Reducing non-productive time of mud pump with acoustic emission monitoring techniques on fluid end parts

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Abstract. This research conducted for overcoming the high non-productive time (NPT) damage of fluid end part mud pump in the drilling of PT. Pertamina PDSI Drilling Rig # 42.2/N1500-E Well SWI-001 at Pali, South Sumatra, Indonesia. The purpose of this study is to provide a solution for detecting early worn out of fluid end part with the innovation of the electric audio module (EAM), which is suitable for conditions in the field. This EAM works using the method of detecting acoustic emission signals from piezoelectric sensors that arise due to the movement of the drilling fluid and fluid end part in the mud pump module body. Then the emitted pulse is forwarded to the EAM, and the results give through two outputs, namely the spectrogram graphic and the acoustic emission sound that enlarged through headphones. The results of this EAM innovation can reduce the NPT in PDSI Rig # 42.3/N1500-E from 34.5 hours to 0 hours, and monitoring can be done remotely up to more than 50 meters no longer on the spot. The application of EAM in drilling rig implies a modification in the maintenance of a mud pump from breakdown to predictive maintenance. It supports the safety aspect considering monitoring which can perform remotely.

Keywords: mud pump, non productive time, electric audio module, fluid end part, wash out, drilling.

1. Introduction
In a drilling rig, there are five operational compiler systems, namely circulatory system, rotating system, hoisting system, power system and blow out preventer system. In 2018, the highest NPT in PT. Pertamina Drilling caused by a high failure in the circulatory system, particularly on the fluid end part (valve disc and valve seating) of mud pump, as shown in Figure 1.

Figure 1. Fluid end part of mud pump
Like the heart in the human body, the mud pump serves to circulate the drilling fluid (mud) from the mud tank - drill pipes - bits - annulus drill holes - back again to mud tanks. The dirt coming out of the borehole carries the cutting of rock formations to condition its properties in the mud tank then circulated back into the borehole. So that if there is any wash out in the fluid end part of mud pump at a certain level, it causes operations to stop so that NPT occurs. The wash out of the fluid end part itself in the form of worn-out caused by the abrasiveness of solid particles cutting rock formations that enter the drilling mud.

The washout in fluid end part which is detected too late will expand until making the house of liquid end part, which called the module worn-out also. If it happens, it will take at least about 10 hours of replacement. The problem arises because the monitoring in the rigs only relies on manual visual leakage through the tale-tell hole as shown in Figure 2 and on the audiometric hearing of personnel for abnormal sounds via steel stick attached to the mud pump module body makes it less accurate. While the fluid end part itself is in the module’s house of a mud pump, then it draws the difficulty to know visual when the worn-out happen gradually. On the other side, the monitoring carried out on the spot near the mud pump, which has high pressure up to 4000 psi and high noise of more than 90 dB. This research aims to create a fluid end part monitoring’s tool that can discover early the worn out and can be manoeuvred at a safe distance more than 50 meters out from the potential danger of high pressure and high interference. This research is significant because it aims to produce a monitoring tool that can meet the needs of two vital aspects, namely the operational aspect and safety aspect. The functional element is related to the early detection of the worn-out to suppress NPT and also the safety aspect to reduce exposure to personnel working hours in the mud pump area while monitoring the work of the mud pump.

**Figure 2.** Module of mud pump. a) Mud pump unit, b) Tell-tale hole on the module

The fluid end part is the section of the mud pump that is most subject to wash out [1]. The washout of the liquid end part is difficult to identify early because the position of the fluid end part is in a mud pump’s house called a module so that it is visually invisible [2]. One method used to detect wear on the fluid end part is to use the acoustic emission technique (AE). The first acoustic emission technique was developed in the 1950s in a variety of applications [1]. AE is a technique that captures transient elastic waves generated by the rapid discharge of energy from a particular energy source [3]. Vishal at al.[4] uses AE techniques to study the behaviour of coal. The mud pump that is currently operating has a varied AE source. At present, fault diagnosis technology based on AE signals is applied to observe damage to rotating machinery such as in diesel engines and piston compressors that work similarly to reciprocating type mud pumps [5]. Shoucheng Deng at al. [1] has researched to detect the wear of fluid end part using the AE technique. They use piezoelectric sensors which placed on each bonnet valve of the mud pump module. The acoustic emission that appears is captured by the sensor and sent to the preamplifier to strengthen the signal and sent to the SAEU2S AE acquisition box. The monitoring output is in the form of an
amplitude chart that fluctuates in various ways and is then analysed [1]. Fluid end part in mud pump must be replaced before any washout occurred widely. Replacement must be considered more often the replacement happened, the higher to the cost incurred [6]. So replacement fluid end part early is cheaper than wait until washout happens on the module’s mud pump.

Based on some of the literature above, we did several tests on the drilling rig site to create a tool that can detect wear of fluid end part (valve disc and valve seating). The experiment is safe to operate and is easy to determine the level of damage when detected. We have three alternative solutions to identify such wear. First, use a health stethoscope with an extended hose. Second, employ a mini microphone. Third, using piezoelectric sensors. At the conclusion of the experiment, we selected a third alternative solution as a result. We completed the test with several features that incorporated into a monitoring tool which we named it as electric audio module (EAM). EAM was developed based on the principle of acoustic emission (AE). EAM can be used to monitor the development of the level of wear of the fluid end part early and safely. In one mud pump, piezoelectric sensors are installed in each bonnet valve module. Piezoelectric will detect fluctuations from acoustic emissions that come out due to the drilling mud and fluid end part in the mud pump module, which then generates acoustic emission pulses in the piezoelectric and flows through the cable to the EAM. At EAM, the electrical pulses are converted again into two outputs. First, the linear programming output read on a laptop with the help of sonic visualizer free software. Second, in the sort of acoustic emission sounds that can be adjusted in volume and heard in headphones. Manual hearing on headphones is needed to ensure spectrogram reading.

2. **Materials and method**

![Flowchart for Implementing Tool Design](image)

**Figure 3.** Flowchart for implementing tool design
This research is carried out by finding the root cause of the problem first and then looking for the dominant root problem and determining the solution, then the answer is realized in the form of a tool for early detection of wear. The research flow is carried out according to the flow chart, as shown in Figure 3.

2.1 Dominant root cause

| No | Root Cause                                                                 | Scale (1 to 10) | RPN (SxOxD) | RPN Cum. | % RPN | % RPN Cum. |
|----|---------------------------------------------------------------------------|----------------|-------------|---------|-------|-----------|
| A  | Leak detection relies only on tell-tale hole and manual sound propagation via steel bars | 8 7 7                      | 392         | 392     | 71.53  | 71.53     |
| B  | Breakdown maintenance on the fluid end part of the mud pump               | 5 4 4                      | 80          | 472     | 14.60  | 86.13     |
| C  | The work area is at high pressure (500–4000 Psi) and noise > 90dB          | 4 5 3                      | 60          | 532     | 10.95  | 97.08     |
| D  | Limited personnel for on-spot monitoring standby                           | 4 2 2                      | 16          | 548     | 2.92   | 100.00    |

There are five root causes of the problem based on the Fishbone diagram in Figure 4 above. But for the material, it is not related to the problem because the fluid end part of the mud pump is...
from the manufacturer's default. For this reason, the determination of the dominant causes of the four root causes of the problem is made using the Pareto diagram based on the comparison of severity (S), occurrence (O), and detection (D) scale as shown in Table 1 and Figure 5. From the Pareto diagram in Figure 5, the dominant root cause is problem number A.

2.2 Alternative solution

| No. | Alternative Solution | Parameter | A | B | C |
|-----|----------------------|-----------|---|---|---|
|     |                      | Medical stethoscope using an extended hose | OK/ NOT OK | OK | OK |
| 1   | Detection distance capability | < 1 meter | NOT OK | OK | < 300 meter |
| 2   | Sensitivity          | 20-20.000 Hz | NOT OK | NOT OK | OK |
| 3   | Safety               | Less (it is still in the ring of fire area) | NOT OK | NOT OK | OK |
| 4   | Maintenance          | Simple | OK | Simple | OK |
|     | Conclusion           | NOT SELECTED | NOT SELECTED | SELECTED |

There are three alternative solutions proposed to solve the dominant root cause of the problem mentioned above, first, using a stethoscope medical device with a lengthened hose to detect abnormal acoustic emissions by audiometry. Second, employ a mini microphone mounted on each mud pump module to identify strange acoustic emissions by audiometry with the volume
adjustment facility via a potentiometer. Third, it uses piezoelectric sensors that are installed in each mud pump module to detect abnormal sound with the reading output of a graphic and sound that can be heard through headphones. The following tabulation comparison between the three is shown in Table 2.

### 2.3 Engineering design

In general, the design consists of input, process and output. The data consists of acoustic emission fluid end part of the mud pump that is captured by piezoelectric sensors located on the bonnet module mud pump. The acoustic emission information is processed in the electric audio module and viewed in the form of reading output spectrogram graphics on laptop displays and sounds heard by personnel via headphones. The details are simplified in the flow process diagram display, as shown in Figure 6.

![Figure 6. EAM flow process diagram](image)

### 2.4 Material

The electronic components making up EAM are Piezoelectric sensor, RCA cable, Pre-amplifier, Power supply, Driver amplifier, Loud speaker, Jack audio 6.5 mm, Jack audio 3.5 mm and Interface cable DB25.

### 3. Results and discussion

#### 3.1 Innovation results

| No. | Before Innovation                                      | After Innovation                                      |
|-----|--------------------------------------------------------|-------------------------------------------------------|
| 1.  | 34.5 hours NPT Rig at well SWI-001                    | 0 hour NPT Rig at well AMJ-002                        |
| 2.  | Monitoring is carried out on the spot about 1 meter from the mud pump. It does not meet safety requirements. | Monitoring is carried out at a distance of more than 50 meters. It meets safety requirements. |
| 3.  | Monitoring is carried out in high noise areas, more than 90 dB due to exposure to the roar of the engine/electric motor of mud pump’s blower | Monitoring is carried out in the ordinary noise area in the office room maintenance function (less than 85 dB) |
| 4.  | Breakdown maintenance on mud pump modules             | Predictive maintenance on modules                     |
The conditions of monitoring the mud pump before and after innovation are shown in Table 3. Before the innovation of monitoring the mud pump as shown in Figure 7 below that there are six times (blue bar graph) of the damage occurred to the fluid end part (valve disc and valve seating) also causes damage to the mud pump module. It means that there are six time delays in knowing the worn out on the fluid end part, so the worn out can cause the extending washout to the part of the fluid end part house that is called as the mud pump module, of course, make NPT for the replacement of the module.

![Figure 7](image7.png)

**Figure 7.** Fluid end part replacement, Cum.NPT, and NPT trending SWI-001 Well before innovation in May-Oct.2018

After the innovation, as shown in Figure 8, there is no damage to the fluid end part (valve disc and valve seating), which causes damage to the mud pump module. It means that wear on the fluid end part can be detected earlier so that the drilling operational can be immediately carried out to make an immediate replacement of the fluid end part so that no washout does not extend to the module.

![Figure 8](image8.png)

**Figure 8.** Fluid end part replacement, NPT, NPT trending for AMJ-002 Well after innovation in July-Sept.2019
3.1.1 **Spectrogram for fluid end part in good condition**

*Figure 9* is a display of fluid end part spectrogram monitoring in brand new condition. There are five graph lines/bands of frequencies are displayed with red colour on linear spectrogram laptop displaying for the perfect condition of the fluid end part. It is recognized by observing the visual aspect of strong red lines at certain time intervals, where it records the collision contact between the valve discs (the position at the cover). It goes down perfectly pounding the entire head of the valve seating surface (the position at the backside) to make sounds with high notes (can be heard via headphones).

![Spectrogram for fluid end part in good condition](image)

*Figure 7. Spectrogram for fluid end part in good condition*

The presence of five frequency lines, marks the second. The graphic display arises because of the high pitch acoustic emission produced by the metal to the metal collision of the valve disc with valve seating as well as the movement of drilling mud or Fluid end part in the mud pump module. The sound produced by the headphone output in the form of high notes such as the clinking of metal to metal collision from valve disc meets with valve seating.

3.1.2 **Spectrogram for fluid end part in worn out condition**

*Figure 10* is a spectrogram display of monitoring fluid end part (valve disc and valve seating) in severe worn out conditions. There are two graph lines of frequencies are displayed with red colour on linear spectrogram laptop displaying for worn out condition of fluid end part. This is known by marking the appearance of no firm red colour on the spectrogram screen. But what appears in the form of a green line of shadows at certain intervals of time. This shows the imperfect collision contact between the valve disc (position at the top) that moves down hits the top of the valve seating surface (position at the bottom) but is not perfect because there is a worn-out valve disc-valve seating section. And this produces sounds with a low tone (can be heard via headphones). The second by marking a decrease in the number of frequency lines, in the example in Figure 10, there are only two frequency lines.
Figure 8. Spectrogram for fluid end part in worn out condition

Because only a few parts of the valve disc surface are mashing part of the surface of the valve seating. This means that both of the valve disc and valve seating parts are worn and are passed by drill fluid. More level of worn out, the red line disappears and the number of spectrogram frequency lines also decreases. And on the headphones if the wash out are getting widely, it produces a hissing sound due to more and more drill mud that is leaking.

3.2 Comparison of results
Shoucheng Deng et al. in 2017 researched to detect wear of Fluid End Part using the Acoustic Rural Emission (AE) technique [1]. Some differences that exist with the results of this innovation include analyzing the amplitude graph, and we analyze the spectrogram graph. They rely on reading the amplitude fluctuation graphs. In contrast, we rely on reading spectrogram graphics and acoustic emission sound. It is amplified by a potentiometer and heard via headphones. They can "calibrate between the visual readings of the spectrogram graphics with the audiometry of headphones".

4. Conclusions
The results of this study can be concluded as follows:

- The Electric audio module (EAM) is proven effective in reducing the non-productive time (NPT) of mud pump fluid end part module on the PDSI Rig # 42.3/N1500-E well AMJ-002 in West Java Indramayu to zero NPT. It can reduce the NPT from 34.5 hours to 0 hours.
- The EAM changed the paradigm of the fluid end part of mud pump maintenance from breakdown maintenance to predictive maintenance.
- The EAM's output is in the form of a spectrogram and sound fluctuation graph display can be adjusted in volume level from the acoustic emission that appears in the mud pump module.
- Monitoring by EAM can be done at a distance more than 50 meters from mud pump, so it complies with the safety aspect, safe from the danger of high pressure and high noise.
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