MAINTENANCE TASK DEVELOPMENT FOR LOCOMOTIVE TYPES CC201 USING RELIABILITY-CENTERED MAINTENANCE II (RCM II) METHOD AT PT KAI DIPO LOCOMOTIVE OPERATIONAL AREA II BANDUNG

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ABSTRACT

PT Kereta Api Indonesia (PT KAI) is a Government-owned corporation that provide train as mass public transportation. PT KAI DIPO Locomotive Operational Area II Bandung (PT KAI DL DAOP II BD) is a plant that operates in Bandung. Locomotive is one of the facilities that is owned by a train. PT KAI implementing preventive and corrective maintenance, with maintenance period for a month, 3 months, 6 months, 12 months, semi-overhaul for every 1 year and overhaul for every 2 years. They also did daily check and monthly check to assess the machine condition. The locomotive system is divided into several system, such as electrical control system, diesel engine, pneumatic system, mechanical system and so on. If serious failures occurs on Locomotive, then it caused the whole train to stop working altogeter. Therefore, improvement on maintenance task for locomotive in PT KAI DL DAOP II BD is needed, as well as determining the optimal maintenance interval while considering maintenance cost, and risk of failure.

The method used in this research is a Reliability Centered Maintenance to find the optimal maintenance strategy and maintenance tasks. This research also using RCM++ software to calculate the optimal maintenance interval for component in Diesel Engine.

First step in research is to conduct a quantitative calculation to determine the Mean Time To Repair and Mean Time To Failure for component in Diesel Engine. Next is conduct qualitative data processing using RCM II. The results are known maintenance strategy and maintenance task for engine components. There are four choosen strategy, they are Schedule On-Condition, Schedule Restoration, Schedule Discard and Failure Finding. After learning care policies for each component, then determined the maintenance intervals and maintenance costs for each component using RCM++ software.

Keyword : RCM II, locomotives, RCM++

I INTRODUCTION

PT Kereta Api Indonesia (PT KAI) is a Government-owned corporation that provide train as mass public transportation. There are 2 services ministered by PT KAI, passenger train and goods train. Locomotive is one of the facilities that is owned by a train. It is a part of the train where machine located and its jobs is to move the whole train. If serious failures occurs on Locomotive, then it caused the whole train to stop working altogeter. PT KAI DIPO Locomotive Operational Area II Bandung (PT KAI DL DAOP II BD) is a plant that operates in Bandung. PT KAI DL DAOP II BD own some type of diesel electric locomotive, they are CC201, CC203, and CC206. PT KAI implementing preventive and corrective maintenance, with maintenance period for a month, 3 months, 6 months, 12 months, semi-overhaul for every 1 year and overhaul for every 2 years. They also did daily check and monthly check to assess the machine condition. The locomotive system is divided into several system, such as electrical control system, diesel engine, pneumatic system, mechanical system and so on. PT KAI DL DAOP II BD has classified the types of failure for locomotive, they are :

Table I. 1 Type of Failure

Type of Failure	Code
Electrical control system	L
Traction motor	TM
Diesel Engine	MD
Pneumatic system	SUT
Upper mechanical	MA
Input air system + Turbo	AI
Governor MD	GOV

Lower mechanical MB

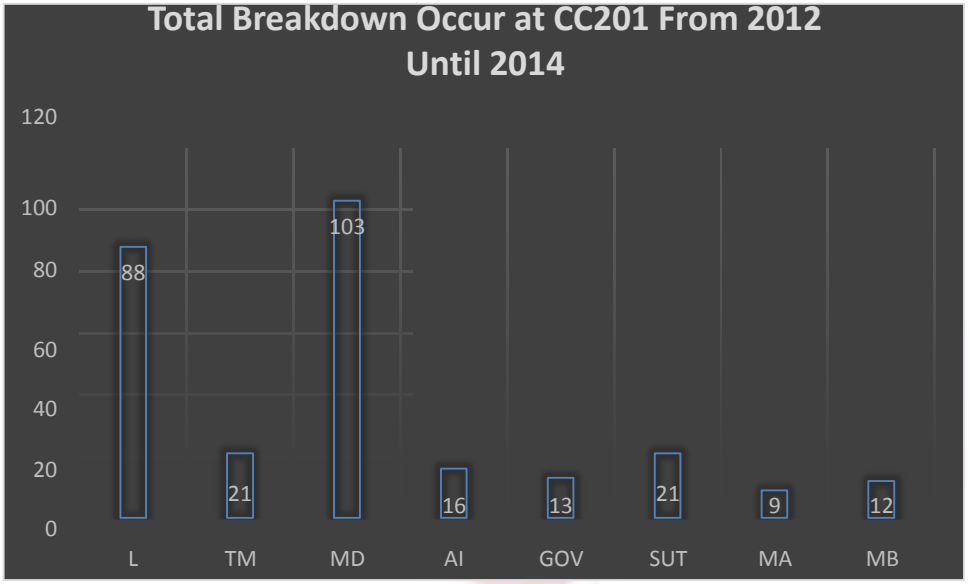

Figure I.1 Total Breakdown Occur at CC201 From 2012 Until 2014

Figure shown above shows the frequency of failure for January 2012 to December 2014. It appears that Diesel engine has the highest failure frequency. Noted the competence that must be achieved by the company are to fulfill customers demand,while the safety aspectalso considered. If company rely their machine on corrective maintenance, it will affect the train performances and total cost spent. Unpredictable breakdown occurs will disrupt the train schedule, whereas the locomotive available are limited. Furthermore, if breakdown occurs in the middle of a train trip, it can cause a significant effect, for example train accident that can harm passenger's life. Therefore, improvement on maintenance activity for locomotive in PT KAI DL DAOP II BD is needed, as well as determining the optimal maintenance interval while considering maintenance cost, and risk of failure using Reliability-Centered Maintenance II (RCM II).

II RESEARCH METHODOLOGY

2.1 Maintenance Strategy

Maintenance is an activity to ensuring that physical assets continue to do what their users want them to do (Moubray, 1991). Meanwhile Ebeling describe maintenance as an activity so the sub system or the broken system will be repaired in the mean condition and in the mean period.(Ebeling, 1997). In general, there are four basic maintenance strategies to address a potential failure mechanism:

2.2.1 Preventive Maintenance

Time based maintenance is a form of maintenance of an asset according to a strict timetable schedule. Time based maintenance consist of three maintenance strategy, they are :

1. Schedule Inspection
2. Schedule Restoration
3. Schedule Replacement

RCM recognize two types of life-limits related to schedule discard/restoration. They are safe-life limits and economic life limits. The maintenance interval for the equipment with safety consequences are range from 0.3-0.5 of MTTF. For the economy life limit, the maintenance interval are range from 0.8-0.9 of MTTF. The formulation to calculate the task interval are:

Safe life limit = 0.3 x MTTF
Economic life limit = 0.9 x MTTF

2.2.1.1 Condition Based maintenance

Condition Based Maintenance (CBM) is a maintenance strategy based on the actual condition of the assets to decide what maintenance to be done. This strategy dictates that maintenance performed when assets shows indicators of potential failure. The determination of maintenance interval for condition based maintenance are based on the P-F interval and the lead time of the component. he maintenance interval shol be less than the P-F Interval and lead time of the component. The task interval should be higher than the lead time, to give opportunity for the company to order the needed component. So, it can either $1/2$ P – F, $1/3$ P – F, $1/4$ P – F, or so on, based on the company condition. The basic formula to calculate condition based task are:

Maintenance Interval (hour) = $\frac{1}{2}$ x PF Interval

2.2.1.2 Failure Finding

If there are no preventive maintenance are suitable to be applied to the assets, then one of the option can be choosen to be applied are failure finding. Moubray define failure finding as task design to check wether something still work. The task iteslf are by simply checking if the equipment still works.
There are some condition to get the failure finding interval, they are:

a) M_{TIVE} = Mean time to failure of the component
b) The unavailability of the component.
c) The calculation of failure finding interval based on the equation

Te formula to calculate maintenance interval for failure finding are:

Failure Finding Interval (FFI) = 2 x Unavailability x M_{TIVE}

2.2.1.3 Run To Failure

In this strategy, assets are deliberately allowed to operate until they breakdown, at which point reactive maintenance is performed.

2.2.2 Breakdown

Breakdown maintenance is maintenance performmed on equipment that has broken down. It is based on a breakdown maintenance trigger. Breakdown maintenance may be either planned or it can be planned. Breakdown maintenance can be more costly than preventive maintenance.

2.2 Mean Time To Failure and Mean Time To Repair

Mean Time To Failure (MTTF) is the average time or failure expectation of a component or system work in normal condition. MTTF often referred as usage estimation of a component. Mean time to repair is the average time for a component to be repaired. The formula to calculate MTTR and MTTF are :

1. Normal Distribution

The parameter for Normal Distribution are mean (and standard deviation (. The cumulative distribution for Normal Distribution is given by :

$$\Phi(\quad) = \Phi\left(\frac{t-\quad}{\quad}\right) \quad \text{.....(II.12)}$$

And the reliability function is given by :

$$\Phi(\quad) = \Phi\left(\frac{t-\quad}{\quad}\right) \quad \text{.....(II.13)}$$

Where the MTTF is equal to mean (.

2. Weibull Distribution

If only two parameters is used, and then it called Weibull distribution with 2 parameters (2-Parameter Weibull). The cumulative distribution for Exponential Distribution is given by :
Where the average failure time with 2-P Weibull is given by :

$$\text{MTTF} = \Gamma\left(1 + \frac{1}{\beta}\right) \quad \text{.....(II.17)}$$

3. Exponential Distribution

The parameter for Exponential Distribution is lambda (, which is constant with time (T).). The cumulative distribution for Exponential Distribution is given by :

$$\Phi(\quad) = 1 - \quad \quad \text{.....(II.14)}$$

Where the average failure time is given by :

$$\text{MTF} = \int_{T}^{\infty} \Phi(\quad)\, \quad = \quad \quad \text{.....(II.15)}$$

2.3 Reliability Centered Maintenance PP (RCM II)

Reliability-centered Maintenance is a process used to determine the maintenance requirements of any physical asset in its operating context(Moubray, 1991). Moubray state that the RCM process entails asking seven question about the asset or system under review.

2.2.1 Failure Mode and Effect Analysis (FMEA)

The failure mode is a condition that can cause functional damage. In a machine, there can be dozens of failure modes. The failure modes include not only the failure that has occurred, but also cover all failure that may occur. If the failure has been known to fashion it is possible to determine the impact of the failure that describes what will happen when the failure modes occur, to further used to determine the consequences and decide what will be done to anticipate, prevent, detect or repair. FMEA itself is the answer 4 questions beginning at 7 basic questions to start analyzing RCM.

2.2.2 The RCM Information Sheet

RCM information sheet is a document containing of the detailed information about function and standard procedure, functional failure, failure model, and the failure effects.

2.2.3 The RCM Decision Sheet

The RCM Decision sheet is to make the last decision about the maintenance activity for every failure. The RCM decision sheet can be seen as in figure II.8. The flow of filling the RCM decision sheet is purposing in the RCM diagram decision

2.4 Maintenance Cost

The calculation of maintenance cost differ from one maintenance strategy to other. The calculation for every maintenance strategy are :

1. Preventive maintenance :
   a. Schedule Replacement = Material Cost + Engineer Cost + Component Cost + Downtime Cost
   b. Schedule Restoration = Material Cost + Engineer Cost + Repair Cost + Downtime cost
   c. Schedule Inspection = Tools Cost + Engineer Cost
2. Corrective Maintenance :
   a. Direct Cost = Material Cost + Engineer Cost + Component Cost
   b. Undirect Cost = Downtime Cost

III DATA ANALYSIS

III.1 Build Equipment Hierarchy

The object of this research is Diesel Engine from Locomotives CC201/CC203/CC206 at PT KAI DIPO Locomotibes Operational Area II Bandung.. Diesel engine located on the level 6 at System Breakdown Structure. For this research, the system are brean until level 8 or maintainable item. The result is there are 41 maintainable item for diesel engine.

III.2 Quantitative Calculation

In this step, there will be calculation for the Mean time to failure and Mean time to repair for every component.

Table III. 1 Maintenance Interval

NO	Component	Proposed Task		NO	Component	Proposed Task	
		Maintenance Strategy	Maintenance Interval			Maintenance Strategy	Maintenance Interval
1	Turbocharger	Schedule On Condition	2356	21	Engine Temperature Switch	Failure Finding	706
2	Fuel Filters	Schedule Discard	2889	22	Low Water Pressure Shutdown	Schedule On Condition	1882
3	Cylinders	Schedule Restoration	519	23	Fuel Booster Pump	Schedule On Condition	2562
4	Valves	Schedule Discard	1037	24	Regulating Valve	Schedule On Condition	2506
5	Vibration Damper	Schedule On Condition	2094	25	Fuel Filters	Schedule Discard	2004
6	Turbin	Schedule Restoration	5492	26	Fuel Injection Pump	Schedule On Condition	2582
7	Blower	Schedule Restoration	4055	27	Relief Valve	Schedule Restoration	3721
8	Engine	Failure	591	28	Piping	Schedule	890

	Control Governor	Finding				Restoration	
9	Thrust Bearing	Schedule On Condition	1144	29	Fuel Nozzle	Schedule On Condition	2510
10	Ignition System	Failure Finding	591	30	Fuel Strainer	Schedule Discard	2929
11	Start Control	Failure Finding	1017	31	Lube oil Filter	Schedule Discard	1284
12	Inlet Water Header	Schedule On Condition	1214	32	Pump Relief Valve	Schedule Restoration	2807
13	Cylinders Liners	Schedule Restoration	1728	33	Press Regulating Valve	Schedule Restoration	4105
14	Filter	Schedule Discard	1413	34	Lube Oil Cooler	Schedule On Condition	912
15	Thermostat Valve	Schedule On Condition	1329	35	Lube Oil Strainer	Schedule Discard	3792
16	Water Pump	Schedule On Condition	1342	36	Screen Inlet	Schedule Discard	2529
17	Piston Type Valve	Schedule Restoration	3405	37	Bleed Air Damper	Schedule Discard	8696
18	Engine Intercooler	Schedule Restoration	1493	38	Intercoolers	Schedule On Condition	1219
19	Flow Control Valve	Schedule Restoration	1971	39	Equipment Air Cleaner	Schedule On Condition	1355
20	Radiator	Schedule On Condition	2345	40	Exhaust Manifold	Schedule Restoration	3918
				41	Intake Manifold	Schedule Restoration	2576

III.3 Qualitative Data Processing

In this step, the information sheet and decision worksheet are made based on the characteristic for every machine. The resume og the information and decision sheet can be seen on table III.

Table III. 2 Maintenance Task for Diesel Engine

No	Maintenance Strategy	Equipment	Failure Mode	Maintenance Task
1	Schedule On Condition	Turbocharger	Low Output	check the seal, vibration, noise
2	Schedule On Condition	Turbocharger	High Output	check the seal, vibration, noise
3	Schedule On Condition	Vibration Damper	The damper is broken	check for vibration, noise, loose seal
4	Schedule On Condition	Thrust Bearing	The bearing is jammed	check for vibration
5	Schedule On Condition	Inlet Water Header	The passage isn't working	check the passage for fracture,displacement
6	Schedule On Condition	Thermostat Valve	The water pressure start building up in the adjecent chamber	check the sensor, tighten the seal
7	Schedule On Condition	Thermostat Valve	The water flow to water tank	check the sensor
8	Schedule On Condition	Radiator	Radiator hosing split	check the hosing split
9	Schedule On Condition	Low Water Pressure Shutdown	The engine doesn't shut down	check the sensor
10	Schedule On	Fuel Booster-	Damage on the	check the body pump housing

	Condition	Pump	body pump housing	for any damage
11	Schedule On Condition	Regulating Valve	There are no fuel pressure	check the fuel pressure
12	Schedule On Condition	Fuel Injection Pump	The pump is broke	check the pump for any vibration, noise
13	Schedule On Condition	Fuel Nozzle	The nozzle tip is hollow	check for any hollow)
14	Schedule On Condition	Lube Oil Cooler	Leakage	check the cooler for leakage
15	Schedule On Condition	Intercoolers	Clogged in the passage	check for clogged
16	Schedule On Condition	Equipment Air Cleaner	Clogged	check for clogged
17	Schedule On Condition	Water Pump	Damage on the pump body	repair the pump body
18	Schedule Discard	Fuel Filters	The filter is loaded of dirt	change the filter
19	Schedule Discard	Valves	Valve body is broken	change the valves
20	Schedule Discard	Filter	The filter is loaded of dirt	change the filter
21	Schedule Discard	Filter	The filter is not working	change the filter
22	Schedule Discard	Fuel Filter	The filter is loaded of dirt	change the filter
23	Schedule Discard	Fuel Filter	The filter is not working	change the filter
24	Schedule Discard	Fuel Strainer	The strainer is clogged	change the strainer
25	Schedule Discard	Lube Oil Filter	There are foreign material on the oil	change the filter
26	Schedule Discard	Lube Oil Strainer	Leakage	change the strainer
27	Schedule Discard	Screen Inlet	The screen inlet is perforated	change the screen inlet
28	Schedule Discard	Bleed Air Damper	The supplement bleed air is damage	change the bleed air damper
29	Schedule Restoration	Turbocharger	No air suspension appear	restore the fan
30	Schedule Restoration	Cylinders	Leakage	weld the cylinder case
31	Schedule Restoration	Turbin	The fan doesn’t spin	clean the fan, weld the fan
32	Schedule Restoration	Blower	The fan doesn’t spin	clean the fan, weld the fan
33	Schedule Restoration	Cylinders Liners	Leakage	weld the cylinders liners
34	Schedule Restoration	Piston Type Valve	The piston is not moving up and down	check the sensor, change the valve
35	Schedule Restoration	Engine Intercooler	Leakage	weld the intercooler, tighten the seal
36	Schedule Restoration	Flow Control Valves	The valve isn't working	change the valve
37	Schedule Restoration	Fuel Injection Pump	The pipe is damage	check the pump for any vibration, noise
38	Schedule	Relief Valve	The valve is	repair the valve

	Restoration		damage	
39	Schedule Restoration	Piping	The pipe is damage	change/weld the pipe, clean the pipe
40	Schedule Restoration	Pump Relief Valve	The valve is loose	Tighten the loose, weld/repair the valve
41	Schedule Restoration	Pressure Regulating Valve	The pressure adjustment screw is loose	tighten the screw
42	Schedule Restoration	Exhaust Manifold	The case is damage	repair/weld the case
43	Schedule Restoration	Intake Manifold	The pipe is damage	change the pipe
44	Failure Finding	Engine Control Governor	Malfunction on rheostat	change the circuit
45	Failure Finding	Ignition System	Spark plug defect	change the wire or the coil
46	Failure Finding	Start Control	The switch is loose	change the circuit, tighten the seal
47	Failure Finding	Engine High Temperature Switch	The bell/light is on when the engine temperature is not excessive	check the sensor, run the bell/light
48	Failure Finding	Engine High Temperature Switch	The bell/light is off when the engine temperature is excessive	check the sensor, run the bell/light

IV CONCLUSION AND SUGGESTION

IV.1 Conclusion

The conclusion of this research are:

1. The system breakdown system from level 6 until level 8 for Diesel Engine show that diesel engine has 41 maintainable item.
2. There are 4 maintenance strategy assign for diesel engine, they are schedule on condition, schedule restoration, schedule discard, and failure finding. From 41 maintainable item on diesel engine, there are 48 maintenance strategy assigned. Based on the analysis using RCM method, the proposed maintenance strategy are consist of 17 schedule on-condition, 11 schedule discard, 15 schedule restoration and 5 failure finding.
3. The maintenance task for every component is different from one to another, based on their failure mode and their maintenance strategy.
4. The maintenance interval for every component are determined based on their maintenance strategy.

IV.2 Suggestion

VI.2.1 Suggestion for Company

1. PT KAI should make a better record system to make structured historical data for future usage. They should make a detail and systematically historical data so that every failure occur can be identify.
2. PT KAI should assign maintenance strategy and task based on the characteristic of the component.
3. PT KAI need to do evaluation to the existing maintenance activity, to know the effectiveness of the existing maintenance.

VI.2.2 Suggestion for Next Research

1. This research doesn't consider about the need for spare part for diesel engine. The next research preferably consider the need for spare part.
2. The next research not only focused only on one system, so the inprove maintenance activity will evaluate from different aspect.

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