Mechanical failure of the Aircraft Landing Gear using Fuzzy Cognitive Mapping.

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Abstract*: *One of the most Important Components in the Entire aircraft is the Landing Gear. In the recent years there has been many incidents were the landing gear has failed both mechanically and also due to pilot's intervention. Taking only the mechanical causes we are applying a Fuzzy model called as Induced Fuzzy Cognitive Mapping to determine the most important cause of mechanical failure of landing gear. The result will render useful mainly in the design of reliable aircrafts as focus can be given on the important causes so as to prevent failures that has been occured by that caused by the factors that was taken to prior consideration.

Index Terms*: *Directed Graph, Fuzzy Cognitive Mapping (IFCM), landing gear, Weighed Matrix.

I. INTRODUCTION

The aviation industry is one of the most important and growing industry in the world. As the importance is increasing from day to day the necessity of passenger safety and air reliability has also continuously increased. This means that it is extremely important to ensure that the aircraft operates in tip- top form from the small operation in an airport till the moment when it stops its operation in the next airport. The more we focus on safety of the airplane it is clearer that the importance lies in the point to point commutation problems. Although, aircraft hijacking has become a crucial problem in modern day aircraft operations, it is more important to focus on the problems that are posed by structural components and other important The aviation industry is one of the most important and growing industry in the world. As the importance is increasing from day to day the necessity of passenger safety and air reliability has also continuously increased. This means that it is extremely important to ensure that the aircraft operates in tip- top form from the small operation in an airport till the moment when it stops its operation in the next airport. The more we focus on safety of the airplane it is clearer that the importance lies in the point to point commutation problems. Although, aircraft hijacking has become a crucial problem in modern day aircraft operations, it is more important to focus on the problems that are posed by structural components and other important systems in an aircraft It has been come into the picture that there has been lot of incidents and meetings pertaining to air safety. From a check, it is evident that the aircraft Landing Gear is one such important component that can clearly define the aircraft's reliability.

In a lament language a Landing Gear can be defined as an undercarriage of an aircraft which is made to serve the purpose of Take-Off and Landing. On performing a historical evaluation over the Landing Gear systems there has been a revolutionary development in terms of its usage. Earlier landing gears were merely wheels that helped to take-off from the ground and later land upon a runway. Whereas now we can see aircrafts that has landing systems to ensure Vertical Operations and has led to a new and comfortable concept of Vertical Take – off and landing (VTOL).

II. DEFINING THE ATTRIBUTES

C1-Improper Fitting
C2-Improper Maintenance Procedures
C3-Parts Worn beyond Lifetime
C4-Improper Installation
C5-Improper Securement
C6-Use of Unapproved Components
C7-Parts Failure or Fatigue
C8-HydraulicLlines Rupture
C9-Electrical Wire Failure & Relays
C10-Actuators and Contactors
C11-Warning Systems Malfunction
C12-Safety Switched Faults
C13-Uplocks failed to release
C14-Down Locks Failure
C15-Jamned Wheels
C16-Improper Lubrication
C17-Insufficient Hydraulic Fluid
C18-Retraction of Landing Gear with Tow Bar still attached.

1. Improper fitting: -

Landing gear is one of the critical sub systems during both landing and takeoff. In this fitting of parts is very important. In case of any improper fittings of any parts (even it may be a small nut) may leads to crash of aircraft.

2. Improper maintenance: -

Maintenance plays dominant role in any part or anything for its proper functioning. In landing gear if the maintenance checks are not done properly then there may be a chance of system failure or hydraulic jam and it leads to improper functioning of the system. That the aircraft may undergone for a crash.

3. Worn out parts: -

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Parts which are worn out are due to improper installation or improper fitting. These worn out parts are leads to structural damage of the system and leads to crash landing or crash of aircraft.

4. Improper Installation: -

Installation of attaching parts of the system should be done exactly without any mistake. If the installation is not done properly then the parts may get worn out from the surface and functioning of the system may get affected which leads to aircraft crash.

5. Improper secure: -

Security of some installed parts should be taken care properly by using safety pins for the nuts and bolts of specified type. If not then those type of parts cause physical failures of the system.

6. Use of Unapproved parts: -

Parts which are using for aircraft manufacturing or repair should contain a specified approval from the aviation authorities like DGCA. They give approval only after proper testing. So by using the unapproved parts the quality may get affected and leads to crashes.

7. Failure and Fatigue: -

Fatigue is one of the important loads acting on aircraft. Thus the parts which are using for aircraft landing systems should be capable to bear the fatigue load acting while landing and takeoff.

8. Hydraulic line rupture: -

Hydraulic system plays a major role in aircraft landing system. The total safety of the aircraft landing based on the landing system (mainly braking system which has hydraulic oil as lubricant). If there is any malfunction in hydraulic system then the whole landing system will get affected.

9. Electrical connection failures: -

Most of the operations in modern aircrafts are doing by electrical signals through electrical wires. If the connection failed due to any reasons then the operations get affected which further leads to crashes

10. Improper contactors and actuators: -

Contactors and actuators are used for hydraulic and pneumatic operations. If the functioning of these parts is improper then the pumping of lubricant oil is not done properly which leads to improper functioning of landing system.

11. Warning system malfunctioning: -

If there is any improper functioning happens in landing system then the warning alarm will on automatically be indicating that. But sometimes there is a malfunction in the alarm system which makes the pilot confuses about the landing system.

12. Jammed wheels: -

Due to Improper maintenance of landing system sometimes the wheels get jammed during takeoff and landing of aircraft. This type of landing gear failure causes major accidents compare to other types of failures. When the wheels are get jammed then the aircraft will not move forward and it may get crashed down at the movement.

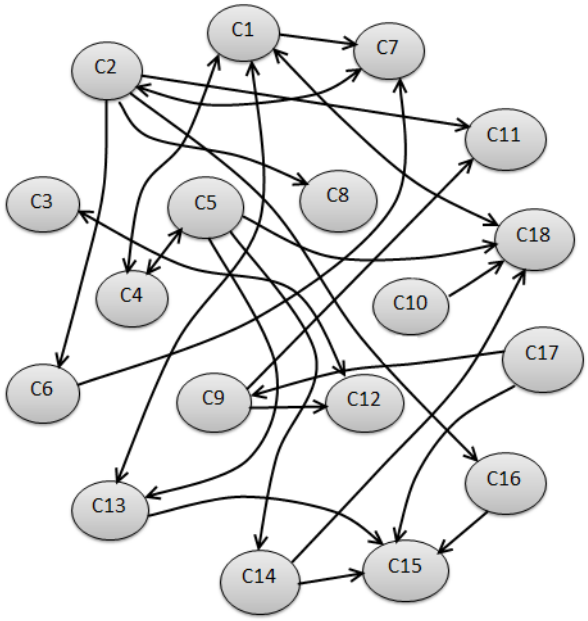
13. Improper lubrication: -

For smooth functioning of landing system the lubrication process plays a major role. All the breaking system and operating system of landing gear are being operated by the lubricating oil process in major part of aircrafts. If the lubrication system gets failed then the whole landing gear system will get affected as there is no proper supply of lubrication process. Sometimes the taxi will not be open up for the landing process of aircraft for which the crash landing need to be done.

14. Insufficient hydraulic fluid: -

Hydraulic system mainly gets operated based on the pressure force applying on the hydraulic system through the oil. This happens only when the sufficient hydraulic fluid present in the system. If the fluid is insufficient then the pressure applied on the system will not be sufficient for the operation of system and the malfunctions will arise.

In the directed graph we will be plotting the various causes as a Domain set of C, where C= {C1, C2, C3….}. Each of the attribute is a defined member in the domain space



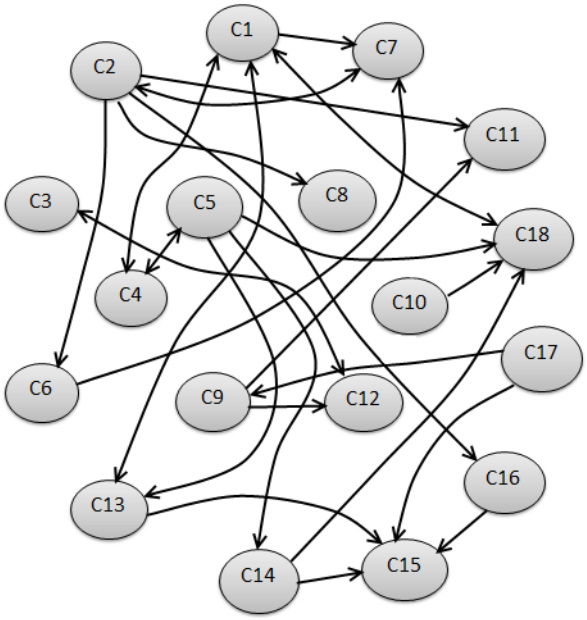


Figure-1 –Directed Graph

The directed graph has been plotted based on the relationship of various concepts to each other.

The property of a Directed graph is that:

- If there exist a direct relationship between the attributes then the value of the relationship is taken 1
- If no relation exists then it is taken as 0.
- If an increase in one attribute leads to decrease in the other then the value is taken as -1.But in our case we will not take the third condition as there exists no cross relationship in the directed graph. The fuzzy directed graph shows that:
- Improper rigging leads to fatigue of parts.
- Improper repairs or maintenance cause problems like use of unapproved parts and rupture of hydraulic lines and also malfunctions of the hydraulic lines.
- Improperly secured parts increases the chance of uplocks and downlocks fail to release and engage respectively.
- Retraction of the landing gear with a tow bar still attached is caused by plenty of factors like failures in contractors and actuators also when downlocks fail to engage.
- Wheels get jammed when there is lack of lubrication and reduced levels of hydraulic fluid.

III. ALGORITHM

The fuzzy cognitive mapping comes with the following set of definitions:

- The nodes in a FCM are having fuzzy sets, then these nodes are called fuzzy nodes.
- FCM having Edge Weights or casualty are from set {-1, 0, 1}, then they are called simple FCM.
  Consider the nodes E_1, E_2, ... , E_n of the FCM. Assume the directed graph is drawn using an edge $e_{i,j}$ ε{0,-1,1}, then that matrix containing these elements are called adjacency matrix of the FCM
- When there is a feedback in FCM in a revolutionary way then the FCM is called a Dynamical system.
- If the FCM settles down with a state vector repeating in the form $A_1 \rightarrow A_2 \rightarrow \ldots\ldots A_n \rightarrow A_1$. Then such an equilibrium is called a limit cycle.
- Now we use the matrix 'M' we determined the problems. Consider Improper Fitting as ON and the remaining nodes in the OFF state.
- i.e.:E1= (1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0) The product of E1 and M are:
- E1*M= (0 0 0 1 0 0 1 0 0 0 0 0 1 0 0 0 0 1) E1'= (1 0 0 1 0 0 1 0 0 0 0 0 1 0 0 0 0 1)
- Now as per Induced Fuzzy Cognitive Map Method, each component in the E1' vector is separately taken and the matrix product is calculated. The vector with maximum ones which occur first is considered as E2
- Iteration Set 1:
- E1'*M →(1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0)*M= (0 0 0 1 0 0 1 0 0 0 0 0 1 0 0 0 0 1)
- E1'*M → (0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0)*M= (1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0)
- E1'*M → (0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0)*M= (0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0)
- E1'*M → (0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0)*M= (1 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0)
- E1'*M →(0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1)*M= (1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0)

After several such iterations it is found that

- E2= E1'*M → = (0 0 0 1 0 0 1 0 0 0 0 0 1 0 0 0 0 1) Product of E2 and M were calculated,
- E2*M → = (3 1 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0)*M E2' = (1 1 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0)
- Iteration Set 2:
- E2'*M → = (1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0)*M = (0 0 0 1 0 0 1 0 0 0 0 0 1 0 0 0 0 1)
- E2'*M → = (0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0)*M = (0 0 0 0 0 0 1 1 0 0 1 0 0 0 0 1 0 0)
- E2'*M → = (0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0)*M = (0 0 0 1 0 0 0 0 0 0 0 0 1 1 0 0 0 1)
- E2'*M → = (0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0)*M = (0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0)
- After the iterations we can see that,
- E3 = E2 = (0 0 0 1 0 0 1 0 0 0 0 0 1 0 0 0 0 1) and hence this point will be taken as the fixed point. When there is a Repeated Occurrence of a threshold value, then the value is considered as the fixed point. The iteration and the calculation gets terminated. Similarly, any one of the State Vectors can be taken and the effect can be analyse

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0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	1
0	0	0	0	0	1	1	1	0	0	1	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
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0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table-1 (FCM Matrix)

IV. CONCLUSION

While on analysis of the mechanical failures by keeping the Improper rigging in ON state we have found that the resultant vector is (0 0 0 1 0 0 1 0 0 0 0 0 0 1 0 0 0 0 1).On using FCM it is observed that improper installation of parts, failure of fatigue parts, Failure of uplocks to release and retraction of landing gear with tow bar being

still attached has been the major reasons for the mechanical failure of the landing gear. It is to be taken at most care that the landing gear health is not affected by compromising one factor over the other as any problem pertaining the landing gear is a question of loss of life and death.

- Fuzzy Cognitive map is a model that is subjected both advantages and disadvantages. Quoting some of the advantages will be the ease of using it in any immeasurable quantity. And as in our case as the result is highly unsupervised this model is more comfortable to use. The disadvantage is that the opinions of the expert can be highly biased

Future Work:

The paper focuses on providing light upon the safety and reliability improvement that can be brought to the aviation industry by improving the safety factor of the aircraft landing gear.

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