Early Detection of Hydrate-Induced Pipeline Blockage in Offshore Energy Systems Using LFM Acoustic Reflection Monitoring

Yang Meng, Yongchen Song, Lunxiang Zhang*

Key Laboratory of Ocean Energy Utilization and Energy Conservation of Ministry of Education, Dalian University of Technology, Dalian, China

Email address:

mmyy@mail.dlut.edu.cn (Yang Meng), songyc@dlut.edu.cn (Yongchen Song),
lunxiangzhang@dlut.edu.cn (Lunxiang Zhang)

*Corresponding author

Abstract

Hydrate formation is a major flow assurance challenge in subsea oil and gas transportation systems and can pose significant risks to the safety, efficiency, and environmental sustainability of offshore energy infrastructure. Accumulation of hydrate particles may gradually restrict pipeline flow, potentially leading to severe blockages, operational interruptions, and increased environmental hazards. Therefore, reliable monitoring technologies capable of detecting hydrate-induced blockage at an early stage are essential for maintaining the stable operation of marine energy transportation systems. This study proposes an acoustic monitoring approach for pipeline blockage detection based on linear frequency modulated (LFM) reflection signals combined with an adaptive matched filtering algorithm. The method utilizes the propagation and reflection characteristics of LFM acoustic signals in pipelines to identify abnormal structural changes caused by partial or severe blockages. By analyzing the reflected acoustic signatures, the proposed technique enables accurate detection and localization of blockage regions along the pipeline. A series of controlled laboratory experiments were performed on a pipeline test platform to investigate acoustic responses under simulated hydrate-like blockage conditions. The experimental results demonstrate that the proposed approach can effectively identify blockage boundaries and accurately determine blockage locations along the pipeline. Compared with conventional acoustic detection approaches, the proposed method provides significantly improved localization performance. The results indicate that LFM acoustic reflection monitoring provides a reliable and efficient tool for early blockage detection in subsea pipeline systems. This technique offers significant potential for real-time monitoring, risk assessment, and preventive maintenance of offshore energy transportation infrastructure, contributing to improved operational safety and enhanced environmental protection in marine energy development.

Keywords

Gas Hydrate, Pipeline Blockage, Acoustic Reflection, Linear Frequency Modulated Signals,
Offshore Energy Infrastructure, Flow Assurance, Subsea Pipelines