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A Study on Maintenance Errors with Emphasis on Non Technical Skills in Aircraft Maintenance By

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Abstract

In the field of aviation, maintenance of aircraft is an important process which has a direct bearing in ensuring safe operations. Aircraft maintenance personnel mainly comprise of aeronautical engineers as well as Aircraft Maintenance Technicians (AMTs) who are imparted with requisite knowledge and technical skills for carrying out aircraft maintenance. The maintenance of aircraft is mainly based on preventive maintenance concept which involves various scheduled activities to be carried out by maintenance personnel at regular time periods as laid down by the OEM (Original Equipment Manufacturer). In spite of carrying out periodical maintenance of highly reliable modern generation aircraft, there is inherent risk in aviation as ‘‘To err is Human” is an unavoidable aspect in maintenance practices. The consequences of any error on the part of maintenance personnel can be catastrophic resulting in loss of aircrew, passengers and may be disastrous depending on the nature of accident. In most of the aircraft accidents, investigations have revealed that the main causes are attributable to lapses in maintenance activities. Such lapses cannot be eliminated completely as per Murphy’s Law which says that “If anything can go wrong, it will”. However, study on behavioural aspects of maintenance personnel and regular audits of workplace have revealed the criticality of Non-Technical Skills (NTS) such as communication, situational awareness, problem solving and adaptability to working under stress. These skills are as vital as the ‘hard’ technical skills which are required to be developed by the maintenance personnel to ensure operational and maintenance safety at workplace.

1. Introduction

The errors caused by the maintenance personnel while carrying out aircraft inspection and maintenance are usually referred to as 'Maintenance Errors or "Human Errors related to Maintenance". In military aviation, every mission undertaken during peace or war is mainly reliant on the technical excellence of the maintenance personnel who work as a team. In case of any deviation from the correct maintenance practices may result in aircraft accidents. The study on majority of accidents are attributed to maintenance errors which includes short cuts, failure to carry out laid down checks, failure to secure components after installation, failure to lock panels after servicing, incorrect adjustments, lack of knowledge or experiences and these errors get repeated after sometime period. In order to reduce the maintenance errors, it is essential to understand the human factors (HF) which involves the understanding of capabilities and limitations of maintenance personnel and various other aspects affecting their performance. The aim of this paper is to study the influence of human factors related to maintenance errors with emphasis on non technical skills in aviation maintenance by analysing few case studies highlighting how the causes or contributing factors manifests as maintenance error resulting into aircraft accident. An insight to non-technical skills by imparting Human Factors training to maintenance personnel would contribute to reliable and effective performance of personnel in aviation industry.

2. Brief on Types of Errors

The maintenance errors can be broadly categorised as Unintentional and Intentional. An unintentional error is an unintentional deviation from accuracy or laid down procedures which may be caused inadvertently due to various reasons like memory lapses, wrong assumptions, incorrect judgement or insufficient knowledge while working on aircraft. For example, an AME (Aircraft Maintenance Engineer) refers to task card for the torque value required for tightening propeller bolts and unintentionally transposed the actual value in Kgf-m instead of N-m units. Likewise, referring to task card which is not updated or using gauges which are not calibrated or following norms set by seniors are purely unintentional. However, an error committed knowingly or intentionally by not following the laid down standard operating procedures (SOPs) is treated as gross violation of act and it amounts to act of sabotage in military parlance. Furthermore, a clearly observable occurrence due to specific action of an individual is referred as an active error. There are latent errors which remain dormant and pertain to organisational issues which get noticed only after it results in the damage of aircraft, equipment, or personnel. For example, in one of the incidents, the pilot experiences nose wheel tyre burst in a fighter aircraft after touchdown. However, he manages to control the aircraft by putting the nose wheel brake OFF which otherwise should be kept ON for effective braking through inertia

pick up system. The tyre burst is an active error in this case and the latent error was due to poor tyre condition for which the wear and tear criteria in inspection card was not amended even after the organisation had switched over from one make of tyre to another make as criteria for wear and tear of tyres was different as per OEM[1].

3. Dirty Dozen (Common Causes Contributing to Aircraft Accidents and Incidents)

It is imperative to understand the human factors in the field of aviation and numerous studies have been carried out by various agencies world over to reduce the accidents by instituting remedial measures based on the investigations. One such analysis carried out by Gordon Dupont, an employee of Transport Canada revealed that there are twelve preconditions which contribute to the errors in aircraft maintenance, known as the Dupont's "Dirty Dozen" [1][2]. These main causes of human errors or "Dirty Dozen" are lack of Communication, Complacency, lack of knowledge, distraction, lack of teamwork, fatigue, lack of resources, pressure, lack of assertiveness, stress, lack of awareness and norms. These are self explanatory and well understood by the maintenance personnel. The foremost cause related to communication both verbal and non-verbal is essential in exchange of correct information between maintenance staff and maintaining proper documentation while working on aircraft [3].In order to eliminate human errors, it is essential to carry out critical analysis of any occurrence to find out answers to 'what happened', 'why it happened' and 'how it happened'.In this regard, several tools for investigation have been developed specifically for airline maintenance. One such tool of Boeing's Maintenance Error Decision Aid (MEDA) includes a comprehensive list of various factors like poor working environment, fatigue, incorrect information, stringent time lines to accomplish task time and many other factors which provide clues to the investigator in establishing the most probable cause of the maintenance error.[4] The European Aircraft Dispatch and Maintenance Safety System (ADAMS) developed subsequently facilitated the investigator to consider the psychological behavioural aspects of maintenance personnel such as lack of situational awareness, preoccupation, mental state in addition to various contributing factors in arriving at the root cause[5]. The Human Factors Analysis and Classification System (HFACS) based on concept of latent and active failures was developed to analyse the causes of accidents in US military. Further, HFACS was modified by US Navy to develop a methodology as HFACS-ME which helped investigator to find out supervisory lapses [6].

4. Emphasis on 'Non Technical Skills'

After critical analysis of the "Dirty Dozen" causes, it is pertinent that it is impossible to achieve zero-error syndrome in aircraft maintenance. However, efforts can be made to minimise the human errors related to aircraft maintenance by ensuring that associated maintenance personnel are proficient in both "technical skills" (update on technical know-how of aircraft systems and functioning of aero engine and various sub-systems, analysing of snags) and other "Non Technical Skills" which complement engineering skills. These non technical skills such as communication, problem

solving, situational awareness, teamwork, managing stress and coping with fatigue are basically cognitive, social and self management skills are essential for the maintenance personnel working on aircraft maintenance to ensure safe and effective task performance. Any shortcoming in non-technical skills increases the possibility of maintenance errors which in turn would result in a mishap at workplace or accident. In this regard, there is need for better understanding of 'Non Technical skills' and implementation of suitable training programs for developing non-technical skills for aircraft maintenance engineers/technicians would certainly enhance their performance.[7][8]

5. Case Studies on Maintenance Errors

There are numerous cases of aircraft accidents and incidents which are attributable to the maintenance problems due to human factors. The details of such cases can be obtained from various open sources like website of FAA, AAIB (www.dft.gov.uk/aaib), ICAO, EASA, CAA, ATA as listed under resources and further reading. This paper intends to highlight the maintenance errors resulting in aircraft accidents and incidents. In this regard, aircraft accidents and incidents database of NTSB was browsed. The database was searched to obtain details of accidents occurring between 2015 and 2019 only (year 2020 was excluded as sufficient data was not available due to Covid-19 pandemic situation). Further, the scope of analysis was limited to maintenance-related accidents involving 'Boeing' aircraft. To obtain the required result set, the field "narrative cause" was used for boolean "OR" operation. Relevant terms like *maintenance*, *servicing*, *installation*, *rigging*, *modification*, *service bulletin*, *repair*, *airworthiness directive*, *overhaul* associated with aircraft maintenance were used. The result was saved in Microsoft Excel format and duplicates were removed after scrutiny.

The figure (below) depicts the year wise total number of aircraft accidents versus number of accidents related to maintenance errors. It has been observed that the number of accidents related to maintenance errors have been reducing considerably which indicates that there has been effective monitoring of incidents and countermeasures instituted by all concerned. For highlighting the importance of 'Non Technical skills' in all maintenance related accidents/incidents, the data was further filtered for the same period for 'Boeing' make only which resulted in five cases. A brief analysis of these accidents/incidents as case studies is described in succeeding paragraphs reveal that the maintenance related errors can never be eliminated completely and requires continuous and concerted efforts in improving the performance of maintenance personnel by implementing suitable 'non-technical training program' after carrying out the TNA (Training Need Analysis) of the maintenance staff by the respective organisation.

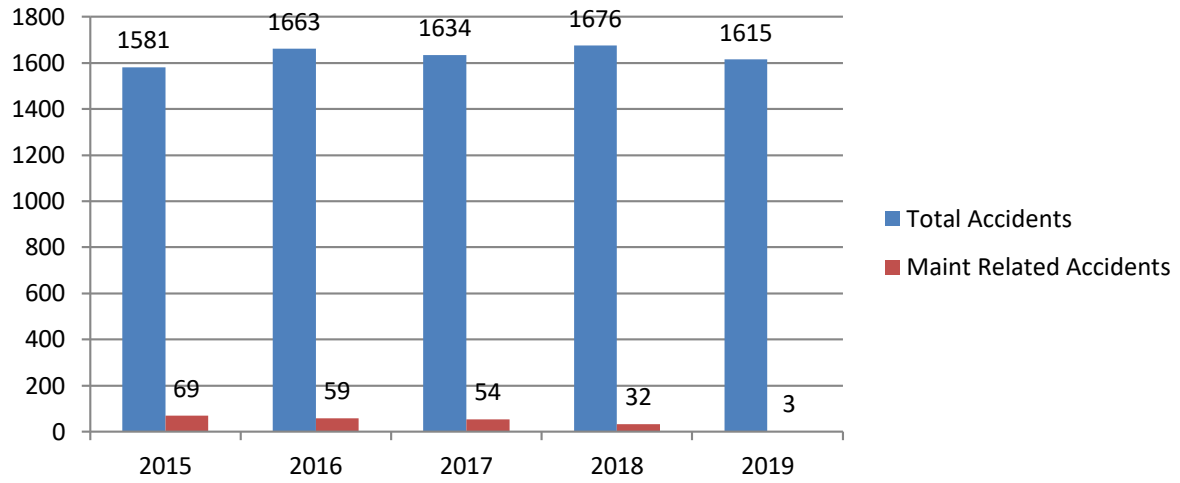

Figure: Summary of total and maintenance related accidents between 2015 and 2019[NTSB]

5.1 Case 1

Occurrence: On 02 Oct 2015, a Boeing aircraft, operated by Delta Air Lines, the pilot reported loud bang followed by decrease in engine rpm of No. 3 engine and increase in jet pipe temperature after about one hour of flight. This was followed by loss of power from the same engine. The pilot switched off the No. 3 engine and declared an emergency to Russian ATC.

Findings: The loss of power in No. 3 engine in-flight was caused by Internal Object Damage (IOD) which was caused by wearing off of a vane hook in the low-pressure turbine (LPT) which got sucked into third stage turbine blades and caused extensive damage to LPT module. The cause was attributable to inadequate overhaul inspection and instructions at the time of overhaul of the LPT module.

Associated Dirty Dozen Cause(s): The associated causes may be attributed to lack of communication, or complacency, or distraction, or fatigue, or stress and not following the laid down instructions as per norms might have led to improper inspection or repair by maintenance personnel.

5.2 Case 2

Occurrence: On 07 May 2018, at zero hours, a Boeing aircraft of Southwest Airlines, was hit by a maintenance truck belonging to Southwest Airlines when the aircraft was being marshalled into its parking bay at Baltimore International Airport. There were no injuries to passengers and crew-members. However, the airplane suffered from substantial damage.

Findings: The maintenance truck driver failed to observe safety precautions while manoeuvring near an aircraft that was being marshalled. This resulted in the truck colliding with the taxiing aircraft.

Associated Dirty Dozen Cause(s): The associated causes may be attributed to lack of communication, or distraction, fatigue or stress on the part of the truck driver

5.3 Case 3

Occurrence: On 06 Sep 2017, at zero hours, a Boeing aircraft of Delta Air Lines, equipped with two Pratt & Whitney turbofan engines, reported fire from left engine under-cowl during take-off from Las Vegas airport (LAS). The flight crew carried out quick emergency procedures by shutting off the left engine and firing of fire bottle. The aircraft made an emergency landing at LAS and the aircraft was made safe by aircraft rescue and fire-fighting team.

Findings: It was found that the left engine under-cowl fire was caused by incorrect installation of a fuel nozzle during engine overhaul at Delta Tech Ops. A fuel nozzle nut was cross threaded due to faulty workmanship, which resulted in fuel leak on hot engine case surfaces causing fire.

Associated Dirty Dozen Cause(s): The associated causes may be attributed to faulty workmanship due to distraction, or complacency, or fatigue, or stress, or work pressure during overhaul.

5.4 Case 4

Occurrence: On 07 Jul 2016, at about 1307h, a Boeing aircraft of Delta Air Lines, experienced a right engine under-cowl fire shortly after takeoff from John F. Kennedy International Airport. The flight crew declared an emergency and initiated shutting off the right engine and the fire warning extinguished. Neither fire bottle was discharged. The flight returned to JFK and landed without incurring any damage.

Findings: The incident was attributable to lapse on the part of Maintenance personnel's failure to ensure proper installation of a fuel tube O-ring, which resulted in an under cowl engine fire during initial climb.

Associated Dirty Dozen Cause(s): The associated causes may be attributed to complacency, or distraction, or fatigue, or stress, or pressure or lack of knowledge while carrying out the maintenance activity.

5.5 Case 5

Occurrence: On 29 Oct 2015, at 12:33 pm, a Boeing aircraft of Dynamic International Airways, caught fire while taxing for departure at the Fort Lauderdale-Hollywood International Airport. The aircraft sustained severe damage from the fire.

Findings: The incident was attributable to lapse on the part of Maintenance personnel's failure to to install the required safety locking wire at the separation of flexible fuel line coupling. Contributing to the severity of the accident was the initiation of the evacuation before the right engine was shut down which led to the passenger's injury.

Associated Dirty Dozen Cause(s): The associated causes may be attributed to distraction, or fatigue, or stress, or pressure while carrying out the maintenance activity and lack of situational awareness at the time of evacuation.

6. Conclusion

The analysis of these accident cases clearly reveal that human factors play a vital role in ensuring the safety of aircraft as well as personnel. The sustenance of aviation industry is mainly dependent on professional competence of the maintenance engineers/technicians. However, the non technical skills of maintenance personnel needs to be integrated with their technical skills for enhancing the safety in aviation. Earlier, maintenance failures were seen as employee's inability to carry out their assigned tasks and the Institutions used to take appropriate disciplinary action by punishing or dismissing the concerned individual instead of identifying and countering error contributing factors. It is essential that aviation industries/organisations pays attention to fatigue management, human factors training with emphasis on developing non-technical skills, and ensures that right person is detailed for the right job with right resources for minimising maintenance errors.

7. Sources for Further Reading

The following agencies have released research and guidance material on the topic of human factors in maintenance.

- Federal Aviation Administration (FAA) http://hfskyway.faa.gov
- International Civil Aviation Organization (ICAO) http://www.icao.int
- European Aviation Safety Agency (EASA) http://www.easa.eu.int
- Transport Canada http://www.tc.gc.ca
- United Kingdom Civil Aviation Authority (CAA) http://www.caa.co.uk
- United States Air Transport Association (ATA) http://www.airlines.org

8. References

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2. Aviation Non Technical Skills Guidebook Chap 15.

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