Maintenance Stategy on Aircraft Engine Fuel and Control System At PT. GMF Aero Asia Cengkareng Services – Indonesia

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Abstract-Most of the Boeing 737-800 Garuda Indonesia flight delays occurring during 2012-2016 are caused by malfunction of Engine Fuel and Control system. This system has a central function in the distribution and control of fuel for aircraft engine operations. It is therefore necessary to evaluate the reliability value of the Engine Fuel and Control system, evaluating the frequency of failure time or damage of components. Engine Fuel and Control components evaluated are 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 the operational time of 500 hours, 1000 hours and 1500 hours is 0.73; 0.52 and 0.36. The critical component based on the reliability value that has reached 0.7 at 1000 hours operation is the fuel flow differential pressure switch. In the appropriate type of maintenance, it was found that the scheduled restoration task for fuel pump components, IDG oil cooler, servo fuel heater and hydro-mechanical unit, and schedule of on-condition task for electronic engine control components, fuel flow transmitter and fuel flow differential pressure switch. Financing of FFDPS components at 70%, 60% and 50%, reliability value was obtained US $ 429.27; US $ 337.56 and US $ 283.66.

Keywords: rebuilder, reliability, safety, SIL
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I. INTRODUCTION

The needs of the community for transportation is increasing, supported by the development of the era that makes the dynamic community has their own busyness which requires to set the time to be effective. Price competition between land and air transportation modes is getting tighter, especially the price difference between the two is getting thinner, so not infrequently people prefer air transportation mode is the plane to reach the goal with more effective time. An airline is an organization that provides aviation services for passengers or goods. They rent or own aircraft to provide such services and may form cooperation or alliances with other airlines for mutual benefit. Garuda Indonesia is a national airline. In 2008, the airline has received IATA Operational Safety Audit (IOSA) certification from IATA, which means Garuda Indonesia has fully complied with international aviation safety standards.

The Indonesian airline is listed as a four star airline from Skytrax, which means having good performance and service. In 2012, Garuda Indonesia joins the Sky Team aviation alliance. Garuda currently has more than 100 new aircraft of various types, and the average age of Garuda Indonesia aircraft is 5.4 years (Corporate Data, April 2015). Based on data delay of departure schedule (delay) and pilot report obtained from PT. GMF Aero Asia as MRO (Maintenance Repair Overhaul) company BOEING 737-800 Next Generation Garuda Indonesia aircraft in 2012-2016 experience delay which occurs mostly due to problems in engine and fuel control (engine fuel and control) on CFM machine 56-7. Engine and fuel control is a fuel engine system and fuel control system that is tasked to distribute fuel from fuel storage tanks, calculate and indicate the quantity of fuel required to drive an aircraft. The engine and fuel control then measure fuel and deliver into combustion chamber. In addition, this machine also sends the fuel needed for other aircraft components or systems that require fuel to perform its operation. Consists of fuel distribution, fuel control and fuel indicating system (Boeing 737-800 NG Aircraft Maintenance Manual).

Therefore, it is necessary to analyze the action to determine the reliability of engine systems and fuel control. Evaluation of reliability will be done by quantitative and qualitative methods, in order to obtain analysis of the influence and great reliability and selection of engine maintenance methods and fuel control should be done so it is expected to reduce or avoid the delay caused by this system.

II. MATERIAL AND METHODS

In this research systematically done the research phase described on the flowchart shown in Figure 1.

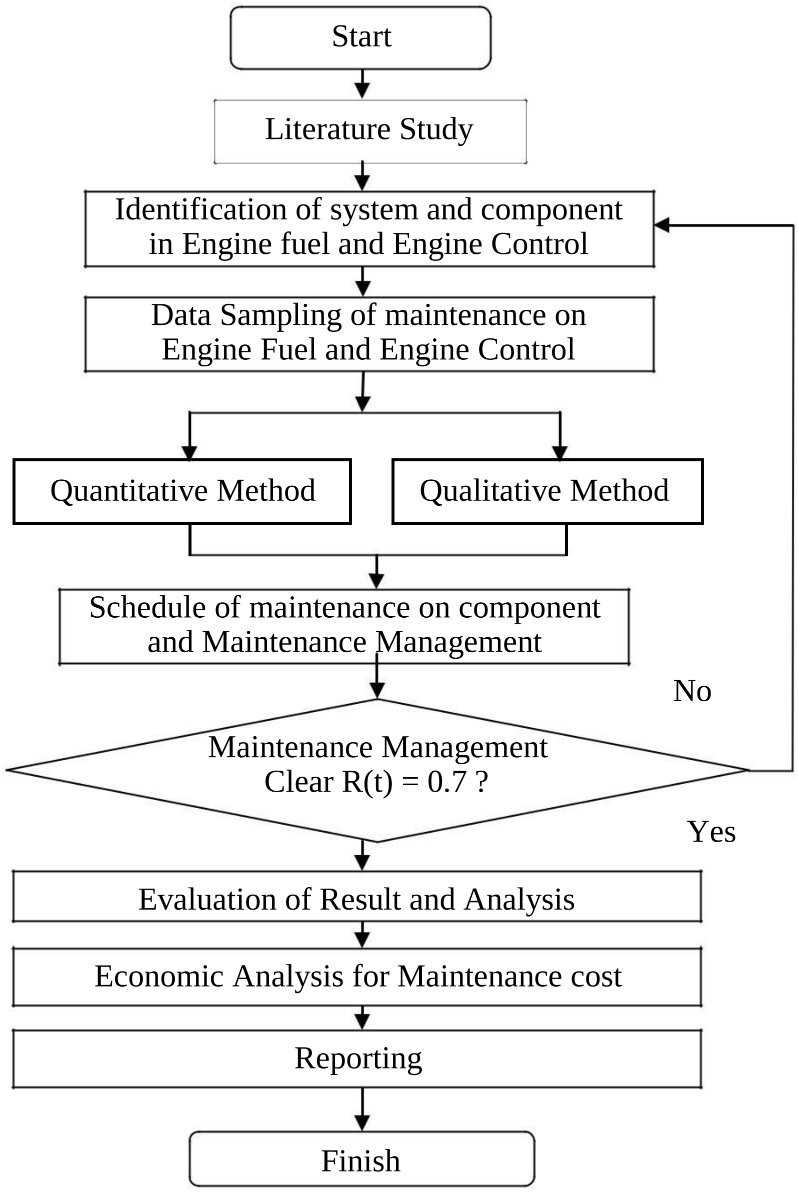

Figure 1: Flowchart of the Research

2.1 Literature and Data Collection Studies

The literature study is a theoretical understanding of process studies and the identification of Engine Fuel and Control components. The main components analyzed for reliability are fuel pump, IDG oil cooler, servo fuel heater, electronic engine control, hydro-mechanical unit, fuel flow transmitter and fuel flow differential pressure switch. In the data collection this final task, the data that need is data maintenance engine fuel and control. Data maintenance is data historical failures and improvements to the often damaged components. In qualitative evaluation, the required data is the maintenance system information by the employee who handles direct damage to Engine Fuel and Control from 2012-2016.

Identification of Systems and Components, Engine Fuel and Control system shown in Figure 2, consists of 3 subsystems, as follows: Fuel Distribution (fuel distribution) is a hydro mechanical system that distributes and controls the flow of

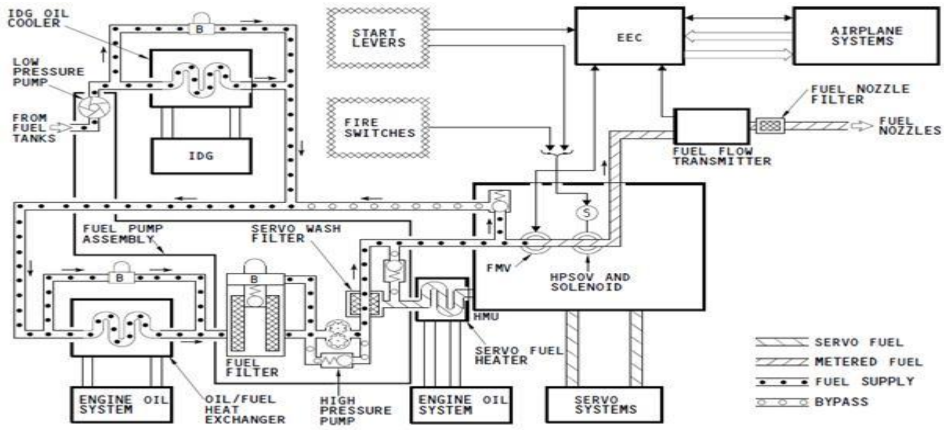

Figure 2**.** Diagram Blok of Engine Fuel and Control system

Identification of Systems and Components, Engine Fuel and Control system shown in Figure 2, consists of three subsystems, as follows: Fuel Distribution (fuel distribution) is a hydro mechanical system that distributes and controls the flow of fuel that flows into the combustor on the engine, Fuel Control, this system consists of EEC and supporting components to control the temperature and pressure of fuel, Fuel Indicating, this system monitors the fuel flow rate and the total quantity of fuel used for operations.

Quantitative and Qualitative Data Processing, Quantitative evaluation on each component of Engine Fuel and Control system is based on reliability, availability, maintainability, and correlation between failure rate of preventive maintenance step implemented on each component . The qualitative evaluation of each component of the Engine Fuel and Control system is in the form of an explanation of the function (system function), followed by the result of data processing of possible failure of each component presented in FMEA table and decision table.

3. ANALISYS AND DISCUSION

3.1. Quantitative Evaluation

Fuel Pump, Data processing with Reliasoft Weibull ++ Version 6 program package obtained the pattern of data failure or TTF distribution from the fuel pump component following the weibull 2 distribution pattern, where the beta parameter is 1.1490 and the eta is 8930.3581. Based on the results of data processing, it can be seen that the reliability of the fuel pump components will decrease to close to 0.7 or 70% after the components operate for 3500 hours. Figure 3 (a,b) represents the failure rate graph for the fuel pump component. Based on the graph, it can be seen that the failure rate is increasing failure rate, which in this case means the optimal preventive maintenance action to be performed on fuel pump components. Based on the increased failure rate, the most effective maintenance action for the fuel pump component is the restoration task schedule in every 3500 hours of operation.

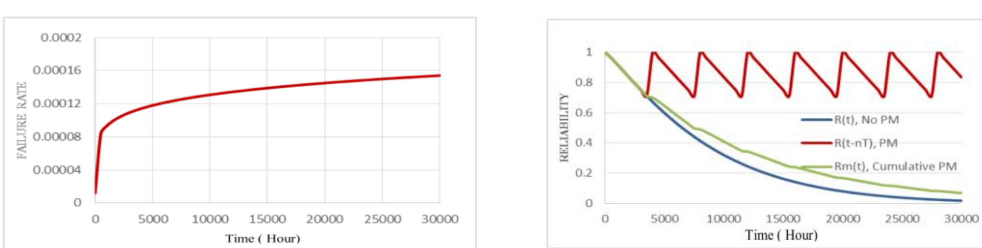

Figure 3. Failure Rate on Fuel Pump (a) and Implementation PM (b)

By implementing preventive maintenance such as Figure 4, illustration of cumulative preventive maintenance implementation on fuel pump. According to Fig. 4, it is evident that the reliability value of the fuel pump component after treatment is

IDG Oil Cooler, The data failure or TTF dispersion pattern of the IDG Oil Cooler component follows the weibull 2 distribution pattern, where the beta parameter is 1.8048 and the eta is 10207.5679. The reliability of the IDG Oil Cooler component will decrease to approximately 0.7 or 70% after the component operates for 5500 hours. Next Figure 4(a) represents the failure rate gap for the IDG Oil Cooler component. Based on the graph, it can be seen that the failure rate is increasing failure rate, which in this case means the optimal preventive maintenance action to be performed on the IDG Oil Cooler component, so the effective maintenance action for the IDG Oil Cooler component is the restoration task schedule. Figure 6 is the result of a periodic maintenance implementation when applied to the IDG Oil Cooler component.

Based on Figure 4(b), it is evident that the reliability value of the IDG Oil Cooler component after treatment is much greater than before the treatment shown on the green line Rm (t) which is well above the blue line R (t) on the graph. So for a component with a failure rate of increasing failure rate the maintenance measures applied will be effective, because the value of its reliability will increase over time. The most effective maintenance action for IDG Oil Cooler is the restoration task schedule in every 5500 hours of operation.

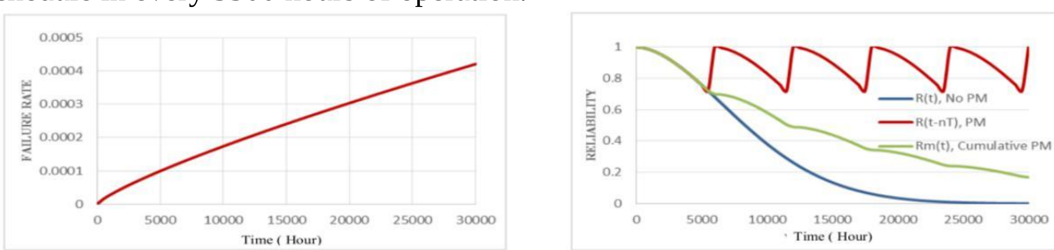

Figure 4. Failure rate on IDG Oil Cooler (a), PM on IDG Oil Cooler (b) Servo Fuel Heater, The data failure or TTF dispersion pattern of the Servo Fuel Heater component follows the weibull 2 distribution pattern, where the beta parameter is 1.7900 and the eta is 11357.1112. The reliability of the Servo Fuel Heater component will decrease to approximately 0.7 or 70% after the component operates for 6000 hours. It is seen that the Servo Fuel Heater component has a good value of reliability with respect to time.

Figure 5 (a,b) is the failure rate gap for the Servo Fuel Heater component. Based on the graph, it can be seen that the failure rate is the increasing failure rate, which in this case means the optimal preventive maintenance action to be performed on the Servo Fuel Heater component, so the effective maintenance action for Servo Fuel Heater is the restoration task schedule.

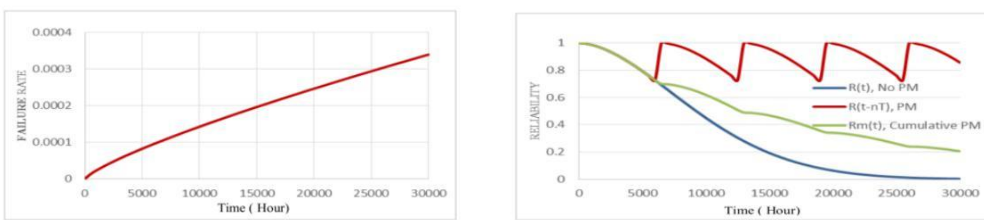

Figure 5**.** Failure rate Servo Fuel Heater (a), PM on Servo Fuel Heater (b)

Based on Figure 6(a,b), it is evident that the reliability value of the servo fuel heater component after treatment is much greater than before the treatment shown on the green line Rm (t) which lies well above the blue line R (t) on the graph. So for a component with a failure rate of increasing failure rate the maintenance measures applied will be effective, because the value of its reliability will increase over time. Effective maintenance measures for the servo fuel heater component are the restoration task schedule in every 6000 hours of operation.

Electronic Engine Control (EEC), The data failure or TTF dispersion pattern of the Electronic Engine Control (EEC) component follows the exponential distribution pattern 1, where the lambda parameter is 0.0001. The reliability of the

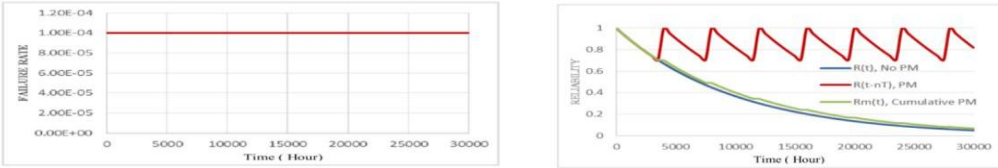

Figure 6. Failure Rate EEC (a), PM on EEC (b)

Figure 7 (a,b) are the result of a periodic maintenance implementation when applied to the Electronic Engine Control (EEC) component. Based on Figure 10 below, it is evident that at the time of periodic maintenance, there is an increase in the reliability of the system, although not significantly. It is characteristic of a component with a constant failure rate. The most effective treatment measure for the EEC component is a schedule on condition task at every 3500 hours of operation.

Hydro-mechanical Unit, The data failure or TTF dispersion pattern of the Hydo mechanical Unit (HMU) component follows the weibull 2 distribution pattern, where the beta parameter is 1.1694 and the eta is 8423.6311. The reliability of the HMU component will decrease to approximately 0.7 or 70% after the component operates for 3000 hours. It appears that the HMU component has a good reliability value against time. Figure 11 is the failure rate graph for the HMU component. Based on the graph, it can be seen that the failure rate is increasing failure rate, it means that the optimal preventive maintenance is done on the HMU component. Based on the increased failure rate, the effective treatment for the HMU component is the restoration task schedule in every 3000 hours of operation. If the preventive maintenance is implemented, Figure 12 is an illustration of the results of preventive maintenance implementation that is cumulatively (continuously) applied to HMU.

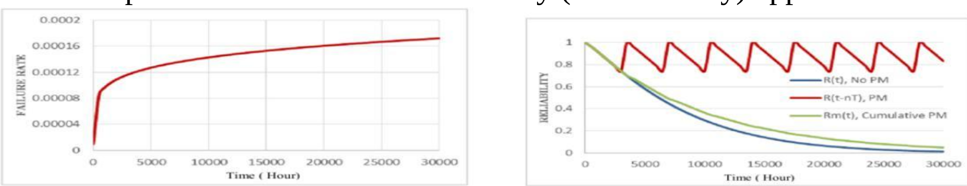

Figure **7.** Failure rate on HMU (a); PM on HMU (b)

Based on Figure 8(a,b) , it is evident that the reliability value of the HMU component after treatment is greater than before the treatment is shown on the green line above the blue line on the graph. So for a component with a failure rate of increasing failure rate the maintenance measures applied will be effective, because the value of its reliability will increase over time.Fuel Flow Transmitter, The data loss or TTF dispersion pattern of the Fuel Flow Transmitter component follows the exponential distribution pattern 1, where the lambda parameter is 0.00005485. The reliability of the Fuel Flow Transmitter component will decrease to approximately 0.7 or 70% after the component operates for 6500 hours. It can be seen that the Fuel Flow Transmitter component has good reliability value with respect to time and quite rarely experience failure mode. The failure rate for the Fuel Flow Transmitter component is shown in Figure 13 below. Based on the following graph, it can be seen that the failure rate distribution pattern for the Fuel Flow Transmitter component follows the exponential data distribution pattern which causes this component to have failure rate with constant failure rate, in which case the optimal preventive maintenance for the fuel flow transmitter component is schedule on condition task.

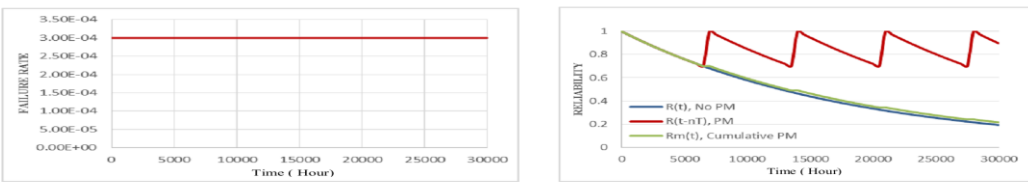

Figure 8**.** Failure rate FFT (a); PM on FFT (b)

6500 hours of operation. Based on Figure 9 (a,b), it is evident that during periodic maintenance, there is an increase in the reliability of this component, although not significantly. This is in accordance with the theory that is a characteristic of the component with a constant failure rate

Fuel Flow Differential Pressure Switch (FFDPS), The data loss or TTF dispersion pattern of the Fuel Flow Differential Pressure Switch (FFDPS) component follows the exponential distribution pattern 1, where the lambda parameter is 0.0003. The reliability of the FFDPS component will decrease to approximately 0.7 or 70% after the component operates for 1000 hours. It appears that FFDPS components have very low reliability values compared to other components over time, and often experience failure modes. Figure 9 (a,b) is the failure rate gap for the Fuel Flow Differential Pressure Switch (FFDPS) component. Based on the graph, it can be seen that the failure rate is constant failure rate, where in this case the optimal preventive maintenance action for the FFDPS component is the schedule on condition task.

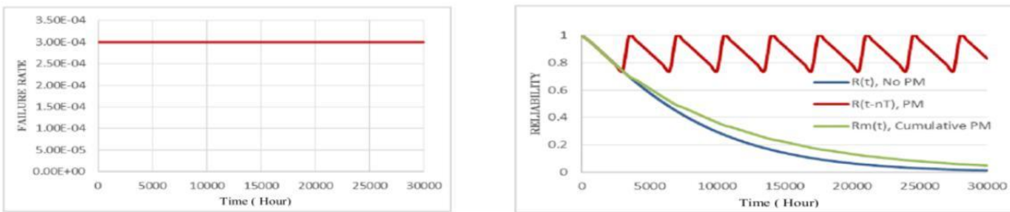

Figure 9**.** Failure rate on FFDPS (a); PM on FFDPS (b)

The FFDPS component also has a failure rate with a constant failure rate, so the appropriate type of maintenance is the scheduled on condition task in every 1000 hours of operation. Based on Figure 10 (a.b), it is evident that during periodic maintenance, there is an increase of the reliability value of this component, although not significantly. This is in accordance with the theory that is a characteristic of the component with a constant failure rate. FFDPS component has a value of reliability for the other components.

Calculation of Reliability System, Based on the results of each reliability analysis on each component, it can be seen in the graph plot reliability that has been presented previously. The result of plot of reliability graph from each component can be done by comparison of all components. Figure 10, shows that FFDPS component has decreased reliability value which is relatively low with time. While the Fuel Flow Transmitter component shows that its reliability value is highest against time compared to other components. Based on the previous identification, it is known that the Engine Fuel and Control system has a series configuration.

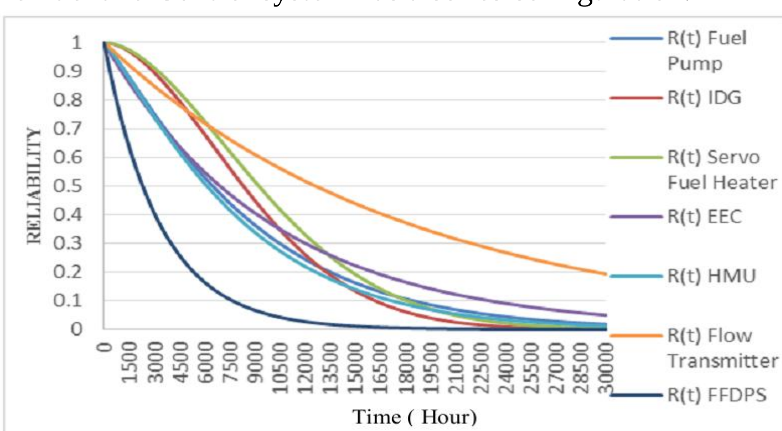

Figure 10**.** Comparation of Reliability all component

To calculate the value of the reliability of the system, first to know the reliability value of each component. Where: R1 = R (Fuel Pump); R2 = R (IDG Oil Cooler); R3 = R (Servo Fuel Heater); R4 = R (Electronic Engine Control); R5 = R (Hydro mechanical Unit); R6 = R (Fuel Flow Transmitter); R7 = R (Fuel Flow

Based on the same equation, the overall reliability value of Engine Fuel and Control is carried out at 1000 hours, 1500 hours and 2000 hours. The calculation results obtained that the overall reliability value of the system during the operational time of 1000 hours is 0.52 at the operational time of 1500 hours is 0.36 and at the operational time 2000 hours 0.25.

3.2. *Cuantitative Evaluation*

- Fuel Pump, The function of the Fuel Pump component is to receive the fuel supply from the aircraft's fuel storage tank, putting pressure on the fuel before then distributing the fuel to the HMU component for further discharge to the combustion chamber. Table 1 FMEA results from Fuel Pump.

Table 1**.** FMEA Fuel Pump

	Failure Mode	Failure Causes	Failure Effect
1	Internal Leakage	Seal and packing on pump worn	The pump is unable to provide maximum pressure (minimum 1000psi)
2	Low fuel pressure	Bearings and gear wear due to corrosion and cavitations	Fuel supply is not maximum and incomplete combustion
3	No fuel flow	Large corrosion occurs in the bearing until a leak occurs	Fuel that flows a little even does not exist and incomplete combustion
4	Over fuel pressure	Fuel filters are clogging due to contaminants	Destructive fuel system components and high part replacement numbers

Based on the failure occurring in the Fuel Pump component, recommended actions are formulated on the decision work table shown in Table 2 of the Decision Worksheet; The determination of evaluation consequence, proactive task, or default action, is determined based on the steps referring to The RCM II Decision Diagram. The evaluation step systematically becomes an interview guide to collect data on this final project. From a systematic failure, it will know the type of failure consequence, whether it affects Safety (S), Environment (E), and / or against Operational (O) (explanation of failure consequence described in Section 2.8.3). Whereas if failure is not definitely known of its influence, it can also be classified on the type of Hidden (H). The effects generated by the failure are marked by affixing the Yes (Y) code if it exists and No (N) otherwise. After that, the next part is the proactive task, in which case the code Yes (Y) or No (N) is the answer to the following questions:

N1: Does a task need to be done to detect a failure or what will happen?

N2: Will the scheduled restoration task be effectively implemented to reduce the failure rate?

N3: Is scheduled discard task effective to reduce failure rate?

Then, the default action is determined by answering the following questions:

H4: Are all the most effective task type search steps for a failure right?

H5: Can an event that contains more than one failure affect safety and environment?

S4: Whether the combination of various tasks will be effective to avoid failure.

Ultimately, action required is a column that contains the necessary and effective actions for failures that occur, relating to failure consequences, proactive task and default action.

Table 2**.** Decision Worksheet Untuk Fuel Pump

FM	*Consequence Evaluation*				*Proactive Task*			*Default Action*			*Action Required*
	H	**S**	**E**	**O**	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	**H4**	**H5**	**S4**	
1	Y	N	N	Y	N	N	Y	-	-	-	*Discard Task*
2	Y	N	N	Y	N	N	Y	-	-	-	*Discard Task*
3	Y	N	N	Y	N	N	Y	-	-	-	*Discard Task*
4	Y	N	N	Y	N	N	Y	-	-	-	*Discard Task*

- IDG Oil Cooler, The IDG Oil Cooler is one of the heat exchanger components used in this system, which serves to keep the oil temperature in the IDG from rising, and to heat the fuel on the machine to make sure no more ice clumps are formed that cause clogging. Table 3 shows the FMEA results of IDG Oil Cooler Table 3. FMEA IDG Oil Cooler

Failure Mode		Failure Causes	Failure Effect
1	Very low temperature	Element heat exchanger out of maintenance	Fuel that flows into the fuel nozzles contain ice clumps

Based on the failure described in the IDG Oil Cooler component, recommended actions are formulated on the decision work table shown in Table 4.

Table 4. Decision Worksheet on IDG Oil Cooler

FM	Consequence Evaluation				Proactive Task			Default Action			Action Required
	H	S	E	O	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	H4	H5	S4	
1	Y	N	N	Y	N	Y	N	-	-	-	Restoration task

- Servo Fuel Heater, Servo Fuel Heater is one component of heat exchanger used in this system, which serves to heat the fuel supply to the servo system in HMU, Servo Fuel Heater using scavenge oil temperature heater to increase the temperature of the fuel leading to the servo. Table 5 shows the FMEA results of the Servo Fuel Heater component.

Table 5. FMEA Servo Fuel Heater

Failure Mode		Failure Causes	Failure Effect
1	Very low temperature	Element heat exchanger out of maintenance	Fuel flowing to the servo system contains ice clumps

Based on the described failure occurring in the Servo Fuel Heater component, the recommended action is formulated on the decision work table shown in Table 6.

Table 6. Decision Worksheet Untuk Servo Fuel Heater

FM	Consequence Evaluation				Proactive Task			Default Action			Action Required
	H	S	E	O	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	H4	H5	S4	
1	Y	N	N	Y	N	Y	N	-	-	-	Restoration task

- Electronic Engine Control (EEC), Electronic Engine Control is a controlling component in the distribution of fuel in this system, which serves as the main controller of the engine system, management power on the engine, in essence all components on the engine is integrated with Electronic Engine Control components. Table 7 shows the FMEA results of the Electronic Engine Control.

Table 7. FMEA Electronic Engine Control

Failure Mode		Failure Causes	Failure Effect
1	*EEC bite not operate*	An error occurred on the connector between EEC and other components	EEC cannot send and receive information signal
2	*EEC Internal Fault*	The internal electronic components are damaged	EEC cannot indicate in a situation
3	*EEC over temperature*	An external EEC protective layer occurs leakage	Electronic components are easily damaged119

Based on the failure described in the EEC component, recommended actions are formulated on the decision work table shown in Table 8.

Table 8. Decision Worksheet Untuk EEC

FM	Consequence Evaluation				Proactive Task			Default Action			Action Required
	H	S	E	O	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	H4	H5	S4	
1	Y	N	N	Y	Y	N	N	-	-	-	On-condition Task
2	Y	N	N	Y	Y	N	N	-	-	-	On-condition Task
3	Y	N	N	Y	Y	N	N	-	-	-	On-condition Task

- *Hydro-mechanical Unit* (HMU), Hydro-mechanical This unit is the same as the EEC is a mechanical controller component, which controls the amount of fuel consumption the engine needs to maintain the speed of rotation machine , and measure the rate of fuel flow leading to fuel nozzles. Table 9 shows the FMEA results of the Hydro-mechanical Unit component.

Table 9. FMEA Hydro-mechanical Unit

Failure Mode (FM)		Failure Causes	Failure Effect
1	*High Fuel Flow*	Valve that regulates fuel flow in HMU is not working properly	Includes high EGT and slow to decelerate
2	*Low speed*	Happiness occurs between the HMU connector section	Causes slow to accelerate engine
3	System *governor* not function	There is a malfunction of the governor system in HMU	Engine performance becomes unstable in operation

Based on the described failure occurring in the Hydro-mechanical Unit component, the recommended action is formulated on the decision work table shown in Table 10.

Table 10. Decision Worksheet for HMU

FM	Consequence Evaluation				Proactive Task			Default Action			Action Required
	H	S	E	O	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	H4	H5	S4	
1	Y	N	N	Y	N	Y	N	-	-	-	*Restoration Task*
2	Y	N	N	Y	Y	N	N	-	-	-	*On-condition Task*
3	Y	N	N	Y	N	Y	N	-	-	-	*Restoration Task*

- Fuel Flow Transmitter, Fuel Flow Transmitter is one of the instrumentation components that support the process of distributing fuel, before fuel to fuel nozzles to next to combustion chamber. The Fuel Flow Transmitter serves to signal HMU on EEC orders. Table 11 shows the FMEA Fuel Flow Transmitter.

Table 11. FMEA Fuel Flow Transmitter

Failure Mode		*Failure Causes*	*Failure Effect*
1	*Abnormal Instrument Reading*	The connector is saggy and there is a mixture of dirt in the fuel	An error occurred in determining the amount of fuel needed

Based on the failure described in the Fuel Flow Transmitter component, the recommended action is formulated on the decision work table shown in Table 12

Table 12. Decision Worksheet for Fuel Flow Transmitter

FM	Consequence Evaluation				Proactive Task			Default Action			Action Required
	H	S	E	O	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	H4	H5	S4	
1	Y	N	N	Y	Y	N	N	-	-	-	*On-condition Task*

- Fuel Flow Differential Pressure Switch (FFDPS); FFDPS is one of the instrumentation components that support the fuel distribution process, FFDPS serves to indicate if the fuel filter is clogging and informs that the valve bypass opens automatically. Table 13 shows the FMEA results.

Table 13. FMEA Fuel Flow Differential Pressure Switch

Failure Mode (FM)		Failure Causes	Failure Effect
1	False Failure Indication	Damage to FFDPS and connector is not installed either	An indication error has triggered a false alarm on the cockpit
2	Actual Failure Indication	Many mixtures of dirt clog up in the fuel filter	Fuel flow is no longer filtered fuel filter but direct bypass

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Based on the failure described in the Fuel Flow Differential Pressure Switch component, recommended actions are formulated on the decision work table shown in Table 14.

Table 14. *Decision Worksheet* for FFDPS

FM	Consequence Evaluation				Proactive Task			Default Action			Action Required
	H	S	E	O	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	H_1 S_1 O_1 N_1	H4	H5	S4	
1	Y	N	N	Y	N	N	Y	-	-	-	*Discard Task*
2	Y	N	N	Y	Y	N	N	-	-	-	*On-condition Task*

3.3. Evaluation of Maintenance Cost

Based on supporting data taken, to determine the calculation of the cost of failure obtained from the PT. GMF Aero Asia Cengkareng, which is the entire cost components that arise due to the failure. The following is a cost calculation analysis for preventive maintenance on Engine Fuel and Control systems.

- Maintenance Cost (CM), Maintenance costs consist of labor costs (overtime pay) and treatment costs e.g. for lubricants, and replacement of small parts such as screws, nuts and bolts. Preventive care activities are performed outside the hours of operation. Because preventive care is done outside normal working hours, the cost of maintenance personnel to be overtime pay is IDR.1.750.000,00
- Repair Cost (CR), Repair costs arise due to component components of the Engine Fuel and Control system that is damaged requires service repair or repair components. The cost of repair (CR) consists of labor costs (CW), recovery costs or component replacements (CC) and operational consequence costs resulting from non-operation of machinery (CO)
- Labor Cost (CW), Labor cost is the cost of labor allocated for maintenance actions during damage to Engine Fuel and Control system components. The manpower assigned to handle such technical issues is as follows.

Table 15. Calculation of Maintenance staff Cost

Competence	amount	Salary/mount	amount
Senior Aircraft Maintenance	1	IDR. 10.000.000	IDR. 10.000.000
Junior Aircraft Maintenance	1	IDR. 7.000.000	IDR. 7.000.000
Senior Aircraft Engineer	1	IDR. 10.000.000	IDR. 10.000.000
Junior Aircraft Engineer	1	IDR. 7.000.000	IDR. 7.000.000
Aircraft Technician	6	IDR. 5.000.000	IDR. 30.000.000
		Total of labor cost :	IDR. 64.000.000

It is assumed that every month there are 160 working hours with details; 1 month = 4 weeks; 1 week = 5 days; 1 day = 8 hours of work So the total cost incurred by the company for labor wage is IDR. 400,000,00 per hour assuming all workers either technician or engineer can be assigned to perform activities in the maintenance effort of machine operation.

- Cost Consequences of Operational Consequences (CO), Operational consequence costs represent costs incurred due to downtime (damage), in this case harms the airline as well as delay because the aircraft cannot operate. If Engine Fuel and Control fails the function of not being able to distribute or manage fuel for engine operation, the aircraft is said to be unable to fly prior to repair. From the airline, it is known that any repair and maintenance activities may cause operational consequences. The consequences include the loss of due to the aircraft being unable to carry passengers and the administration at the airport, resulting in operational consequences for the airline to reach IDR. 84.825.000,00 per hour.

- Repair Cost (CR), These repair costs arise as a result of damage from engine per hour, For MTTR = 12 hours, the CR calculation is obtained: CR = IDR. 822.150.000 + ((IDR 400,000 + IDR 84,825,000) x 12 hours) = IDR. 822.150.000 + (IDR 85.225.000 x 12 hours)= IDR. 1.843.650.000, In Table 16, it is a recap of the results of all components evaluated.

Table 16**.** Recapitulation of Improvement component Cost

Component	Cc(IDR)	C_W (IDR)	C_o (IDR)	MTTR	C_R (IDR)
Fuel Pump	822.150.000	400.000	84.825.000	12.00	1.844.850.000
IDG Oil Cooler	204.088.950	400.000	84.825.000	5.00	630.213.950
Servo F.Heater	328.442.400	400.000	84.825.000	5.25	775.213.950
EEC	4.110.750.000	400.000	84.825.000	6.17	4.636.588.250
HMU	528.955.650	400.000	84.825.000	6.33	1.068.429.900
Fuel F.Transm	160.841.250	400.000	84.825.000	5.50	629.578.750
FFDPS	131.165.550	400.000	84.825.000	3.60	437.975.550

- Preventive Maintenance Costing (C_{PM})Prior analysis has been done to calculate the reliability of each component on Engine Fuel and Control. On the calculation done until the time span of 30,000 hours. The time span is captured reliability value when it reaches 70%, 60% and 50% for each component. At each value of reliability is analyzed to calculate the cost at the time of preventive maintenance. Here's an example of the cost of preventive maintenance on the fuel pump.

  Preventive Maintenance Cost (CPM) on fuel pump when reliability value ≈ 70% = IDR.121.439 per hour.

Financing on the fuel pump when the reliability value of ≈ 70% is IDR. 121.439.4 x 12 hours = IDR. 1.457.272,8. On preventive maintenance with 70% reliability is obtained 8 times during 30.000 hours operation, so the total cost is IDR. 11,658,164 or US $ 893.34. Preventive Maintenance Cost (CPM) on fuel pump when reliability value ≈ 60% = IDR.121.439 per hour = IDR.128.114 per hour. Financing on fuel pump when reliability value ≈ 60% is IDR. 128.113.9 x 12 hours = IDR. 1.537.366,8. On preventive maintenance with 60% reliability obtained 7 times during 30.000 hours operation, so the total cost obtained by IDR. 10,761,572 or US $ 824,64. Financing on fuel pump when reliability value ≈ 50% is IDR. 128.113.9 x 12 hours = IDR. 137.762 per hour. Financing on fuel pump when reliability value ≈ 50% is IDR. 137.762.9 x 12 hours = IDR. 1.653.154,8. On preventive maintenance with 60% reliability obtained as much as 6 times during 30.000 hours of operation, so the total cost is IDR. 9,918,876 or US $ 760,06.

Table 17 shows the complete calculations on all components evaluated; In the calculation of fees that have been made, the US $ exchange rate used is based on Bank Mandiri rate as of October 23, 2016 at 13:30 WIB, at a price of IDR. 13,050.00. The result of cost calculation has been done shows that the cost of preventive maintenance on each component is different. If preventive maintenance is applied to a greater reliability value, then the required cost will also be greater. In terms of improving this quality the company must ensure the reliability value of each component is above the applicable standards

Table 17. Recapitulation of Preventive Maintenance Cost

Component	C_M on Reliability {R(t)}					
	70 %		60 %		50 %	
	IDR	USD	IDR	USD	IDR	USD
Fuel Pump	11.658.18	893.34	10.761.57	824.64	9.918.88	760.06
IDG O.Cooler	1.067.03	81.76	915.95	70.18	815.46	62.48
ServoF.Heater	1.057.35	81.02	1.041.88	79.83	963.04	73.79
EEC	16.287.25	1.248	12.796.61	980.50	11.167.19	855.70
HMU	4.109.76	314.92	3.495.76	267.87	2.700.90	206.96
Fuel F.Transm.	701.15	53.72	584.61	44.79	465.13	35.64
FFDPS	5.602.05	429.27	4.405.28	337.56	3.701.78	283.66

4. CONCLUSION

Based on research that has been done before, it can be drawn conclusions to answer the research objectives are as follows. The rate of decline in value R (t) to reach the value R (t) that the company set before 0.7. In Fuel Pump 3500 hours of operation is obtained. At IDG Oil Cooler obtained 5500 hours of operation. At Servo Fuel Heater obtained 6000 hours of operation. In the Electronic Engine Control, 3500 hours of operation are obtained. At Hydro-mechanical Unit was obtained 3000 hours operation. In Fuel Flow Transmitter obtained 6500 hours of operation. In Fuel Flow Differential Pressure Switch obtained 1000 hours of operation is the worst.

Fuel Pump must be done scheduled restoration task every 3500 hours of operation.- IDG Oil Cooler must be done scheduled restoration task every 5500 hours operation.- Servo Fuel Heater must be done scheduled restoration task every 6000 hours of operation.- Electronic Engine Control must be done scheduled on-condition task every 3500 hours operation.- Hydro-mechanical Unit must be done scheduled restoration task every 3000 hours operation.- Fuel Flow Transmitter must be done scheduled on-condition task every 6500 hours operation.- Fuel Flow Differential Pressure Switch must be done scheduled on-condition task every 1000 hours operation

In the analysis of preventive maintenance financing performed when the reliability value reached 70%, 60% and 50% respectively obtained on each component. In Fuel Pump obtained US $ 893.34; US $ 824.64 and US $ 760.06. At IDG Oil Cooler obtained US $ 81.76; US $ 70.18 and US $ 62.48. On Servo Fuel Heater obtained US $ 81.02; US $ 79.83 and US $ 73.79. At Electronic Engine Control obtained US $ 1,248,06; US $ 980.58 and US $ 855.72. At the Hydro-mechanical Unit obtained US $ 314.92; US $ 267.87 and US $ 206.96. In Fuel Flow Transmitter, it is obtained US $ 53,72; US $ 44.79 and 35.64. In Fuel Flow Differential Pressure Switch obtained US $ 429.27; US $ 337.56 and 283.66.

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