# A Study of Foreign Object Damage (Fod) and Prevention Method at the Airport and Aircraft Maintenance Area

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***Abstract:-*** **Foreign object damage (FOD) is a common risk for aviation industry that causes potential damage for an aircraft ,external FOD hazards include bird strikes , sand stormes ,ash clouds on the runway .Internal FOD Hazards creates an interference with flight safety by means of sort out electrical connections, improper control cables etc,since long time ago and it has contributed to many terrible incidents .The cost of FOD obstrucles every year is very high, which is around RM 1.2 billion. Therefore, FOD has to be eliminated without creating an impact on performance and it should proper technique and strategy has to be taken by the designated organizations including airlines to further eliminate the FOD occurrences. It is not easy to control FOD due to some circumstances and complications such as inappropriate working behaviour, poor working environment, insufficient damage tolerances and technology and also disorganized housekeeping system. The main purpose of this research is to discuss and explain further about FOD and its techniques to prevent FOD. FOD is a universal concern in aviation industry and it is one of the reasons that contribute to aircraft failure and unwanted damages such as fatalities and casualities. Throughout this research, many information related to FOD problems and and its catastrophic failures,their impact on aviation industry are gathered and discussed.**

## 1.INTRODUCTION

Foreign object damage (FOD) is a big problem in aviation maintenance industry that reduces the level of safety for an aircraft. In fact, it can only be controlled and minimized properly by using the right and precise control method. Basically, FOD is known as foreign object (FO) that can cause severity and destruction to the aircraft such as engine failure and loss of human life. Nowadays, there are many cases of FOD that happened due to some reasons and this situation leads to a survey on aviation safety in the aviation industry. The result has indicated that FOD is the most potential ground base cause that contributes to catastrophic aviation failure. Basically, this research will focus on FOD sources and also its prevention method at airports and maintenance areas where the most common FOD cases happened. Apart from that, this paper is aimed to classify FOD based on their specification, understand the consequences of FOD to the aircraft and identify the cost contributed by FOD. Throughout the completion of this research, several methods had been used to gather reliable information and data. Most information was obtained through research from reliable sources such as internet, technical report, books, articles and journals. Moreover, Federal Aviation Administration (FAA) and ATSB websites were really useful in searching for information, especially for FOD occurrences and the FOD Prevention Program. Beside these sources, the National Aerospace FOD Prevention (NAFPI) Conference was also very helpful in providing the most current and updated information, which also included opinions from many types of aviation organizations. Furthermore, another method that had been used in this research was analyzing the conducted surveys by authorised agencies, airline operators and aviation companies.

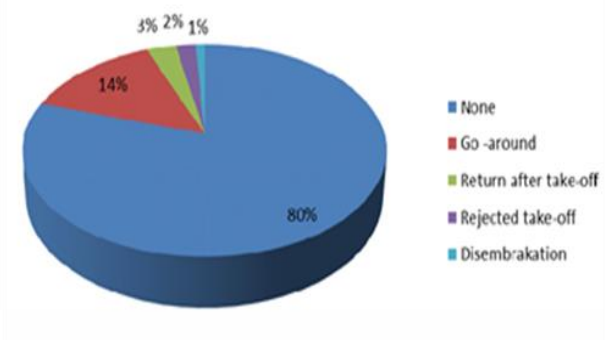


FIG 1.1:. CONSEQUENCES OF REPORTED FOD OCCURRENCES

## *2.FOREIGN OBJECT SOURCES AND PROBLEMS*

### *2.1 DEFINITION OF FOD*

FOD includes debris, substances or articles that have the potential to cause damage to any vehicle or system. In other words, FOD can be defined as anything that is around or

inside the aircraft and flight line operations that does not belong there. FOD varies in sizes and it has the capability to create hazard to equipment or personnel. Another definition of FOD is the damage on aircraft, helicopters, launch vehicles, engines or other aviation equipment. which takes place when a foreign object smashes the engine, flight controls, airframe and the other operating systems. Based on Federal Aviation Authority (FAA), FOD is principally known as a hazard element that can severely harm the airport, personnel and equipment. In fact, the most serious case of FOD had involved personnel injuries or death and in most cases, it usually occurred during aircraft close-proximity taxing when the personnel was exposed to adverse effects of high velocity jet blast. The harsh blast forced FOD through the airport and often caused injuries to personnel who were working around that area. the impact of soft body damage can result from flexible objects such as birds, ice slabs and plastics. For instance, it can usually be seen by a large radius curvature of deformation to the turbine blade fan. Meanwhile, hard body impact damage occurs with uneven appearances. For example, tear to airfoil's leading and trailing edges at the turbine blade section as a result of impact by rigid parts like metal parts, concrete and rock.

*2.2. FOD SOURCES*

Through the researches and surveys done by FAA, there are many types of FOD that can be found in many forms. None of them is beneficial since they cause difficulties to airline operators, especially in maintaining safety on airfield operations. There are many types of FOD that vary in materials, colours and sizes. In general, there are four basic classes of FOD: metal, stone, miscellaneous and birds. Based on the research done by the French Study on Automatic Detection Systems, over 60% of the collected known FOD items were made of metal, followed by 18% made of rubber

| Types of FOD | Sources |
|---|---|
| Personnel | It is normally caused by poor working behaviour and inappropriate housekeeping |
| Airport infrastructures | Sign, pavements and lights |
| Environment | Wildlife, snow and ice |
| The equipment operating on the airfield | Aircraft airport operations vehicles, maintenance equipment, fuelling and construction equipment. |
| Aircraft and engine fasteners | Nuts, bolts and washers |
| Aircraft parts | Fuel cap, oil stick, trapdoors and tyre fragments |
| Flight line items | Nails, personnel badges, luggage tags, soda can, etc. |
| Runway and taxiway materials | Concrete and asphalt chunks, rubber joint materials and paint chips |

TABLE 2.2.1 TYPES AND SOURCES OF FOD

In winter conditions, FOD tends to be more predominant especially when aging pavement infrastructure may be frozen, and began to crack and break into pieces. In windy weather condition, movement of the wind can propel the FODs such as sand, papers and plastic bags from non-critical area into the runway. The knowledge of all these effects indirectly creates awareness among airline operators about the unpleasant effects of weather conditions and gives them ideas on how to solve this problem.

*2.3. FOD ITEMS LOCATION*

Many types of FOD items with variety of sizes were found and 55% of them were located at aircraft stand area or parking area where the aircraft normally parked at the airport.

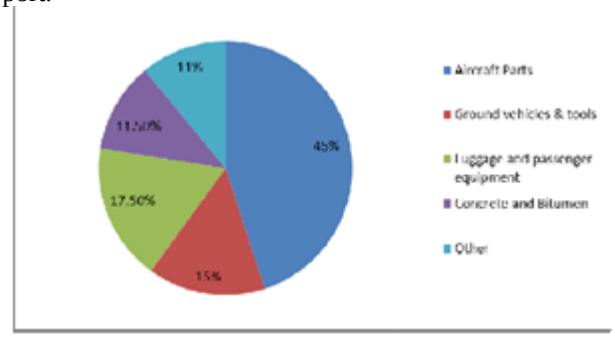


FIG 2.3.1:SOURCES OF FOD ENGINE DAMAGE

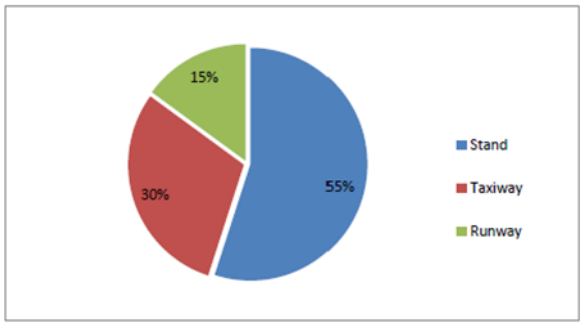


FIG 2.3.2 :. FOD ITEM LOCATIONS

*2.4 PROBLEMS ASSOCIATED WITH FOD*

In the aviation industry, there are many catastrophic problems associated with FOD. Frequently, the problem is damage or destruction to the aircraft parts. The damage can be divided into two categories: minor and major damages. An example of minor damages is a skin dent while for major damages, they include control surface malfunction, jammed flight controls, electrical shots and also engine failure. According to ATSB , about 11% of FOD occurrences led to airframe wheel and engine damages. These damages give financial impact to the organization and contribute to a massive amount of direct and indirect costs. Direct costs involve all maintenance fees to repair the damages due to FOD. On the other hand, indirect costs include flight delays, cancellations, lost revenue, schedule disruptions and additional works by employees.

*2.4.1 ENGINE DAMAGE*

Aircraft engine has a high tendency to be ingested by FOD. Ingested objects in a form of soft and hard materials of all sizes and shapes are causing big problem once they strike rotating blades, static vanes, and other parts of the engine, thus reducing the strength of the component . Furthermore, ingestion by hard body object can cause damage to the engine rotating assemblies, which leads to vibration and disruption of airflow at the early stage of the compressor section. It will cause the compressor to stall and eventually reduce the performance of the engine. A study found thatFOD is of great concerninthe gas turbine engines because it can have deleterious effect to the rotating components in modern

aircraft engines. In fact, in some severe cases, replacement of a new engine is necessary.Internal damages can give more significant effects since it often cannot be seen by the normal eyesight. The impact of FOD on gas turbine engine blade can be divided based on the severity of the damage asMinor – no more than blade blending is required ,Moderate – replacement of blade on single stage is required ,Severe – replacement of blade on more than on stage is required,Very severe – blade replacement is required plus repair of additional damage incurred to the other engine areas

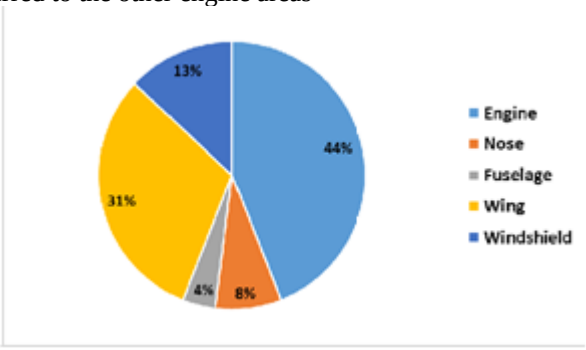


FIG 2.4.1.1.LOCATION ON THE AIRCRAFT WHICH WAS STRUCK AND DAMAGED BY BIRD(S)

FIG 2.4.1.2 ENGINE BLADE DAMAGE DUE TO AN INGESTION OF A SMALL BIRD

*2.4.2.TYRE DAMAGE*

The damage on the aircraft tyre usually happens due to the penetration of FOD into the aircraft tyre. In worst cases, it can cause tyre burst that leads to many unwanted circumstances and even loss of life. Moreover, FOD can cause the tyre treads of the nose or the main landing gear to detach. If this happen during take-off and landing, the detachment of the tyre treads will cause damage.to the aircraft sections such as fuselage, wings, engine intake and compressor. The detachment of the tyre treads starts with a penetration and normally happens in take-offs and landings.

*2.4.3.AIRFRAME DAMAGE*

In some cases, FOD may penetrate through the windshield and cause injury to the pilots. Around 13% of incidents caused by bird strike involved fatal injuries from damages to the windshield. In order to avoid this problem from happening, aircraft manufacturers have to ensure the strength and durability of the windshield by making improvement in its structure. Penetration of FOD on the pressurisation area can cause rapid depressurization .The main purpose of cabin pressurisation is to maintain a safe and comfortable environment for crew and passengers in the aircraft, which is flying at low outside atmospheric pressure. Depressurisation of the aircraft is very dangerous to everybody inside the aircraft and put the crew and passengers at risk of hypoxia, altitude sickness, barotrauma and decompression sickness.

*2.4.4 FUEL EFFICIENCY*

FOD ingestion has a tendency to drop engine's operating efficiency. This often happens when the blades are blended, which causes a slight increase in fuel consumption,When FOD has caused damage to the aircraft, the aircraft is normally parked at the designated area to let the maintenance personnel to inspect, and repair it if necessary. The aircraft will only return to service after the damage has been repaired. If major repair has to be conducted, the aircraft will be grounded for a long time and this causes flight cancellation. The cost of aircraft delay and cancellation fees are significantly high, hence gives big impact to airport and airline operators.

*2.4.5.FOD PREVENTION*

FOD prevention is a method or technique to prevent FOD and promote safety in aviation world. The main purpose of FOD prevention is to reduce FOD occurrences around the airport and maintenance areas. Nowadays, most airports and airline operators have realized the importance of FOD prevention. The most important factor that contributes to the success of this method is the ongoing support and commitment from the top organisation leadership management. Without this, the effectiveness of FOD prevention cannot be achieved and it will continually suffer with lack of credibility.A successful FOD prevention can be achieved by having procedures and implementation of Safety Management System (SMS).This system is highly beneficial because it gives major contribution for the organisation to establish decisions, attitudes, techniques of operation regarding safety culture and other related issues.Through good safety culture, all duties and procedures about FOD prevention can be clearly defined and well understood. After all, designated personnel should have good personalattitudes and know their responsibilities regarding FOD hazards and how to eliminate it.

*2.4.6.FOD PREVENTION AND AWARNESS*

FOD prevention program is a guideline for an organization to eliminate and reduce any consequences of FOD. Normally the program is based on certain standards and guidelines that are issued by the aviation authorities such as National Aeronautics and Space Administration (NASA) and FAA. The researches that have been done clearly show that most organizations in aviation industry are practicing the same procedure of FOD prevention program such as in several aviation companies and agencies including Bell Textron Helicopter, NationalAerospace FOD Prevention Inc. (NAFPI), Research andTechnology Organization (RTO) and FAA. In order to achieve the ultimate goal of this program, there are three considerations to be applied: FOD designation / sensitive area, awareness and FOD airside activities preventive

measure.FOD designation area is essential to prevent FOD. This area should be designed based on maintenance activities that have been done and risks associated with FOD. However, there are many consequences and a high probability of FOD is not controlled or found in this area.

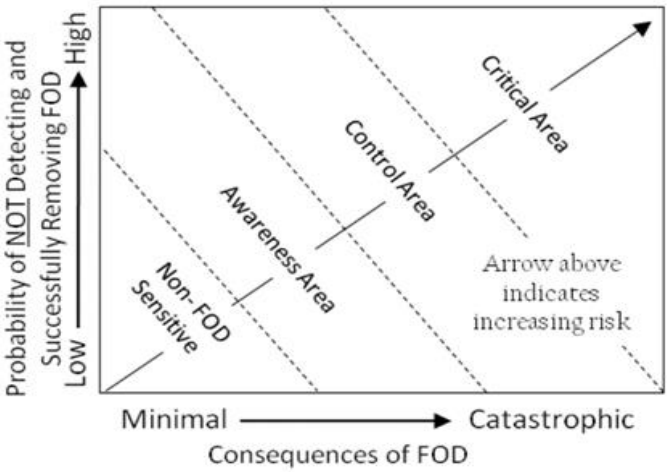


FIG 2.4.6.1.FOD SENSITIVE AREAS BY THE COMBINATION OF PROBABILITY AND CONSEQUENCES

During windy weather conditions, debris such as plastic and cargo strapping are easily blown and they cause FOD hazards in air cargo areas. In this case, airport management should establish proper procedures on collecting the FOD, possibly by fixing fences at the right area. Since the fences trapped the blowing debris, it must be removed regularly to make sure FOD will not come back to the air cargo area.

## 3.DISCUSSION

The aviation industry has a number of methods to fight against FOD hazard. In fact, guidelines from FAA A/C and NAFPI FOD prevention manual provide good and precise orientation for organizations to develop their FOD prevention program. Fortunately, the guidelines are free and easy to be accessed and adapted. Organizations that want to establish a FOD prevention program must have sufficient and adequate reliable sources before starting to emphasize on human error reduction in their FOD control measures.Furthermore, there is no such thing of 100% FOD free at the airport and maintenance area due to the inexorable presence of debris that is impossible to be totally eliminated. However, the percentage of FOD can absolutely be reduced with the implementation of FOD control methodologies and the introduction of FOD detection technologies such as radar, camera and sensor at airport area. These technologies are really effective and convenient to be practiced. Implementation of these technologies at the airport are based on a number of factors including the type of aircraft operating, the number and size of the active runway and taxiways, and finally the location of the airport.Technically, the airport operator should perform FOD risk assessment in order to identify the major FOD risk that has high tendency to occur. This assessment should include risk type, risk response, probability of the risk to happen, severity of the risk and lastly, effective action that should be taken in order to eliminate the risk. By having this assessment, the organizations can determine the level of the risk and construct mitigation strategies. This way, the presence of debris can be totally eliminated and this indirectly reduces the risk of having FOD at airport area.

## 4.CONCLUSION

The most effective way to eliminate FOD is by developing FOD awareness among the people who are involved in aviation industry. Due to dangers of FOD, the aviation authority, organization or company has taken appropriate action to minimize this problem by having FOD prevention program and also applying other prevention methods. The prevention program includes all techniques to eliminate FOD or everything that is prone to FOD. It is indeed one of the most effective measures to eliminate FOD in today's aviation world. The success of this program starts at the top level of an organization itself and it gets more comprehensive when there is a continuous solid support from the subordinates. Everybody in the organization must always be sensitive to the impact of FOD and needs to put an extra effort to eliminate this particular problem. After all, the most critical goal of the FOD prevention program is to promote unlimited safety level in aviation world. This is just to make sure that FOD will not become predominant and create catastrophic failures to the aircraft, as well as everyone who is flying on it.

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