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Machine Learning Approach Based on Smart Ball COMSOL Multiphysics Simulation for Pipe Leak Detection

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Abstract
Due to the changing flow conditions during the pipeline's operation, several locations of erosion, damage, and failure occur. Leak prevention and early leak detection techniques are the best pipeline risk mitigation measures. To reduce detection time, pipeline models that can simulate these breaches are essential. In this study, numerical modeling using COMSOL Multiphysics is suggested for different fluid types, velocities, pressure distributions, and temperature distributions. The system consists of 12 meters of 8-inch pipe. A movable ball with a diameter of 5 inches is placed within. The findings show that dead zones happen more often in oil than in gas. Pipe insulation is facilitated by the gas phase's thermal inefficiency (thermal conductivity). The fluid mixing is improved by 2.5 m/s when the temperature is the lowest. More than water and gas, oil viscosity and dead zones lower maximum pressure. Pressure decreases with maximum velocity and vice versa. The acquired oil data set is utilized to calibrate the Support Vector Machine and Decision Tree techniques using MATLAB R2021a, ensuring the precision of the measurement. The classification result reveals that the Support Vector Machine (SVM) and Decision Tree (DT) models have the best average accuracy, which is 98.8%, and 99.87 %, respectively.

KEYWORDS: Leakage Detection, Fluid Flow, Heat Transfer, Pipeline Monitoring, SVM, DT, Computational Fluid Dynamics.

I. Introduction

According to the Worldwide World Energy Report in 2020, natural gas and fossil fuels accounted for 30% of the global demand for energy production[1]. Fuel delivery, including fuel supply through fluid pipes, is essential to energy provision [2]. Applied stress, environmental factors, and noise levels are among the many challenges that pipelines encounter, with mechanical systems deteriorating to various extents [3]. Certain factors in the leakage phenomenon are challenging to measure in actuality. Some researchers have recently embraced computational fluid dynamics as a technique to aid in this process. Many industrial operations involve the simultaneous flow of two immiscible liquids in vertical pipes, one of which is the petroleum industry [4]. Because of the importance of the topic, many authors have focused their attention on the study of methods that could be used to identify leaks in pipelines that are used for the production and transit of oil [5]–[7]. At the current time, many different techniques for detecting leaks, including those based on harmful pressure waves, acoustic sensors, satellite surveillance, mass and volume balance, and analytical model-based procedures, have been put into practice. These methods depend on many aspects of the process, such as the temperature, pressure, mass and volumetric flow rates, and so on [8].

According to Dong et al. [9], the most beneficial of these technologies is the negative pressure strategy since it offers great leak sensitivity and availability. Unfortunately, this method has a high likelihood of creating a false alert if the pressure measurement records indicate significant changes or if the leak is tiny (0.5% of nominal flow) [10]. As a result, it needs to investigate using numerical methods into the hydrodynamics of heavy oil-water flow in a vertical pipe with a slight leak, which is much more challenging to detect using conventional methods [11]. Pipelines that are utilized in real-time operations are frequently situated in extreme environments, such as those found in the sea, where they have been subjected to the pressure that is exerted by the water; in the middle of the desert; or even underground, where they are subjected to the force that is exerted by the