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Case Study Article

Failure Mode and Effects Analysis on the Hydraulic System of Aircraft Ilyushin-76

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Abstract

The emergence of accidents in industrial and aerospace environments has increased with the increase of activities in this field and the use of machinery. In traditional systems, after accidents and irreparable damage occur, research is done to investigate the defects and their causes. But today, due to the existence of different methods of hazard identification and risk assessment, before the occurrence of accidents, it is possible to identify accident hotspots and critical areas and to prevent and control them. Reviewing the analysis of failure modes and their effects (FMEA) is one of the industry's common risk assessment methods. Its purpose is to analyze the failure to obtain a comprehensive repair program that leads to the continuation of the operation of physical assets. In this study, with the help of the FMEA method, the risk priority number of the Ilyushin-76 aircraft hydraulic system was calculated, and its critical parts were identified. Due to the shortcomings of the usual risk priority number in the FMEA method, side methods of aggregation of ideas and Schaefer evidence theory were used to calculate the risk priority number. Using these methods, involving probabilities in the expression of opinion, the results of determining critical components became closer to reality. From the results obtained from the study and evaluation of critical components by the two usual RPN methods and Schaefer evidence theory, nine highly critical components are obtained jointly.

Keywords: Risk; Hydraulic system; RPN; Reliability; Ilyushin; Failure mode.

1. Introduction

The hydraulic system in all aircraft is one of the main systems and as a power transmission and flight control system, its optimal and correct operation has always been necessary and of great importance. Hydraulic power is distributed to all parts of the aircraft through pipes and lines, and a number of components are used along these pipes, each of which, in turn, is important. This importance stems from the fact that the main systems, such as the aircraft landing gear and the main and secondary command systems, draw their power from the hydraulic system, and in fact, the correct operation of these systems is highly dependent on the performance of the hydraulic system.

The aviation industry is one of the most complex and risky industries; identifying the hazards and risks in it has a special priority and the failure analysis process should be examined before any event and preventive action should be taken to prevent the occurrence of an event. Preventive maintenance is a key part of supporting hydraulic systems to increase component life and reduce machine downtime, and like any functional system, failure analysis must be performed to eliminate subsequent minor failures. Using the failure mode analysis method, the hydraulic system or subsystems can be examined to identify possible defects in all its components and try to reduce the effects of possible defects on other parts. Accordingly, and considering the accidents and air events that have occurred, research needs to identify and analyze breakdown modes and their effects in sensitive jobs focusing on aircraft maintenance and repair. Quantitative analysis is based on mathematical calculations and the use of software programs. Since the hydraulic system is one of the main systems of the aircraft, identifying the risk of its occurrence and exhaustion is of particular importance [1].

W. G. Zhang and G. M. Lin, in an article have analyzed the failure of the aircraft hydraulic system. Aircraft failure is characterized by secrecy, complexity, and uncertainty. Therefore, if the aircraft's hydraulic systems fail, it will have a long and inefficient maintenance cycle. The process of investigating aircraft failure modes in this article was based on the analysis of oil pollution, breaking of hydraulic pipes, high oil temperature, and leakage. Statistical data show that 60% of pollutants enter the hydraulic system during the installation process. Therefore, solid particle contamination is the main cause of the hydraulic system problem. These particles enter the system from the outside. The second type of pollution particles is caused by the wear of parts. When the system works for a long time, the oil oxidizes and produces a colloidal precipitate. Therefore, in the process of assembly and disassembly of parts and daily maintenance, it prevented the entry of polyester fibers and solid particles into the mouth of the pipe and used silk fabrics instead of cotton to clean the parts of the hydraulic system. Also, from the analysis of accidents caused by hydraulic pipe fractures, pipe fractures have actually been a type of failure fracture. The main reason for pipe failure is that the hydraulic system operates at high pressure, large current pulse, large hydraulic shock, and a high-frequency oscillation environment.

For this reason, the system oil pipe suffers from radial vibration and bending vibration. Due to the vibration should be the size and material of the hydraulic pipe should be made according to the required pressure. Under normal circumstances, the high-pressure system should choose stainless steel pipe and aluminum pipe. When choosing a pipe, the surface of the pipe should not have clear machining tools or micro-cracks, and when installing the pipe, prevent differences between the pipes and use suitable support for installation [2].

X. N. Luo, Y. Yang, in an article reviewed the reliability analysis for hydraulic boosters of aircraft control surfaces. In this work, hydraulic system failures are categorized as follows:

1. Malfunction of control levels
2. Hydraulic pump failure
3. Oil pollution
4. Abrasion in the hinge joint
5. Distribution valve wear
6. Lubrication and oil leakage (leak of sufficient oil)

If any of these failures occur, it will lead to system failure and, consequently, catastrophic consequences such as a plane crash. The obtained results show that the following steps should be taken to prevent defects and increase reliability.

1. Comprehensive inspection of the aircraft should be performed regularly to ensure that the aircraft can fly the body of the system and without any safety hazards.
2. Mechanical design should be improved and high-hardness materials should be selected to produce connection mechanisms and reinforcing supports.
3. For hinged joints that are always worn, it is necessary to periodically lubricate to prevent wear and tear that leads to defects
4. For the hydraulic booster, the appropriate oil must be selected and the aeration of the hydraulic cylinder must be ensured. It is necessary to prevent vibrations due to the reduction of the elastic coefficient of the oil volume. After a specified time of flight, the oil must be a drain and tested [3].

A. Lališa, S. Bolčekováa, O. Štumbauer, studied the ontology-based reliability analysis of aircraft engine lubrication systems. This article focuses on identifying the limitations and deficiencies of reliability methods that are currently used in the aviation industry. The goal is to propose a solution to address these issues and, consequently, improve the way reliability analyses are carried out in the industry. In collaboration with an aircraft engine manufacturer. The results show that the ontology-based approach has significant potential for improving the consistency and overall quality of the reliability analyses in aviation [5].

P. Gao, et al., reviewed the vibration analysis and control technologies of the hydraulic pipeline system in aircraft. An aircraft hydraulic piping system is a high-pressure and high-pressure system, including pipe bodies, pipeline fittings, support parts (brackets and clamps) and so on. Hydraulic pipes pass through all parts of the aircraft and intersect due to space constraints, and the space between the pipes and other adjacent parts is very small. The vibrations of the fuselage and the engine are very high in flight, and this causes the hydraulic pipeline system to vibrate severely. Excessive vibration can cause friction or damage to the surface, as well as collision with adjacent pipes and loss of pipe connections. According to US statistics, fuel and hydraulic pipeline system faults account for 50 to 60 percent of all aircraft component faults, which have a significant impact on flight safety [4].

M. Mohammad pour, P. Mohamad, J. Ilkandi, studied the Risk Assessment for the Lubrication Filter of Turbo-Jet by Modified FMEA. In this study, after introducing the FMEA method and how to implement it, its limitations are examined and then an improved method for calculating RPN is introduced. Then, using this method, based on the risk factors determined by the three expert teams, the risk priority numbers for the failure modes of the oil filter of the jet engine lubrication system are obtained. From the results of this study, this method has been used to evaluate the semi-quantitative reliability of a jet engine oil filter. The predominant failure mode for the filter is introduced and then it is decided to prioritize the numbers close to each other and almost equal, to prioritize them again based on the probability of the causes of failure, qualitatively and engineering judgment [6].

S. S. khezrpour, and A. Fayazi, studied the effect of a note focusing on reliability on the behavior of the Bell 205 and 212 helicopter hub assemblies in the Iranian helicopter fleet at Penha for a period of 25 years (1987 to 2012). They used the Weibull distribution to validate the mathematical calculations of the reliability of the system. And coded it with Fortran software and then compared the result with the mini-tab software. In this study, parts are divided into three categories based on service life: 1. Parts that do not necessarily have a service life and are used 2. Parts that are repaired over a period of time, 3. Parts that are repaired under the conditions created.

They divide the breakdown of parts and the impact on the performance of the helicopter into three categories: First, the breakdown that causes the accident. The second is the failure that stops the flight operation and the third is the failure that occurs during the flight and the flight process does not stop. One of the results of this study is the weakness in the design and materials used in that set, which suggests building a hub with composite materials due to its lighter, longer service life, lower notes, lower cost and higher reliability [8].

L. T. Ostrom, and C. A. Wilhelmsen, discuss risk assessment methods in a book chapter untilled the development of risk assessment in repair and periodic inspections in the aviation industry. Among the various risk assessment methods, they have introduced two methods, FMEA and error and event tree analysis, which are more widely used in the aviation industry. In this chapter of the book, practical examples are also given. As a result, FMEA has been considered as a powerful tool with a wide range of applications for analyzing the performance of the aircraft net [7].

W. Jiang, X. Chunche, W. Boya, Z. Deyu, in an article as a modified method of FMEA in assessing the risk of aircraft turbine rotor blades, have introduced the Scheffer Evidence Theory method. This method has always been combined with the FMEA method due to its effectiveness in dealing with unspecified and uncertain cases. Schaefer's theory was introduced by Dempster and completed and developed by Schaefer. This theory is widely used in decision-making methods and the process of uncertain information. This theory is used to quantify uncertainty and uncertainty in the analysis of reliability and failure. This theory is used to analyze different states of exhaustion when specialists have different assessments.

As a result of this study, a new method was proposed to correctly assess the level of risk. And that is at a time when the hypothesis cannot be fundamentally combined with Dempster's law. The main point in this article is that the reliability coefficient can be used based on the distance of evidence. The results obtained in this study and numerical examples in the real risk analysis of turbine components have proven that the proposed method is useful and is closer to the accuracy of this proposal. But it can still be improved in some respects, like the expert weighting that was not included in this study [9].

Y. T. Jou, K. H. Yang, L. L. Ming, S. L. Cheng, investigated the effects of failure modes and analysis methods on the aircraft braking system. Failure mode and sensitivity analysis (FMECA) is an engineering technique that was first developed as a formal design method in the 1960s. FMECA is a systematic method that prioritizes the effects of different failure and significance modes. Typically, the FMECA process must be performed in two separate analysis processes that use the Risk Priority Number (RPN) to prioritize each potential failure situation in the first design phase and then (CA) to identify the risk of failure with critical analysis. If designers can identify items with higher potential risk and take corrective action as soon as possible during the product design phase, development time will be reduced and the product life cycle cost will be reduced [10].

Z. Mehmood, A. Hameed, A. Javed, A. Hussain, studied the analysis of the premature failure of aircraft hydraulic pipes, which poses potential hazards to aircraft. Factors related to pipe failure include material characteristics, pipe geometry, environmental conditions, external/internal loading conditions, residual stresses and fabrication defects. The interaction of these factors is highly analyzable. In the aircraft system, compressive stresses and the passage of fluid flow results in cyclic stresses that lead to pipeline failure. In this study, failure in broken surfaces has been observed through electron microscopy (SEM) and has been analytically calculated by solving the kinematic equations of motion of the forces produced by hydraulic pressure on the bend of the pipe. From the results of this paper, this assessment is performed for the failure of prematurely damaged aircraft hydraulic pipes. Hydraulic pressure fluctuations, pipe geometry (curvature and constraints) and the stress concentration of the peripheral grooves produced due to the corrugation of the pipe cover are the three contributing factors to pipe failure. However, pressure fluctuations and changes in pipe geometry always worsen the situation to cause premature failure. Therefore, folding of the cover on the pipe is the main cause of pipe failure and is unsuitable for aircraft hydraulic pipes [11].

S. Oveisi, and M. A. Farsi, studied the software safety analysis with UML-Based SRBD and fuzzy VIKOR- Based FMEA. They use reliability block diagrams to check systems' safety and reliability. A reliability block diagram is a diagrammatic method for showing how component reliability contributes to the success or failure of a complex system. The proposed VIKOR-based SFMEA and RPN are used to risk analysis of high-risk events [12].

A review of past research has shown that there is not a relatively large amount of work on the use of failure modes analysis of the Ilyushin hydraulic system.

The rest of this paper is organized as follows: Section 2 introduces the aircraft Ilyushin-76 and the hydraulic system of this aircraft. Section 3 is devoted to the research method of this article. Section 4 reviews and analyzes the results obtained, and finally, the last section summarizes and concludes this research.

2. Aircraft Ilyushin-76

Ilyushin-76 is a heavy transport four-engine jet aircraft manufactured by Ilyushin-76 Aircraft Manufacturing Company in Russia. The aircraft is designed for hard conditions and has the ability to take off, fly and land at short distances and in rugged terrain in all weather conditions. Since its entry into service, the aircraft has been known as a turning point in the field of air cargo and even bulky and heavy cargo and is capable of carrying passengers on two floors with a capacity of 250 people. The aircraft is capable of carrying 57 tons of cargo at 5,000 kilometers per hour [13].

Due to the special type of landing gear, Ilyushin-76 aircraft is able to land and take off from uneven runways. The large wings of this aircraft can create a lot of lifting force; the horizontal rudder location at the highest point of the vertical rudder of the tail, together with the high force from powerful engines, enables the aircraft to land and take off in short runways. Large doors on either side of the aircraft make it possible to launch cargo from the aircraft with an umbrella.

The specifications of the basic and basic model of this aircraft are as follows:

• The length of the plane is 64.59 meters
• Distance between two tips 5.50 meters
• Height from the ground to the horizontal rudder tip 14.76 meters
• The empty weight of the aircraft is 90 tons
• Maximum loaded weight 57 tons
• The maximum speed of the aircraft is 900 km per hour

2-1 Ilyushin-76 aircraft hydraulic system

The hydraulic system in all aircraft is one of the main systems and its optimal and correct operation is always necessary and of great importance, which makes the maintenance and repairs and periodic inspections on the continuation of the process of operation and safety of Ilyushin-76 aircraft very much. In this section, the performance of the hydraulic system of this aircraft has been explained.

2-2 Operation of Ilyushin-76 aircraft hydraulic system

In this aircraft, there are two separate hydraulic systems, each of which has two hydraulic pumps that are driven by an engine and a hydraulic pump that is driven by an electric motor, Fig. 1. The pumps related to the hydraulic system number one are located on the engines number one and two, the pumps related to the number two system are located on the engines number three and four, and the electric pumps are located on the accessories of the main landing gear of the aircraft. In general, all the accessories of the hydraulic system are number one on the left side of the aircraft and number two on the right side. The pressure of the systems is equal to 210 kg / cm2 and its type of hydraulic oil is AMG-10 [14].

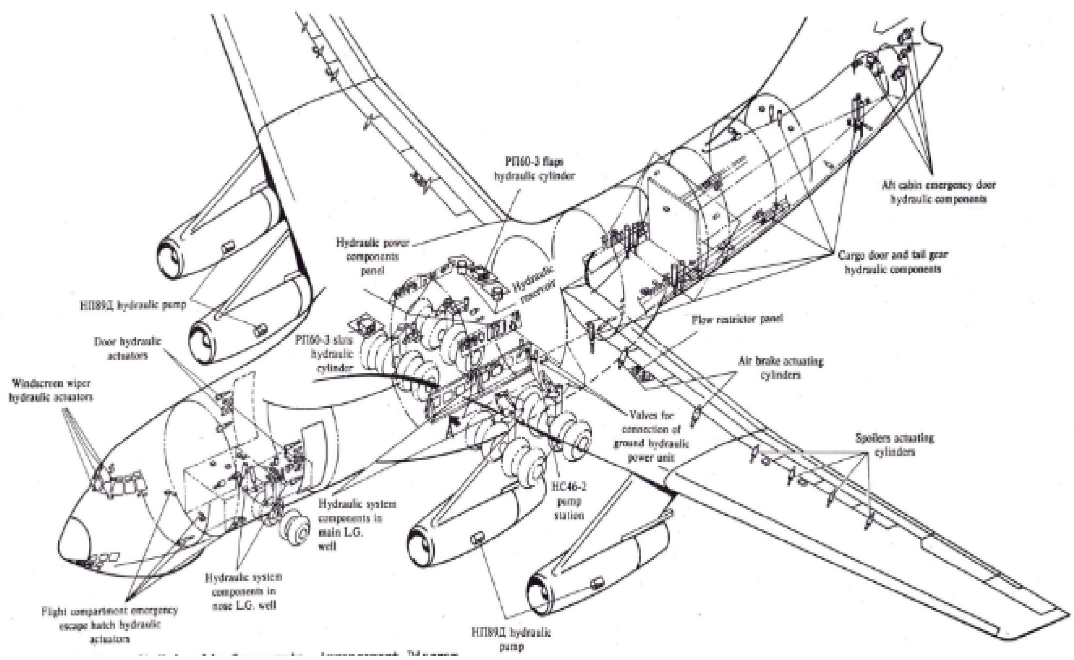

Figure 1 Hydraulic structure of Ilyushin aircraft [13]

Figure 2 shows all components of the Ilyushin aircraft. The source of hydraulic power generation in each of the two hydraulic systems of this aircraft consists of two pumps of variable output type with positive displacement, whose model is NP89D.

NP89D pumps are equipped with a component called a feed governor to adjust the pump output depending on the pressure required by the hydraulic subsystems. When the pump output reaches zero, the system pressure rises to a pressure of 210 kg per cubic centimeter to protect hydraulic pumps from overheating when their output is low. If inside the hydraulic pumps, the governor feeder failure occurs when the pump output current is zero, the pressure of the hydraulic system will increase. To overcome this situation and protect against overheating in the systems, each system is equipped with a safety valve, model GAE86M, which operates at a pressure of 240 kg per cubic centimeter is set.

The suction line and the pressure line of the NP89D pump are each equipped with a valve with quick separation capability, which allows us to get off and on the pump without losing hydraulic oil when unloading and mounting the pump. The valve model is related to the pressure line from model 99 AT04-3. The model related to the suction line is 99AT08-3.

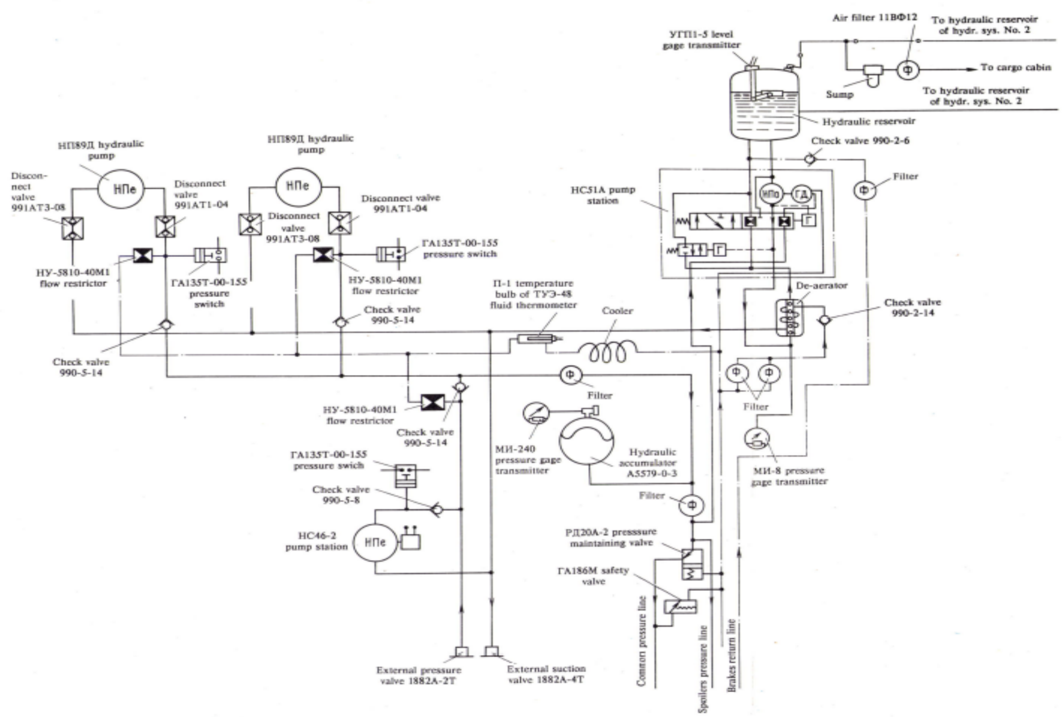

Figure 2. Separated structure of aircraft hydraulic system with parts [13]

Each of systems number one and two has a pump station, the type of model NOS 2-46, which works with AC power. In flight, when the main pumps are lost (mounted on the motors) and if the hydraulic tester is not available, it can be turned on the ground for 2 to 5 minutes, and the required pressure of the subsystems is provided. This pump is switched on and off by two switches located in the hydraulic system panel, which is located on the left side of the pilot. These pumps can also be turned on or off on the ground with the help of two switches located on the rear spanner. These switches are activated after the main switch located in the hydraulic panel is made available to the user in the ID panel mode.

To check the pressure condition in the main pumps of the hydraulic system and the pump position of the pressure sensor switches, model GA135T-00-155 is mounted in the outlet pressure path of the main hydraulic pumps and the pump station. If the hydraulic pressure in these lines falls below at least 155 kg / cm2, the switch operates and turns off the pump light on the hydraulic panel. If the pressure rises and reaches a maximum of 185 kg / cm2, the relevant light turns on (to check the operation of the lamp indicating the pump, press the button related to the motor pump check).

To maintain the hydraulic pressure at a constant level and also to reduce fluctuations in the oil flow, a spherical hydraulic accumulator of type A5579-0-3 is installed in the pressure lines of each hydraulic system. The nitrogen compartment of the accumulator is served with nitrogen up to a pressure of 75 kg / cm2 (in case the hydraulic system pressure is zero). Nitrogen is served by a ground pressure source. The hydraulic pressure in the accumulator can be seen by a ME-240 electrical indicator.

When the amount of used oil and the amount of returned oil are not equal in the system (when charging the accumulator, operating or releasing aircraft brakes, operating single actuators, etc.), excess oil is returned to the tank by the NS51A pump. Is given while the oil shortage is also done by this pump is compensated by the hydraulic tank [14].

3. Failure mode and effect analysis

The failure and effect Analysis Method (FMEA) was recognized in 1949 by the United States Armed Forces with the introduction of the 1629 standard method for performing the effect of failure and critical analysis. The purpose was to "classify" depletions according to their impact on the success of the mission and the safety of personnel and equipment. It was then adopted in the Apollo space program to reduce the risk. His return to earth accelerated with confidence, which means having an effective strategy for managing and controlling the occurrence of failure and its root causes [15].

In the late 1970s, Ford Motor Company introduced this method to the automotive industry for safety and monitoring following the Pinto order. They also used it to improve production and design. In the 1980s, the automotive industry began to implement this method by standardizing its structure and methods, although this method was developed by the military [16].

This analysis is an engineering method used to identify potential errors, problems in a system, process, product, service, and effects. This method is one of the many tools that seek to identify potential problems in the early stages of product and process design. The sooner a malfunction is detected, the lower the cost. This is one of the important principles of quality [17].

FMEA process steps

1. Forming a multifunctional team
2. Process identification, the system under study
3. Specify the steps of the process or system components
4. List potential failure situations for each of them
5. Determine the potential effects of each of these failure states
6. Determine the causes of each of these states of exhaustion
7. List current controls to identify and prevent failure
8. Calculate the Risk Priority Number (RPN)
9. implement preventive and corrective measures
10. Review the risk priority number

3.1. FMEA components

Potential Failure Mode is any type of exhaustion or problem that occurs in the operation of equipment, machinery, product, process, or design and causes them to not perform their function properly.

Occurrence or occurrence of exhaustion (O) is an estimate of the frequency of states of exhaustion (how much error occurs), the number of events is usually between 1 and 10. The number 1 indicates an impossible event and the number 10 means that the event certainly occurs.

The potential effect of failure**,** Potential effects and consequences are states of exhaustion. These effects are considered in terms of impact on the customer (internal and external), environment, safety and financial dimension.

Severity**;** It is a rating that indicates the severity of the effect of exhaustion on the product or customer (internal or external), the severity of exhaustion is usually given between 1 and 10 points; the number 1 indicates that the effect of exhaustion is not serious and the number 10 indicates the worst effect and possible consequences of exhaustion for the product and the customer. Depending on the type of activity and the nature of the organization, organizations can have a specific implementation method within the organization and consider the consequences of exhaustion in addition to the product and the customer on the environment, safety and occupational health.

Current process control; These controls are methods that are used to prevent exhaustion or causes of exhaustion or to identify exhaustion or their causes.

Detection; Discovery is an estimate of the chance that the current control (s) will be able to identify the state of exhaustion or (causes of exhaustion) before the exhaustion occurs or reaches the customer. Because in any type of FMEA, large numbers indicate an increased risk of occurrence and small numbers indicate a low probability of occurrence, small numbers for the probability of detection mean that the depletion is detected and discovered before it occurs either by the customer or after the next operation. Therefore, the number 1 in the probability detection table indicates that exhaustion must be identifiable and the number 10 is undetectable.

Risk Priority Number (RPN) is an indicator for prioritizing failure situations based on their potential risk and, therefore, only makes sense in comparison with other RPNs and failure. The risk priority number is obtained by multiplying the severity of * the occurrence * of the diagnosis. Prioritizing corrective action based only on RPN is wrong, and other parameters, such as intensity score and occurrence, should be considered [18].

In this study, in addition to the main FMEA method, which classifies the critical parts of the hydraulic system of the Ilyushin-76 aircraft using the risk priority number (RPN), three side methods of risk identification have been used to reduce uncertainty and eliminate defects in the method (RPN).

1. Structured interview method A questionnaire is prepared, and the team members are asked to record their opinions based on knowledge and experience using three tables (probability of occurrence, severity, and discovery)].

2. The method of aggregating opinions is one of the methods of expert judgment in which the probability of exhaustion is estimated by a group of experts and is used when there is no estimate of the probability of exhaustion. In this method, experts estimate the probability of exhaustion individually and then these probabilities are summed by geometric mean.
3. Dempster-Schaefer Evidence Theory: Due to the lack of uncertainty in the FMEA method, uncertain details are expressed in the problem by which the system parameters cannot be determined correctly. Dempster-Schaefer's theory of evidence attempts to reduce uncertainty as much as possible, through which qualitative and quantitative information on a particular subject is controlled and model outputs can be evaluated and controlled. Evidence theory is used as a tool to analyze uncertainty in inaccurate probability theory. This theory is based on a belief that results from evidence and discusses existing beliefs about a situation or a system of situations [18]. Uncertainty about the evaluation information of several experts in FMEA and the method of gathering information of several experts about risk factors, the results of the evaluation of each expert with respect to each risk factor of each state of exhaustion is considered as a body of new evidence in this theory [19].

Classification of parts according to their importance and criticality, based on the experience of experts and flight defects of the aircraft archived in the Job Control Branch and the Maintenance Group Form Branch, was classified into 37 parts. Ilyushin-76 Aircraft with 45 years, 26 years, 19 and 13 years, and two master's degrees and one diploma and one bachelor's degree, to identify and list each of the failures and calculate the importance of each risk 37 pieces, the probability of discovery, The severity of the effects and the causes of their exhaustion according to the experience and events that occurred, identified with the help of prepared tables (questionnaire) In the Shaffer Dempster method, the expert presents from zero to one hundred percent to the number he has given to the part under consideration (RPN), and this percentage is applied as a decimal in the number. For example, in the usual method, the expert has given the intensity of the occurrence of a piece to be 8. If 70% of the experts believe in this number, it is 0.3 less than the expert of the usual method, which is 7.7 in the code method. After that, the usual (RPN) and (RPN) Shaffer Evidence Theory (D - S) were calculated and evaluated.

Due to the fact that no required technical publications and circulars have been sent to the aircraft maintenance department by the Ilyushin-76 aircraft manufacturer due to the sanction conditions, so we will file them according to the flight defects in the Jab control section and the maintenance group form branch. We examined the hydraulic components of the aircraft, which is about 20 to 30% of flight defects related to this system. And this is the highest percentage compared to other systems.

Relative Quantity is based on the number of flight and ground defects of each piece in a period of about 15 to 20 years, which is archived in the work control branch and the maintenance group form branch, on the total quantity (Quantity). For example, the number of faults of the hydraulic pump is 20, which is divided by the total faults of 307 and the relative quantity (Relative Quantity) (0.06514658).

Table 1 Quantitative transformation of the probability of failure [17].

Possible rate (base)	Occurrence No.
0.5000	10
0.3333	9
0.1250	8
0.0500	7
0.0125	6
0.0025	5
0.0005	4
0.0006	3
NA	2
NA	1

Then, using the interpolation method (the following equation) and table 1, the probability of events (O Value) obtained with the parameter y was obtained.

y_1 =Low Occurrence Number

$y_2 = High$ Occurrence Number

x=Relative Quantity

$x_1 = Low\ Possible\ rate$

$x_2 = High\ Possible\ rate$

$y_1 = 7$

$y_2 = 8$

$x_1 = 0.05$

$x_2 = 0.125$

$x = 0.065$

As an example, we obtained the probability of failure of the motor hydraulic pump part from the above relation.

Y=0 Value=?

$y = 7 + (0.065 - 0.05)\left(\frac{8-7}{0.125-0.05}\right) \quad \Rightarrow y = 0\ Value = 7.2$

Using the relation of calculating the risk priority number (RPN) from the product () intensity * occurrence * diagnosis (during two common methods (RPN) and Shaffer evidence theory (D - S) was obtained. Four (RPN) obtained with the method of aggregation of opinions were added together, and their mean was calculated.

4. Results and discussion

The main method used in this research is to classify the components of the hydraulic system of Ilyushin-76 aircraft by the FMEA method by calculating the risk priority number (RPN). In order to reduce the uncertainty and eliminate the drawbacks of this method, two side methods of aggregation of opinions and Shaffer evidence theory (D - S) have been used.

In accordance with table 2, in order to decide on the level of risk, the amount of risk priority number (RPN) at three levels of acceptable (1-100), tolerable (100-200), and unbearable (200-1000) in providing a risk assessment model. Occupational and workplace health is defined in the transportation of petroleum products [20].

Table 2. Risk level based on RPN [20]

Risk level based on RPN	Risk classification
1-100	Acceptable
100-200	Unacceptable/tolerable
200-1000	Unbearable

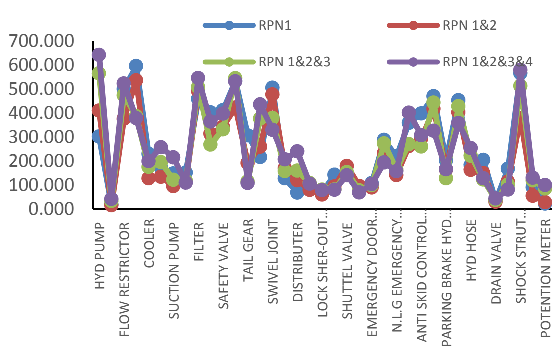

Figure 3. Scheme of Aggregation of Opinions Routing (RPN).

By entering the priority risk numbers of the parts in the usual way and the Dempster Shaffer in the Excel software space, figures 3 and 4 are drawn, and the critical parts of the two methods are identified. According to the diagrams below, the most critical part is the **(**HYD PUMP**)** amplifier, and the least risky part is the pressure sensor switch **(**Press S / W**)** related to the warning system. The very critical parts obtained in both methods indicate the application of these two methods and the cases reported by the opinions of technical experts and the recorded flight defects.

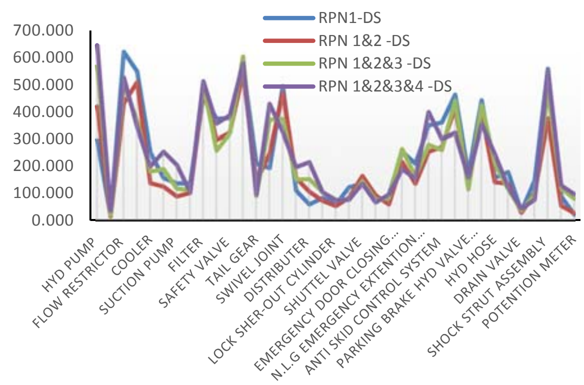

Figure 4. Scheme of Aggregation of Opinions (RPN) Schaefer Evidence Theory

The critical classification of components was limited to 37 components identified in the subset and while summarizing the system-threatening hazards, the following results are summarized:

1. According to the above risk classification table, based on RPN, nine pieces are at an acceptable level, 12 pieces are at a tolerable level and 16 pieces are at an unbearable level. Examining the nine components with the highest risk priority number in the four RPNs, we examine the most critical components of aggregation.
2. Schaefer's evidence theory, the aggregation of opinions in a continuous and convergent number of priority parts, has a great effect and reduces the scattering of individual opinions.
3. Consolidation of opinions reduces individual mistakes in identifying critical parts of the system.
4. Since the level of experience and expertise of individuals is different and the definite statement in determining the parameters of the risk priority number seems to be complex, so the use of Schaefer evidence theory (involving probabilities in the expression of opinion) results when aggregating opinions more than it comes close to reality.
5. Ensuring the results obtained are determined if the critical components identified in the aggregation of comments with a non-probability priority number are obtained with the list identified by the method of aggregation of comments with the same probability priority number.
6. If the sub-method is used along with the risk priority number (aggregation of opinions or code evidence theory) obtained, it will lead to a more accurate number for each piece.

7. With the same critical components identified, these components need more attention and specific net program determination

5. Conclusion

In this article, the risk of the hydraulic system of the Ilyushin aircraft was investigated using the FMEA method. The RPN number was calculated using the expert opinion forms for hydraulic system parts. After calculating the RPN, Schaefer's evidence theory was also used to ensure the accuracy of the obtained results. The obtained results show that out of 37 critical parts: 9 parts are acceptable, 12 parts are tolerable, and 16 parts are intolerable. According to the obtained results, the following suggestions are given to improve the maintenance process of the mentioned aircraft.

Due to the fact that some non-destructive testing methods are used to detect superficial and slightly subsurface defects. Therefore, defects that exist in the depth of the piece or defects that are parallel to the field lines (due to no field leakage in the piece) cannot be detected by this method. Therefore, non-destructive methods such as radiography and radiography can be used to test non-destructive parts.

Aircraft period visits are performed annually or during 300 hours of flight according to the existing technical instructions. It is suggested that this period be reduced to control the occurrence of exhaustion of related systems and components.

Many of the parts studied in this study are replaced at the overhaul of the aircraft, so to reduce the flight risk and failure of the part, a time change period (life period) should be considered.

Due to the boycott and non-assignment of parts from relevant bases and the lack of an electromechanical depot of Ilyushin-76 aircraft parts in the readiness and air support of Nahaja, we can learn from the experiences of the technical specialists of this unit who perform repairs on both western and eastern aircraft. Using a tester and tools for Western aircraft in the form of electromechanical depots, make a series of major repairs of Ilyushin-76 parts and return them to the open life cycle. Parts such as the accumulator, gland joint, snowplow, level booster and hydraulic damper can be repaired and returned to the life cycle in the form of an electromechanical depot by the technical personnel of this unit.

Ilyushin-76 aircraft, especially its hydraulic system, which is one of the most sensitive systems of this aircraft, should not be neglected due to the special and high sensitivity of this system in the aircraft and the dependence on other systems such as landing gear, control commands and brakes to this system need to be optimized and upgraded, and to increase flight safety.

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