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Non-destructive methods for assessment of district heating pipes: a pre-study for selection of proper methods

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Abstract

Many energy companies are facing renewal of their district heating and cooling (DHC) network. However, there are no non-destructive methods to determine the performance of existing pre-insulated pipes during operation. A pre-study has led to a selection of a couple of non-destructive methods that will be further evaluated and tested in field and in laboratory. Two non-destructive methods, individually or in combination, are considered interesting for further studies. A cooling method and a method for evaluation of the temperature coefficient of resistance (TCR), which aims at using the existing copper wire in pre-insulated pipes.

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Keywords: District heating pipes; lifetime status; non-destructive methods; degradation; PUR, Cooling methods; TCR-method

1. Introduction

DHC-systems may consist of hundreds of kilometers of pipes which most likely are of different quality concerning carrier pipe, insulation, single and twin pipe. A system normally grows gradually and thereby the age and type of pipes consequently vary with time. DHC-networks have been used for decades and they expanded a lot in the 1960s in the US and Europe, the pipe types that have been used varies [1]. Pipes with for example polyurethane (PUR) insulation have been used for decades, especially in Sweden.

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Many energy companies need to renew their district heating (DH) networks. The Energy companies can measure what they produce in heat energy and what they deliver, so the heat losses for the whole network can be calculated. In Sweden, around 10% of the energy supplied to the district heating networks are lost through heat losses from the distribution pipes [2]. There is though no method to assess the status of the different parts of the piping network, in terms of local heat losses. Consequently, the desire to detect and monitor the location of potential hot spots (poor insulation) in DH networks is a significantly favourable issue for energy companies. It is favourable for many energy companies to estimate the remaining service life of pre insulated district heating pipes. The length of the pipe stretch that might need to be changed has to be long enough in order to make the excavation and change beneficial. Beneficial lengths for change depend on the thermal quality, but also on other factors like for example accessibility of the existing pipes; reasonable lengths are predicted to be in the kilometre scale. Today the time domain reflectometry method (TDR) is used for detection of moisture/water intrusion into the insulation part of the pipes. This method is well functioning for the purpose of finding suspected water leaks but not for thermal status identification of longer stretches. The European Standard EN 253:2009 states that pre insulated pipes should survive for at least 30 years at a constant operating temperature of 120˚C and new pipes should have a thermal conductivity coefficient at 50 °C (λ_{50}) ≤ 0,029 W/m·K) [3].

1.1. Single pipe with PUR insulation

A common type of pipe in Swedish DH-systems consists of an inner pipe of steel and an outer casing of Polyethylene (PE). As it is illustrated in Figure 1, there is a PUR-insulation together with two thin 1.5 mm^2 copper wires between the inner pipe and outer casing, a typical pipe product that has been used during decades. The copper wires are used for moisture detection by using TDR-method. Aging and degradation of the PUR insulation takes place due to high temperatures in the inner steel pipe (carrier pipe) and intrusion of gasses through the PE-casing pipe. Thermal properties of pre-insulated pipes, which normally are filled with PUR, deteriorate during the real operation conditions. The degradation of PUR occurs due to diffusion of gas molecules between the foam and surrounding air. In this process oxygen and nitrogen molecules penetrate from air to the foam bubbles and replace the blowing agent gases, which are mainly cyclopentane and carbon dioxide [4].

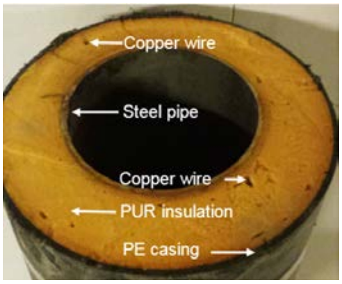

Figure 1. An old and naturally aged district heating pipe with a carrier pipe of steel, PUR foam insulation, copper wires and casing of PE.

Aging of the pipe insulation leads to higher heat losses. Temperature is the most significant factor that accelerates the aging process of insulation [5]. Therefore, when the PUR-insulation is exposed to high temperatures, thermal conductivity coefficient, λ, of insulation increases and subsequently greater heat flow (losses) is expected, based on Fourier's law (Eq.1).

$$q = -\lambda.\nabla T = -(\lambda.\frac{\partial T}{\partial x}, \lambda.\frac{\partial T}{\partial y}, \lambda.\frac{\partial T}{\partial z}) \ [\mathrm{W}\cdot m^{-2}] \quad (1)$$

Where:

q = Heat flow [$W \cdot m^{-2}$]

λ = Thermal conductivity [$W \cdot m^{-1} \cdot K^{-1}$]

∇T = Temperature difference [K]