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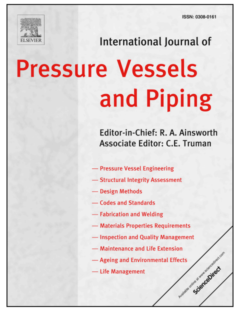

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Thermal Insulation of Subsea Pipelines for Different Materials

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ABSTRACT

Thermal insulation is widely used in offshore oil production for flow assurance design. Research efforts have concentrated on the thermal and mechanical properties of the insulation material, but few publications have focused on the optimization of the insulation. For certain subsea production systems, several optional insulation materials are available. The distribution of insulation along a subsea system to fulfill thermal requirements is not unique to each insulation material. Manually defined insulation designs often lead to a conservative approach that consumes more material than necessary. To find the most economical design, an optimization method combined with machine learning techniques is presented. A subsea production system using different insulation materials is assessed in the case study and optimization results are discussed. Four different insulation materials are used, and 2000 models are simulated for each material to prepare the training data for the machine learning algorithm. The trained algorithm is able to predict the minimum temperature of the system with an error smaller than 5.5%. Genetic algorithm and particle swarm optimization are used to find the most efficient insulation distribution for each material. The optimized costs related to each insulation material are then compared. The results show that the proposed method is capable of defining material and thickness variations throughout the subsea system with the aim of reducing costs.

Keywords**:** Subsea production system, insulation distribution, optimization, machine learning technique, genetic algorithm, particle swarm optimization.

NOMENCLATURE

PT Pressure and temperature

GA Genetic algorithm

PSO Particle swarm optimization

WAT Wax appearance temperature

PLET Pipeline end termination

LR Linear regression

R_i external diameter of the *i*th subsea pipeline

x_i insulation thickness of the *i*th subsea pipeline

L_i length of the *i*th subsea pipeline or flowline section

$T_{\min}$ minimum temperature of the subsea system

C_0 critical temperature level

m total number of pipeline sections

n total number of gathered data point

$X^{(j)}$ insulation thickness for the pipeline from *1* to *m* at the *j*th data point

$T_{\min}^{(j)}$ minimum temperature of the subsea system at the *j*th data point

ε errors and discrepancies

θ^T *m*th-dimension vector comprising