Analysis of low fuel pressure on the common rail system on the engine of wheel loader WA500-3 (case study at PT Sapta Indra Sejati site Sambarata)

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Abstract. Common rail systems in diesel engines offer several advantages over traditional fuel injection systems, such as older mechanical injection systems. These advantages include precise fuel injection control, higher fuel efficiency, reduced noise and vibration, lower emissions and many other advantages. One type of heavy equipment that has used the common rail system on its engine is the WA500-3 wheel loader. One of the WA500-3 units experienced problems with symptoms of unstable low engine speed and low power. This causes disruption in the operation of the wheel loader thereby reducing its productivity. In order to overcome the problem so that the unit can operate again at maximum capacity as well as increase knowledge and understanding in dealing with disturbances in the common rail diesel engine system, it is necessary to conduct a more in-depth investigation of this problem. This problem is overcome using a eight-step troubleshooting method, namely: Troubleshooting chart, Possibility Cause, Observe and Diagnostic, Collect Data, Analysis, Suspected Cause, Conclusion, and Action to Improvement. Through this troubleshooting process, the cause of the problem was found in the pressure limiter which had a worn out valve guide causing pressure leak from the common rail system which in turn causing low pressure in the injectors. The injectors cannot supply the cylinders with adequate fuel which then shown the symptom as engine low power. Repairs were made by replacing the pressure limiter.

Keywords: Analysis, Common rail, Diesel engine, Fuel system, WA 500-3.

1. Introduction

Wheel loaders are an essential piece of equipment in the mining industry, and they play a crucial role in many mining operations. Wheel loaders are important in mining because it can used to move large amounts of material around mining sites. They can be used to load and transport materials such as ore, coal, and waste rock from one location to another. This helps to increase efficiency and productivity in mining operations. They are equipped with powerful engines and hydraulic systems that allow them to move large amounts of material quickly and efficiently. Wheel loaders are also a versatile machines that can be used for a variety of tasks in mining operations. They can be equipped with different attachments such as buckets, forks, and grapples, which allow them to perform different tasks such as digging, loading, and lifting. Nowadays, wheel loaders are designed with safety in mind. They are equipped with features such as backup cameras, alarms, and safety lights to help prevent accidents and injuries in mining operations [1].

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One type of wheel loader that are commonly used in mining industries, especially in the region of East Kalimantan is the WA500-3 wheel loader which is produced by Komatsu. This wheel loader uses SA6D140E-3 type Komatsu engine that already utilizing Common Rail Injection (CRI) fuel system [2]. Common rail systems in diesel engines offer several advantages over traditional fuel injection systems, such as older mechanical injection systems. These advantages include precise fuel injection control, higher fuel efficiency, reduced noise and vibration, lower emissions and many other advantages [3][4][5][6].

One of the users of the WA500-3 wheel loader is PT indra Sapta sejati, which operates at the Sambarata site in Berau Regency, East Kalimantan Province. At the time of data collection, the company operates six WA500-3 units in it's mining operation. One of these wheel loader units then was experiencing problems with symptoms of unstable engine rotation at low idle. This symptom causing the unit unable to operates smoothly, because in its operation the unit is much in low idle state between waiting time for loading the trucks. This disorder if left unchecked can affect the productivity of the unit, even if it continues can cause more severe damage. therefore, it is necessary to analyze the cause of the disorder and the steps to resolve the disorder so that it does not occur again.

2. Methods

In carrying out this research, a number of data and methods are needed to analyze the fault symptoms that occur in the WA500-3 wheel loader unit.

2.1 Data collection

There are several data that needed to be collected in order to achieved a precise analysis. The method of data collection carried out is as shown in Table I.

TABLE I. DATA TYPE AND COLLECTION METHODS

Data Type	Data Description	Data source	Methods of data collection
Qualitative	Actual condition on the field	Primary	Observation on the troubled unit, completed with documentation
Qualitative	Troubleshooting method	Secondary	Literature study: shop manual WA500-3
Quanitative	Comparison of actual data and standard data from the shop manual	Secondary	Literature study: shop manual WA 500-3 and MCR document (Mechanical Condition Report)

2.2 Fault Analysis Methods

The fault analysis was conducted by applying the eight-step troubleshooting method as in [7] and [8] which can be described as follows:

1) Troubleshooting chart

In the implementation of this step, it begins with collecting information about the machine unit that is experiencing problems, such as; customer name, type and serial number of the unit, details of the location.

Then as much as possible get information about the trouble, such as: the condition of the damage, the work done by the unit when the trouble occurred, the environmental conditions around the place of operation, records of problems that have occurred before.

From the data obtained, then a troubleshooting chart is prepared which is obtained from the shop manual.

2) Possibilities Cause

Possibilities cause is a step to determine temporary conjectures about the cause of the disturbance sourced from information submitted by operators related to complaints experienced while operating heavy equipment units and compared to the troubleshooting chart, this step usually results in several possibilities causes that need to be investigated further. Determining the possible cause is also useful in determining engineering and equipment preparation for the next step.

3) Observe and Diagnostic

This Observe and Diagnostic step is carried out to obtain preliminary data used in fault analysis by observing systems or components related to possible causes and performing diagnostics on components and systems where the fault occurs. Initial observations are made with a visual physical examination of the components and systems involved. If strong evidence is found that no damage has occurred, then one by one the possibilities causes can be eliminated. If there is a chance of a possible cause occurring, diagnostic steps can be taken to determine the most likely possible cause.

4) Collect Data

At this stage, a strong possibilities cause is established. Thourough inspections and measurements and tests are carried out directly on the component or system which are suspected as the cause of the problem. If necessary, the unit can be operated to confirm the trouble that occurred. The results of measurements and tests are then recorded.

5) Analysis

The data that has been obtained can be processed by comparing the actual data with the reference data in the reference. Data that can be processed is data that is taken actually at the time of trouble, the location of the unit operation and in accordance with the engine testing standards and is done correctly and matches the complaints that occur on the unit.

6) Suspected Cause

With the help of the Troubleshooting Chart, find the component or system that has the greatest possibility of not functioning normally, causing trouble to the unit.

It is important to note whether the abnormality is just a result of an abnormality in another component or system or is the main cause of the trouble.

7) Conclusion

In this step, the cause of the fault is confirmed by examining the suspected cause. The repair step is also determined at this point, such as recommending a new part, repair, or reconditioning.

8) Action to Improvement

The last step is to repair the unit in accordance with the recommendations from the conclusion step. Damage that occurs must be handled properly and thoroughly so that the same trouble does not occur again.

3. Results And Discussion

3.1 Unit Data

Unit data that has been obtained from the results of observations, documentation and MCR (Machine Condition Report) which is the results of the Machine Inspection Program on the WA500-3 wheel loader unit experiencing problems are shown in Table I.

TABLE II. UNIT INFORMATION

Item	Description
Unit model	WA500-3
Serial no.	520006
Engine model	SA6D140E-3
Engine serial no.	110433
Unit owner	PT. Sapta Indra Sejati
Hours Meter	92776

3.2 Fault Analysis

Result of inspection and measurement

1) Engine speed measurement

This test aim to gain the knowledge of the actual enfine idling speed. Engine speed measurement is done with a multi-tachometer in the unit of revolution per minute (rpm).

a) Low Idling Engine Speed Measurement

After the multi tachometer tools are connected on the speed sensor, then turn on the engine in low idling position, then release the parking brake and run the engine. The low idling engine speed is visible on the multitachometer screen. The measurement results of the low idling engine speed reached 640 rpm.

b) High Idling Engine Speed Measurement

After the multi tachometer tool is installed on the speed sensor, then start the engine in the high idle position, then release the parking brake and run the engine. The high idling engine speed rpm is visible on the multi tachometer screen. The results of the low idling engine speed rpm measurement reached 1889 rpm.

c)T/C Stall Engine Speed Measurement

After the multi tachometer tool is installed on the speed sensor, the engine is started, then the gearshift lever is moved to position F4, the parking brake is released and running the engine with a high idling position so that the engine speed t/c stall rpm is visible on the multi tachometer screen. The measurement results of engine speed t/c stall rpm reached 1893 rpm.

The result of engine speed measurements are then compared to the standard value from the shop manual. The data comparison is shown in Table III.

TABLE III. RESULT OF ENGINE SPEED MEASUREMENT

Engine Speed	Standard	Actual
Engine Low Idling	725±50 rpm	640 rpm
Engine High Idling	2300±50 rpm	1889 rpm
T/C Stall	2100 rpm	1893 rpm

2) Engine Control Module (ECM) inspection

Inspection then carried to the Engine Control Module. The screen shows error code 7b. According to the shop manual this means: no-pressure feed by supply pump. Based on this data, it can be assumed that the next action is to check the unit's fuel system. these inspection steps are: conducting a visual inspection of the fuel pump, primary pipping, common rail and secondary primary pipping by starting the engine at low idling and stopping the engine, so that afterwards conduct a visual inspection of these components, to determine whether there are signs of leakage or seepage of fuel (diesel) in these components.The ECM is shown in Fig.1.

Fig. 1. Inspection on the ECM information screen

After the inspection, the result was that no seepage occurred in the component parts checked, thus it was declared that there was no leakage. A summary of the inspection results is shown in the Table IV.

TABLE IV. RESULT OF VISUAL INSPECTION

Visual Inspection	Standard	Actual
Fuel Pump	No leaks allowed	No leaks found
Primary Pipping	No leaks allowed	No leaks found
Common Rail	No leaks allowed	No leaks found
Secondary Pipping	No leaks allowed	No leaks found

After it is found that there are no leakage occurred, the inspection continued to measurement of low pressure circuit system.

3) Low Pressure Circuit pressure measurement

Measurements are made with measuring tools in the form of a 10 kg / cm2 pressure gauge which is installed at the measurement pressure tap point located between the feed pump-fuel filter-supply pump. After the tools are installed, start the engine with a high idling position, so that the needle of the pressure gauge moves and shows the system pressure. The low pressure circuit measurement is shown in Fig.2.

Fig. 2. Low pressure circuit measurement

The result of the low pressure circuit pressure measurement is shown in Table V. This shows that the actual value is still within the allowable value. This means that the low pressure circuit is in good condition.

TABLE V. RESULT OF THE LOW PRESSURE CIRCUIT PRESSURE MEASUREMENT

Time for measure	Standard	Actual
Run engine at high idling	1,5-3,0 kg/cm2 (0,15-0,30 Mpa)	2,0 kg/cm2

4) Pressure Limiter Fuel Drainage Volume Measurement

The measurement is done by removing the pipping outlet of pressure limiter and redirected it to the another hose that inserted into the measuring cup. The engine is cranked for one minute and the amount of fuel comes out of the pressure limiter drainage port is measured. Result of this measurement is shown in Table VI. This indicates that the fuel drain on the pressure limiter is excessive.

Excessive fuel drain on the pressure limiter of a common rail system can be caused by injection fusion. Injection fusion occurs when two consecutive injection current-pulses are approached to each other, causing the fusion of the two injections, which leads to an undesired excessive amount of injected fuel. This can worsen particulate emissions and fuel consumption. The reason for injection fusion is mainly due to the time delay between the electrical signal to the solenoid and the needle lift at both valve opening and closure. In particular, the dwell-time range inside of which injection fusion occurs was shown to decrease by reducing the nozzle closure delay[9].

TABLE VI. RESULT OF PRESSURE LIMITER FUEL DRAINAGE VOLUME MEASUREMENT

Condition	Standard	Actual
Engine cranked for one minutes	Max. 10 cm3/min	±40 cm3/min

3.3 Problem Analysis

This pressure limiter component is connected to the common rail, which functions as a valve for the return path of fuel from the common rail to the fuel tank. With the factory setting, the pressure limiter valve will open if the fuel pressure in the common rail reaches 1430 Kg / cm2[8].

The pressure limiter in a diesel common rail injection system is a component that limits the maximum pressure that can be generated in the common rail. This is important because if the pressure becomes too high, it can cause damage to the fuel injectors and other components of the system[10]. The pressure limiter works by regulating the flow of fuel to the common rail, which in turn controls the pressure in the rail. When the pressure reaches a certain level, the pressure limiter opens up and allows fuel to flow back to the fuel tank, which reduces the pressure in the common rail[11]. This process is repeated continuously to maintain the pressure within a safe range. The pressure limiter is a critical component of the common rail injection system, as it helps to ensure that the system operates safely and efficiently[12].

Based on the results of the MCR (Machine Condition Report) data obtained, it is concluded that there is wear on the pressure limiter inner parts valve (guide), which resulted in leakage of the pressure limiter from the common rail. The guide in the pressure limiter is shown in Fig.3.

Fig. 3. Pressure limiter valve guide

The wear on the valve guide causes pressure leakage. The pressure limiter valve opens prematurely (opens before reaching the specified pressure) so that the pressure on the common rail is inadequate to push fuel on the injector (fuel low pressure in common rail). The low pressure also means less volume of fuel sprayed by the injector into the cylinder, resulting in symptom of low engine power

Wear on the guide because the guide is a component that rubs directly mechanically with the body. The friction is driven by fuel pressure after the fuel pressure reaches 140 Mpa (1430 kg/cm2) setting the pressure limiter, thus opening the fuel line. After the fuel pressure returns to normal, it will be pushed back by the spring to close the fuel line after the pressure returns to normal below the pressure limiter setting.

The wear also can be caused by the use of contaminated fuel which causing the loss of lubrication properties of the diesel fuel. Contamination of fuel can be caused by diesel fuel mixed with water and exposed to sunlight (heat), this occurs due to inadequate storage such as storage in an open area that is subjected to rain, sunlight and condensation. The actual fuel storage in the field is shown in Fig.4.

Fig. 4. Inadequate fuel storage

4. Action to Improvement

After it is known that there is an abnormality in the measurement results of from pressure limiter fuel drainage volume, it is confirmed that there is a fuel leak from the common rail leading to the return channel of the fuel tank. Thus, the solution to the problem is to replace the pressure limiter assembly in accordance with the recommendations from the WA500-3 shop manual.

To make sure the leakage problem at the pressure limiter has been resolved, re-measurement of variables that were previously not within standardized limits, namely:

- Pressure limiter fuel drainage volume,
- Engine low idling, high idling, and t/c stall rpm value.

Results of this re-measurement is shown in Table VII, the measurement results of low idling, high idling and t / c stall engine speed are in accordance with the standard, also the error code 7b on the ECM (Engine Controller Module) screen no longer appears. Thus the inspection results is showing normal condition and the WA500-3 wheel loader unit can return to operation with good performance.

TABLE VII. MEASUREMENT RESULT AFTER IMPROVEMENT ACTION

Item	Condition	Unit	Standard	Actual before	Actual after
Engine Speed	Engine Low Idling	rpm	725±50	640	740
	Engine High Idling	rpm	2300±50	1889	2300

	T/C stall	rpm	2100	1893	2100
Fuel Return	Pressure Limiter	cm3/min	max. 10	±40	0

In addition to replacing components, diesel fuel samples were taken from the wheel loader unit to check for contaminants in the fuel also fuel quality standards and storage standards are established to ensure that the fuel remains free of contaminants to prevent unnecessary wear on the fuel system components.

5. Conclusion

Analysis of low fuel pressure on the common rail system on the engine of wheel loader WA500-3 has been done. The cause of fuel low pressure in common rail is the result of fuel leakage in the common rail pressure limiter, due to wear on the valve guide. This conclusion was determined after an abnormal value was obtained in the measurement results of fuel drainage from pressure limiter. The impact caused by fuel low pressure in common rail is engine low power. This is indicated by the measurement results of low idling, high idling and t/c stall engine speed, where the engine rpm does not meet the standard limits. To solve the problem of fuel low pressure in common rail is to replace the pressure limiter with a new one.

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