Design Clutch Wear Monitoring to Provide the Right Time to Change the Clutch and Prevent Unscheduled Breakdown on Heavy Duty Trucks

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***Abstract*—Heavy-duty trucks are a long-term investment capital in the field of heavy equipment. There are still many trucks that experience breakdowns. The most common damage is clutch damage. This research using experimental methods to designs a clutch wear monitoring tool that can send real-time notifications (using the internet of things). This device uses an ultrasonic sensor to detect clutch wear and combines it with the SIM800L GSM Module as a data sender. Vehicle owners or foreman mechanics can monitor via the Blynk application. This notification is in the form of a clutch condition still in a clutch normal, clutch warning and clutch limit.**

***Keywords*—heavy-duty trucks, clutch wear monitoring, ultrasonic sensor, Blynk, SIM800L.**

I. Introduction

The clutch is one of the components on the truck that connects and disconnects the engine speed to the transmission unit. Although very simple, the components that are part of this power train system have a very important role. Without a clutch, the transmission gear will not enter easily when the truck shifts gears [1]. Using manual transmission on trucks is still very popular, so operating techniques and periodic checks are needed.

Based on the investigation results, it was found that incorrect operation and delay in changing the clutch were the main factors for the breakdown of the clutch. In the current condition, checking the clutch wear is done manually through the clutch booster. The booster clutch is located under the unit and is often covered in dirt. This is often forgotten by mechanics or operators when doing daily checks.

Referring to the warranty rules and claims for damage to the unit, the clutch component is a component that cannot be insured [2]. In the event of a breakdown, the customer will receive financial losses in clutch component costs, clutch replacement services and loss of production time.

Developments in recent years have supported the integration of instrumentation into various equipment and have followed better tools to analyze equipment conditions. With a system like this, a maintenance officer will immediately be more capable and agile in determining the right time to carry out maintenance at various points of one or several types of equipment at once. Condition Based Maintenance would ideally support the maintenance personnel/team to do the right thing, reducing auto parts costs, downtime, and time wasted waiting for maintenance to arrive. Condition-based maintenance (CBM) is recognized as the most efficient strategy for performing maintenance in various industries [3].

Industrial networks are improving by emerging technologies such as wireless communication technologies, Internet of Things (IoT), cloud computing, big data, etc. [4]. IoT has become the development of wireless technology, Micro Electromechanical Systems, and the Internet. IoT is closely related to the term machine to machine in manufacturing and electricity, oil and gas.

Technology is continuously and rapidly changing industrial processes. Sometimes it is difficult for businesses to integrate new technologies into existing ones [5].

II. Methods

A. *Concept Design*

A clutch wear monitoring device will be applied on heavy-duty trucks. The ultrasonic sensor will measure distance rod indicator (located on servo booster clutch) and display the value to LCD (located on inside cabin) and mobile phone via Blynk application.

The hardware component designs into three assembly component devices are input device, processing device and output device [6]. There is component using for three assembly devices: Input devices (HC-SR04 ultrasonic), Processing devices (Adjustable timer, Arduino Mega, RTC Module, SD Card module and GSM module), and Output devices (LCD I2C, LED and Buzzer). The advantage of an ultrasonic sensor is suitable for detecting an object more than 1 meter, unaffected by direct sunlight or other light sources that can interfere with infrared devices, more accurate of capable placing objects within 5 mm and able to measure liquid and transparent objects [7].

This device design can 4 things:

1. Read the value of the distance of rod on servo clutch booster.
2. Sensor housing can protect from noise interference, so it does not affect the sensor's performance when taking measurements.
3. Display notification, LED lamp and buzzer when clutch measure distance following parameter:
    a. If the value distance is 23 – 38 mm the LCD displays the value, LCD displays clutch normal, LED bar green turn on, buzzer sound turns off and not send SMS push notification.
    b. If the value distance is 39 – 44 mm the LCD displays the value, LCD displays clutch warning, LED bar yellow turn on, buzzer sound turns off and not send SMS push notification.
    c. If the value distance is up to 39 mm the LCD displays the value, LCD displays clutch limit, LED red bar turn on, buzzer sound turns on and send SMS push notification.
4. Monitoring clutch condition via Blynk Application.

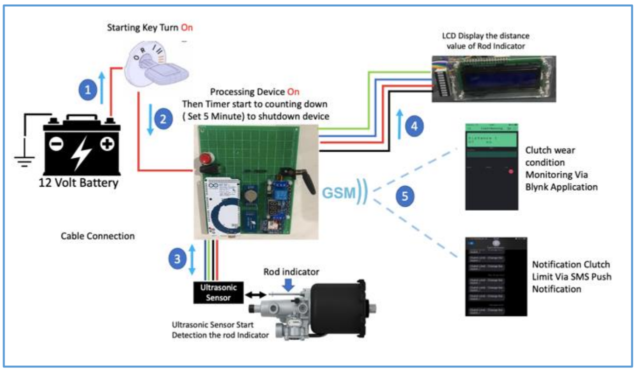

Fig. 1. Clutch wear monitoring

Referring to Fig. 1, this is an explanation of how this device works:

1) The 12-volt battery becomes the device's power source and is connected via a cable to the ignition of the truck unit.
2) The ignition is connected to the processing device via a cable. When the ignition is in the on position, the device turns on, and the timer turns on. The timer is set to count down for 5 minutes and then turn off the device.
3) When the device is on, the ultrasonic sensor gets a power supply through the cable and starts to calculate the distance of the indicator rod. as a safety measure and simplify the installation process in the servo clutch booster the sensor will be inserted into the plastic housing box. This plastic housing box is given a silicone seal to prevent water from entering and damaging the sensor.
4) The ultrasonic sensor measurement results will be sent back to the processing unit and displayed via the LCD display, which is connected via a cable. Housing LCD display equipped with color led bar graph and buzzer. This buzzer will sound when the clutch limit condition is detected.
5) The device transmits real-time distance measurement data via the GSM internet network. To be able to monitor wirelessly via mobile phone, the user must install the Blynk application. To get an SMS notification when a clutch limit occurs, the user must register a handphone number. This mobile number will be entered into the data sender coding of the GSM module component.

B. *Sensor Calibration*

Before experimenting, we must calibrate the ultrasonic sensor. To get this value, we perform data regression analysis on three clutch conditions and calculate the average value, standard deviation, percentage of precision and rate of accuracy.

$$Precision = \left[1 - \frac{\Delta x}{\overline{x}}\right] \text{X } 100\ \% \quad (1)$$

$$\Delta x = \sqrt{\frac{\sum_{i=0}^{n}(x\ x_i)^2}{n\ (n-1)}} \quad (2)$$

$$\overline{x} = \frac{1}{n}\sum_{i-1} x_i \quad (3)$$

$$Accuracy = \left(1 - \left|\frac{H-\overline{x}}{H}\right|\right) \text{X } 100\% \quad (4)$$

Δx = Standard deviation
$\overline{x}$ =Average actual value
H = Target value

Based on 40 experiments for each clutch condition, we get the value as shown as Table 1.

TABLE I
ANALYSIS REGRESSION LINIER

CLUTCH CONDITION	CLUTCH NORMAL	CLUTCH WARNING	CLUTCH LIMIT
TARGET VALUE	24 mm	39 mm	48 mm
AVERAGE ACTUAL VALUE	24.32 mm	39.32 mm	48.12 mm
STANDARD DEVIATION	0.47	0.53	0.33
PRECISION (%)	98.05%	98.66%	99.30%
ACCURACY (%)	98.68%	99.19%	99.75%

The calibration error on the HC-SR04 ultrasonic sensor data sheet is not listed, so further calculations are required. The calibration error is obtained from the calculation equation comparing the target value data with the average actual value. To get this equation using trendline chart in excel.

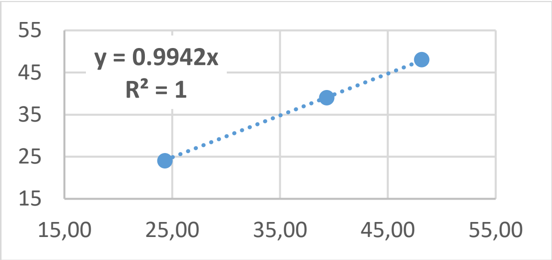

Fig. 2. Calibration error value

From the Fig. 2, we can get value for calibration error Y = 0.09942x and Regression (R^2) = 1. The next step, input the calibration error value to the Arduino sketch to calibrate the sensor.

III. Result and Discussion

The experimental procedure on this study described into four methods, there is:

1. The time it takes for the device to communicate with the internet.

Based on 20 experiment numbers on each location, we can get the average speed of a device from the time it is turned on until it connects to the Telkomsel GSM network. The result in the Jakarta area is 34.25 seconds and the Bekasi area 33.05 seconds. The difference in time between the two test locations is caused by choice of GSM provider, signal traffic density, and access hours. The average speed of access time is needed as the waiting time for the device to communicate with the Blynk application in monitoring clutch wear and sending SMS notifications to mobile (IoT) devices. In this case, further testing is needed in several locations and using various GSM providers operating in Indonesia.

2. Device accuracy for each clutch condition

The accuracy is showing in Table 2 of the device in three-parameter conditions between 99.49% - 99.80% with range inaccuracy (error) 0.20% – 0.50%. The precision value of a device is between 99.08% - 99.61%. The highest standard deviation value expresses as of statistical error is 0.36 mm. From this result, accurate device monitoring in any clutch condition percentage of an inaccuracy (systematic error) 0.50% and standard deviation (statistical error) 0.36 mm.

TABLE II
ACCURACY RESULT AFTER CALIBRATION

CLUTCH CONDITION	CLUTCH NORMAL	CLUTCH WARNING	CLUTCH LIMIT
TARGET VALUE	24 mm	39 mm	48 mm
AVERAGE ACTUAL VALUE	24.12 mm	39.15 mm	48.10 mm
STANDARD DEVIATION	0.33	0.36	0.30
PRECISION (%)	98.61%	99.08%	99.37%
ACCURACY (%)	99.49%	99.62%	99.80%

3. Device accuracy when interference with noise.

Table 3 is showing the accuracy sensor with noise interference. When the ultrasonic sensor is taking measurements, then the sensor will be interference with six audio frequencies (6 types):

a. Bass (B) range 69-250 Hz: experiment set to 250 Hz.
b. Lower Midrange (LM) range 250 -500 Hz: experiment set to 500 Hz.
c. Midrange (M) range 500Hz - 2 kHz: experiment set to 2 kHz.
d. Higher Midrange (HM) range 2 - 4 kHz: experiment set to 4 kHz.
e. Presence (P) range 4 – 6 kHz: experiment set to 6 kHz.
f. Briliance (Br) range 6-20 Khz: experiment set to 20 kHz.
g. Sound level set to 110 dB (simulation noise from engine/gearbox transmission).

TABLE III
ACCURACY WITH NOISE INTERFERECE

Clutch Condition	Clutch Normal	Clutch Warning	Clutch Limit
Target Value	24	39	48
Average	24.24	39.14	48.14
Standard dev	0.44	0.37	0.37
Precision	98.17	99.06	99.24
Accuracy	99.01	99.63	99.70

To get a correlation when the tool takes measurements without any interference when a disturbance occurs, a statistical t-test must be carried out. The t-test uses the two-sample paired method with the data analysis tool pack in Microsoft Excel.

TABLE IV
T-TEST COMPARATION WITH NOISE INTERFERENCE

	Before	After
Mean	37.08333333	37.15
Variance	99.87429379	98.46864407
Observations	60	60
Pearson Correlation	0.999022431	
Hypothesized Mean Difference	0	
Df	59	
t Stat	-1.157976291	
P(T<=t) one-tail	0.125769922	
t Critical one-tail	1.671093032	
P(T<=t) two-tail	0.251539844	
t Critical two-tail	2.000995378	

Referring to Table 4, the results obtained are t-stat (-1.157) < t critical two-tail (2.000) and P two-tail (0.25) > alpha (0.050). So, it can be concluded that noise interference does not affects device accuracy.

The statistical error (deviation) from the mean value before (37.083 mm) and after (37.15 mm) there was 0.067 mm. For further research, it is better to modify the sensor housing tightness. Modifications can be made by changing the type of sensor housing material, increasing the housing thickness, or adding sound insulation around the housing.

4. The function of the device is to monitor clutch condition and send SMS push notification functions work when clutch limit (IoT work Test) as shown in Table 5.

TABLE V
INTERNET OF THINGS (IOT) FUNCTION

Distance (mm)	Output Device (LED, LCD)	Output device (buzzer)	Blynk Monitoring	SMS Notif
24-38 mm		OFF		Not Send
39-44 mm		OFF		Not Send
> 45 mm		ON		

The device is functioning properly and following the design parameters of the program. The clutch wear monitoring process can be done through the LCD display or the Blynk application. Buzzer alarm notification and SMS push notification occur during clutch limit wear conditions. Based on these results, the answer to this research question is to design a device that can monitor clutch wear in various situations and send notifications when clutch wear reaches the limit. Further research can be added regarding the mileage counter sensor and operating hour counter on the truck. This sensor is one of the cornerstones in predicting the service life of the clutch disc, starting from a new clutch disc to replacing a clutch disc.

IV. CONCLUSION & RECOMMENDATION

A. *Conslusion*

Based on the results of data analysis from a series of experiments that have been carried out, the conclusions of this study are as follows:

1. The clutch wear monitoring device accurately measures various clutch wear conditions based on the length of the servo booster clutch rod indicator with a percentage of an inaccuracy (systematic error) of 0.50% and standard deviation (statistical error) of 0.36 mm.
2. The interference noise did not affect the device accuracy.
3. Clutch wears monitoring device functions well in monitoring clutch wear in various conditions. This device can also provide SMS and buzzer notifications when a clutch disc occurs in limit conditions. The internet of things (IoT) work system can be applied in measuring clutch wear on heavy-duty trucks to prevent unscheduled damage due to late clutch disc replacement.

B. *Recommendation*

Due to the limitations of test equipment, testing time and object of testing, many of these testing experiments are carried out through simulations so that several recommendations are needed for further research, including:

1. Do a test of this device in actual conditions to find out the durability of hardware components and the lifetime of this device.
2. For measuring accuracy improvement, using a linear variable differential transformer (LVDT) instead of ultrasonic is proposed.
3. The design of this device can be made more compact, and the use of hardware is simpler to reduce costs.

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