240 (2024) 213039

Contents lists available at ScienceDirect

Geoenergy Science and Engineering

journal homepage: www.sciencedirect.com/journal/geoenergy-science-and-engineering

ESP vibration prediction based on pump operating conditions in laboratory using machine learning

Thuy Chu [a,*], Tan C. Nguyen [a], Hyunsang Yoo [a], Jihoon Wang [b]

[a] New Mexico Tech, USA
[b] Hanyang University, South Korea

ARTICLE INFO

Keywords:
Electrical submersible pump
Modeling
Vibration
Machine learning

ABSTRACT

Electric Submersible Pump (ESP) is an effective artificial lift method of pumping medium to high production fluids. However, it is prone to failure because most of the system is located downhole. When mechanical defects start to develop, vibration signal changes. By examining the variation in vibration, component failures can be located and predicted. The objective of this study is to creates a machine learning model to predict ESP vibration using experimental data. The dataset that was utilized to create the model has more than a million data points collected from laboratory. Based on pump performance, the experimental data are divided into three groups: normal, advised and failing pump conditions. The model features are operating time, pump speed, oil flow rate, water flow rate, pump intake pressure, motor temperature, free gas percentage and liquid/mixture density and viscosity. Among the algorithms used to develop the model, random forests regression produces results with acceptable accuracy while not requiring too much computing power. Because of that, random forests regression was used for further optimization and simulation. The results of the model show that pump speed and operating time have the biggest effects of all the features. Due to the limited range of experimental data, in some cases, it is either unknown or unclear how the features affect ESP vibration, particularly in advised and failing pump conditions. The model's vibration predictions closely match the results of the experiments. This model can be used to forecast pump vibration under a particular operating condition by incorporating into the ESPSim program. The predicted vibration magnitude can be compared to the actual value to determine whether an ESP is in failing condition. With this information, the amount of downtime when the pump fails could be minimized. The extreme downhole conditions can also cause sensor cables to break and become incapable of transmitting data to the surface. Operators can use predicted ESP vibration to get an idea of the status of the pump.

1. Introduction and literature review

Electric Submersible Pump (ESP) is an artificial lift method to pump fluids that involves a downhole multistage centrifugal pump. An ESP system has surface and subsurface equipment as shown in Fig. 1. Because the main ESP components are installed inside the wellbore, it is susceptible to faults and defects. Mubarak et al. (2003) study shows that motors and pumps commonly fail (Fig. 2). Vibration Analysis (VA) is a reliable maintenance method to determine faults early. It helps prevent premature failure due to undetected problems. The magnitude of vibration generated by a machine could more or less represent its health. An unexpected increase in vibration magnitude could indicate a mechanical failure. In addition, excessive vibration could lead to failure early on. Regres et al. (2021) stated that vibration is the most common cause of failure in ESP systems. Unexpected failures could cause a significant loss in production rate and eventually require time-consuming intervention or installation of a new pump. Hence, it is important to monitor ESP vibration.

A model to predict ESP vibration has been developed based on ESP operating conditions obtained from experiments described by Chu et al., 2024b. Random forest regression technique was used in Python language to develop the model to achieve accurate results without demanding too much computing power. The predicted vibration magnitude can be compared to the actual value to determine whether an ESP is in failing condition. This information could be useful to minimize downtime when the pump is down. In addition, because of severe downhole conditions, there are cases where sensor cables are damaged and unable to transmit data to the surface. The predicted vibration from

* Corresponding author.
E-mail address: thuy.chu@student.nmt.edu (T. Chu).

https://doi.org/10.1016/j.geoen.2024.213039
Received 19 November 2023; Received in revised form 8 June 2024; Accepted 8 June 2024
Available online 10 June 2024