Airman

Jurnal Teknik dan Keselamatan Transportasi

ISSN: 2622-0105 (print) | 2716-1196 (online)
http://jurnal.poltekbangmakassar.ac.id/

Evaluation of Reliability Automatic Flight Control System Actuator of Helicopter Sikorsky S-76 C++

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Article info

Received: 17-6-2024
Final Revision: 10-6-2024
Accepted: 26-6-2024
Available online: 30-6-2024

Keywords: Reliability; AFCS Actuator; Weibull; FMEA.

ABSTRAK

The Automatic Flight Control System (AFCS) Actuator is one of the components of the AFCS installed on the Sikorsky S-76 C++ helicopter. This system functions as a helicopter control center. It plays an important role in assisting the pilot in maintaining the selected helicopter attitude and improving handling characteristics by providing static and dynamic stabilization of the helicopter's pitch (fore-aft movement), roll (lateral movement), and yaw (directional movement). **The problem** raised in this research is that there were 94 replacements for the AFCS Actuator component with Part Number 76900-01802-106 which were carried out in the period from 2012 to 2022. So, attention needs to be paid to maintaining the reliability and function of the component remains good. **This research aim** is to obtain the failure rate value for the AFCS actuator component so that the reliability value and effective maintenance methods for the AFCS actuator component can be known. **The method used** in the research is to carry out reliability analysis using the Weibull Distribution to obtain the MTTF value of the AFCS actuator component, then analyze the causes of failure using the failure mode and effect analysis (FMEA) method. **The results** of this research showed that the MTTF of the AFCS Pitch, Roll, and Yaw Actuator were respectively 2526 FH, 3248,761 FH, 1625,655 FH and the failure rate for the MTTF was 0.00043413 for the Pitch Actuator, 0.000263 for the Roll Actuator and 0.000875 for Yaw Actuator. Based on the FMEA analysis, corrective action was obtained to increase component reliability, namely carrying out scheduled inspections on components with a focus on the rod end actuator, connector on the actuator, and tension cable to the tail rotor.

Reccomended Citation:

APA Style

INTRODUCTION

Every aircraft operated must be maintained in such a way as to meet airworthiness standards that support aviation security and safety. Every person who operates an aircraft is obliged to maintain the aircraft, aircraft engines, aircraft propellers, and components to maintain reliability and airworthiness on an ongoing basis (UU No. 1 Tahun 2009). Airplanes have thousands of components in the system. Hence, efforts and actions need to be taken in the form of scheduled and effective inspection, repair, service, overhaul, and replacement of parts to ensure the reliability of the aircraft, its components, and equipment so that they are always in airworthy condition (Silva et al., 2023). The main goal of maintenance is to ensure that a system continuously performs its intended function at the designed level of reliability and safety (Harry A. Kinnison & Tariq Siddiqui, 2012). If a system is not maintained properly, it will eventually stop performing its function, losing safety, availability, and also reliability, which will result in several losses including structural, economic, and in the worst cases, fatal human injuries. the reliability of components and systems

Airman: Jurnal Teknik dan Keselamatan Transportasi
Volume 7 issue 1 June 2024 | page 13-23
DOI: http//doi.org/10.46509/ajtk.v7i1.441

will decrease over time, poor reliability values can also make maintenance ineffective and detrimental to operations (US Navy, 2007).

In general, maintenance is divided into 2 categories, namely preventive maintenance which is carried out to prevent damage to the system to an unusable level and keep it in operational condition, and corrective maintenance which is carried out in response to unplanned operational events such as damage, component failure, and defects. discovered during scheduled inspections, hard landings, and lightning strikes on aircraft (Hobbs, 2021). It is common to group aircraft maintenance tasks into work packages based on comparable intervals. The goal is to make maintenance tasks simpler, more effective, and more efficient. The following intervals are used as suggestions for implementing this package, namely flight hours, flight cycle, and calendar (Mora, 2012).

Based on component exchange data (Component Change Report) obtained from the Technical Record of PT. Pelita Air Service as the operator (AOC 121) of the Sikorsky S-76 C++ aircraft from 2012 to 2022. There were many maintenance activities due to problems with the Automatic Flight Control System. Most of the maintenance activities that occur are caused by premature failure of the AFCS actuator components. The AFCS Actuator is a hard-time component with an operating time of 4500 Flight Hours (Sikorsky, 2020). Based on data from the component change report and the Flight and Maintenance Log, there have been 94 component replacements with P/N 76900-01802-106 on the Sikorsky S-76 C++ helicopter. which is operated by PT Pelita Air Service. These component replacements are caused by various failure modes. Some of the failures that occur are stuck, vibration, unstable, kicking, and trim fail. So, an evaluation is needed to determine the reliability value of the AFCS Actuator component and effective maintenance methods to increase its reliability.

Based on research (Rahmawati & Mulyani, 2020), reliability programs are one of the developments in maintenance programs that must be implemented today. Its implementation aim is to obtain effective implementation of activities and maintenance in terms of time and cost. So carrying out reliability analysis can help operators operate aircraft with a higher level of safety and efficiency. The probability that a system or component will be able to perform its task within a certain time frame and under certain circumstances can be estimated with the help of reliability evaluation. Systems or components can still work even though they cannot fully carry out their duties (Dhillon, 2004). Reflecting on research conducted by (Gilang Nugraha, 2017)where Garuda Indonesia's Boeing 737-800 NG aircraft from 2012 to 2016 experienced delays which occurred mostly due to problems with the engine and fuel control. On the CFM 56-7 engine, the evaluation is carried out concerning the frequency of component failure or damage. The components in Engine Fuel and Control that were evaluated were the fuel pump, IDG oil cooler, servo fuel heater, electronic engine control, hydro-mechanical unit, fuel flow transmitter, and fuel flow differential pressure switch. The overall system reliability value at operational times of 500 hours, 1000 hours, and 1500 hours is 0.73; 0.52, and 0.36. The critical component based on its reliability value which has reached 0.7 after 1000 hours of operation is the fuel flow differential pressure switch. With the appropriate type of maintenance, scheduled restoration tasks are available for fuel pump components, IDG oil cooler, servo fuel heater, and the hydro-mechanical unit, as well as scheduled on-condition tasks for electronic engine control components, fuel flow transmitter, and fuel flow differential pressure switch.

The Sikorsky S-76 C++ is a medium-sized multi-purpose commercial helicopter made by the Sikorsky Aircraft Corporation from the United States. The S-76 C++ is driven by two turboshaft engines that drive the main rotor and tail rotor, each with four blades. The landing gear for the S-76 C++ helicopter can be retracted. This helicopter uses an Arriel 2S2 multi engine providing increased performance in hot or high conditions. This helicopter is 16 m long, with a height of 4.41 m, a fuselage width of 2.44 m, and a blade span of 13.41 m. This helicopter can accommodate 2 crew and up to 12 passengers. This helicopter is capable of flying as far as 762 km with a cruising speed of up to 287 km/hour and flying as high as 7,050 ft. In operation, this helicopter is powered by two Arriel 2S2 engines which can produce 1,032 shp and a fuel tank of 281 US. gal (Sikorsky, 2007). On the Sikorsky S-76 C++ helicopter, the Automatic Flight Control System plays an important role in assisting the pilot in maintaining the selected helicopter attitude and improving handling characteristics by providing static and dynamic stabilization of the helicopter's pitch (fore-and-aft movement), roll (lateral movement), and yaw (directional movement) (Sikorsky, 2020). This system maintains the helicopter's attitude and does not allow the helicopter to deviate into undesirable flight conditions (Ozcan, 2019). The working principle of AFCS is to correct the signal. This signal comes from the difference between the flight attitude which was initially determined through the control settings (AFCS control panel), and the actual flight attitude. The actual flight attitude is obtained through the vertical gyro and rate gyro. This signal is then processed using an AFCS amplifier. The correction signal produced by the amplifier will be transferred to each actuator, which converts the electrical input signal into mechanical output movement. This mechanical movement then changes and sets a new flight control position, to correct the initial disturbance that caused the signal error. The actuator is an integral part of the Automatic Flight Control System which functions to convert electrical input into mechanical output. The resulting mechanical output is in the form of lengthening and retracting movements (extend and retract). This actuator is installed in series with the flight control push-rod, and is connected to the servo actuator which is responsible for changing the pitch of the rotor blade and each movement of the cyclic stick on the pitch axis moves the actuator assembly automatically. whole.

The maintenance program is a maintenance program prepared by an aircraft operator in the form of a document that explains the specific schedule, maintenance tasks, and frequency of their completion as well as related procedures such as the reliability program required for the safe operation of the aircraft (Civil Aviation Safety Regulation (CASR) Part 1: Definitions and Abbreviations., 2006). In its development, program reliability is needed to obtain effective implementation of activities and maintenance (Rahmawati & Mulyani, 2020). So further analysis is needed regarding reliability, where according to (Ebeling, 1997) Reliability is the possibility that a system or component will be able to perform its intended function within a predetermined time. Failure data is organized by part number to determine the reliability of a component. Because reliability estimates are specific to one failure mode, the data is re-categorized depending on the failure mode (Suciati & Suwondo, 2019). There are two methods generally used to evaluate reliability, namely, quantitative and qualitative evaluation. Quantitative evaluation can be divided into large parts, namely analytical (statistical) evaluation and evaluation using simulation methods. Meanwhile, Qualitative Evaluation Qualitative Evaluation is an evaluation of the mode and impact of failure to determine an effective treatment method. To apply these two methods, you can use the Weibull distribution and FMEA (Priyatna, 2000). Weibull is one of the most widely used probability distributions in reliability, this distribution is a versatile distribution that can take on the characteristics of other types of distribution, based on the value of the parameter form (Otaya, 2016). Calculation of the Weibull distribution is important, especially in the aviation and aerospace sector to reduce the level of risk of failure in a system or component to support the maintenance process and also develop reliability in component or system design (Fidanoglu et al., 2017). FMEA is a “reliability tools” technique that helps define, identify, prioritize, and eliminate known and/or potential system, design, or production process failures before they reach the customer. The goal is to eliminate failure modes or reduce their risks (Stamatis, 2015; Wang, et al. 2023).

Therefore, analysis is needed to determine the reliability of the AFCS Actuator components on the pitch, yaw, and roll control axes. Reliability evaluation will be implemented to obtain an analysis of the influence and magnitude of reliability and the selection of maintenance methods for a component that should be carried out so that it is hoped that it can reduce or avoid failures in this system.

METHOD

Systematically, this research uses the Weibull distribution method for quantitative analysis techniques, and FMEA for qualitative techniques. Quantitative research is systematic scientific research into parts and phenomena and the causality of their relationships (Jannah, 2016). Typically, the sample size for quantitative research is chosen depending on the size of the population at hand. Certain formulas are used in processing samples. Qualitative research is essentially a deductive-inductive technique widely used in research. This method is based on a theoretical framework, expert opinions, and researchers' understanding based on their experience, which is then transformed into problem-solving and solutions (Hardani, 2020)..

Data from the document study was obtained by understanding the documents related to the Automatic Flight Control System Actuator. This data can be obtained from the company's Flight Maintenance Logbook (FML) and Component Change Report related to the Automatic Flight Control System, especially the AFCS Actuator. Data from the literature study was obtained by understanding books and literature related to the Automatic Flight Control System Actuator. This data can be obtained from the Aircraft Maintenance Manual (AMM), Airworthiness Limitation (AWL), as well as the company's Component Change Report and other literature related to the Automatic Flight Control System. Interviews or what can be called interviews are a data collection method that is often used in descriptive research, both qualitative and quantitative. In practice, interviews are carried out directly through face-to-face meetings between researchers and individual respondents (Prayitno & Supardam, 2023). Interviews were conducted with engineers holding AMEL (Aircraft Maintenance Engineer License) with type rating Sikorsky S-76 C++ at PT. Pelita Air Service which understands the ins and outs of the Automatic Flight Control System.

In this research, the results of data collection through document studies, literature and interviews were analyzed using quantitative methods - Weibull distribution by calculating reliability values, determining maintenance schedules (Time to Repair), and preventive maintenance according to existing data. In determining the distribution in reliability assessments, this research uses Minitab 21 software to determine the type of distribution that is appropriate to the distribution of the data. According to (Abernethy, 2006) quoted from his book entitled "The New Weibull Handbook", the three best methods for determining goodness of fit are: Critical Correlation Coefficient, Anderson-Darling, and likelihood ratio. Using the correlation coefficient (r) is a better and simpler approach to assessing goodness of fit in linear regression. The smallest Anderson-Darling value (Ferdinand et al., 2023) and a higher correlation coefficient value indicates a stronger alignment between the distribution and data (Darmawan, 2016).

Next, a qualitative analysis was carried out using the FMEA (Failure Mode and Effect Analysis) method to obtain the causes of failure, determine the consequences of failure and find out how to handle failure. Qualitative research is essentially a deductive-inductive technique widely used in research. This method is based on a theoretical framework, expert opinions, and researchers' understanding based on their experience, which is then transformed into problem-solving and solutions (Hardani, 2020). Failure Mode and Effect Analysis (FMEA) is the method used in this qualitative approach. Finding all potential reasons for the failure of a process or product is the main target of FMEA (McDermott et al., 2013). The goal of Failure Mode and Effect Analysis, or FMEA, is to outline each potential failure, its impact on the system, the probability of occurrence, and the likelihood of the failure mode being detected. FMEA offers a strong basis and entry point for the categorization of component characteristics. Allocating resources to opportunities that will have the greatest impact on reducing failure rates is one of the goals of FMEA in improving reliability (Guo et al., 2016).

RESULTS AND DISCUSSION

1. RESULT

The analysis used in this evaluation is to determine the best parameters for the distribution of component failure data (TTF) and choose the right time to take corrective action (TTR). It was recorded that there were 94 maintenance activities on the AFCS Actuator and 83 of them were unscheduled replacements in the period 2012 to 2022. So 88% of AFCS component replacements with P/N 76900-01802-106 were unscheduled removal. The results of parameter calculations using the Least Square Estimation Method are in Table *1*.

Table 1. AFCS Actuator Distribution Parameter Table

Parameter	**Estimate**		
	Pitch	**Roll**	**Yaw**
Shape (β)	1,12	0,76	1,21
Scale (η)	2571,92	2768,4	1360,99
Minimum life (γ)	60,49	-21,35	347,2

Based on the results of calculating the Mean Time to Failure (MTTF) of each component using the Weibull distribution, it shows that 60% of Pitch Actuator failures occur before 2526 FH, 70% of Roll Actuator failures occur before 3248 FH and 80% of Yaw Actuator failures occur before 1625 FH. This shows that more than 60% of Actuators are damaged before the average failure time (MTTF). Table *2* shows the results of MTTF calculations.

Table 2. Mean Time to Failure AFCS Actuator

Component	**MTTF (FH)**
Pitch AFCS Actuator	2526
Roll AFCS Actuator	3248
Yaw AFCS Actuator	1625

The reliability of the Pitch Actuator component has decreased to close to 0.34 or 34% at the average time to failure (MTTF) of 2500 hours. The reliability of the Roll Actuator component decreased by close to 0.4 or 40% at a mean time of failure (MTTF) of 3200 hours. The reliability of the Yaw Actuator component has decreased to close to 0.32 or 32% at the average time to failure (MTTF), which is 1600 hours.

Table 3. Comparison of the Reliability of All AFCS Actuators Over Time

No	Time (t)	R(t) Pitch	R(t) Roll	R(t) Yaw	No	Time (t)	R(t) Pitch	R(t) Roll	R(t) Yaw
1	100	0,983	0,967	1,245	23	2300	0,376	0,530	0,177
2	200	0,941	0,941	1,139	24	2400	0,360	0,516	0,162
3	300	0,901	0,916	1,043	25	2500	0,345	0,502	0,148
4	400	0,862	0,891	0,954	26	2600	0,330	0,488	0,136
5	500	0,825	0,867	0,873	27	2700	0,316	0,475	0,124
6	600	0,790	0,844	0,799	28	2800	0,303	0,462	0,114
7	700	0,756	0,821	0,731	29	2900	0,290	0,450	0,104
8	800	0,724	0,799	0,669	30	3000	0,277	0,438	0,095
9	900	0,693	0,777	0,613	31	3100	0,265	0,426	0,087
10	1000	0,664	0,756	0,561	32	3200	0,254	0,414	0,080
11	1100	0,635	0,736	0,513	33	3300	0,243	0,403	0,073
12	1200	0,608	0,716	0,470	34	3400	0,233	0,392	0,067
13	1300	0,582	0,697	0,430	35	3500	0,223	0,382	0,061
14	1400	0,557	0,678	0,393	36	3600	0,213	0,371	0,056
15	1500	0,534	0,660	0,360	37	3700	0,204	0,361	0,051
16	1600	0,511	0,642	0,329	38	3800	0,196	0,352	0,047
17	1700	0,489	0,624	0,301	39	3900	0,187	0,342	0,043
18	1800	0,468	0,608	0,276	40	4000	0,179	0,333	0,039
19	1900	0,448	0,591	0,252	41	4100	0,172	0,324	0,036
20	2000	0,429	0,575	0,231	42	4200	0,164	0,315	0,033
21	2100	0,411	0,560	0,211	43	4300	0,157	0,307	0,030
22	2200	0,393	0,545	0,193	44	4500	0,144	0,290	0,025

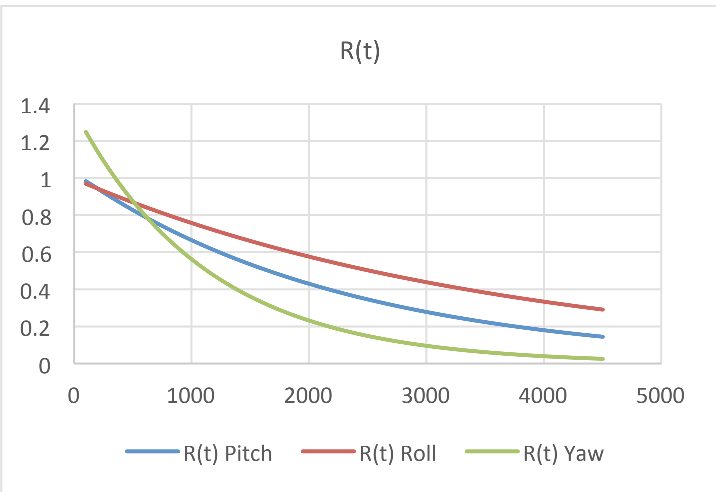

Figure 1. Comparison of the Reliability of All AFCS Actuators Over Time

Based on Figure *1*, it shows that the AFCS Actuator component has a relatively high decrease in reliability value relative to the hard time specified by the factory. Meanwhile, the Roll Actuator component is the component with the highest reliability value and the Yaw Actuator component shows that the reliability value is the lowest over time.

The results of the FMEA analysis that has been carried out show that the main causes of the low-reliability value of the AFCS Actuator are the motor on the actuator, which is often damaged, inappropriate rigging of the helicopter flight control, the tension cable on the tail rotor which causes excessive load on the actuator motor and failure of the input circuit to the actuator. So, the corrective action for this problem is that a scheduled inspection needs to be carried out every 500 FH on the cause of the AFCS Actuator failure. The inspection focused on the actuator rod end, connector on the actuator, and tension cable to the tail rotor.

2. DISCUSSION

The quantitative evaluation in this research follows the calculation stages using equations and stages in the Weibull distribution. The first stage in determining the failure rate and reliability value is to determine the correlation coefficient of the Weibull distribution. Weibull is one of the most widely used probability distributions in reliability, this distribution is a versatile distribution that can take on the characteristics of other types of distribution, based on the value of the parameter form (Otaya, 2016). In this study, the 3-parameter Weibull distribution was used for the pitch AFCS actuator with a correlation coefficient value of 0.975, roll AFCS actuator with a correlation coefficient value of 0.983, and yaw AFCS actuator with a correlation coefficient value of 0.994.

The second stage, after determining the correlation coefficient, then determine the parameters that will be used. To obtain MTTF values and reliability, distribution plotting is required as previously explained. After the appropriate distribution is obtained, the next step is to determine the parameter values for the distribution used. When the parameters are obtained, the MTTF, reliability value, and failure rate are then calculated based on the existing distribution (Dhamayanti et al., 2016). In Weibull calculations, determining the β parameter is known as the slope parameter or shape parameter. Beta determines which member of the Weibull family of failure distributions best fits or describes the data. Next, determine the scale parameter or parameter η. eta is a scale parameter that affects the mean and spread or dispersion of a distribution. The last is the γ parameter or location parameter (minimum life parameter), known as the guaranteed minimum life parameter in the three parameters of the Weibull distribution, normal and log normal.

The steps for determining the parameters in the Weibull distribution using the Least Square Estimation Method (Abernethy, 2006) include adjusted rank, median rank, and linear regression. Adjusted rank is the value used to perform linear regression and Least Square Estimation. After obtaining the adjusted rank (i) calculation results, the next step is to calculate the median rank. Next, calculate linear regression using the equation: Y = A + BX, where Y is ln (failure rate). After the data was processed using the Least Square Estimation Method, the parameter estimation results were obtained, namely, for the pitch parameter the Shape value (β) was 1.12, the Scale value (η) was 2571.92 and the Minimum life (γ) value was 60.49. For the roll parameters, the Shape (β) value is 0.76, the Scale (η) value is 2768.4 and the Minimum life (γ) value is -21.35. For the yaw parameter, the Shape (β) value is 1.21, the Scale (η) value is 1360.99 and the Minimum life (γ) value is 347.2.

The third stage, calculate the Mean Time to Failure (MTTF). MTTF is the average, or expected value, of a probability distribution. The MTTF of the failure distribution is just one of several central measures (Ebeling 1997). MTTF is used as input to optimize preventive maintenance intervals. The results of reliability calculations will provide insight into the root cause of failure. The MTTF value is obtained by entering the calculated parameters for pitch, roll, and yaw into the calculation equation $\mathrm{MTTF} = \gamma + \eta\Gamma\left(1 + \frac{1}{\beta}\right)$. The results of the MTTF calculation on the AFCS Actuator pitch obtained an MTTF value of 2526.23 Flight Hours (FH). The results of the MTTF calculation on the AFCS Actuator roll obtained an MTTF value of 3248.76 Flight Hours (FH). The results of MTTF calculations on the AFCS Actuator yaw obtained an MTTF value of 1625.65 Flight Hours (FH).

The fourth stage determines the failure rate value. The failure rate is damage per unit of time or the percentage of direct damage to components that survive until that time, expressed as the failure rate (Wahyunugraha et al., 2013). To obtain the failure rate value, you need to process the equation

$\lambda(t) = \frac{\beta}{\eta}\left[\frac{t-\gamma}{\eta}\right]^{\beta-1}$. The calculation result of the failure rate on the AFCS Actuator pitch is 0.00043357 failures/hour. The calculation result of the failure rate on the AFCS Actuator roll is 0.000263 failures/hour. The calculation result of the failure rate on the AFCS Actuator roll is 0.000875 failures/hour.

The fifth stage determines the reliability value R(t). Reliability is the possibility that a system or component will be able to perform its intended function within a predetermined time (Ebeling, 1997). The value of time (t) used is the value of MTTF. The reliability value can be obtained using the equation, R(t) = $e^{-(\frac{t}{\eta})^{\beta}}$. Component failure rate is a variable that must be monitored in data processing. The results of reliability calculations on the AFCS actuator pitch obtained a reliability value of 34.09%. The results of reliability calculations on the AFCS actuator roll obtained a reliability value of 40.87%. The results of reliability calculations on the AFCS actuator yaw obtained a reliability value of 32.19%. Then a Cumulative Density Function (CDF) calculation is carried out to determine the possibility of failure in time (MTTF) using the equation F (t) = 1 – $e^{-(\frac{t}{\eta})^{\beta}}$.

The CDF calculation results for the AFCS Actuator pitch are 66%. the reliability of the AFCS Actuator Pitch component in the mean time to failure (MTTF) will decrease to close to 0.66 or 66% after the component has operated for 2500 hours. It can be seen that the AFCS Actuator Pitch component has a low reliability value over the time specified by the manufacturer (4500 FH). The CDF calculation result on the AFCS Actuator roll is 60%. The reliability of the Roll Actuator component on the MTTF will decrease to close to 0.6 or 60% after the component has operated for 3200 hours. It can be seen that the Roll AFCS Actuator component has a fairly low-reliability value over the time specified by the factory, namely 4500 FH. The CDF calculation results for the AFCS Actuator yaw are 68%. The reliability of the Yaw Actuator component on the MTTF will decrease to close to 0.68 or 68% after the component has operated for 1600 hours. It can be seen that the Yaw AFCS Actuator component has a very low-reliability value over the time specified by the factory, namely 4500 FH.

Based on CDF calculations, the possibility of failure in the MTTF of each component is around 60%. The AFCS Actuator component has a relatively high decrease in reliability value concerning the hard time specified by the factory. The Roll Actuator component is the component with the highest reliability value and the Yaw Actuator component shows that the reliability value is the lowest over time.

Qualitative evaluation in this research uses Failure Mode and Effect Analysis (FMEA), data from the qualitative evaluation involving resource persons consisting of S-76 C++ engineers who understand the systematics of AFCS. Data in the form of causes of damage to AFCS Actuator components using discussion and interview methods with a team of resource persons. Data processing resulting from interview discussions and literature studies is presented in the form of a Failure Mode and Effect Analysis worksheet and Risk Priority Number (RPN) table.

The purpose of the Potential failure mode is to show the types of failures in the AFCS Actuator that have occurred during the operation of the Sikorsky S-76 C++ helicopter. The purpose of the potential cause of failure is to identify the main reason for the failure that occurred. Apart from that, the potential effect of failure tries to explain how a component is harmed and what consequences occur when carrying out system functions. Meanwhile, recommended action is a recommended step to reduce the impact of failure mode. These results were determined from literature studies and also discussions with related engineers.

In the pitch actuator component, there are three failure modes, namely: trim fail, vibration, and stuck. From the failure mode trim fail, it is found that the potential effect of failure is in the form of an inappropriate helicopter attitude which is set with the potential cause of failure being the limitation of the trim motor receiving excessive force so that it fails to work so the recommended action is to maintain the flight control tension cable, to reduce the load on the trim motorcycle. From the failure mode vibration, the potential effect of failure is obtained in the form of wear on the rod end of the Actuator with the potential cause of failure being a decrease in motor performance on the Actuator, so the recommended action is to turn on the inverter and check the input circuit. From a stuck failure mode in the form of Trim Fail Autopilot Disengaged with the potential cause of failure in the form of a motor in the actuator that has been damaged or a jammed gearbox so the recommended action is to replace the unit that is stuck.

In the roll actuator component, there are three failure modes, namely: trim fail, stuck, and unstable. From the failure mode trim fail, it is found that the potential effect of failure is in the form of an inappropriate helicopter attitude which is set with the potential cause of failure being the limitation of the trim motor receiving excessive force during bad weather so that it fails to work so the recommended action is to maintain the flight control tension cable, to reduces the load from the motor trim. From the stuck failure mode, the potential effect of failure is obtained in the form of Trim Fail Autopilot Disengaged with the potential cause of failure in the form of the motor in the actuator being damaged or the gearbox being jammed so the recommended action is to replace the unit. From unstable failure mode in the form of Trim Fail Autopilot Disengage with the potential cause of failure in the form of a continuously moving control surface so that the helicopter is unstable so the recommended action is to carry out periodic inspections of the input circuit to the motor actuator.

In the yaw actuator component, there are four failure modes, namely: trim fail, kicking, stuck and unstable. From the failure mode trim fail, it was found that the potential effect of failure was in the form of an inappropriate helicopter attitude which was set with the potential cause of failure being the limitation of the trim motor receiving excessive force in bad weather so that it failed to work so the recommended action was to maintain the flight control tension cable, to reduces the load from the motor trim. From the kicking failure mode, the potential effect of failure is obtained in the form of wear on the actuator rod end with the potential cause of failure being that the motor in the actuator is damaged or the gearbox is jammed, so the recommended action is to maintain the flight control tension cable, to reduce the load on the motor trim. From the stuck failure mode, the potential effect of failure is obtained in the form of Trim Fail Autopilot Disengage with the potential cause of failure in the form of Actuator Vibration so the recommended action is to Replace the unit. From the unstable failure mode, the potential effect of failure is obtained in the form of the control surface moving continuously so that the helicopter is unstable with the potential cause of failure being a failure of the input circuit to the motor so the recommended action is to carry out periodic inspections of the input circuit to the motor actuator.

Next is determining the numbers for Severity, Occurrence, and Detection, as well as calculating the Risk Priority Number (RPN) value. RPN is a value that identifies high-risk areas or failure modes. Based on the equation below, the RPN value can be obtained. The highest RPN value will be the priority for carrying out treatment based on existing solutions. The highest RPN value will be the priority for carrying out treatment based on existing solutions. The final result of the failure mode, rated Severity (S) to indicate the seriousness of the final effect, the cause of the failure mode, Detection (D) to indicate the difficulty of detecting the final effect of the cause or failure mode, and the cause of the failure mode, Occurrence (O) to indicate possible causes and immediate failure modes (Agbakwuru et al., 2023). The RPN value is obtained by calculating the severity, occurrence, and detection values. From the calculation results, the RPN value of the pitch actuator for failure mode trim fail is 400, vibration is 320, and stuck is 360. The RPN value of the roll actuator for failure mode trim fail is 360, stuck is 360, and unstable is 320. The RPN value of the yaw actuator for failure mode trim fail is 320, kicking is 360, stuck is 400, and unstable is 320. It can be concluded that the failure mode with the highest RPN value is stuck on the Yaw Actuator and trim fails on the Pitch Actuator.

CONCLUSION

The Reliability Value of the Automatic Flight Control System Actuator component with P/N 76900-01802-106 for the past 10 years has been below the time offered by the Sikorksy manufacturer, namely 4,500 FH. Based on the 3 components in the research, it can be concluded that the average time to failure (MTTF) is: Pitch Actuator, 2500 Flight Hours with a reliability value of 34.09% then for Roll Actuator, 3200 Flight Hours with a reliability value of 40.87%, next to the Yaw Actuator, 1600 Flight Hours with a reliability value of 32.19%. So good inspection and management is needed to ensure component performance remains following established standards. a reduction in the overhaul schedule is required and a scheduled inspection of components needs to be carried out based on the MTTF value that has been obtained. Evaluation using Failure Mode and Effect Analysis (FMEA) shows that Trim failure in the Pitch Actuator and stuck Yaw Actuator actuator are the failure modes with the highest priority. So the corrective action for this problem is that a scheduled inspection needs to be carried out

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every 500 FH on the cause of the AFCS Actuator failure. The end, connector on the actuator, and tension cable to the tail rotor.

ACKNOWLEDGMENTS

In compiling this research, the author did not escape various difficulties and obstacles, but with the help and encouragement from various parties, this writing was finally completed. The author would like to express his deepest gratitude to the contributing institutions that assisted with funding, research facilities, or meaningful suggestions in improving this research.

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