JUMANTARA

Jurnal Manajemen dan Teknologi Rekayasa
ISSN: 2964-0741 (Print)
ISSN: 2962-7079 (Online)
DOI: 10.28989/jumantara.v4i2.2825

Fault Tree Analysis of Nose Landing Gear Failure Function of Boeing 737-800 Next Generation Aircraft

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Article Info

Article history:

Received January 21, 2025
Accepted May 27, 2025
Published July 1, 2025

Keywords:

Retract actuator
Slow to retract
Troubleshooting
Fault tree analysis

ABSTRACT

The retract actuator is one of the main parts of the landing gear, which functions to retract or extend. The retract actuator must be free in its operation and its movement must also be smooth. The aircraft experiences a functional failure if the retract actuator is in a slow to retract condition, where there is a slowdown during retract and extend. Careful initial handling is required and in accordance with aircraft maintenance handling procedures. Indications of initial failure can be obtained by connecting the same component maintenance log book on the same type of aircraft. This study uses the Fault Tree Analysis (FTA) method on the Boeing 737-800 Next Generation aircraft in the Merpati Maintenance Facility hangar. The source of data entered comes from the component maintenance log book on the aircraft with the same type. After the analysis was carried out, the minimum cut set results were obtained with calculations consisting of 18 basic events.

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1. INTRODUCTION

Airplanes are one of the most popular forms of transportation for everyone on earth, besides being a transportation that has high technology from other forms of transportation, such as cars, trains, ships, and other transportation. The benefits of aviation are felt to continue to increase by the world community every year, growth in terms of finance, especially the development of the world market, and its increasingly easy process[1], [2]. In terms of individual benefits, countries and regions are also profitable. To support this aircraft to remain at the highest level of transportation, one of the requirements is the best and most coordinated maintenance process[3]–[8]. The purpose of carrying out aircraft maintenance is so that an aircraft remains in an airworthy, safe, and reliable condition. With the maintenance, it is expected to produce comfort both while still on the ground and in the air for customers or aircraft passengers so as to increase the productivity of the related company[9].

Maintenance on the Boeing 737-800 NG aircraft is carried out periodically because the time limit (age) of each component in the aircraft is different, so that when the aircraft has entered the schedule for maintenance, the inspection is more emphasized on components that have reached or are approaching their time limit[10]–[12]. One of the systems on the Boeing 737-800 NG aircraft is the landing gear, which plays a significant role in aircraft operation. The landing gear consists of two main landing gears and one nose landing gear. The main landing gear is located on the inboard of each nacelle and behind the rear wing spar, while the nose landing gear is located under the aft bulk head of the control cabin, which is used to help support the front of the fuselage. This is also used to direct the aircraft when on the ground. The nose landing gear is equipped with a steering system while the main landing gear is equipped with a brakes system.

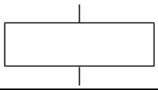
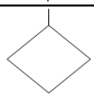
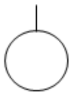
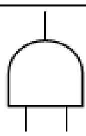
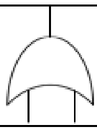
If there is damage to one of the components in the nose landing gear, it will affect the operation of the system, such as damage or leakage in the nose landing gear component which will affect takeoff and landing. As a result, the aircraft cannot land safely. One component is installed in the nose landing gear, namely the retract actuator. Retract is when the landing gear folds or enters the fuselage, while extend is the landing gear to open or exit again.

To shorten the repair time, an analysis of the cause of the damage was carried out using the Fault Tree Analysis (FTA) method. The FTA method is used for time efficiency, namely by collecting maintenance data from aircraft maintenance log books of the same type on the same components. FTA is deductive, meaning that the analysis starts from the peak event (system failure) and works backward from the top of the tree to the leaves of the tree to determine the root cause of the peak event. The results of the analysis show how different components that experience failure or certain environmental conditions can combine to cause system failure. After the construction of the fault tree, the analysis is carried out at two levels: the qualitative level and the quantitative level. Qualitative analysis is usually carried out by reducing the fault tree to a Minimal Cut Set (MCS), which is the sum of the disjoint products consisting of the smallest combination of elementary events necessary and sufficient to cause the peak event[13]–[17].

2. RESEARCH METHODS

Fault tree analysis (FTA) is a method or technique used to find the root of a problem. FTA itself is one of the risk management methods, the method used is to find a problem that occurs to overcome failure. This Fault Tree Analysis method is effective in finding the core of the problem because it ensures that an unwanted event or loss incurred does not originate from a single point of failure. Fault Tree Analysis identifies the relationship between causal factors and is displayed in the form of a fault tree involving simple logic gates[14]. The FTA method, which is based on logic diagrams, can reveal the relationship between essential events and peak events through logic gates. This can provide quantitative and qualitative analysis. The symbols in fault tree analysis can be seen in Table 1 below:

Table 1. Fault tree analysis

Symbol	Information
	*Top Event*
	*Intermediete Event*
	*Undeveloped Event*
	*Basic Event*
	*Logic Event AND*
	*Logic Event OR*

Explanation of the symbols in the fault tree analysis (FTA) above as follows:

a. Rectangle
   The rectangle image shows an event at the top level (top event event).
b. Rectangle
   The rectangle image shows an event at the middle level (intermediate fault event) in the fault tree.
c. Diamond
   The diamond image shows an unexpected event (undeveloped event). Unexpected events can be seen in the fault tree and are considered the earliest events that cause damage.
d. Circle
   The circle image shows an event at the bottom level (basic event).
e. AND Gate

 ISSN : 2964-0741 (Print), 2962-7079 (Online)

An output event occurs if all input events occur simultaneously.

f. OR Gate

An output event occurs if at least one input event occurs.

3. RESULTS AND ANALYSIS

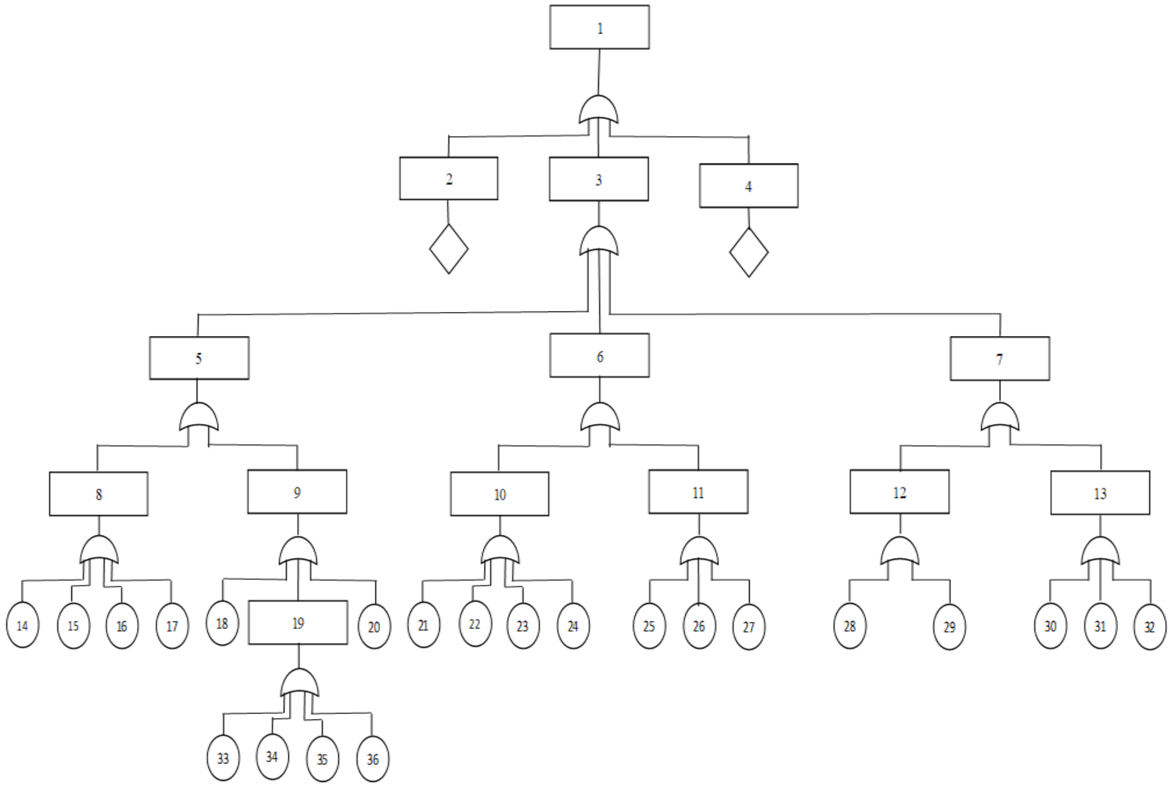


Figure 1. Fault tree analysis results

In fault tree analysis (FTA) there is a numbering that functions to provide a name according to the problem that occurs, for the numbering in the fault tree analysis (FTA) of the Boeing 737-800 NG aircraft there are 35 numbers. Table 2 is an explanation of the FTA:

Table 2. Fault tree analysis results

No.	Failure	No.	Failure
1.	Loss of NGL capability when retracting	19.	Leakage in hydraulic up hose
2.	No hydraulic power	20.	FOD damage
3.	Mechanical failure	21.	Pin damage
4.	No electrical power	22.	Lack of grease
5.	Retract actuator failure	23.	FOD damage
6.	Lock actuator failure	24.	Wear limits on washer
7.	Lock mechanism failure	25.	Due to dirt
8.	Internal damage	26.	FOD damage
9.	External damage	27.	Hydraulic line connector corrosion
10.	Top pin damage	28.	Wear limit
11.	Bottom pin damage	29.	Incorrect installation
12.	Bushing damage	30.	Corrosion on spring assembly
13.	Lock actuator corrosion	31.	Corrosion on lock link assembly
14.	Attachment bolt damage	32.	Lack of grease
15.	Chrome piston scratches	33.	Damage bolt
16.	Actuator tube seal damage	34.	Damage clamp
17.	FOD and corrosion damage	35.	Over pressure
18.	Hydraulic connections leak	36.	Damage on reducer due to wear limit

Fault tree analysis (FTA) is one method that can be used to find the root cause of various problems that exist. By using FTA, the root cause of the problem can be found from the results of interviews with operators.

This is also an analytical tool that graphically translates combinations of what causes system failure. This technique is useful for describing and assessing events in the system.[12].

Nose landing gear loses nose landing gear capability when retract (TE)
TE = 1 = 3
TE = 3 = 5 + 6 + 7
TE = 5 = 8 + 9
TE = 6 =10 + 11
TE = 12 + 13

TE = 8 = 14 + 15 + 16 + 17
TE = 9 = 18 + 19 + 20
9 = 18 + 33 + 34 + 35 + 36 + 20

TE = 10 = 21 + 22 + 23 + 24
TE = 11 = 25 + 26 + 27

TE = 12 = 28 + 29
TE = 13 = 30 + 31 + 32

TE = 1 = 5 + 6 + 7
= 8 + 9 + 10 + 11 + 12 + 13
= 14 + 15 + 17 + 18 + 19 + 20 + 21 + 22 + 23 + 24 + 25 + 26 + 27 + 28 + 29 + 30 + 31 + 32

Thus there are 18 minimal cut sets (MCS) number 14 + 15 + 17 + 18 + 19 + 20 + 21 + 22 + 23 + 24 + 25 + 26 + 27 + 28 + 29 + 30 + 31 + 32. The probability of TE can be calculated by adding the failure probabilities of the 18 MCS. In general, the following are some factors that may be the cause of the deceleration of the nose landing gear retract actuator on the Boeing 737-800 Next Generation aircraft.

4. CONCLUSION

Causes of possible failures in the retract actuator using the fault tree analysis (FTA) method, the failure tree is reduced to a minimal cut set (MCS). Minimal cut set (MCS). is the number of separate products consisting of the smallest combination of basic events necessary and sufficient to cause a top event. The results of the minimum cut set obtained 18 basic events: damage to the attachtmen bolt, scratches on the chrome piston, damage to the seal in the actuator tube, fod damage and corrosion, leakage of hydraulic connections, leakage of the hydraulic up hose, fod damage, damage to the pin, lack of grease, fod damage, wear limits on the washer, due to dirt, fod damage, hydraulic line connector corrosion, wear limits, wear limits, installation errors, corrosion on the spring assembly, corrosion on the lock link assembly, lack of grease, trouble that can cause failure in the Top Event (TE) loss of NGL capability when retracting. After obtaining the possibility of failure, repairs are carried out by prioritizing the possibility of failure.

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