Travel Mis-Operation Prevention Using Automatic Warning System for Excavator

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***Abstract*—Excavator is one of the typess of heavy equipment for digging, moving and loading materials to the dump truck. The undercarriage is the most extensive damage components in excavators. The travel usage errors may increase the potential damage to the undercarriage. This paper proposes Travel mis-operation prevention to avoid damage the undercarriage using automatic warning system through travel time and temperature monitoring. The experiment's results shows that there is a significant relationship between travel time and temperature rise in motor travel. To minimize travel operation errors by operators and excavator's damage, both operating conditions above also be known by supervisor or control room using application of Internet of think (IoT) technology.**

***Keywords*—excavator, undercarriage, wireless, temperature, heavy equipment.**

I. Introduction

Excavators (Fig. 1) are the most versatile type of machine because it is able to handle a wide range of other machine jobs. In accordance with its name, this machine has a main function in excavation work. Among the many working functions of excavators include digging the ground, making trenches, loading materials into dump trucks or wood to trailers.

Fig. 1 Heavy equipment hydraulic excavator type

If combined or replaced attachment, then an excavator can also be used to break up rocks. With a number of excavator's functions, this machine is also one of the famous equipment to be used in the mining, construction, agribusiness and forestry industries. Excavators are the most popular heavy equipment with the largest population in Indonesia as shown in Fig. 2.

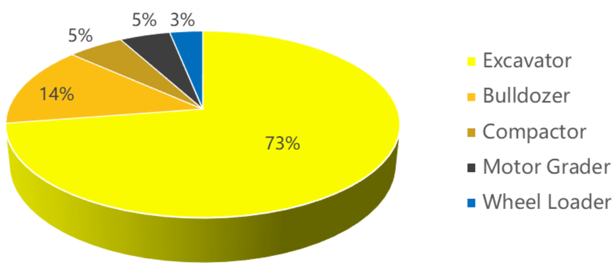


Fig. 2 Komatsu excavator population across Indonesia

Undercarriage is one of the main components of the excavator unit located at the bottom or called as the lower structure that has the main function as a driver so that the excavator can move [1]. As long as the excavator is on moving operation, the undercarriage component will always rub, collide with the contours of the road and withstand the weight of the excavator itself.

Based on operating condition above, the undercarriage has the potential to be damaged and requires part replacement. It may cause the large maintenance costs. Undercarriage maintenance is the largest contribution of total maintenance costs. Undercarriage maintenance takes up about 45-60% of the excavator's maintenance costs [1]. On the other hand, if we look closely, these components have been arranged compactly with the aim of damage caused by something external [2]. However, in its implementation, the undercarriage components do not escape damage, both caused by external and internal factors, namely the physical strength of the components themselves and the accuracy of their special methods during travel operations.

The excavator problem ranking is shown in Table 1. The undercarriage is the second highest position after the fuel system [3]. It shows that the undercarriage is the important components in excavator.

TABLE I
FREQUENTLY EXCAVATOR COMPONENT PROBLEM

Group Component	Note
Fuel System	1st
Undercarriage	2nd
Engine	3rd
Hydraulic System	4th
Cooling System	5th

The main operation of the excavator are digging, loading swing and traveling [5]. Each operation have to follow procedures to avoid mis-operation [5]. Meanwhile, the majority operation of excavator are digging, loading and swinging, while traveling is limited operation. If it is necessary to move quite far away, it is highly recommended to be transported by truck, or if it is necessary to travel a long distance, it must be done with certain procedures [6]. In real operation condition, however, there are many inconsistencies in carrying out the operation properly.

Fig. 3 shows monthly summary travel time on excavator. The travel operation is still quite long, which is 30 to 40 hours per month [3].

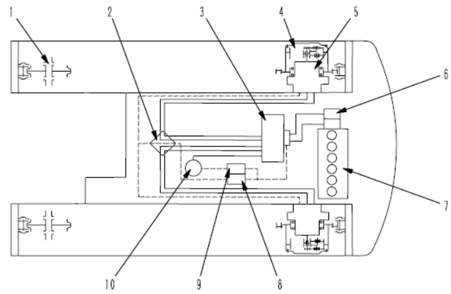
Fig. 3 Monthly summary travel time on excavator

II. METHODS

A. Basic Movement Mechanism of Excavator

All movement and functions of excavator are accomplished through the use of hydraulic fluid, with hydraulic cylinders and hydraulic motors. The power generated by the engine is converted into hydraulic power by a large hydraulic pump called the main pump.

Fig. 4 depicts that hydraulic pump converts mechanical power into hydraulic power to move an excavator. The flow of hydraulic oil is regulated by a control valve whose is regulated by a pressure pilot mechanism called proportional pilot control (PPC) which becomes one with lever on the operator. Then the oil will be distributed to the actuator by operator lever [1]. For travel movement, the control valve will distribute the oil to the travel motor through the hose using the travel lever by operator. Because the position of the motor travel is in the lower structure, an additional swivel joint is needed as connection.



1. Idler
2. Center swivel joint
3. Control valve
4. Final drive
5. Travel motor (HMV120)
6. Hydraulic pump (HPV95 + 95)
7. Engine (SAA6D107E-1)
8. Travel speed solenoid valve
9. Swing brake solenoid valve

Fig. 4 Excavator power distribution mechanism [7]

B. *Travel Mis-operation Prevention using Warning System*

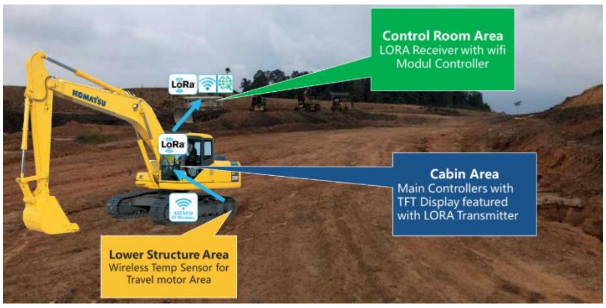


Fig. 5 Mapping concept of automatic warning system

This system will read the engine rpm signal, the travel PPC (Proportional Pilot Control) switch as an indicator that the excavator is traveling, then the Arduino starts run the timer [8], and the input from the hydraulic temperature sensor will be displayed on the TFT Display. If the duration or temperature of hydraulic oil exceeds the allowable standard, the controller will send a warning signal to stop the excavator for 30 minutes and then send information via LoRa to supervisor or control room. The proposed system is divided into 3 devices namely Lower Structure area, cabin Area and Control Room Area as shown in Fig. 5 and Fig. 6.

- Lower Structure Area Module

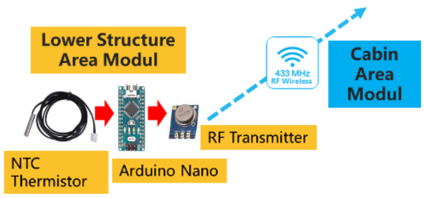


Fig. 6 Lower structure area module

The module function is to read the real temperature in the final drive area. RF transmitter is installed in the system to transmit temperature data from the sensor to the cab operator without cables [9]. The advantage of the system is the upper components of the excavator can rotate freely against the bottom components.

- Cabin Area Module

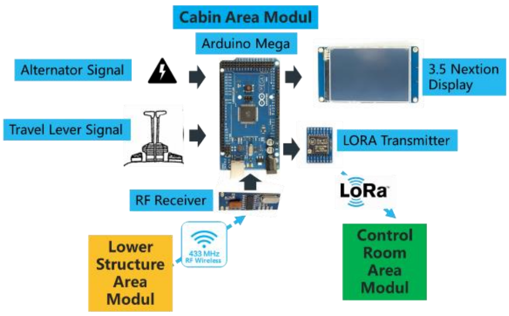
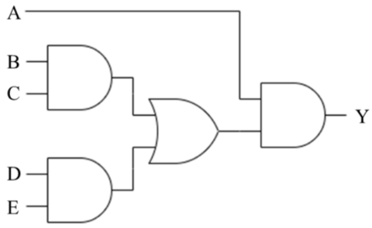


Fig. 7 Cabin area module

Cabin area module scheme is shown in Fig. 7. The function of the module is to display data to the operator through the TFT screen [10]. RF receiver is installed to receive data from the lower structure area. Moreover, the device is also equipped with LoRa Transmitter to transmit temperature and time data to the control room. LoRa wireless sensor networks can be used to build a wide array of applications [11]. The following logic functions is applied to perform movement detection with the output run timer.



A = Signal Alternator Output
B = Forward Right Lever oil Pressure Sensor
C = Forward Left Lever oil Pressure Sensor
D = Reverse Right Lever oil Pressure Sensor
E = Reverse Right Lever oil Pressure Sensor
Y = Travel timer

- Control Room Area module

This module is used to send data from the cabin area through LoRa to the control room via the internet or the Wi-Fi network as shown in Fig. 8. By using ESP8266 and LoRa Receiver, the coverage of this project become wider without internet facilities.

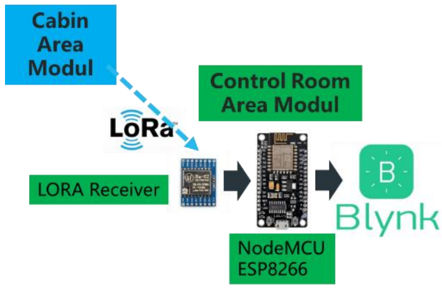


Fig. 8 Control room area modul

III. RESULT AND DISCUSSION

Sensor is very important device to read a real data [12]. To ensure the data is correct, the sensor validation has been carried out by comparing with standard thermometer readings. The results of temperature sensor validation are depicted in Fig. 9.

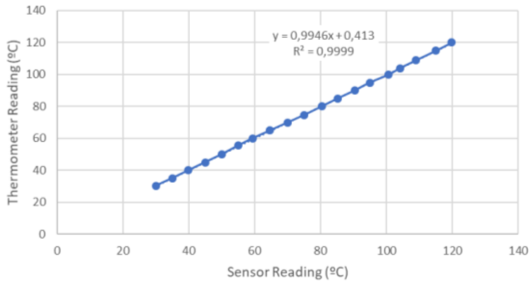


Fig. 9 Temperature sensor validation

By utilizing the trendline feature on the Scatter chart Microsoft excel, the most appropriate of linear equation is obtained with root square 0.9999.

$$y=0.9946x - 0.413$$

The equation's above is used as a reference to the programming sensor in the microcontroller to get a new value after calibration [13].

A. *Experimental Results for Temperature Readings by Sensors via Wireless Module RF433*

Because the device is designed to use the wireless feature to reach locations, it is very important to do measurements between the actual temperature and the temperature data on the wireless receiver module [9].

TABLE II
TEMPERATURE READING MEASUREMENT RESULTS VIA RF WITHOUT BARRIER

Distance (m)	Thermometer (ºC)	Sensor (ºC)	Judgement
2	29.0	28.5	Data Received
5	30.3	30.0	Data Received
7	32.4	32.4	Data Received
10	33.7	33.9	Data Received

Experiments were conducted on two conditions, there are wireless connection without barriers and wireless connection with barriers to represent actual conditions. Table 2 shows that there is no significant discrepancy for distances 2, 5, 7 and 10 meters. The results show that the data is well received up to a distance till 10 meters without a barrier.

TABLE III
TEMPERATURE READING MEASUREMENT RESULTS VIA RF WITH BARRIER

Distance (m)	Thermometer (°C)	Sensor (°C)	Judgement
2	30	29.7	Data Received
5	32.4	32.5	Data Received
7	33.6	33.8	Data Received
10	35.2	35.4	Data Received

Then the wireless connection with barriers experiment was conducted as shown in Table 3. There is also no significant reading difference either within 2, 5, 7, and 12 meters. The module is able to receive data very well till 10 meters with barrier.

B. *Experimental Results for Reading Data Transmitted Through LoRa*

Experiments has been done by taking 3 modules into separate locations. RF Transmitter (Lower Structure Area) is placed at the bottom of Table 4, while the RF Receiver (Cabin Area) is placed on top of the car with a distance of more than 2 meters and blocked by the body of the car. LoRa Receiver was moved with a variety of distances.

TABLE IV
RESULTS OF MEASURING THE DISTANCE OF LORA

No	Distance	Status
1	144 m	Data Received
2	223 m	Data Received
3	334 m	Data Received
4	637 m	Data Received
5	844 m	Data Received
6	911 m	Data Received
7	1000 m	Data Received
8	1100 m	Data not Received

Testing of LoRa transmissions was conducted at 8 exposure points. Starting from the first point with a distance of 144 meters, the transmission is still good and data is received from the sender to the receiver. Similar results were also obtained for the other six points, namely 223 meters, 334 meters, 637 meters, 844 meters, 911 meters and 1 kilo meter. Data transmission is fail when the distance between the transmitter and receiver reaches more than 1 kilo meter. The experiment's results confirm that the maximum transmission data from the device is 1 kilo meter, and it is quite enough in the real application.

IV. CONCLUSIONS AND RECCOMENDATIONS

A. *Conclusion*

This study has proposes monitoring of travel operating errors on excavators, providing early alerts and quick action to avoid mis-operation. By using LoRa, notifications of excavator operation can be sent to supervisors without the internet network. The temperature and travel time of excavators are main monitoring parameters.

The experiment's results show that operation of travel excavators can be monitored remotely by using radio frequency as well as internet networks. By utilizing a cost of only 0.1% of the excavator price, the proposed study can prevent travel operating errors on the excavator and can be used as a surveillance tool to the operator to ensure that excavators can operate properly and follow travel operating procedures.

B. *Recommendation*

It is necessary to test the proposed modules in the real system because in the real system, excavator works in higher pressure may cause higher temperature. Moreover, remote frequency radio functions (LoRa) will be more accurate if conducted at the excavator site and to obtain a wider LoRa range, it is necessary to add a pole for the receiver antenna and installation of transmitter antenna installation outside the cab area [11].

The further project is suggested to add action function from control room to stop the machine when warning system are not executed by the operator.

REFERENCES

[1] Unitet Tractors, *Final Drive & Undercarriage*, Technical Training Department: Jakarta, 2011.

[2] S. V. O. Ama, *Analisa Kerusakan Komponen Undercarriage Excavator PC-200 Hyundai Robex Dengan Metode FMEA*, Thesis, Sanata Dharma University, 2020.

[3] U. Tract, *Summary Problem*, 2021.

[4] Kementerian Pekerjaan umum dan Perumahan Rakyat, *Modul Pelatihan Berbasis Kompetensi Sektor Konstruksi Golongan Pokok Operator Excavator*, Jakarta, 2016.

[5] Y. Sakaida, K. Kawabatta, D. Chugo, H. Asama, "The analysis of excavator operation by skillful operator", The 23rd International Symposium on Automation and Robotics in Construction 2006, pp. 543-547, Tokyo, Japan, October 2006.

[6] Komatsu, *Operation & Maintenance Manual Komatsu Excavator PC200-8M0*, 2012.

[7] Komatsu, *Shop Manual Komatsu Excavator PC200-8M0*, 2012.

[8] J. Bayle, *C Programming for Arduino*, Packt: United Kingdom, 2013.

[9] F. Setyawan, A. A. Fikri, A. N. Fuad, R. Rohim, R. Firmansyah, "Telemetri flowmeter menggunakan Rf modul 433mhz berbasis Arduino," *Journal of Electrical and Electronic Engineering-UMSIDA*, 1 (1), pp. 8-14, 2017.

[10] https://electropeak.com/learn/absolute-beginners-guide-to-tft-lcd-displays-by-arduino/

[11] P Seneviratne, *Beginning LoRa Radio Networks with Arduino*, Apress: New York, 2019

[12] J. D. Sembiring,H. J. Berchmans, and G. Baskoro. "Fuel filter data monitoring and auto switching at komatsu engine with arduino to improve life cycletime main fuel filter usage," 1st Proceedings

of The Conference on Management and Engineering in Industry (CMEI 2019), vol. 1, pp. 9-12, Tangerang, Indonesia, August 2019.

[13] J. Fraden, *Handbook of Modern Sensors*, Springer: USA, 2015.