

ANTI-ICING ENGINE DAMAGE ANALYSIS BOEING 737 - 800 NG WITH FAULT TREE ANALYSIS METHOD

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Abstract

An *Anti-icing system* is a system that aims to prevent the formation of ice when the plane is in the air. The formation of ice in aircraft is of great concern because an airplane flight will pass through the atmosphere, which will experience the formation of the ice at a certain altitude. The formation of such ice will cause a hazard to the aircraft. So that the ice protection system, namely the anti-icing system, is very concerned so that it is always in a serviceable condition. In this study, direct observation and fault tree analysis were used to determine the cause of failure of the Boeing 737-800 NG anti-ice system engine and anti-icing cowl inlet. The results of the analysis using the fault tree analysis method obtained essential events, namely: actuator fails, electrical connector disconnected, Control Selenoid Trouble, Regulator Trouble, Sense Line Connector Trouble, Engine Fault, Engine Control Trouble, Engine Duct Trouble, Panel Button Problem, EICAS Module Problem, No Source Electricity, Negative Electrical Source, Wiring Problem.

Introduction

Airplanes are a very fast-growing mode of transportation; seen from every year airlines must add to their fleet to serve passengers on the move. With the increase in the fleet every year, it is hoped that this mode of transportation will be more advanced in the future. Airlines are adding to their fleets to serve the community and carrying out maintenance or maintenance in each of their fleets so that passengers feel comfortable traveling by aircraft and for the safety and feasibility of aircraft. Maintenance on this aircraft is also carried out regularly and periodically to keep the aircraft in good condition without the slightest error.

In this case, maintenance of the Boeing 737-800 is carried out regularly and periodically to see the feasibility of the aircraft. This maintenance includes the alignment of the aircraft components from the nose to the aircraft's tail. One of the treatments on the Boeing 737-800 is the anti-icing system on this system, which aims to prevent the formation of ice when the plane is in the air. The formation of ice on the plane is essential because an airplane flight will pass through the atmosphere which at a certain altitude will experience the formation of ice, this

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needs to be avoided so as not to cause problems in order to achieve comfort in flight. The formation of ice will cause danger to the aircraft. Many aircraft are now using an ice protection system, namely an anti-icing system along with the times.

The anti-icing system is completely hot air produced from bleed air, combustor chamber and exhaust on the engine. Hot air will be flowed to several parts of the aircraft that have the potential to form ice such as wings, engine cowl inlet, pitot, and windows. This anti-icing system is controlled by the pilot on the P5 panel, when the anti-ice engine switch is in the on position, the valve will open, after that the hot air generated from the bleed air, combustor chamber, and exhaust will flow through the valve to the wing and the engine cowl inlet.

The problem with the anti-icing system occurred when the author carried out periodic maintenance at the line station on the anti-ice engine cowl valve for the Boeing 737-800 NG, in which the problem was found that the indicator on the P5 panel when the engine anti-icing cowl engine valve was ON switch was slow, Dim and only Bright. From this trouble, the author is interested in discussing and identifying the causes of problems with the anti-ice engine. Seeing this problem, the author will conduct research using the fault tree analysis method because it makes it easier to determine a problem.

Method

Fault tree analysis (FTA) is a method or technique used to find the root cause. FTA itself is a risk management method, the method used is to look for a problem that occurs to deal with failure. This method aims to determine the causal factors that are most likely to cause failure and investigate a failure.

In this study, FTA was used to find the source of failure in the anti-icing engine system where in this failure there was damage to the valve which was corroded due to hot air flowing from the engine (Gachlou et al, 2019). According to the FTA method based on logical diagrams, it reveals the relationship of the essential events and peak events through logical gates. It can provide quantitative and qualitative analysis. The symbols in the fault tree analysis can be seen in Figure 1 below:

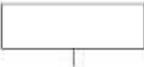
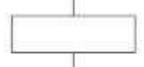
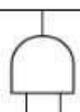
| Simbol | Keterangan |
|---|---------------------------|
|  | <i>Top event</i> |
|  | <i>Intermediate event</i> |
|  | <i>Undeveloped event</i> |
|  | <i>Basic event</i> |
|  | <i>Logic event AND</i> |
|  | <i>Logic event OR</i> |

Figure 1
Fault tree analysis symbol

Fault tree analysis uses 2 main symbols called events and gates, there are three types of events, namely: 1. *Primary Event*

A primary event is a stage in the product use process that may fail when it fails. For example when inserting a key into a padlock, the key may fail to fit into the lock. Primary events are further divided into three categories namely: Basic events, Undeveloped events, External events.

2. *Intermediate event*

Intermediate events are the result of a combination of errors, some of which may be primary events. This intermediate event is placed in the middle of a fault tree.

3. *Expanded Event*

Expanded Events require a separate fault tree due to their complexity. For this new fault tree, the expanded event is an undesired event and is placed at the top of the fault tree (Foster, 2004).

Boolean algebra is algebra that deals with binary variables and logical operations. The variables are represented by the letters of the alphabet, and the three basic operations with AND, OR and NOT (complement). A boolean function consists of variables representing an equal sign and an algebraic expression. A boolean function is expressed in a truth table, this truth table is a binary number 0 and 1 assigned to binary variables and a list that shows the value of the function (Rs Putra, 2018).

Let B be a set defined by two binary operations, (+) and (*) and a unary operation denoted (') let 0 and 1 represent two distinct elements of B then $(B, +, *, ', 0, 1)$ is called Boolean algebra if the following axioms apply to every element a, b, c of the set B (Lipschutz, 2001).

- 1) Commutative Law
 - $a + b = b + a$ (1)
 - $a * b = b * a$ (2)
- 2) Distributive Law $a + (b * c) = (a + b) * (a + c)$(3)
 - $a . (b + c) = (a * b) + (a * c)$ (4)
- 3) Identity Law
 - $a + 0 = a$(5)
 - $a * 1 = a$(6)
- 4) Complementary Law
 - $a + a' = 1$(7)
 - $a * a' = 0$(8)

The minimum cut set is a qualitative analysis that uses Boolean Algebra. Boolean algebra can be used to simplify or describe complex and complex logic circuits into simpler logic circuits (Widjanarka, 2006).

A fault tree provides valuable information about the various fault events that lead to a critical system failure. The cut-set method is to find out the list of failure events that occur later in the peak event. At the same time, the minimum cut sets are a list of minimum conditions that are sufficient and necessary for the peak event. The combination of various fault events is called a cut set. In fault tree terminology, a cut set is defined as a basic event that will result in a TOP Event if it occurs (simultaneously). A Cut Set is said to be a minimal cut set if the Cut Set cannot be reduced without losing its status as a cut set.

Results and Discussion

Table 1
Engine Failure Analysis Anti ice system Boeing 737-800 NG Part 1 Engine
Failure Analysis Anti ice system Boeing 737-800 NG Part 1part 1

| N | Type of | Cause of Failure | Gate | Description | Reference |
|----------|--------------------|-------------------------|------------------------|---------------------------------|------------------|
| a. | Inlet cowl thermal | Source | anti icing failure(2) | informa | |
| b. | Engine anti ice | Engine anti ice | system trouble | If one of the causes of failure | tion |
| 1 | system failure | (1) | (3) | OR occurs, it can cause engine | |
| | | | | anti-ice system failure | |
| | | c. | Engine anti icing | | |
| | | | indication trouble (4) | | |

| | | | |
|---|---|---|---------------------------|
| Inlet cowl 2 thermal anti icing failure (2) | a. Inlet cowl TAI valve trouble (5) | If one of the causes of failure OR occurs, an inlet cowl thermal | Source informa tion |
| | b. Inlet cowl TAI anti-icing failure will occur pressure switch (6) | | |
| Engine anti ice 3 system trouble (3) | a. Engine trouble (7) b. Hot air distribution problem (8) | If one of the causes of failure OR occurs, there will be engine anti-ice system trouble | Source informa tion |
| Engine anti 4 icing indicating trouble (4) | a. EICAS problem (9) b. Electrical supplay trouble (10) | If one of the causes of failure OR occurs, engine anti-icing indicates trouble will occur | Source informa tion |

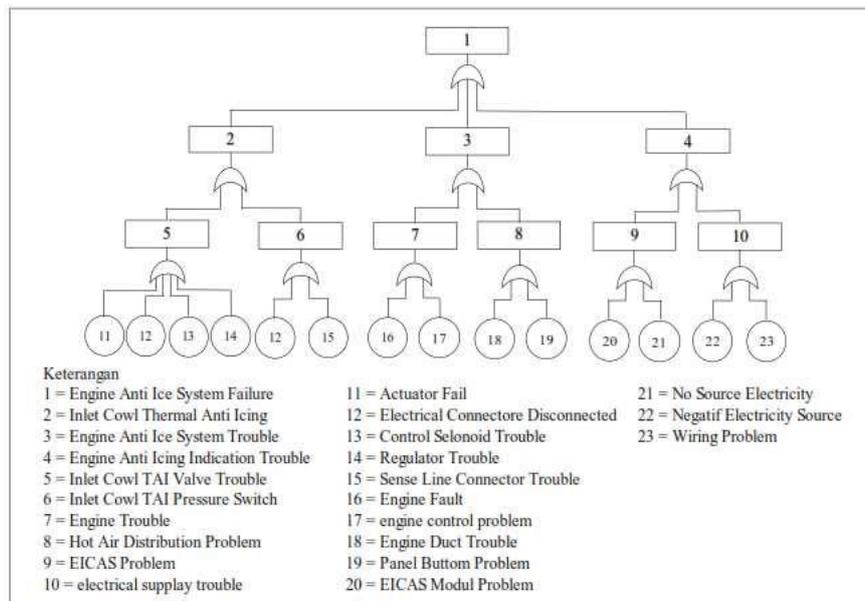
There were four failures from the inlet cowl TAI trouble, namely actuator failure, electrical connector disconnected, control solenoid trouble, and regulator trouble. If one of the failures occurs from this failure, the inlet cowl TAI valve has trouble. From the failure of the inlet cowl TAI pressure switch trouble, there are two possibilities: connected electrical trouble disconnected and sense line connector trouble. If one failure occurs, the inlet TAI pressure switch will be in trouble from this failure. From the failure of the engine problem, there are two possible failures, namely engine fault, and engine control problem. If one of the possible failures occurs, the engine will have a problem. From the failure of the hot air distribution trouble, there are two possibilities, namely the engine duct problem and the panel bottom problem, if one of the possible failures occurs then the hot air distribution will have trouble. From the EICAS trouble, there are two possible failures, namely the EICAS trouble module and No source electricity, from this failure, if one failure occurs, EICAS will have trouble. From the possibility of an electrical supply trouble failure, there are two possibilities, namely a negative electrical source and a wiring problem, if one of the possible failures occurs then the electrical supply will have trouble. The explanation above is shown in the form of an analysis of the engine failure analysis table for the Boeing 737-800 NG part 2, which can be seen in Table 2 below.

Table 2
Engine Failure Analysis Anti ice system Boeing 737-800 NG Part 2
Engine Failure Analysis Anti ice system Boeing 737-800 NG Part 2

| NO | Type of Failure | Cause of Failure | Gate | Description | Reference |
|----|-----------------|--------------------------|------|---|-----------------------|
| | | a. Actuator fail (11) | | If one of the causes of failure occurs, there will be an inlet | Source information |

| | | | | | |
|----|--|---|----|---|--------------------|
| 5 | Inlet cowl TAI valve trouble(5) | b. Electrical connector disconnected (12) | OR | cowl TAI valve trouble | |
| | | c. Control selenoid trouble (13) | | | |
| 6 | Inlet cowl TAI pressure switch trouble (6) | d. Regulator trouble (14) | OR | If one of the causes of failure occurs, there will be an inlet cowl TAI pressure switch trouble | Source information |
| | | a. Electrical connector disconnected (12) | | | |
| 7 | Engine b. Engine duct trouble (18) | b. Sense line connector trouble (15) | OR | If one of the causes of failure occurs, an engine problem will occur (7) problem (17) | Source information |
| | | a. Engine fault (16) | | | |
| 8 | Hot air distribution (8) | a. Engine duct trouble (18) | OR | If one of the causes of failure occurs, there will be a failure in the hot air | Source information |
| | | b. Panel button problem (19) | | | |
| 9 | EICAS electricity (21) | a. EICAS modul problem (20) | OR | If one of the causes of failure occurs, an EICAS failure will occur problem (9) | Source information |
| | | b. No source (9) | | | |
| 10 | Electrical supply (22) | a. Negatif electrical source (22) | OR | If one of the causes of failure occurs, there will be a failure in the electrical supply | Source information |

trouble
(10) b. Wiring problem
(223)



After making the FTA above, the next step is to determine the Minimum Cut Set (MCS) for the anti-ice system engine failure which is explained by Boolean algebra, as follows:

$$\begin{aligned}
 \text{Top event (1)} &= 2 + 3 + 4 \\
 &= (5+6) + (7+8) + (8+9) \\
 &= ((11+12+13+14) + (12+15)) + ((16+17) + (18+19)) \\
 &+ ((20 + 21)+(22+23)) \\
 &= 11+12+13+14+15+16+17+18+19+20+21+22+23
 \end{aligned}$$

From the results of the MCS above, it can be concluded that there were 13 essential events that could lead to the occurrence of top events. Basic events that can cause engine anti-ice system failure on a Boeing 737-800 NG aircraft are as follows:

1. Code 11 = *Actuator Fail*
Conditions where this damage can cause the valve not to work
2. Code 12 = *Electrical Connectorr Disconnected* Damage to the connector connected to the power source
3. Code 13 = *Control Selenoid Trouble*
This condition is where the solenoid does not receive an electrical signal from the battery and causes the cowl inlet valve not to work.
4. Code 14 = *Regulator Trouble*
This damage causes the cowl valve component to losing control of the valve.
5. Code 15 = *Sense Line Connectore Trouble*
This condition is where the connector connected to the power source
6. Code 16 = *Engine Fault*

This failure condition causes it not to work.

7. Code 17 = *Engine Control Trouble* This condition causes engine failure.

8. Code 18 = *Engine Duct Trouble*

This condition causes the air distributed to the anti-icing engine to be not optimal.

9. Code 19 = *Panel Buttom Problem*

This failure causes the button cannot to function normally.

10. Code 20 = *EICAS Modul Problem*

This failure causes the indication on the engine not to function normally.

11. Code 21 = *No Souce Elecricity* This failure causes no electric current.

12. Code 22 = *Negatif Electrical Source*

This condition causes the module not to be supplied with electric current

13. Code 23 = *Wiring Problem*

Conditions where the wiring will be a problem in EICAS

Conclusion

The causes of failures that occur in the anti-icing engine B737-800 NG using the fault tree analysis (FTA) method. The results obtained from the minimum cuts set from Boolean algebraic calculations consisting of 13 basic events on the engine anti icing system, namely as follows: actuator fail (11), electrical connectorr disconnected (12), Control Selenoid Trouble (13), Regulator Trouble (14), Sense Line Connectore Trouble (15), Engine Fault (16), Engine Control Trouble (17), Engine Duct Trouble (18), Panel Buttom Problem (19), EICAS Module Problem (20), No Souce Elecricity (21), Negative Electrical Source (22), Wiring Problem (23).

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