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Moveable Inspection Ball Simulation for Pipe Leakage Detection using an Acoustic Sensor

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***Abstract*— During the pipeline lifecycle, the impact of design, welding fractures, corrosion, and other issues cause pipeline leaks, leading to considerable economic losses and environmental pollution. Internal leak detection localization systems are sensitive to oil, gas, water, and multiproduct pipelines. Under steady circumstances, conventional leak detection methods are often employed to calculate the likelihood of a leak based on fluid flow variations at each inlet and outlet. Leaks occur when operational changes create transitory circumstances that cause local pressure and flow variations. An effective monitoring system must be in place and evaluated regularly for accurate leak detection, even under transitory settings. This paper discusses preliminary numerical modeling targeted at creating inspection techniques for pipe leakage detection utilizing the acoustic physics of a smart ball sensor and COMSOL Multiphysics 5.6. The simulation examines the effects of flow regime, leak location, ball placement, ball diameter, and leakage noise on the propagation of sound pressure levels inside the pipe and around the sphere. The simulated data is utilized to fine-tune the control strategy inside the mobility test ball. According to the research, water is more susceptible to sound energy than other fluids. The influence of oil on sound energy is larger. The ball diameter affects the fluid's hydrodynamics, although the diameter is readily used for oscillation reflection.**

Keywords—fluid flow, leakage, smart ball, CFD, pipelines.

I. INTRODUCTION

Leakage is one of the most critical issues in a pipe system. Pipeline leaks occur in all businesses that use pipe systems, resulting in major losses for fluids delivery firms globally (water, gas, and oil). This happens when the pipe confronts various real-world issues, such as the pipe's life span expiring, pressure from above the surface, or the soil structure around the pipeline moving or changing [1]. The rapid rise in the world's population and industrial development has led to an increase in the consumption of fossil fuels such as petroleum and natural gas [2]. According to the Global World Energy Outlook [3,], energy production from natural gas and fossil fuels will account for 30% of global demand in 2020. Fuel transportation, such as natural gas pipe distribution, is a critical issue in energy supply [4]. Pipes are susceptible to a range of factors as a result of mechanical component failure, including yield stress, ambient conditions, and the presence of sound pressure [5]. Because pipeline failure produces enormous environmental pollution in addition to the hazard present, the various mechanical conditions must be handled [6]. Pipelines used in real-time operations are found in severe conditions such as the marine environment undersea pressure, remote desert locations, and underground, where soil stress pressures are applied. Another concern is the irregular operation of natural gas flow, which increases the probability of pipeline damage [7]. The most severe problem is the difficulty in detecting leaks due to physical corrosion and pipeline age [8]. The situation has worsened for an extended period of operation without any detection. The change in fluid flow pattern is a typical approach for detecting leakage [9], and leakage may produce a sudden shift in pressure in the free stream, creating flow distortion [10]. The vibration is consistent over the length of the pipe, but the leakage point exhibits non-uniform behavior [10][11]. Various factors can affect flow distortion, such as flow rate, leakage point location, ball position, ball diameter, and fluid type [12].

Academic scholars and industry have created several practical detection approaches. Among the earliest detection approaches are hearing systems, which employ differences in sound quality and loudness caused by leakage noise from the equipment as signals to identify leaks [12],[13]. This strategy is not only time-consuming and unreliable due to the enormity of water pipeline networks but also depends on the experience and competence of the detection personnel. Ground-penetrating radar may identify pipeline breaches by detecting soil holes caused by water leaking. This strategy is challenging to use and prohibitively expensive due to regional changes in geological structure [14],[15]. Researchers have developed similar leak detection techniques, such as the pressure gradient, negative pressure wave, and flow rate balancing approach [16]-[18]. Because water pipeline flow rates vary all the time, these methodologies, although relatively sensitive to flow rate and pressure, tend to provide false-positive results when the flow rate varies considerably. The frequency of pipeline vibration is linked with leaking status and is focused on the spectrum of leakage signals [19]. Watanabe [20] was a pioneer in the study of acoustic waves. He investigated the pipeline and discovered a strong positive and negative pulse