Monitoring Heavy Equipment Coolant Temperature to Prevent Engine Overheat Using IoT

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Abstract*— All heavy equipment, including bulldozers, are expected to always be ready to operate and have maximum performance. However, there are still many bulldozers that have problems, one of which is engine overheating. This overheating can be caused by a reduced amount of coolant due to a leak or an inappropriate cooling fan rotation speed due to a loose fan belt. This study aims to monitor and provide early warning of rising coolant temperature along with the possibility of reducing the amount of coolant and decreasing the cooling fan rotational speed. This research was conducted by developing monitoring and warning devices, apart from being known by the operator, it can also be known by the maintenance department in a different place with the use of IoT. The result of experiment shows that condition of the high temperature engine coolant, reduced amount of coolant, and reduced cooling fan rotational speed, can be immediately known by operators and the engine speed can be automatically set to the medium range when abnormality in cooling system occurs, according to the manufacturer's recommendations. This condition of cooling system can also be known by other parties used Blynk application.

Keywords*—bulldozer, engine overheat, monitoring, IoT, Blynk.

I. Introduction

Heavy equipment is widely used in the construction and mining sectors to carry out earthworks. Bulldozer is one of the models of heavy equipment that has a function to push the soil or others material. By installing special work equipment, bulldozers can also be used for ripping or towing work. Komatsu is a bulldozer brand with D85ESS-2 as one of its models. Bulldozer consists of several systems and many components to be able to carry out its function. One of them is engine as a source of power or rotation. Work principal engine to generate power or rotation is to convert thermal energy into mechanical energy. During this process, a lot of heat is created. In general, the engine is equipped with a cooling system, to keep the engine working temperature within standard value.

Referring to the summary problem D85ESS-2 [1] there were 25% cases of engine problem. If this engine problem is described in more detail in each system on the engine, then it is obtained that 49% of the problems occur in the cooling system. Where the percentage is the highest compared to other system problems. Furthermore, it was also found that the three main problems in the cooling system are leaking of coolant, drop in heat dissipation efficiency, and defective of coolant circulation, where the percentages are 39%, 31%, and 30%, respectively. Problems with the cooling system along with the three main causes, will result in engine overheating. An engine is said to overheat if the coolant temperature exceeds the standard working temperature [2]. If this overheating condition occurs repeatedly or no treatment is done, it will cause more losses than the necessity of replacing components that have premature damage due to overheating. This engine overheating also has an impact on the inoperability of the bulldozer or known as an unscheduled breakdown, so that productivity decreases and can harm the bulldozer owner.

Komatsu bulldozer D85ESS-2 is not equipped with a proper warning system for engine coolant high temperature that has the potential to cause engine overheating problems (Fig 1). It only has an analogue temperature gauge that installed on the front panel to monitor the engine coolant temperature.

Fig. 1. D85ESS-2 engine coolant temperature monitoring

The temperature gauge can only be seen by the operator who operates it. So, it is very necessary for operator discipline to always monitor this temperature gauge, while operating the bulldozer. If the needle on the coolant temperature gauge starts to enter the red range, the operator must immediately stop the work, then run the engine under no load at a midrange speed and wait for the indicator to go down to the green range [3]. Stopping the engine suddenly when the engine overheats, engine life may be greatly shortened. Failure to perform this procedure can result in premature damage to engine components.

II. METHODES

A. Conceptual Design

As previously explained, there are several possible causes of coolant overheating, including lack of cooling water, drop in heat dissipation efficiency, and defective cooling circulation system. Especially for the latter causes, has been carried out by previous researchers [4]. This research focus on the lack of cooling water and drop in heat dissipation efficiency. Reducing the amount of coolant or even running out, will cause the process of taking heat from engine components to be released into the air, will be ineffective. The reduced amount of coolant in the cooling system, can be detected through the level indicator on the sub tank or reservoir. On the other hand, the release of heat from the coolant when the coolant passes through the radiator will also be ineffective if the air exhaled by the fan decreases in intensity. The rotational speed of the cooling fan will greatly affect the intensity of the air flowing through the radiator to take heat from the coolant. Based on these things, a device was developed that can monitor the reduced amount of coolant and the reduced speed of the cooling fan also the coolant temperature itself. In addition, it also equipped with a warning of the occurrence of abnormal conditions or actions that need to be taken immediately when the abnormal conditions occur. The basic concept of the tool to be developed can be seen in the following Fig. 2.

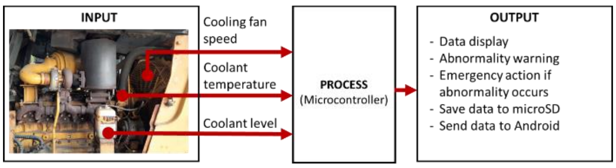

Fig. 2. Input, process, and output diagram.

Amount of coolant in the sub tank, rotational speed of the cooling fan, also coolant temperature itself will be read by the sensor and become input for further processing by the microcontroller. The microcontroller will then decide based on the information provided by the three sensors, whether there is an abnormal condition in one of the three. Furthermore, the microcontroller will give a warning that there has been an abnormality in the cooling system and an emergency actions will be taken in accordance with the manufacturer's recommendations. All this information can be seen by the operator form the display, send to the maintenance department or operation supervisor using IoT (Blynk application) and stored on the memory card. More specifically, the abnormal conditions in the cooling system are coolant temperature high if above 85°C, coolant level low if under the lower mark on the sub tank/reservoir, and cooling fan speed low if fan speed at maximum deflection of fan belt and engine speed low idle. Fig. 3 and Fig. 2 are the concept of how the monitoring and warning device works in general also device block diagram with list of material and components are used on the device.

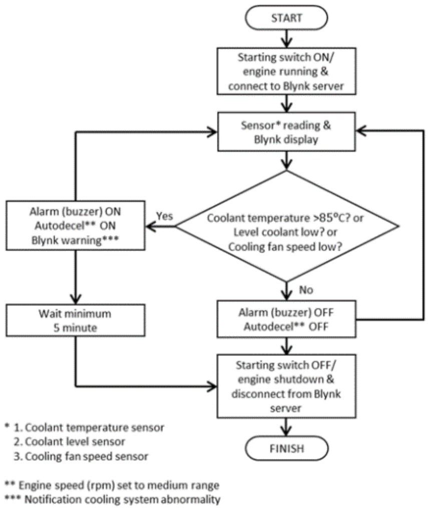

Fig. 3. Monitoring and warning flow diagram.

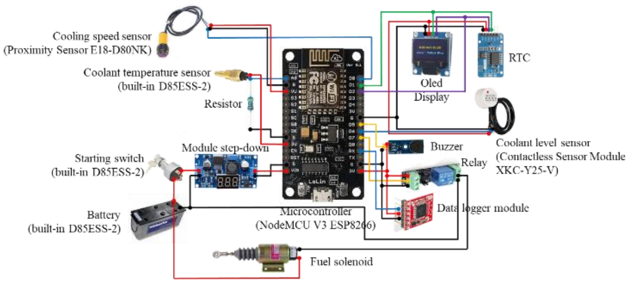

Fig. 4. Device block diagram.

B. Sensor Working Test

Before assembling all components including sensors according to the block diagram above (Fig. 4), a work test is carried out first. The test for temperature sensor is carried out by comparing the sensor readings with the industrial digital thermometer reading as shown in Fig. 5.

Fig. 5. Temperature sensor working test.

From the test it is found that the maximum difference coolant temperature reading between thermometer and temperature sensor is 0.19°C when thermometer reading 25.50°C and sensor reading 25.69°C. With x is the test value and NA is correct value, then the error and accuracy are [5]:

$$Error\ (\%) = \frac{x - NA}{NA} \times 100\% \quad (1)$$

$$Accuarcy\ (\%) = 100\% - Error(\%) \quad (2)$$

It can be said that the error percentage is 0.75% or in other words, the sensor accuracy is 99.25%. To get a correlation coolant temperature reading between thermometer and temperature sensor, a statistical t-test is carried out. The result of t-test obtained are t-stat (-0,000456285) < t critical two tail (2,073873068) and P two-tail (0,99964005) > alpha (0.050). So, it can be concluded that there is no different between coolant temperature reading by thermometer and temperature sensor. The statistical error (deviation) from mean value thermometer reading (57,64°C) and sensor reading (57,64°C), there was 0,0034°C.

Testing the function of the coolant level sensor is done by placing the sensor in front of the fluid that is accommodated in a container, then ensuring the digital output value and whether the LED indicator is on (Fig. 6).

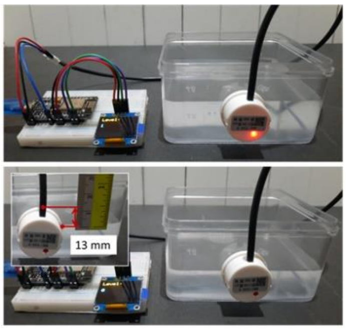

Fig. 6. Level sensor working test and position setting.

The results of the tests carried out, it was found that the digital output of the sensor will be 0 if the fluid level is reduced to 13 mm below the upper outer diameter of the sensor level.

As for the fan speed sensor as shown in Fig. 7, the test is carried out by first finding the value of cooling fan speed at maximum deflection of fan belt and engine speed at low idle condition. This is done because there is no minimum standard for cooling fan speed in the Komatsu bulldozer D85ESS-2 [1,3].

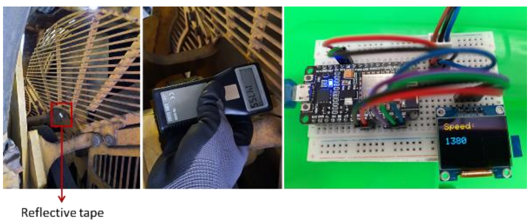

Fig. 7. Fan speed sensor working test.

After measuring the cooling fan speed using an industrial tachometer, then use a series of cooling fan speed sensors consisting of an infrared proximity sensor E18-D80NK as a speed sensor, NodeMCU microcontroller, and a 0.96-inch OLED display to read cooling fan speed under similar conditions [6-10]. The test results show that there is a difference of 6.5% between the speed sensor readings and the industrial tachometer readings. In other words, the sensor accuracy is only 93.5%. The difference 6.5% (95 rpm) then will be add to Arduino coding.

III. Result and Discussion

As previously described, most of the components contained in the block diagram or circuit are placed in one box, except for the three sensors, namely the coolant temperature sensor, coolant level sensor, and cooling fan speed sensor and fuel solenoid.

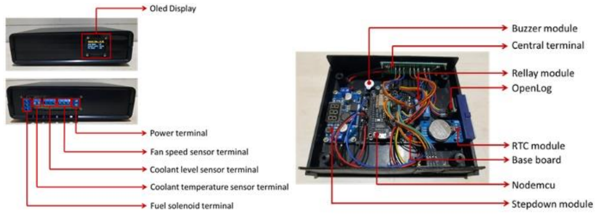

Fig. 8. Front, back, and inside box view.

The box (Fig. 8-Fig.10) is then placed on top of the panel and gauge for easy access or viewing by the operator operating the bulldozer.

Fig. 9. Box location.

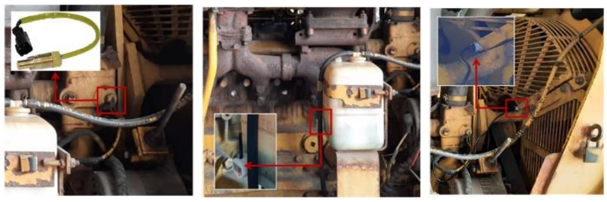

Fig. 10. Temperature, level, and speed sensor location.

The display on the Blynk application (Fig. 11) is made in such a way that it can display information related to the working conditions of the engine cooling system

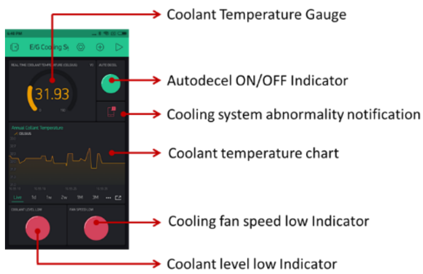

Fig. 11. Blynk application display.

The device that has been designed, validated, or tested the function of the sensors, and installed on the bulldozer, then carried out several simulations of conditions to ensure whether the tool can work according to the program that has been made previously. Considering that the coolant temperature sensor which is the main sensor is attached to the thermostat housing and it is risky if it is removed to simulate a temperature increase, the simulation is not carried out when the tool is installed in the bulldozer, but by creating the conditions needed in a separate place. The Fig. 12 below shows the simulation results for condition 1 as shown in Table 1.

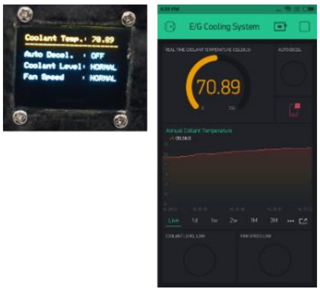

Fig. 12. First state simulation display result.

TABLE I
FIRST STATE SIMULATION RESULT

Parameter	Simulation Condition	Set Parameter	OLED Display	Blynk App. Display
Coolant temperature	Normal	< 85ºC	78.89	78.89
Coolant level	Normal	Above lower mark	NORMAL	LED OFF
Cooling fan speed	Normal	Above 1475 rpm	NORMAL	LED OFF
Autodecel	-	-	OFF	LED OFF

The Fig. 13 below shows the simulation results for condition 2 as shown in Table 2.

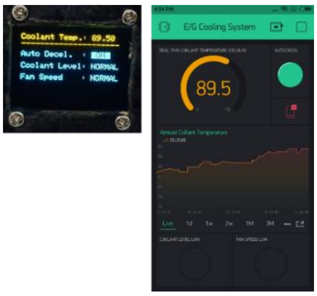

Fig. 13. First state simulation display result.

TABLE II
SECOND STATE SIMULATION RESULT

Parameter	Simulation Condition	Set Parameter	OLED Display	Blynk App. Display
Coolant temperature	Normal	> 85ºC	89.50	89.5
Coolant level	Normal	Above lower mark	NORMAL	LED OFF
Cooling fan speed	Normal	Above 1475 rpm	NORMAL	LED OFF
Autodecel	-	-	ON	LED ON

The Fig. 14 below shows the simulation results for condition 3 as shown in Table 3.

Fig. 14. Third state simulation display result.

TABLE III
THIRD STATE SIMULATION RESULT

Parameter	Simulation Condition	Set Parameter	OLED Display	Blynk App. Display
Coolant temperature	Normal	< 85ºC	93.41	93.41
Coolant level	Normal	Above lower mark	NORMAL	LED OFF
Cooling fan speed	Normal	Below 1475 rpm	LOW	LED ON
Autodecel	-	-	ON	LED ON

The Fig. 15 below shows the simulation results for condition 4 as shown in Table 4.

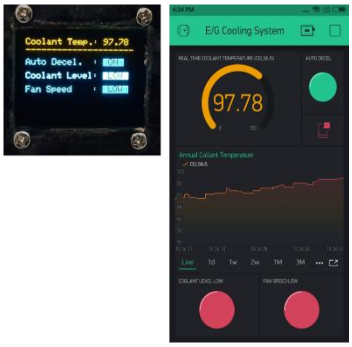

Fig. 15. Fourt state simulation display result.

TABLE IV
FOURTH STATE SIMULATION RESULT

Parameter	Simulation Condition	Set Parameter	OLED Display	Blynk App. Display
Coolant temperature	Normal	< 85ºC	97.78	97.78
Coolant level	Normal	At lower mark	LOW	LED ON
Cooling fan speed	Normal	Below 1475 rpm	LOW	LED ON
Autodecel	-	-	ON	LED ON

In addition to displays that information on the condition of coolant temperature, coolant level, and cooling fan speed, including information on whether the autodecel function is working or not, several outputs from processes such as buzzer alarms and relays to activate the fuel solenoid including the fuel solenoid can also be seen whether it is working. The Table 1-Table 4 shows the experimental results for buzzer alarms, relays, and fuel solenoids. Especially for the autodecel function, which will set the engine speed to a low idle when an abnormal condition occurs in the cooling system, information on whether this autodecel works can already be displayed on the OLED display and the Blynk application. In addition, the relay that connects the current from the battery to the fuel solenoid can also work, including the fuel solenoid. However, the placement of this fuel solenoid requires further consultation with the principal in this case is Komatsu, considering that it is necessary to manufacture a bracket as a holder for this fuel solenoid, in which this bracket then needs to be adjusted again with other components found on the engine is shown in Fig. 16.

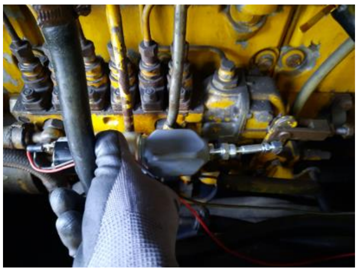

Fig. 16. Fuel solenoid placement.

IV. Conclussion and Recomendation

A. Conclusion

This study was conducted to monitor coolant temperature and give early warning of potential engine overheating, then automatically take the necessary countermeasures in accordance with the manufacturer's recommendations.

The result of experiment shows that condition of the high temperature engine coolant, reduced amount of coolant, and reduced cooling fan rotational speed, can be immediately known by operators. The result of the study shows that the engine speed can be automatically set to the medium range when abnormality in cooling system occurs, according to the manufacturer's recommendations.

The result of study shows that the Blynk application, can be used to send information about the condition of the engine cooling system, so that the information can also be known by other parties.

B. Recommendation

Considering that the tool made in this study is still a prototype, so it is necessary to use components that have been tested for reliability. Especially for the coolant level sensor and cooling fan speed sensor, it is better to use a sensor that has an operating ambient temperature specification that matches the ambient temperature around the engine. The placement of other components, including the installation of cable lines, further needs to be ensured that they will not damage the components or the cable itself or cause damage to the original components of the bulldozer.

For data transmission, it is necessary to develop other media besides the use of the internet or Wi-Fi, for example the use of radio frequencies, considering that many heavy equipment such as bulldozers are operated in areas without an internet connection.

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