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Investigation on Maintenance Costing And Impact To MROs Due To Foreign Object Damage

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Abstract

Safety is the utmost priority in aviation. High profile incidents such as Air France Concorde crash in 2000 and the miracle of the Hudson Plane crash in 2009 primarily illustrate threats faced by the industry every day, which has been known as FOD. This paper concisely discusses towards understanding of FOD. Various sources, types, standards and control measures taken regarding FOD are discussed. Also, based on investigation model, this paper principally associates impacts and maintenance cost incurred due to FOD. Results show that FOD has not only caused damage which increase the repair cost of aircraft but in fact, the effect can extensively go across to the whole aviation industry. Various subsequent events because of FOD occurrences also affect the airline business in long term. This study provides an important contribution to new metric and approaches in addressing FOD measures which are money and standard documentation analysis.

Key-word: - FOD, cost

1. Introduction

"Aviation is a very costly business. Every second means money".
"Runway safety cannot be understood without addressing FOD".

Two statements above by E. Miart of Eurocontrol, 2009 as cited in Insight Sri (2010, p.27) reflect two focal points that drive the aviation industry which are safety and money. Firstly, the safety cannot be achieved if there are FOD. As safety is a paramount concern in the industry, anything that can compromise safety will not be tolerated as this costs lives, damages and money. Secondly it is essential for commercial airlines or even military to maintain low operational and maintenance costs without degrading the flight safety. Despite of scheduled maintenance that aircrafts are subjected due to completion of their flight hours, there are a lot of cases where the aircrafts have been suspended for immediate repair. One main factor attributed to this matter is Foreign Object Debris (FOD) or previously known, Foreign Object Damage.

FOD can exist in variety forms, comes from various sources and can be anywhere. The presence of FOD either on airport runway, ramps, aprons, taxiways or during aircraft in-flight is definitely hazardous. Besides material and financial losses, FOD can cause catastrophic failure of the aircraft systems. Briefly, these system failures would create a major exposure towards the safety of air travel which the ultimate point is the aircraft crash and fatalities. This can be illustrated through the case of flight F-BTSC, Air France Concorde, which occurred in the year of 2000. Additionally, aviation industry has been rapidly growing over the years. On the other hand, with global financial crisis happened continuously nowadays plus Eurozone crisis (Polek, 2011) and other economy instability, many major airlines strive to stay financially viable amidst the fierce competition in the industry. According to IATA website (2014), there are 251 international airlines currently registered with the association.

This number however does not include other non-member operating airlines, for example domestic aircraft operator, low cost airlines and charter carriers. In addition, Air Transport Action Group (ATAG, 2015) estimates there are over 1397 airlines operating more than 23,000 aircraft, which provide service to over 3700 airports at present. Now, this situation might reflect how competitive the markets between airlines. Inevitably, the main concern when addressing FOD usually revolves around its negative financial impact to the airlines and to a larger extent, the global aviation industry. Hence, one way to maintain their sustainability in the industry apart from buying in more passengers is by reducing unnecessary costs, which can be due to FOD.

In term of money, it was reported that billions of dollars have been spent only for repairing the aircraft directly due to FOD. Prather (2011, p.1) cited that US aviation industry incurs roughly $474 million or £310 million per year due to FOD problems. This cost however, excludes other indirect loss which might incur more significant figure. In addition, FOD has cost aircraft operators as high as 13 millions pound sterling per airport per year (McCreary, 2008). Furthermore, the occurrences of FOD cause additional work for airlines management and staff. This suggests the loss and cost liability of FOD will not be just incurred by one party, but all players in the aviation industry can also be affected.

Hence, this FOD impact shall be highlighted as a universal concern for anyone who is involved with aviation industry. The discussion of the literature begins with fundamental understanding of several terms in the paper. Next, a detail discussion including its different forms and sources, followed by other related features such as regulations, aviation personnel attitudes, and its impacts. Additionally, the impacts will cover wide aspects including aircraft structural damage, its associated cost and relevant examples of case studies based on the most available statistical data.

2. Methodology

The research was carried out based on two comprehensive approach; primary and secondary data. The primary data used qualitative approach which the information was obtained from surveys and sets of interview conducted on the aviation population. In qualitative research, the researcher focus on investigating, examining and describing people and their natural setting. Meanwhile the secondary data is archived in form of report, extensive literature, bulletin and advisory circular from various aviation publications.

2.1 Primary data

Sets of interviews with professional of the subject matter were set up to collect specific information especially regarding financial figure, costs and frequency FOD occurrences. This includes verbal communication and sending e-mail to aircraft tyre manufacturing company, airline and airport authority. Two surveys were also initiated as there were lacks of cooperation from airline and airport management. The first survey, “Maintenance costing and impact to MRO due to FOD” was designed to ascertain aviation personnel’s perspectives about current ways of investigating FOD impact and its concern. Specifically, the survey was aimed to address relations between aviation personnel awareness and FOD. As this research focused on FOD that is initiated on aircraft maintenance, operational and movement area, the survey instruments were constructed to gather data from any aviation personnel background. The second survey, “FOD and public perception” solely aimed to ascertain public responses towards the effect of FOD.

2.1 Secondary data

The literature is to document FOD Damage and its financial liability in global aviation industry. The reports written by McCreary *(The economic cost of FOD to airlines, 2008)* and Procaccio *(Effectiveness of FOD control measures, 2008)* are major reference in collecting the figures. The researcher also used internet to access some classified and public documents or articles from aviation authorities such as Advisory Circulars. In addition to acquire more details about FOD maintenance cost incurred by an aviation organization, the researcher attempted to file Freedom of Information Act (FOIA) from Civil Aviation Authority and Ministry of Defence of UK by requesting them to disclose details of each aircraft incident regarding latest FOD events including the cost analysis.

3. Literature Review

3.1 Definition

Firstly, an acronym of FOD commonly refers to, either Foreign Object Damage or Foreign Object Debris. According to FAA (2013) as defined in AC 150/5210-24**,** Foreign Object Damage means “any damage caused by a foreign object physically or in economic term, which may or may not downgrade the safety requirement or performance characteristics of the product”. Meanwhile, the term Foreign Object Debris as according to NAFPI means “substance, debris or article to a vehicle or system which would potentially cause damage”. Additionally, the scope of ‘debris’ definition was then broadened up by including live objects such as bird strikes and wildlife. This is accordance with the new definition as proposed by ICAO (2010) which defines FOD as “any object, animate or inanimate, located in an inappropriate location on the movement area that has the potential to injure humans and damage aircraft and vehicles”. By the definition, the movement area includes air operations areas (AOA) such as taxiways, runways, apron, aerodrome, gates and including its aerospace.

A point often overlooked is the confusion when addressing the term FOD. Some people use the term FOD might refer it as the damage posed to the aircraft due to foreign debris, meanwhile another people who are listening might interpret the acronym FOD as for the debris itself. This is because the term ‘damage’ had become norm in military aviation since ages ago. Nevertheless, FAA (2009) has officially replaced the word ‘damage’ to ‘debris’ as outlined in AC 150/5220-24, Airport Foreign Object Debris Detection. By making a correlation between both terms, this new definition seems more relevant. This is supported by McCreary (2010) which claimed that debris might be there without causing damage but damage cannot be accompanied without having debris. Moreover, most FOD detection technologies and prevention measures work by identifying and collecting the actual debris, despite of the damage. Therefore, for this report’s purposes, the use of abbreviation FOD will stand for ‘Foreign Object Debris’ meanwhile ‘FOD Damage’ will be referring to damages caused by the FOD itself.

Secondly, MRO as in aircraft maintenance context, basically it means Maintenance, Repair and Overhaul meanwhile taking the industry as a broader context; MRO refers to Maintenance, Repair and Operation (WebFinance Inc., 2015). Therefore, the impacts of FOD as will be highlighted in this paper includes on any operational and maintenance activities that have relations with aircraft. On contra, the MRO activities, instead of repairing aircraft damages due to FOD for example, also can become a place where FOD can be found because its complex working environment.

Thirdly, maintenance costing is expenditures incurred to restore the aircraft components and structures in airworthy conditions. This was reinforced by Friend (1992) as cited in Transport Studies Group (2008) which explains all work done related to the aircraft to ensure good operational practices are considered maintenance costs. Furthermore, this is not limited to the costs due to material losses only but cited in IDCON (2014), should also include labour, time-consuming and all other events that can get bad impacts because of the loss. Hence, this means the costs incurred can be accessed from both views, in terms of maintenance and flight operations.

3.2 How FOD come into the system?

Various sources of FOD make it more difficult to maintain the safe airfield operation. Moreover, the FOD has the ability to self-relocate. FOD can be grouped into two; biological and non-biological elements. Four common ways FOD can start to appear which are personal belongings, airport infrastructure, aircraft and ground operations. While biological elements are more difficult to fight against, including bird strikes, animal ingestion and weather related conditions such as snow, ice, hail or volcanic ash.

i) Embedded metal in tyre *ii) Pavement destruction present as FOD* *iii) Direct damage result due to FOD*

Figure 1 Example on type of FOD and its damage

4. Findings and Discussion

The research findings in this article are divided into two sections such as direct cost and indirect costs. The direct cost principally constitutes with structural damage meanwhile indirect costs relates with operational and sequence consequence to the management.

Direct cost

<u>Overall direct cost of FOD: NAFPI figure</u>

Based on NAFPI’s estimation, FOD damage has caused loss of $4 billion to the whole aviation industry, encompassing civil and military (McCreary, 2010, p.146). This figure however only addresses direct MRO cost but not taking in other indirect expenditure (Bachtel, 1998). A further noteworthy study by Procaccio (2008) mentions that, NAFPI concluded those amounts by inferring FOD loss which had been generated by Air Transport Association (ATA) and Royal Air Force (RAF), UK during fiscal year 1994/1995.

ATA

As stated by Collier (1995), a study on FOD trends conducted by ATA from 1992 to 1994 revealed that $7.4 million loss averagely had been spent annually due to FOD. At that time, there were 886 airlines operating worldwide and NAFPI mentioned that at least 100 airlines were equated to the economic scales. Based on this, multiply by 100, NAFPI calculated that FOD had incurred $740 million to the civil airlines. NAFPI also assumed that the other related-aviation industry such as MRO, manufacturing and private airlines are exposed to FOD hazards.

By considering those other factors, assumption was made by NAFPI to add an extra $1 billion into the cost. Therefore, the accumulated cost of FOD had become $1.74 billion for civil aviation industry (cited by Procaccio, 2008, p.12).

RAF

In 1994, RAF database showed that there were 129 aircraft engines belong to RAF fleet which had been scrapped due to FOD damage. It was also reported that the repair and replacement cost of the damaged engines took around $30 to $70 million. Owing to other miscellaneous expenditures, NAFPI rounded the figure to $100 million. Additionally, by assuming there were 20 other countries that possess comparable size to the RAF during that time, the global military aviation was said to incur $2 billion loss (Chaplin, 2004 as cited by Procaccio (2008). Hence, by adding the total costs of FOD damage in both military and civil aviation industry as described above, this is how NAFPI has approximately reached the collective amount of $4 billion.

Cost trend of FOD in military aviation

It could be said that the figure arrived by NAFPI was the best estimate for that particular time. However, in conjunction with the global aviation industry, there are two lacks in NAFPI's estimation. Firstly, NAFPI failed to provide proved details for the surplus $1 billion and secondly, NAFPI failed to provide concrete reasons of choosing RAF fleets as their basis to address global military aviation. This contrast sharply with Procaccio (2008) as which according to him the largest military aircraft fleet was held by US.

Hence, by using the same method as NAFPI but utilizing US military records as the baseline of calculating FOD cost on global military scales, a new improved amount can be figured out. Between 2002 and 2005, it was found that FOD mishaps had directly cost US military $120 million per year. Up to 2004, there were about 66,000 rotor-wing and fixed military aircraft operated by countries all over the world which 18,169 of them were belong to US (Procaccio, 2008). This $120 million then was divided by the amount of aircraft possessed by the US military to obtain the direct cost of FOD Damage per aircraft. This cost per aircraft then is multiplied by 66,000 aircraft to provide overall estimation.

Cost of FOD Damage per aircraft= $120 million/ 18,169 = $6,604

Overall estimation= $6,604 x 66,000 = $436 million.

To this date there are 50,505 military aircraft over the world and 13,892 are possessed by US (Writer, 2015). By extrapolating the same cost and calculation method, it is found that direct cost of FOD Damage incurred by military aviation does not change which is $436 million. However, this amount cannot be used as a good metric because the average direct cost of FOD Damage incurred by US military at present may have changed over the past 10 years.

Cost trend of FOD in civil aviation

Till now, there are still no standardised and realistic approaches to measure FOD from the cost perspective (McCreary, 2010). It was also mentioned by Procaccio (2008) before, that there were too much numbers flying around when talking about cost of FOD Damage. In the context of civil aviation numbers, perhaps the best proxy for FOD direct cost trends may come from Insight Sri Ltd study as it collectively considers the cost to both airlines and airports. Based on actual FOD Damage incidents and aircraft maintenance logs that have been shared by two major US commercial airlines anonymously, a study by Insight Sri in 2008 reaches the best estimates of total direct cost FOD per flight by taking top down approach. By assigning the total repair expenses to the frequency of the FOD Damage posed on three major aircraft structures respectively as mentioned above; engine, tyre and aircraft body, the data analysed has proposed for each flight movement, the inflated direct cost of FOD for airlines is $24 (McCreary, 2008). Synthesis of the cost is shown in table 1. Furthermore, the economic impact of FOD in this study reflects aircraft traffic at the 300 largest and busiest commercial airports which have seen about 55 million of aircraft movements in every year (Procaccio, 2008). In order to equate on a global scale, this is important as the larger proportion maximise a chance of uncovering a significant difference and providing more reliable data (http://www.conceptstew.co.uk/PAGES/nsamplesize.html, no date). In every 10,000 movements, based on the FOD cost per flight, the airlines is said to incur collectively $223,400 in direct MRO cost only. When being calculated, this is equal to an overall direct cost of $1.24 million.

DIRECT COST OF FOD (£)	Per 10,000 movements	Per flight	Per passenger
Engine maintenance	133,700	14	0.1
Tyre replacement	37,200	4	0.02
Aircraft body repair	605	0.1	0.0003
TOTAL (£)	TOTAL (£)	18	0.12

Table 1: Synthesis of direct maintenance cost due to FOD by aircraft parts according to Insight Sri Research in 2008

Calculation:

FOD cost for 10,000 movements = £172,000

FOD cost for 1 movement = £172,000/ 10,000
= £17.2

FOD cost for 55 million movements= £17.2 x 55,000,000 = £946,000 or $1.24 million.

These estimated figures are the best guess with a better calculation method. By synthesizing the typical cost per flight movement and per person, average total cost can be easily calculated if total annual movement at particular year is known (Anthony, 2008). The same method was also used by Allan and Orosz (2001) when addressing bird strikes cost to commercial aviation. However, a further research in 2010 mentions that this calculation approach is not very constructive due to frequency of FOD Damage was not well addressed. Plus, the issue of various FOD on runway was not accounted and bird strikes damages were treated as separate FOD (McCreary, 2010).

Question	Answer	Frequency	Percentage (%)
Q1: Do you know what FOD is and how it looks like?	Yes	16	7.8
	No	188	92.2
Q2: How frequent do you travel with particular airlines?	Once a year	2	1.0
	Twice a year	48	23.5
	More than two times in a year	154	75.5
Q3: What do you expect most when travelling with aircraft?	Cheap	87	42.7
	Safety	183	89.7
	Punctuality	195	95.6
	Good services	49	24.0
Q4: How do you assume an airline with always delayed aircraft?	It is very disappointing	144	70.6
	It does not bother me	0	0
	I will think many times to purchase tickets from the same airlines	60	29.4
Q5: Do you know FOD can cause delay to aircraft?	Yes	15	7.4
	No	189	92.7

Table 2: Result of second survey, “FOD and public perception”

Indirect cost

The damaged aircraft requires non-routine maintenance and repair activity, which will potentially delay the aircraft departure or arrival. While delays are common problems posed by FOD damage, any interference onto flight operation may also cause another hidden expenditure. This can be expressed as follow-on expanses directly caused by withdrawing the aircraft from its pre-planned operation. From each primary flight delay or cancellation, it leads to many subsequent fail events (McCreary, 2008). Examples of the events which will cost more money are briefly listed in table 2. Surprisingly, the later study found that the total FOD damage cost can increase by a multiple at least 10 times when all the indirect costs of these events are taken into account (McCreary, 2010)

No	Categories	Effects
1	Immediate airline delay	• Delay for planes in air, at gate and on runway or taxiway • Increase gate and other airport fees • Increase gate staff or ground crew fees • Cost to change aircraft • Cost of rental for replacement equipment
2	Airport operation and traffic control	• Taxiway or runway inspection and clean-up • Delays due to closed runway and airport • Reduce airport efficiency • Airport safety expenditure increased thus increasing landing fees
3	Crew and staff	• Loss of productivity due to injured personnel • Lost time and overtime • Need to find crews replacement • Morale down • Add up cost for hiring and crew training
4	Maintenance and flight operation	• Unscheduled maintenance, which will increase workload during scheduled maintenance • Loss of fuel efficiency • Reduce life limit or increase operating cost on remaining equipment • Loss of aircraft spares or specialized equipment • Degrades on-going aircraft engine fuel efficiency
5	Passenger	• Missed flight connections • Incurs new rebooking fees • If long period delays, this will cost hotels and meal vouchers to be provided for passengers • Take replacement flights on other carriers
6	Regulatory cost	• Cost of the incident investigation • Administrative cost for airline and airport to monitor and report procedure
7	Environmental impact	• Waste of fuel burnt by aircraft and ground vehicle • Increase carbon emission and environmental issues
8	Corporate and business impact	• Cost for media and press release response • Cost for corrective action • Increase insurance premiums • Damage to reputation and loss of business • Likely to be responsible for corporate manslaughter allegations • Incur legal fees claimed by passenger, airport, other airlines and regulatory body Insurance deductibles

5. Conclusion

To summarise, several points and information can be confirmed in this investigation. Based on the definition laid out, the wide range forms of FOD and no current international standard taxonomy of FOD makes it pretty difficult to be alleviated. Thus, it is impossible to totally eliminate FOD. Plus, depending on the various situation and environment involved, the presence of FOD to cause damage is indefinite. As for example, an employee's ID tag that being carried along by himself during working hours is not something unfamiliar, but when it is on jet engines or aircraft surrounding area, which can potentially trouble the flight operation, it is then be treated as FOD. Similarly, at first the aircraft skin is just parts of the aircraft airframe. When it is stripped and exists unattended, it has potential to create FOD Damage to the aircraft itself. Despite of many definitions, in short, they share similar characteristic which; anything can be FOD when it is at the wrong place at the wrong time.

Secondly, FOD Damage incurs high cost either directly or indirectly. It is noted the damage predominantly affects financial. In particular, the indirect cost of FOD Damage seems to cause more significant amount of money. Nonetheless, the cost and losses because of FOD Damage does not only affect an individual organization, but are borne by all entities related to aviation including passengers who board the aircraft. FOD can result aircraft crash which lead to total destruction, disruptions in maintenance and operation schedule, waste of time and irreplaceable loss of lives.

Thirdly, while many information, regulation, case studies and control methodologies about FOD are attainable, accurate data on FOD events together with on-track frequency and cost analysis are inaccessible, not only to the public but also to most of aviation workers. If the well amount of FOD loss can be circulated in every airline, airport, MRO organization and aircraft manufacturer, it is claimed being able to raise FOD awareness, which proposing money or financial cost as another metric for FOD control. However, from the investigation, the aviation organization and industry as a whole fail to provide an international standard matrix or database for each FOD Damage incident. Most obviously, the industry does not have a standard calculation method to evaluate the universal cost incurred caused by FOD Damage. This implies the fourth assumption about the importance of documentation and FOD analysis are essential, as well as to include the actual numbers of MRO cost.

Great fires erupt from tiny sparks. As long as there are possibilities of FOD to present and cause damage, additional expenditures are continuously required. Henceforth, as said, it is always better to take proactive measures which means of prevention to avoid further loss and cost. Conclusively, FOD is an important issue that must be unceasingly monitored by the industrial players. On the whole, FOD offers no benefits to the aviation industry.

RECOMMENDATIONS

While many tools, conferences, procedures, programs and technologies have been developed to administer FOD problems, another strategic parameter seems essential to nourish awareness among people. FOD and FOD Damage are threatening but do not always result in fatalities or plane crash which mostly people are afraid of. On the other way round, FOD inevitably and persistently concerns with money. Therefore, it is recommended that annual trends of financial cost incurred due to FOD as a new metric to be incorporated in FOD management program. In order to achieve that, ICAO coupled with NAA should introduce a standard FOD Damage calculation and analysis method, data collection device and also reporting matrix so that basic line trends can be easily identified. Plus, regulation must be set up to make these requirements compulsory for every airline and airport management worldwide. Besides, a new direction of research should highlight on how to reduce impacts from high operational and maintenance cost in case FOD Damage still occurs. Finally, FOD prevention requires concerted efforts and collective actions by all people including aircraft passengers. So, the researcher would like to propose that education about FOD should not be only disseminated among aviation personnel, but it would be better if the public are lightly informed about FOD. This FOD educational lesson may be at least broadcast on video via in- flight entertainment.

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