NEW MATERIALS AND CONSTRUCTIONS FOR IMPROVING THE QUALITY AND LIFETIME OF DISTRICT HEATING PIPES

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ABSTRACT

Polyethylene terephthalate (PET) foam seems to have the potential to compete successfully with PUR foam as insulating foam for district heating pipes of small dimensions at low temperatures (<100˚C).

INTRODUCTION

New materials and constructions for district heating pipes must be very efficient from different points of view: Mechanical, thermal, environmental and economical. In this project the efficiency of PET foam as an insulating material has been studied and the results will be briefly described below.

MECHANICAL PERFORMANCE

The mechanical performance has been studied using the European standard EN 253:2003 as the reference. This standard is written with respect to polyurethane (PUR) foams for pre-insulated district heating pipes. The standard applies for continuous operation at 120 ˚C for 30 years. However, for pipes of small dimensions, outer diameter ≤120 mm, both temperatures and mechanical loads are lower.

Compressive strength

The short-term compressive strength decreases with increasing temperature with a drastic change at approximately 80ºC. This is due to the material's glass transition temperature. It can be seen that the compressive strength at high temperatures does not fulfil the requirements of 0.3 MPa for the PUR foam according to EN 253. It should be kept in mind, however, that this requirement is likely unnecessarily conservative for small pipes.

The short-term elastic modulus behaves in a similar fashion, with an obvious temperature dependence and a significant drop of stiffness around the glass transition temperature.

Water permeability and vapour resistance

The tested PET foams were impermeable to liquid water and only vapour diffused through the PET foam. The vapour resistance was approximately 10 times greater for the PET foam than for a regular PUR foam.

Water absorption

The water absorption for PET foam was found to be 7 %- vol. The requirement on PUR foam in EN 253 is a maximum of water absorption of 10 %. PUR foam usually absorbs around 5 %.

Glass transition temperature

The results verify that the PET foams turn softer at approximately 80 ºC, as could also be seen from the short-term compressive strength measurements. It is not possible to make a direct comparison with PUR. PUR is a thermoset material which does not undergo this kind of phase transition.

Creep behaviour

The creep properties of PET foam seem to be very good. Extrapolation of the creep curves to 30 years of technical service does not indicate any significant creep deformation, neither at room temperature nor at 80 ºC.

Flexibility – bending properties

Samples of PET taken parallel to the extrusion direction are much stiffer and much more brittle, while samples taken parallel to the cross direction are so flexible that no fracture was seen up to the testing limit of 12 % strain. The material can easily be processed to withstand bending strains to a sufficient degree for flexible district heating pipes.

The PUR foams behave in a little more brittle manner. The "flexible" PUR foam did not exhibit a significantly more flexible behaviour than the rigid PUR foam. A strain limit of approximately 11 % was seen for both materials. It is also interesting to note that the flexible foam is much stiffer than the rigid foam.

INSULATING PERFORMANCE

A newly produced PUR foam has a little lower thermal conductivity than a new PET foam (both foams were blown with cyclopentane and of the same density). The difference depends mainly upon smaller cells and a lower content of air in the cell gas of the PUR foam.

In microcellular PUR foams the cell size is around 0.1-0.2 mm and in the PET-foams studied the cell size varies between 0.6 to 1.0 mm. However, the PUR foam has been developed during more than 50 years but the PET foam during less than 10 years and can thus be expected to be further developed. In the future a new PET foam will probably exhibit the same thermal conductivity as a PUR foam.

The results from the determination of the diffusion properties gave a clear cut indication that the long term thermal performance of a PET foam is better then that of a PUR foam. The effective diffusion coefficients of oxygen, nitrogen and carbon dioxide in a PET foam are about 5-15 times lower than those in a PUR foam.

The long term thermal conductivity has been calculated for three different district heating pipes of the same dimensions (DN 40/125): 1. PUR foam insulation, 3.0 mm thick polyethylene casing, 2. PET foam insulation, 3.0 mm thick PET casing and 3. PET foam insulation without any casing. See Figures 1-3 and Table 1. In these calculations it was assumed that the PET foam had been further developed so that the cell sizes of the PET and PUR foam were the same. Due to the slow diffusion in the PET foam, the decrease of insulating capacity of the PET foam insulated pipe without casing is even less (about 6%) than that of the PUR insulated pipe with 3.0 mm HDPE casing (about 16%). The PET insulated pipe with 3.0 mm PET casing exhibits the slowest decrease (about 3%) of insulating capacity during 30 years among the three alternatives studied.

Table 1. The equivalent thermal conductivity and heat losses for PUR and PET insulated district heating pipes (DN40/125) over an operation period of 30 years.

Type of pipe		Equivalent over 30 years	
Insulation	Casing	Thermal conductivity of the foam $W \cdot m^{-1} \cdot K^{-1}$	Heat Flow $W \cdot m^{-1}$
PUR	HDPE 3mm	0.0294	13.3
PET	PET 3mm	0.0256	11.6
PET	no casing	0.0288	13.1

ENVIRONMENTAL PERFORMANCE

From the present study it can be concluded that PET foam has the potential to compete successfully in terms of environmental performance with cyclopentane blown PUR foam as insulating foam for district heating pipes. The possibility to produce cyclopentane blown PET foam of low density will increase the competitiveness of PET foam. Unfortunately this possibility did not exist at the time of the environmental study. Commercial methods to produce PET foam for the insulation of district heating pipes must be developed. Utilization of recycled PET can reduce the environmental impacts from the production phase of the pipes life cycle and would contribute to the efficient use of resources in society.

There is also a need to find alternatives to PUR foam, due to the toxicity of the isocyanates, one of the main components in PUR foam production. Another aspect is that welding close to PUR foam may give rise to high concentrations of hazardous compounds in the work environment.

ECONOMIC ASPECTS

The prices of PET and PUR foam have been about the same during the last years. The possibility of utilising recycled material in the production of PET foam will decrease material costs.

CONCLUSIONS

According to the present study PET foam seems to have the potential to compete successfully with cyclopentane blown PUR foam as insulating foam for district heating pipes of small dimensions at low temperatures (<100˚C).

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Dr. Morgan Fröling, Department of Chemical Environmental Science, Chalmers University of Technology, Sweden. is responsible for the environmental study.

Dr. Camilla Persson, Department of Building Technology, Chalmers University of Technology, Sweden, has performed the calculations necessary for Table 1 and Figures 1-3.

The PET foam was produced by B.C. FOAM s.p.a., Volpiano, Ttaly.

REFERENCES

The full report with all references will be published by IEA.

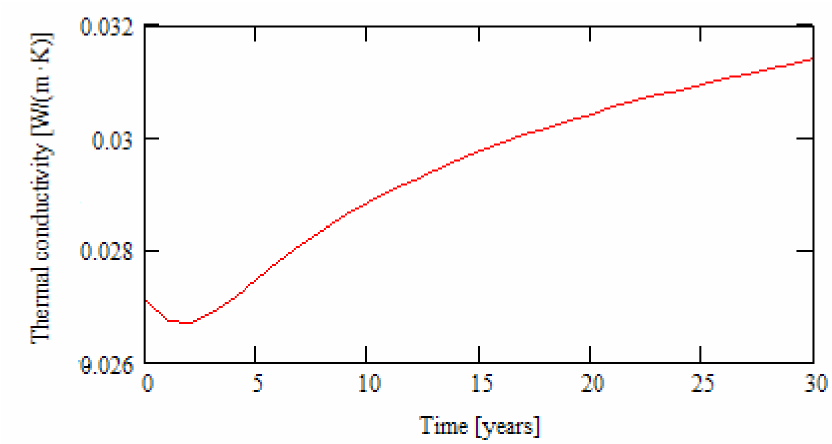

Figure 1. Thermal conductivity over time for a PUR insulated district heating pipe (DN40/125). Service pipe temperature 80 ˚C and casing temperature 15 ˚C. Casing material HDPE, thickness 3.0 mm.

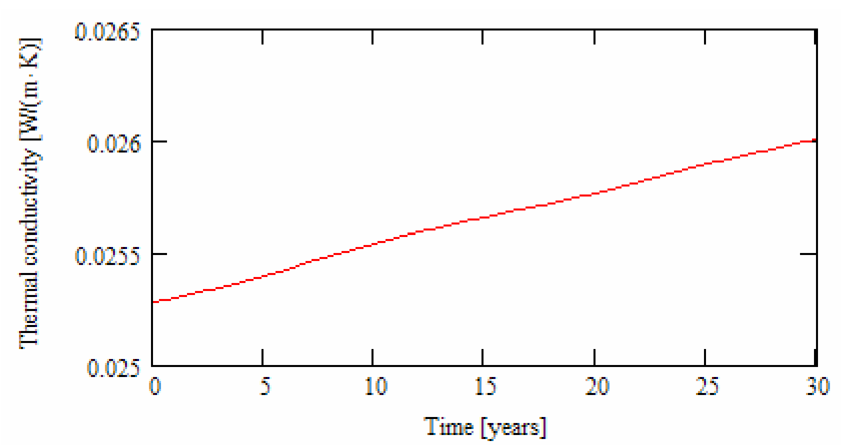

Figure 2. Thermal conductivity over time for a PET insulated district heating pipe (DN40/125). Service pipe temperature 80 ˚C and casing temperature 15 ˚C. Casing material PET, thickness 3.0 mm.

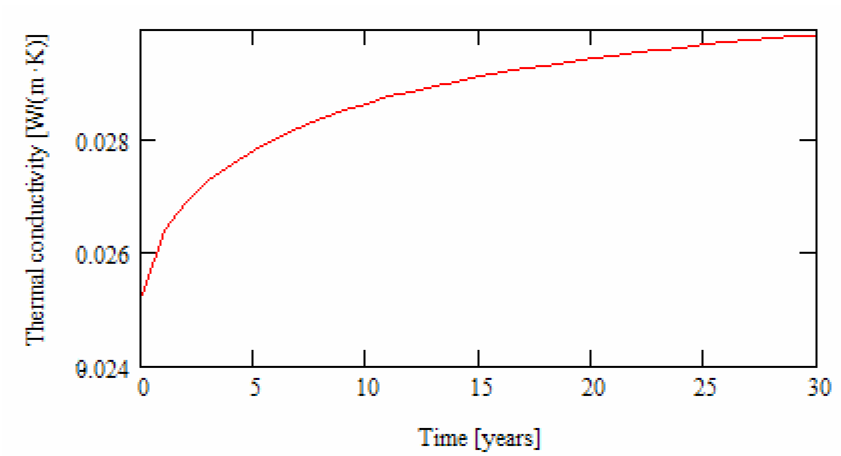

Figure 3. Thermal conductivity over time for a PET insulated district heating pipe (DN40/125). Service pipe temperature 80 ˚C and outer surface temperature 15 ˚C. No casing.