

Reliability Analysis of Aircraft Hydraulic Control System based on GO Methodology

Lina Zhang^a, Yanjun Li^b, Jian Zhang^c

College of Civil Aviation, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, China

^aemail: 747931881@qq.com, ^bemail: lyj@nuaa.edu.cn, ^cemail: 1540079310@qq.com

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Abstract. Aircraft hydraulic system is an important part of an aircraft, its reliability is of great significance to the aircraft flight safety. This paper puts forward an aircraft reliability analysis method of hydraulic control system based on the GO methodology, which is based on the thorough research of GO methodology and aircraft hydraulic control system. Firstly, simplify the aircraft hydraulic control system principle diagram and establish the GO diagram. Then, establish the GO diagram according to the reliability of each component. Finally, calculate the reliability of the hydraulic control system based on the principle of GO diagram and operation rules and improve the reference for the design of aircraft hydraulic system.

Introduction

Aircraft hydraulic system is an important part of aircraft electromechanical system [1], which mainly provides power of control to the aircraft control system, landing gear system and reverser sleeve. It is frequently used frequently in the phase of flight and landing [2], its performance directly affects the safety of the aircraft flight. So it is very important to guarantee the reliability and safety of the aircraft hydraulic system that is vital to reduce the accidents and ensure the safety of flight.

GO methodology is a kind of reliability analysis technology of system oriented by success and failure states [3][4], which can be applied to the reliability and security analysis of system with multi-state, timing, and feedback. GO methodology was firstly proposed by the United States science company named Kaman in the 60's [4]. In the 1980s, the United States Electric Power Research Institute (EPRI) developed a common program of GO methodology [5], which can be used to solve the reliability problem of complex systems. In the 90's, scholars had studied the GO-FLOW methodology, which can be used to analyze the reliability of orderly and changing state system.

In this paper, we first analyze the working principle of a certain type of aircraft hydraulic system, then convert the system schematic diagram to GO diagram. Finally, use the calculation formula of GO methodology, incorporate the operator and the signal flow in the GO diagram for quantitative calculation of the system and compute the reliability of hydraulic system.

GO Methodology

The main step of using GO methodology is to analyze the reliability of the system which includes the establishment of GO diagram and the GO operation whose two elements are operators and signal flow. The basic principle is the representation of the elements and the connections between the units with the operators and signal flows respectively and then conversion of the system diagram into GO diagram. Input the data of all operators and start GO operations which includes qualitative and quantitative calculation after establishing GO chart.

GO methodology has 17 types of standard operators, as shown in Figure 1, including the name of the operator type, t operator type No. represented with number, the input signal represented with 'S', output signal represented with 'R'. The property of operator includes type, data and operation rules, Type is the main property of the operator, which reflects the functions and characteristics of

the unit represented by the operator. Different operators represent different unit functions, data requirements and operation rules.

The signal flow represents the input, output of the system unit, the connection of units and connects GO operators to generate GO diagram [6]. The property of the signal flow includes state value and probability. When the GO methodology is used for the multi-state system, the system has 0,..... , N in total of (N+1) state, 0 represents the state of advance, the state value 1,..... , N-1 represents a variety of successful states, N represents failure state, the corresponding state probability value is $P(0), P(1), \dots, P(N)$; $\sum_{i=0}^N P(i) = 1$; for timing systems, the 0~N state value can be a time point, representing a series of specific time values

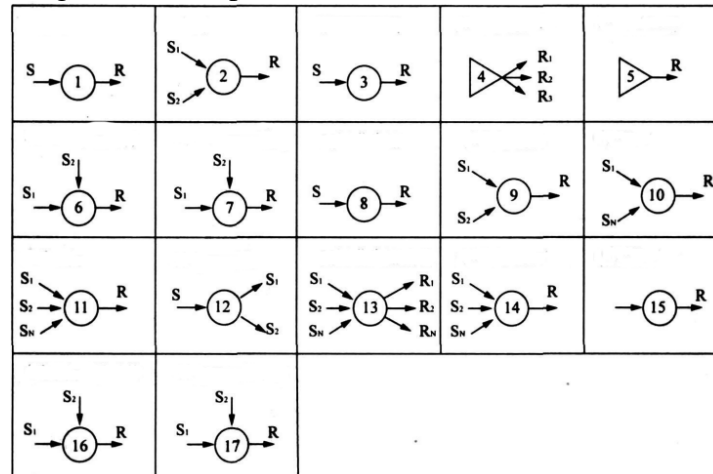


Fig.1 Standard operator types of GO methodology

Aircraft Hydraulic System

The main hydraulic system A of B737NG aircraft is mainly composed of fuel tank, overheat / fire protection panel, motor pump stop valve, hydraulic panel, motor pump, electric pump, pressure module, oil filter assembly, heat exchanger and return filter module. The system provides pressure for the following system: Power conversion assembly motor, the left thrust reverser, retractable landing gear, nose wheel steering, alternate brakes, flaps, autopilot, elevators, elevators sensory load, 2, 4, 9, and 11 flight spoiler, 1, 6, 7 and 12 ground spoiler, direction rudder.

Figure 2 shows its working principle, reservoir pressurization module provides filtered and pressured air for main hydraulic system and then arrives tank by tank pressurization assembly to provide oil for electric motor driven pump (EMDP) and engine driven pump (EDP). System A EDP supply shutoff valve control oil provided for EDP. Pressure module provides constant pressure. Heat exchanger cools oil. The case drain filter module cleans oil before entering heat exchanger.

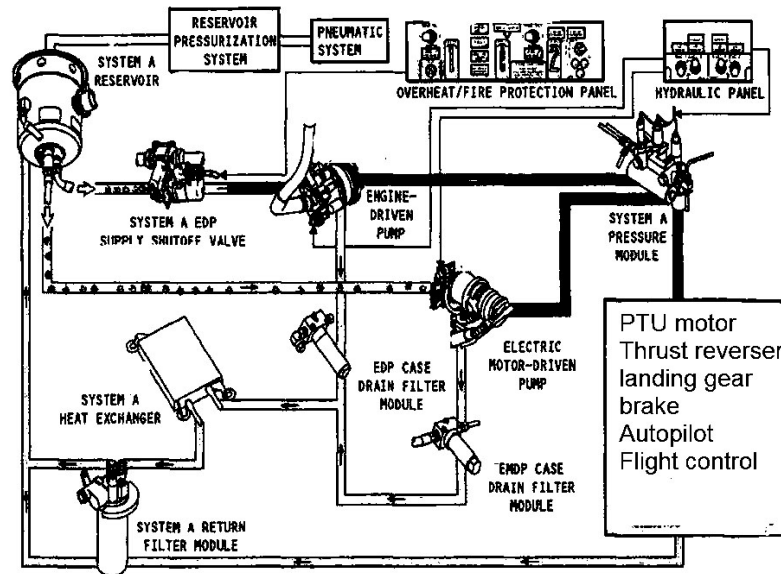


Fig.2. A hydraulic system schematic of B737NG series aircraft

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GO chart establishment

Booster components provide filtered and pressurized air to the main hydraulic system, which is the input of the system with the two states that is success and failure and represented with operator 5; Reservoir pressurization module, system A EDP supply shutoff valve, EMDP, EDP case drain filter module, EMDP case drain filter module, system A pressure module, system A return filter module all have two state that is success and failure and represented with operator 1; Only EDP case drain filter module and EMDP case drain filter module work together, system A heat exchanger can work normally with the two state that is success and failure and represented with operator 10; System A reservoir provide oil for system A EDP supply shutoff valve and EMDP and then for system A pressure module and EDP case drain filter module, so it can be represented with operator 5

In this paper, the B737NG hydraulic system schematic diagram is simplified, as shown in Figure 3. The components of the system are represented with the corresponding operator while input and output are represented with signal flows and then transform the system schematic diagram into GO diagram. As shown in Figure 4, the GO diagram has 12 operators and 12 signal flows. The first number in the operator represents the operator type, the second represents the operator number and the number in the above of the signal flow represents the stream number.

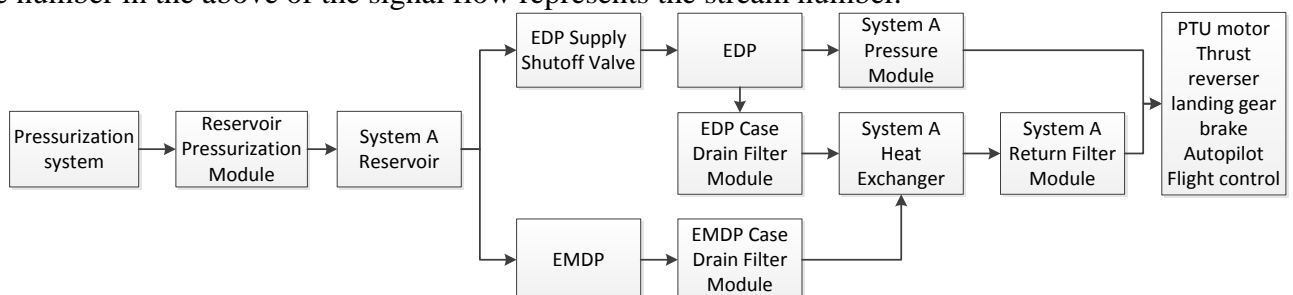


Fig.3. B737NG hydraulic system A simplified diagram

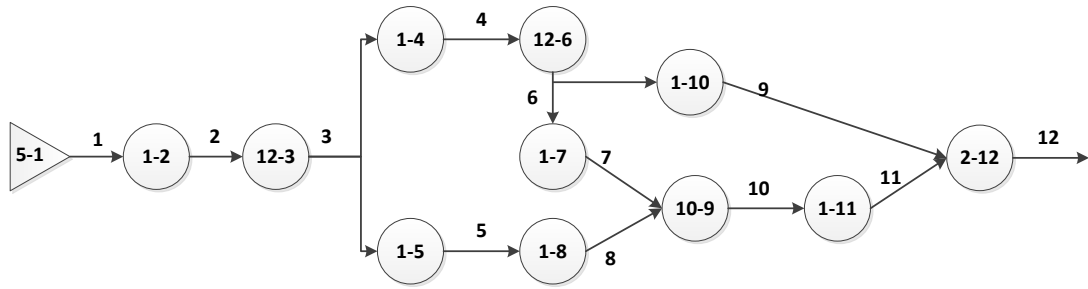


Fig. 4. GO diagram of hydraulic system A

Quantitative calculation of the system

' P_{Si} ' represents the success probability of signal flow 'i', ' P_{Ci} ' presents the success probability of operator 'i'. Calculate with the formula in references [7][8] and obtain calculation expression of success probability for each signal stream. Among them, the input operator: $P_{S1} = P_{C1}$; signal flow 3: $P_{S3} = P_{C1}P_{C2}P_{C3}$; signal flow 6: $P_{S6} = P_{C1}P_{C2}P_{C3}P_{C4}P_{C5}P_{C6}$; signal flow 7: $P_{S7} = P_{C1}P_{C2}P_{C3}P_{C4}P_{C6}P_{C7}$; signal flow 8: $P_{S8} = P_{C1}P_{C2}P_{C3}P_{C5}P_{C8}$; signal flow 10 cannot be directly calculated by the AND gate probability formula, the formula was modified as $P_{S10} = P_{C9} \frac{P_{S7} \cdot P_{S8}}{P_{S3}} = P_{C1}P_{C2}P_{C3}P_{C4}P_{C5}P_{C6}P_{C7}P_{C8}P_{C9}$, signal flow; 9: $P_{S12} = P_{C1}P_{C2}P_{C3}P_{C4}P_{C5}P_{C6}P_{C10}$; signal flow 11: $P_{S11} = P_{S10}P_{C11}$; signal flow 12: $P_{S12} = \frac{P_{S9} \cdot P_{S11}}{P_{S6}} = P_{C1}P_{C2}P_{C3}P_{C4}P_{C5}P_{C6}P_{C7}P_{C8}P_{C9}P_{C10}P_{C11}$.

Table 1 Operator Data of Hydraulic System A

No.	Type	Unit name	Success probability
1	5	Pressurization system	0.9988
2	1	Reservoir pressurization module	0.9997
3	12	System A reservoir	0.9975
4	1	EDP supply shutoff valve	0.9987
5	1	EMDP	0.9991
6	12	EDP	0.9979
7	1	EDP case drain filter module	0.9985
8	1	EMDP case drain filter module	0.9994
9	10	System A heat exchanger	0.9983
10	1	System A pressure module	0.9989
11	1	System A return filter module	0.9992
12	2	AND gate	—

Signal flow 12 represents the output of the system, according to the above data and the calculation formula of the signal flow, the reliability results of the hydraulic system A are shown in Table 2

Table 2 Reliability Calculation Results of Hydraulic System A

Signal flow	Success probability	Signal flow	Success probability
1	0.9988	7	0.9911
2	0.9985	8	0.9945
3	0.9960	9	0.9915
4	0.9947	10	0.9905
5	0.9951	11	0.9897
6	0.9926	12	0.9849

Reliability evaluation

The probability of the output signal 12 is a quantitative evaluation to the reliability of the hydraulic system A. As shown in the table 2, the normal probability of hydraulic system A is 0.9849, the failure probability is 0.0151.

Conclusion

Aircraft hydraulic system is a very complex system and ensuring the reliability of aircraft hydraulic system plays a vital role in flight safety. In this paper, the GO methodology is used in the reliability analysis of aircraft hydraulic system, the application is very convenient and easy to popularize. By analyzing the working principle diagram of the hydraulic system of B737NG series, the GO model of aircraft hydraulic system reliability is established by using GO principle. The model is universal and can carry out accurate calculation. It not only calculates the reliability of the whole system, but also can obtain the reliability of each link, that provides a method and guidance for aircraft hydraulic system reliability analysis.

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