوشن



كلية الإدارة

قسم / تخصص إدارة الأعمال

Research Title:

The Effect of The Hot And Harsh Environment On The Aircraft Performance

A Study On The Operators In The Kingdom of Saudi Arabia

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Introduction:

The Kingdom of Saudi Arabia is a major player in the world of aviation for a couple of key reasons:

- **Hajj & Umrah:** Millions of Muslims travel to Saudi Arabia each year for Hajj, the pilgrimage obligatory for all Muslims who are able. Umrah, a shorter pilgrimage, also attracts a significant number of visitors. This massive influx of pilgrims necessitates a robust and efficient aviation industry to handle the transportation needs. Saudi Arabia plays a critical role in facilitating these journeys of faith.
- **Geographic Location:** Sitting at the crossroads of three continents – Asia, Africa, and Europe – Saudi Arabia is a natural stopping point for flights traveling between these regions. This prime location makes it a crucial link in global air travel.
- **Economic ambitions:** The country's Vision 2030 plan heavily emphasizes developing their aviation sector. This includes expanding existing airports, building new ones, and establishing Saudi Arabia as a major tourism hub. They're investing heavily to create a modern and efficient aviation infrastructure.

In essence, Saudi Arabia's importance in aviation stems from its religious significance, its geographical advantage, and its future-oriented economic

plans. These factors combine to make it a crucial player in the global aviation landscape.

The safety and efficiency of modern aviation hinge on a delicate balance between cutting-edge technology and meticulous maintenance practices, especially for aircraft operating in hot and harsh environments. These environments, characterized by extreme temperatures, dust, sand, or high humidity, significantly threaten aircraft performance and longevity.

The unrelenting heat can lead to accelerated wear and tear on critical components of the aircraft, while harsh elements like dust and sand exacerbate this effect. Furthermore, hot and humid conditions create a breeding ground for corrosion, jeopardizing the integrity of aircraft modules (fuselage, powerplant, auxiliary power unit, landing gears, wings, and harnesses). These factors, combined with the potential for reduced engine thrust due to sand build-up on the high-pressure compressor (HPC) and high-pressure turbine (HPT). In addition, the increase in the engine exhaust gas temperature (EGT) because of the sand and corrosion build-up and the high outside temperature highlights the critical need for a robust and proactive approach to preventive maintenance.

The Kingdom of Saudi Arabia is in the Middle East region, and the weather environment is considered as hot and harsh due to the extremely high temperature in the summer and the high volume of sand in the air in all seasons

of the year, even in mid-altitude like 20,000 ft, the air is carried of sand. Also, The Kingdom of Saudi Arabia has airports in sea cities, especially the main cities with an international airport like (Jeddah and Dammam). The aircraft ground time is very high, an excellent opportunity for corrosion to build up on the aircraft modules.

This research paper delves into the impacts of hot and harsh environments on aircraft, exploring the detrimental effects on components and overall performance. We will then examine the significance of preventive maintenance programs in mitigating these challenges. By analyzing the benefits of early problem detection, improved safety, and extended aircraft lifespan, this paper aims to shed light on preventive maintenance's crucial role that ensuring aircraft's safe and efficient operation in demanding environments.

Study Problem:

The environment of the Kingdom of Saudi Arabia poses formidable obstacles to aircraft performance and maintenance, with temperatures soaring above 45°C and occasionally surpassing 55°C for prolonged periods annually. These extreme conditions not only test the limits of aircraft systems and materials but also burden maintenance operations substantially. Despite this issue's critical nature, there is a notable shortage of comprehensive studies addressing the specific challenges faced by aviation professionals in the Kingdom of Saudi Arabia's unique environment. The scarcity of research in this area underscores the importance of investigating the impact of such environments on aircraft safety, reliability, and maintenance practices, prompting the need for a detailed examination to enhance operational efficiency and safety in the region.

Moreover, the environment of the Kingdom of Saudi Arabia is characterized by extreme heat and harsh conditions for about six months of the year, with temperatures frequently surpassing 45°C and occasionally exceeding 55°C in certain regions. These extreme environmental conditions pose significant challenges to the region's aircraft performance and maintenance operations. High temperatures can impact aircraft aerodynamics, leading to reduced lift and engine performance, which may affect the overall safety and efficiency of flights. Additionally, the scorching heat can accelerate wear and tear on aircraft components, increasing the frequency of maintenance checks and repairs. The

harsh desert environment, with its dust storms and sand particles, can also contribute to engine abrasion and corrosion. In addition, the high humidity that is very high and reaching approximately 99% in the sea cities is major factor to produce a corrosion in the aircraft parts. necessitating specialized maintenance practices to ensure the longevity and airworthiness of aircraft operating in the Kingdom of Saudi Arabia. Understanding and mitigating the effects of these environmental factors on aircraft performance and maintenance are critical for ensuring the safety and reliability of aviation operations in this challenging region.

The Importance of The Study:

The Kingdom of Saudi Arabia's geographical location in a dry and hot region exposes it to formidable environmental challenges, with certain cities experiencing high humidity levels, further impacting aircraft and engine performance and maintenance procedures. Understanding the specific risks and strains of these extreme conditions on aviation operations is crucial for ensuring the safety and efficiency of aircraft operations in such environments. This study is essential to identify the human factor risk associated with maintenance personnel working under these conditions, ensuring their well-being and the longevity of aircraft components subjected to the harsh climate of the Kingdom of Saudi Arabia. By delving into these intricate dynamics, the study aims to offer insights that can enhance the maintenance protocols and operational strategies tailored to the unique environmental demands of the region, ultimately contributing to safer and more reliable aviation practices. Notably, no previous studies have addressed this specific matter.

Moreover, the Kingdom of Saudi Arabia faces significantly challenging environmental conditions, particularly during the scorching summer months when the maximum temperature can reach 50 to 60 degrees Celsius. These unique environmental characteristics directly impact aircraft operational performance, affecting reliability, serviceability, aircraft availability, and maintenance costs. Failure to address the hot and harsh environment in the

Kingdom of Saudi Arabia can lead to issues such as maintenance difficulties, reduced aircraft availability, and disruptions to flight schedules. This study endeavors to understand and mitigate the impact of the challenging environment, supporting operators in optimizing aircraft performance, on time performance, and flights availability in the Kingdom of Saudi Arabia.

Objectives of The Study:

This study aims to provide an in-depth and meticulous analysis of the numerous and intricate effects of the hot and harsh environment in the Kingdom of Saudi Arabia on various aspects of aviation operations. In this extensive investigation, the study will delve into evaluating the influence of challenging environmental conditions on:

- aircraft performance efficiency
- maintenance costs, and reduced the unscheduled maintenance intervals
- engine deterioration rates and classify the engine mean time before unscheduled removal (MTBUR)
- potential maintenance personnel errors due to the adverse environment
- the durability of aircraft components under such harsh operating conditions
- examining the impact on fuel consumption and emission rates

The continuous endeavors of aircraft operators in the region to develop and implement predictive maintenance strategies accentuate the critical and immediate necessity to delve into and resolve the efficiency challenges commercial aircraft operating in this specific geographical area face. This comprehensive research initiative seeks to offer invaluable insights to enhance aircraft performance, optimize maintenance practices, mitigate environmental

risks, and ultimately elevate operational efficiency in this demanding environment. By thoroughly evaluating the multifaceted effects of the environmental conditions in the Kingdom of Saudi Arabia on aviation operations, this study not only aims to bridge the existing research gaps but also intends to provide innovative solutions to tackle the complexities associated with operating aircraft in such arduous circumstances.

Study Questions:

- What is the specific temperature range experienced at the major airports in the Kingdom of Saudi Arabia, and how does this impact engine thrust, take-off performance, and fuel efficiency?
- How do dust and sandstorms prevalent in the Kingdom of Saudi Arabia affect aircraft's engines?
- Does the humidity level in different regions of the Kingdom of Saudi Arabia contribute to corrosion or other performance issues for aircraft?
- How significantly do hot air and sand/dust at the Kingdom of Saudi Arabia airports reduce an aircraft's thrust-to-weight ratio, affecting take-off weight limitations and runway requirements?
- To what extent does the hot environment decrease fuel efficiency for aircraft operating in the Kingdom of Saudi Arabia, and how does this translate into airline operational costs?
- Do hot and harsh conditions increase the risk of in-flight malfunctions or equipment failures for aircraft operating in the Kingdom of Saudi Arabia?
- What do the Kingdom of Saudi Arabia operators employ the existing preventive maintenance practices to mitigate the effects of harsh environments on aircraft performance?

- Are there opportunities to optimize the preventive maintenance schedules or techniques to address the specific challenges of the Kingdom of Saudi Arabia environment better?
- How do the costs associated with more frequent or specialized maintenance procedures compare to the potential cost savings from preventing performance degradation and equipment failures?
- Do the specific environmental challenges differ between regions within the Kingdom of Saudi Arabia (coastal vs. desert), and how does this impact aircraft performance and maintenance needs?
- How do the effects of hot and harsh environments vary depending on the aircraft type operated by the Kingdom of Saudi Arabia airlines (commercial jets, cargo planes, helicopters)?
- Are there any specific regulations or guidelines from the Kingdom of Saudi Arabia aviation authority regarding aircraft maintenance practices in harsh environments?

Research hypotheses:

The research hypotheses suggest that operating an aircraft in the hot and harsh environment of the Kingdom of Saudi Arabia, in comparison to a clean environment, will substantially impact aircraft performance and operation. It is postulated that maintenance costs may escalate by an estimated 30%, fuel consumption could significantly increase by around 40%, and engine deterioration may rise by approximately 50%. Due to the challenging environmental conditions, maintenance personnel could experience a notable elevation in the risk associated with human factors. This increased risk may contribute to a higher occurrence of maintenance errors and potentially lead to extended maintenance intervals, further impacting aircraft efficiency and safety standards. Combining these factors emphasizes the need to comprehensively evaluate the implications of operating aircraft in such demanding environmental conditions to ensure optimal performance and safety measures are maintained.

Previous studies and theoretical framework:

The essentiality of thoroughly investigating prior studies and constructing a sturdy theoretical framework for this research is underscored by the critical need to expand on established knowledge, bridge existing gaps within current literature, and establish a firm groundwork for the study. Regrettably, despite exhaustive efforts, no previous studies were found that specifically addressed the impact of the hot and harsh environment on aircraft performance in the Kingdom of Saudi Arabia or analogous environmental conditions in other countries. This scarcity of literature clearly emphasizes the novelty and importance of this study in offering pioneering insights and a deeper comprehension of this specialized area of research.

Methodology and research method:

This comprehensive study significantly emphasizes the pivotal objective of meticulously quantifying and critically analyzing the profound impact of the environment on aircraft performance when confronted with the intense heat and harsh conditions prevailing in the Kingdom of Saudi Arabia, known for its extreme temperatures exceeding 40°C. The research is meticulously structured to engage with actual operators in the Kingdom of Saudi Arabia, with a deliberate intention to glean invaluable insights and proffer actionable recommendations to enhance these operators' operational efficiency and preparedness.

By profoundly investigating this unique and challenging environment and its consequential effects on aircraft operations, the study imparts indispensable information that can refine operational strategies and optimize performance under prevailing climatic adversities. This study endeavors to push boundaries in understanding the intricate nuances of aviation operations within such demanding environments, contributing significantly to the overall resilience and effectiveness of aircraft operations.

Study tool:

Data collection is a critical component of any research study, as it provides the foundation for analysis and conclusions. The data collection involved directly engaging proficient operators to gather valuable insights on internal operations within engineering and operational departments. This essay will delve into the methods and tools used to collect data, highlighting the importance of operator engagement in enriching the study.

The first step in the data collection process was to engage proficient operators responsible for internal data collection within their respective departments. These operators played a crucial role in providing firsthand insights and perspectives essential for understanding the intricacies of the operational processes being studied. The study captured a more authentic and comprehensive view of the subject matter by involving those directly involved in data collection daily.

Direct interviews were conducted with the operators' engineering team to gather data effectively. These interviews served as a platform for exchanging information, sharing experiences, and eliciting feedback that was instrumental in shaping the direction of the study. A semi-structured questionnaire was developed as the primary data collection tool, with careful consideration given to its construction and refinement.

The questionnaire underwent a meticulous refinement process involving iterative feedback loops with the operators and other stakeholders. This iterative approach ensured that the questionnaire was tailored to suit the specific needs of the study and was designed to collect valid and reliable data. By incorporating operator feedback and refining the questionnaire, the study enhanced the quality and depth of the data collected.

This study tool facilitated valuable data collection and fostered a sense of collaboration and engagement between the researchers and the operators. By involving the operators in the data collection process, their expertise and insights were leveraged to enrich the study and provide a more nuanced understanding of the subject matter. This participatory approach enhanced the study's credibility and helped build a rapport with the operators, ensuring their continued cooperation and support throughout the research process.

In conclusion, using proficient operators as crucial stakeholders in the data collection proved invaluable in enriching the study. The study gathered relevant and reliable data by directly engaging with operators and utilizing a carefully constructed questionnaire, contributing to a more comprehensive analysis of the subject matter. This approach strengthened the research findings and established a collaborative relationship between the researchers and the operators, paving the way for future cooperation and knowledge-sharing endeavors.

Study Limitation:

Data Availability:

- **Limited Local Data:** Research specific to the Kingdom of Saudi Arabia's climate and aircraft types might be scarce. You might need to rely on data from other hot and arid regions, which may not perfectly match Saudi Arabia's specific conditions.
- **Proprietary Data:** Detailed performance data from airlines might be considered commercially sensitive and challenging to obtain.

Environmental Factors:

- **Variability Within the Kingdom of Saudi Arabia:** Climate conditions can vary across the country. Generalizing results from one region to the entire country might not be accurate.
- **Focus on Temperature:** Hot temperatures are a significant concern, but other factors like sandstorms and high humidity can also impact performance and might not be well-represented in existing research.

Aircraft Factors:

- **Aircraft Model Specificity:** The impact of hot environments can vary depending on the specific aircraft model and engine type. Research might not be directly applicable to your target aircraft fleet.

- Limited Testing Data: Finding data on how specific aircraft models perform under sustained hot and harsh conditions might be challenging.

Operational Factors:

- Flight Procedures: Airline practices like takeoff weight restrictions or adjusted climb profiles in hot weather might not be well-documented or publicly available.
- Maintenance Practices: The impact of more frequent inspections or specific maintenance procedures for hot climates might be difficult to quantify.

General Limitations:

- Cost and Time: Conducting tests or simulations to gather data can be expensive and time-consuming.
- Focus on Averages: Research might focus on average performance impacts, but real-world scenarios can involve various factors, leading to more variable outcomes.

Here are some suggestions to mitigate these limitations:

- Collaboration: Consider contacting the Kingdom of Saudi Arabian airlines, aviation authorities, or research institutions to see if they have relevant data.

- Focus on Available Data: While specific Saudi data might be limited, use data from other hot regions, acknowledging the potential for geographical variations.
- Case Studies: If detailed performance data is unavailable, consider case studies that analyze specific hot weather operational challenges faced by airlines.
- Expert Interviews: Talk to the Kingdom of Saudi Arabian pilots, mechanics, and airworthiness experts to gain practical insights.
- Focus on Mitigation Strategies: Even if quantifying performance impacts is difficult, research existing strategies used by airlines to mitigate hot weather effects on aircraft in other regions.

List of references and preliminary sources:

- The Maintenance Planning Document (MPD) is a crucial publication issued by the type certificate holder within the aviation industry. This document is a comprehensive compilation of all the requirements that must be followed and implemented in the Aircraft Maintenance Program. By outlining these requirements, the MPD plays a vital role in the safety and airworthiness of the aircraft throughout its service life.

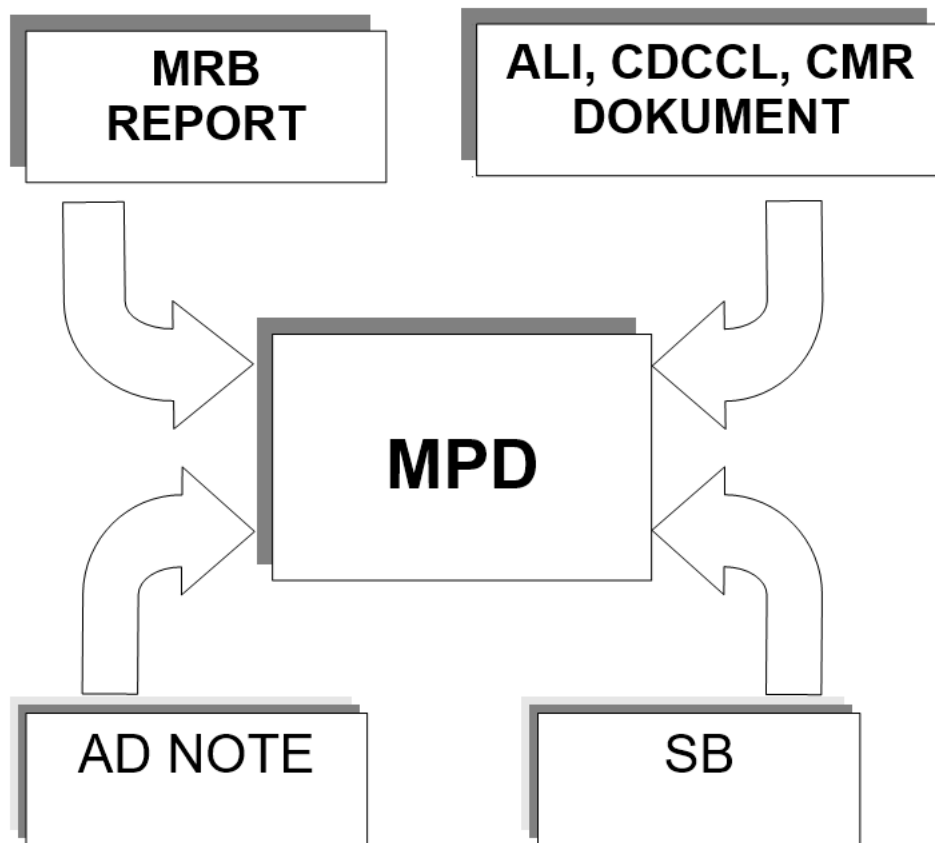
One of the critical aspects of the MPD is its connection and integration with other essential manuals and publications, such as the Aircraft Maintenance Manual (AMM) and Structure Repair Manual (SRM), which the manufacturer also issues. The MPD, along with these related documents, collectively provides detailed guidelines and instructions for the maintenance and repair of the aircraft.

To facilitate efficient referencing and task identification, the MPD and associated manuals typically utilize the ATA 100/AMTOSS system of task numbering. This standardized system allows maintenance personnel to quickly locate specific tasks and procedures within the various manuals, ensuring consistency and clarity in the maintenance process.

Overall, the Maintenance Planning Document serves as a crucial tool for operators, maintenance personnel, and regulatory authorities in guaranteeing aircraft Overall, the Maintenance Planning Document

serves as a crucial tool for operators, maintenance personnel, and regulatory authorities in guaranteeing aircraft's proper maintenance and airworthiness. Through its detailed requirements and linkages with other manuals, the MPD plays a vital role in safeguarding the safety and dependability of aircraft operations, thereby significantly influencing the overall prosperity and longevity of the aviation sector's proper maintenance and airworthiness. Through its detailed requirements and linkages with other manuals, the MPD plays a vital role in the safety and dependability of aircraft operations, thereby significantly influencing the overall prosperity and longevity of the aviation sector. refer to EASA Part M - AMC M.A.302(d) Aircraft maintenance program.

Integration of sources in MPD:



- Mean Time Between Failure (MTBF) is a crucial concept in reliability engineering and analysis. It refers to the average time interval between occurrences of failures in a system or a subsystem. In other words, MTBF estimates how long a system is expected to operate without experiencing a failure. MTBF is a key metric used by engineers and designers to assess the reliability of a system. A higher MTBF value indicates that a system is more reliable and has a lower probability of failure within a given time frame. On the other hand, a lower MTBF value suggests that the system is more prone to failures and may require more frequent maintenance and repair. It is important to note that MTBF does not guarantee how long a

system will operate without failure. It is an average estimation based on historical data and analysis. Factors such as operating conditions, environmental factors, quality of components, and maintenance practices can all influence the actual reliability of a system.

In contrast to MTBF, Mean Time Between Outages (MTBO) is a term more commonly used in the context of services and facilities. While MTBF focuses on the reliability of hardware systems, MTBO measures the average time interval between service outages or disruptions. For example, in telecommunications or utility services, MTBO provides insights into a service's overall availability and uptime.

Both MTBF and MTBO are essential metrics for assessing the reliability and availability of systems and services. By understanding and monitoring these metrics, engineers and operators can make informed decisions to improve reliability, minimize downtime, and enhance overall system performance. Refer to FAA-HDBK-006D October 8, 2020

- The hot and harsh environment in aviation industries refers to conditions that pose significant challenges and potential hazards to both aircraft and personnel. These conditions can arise from various factors, such as extreme temperatures, high altitudes, rugged terrain, and harsh weather patterns. Understanding and effectively managing hot and harsh

environments is essential for ensuring aviation operations' safety, efficiency, and success.

One key aspect of a hot environment in aviation is high temperatures. Extreme heat can adversely affect aircraft systems, engines, and components, leading to decreased performance and potential malfunctions. Heat can also impact the operational capabilities of personnel, as working in sweltering conditions can be physically taxing and increase the risk of heat-related illnesses. Proper cooling systems and maintenance procedures are critical for mitigating the effects of high temperatures in aviation environments.

Additionally, a harsh environment in aviation can be characterized by challenging terrain or weather conditions. For example, mountainous regions, deserts, and Arctic environments present unique challenges to aircraft operations due to multiple factors, such as limited navigational aids, unpredictable weather patterns, and extreme wind conditions. Pilots and maintenance personnel must be well-trained and equipped to handle these challenges effectively.

Proper planning and risk management are essential in navigating hot and harsh environments in aviation. It includes conducting thorough weather assessments, considering the limitations of aircraft and personnel, and implementing contingency plans to address unforeseen circumstances.

Regular maintenance and inspections of aircraft systems are crucial for detecting and addressing potential issues in advance.

In conclusion, a hot and harsh environment in aviation industries encompasses a range of challenging conditions that require careful attention and proactive management. Aviation professionals can ensure safe and successful operations in diverse and demanding environments by understanding the risks and implementing mitigation measures. Refer to the email received by Saudia Airlines Power plant engineer.

- The definition of on-time performance OTP On-time performance (OTP) is a widely used metric to measure punctuality across various public transportation systems, most notably aviation. It essentially tells how well a service adheres to its published schedule. It compares the number of on-time arrivals or departures with the total number.

An arrival or departure is typically considered on time if it occurs within a specific window (usually 15 minutes) of the published schedule. This standardized approach allows for fair comparisons between different service providers.

OTP is generally expressed as a percentage. A higher percentage signifies a more reliable service with fewer delays.

It does not necessarily reflect the entire journey experience, such as delays within the travel itself. Refer to the email received by the Saudia Airlines' Power plant engineer.