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REAL-TIME TEMPERATURE MONITORING VHMS DASHBOARD DEVELOPMENT TO REDUCE COMPONENT UNSCHEDULED BREAKDOWN

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ABSTRACT

The coal mining industry relies on heavy equipment such as excavators and bulldozers and their efficiencies are critical for the productivity. This paper addresses the issue of unscheduled breakdowns due to high operational temperatures which impacts productivity, equipment availability and maintenance costs. The existing Vehicle Health Monitoring System (VHMS) from Komatsu Original Manufacturing lacks of real-time data for coolant temperature. The data recording is only every 20 hours and data reporting to the monitoring system is transferred daily. This lack of data is leading to unable for identifying the causes of problems. This study proposes a real-time temperature monitoring dashboard for the VHMS to track and manage Komatsu equipment temperature limits and to upgrade the existing system to record temperature data in every second instead of every 20 hours. This fine data collection provides enough information for a comprehensive analysis of machine conditions. This allows for quick identification of abnormal temperature trends, leading to timely maintenance and failures prevention. The new dashboard system provides immediate access to detailed temperature data, facilitating prompt decision-making in maintenance process. It also involves setting new temperature limits to prevent overheating and reduce unscheduled component breakdown from 25% in 2019 to 0% in 2023 and 2024. Implementing a real-time temperature monitoring dashboard is expected to improve equipment availability, reduce breakdowns, optimize maintenance schedules and lower operational costs in the coal mining industry

Keywords: *VHMS, unscheduled breakdown, Komatsu, Temperature analysis, Real-time monitoring, Engineering Management.*

INTRODUCTION

The coal mining project in North Borneo (BDMA) is facing losses due to not meeting the Operating Budget (OB) caused by decreased physical availability from unscheduled component failures linked to temperature issues. From 2018-2019, Komatsu Remanufacturing Asia (KRA) analysis revealed that many component failures were due to elevated working temperatures, leading to increased downtime, higher operational costs, and reduced Performance Availability (PA). In 2019, 25% of planned overhauls were due to temperature related damage. The original VHMS monitor only tracks engine temperature without real-time capabilities, making it difficult to detect overheating problem, causing delayed responses. The VHMS system's data collection is also slow with trend data availability only after 20 working hours, hindering timely analysis and response to high temperatures or low oil pressure problems. This delayed data contributes to component damage as the overheating warning system activates at 102 degrees while damage can occur at 90 degrees.

LITERATURE REVIEW

Komatsu PC2000-8, PC1250-8, D375A

In this study, Komatsu heavy equipment PC2000-8, PC1250-8 and D375A are used for analysis. The Komatsu PC2000-8 excavator features a Komatsu SAA12V140E engine driving a sophisticated hydraulic system for precise operation of its boom, arm, and bucket, with a cooling system and transmission for stability and mobility (Komatsu, 2007). The PC1250-8, also a heavy-duty excavator, offers around 400 kW (536 HP) and advanced hydraulic and telematics systems for efficient performance and reduced costs (Komatsu, 2007). The Komatsu D375A bulldozer, equipped with a 455 kW (610 HP) engine, features a power shift transmission and heavy-duty hydraulic system for precise control and robust performance in mining (Komatsu, 2007).

Development of VHMS for large sized Komatsu equipments

Large and medium sized construction equipments use dynamic management systems for remote monitoring and control, tracking vehicle position, service data, and fuel levels to improve efficiency and machine allocation. In contrast, large equipments require systems that analyze physical condition and predict issues due to extended operational hours. The Vehicle Health Monitoring System (VHMS) and WebCARE address these needs by providing continuous data collection, predictive maintenance, and real-time monitoring to reduce costs and downtime. VHMS integrates sensors, data analysis, and satellite communication for global access and accurate diagnostics. Recent advancements include real-time temperature monitoring using Arduino and GPRS, improvements in engine overheating prevention, and enhanced IoT systems for reliable monitoring, benefiting both current practices and future research (Murakami, 2002).

Effect of Temperature on Engine Performance

Temperature influences engine lifespan in two primary ways: first, by causing the expansion of metal components at high temperatures, and second, by impacting the engine oil cooling process, which in turn affects lubrication quality (Konda, 2017). The study on engine oil viscosity and temperature shows that higher temperatures reduce viscosity, affecting lubrication effectiveness and increasing wear. Farhanah (Farhanah, 2015) found that at high temperatures and speeds, oil B performs better, while oil C excels in low temperatures. Engine components, such as pistons and valves, operate under high temperatures and pressures, requiring effective lubrication to prevent wear and damage. Viscosity decreases with rising temperatures, making oil less effective as a cushion and heat transfer medium. High temperatures can lead to oil thinning, reduced lubrication, and increased friction, potentially causing engine failures and overheating. Proper oil temperature management is crucial to maintaining engine performance and longevity (Wearcheck, 2008).

Real-Time Data Monitoring for Rapid Equipment Failure Prevention

The advancement of IoT has transformed temperature monitoring by enabling real-time sensor data collection, helping businesses enhance operations and mitigate risks. It utilizes interconnected devices, cloud computing, and advanced analytics to remotely monitor temperature levels and send real-time alerts (Short, 2019). While IoT offers benefits like proactive maintenance and cost reduction, challenges such as standardized protocols and enhanced data analysis remain, especially in complex environments like coal mining (Adeyeri, 2018).

The Importance of Focus Group Discussions In Engineering Management

Focus group discussions (FGDs) are structured interviews conducted with a small, diverse group of participants led by a facilitator to explore a specific topic. Commonly used in social sciences, marketing, and healthcare, FGDs are increasingly being adopted in engineering management (Smith, 2018). They assist in identifying and diagnosing issues by gathering qualitative data from various stakeholders, offering a deeper understanding of problems (Dinter, 2022). Additionally, FGDs promote collaborative problem-solving by leveraging diverse expertise to develop innovative solutions (Jones, 2020). They also support decision-making by providing a platform for input and real-time feedback, leading to more informed choices (Lee, 2021). Moreover, FGDs contribute to conflict resolution by fostering communication and mutual understanding among stakeholders (Brown, 2019).

METHODOLOGY

The research methodology follows the DMAIC (Define, Measure, Analyze, Improve, Control) framework, as illustrated in Figure 1, and applies a cyclical continuous improvement approach. To facilitate the implementation of DMAIC, focus group discussions and collaborative teamwork were conducted.

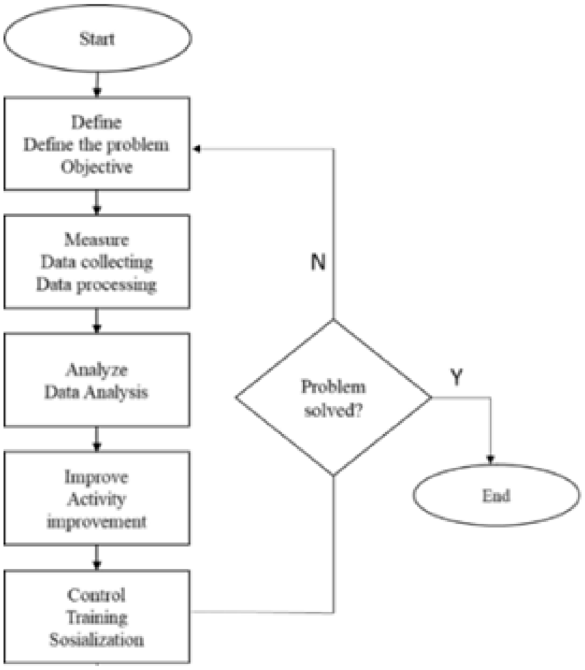


Figure 1. research DMAIC process

Formation of Task Force Team (TFT)

The research framework begins with the formation of a group called the Task Force Team (TFT). This team is made up of three sub-teams: the brainstorming team, the development team, and the action team, as shown in Fig. 2.

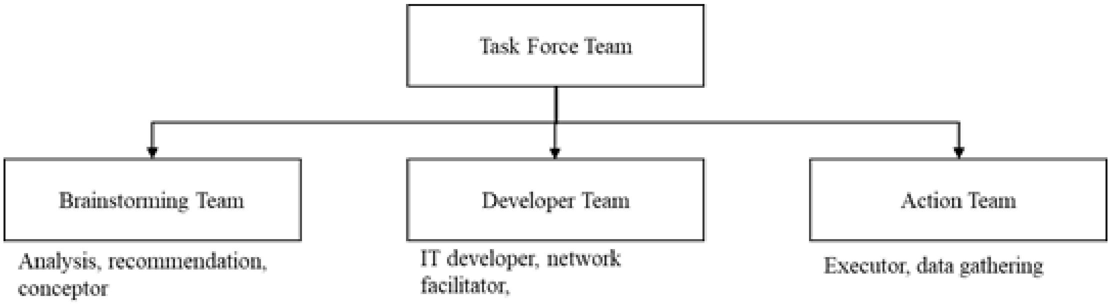


Figure 2. Task Force Team structure

The brainstorming team is responsible for analyzing the problem and generating solutions to address it. The developer team is tasked with digitizing temperature and other data based on the requirements provided by the brainstorming team, enabling them to analyze the data effectively. The action team is in charge of collecting field data, carrying out activities requested by the brainstorming team, and taking proactive measures to reduce temperature whenever real-time data indicates an increase.

Development of real-time monitoring

A dashboard system has been developed to display the real-time working temperature data of the hydraulic, engine, and transmission systems across all units. All real-time data captured by the VHMS is stored in a dedicated dashboard for continuous monitoring. The system features real-time recording, ensuring that historical data is saved on the server. Additionally, a warning system has been implemented, sending alert messages via WhatsApp.

The VHMS data delivery system uses VHMS auto-download tool where the data is sent via the transmitting antenna to the office server as shown in Fig.3.

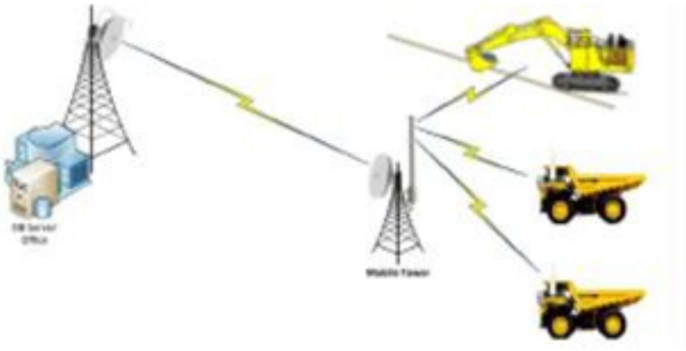


Figure 3. Data transfer networking

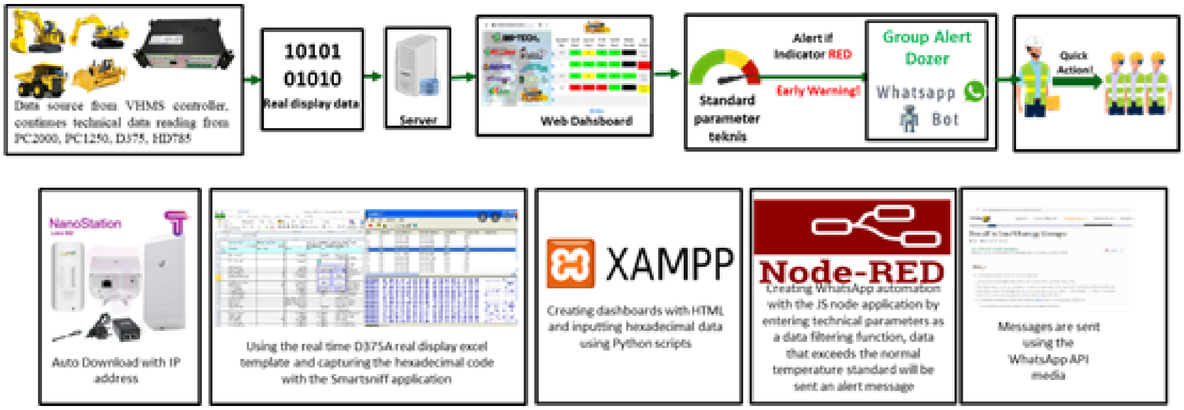
The real-time dashboard process includes three key stages: data collection, processing, and analysis. In the data collection phase, information is gathered from the unit's sensors and controllers. Field data collection involves assessing the mechanical system's status, operating conditions, and environmental influences. Data testing is conducted through trial and error in real-world conditions, where actual temperature measurements are compared with thermal camera readings.

To extract data from the controller, SmartSniff69 functions as a data converter. This packet capture tool is designed for TCP/IP packets and presents the collected data as client-server interactions. It can display information in ASCII mode for text-based protocols such as HTTP, SMTP, POP3, and FTP or as a Hex dump for non-text-based protocols. SmartSniff69 offers three packet capture methods: raw sockets, the WinPcap capture driver, and the Microsoft Network Monitor driver for older systems (Sikos, 2020).

The real-time temperature monitoring dashboard is designed to integrate all data into a single interface, allowing simultaneous monitoring of all units. Accessible via a web browser, it can be viewed on any device.

Figure 4. Flowchart of real-time data processing of VHMS temperature data

Fig. 4 illustrates the flowchart of the real-time data flow process on the Dashboard. Real-time data is collected via the Smartsniff application, then restructured using Python and integrated into the Dashboard through Node-RED. An automated color-coding system is implemented to indicate temperature limits, while a warning message system uses WhatsApp to send alerts. The steps of data processing are shown in Fig. 5.



Data source from VHMS controller, continues technical data reading from PC2000, PC1250, D375, HD785

Auto Download with IP address

Using the real time D375A real display excel template and capturing the hexadecimal code with the Smartsniff application

Creating dashboards with HTML and inputting hexadecimal data using Python scripts

Creating WhatsApp automation with the JS node application by entering technical parameters as a data filtering function, data that exceeds the normal temperature standard will be sent an alert message

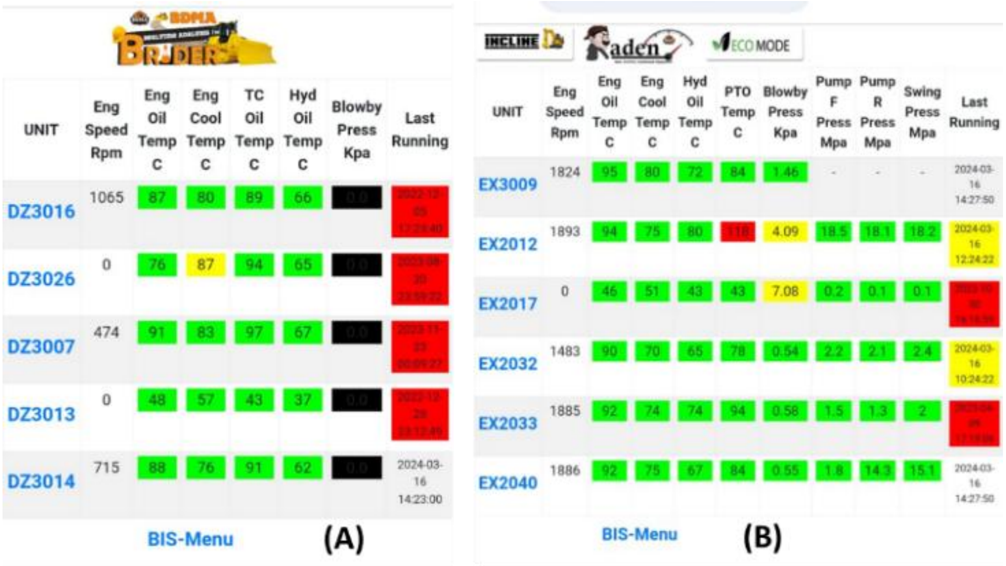
Messages are sent using the WhatsApp API media

Figure 5. Applications used in the Dashboard data processing

Data analysis is conducted using a temperature vs. time graph. Additional graphs are utilized, such as one for engine speed to verify engine operation and another for fan speed to monitor real-time ambient temperature conditions.

RESULTS

Example of dashboard and data logger display is shown in Fig. 6 to monitor real-time temperature data for 10 units. Red color is indicating a problem in the unit and a warning message is sent to the team for fixing the issue.



UNIT	Eng Speed Rpm	Eng Oil Temp C	Eng Cool Temp C	TC Oil Temp C	Hyd Oil Temp C	Blowby Press Kpa	Last Running
DZ3016	1065	87	80	89	66	0.0	[illegible]
DZ3026	0	76	87	94	65	0.0	[illegible]
DZ3007	474	91	83	97	67	0.0	[illegible]
DZ3013	0	48	57	43	37	0.0	[illegible]
DZ3014	715	88	76	91	62	0.0	2024-03-16 14:23:00

UNIT	Eng Speed Rpm	Eng Oil Temp C	Eng Cool Temp C	Hyd Oil Temp C	PTO Temp C	Blowby Press Kpa	Pump F Press Mpa	Pump R Press Mpa	Swing Press Mpa	Last Running
EX3009	1824	95	80	72	84	1.46	-	-	-	2024-03-16 14:27:50
EX2012	1893	94	75	80	118	4.09	18.5	18.1	18.2	2024-03-16 12:24:22
EX2017	0	46	51	43	43	7.08	0.2	0.1	0.1	[illegible]
EX2032	1483	90	70	65	78	0.54	2.2	2.1	2.4	2024-03-16 10:24:22
EX2033	1885	92	74	74	94	0.58	1.5	1.3	2	[illegible]
EX2040	1886	92	75	67	84	0.55	1.8	14.3	15.1	2024-03-16 14:27:50

Figure 6. Mobile view of real-time temperature monitoring dashboard for units: D375A (A), PC1250-8 and PC2000-8 (B)

Fig. 7 displays the real-time temperature monitoring dashboard for the Komatsu D375A. The dashboard can be accessed through a browser by using the intranet link.

UNIT	Eng Speed Rpm	Eng Oil Temp C	Eng Cool Temp	TC Oil Temp C	Hyd Oil Temp C	Blowby Press Kpa	Last Running
DZ3016	746	94	83	100	70	7.17	2022-07-28 10:03:30
DZ3026	1883	91	83	96	67	0.28	[illegible]
DZ3007	78	66	59	55	40	0.02	[illegible]
DZ3013	722	72	64	58	39	0.0	[illegible]
DZ3014	0	91	77	90	65	0.0	2022-07-28 11:49:11

Figure 7. Website view of real-time temperature monitoring dashboard for unit D375A

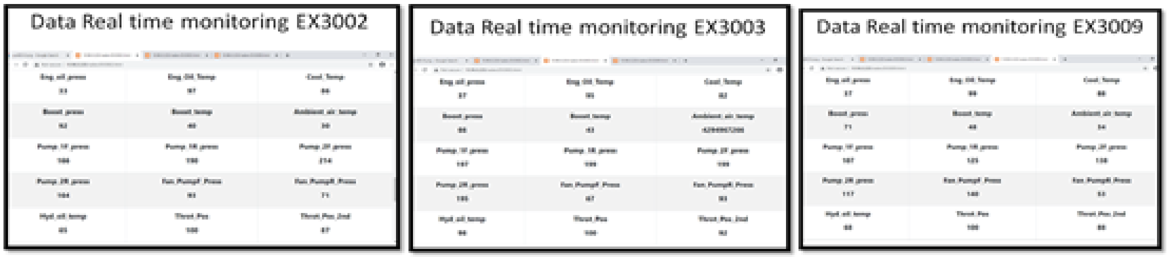
Detailed rules in the dashboard for warning system and color indicators are shown in Table 1.

Table 1: Detailed rules in the dashboard

Code	Item Description	Remark item
A.	List of unit codes for D375A at the KPP BDMA site	
B.	Real-time engine speed data (RPM)	Engine speed data is the rotational speed of the engine per minute displayed in real-time. The purpose of displaying this data is to know whether the unit is running, idling, or operating normally.
C.	Real-time engine oil temperature data (°C)	Value ≤ 0, black
		0 < value ≤ 60, no color (white)
		60 < value ≤ 95, green
		95 < value ≤ 100, yellow
		100 < value ≤ 130, red
		130 < value, black
D.	Real-time water coolant temperature data (°C)	Value ≤ 0, black
		0 < value ≤ 50, no color (white)
		50 < value ≤ 86, green
		86 < value ≤ 90, yellow
		90 < value ≤ 120, red
		120 < value, black
E.	Real-time transmission oil temperature data (°C)	Value ≤ 0, black
		0 < value ≤ 60, no color (white)
		60 < value ≤ 95, green
		95 < value ≤ 100, yellow
		100 < value ≤ 130, red
		130 < value, black
F.	Real-time hydraulic temperature data (°C)	Value ≤ 0, black
		0 < value ≤ 30, no color (white)
		30 < value ≤ 80, green
		80 < value ≤ 85, yellow
		85 < value ≤ 110, red
		110 < value, black
G.	Real-time blow by pressure data (Kpa)	Value ≤ 0, black
		0 < value ≤ 0.01, no color (white)
		0.01 < value ≤ 3.43, green
		3.43 < value ≤ 7, yellow
		7 < value ≤ 30, red
		30 < value, black
H.	Real-time data time	Shows the time when real-time data is displayed, so it can be validated whether there is a delay and to indicate when the data was taken.
		When time shows the same time or within a 1-hour range from the current time, the time color is white.
		When time shows a time longer than 1 hour up to 7 hours, the time color is yellow.
		When time shows a time longer than 7 hours, the time color is red.
		The data logger stores data on the server, and the data is broken down into 1-hour intervals.
I.	Intranet web address	web address to access the dashboard

Real-time monitoring dashboard PC2000 to analyze high temp problems

The real-time monitoring dashboard helps analyze heat issues in specific units. Figure 8 displays data from three PC2000-8 units, revealing that EX3003 has the highest hydraulic temperature among them. Additionally, the fan pump pressure in EX3003 is also the highest. Since the pump drives the oil cooler motor fan, this data suggested a potential issue with EX3003. As a result, the Task Force team inspected the unit and discovered a problem with the oil cooler fan motor.

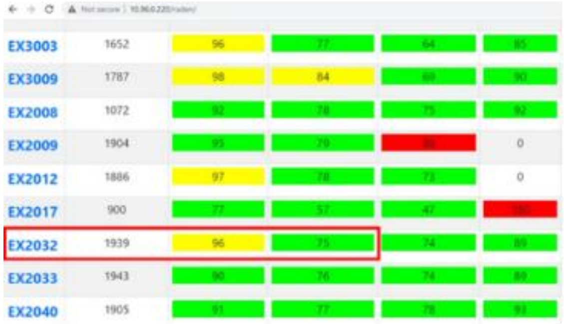


Data Real time monitoring EX3002

Data Real time monitoring EX3003

Data Real time monitoring EX3009

Figure 8. Real-time data comparison for 3 different PC2000-8



EX3003	1652	96	77	64	85
EX3009	1787	98	84	69	90
EX2008	1072	92	78	75	92
EX2009	1904	95	79	[illegible]	0
EX2012	1886	97	78	73	0
EX2017	900	77	57	47	[illegible]
EX2032	1939	96	75	74	89
EX2033	1943	90	76	74	89
EX2040	1905	91	77	78	93

Figure 9. Dashboard showing EX2032 (PC1250-8) to have engine oil and coolant temperature different more than 20^{o}C

Predict failure of engine oil cooler by analysis of real time different temperature

The troubleshooting process for EX2032 identified a temperature difference of 21 degrees between the coolant and engine oil, as shown in Figure 9. Analysis revealed that the rising engine oil temperature correlated with decreasing oil pressure, aligning with established findings on oil viscosity and bearing capacity. Inspection of the PC1250-8 cooling system suggested a blockage in the oil cooler element or an issue with the oil cooler thermostat. Further investigation uncovered that a prior incident had caused coolant to mix with the oil, creating gel-like contaminants that clogged the oil cooler. Despite replacing the oil, changing the water pump, and flushing the system, the blockage persisted. As a result, replacing the oil cooler element was recommended. After replacement, engine oil temperature decreased, and oil pressure returned to normal levels as shown in figure 10.

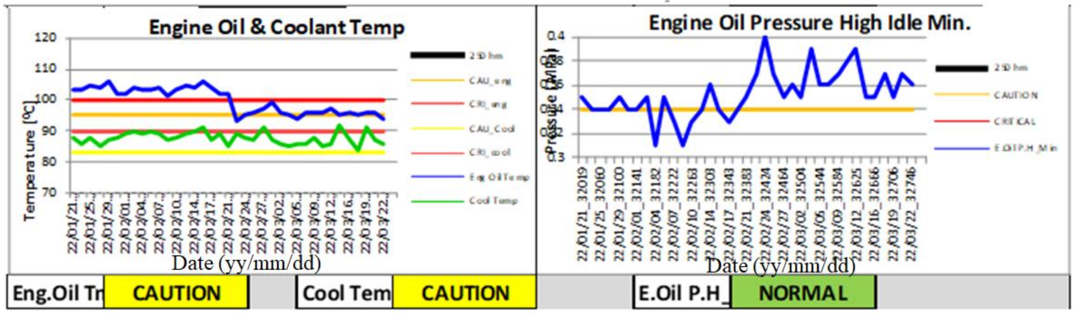


Figure 10. Result after replacement oil cooler engine

Real-time monitoring dashboard to analyze dozer high coolant temperature

Real-time monitoring data of heavy loaded dozer shows the increase in coolant temperature when engine at low RPM as shown in Fig.11. Low engine rpm is followed by a decrease in engine fan speed that reduces heat transfer in the radiator. Solution from the Task Force team is to increase the size of the radiator.

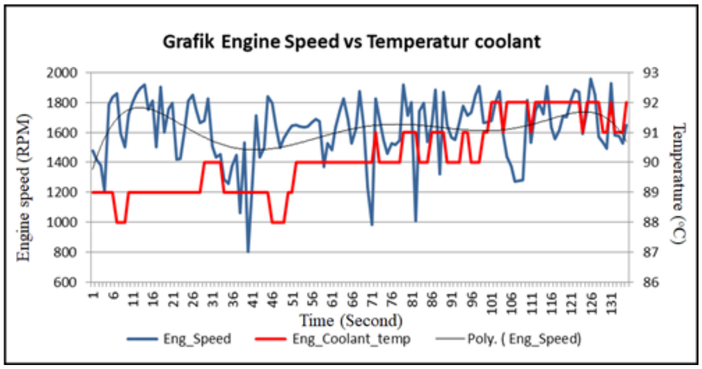


Figure 11. Graphs comparing coolant temperature and engine speed in every second

Following the radiator replacement, the temperatures of the engine oil, coolant, and transmission significantly decreased. The coolant temperature dropped from 102°C to 87°C, which is even lower than the 90°C recorded in the new D375A-5 unit. As shown in Figure 12, despite reductions in engine speed and fan speed, the coolant temperature remained below 90°C after the radiator upgrade.

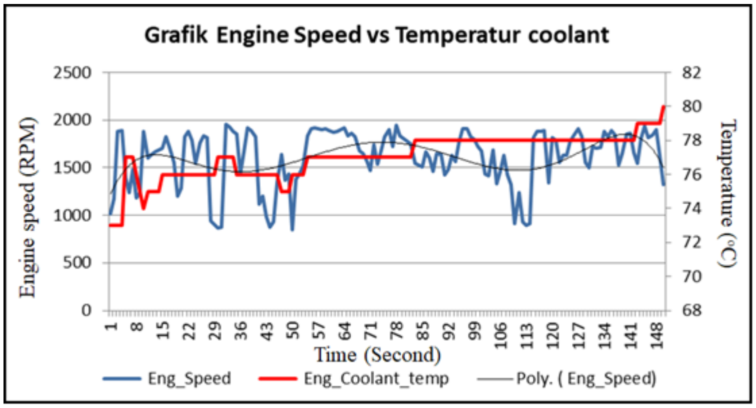


Figure 12. Graphs of coolant temperature and engine speed in every seconds after improvement

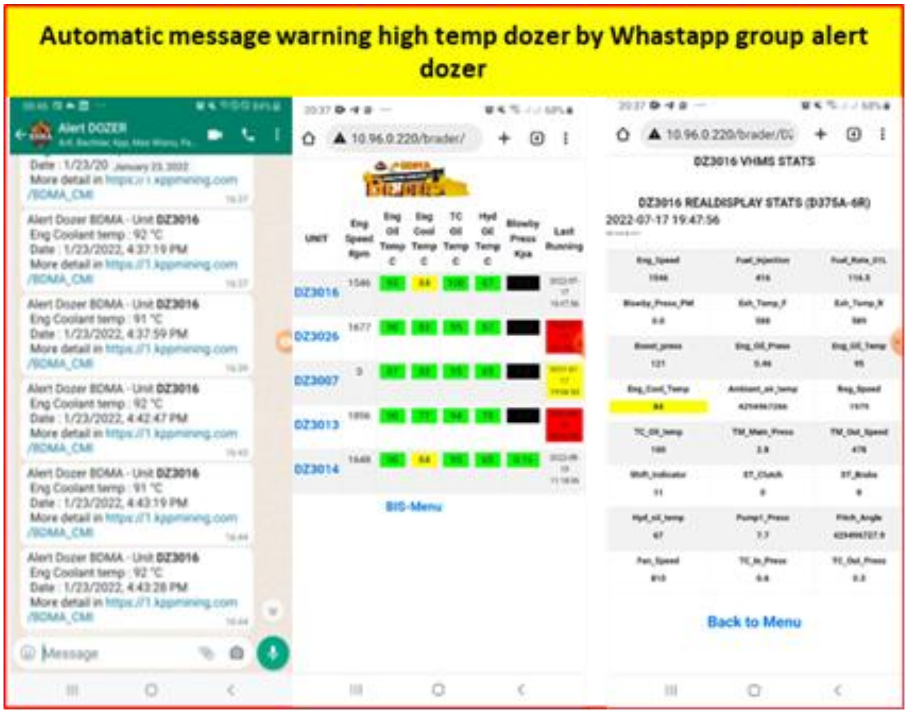
Real-time monitoring dashboard for proactive maintenance

Real-time monitoring dashboard enables proactive maintenance by detecting potential temperature issues. When the dashboard indicates an abnormal coolant temperature, the action team promptly collaborates with the operation team to stop the unit and perform an inspection, preventing overheating. Following this procedure helps eliminate overheating problems entirely.

An alert system was developed using raw real-time data to send notifications via WhatsApp when abnormal temperatures are detected. The system uses a red-colored indicator variable to trigger the alert message, as shown in Figure 13.

Verification data and result

Following the implementation of the real-time monitoring dashboard and automatic alert message system, a decline in the coolant temperature trend was observed, as depicted in Figure 14, with temperatures consistently staying below 90°C. Consequently, there were no instances of overheating, as shown in Figure 15. This improvement was achieved through focus group discussions and the Task Force Team, which tackled technical unit issues, enabling more precise and comprehensive problem-solving. Furthermore, the real-time monitoring dashboard proved effective in identifying potential unit issues.



Automatic message warning high temp dozer by Whastapp group alert dozer

Date : 1/23/20
More detail in https://1.kppmining.com/BDMA_CMI

Alert Dozer BDMA - Unit **DZ3016**
Eng Coolant temp : 92 °C
Date : 1/23/2022, 4:37:19 PM
More detail in https://1.kppmining.com/BDMA_CMI

Alert Dozer BDMA - Unit **DZ3016**
Eng Coolant temp : 91 °C
Date : 1/23/2022, 4:37:59 PM
More detail in https://1.kppmining.com/BDMA_CMI

Alert Dozer BDMA - Unit **DZ3016**
Eng Coolant temp : 92 °C
Date : 1/23/2022, 4:42:47 PM
More detail in https://1.kppmining.com/BDMA_CMI

Alert Dozer BDMA - Unit **DZ3016**
Eng Coolant temp : 91 °C
Date : 1/23/2022, 4:43:19 PM
More detail in https://1.kppmining.com/BDMA_CMI

Alert Dozer BDMA - Unit **DZ3016**
Eng Coolant temp : 92 °C
Date : 1/23/2022, 4:43:28 PM
More detail in https://1.kppmining.com/BDMA_CMI

DZ3016 VHMS STATS

DZ3016 REALDISPLAY STATS (D375A-6R)
2022-07-17 19:47:56

Figure 13. Panel of alert system and link to the dashboard

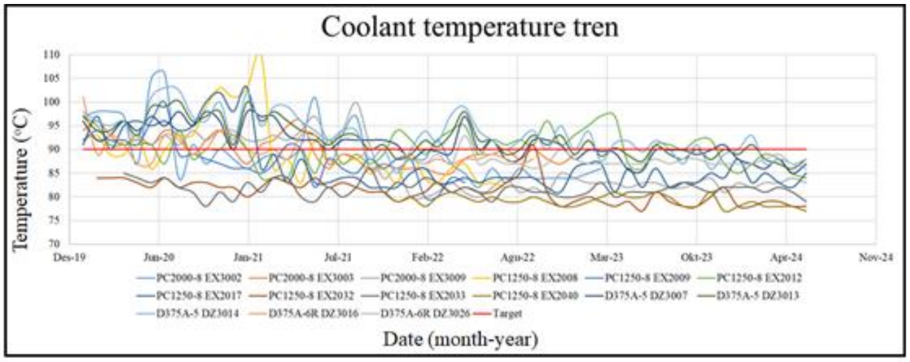
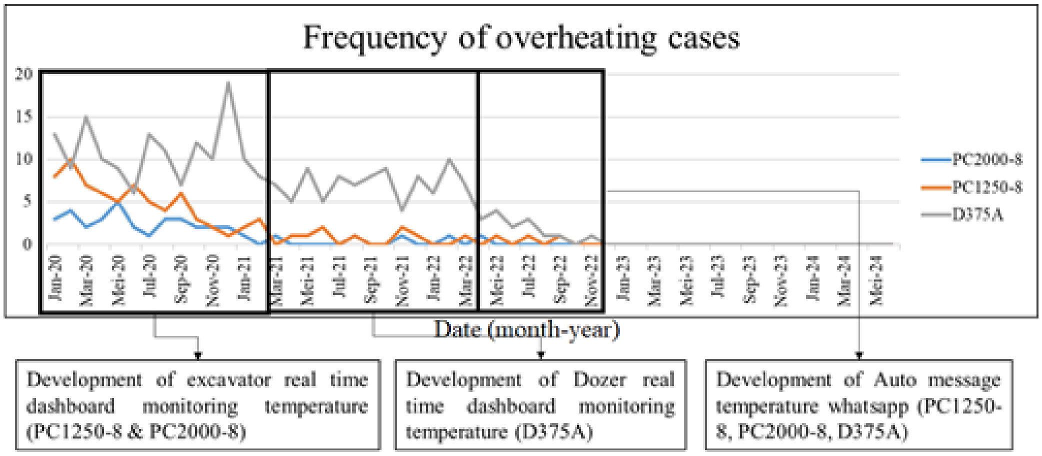


Figure 14. Coolant temperature after the improvement

Figure 16 illustrates a significant decline in unscheduled component breakdowns caused by temperature issues. In 2019, these breakdowns constituted 25% of the total planned overhaul components. However, during the improvement process in 2020, 2021, and 2022, this percentage dropped to 13%, 11%, and 4%, respectively. By 2023 and 2024, no component damage due to temperature issues was recorded.



Development of excavator real time dashboard monitoring temperature (PC1250-8 & PC2000-8)

Development of Dozer real time dashboard monitoring temperature (D375A)

Development of Auto message temperature whatsapp (PC1250-8, PC2000-8, D375A)

Figure 15. Trend of overheat problems and time frame of the improvement

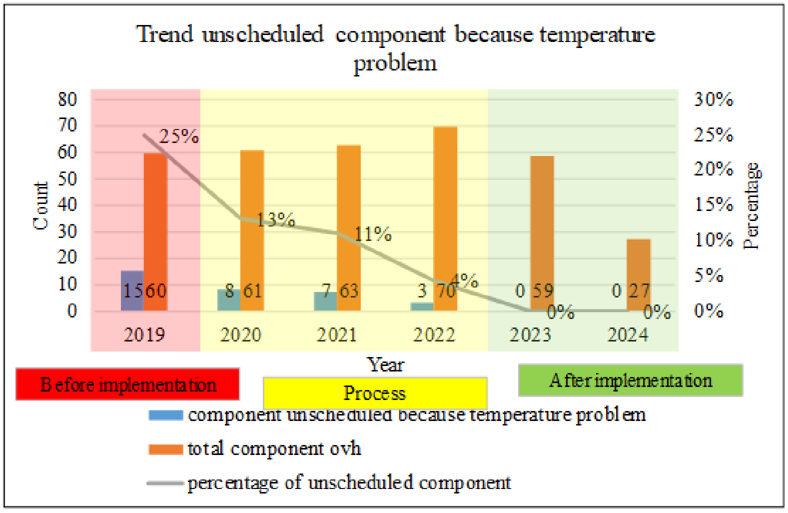


Figure 16. Trend of unscheduled component breakdown because temperature problem before and after the improvement

CONCLUSIONS

The implementation of real-time temperature monitoring dashboards has been highly effective in preventing unscheduled component failures caused by high temperatures. The percentage of component breakdowns decreased from 25% in 2019 to 0% in 2023 and 2024. Lowering the coolant and oil temperature limits has proven to be a key factor in enhancing component reliability. The updated temperature limits are as follows:

- Maximum coolant temperature = 90°C
- Maximum engine oil temperature = 100°C
- Maximum hydraulic oil temperature = 80°C
- Maximum PTO oil temperature = 100°C
- Maximum transmission oil temperature = 115°C

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