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Death of an Airline: Aviation Safety Investigation

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Abstract

This paper analyzes the Nation Air airline crash through the Human Factor Analysis and Safety Classification (HFACS) model, designed for aircraft accident investigations. The crash of the McDonnell Douglas DC-8-61, registered C-GMXQ, near Jeddah-King Abdulaziz International Airport (JED), resulted from a series of human errors and oversights, rather than inherent design flaws. Despite established protocols, the crew did not abort take-off below the decision speed (V1), nor did they employ the emergency checklist after take-off. Additionally, significant miscommunications occurred between the crew and air traffic control (ATC), exacerbated by the heavy Hajj season traffic.

Maintenance practices also contributed to the accident. The maintenance team, lacking formal Aircraft Maintenance Engineer (AME) licenses, performed substandard checks. Tire pressures were not adequately documented, and unsafe supervision led to critical oversights. The aircraft's maintenance records were incomplete, and there was a lack of accountability and proper training. Furthermore, fire hazards related to the underinflated tires and magnesium alloy rims were not effectively managed.

This investigation highlights the necessity for stringent adherence to safety protocols, comprehensive training, and effective communication within the aviation industry to prevent similar tragedies. Recommendations for improved maintenance practices and enhanced crew resource management are also provided.

Keywords: Aviation, Safety, DC-8, ATC, AME, JED

1. Introduction

Incident Overview

A McDonnell Douglas DC-8-61 passenger aircraft, registered as C-GMXQ, was destroyed in an accident near Jeddah-King Abdulaziz International Airport (JED), Saudi Arabia. Tragically, all 261 individuals on board perished [1].

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Figure 1: NationAir DC-8-61

Flight Details

The flight details of NationAir is listed in Table 1 below.

In summary, it was observed that no pressure was being exerted on the centerpiece, indicating a potential area for improvement in the load distribution. The center piece did not contribute significantly to supporting the modules in the stack, as the top nub was found to be too short. Consequently, the centerpiece functioned merely as a spacer rather than providing substantial structural support.

Table 1: Flight Details

Status	Final
Date	Thursday, 11 July 1991
Time	08:38
Aircraft Type	McDonnell Douglas DC-8-61
Operating for	Nigeria Airways
Leased from	Nationair
Registration	C-GMXQ
Construction No.	45982 / 345
First Flight	1968
Total Airframe Hours	49,318
Total Cycles	30,173
Engines	4 Pratt & Whitney JT3D-3B (Q)
Crew	Fatalities: 14 / Occupants: 14
Passengers	Fatalities: 247 / Occupants: 247

Total	Fatalities: 261 / Occupants: 261
Aircraft Damage	Destroyed
Aircraft Fate	Written off (damaged beyond repair)
Location	2.8 km (1.8 miles) from Jeddah-King Abdulaziz International Airport (JED), Saudi Arabia
Phase	Approach (APR)
Flight Nature	International Non-Scheduled Passenger
Departure Airport	Jeddah-King Abdulaziz International Airport (JED/OEJN), Saudi Arabia
Destination Airport	Sokoto Airport (SKO/DNSO), Nigeria
Flight Number	2120

Aircraft Ownership and Operation

The DC-8 jetliner was owned by the Canadian airline NationAir, which operated the aircraft on behalf of Nigeria Airways to transport Hajj pilgrims between Nigeria and Saudi Arabia. Nigeria Airways Flight 2120 departed from Jeddah's Runway 34L at 08:28, destined for Sokoto (SKO), Nigeria.

Pre-Flight and Initial Anomalies

Approximately 15 seconds post-brake release, an oscillating sound was detected in the cockpit. The flight engineer queried, "What's that?" to which the first officer responded, "We got a flat tire, you figure?" The oscillating sound recurred shortly thereafter. The captain asked the first officer, "You're not leaning on the brakes, eh?" The first officer confirmed, "No, I'm not. I got my feet on the bottom of the rudder." At this juncture, the aircraft had accelerated to approximately 80 knots. Runway marks indicated the initial breakup of the No.1 wheel, and rubber deposits from the deflated No.2 tire were also observed [2].

Takeoff and Initial Flight

At 28 seconds after brake release, a speed of 90 knots was called out by the captain and acknowledged by the first officer. The captain announced V1 approximately 45 seconds post-brake release. Two seconds later, the first officer remarked on a "sort of a shimmy." The captain commanded "rotate" at 51 seconds, and the aircraft subsequently lifted off the runway. Eyewitnesses reported observing flames near the left main landing gear, which extinguished once the undercarriage was retracted.

Flight Anomalies and Communication Challenges

Over the ensuing three minutes, multiple system anomalies were observed, including pressurization failure, a gear unsafe light, and hydraulic loss. The captain requested a level-off at 2000 feet due to the pressurization issue. During his radio communication, he mistakenly used the callsign "NationAir 2120" instead of "Nigerian 2120." This led the air traffic controller to misinterpret the transmission as originating from a Saudi flight returning to Jeddah and subsequently cleared the aircraft to 3000 feet.

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This misunderstanding persisted for three minutes, with the controller assuming all communications were from the Saudi flight [1].

Emergency Declaration and Final Moments

Approximately four minutes post-brake release, the captain reported leveling at 3000 feet, followed by the first officer declaring an emergency, citing suspected blown tires. As the aircraft continued a downwind heading, a flight attendant reported severe smoke in the rear cabin. Shortly after, the first officer stated, "I've got no ailerons," to which the captain responded, "OK, hang on, I've got it." This was the final entry on the CVR, which ceased recording at 08:33:33 [2].

Fire and Structural Destruction

During the downwind and base legs, the cabin floor above the wheel wells was consumed by fire, leading to cabin furnishing sagging into the wheel wells. Upon probable gear extension at 11 miles on final approach, the fire had compromised the seat harness, causing the first body to fall out. Subsequent structural destruction enabled further body and seat assembly losses. Despite significant airframe damage, the aircraft remained controllable.

Figure 2: NationAir Flight 2120 Crash Site

Crash and Aftermath

At eight minutes post-brake release and ten miles from the runway, the captain declared an emergency for the third time, stating, "Nigeria 2120 declaring an emergency, we are on fire, we are on fire, we are returning to base immediately." The aircraft descended nose-down and impacted the ground 9,433 feet (2,875 meters) short of the runway at 08:38 [2].

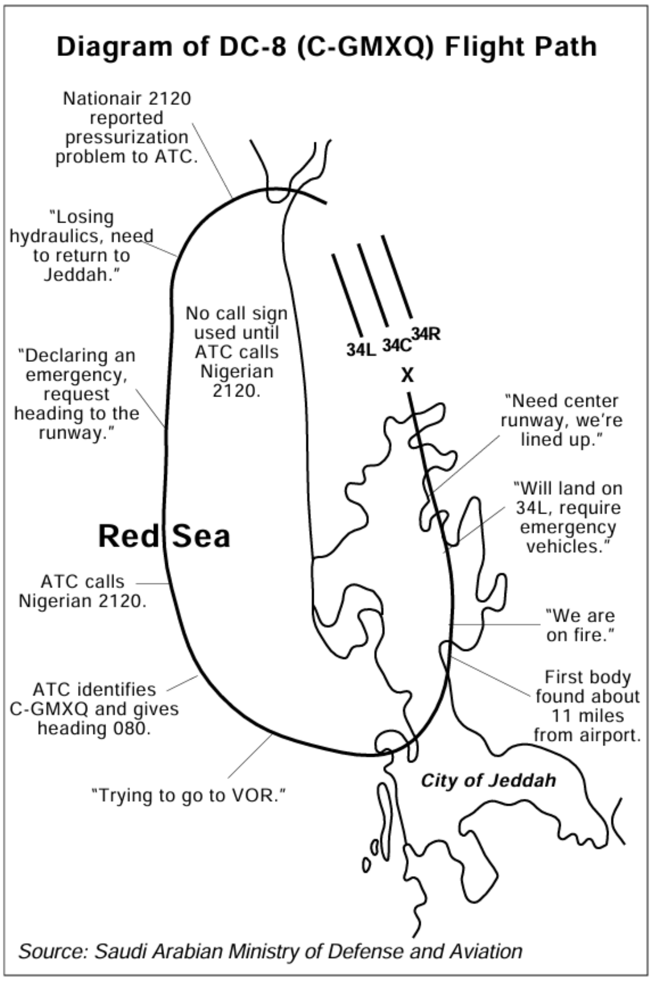

Figure 3: NationAir Flight 2120 flight path [1]

2. Findings

(A) Maintenance Practices

During the deployment, three distinct checklists were employed:

a) Transit Check: A four-page checklist utilized whenever a turnaround was less than four hours. This checklist mandated an inspection of the tires for their condition but did not specifically require checking the tire pressure.

b) Preflight Check: An eleven-page checklist conducted on the first flight of each day and whenever a stop exceeded four hours. This checklist required a tire pressure check and specified the necessary pressure without any tolerance. However, there was no designated space to record the pressures, and only one spot to initial that all checks had been completed.

c) A-Check: A twenty-page checklist performed every 125 flight hours. This comprehensive check required the recording of each tire's pressure in a designated block and a sign-off for each entry. Records indicate that this A-check was conducted in Accra on July 6, 32.5 hours before it was due. At the time of the accident, 8.2 hours remained before the next A-check was required, and only the twentieth-page certification was pending completion. The company did not provide for a progressive A-check.

A forensic examination of the A-check sheet revealed that the pressure for tire #2 had been recorded as 160 psi (while the required pressure was 180 psi), and the pressure for tire #4 was recorded as 155 psi. Both of these entries had been altered to reflect 180 psi and were signed off by the A&P mechanic. The remaining tire pressures were signed off by the avionics specialist. Maintenance records submitted to the company lacked specific flight details, such as aircraft registration and hours completed in the header section.

Maintenance records were often completed at the end of the day, with checklists filled out from memory and signed later. Not all maintenance defects and actions were recorded in the aircraft journey log. Furthermore, not all maintenance records for the deployment could be located at the maintenance control center following the accident.

The flight engineers habitually accepted the aircraft for subsequent flights without verifying the completion of the required checks. They operated under the assumption that all checks had been properly conducted. There existed some ambiguity regarding the correct procedure for documenting tire pressure irregularities.

Specifically, there was uncertainty as to whether the mechanic should:

1. Record the low pressure and subsequently top it up.
2. Omit recording the low pressure and only document the corrected pressure.
3. Record the low pressure, then cross it out and document the corrected pressure.

The check sheets provided no guidance on the appropriate procedure. The lead mechanic reported the aircraft's condition to the company via telephone on a daily basis.

(B) Engineering & Technical Operations

Tire Pressure and Maintenance Protocols

The company's checklists stipulated a main tire pressure of 180 psi with no tolerance. They also specified that if the main tire pressure fell below 146 psi, the tire was to be replaced. Additionally, if a tire was flat and had been taxied while flat, the axle mate tire was also required to be replaced.

The Douglas DC-8 Maintenance Manual provides a tire inflation chart that correlates tire pressures with the aircraft's gross weight. The chart allows a tolerance of +5 -0 psi. At a gross weight of 325,000 lbs., the tire pressure should be 195 psi. At the recorded gross weight of the aircraft, the minimum tire pressure should have been 183 psi. The chart permits the operator to maintain tire pressure at the maximum gross weight level even at lower gross weights. At 180 psi, the maximum allowable gross weight would have been 310,000 lbs., but the recorded takeoff weight was 313,493 lbs.

The recommended guidelines for tire replacement are as follows:

1. If the pressure is less than 15 psi below the required level, add air and record (166 psi+).

2. If the pressure is more than 15 psi, but less than 30 psi below the required level, replace the tire (151 psi to 165 psi).
3. If the pressure is more than 30 psi below the required level, replace both tires on the axle (150 psi-).

The pressures of tire #2 and tire #4 were recorded as 160 psi and 155 psi, respectively. According to the recommended guidelines, both tires should have been replaced, but they were not.

Aircraft Tire Characteristics and Maintenance

The following information is derived from a Goodyear publication titled "Aircraft Tires Care and Maintenance":

Aircraft tires must support significant weight and operate at high speeds, making them subject to unique demands. An average-sized aircraft tire consists of 50% rubber, 45% fabric, and 5% steel by weight. These tires can lose up to 5% of their inflated pressure per day. Heat build-up is a critical concern, primarily generated by the traction wave at the rear of a rotating tire as it regains shape. Underinflation is particularly hazardous as it transfers the load to the adjacent tire, increasing deflection and heat generation. Nylon, a common material in aircraft tires, melts at just over 200°C (400°F) and loses 50% of its tensile strength at that temperature. A tire underinflated by just 10% loses 90% of its performance capability. The aircraft had flown seven times between Accra and Jeddah over three days (8-10 July 1991) with low-pressure tires #2 and #4, leading to a daily loss of 5% inflation pressure.

Material Composition and Fire Hazards

Aircraft tire rims in the early 1990s were made from magnesium alloy, chosen for its low density (two-thirds that of aluminum) and superior corrosion resistance. However, magnesium is highly combustible, posing significant hazards. Aircraft fluid lines are typically composed of metal tubing or flexible hoses carrying mineral oil-based hydraulic fluid, which is volatile and highly flammable. The DC-8's integral fuel tanks are constructed from aluminum sheet metal with internal baffles. The central fuel tank is located ahead of the main landing gear well. The aircraft was not equipped with tire-pressure or overheating warning sensors, which could have provided additional cues for decision-making.

Accident Sequence and Consequences

During takeoff, the underinflated #1 and #2 axle mate tires ruptured and ignited due to the scraping of magnesium alloy rims on the runway. Upon retraction, the fire contacted hydraulic fluid lines and electrical wiring, with the volatile mineral oil exacerbating the fire. The fire compromised the aircraft's structure by melting the aluminum alloy and penetrating the central fuel tank, igniting the fuel. The fire temperature exceeded 650°C, the melting point of aluminum. The fire spread rapidly throughout the aircraft due to the blowtorch effect provided by high-speed air.

The fire caused a loss of pressurization and destroyed hydraulic lines and electrical wiring, leading to the failure of critical flight controls such as ailerons, flaps, air brakes, and elevators, ultimately resulting in the crash.

(C) Air Traffic Control

During the early 1990s, Jeddah's King Abdul-Aziz International Airport was not among the busiest airports. However, there was a significant increase in air traffic during the Hajj season. Air traffic control (ATC) officers were not accustomed to handling such a high volume of commercial and chartered aircraft simultaneously.

The ATC officer acknowledged the captain's request without verifying the call sign. Consequently, when the captain requested to level off at 2000 feet due to a pressurization issue, the ATC officer mistakenly assumed the communication was from the Saudi 738 aircraft, which had a similar pressurization problem, and instead instructed them to level off at 3000 feet. This miscommunication constituted a breach of ATC regulations as defined by the International Civil Aviation Organization (ICAO).

Furthermore, the ATC officer did not inform the captain about the blown tires, despite having a visual reference of the aircraft on the runway. The ATC officer failed to provide the captain with essential information.

(D) Human Factors

To analyze human factors, the Human Factor Analysis and Safety Classification (HFACS) model was employed, which is primarily designed for aircraft accident investigation. The Nation Air airline crash was not solely attributable to the design flaws inherent in the DC-8 aircraft. Investigations and findings indicate that the crash resulted from a long chain of human errors and oversights. While the ultimate responsibility for the safety of aircraft operations rests with the airline and the pilot, this responsibility is compromised when preconditions, such as mismanagement within the airline company, are present.

As previously mentioned, unsafe acts were committed by maintenance personnel and flight crew. The maintenance team for the deployment was selected by the lead mechanic and comprised himself, an avionics specialist, and an A&P mechanic. Although all three individuals were experienced with aircraft, none held an Aircraft Maintenance Engineer’s (AME) license.

Despite the flight engineers holding AME licenses, they did not oversee or perform any of the maintenance tasks. There were improper maintenance checks and a failure to adhere to properly written maintenance procedures. The preconditions leading to these unsafe acts included the failure to conduct proper independent verification of the maintenance performed. Additionally, there was inadequate training for maintenance procedures, as evidenced by the fact that the lead mechanic received only on-the-job training without any formal instruction.

Moreover, there was an absence of adequate crew resource management to address failures, and supervision was unsafe. Not all maintenance records were logged in the aircraft journey log. Such practices reflect a lack of supervisory oversight and the absence of proper procedures to enforce rules and regulations. These issues can be traced back to organizational failures. According to Nation Air, the deployment team for servicing was ill-defined and fragmented. This is underscored by the fact that the operator's maintenance and operating documentation for the DC-8 did not contain sufficient information for the proper maintenance and operation of aircraft tires. The maintenance team was outsourced to a third party, making it difficult for Nation Air to implement proper delegation of authority or management practices. There was a lack of formal accountability for actions taken by the third party. These human factors, at various levels of classification, were instrumental in the DC-8 air crash.

(E) Aircraft Operations

The decision to abort take-off due to an emergency is typically executed only if the aircraft's speed is below the take-off decision speed, known as V1. In this incident, the crew became aware of unusual symptoms within seconds of the take-off roll, at an airspeed of approximately 60 knots—well below V1, at which point the take-off could have been aborted. This action was inconsistent with the company's standard operating procedures and Canadian aviation regulations. Furthermore, the crew did not utilize the emergency checklist after becoming airborne.

3. Conclusions

Based on the findings and analysis of the Nation Air airline crash and the information provided, the following aviation safety recommendations are proposed:

1. Strict Adherence to Safety Protocols:
    - Ensure that all flight crew strictly adhere to standard operating procedures, including the decision to abort take-off if unusual symptoms are detected below V1 speed. Reinforce the use of emergency checklists in-flight emergencies.
2. Enhanced Communication and Verification:
    - Implement a robust communication protocol between flight crew and air traffic control (ATC). Verify call signs to avoid miscommunication and ensure essential information, such as aircraft condition and anomalies, is promptly relayed to the crew.
3. Improved Maintenance Procedures:
    - Mandate that all maintenance personnel hold the necessary Aircraft Maintenance Engineer (AME) licenses and receive comprehensive formal training. Establish procedures for independent verification of maintenance tasks to prevent oversights and ensure proper documentation.
4. Regular Audits and Inspections:
    - Conduct regular audits and inspections of maintenance records and practices to ensure compliance with established procedures. Implement strict accountability measures for maintenance actions, including those performed by third-party contractors.
5. Training and Crew Resource Management (CRM):
    - Provide extensive training on maintenance procedures and emergency protocols. Enhance crew resource management (CRM) to improve coordination and decision-making during emergencies. Ensure that all crew members are familiar with and can execute CRM principles effectively.
6. Installation of Safety Sensors:
    - Equip aircraft with tire-pressure and overheating warning sensors to provide real-time alerts to the crew. These sensors can help identify potential issues early and prevent accidents.

7. Fire Hazard Mitigation:
    - Implement measures to mitigate fire hazards associated with aircraft materials, such as magnesium alloy rims and volatile hydraulic fluids. Ensure that materials used in aircraft construction meet the highest safety standards and are regularly inspected for potential risks.
8. Documentation and Record-Keeping:
    - Ensure that all maintenance activities are thoroughly documented and recorded in the aircraft journey log. Maintain complete and accurate records to facilitate post-accident investigations and continuous safety improvements.
9. Clear Guidelines and Procedures:
    - Develop and disseminate clear guidelines and procedures for all maintenance activities, including tire pressure checks and adjustments. Ensure that maintenance personnel understand and follow these procedures accurately.
10. Organizational Accountability:
    - Establish a culture of accountability within the airline and its contractors. Ensure that all organizational levels, from management to maintenance personnel, are committed to maintaining the highest safety standards and following established protocols.

Implementing these recommendations can significantly enhance aviation safety, reduce the risk of accidents, and improve overall operational efficiency within the aviation industry.

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