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Diagnosis of electrical submersible pump failure using deep learning model with sand-water flow experimental data

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ABSTRACT

Reliability of electrical submersible pump (ESP) failure diagnosis is crucial because unexpected failures can lead to additional production costs. This study presents a deep-learning method based on a long short-term memory autoencoder (LSTM-AE) model with principal component analysis (PCA) for ESP failure diagnosis. To obtain data on variables related to ESP failure, a sand–water flow experiment was designed and conducted. An LSTM-AE model was then developed based on the PCA of the experimental data, demonstrating a failure diagnosis accuracy of 90.69%, which is higher than that of the LSTM-AE model without PCA. The failure-detection point was predicted, closely aligning with the initial point of failure. To assess its suitability for field applications, the proposed LSTM-AE model with PCA was tested with data from the Sandy 03 well in the Permian Basin, USA. The LSTM-AE model with PCA achieved a failure diagnosis accuracy of 81.81%, and the initial failure detection point was accurate. These results indicate that the LSTM-AE model with PCA can effectively capture long-term dependencies in time-series data and provide reliable ESP failure diagnosis. By accurately identifying potential failures, this approach offers significant potential for improving operational efficiency and reducing maintenance costs in ESP systems.

1. Introduction

An artificial lift (AL) method is required when a reservoir does not have sufficient energy to naturally produce oil and gas at the desired rate (Bates et al., 2004; Kolawole et al., 2019). Nearly half of the world's 2 million oil wells are supported by AL methods, illustrating the widespread use of this technology (Lea, 2007). According to Mordor Intelligence (2020), recent market research indicates that the number of AL systems will expand at a compound annual growth rate of around 4.5% between 2022 and 2027. The Asia–Pacific region is among the fastest-growing AL markets, while North America led the global AL system market in 2021 (Intelligence, 2020). As shown in Fig. 1, North America is likely to dominate the market due to its many mature reservoirs and increasing energy demands.

Electrical submersible pumps (ESPs) are one of the most common AL methods because they are efficient and can reliably shift large fluid volumes (Fakher et al., 2021; Pineda et al., 2023; Verde et al., 2024). More than 60.0% of the world's oil is produced using ESP systems (Nguyen, 2020a), and over 90.0% of offshore wells use ESPs to pump oil and water to the surface. ESPs are also used in various other fields, including agriculture and geothermal energy (Bogdevičius et al., 2018; Mottaleb, 2018; Yu et al., 2019).

Although ESPs are generally reliable, their failure can occur for many reasons, including high gas volumes, solid production, high temperatures, and a corrosive environment, and this failure can occur without precursors (Gupta et al., 2016a; Wei et al., 2024). In particular, sand production resulting from the loss of pressure during fluid production weakens rock strength and erodes ESP components, making it the primary cause of ESP failure (Boudi, 2016; Zhu et al., 2021). Significant losses can accrue following unexpected ESP failure because finding a replacement ESP can take time (Gupta et al., 2016b). Previous research has shown that the cost of lost production can be up to $3 million, while the cost of intervention can be up to $1 million per well per year

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