Field Joint Coatings for Deep Sea Pipelines

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Heerema Marine Contractors

Heerema Marine Contractors (HMC) is contracted to install pipelines in the sea. The metallic pipes, generally of carbon steel, need not only to be protected against corrosion, but also to be insulated to maintain the temperature of the pipe content and assure the flow. Therefore a thick multilayer polymer coating is applied.

The individual pipe sections (12 m) are coated with a factory-applied coating (FAC) along their full length. This coating is cut back at the ends before welding the pipes together during a J-lay or reel-lay installation. After welding, a field joint coating (FJC) is applied over the welded area. Ensuring optimal application conditions for the coating during an offshore installation is far from straightforward.

Pipe sections
Welded together

Surface cleaning
Grit blasting

FBE application
Corrosive protection

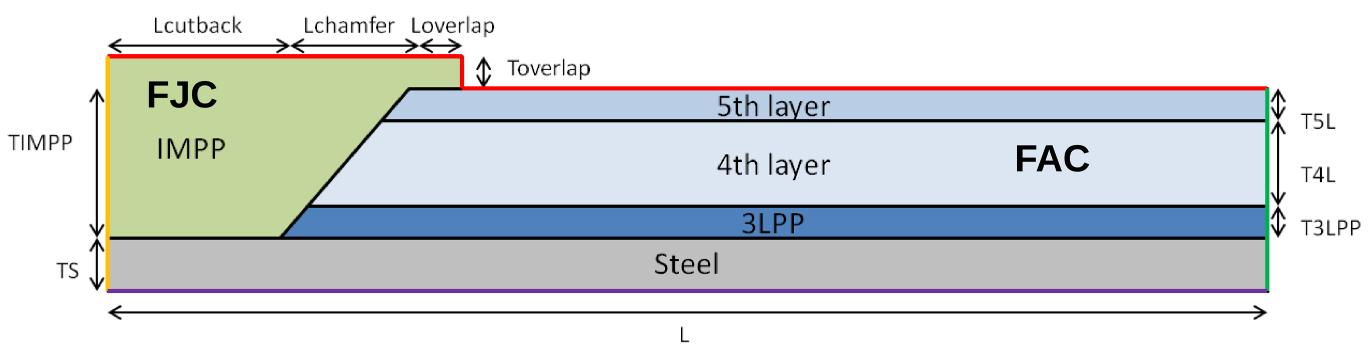
Injection moulding
Thermal insulation

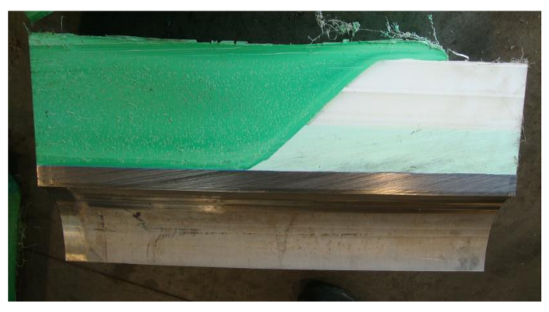
Field joint
Needs cooling

Objectives

In order to optimise the application process of the field joint coating, deep insight into the cure and crystallisation kinetics, together with a good comprehension of the heat transfer in the field joint is required. Experimental data on the raw materials, acquired by thermal analysis, were used to determine the crystallisation[1] and cure[2] kinetics model, which was subsequently implemented in a 2D axisymmetric finite element model.

Cross section model with dimensions (mm) and boundary conditions: symmetric, outflow, convective cooling h_1, convective cooling h_2





The cooling process of a field joint coating is simulated, computing the temperature and crystallinity profiles throughout the coating, as a function of time using crystallisation kinetics model obtained from experimental data. These result are then compared with industrial tests.

1. J.D. Hoffman, R.L. Miller, *Polymer* **1997**, *38*, 3151-3212
2. G. Van Assche, A. Van Hemelrijck, H. Rahier, B. Van Mele, *Thermochim. Acta* **1995**, *268*, 121-142

Computational Methods

A crystallization model[3] consisting of a set of ordinary differential equations (ODEs) was developed based on thermal analysis. Using domain ODEs the crystallization model was implemented in COMSOL Multiphysics and coupled with the heat transfer. The physically realistic values of relative crystallinity α are between 0 and 1 and this is ensured using a transformation function:

$$\alpha = \frac{erf(b)}{2} + \frac{1}{2}$$

$$\frac{dN}{dt} = -N\left(q(T) + \frac{1}{1-\alpha}\frac{d\alpha}{dt}\right) + (1-\alpha)\frac{dN_0(T)}{dT}\frac{dT}{dt}$$

$$\frac{dN_{at}}{dt} = \frac{q(T)N}{1-\alpha}$$

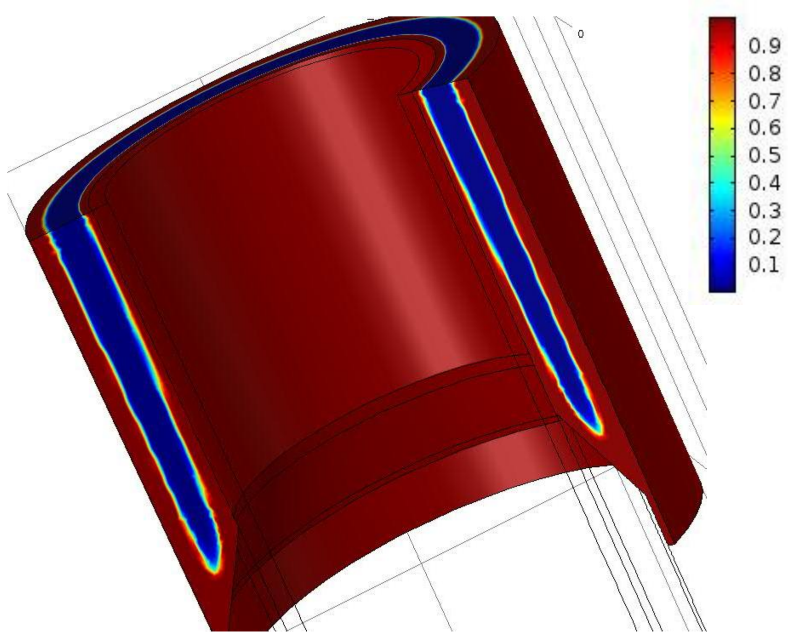
$$\frac{d\alpha}{dt} = 4\pi(1-\alpha)G\left(F^2 N_{at} - 2FP + Q\right)$$

$$\frac{dF}{dt} = G(T)$$

$$\frac{dP}{dt} = \frac{FNq(T)}{1-\alpha}$$

$$\frac{dQ}{dt} = \frac{F^2 Nq(T)}{1-\alpha}$$

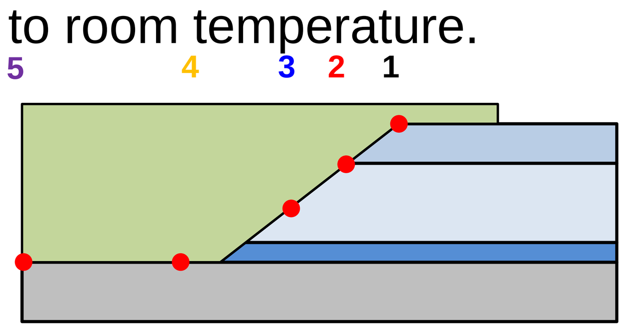
3. J.M. Haudin, J.M. Chenot, *Intern. Polym. Process* **2004**, *19*, 267-274 & 275-286



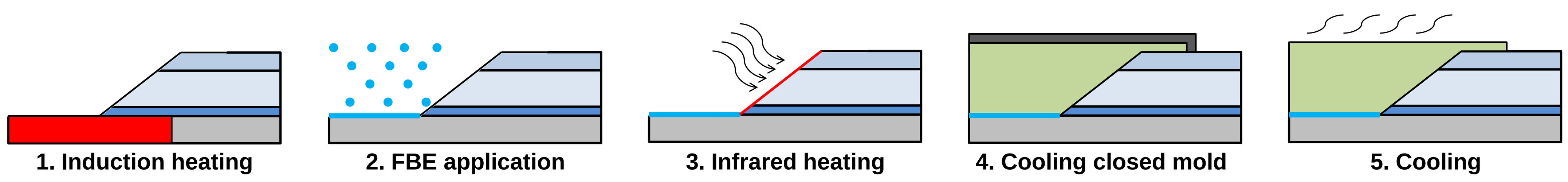
Crystallinity profile of the FJC

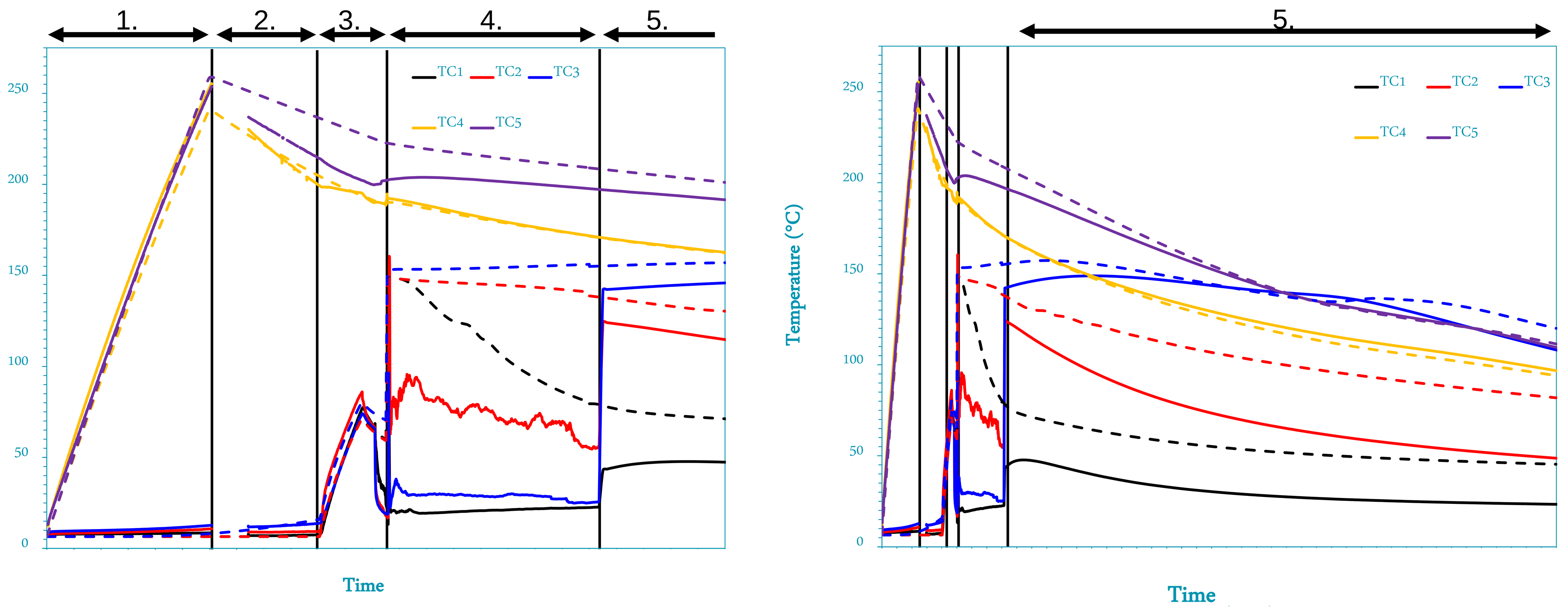
Results

The heating and cooling processes during the FJC application process where modelled. The first step is the induction heating of the steel pipe, followed by the application of a thin layer (300 µm) of fusion bonded epoxy (FBE). Thereafter the chamfers are heated by IR irradiation. In a next step a cold mould is placed around the field joint cavity and about 200 kg of PP is injected into the mould. After 20 minutes the mould is opened and the FJC is allowed to cool down to room temperature.

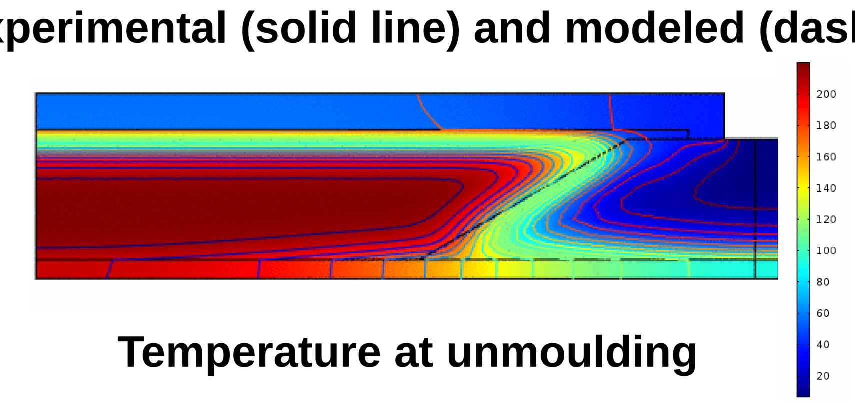


Locations of the thermocouples

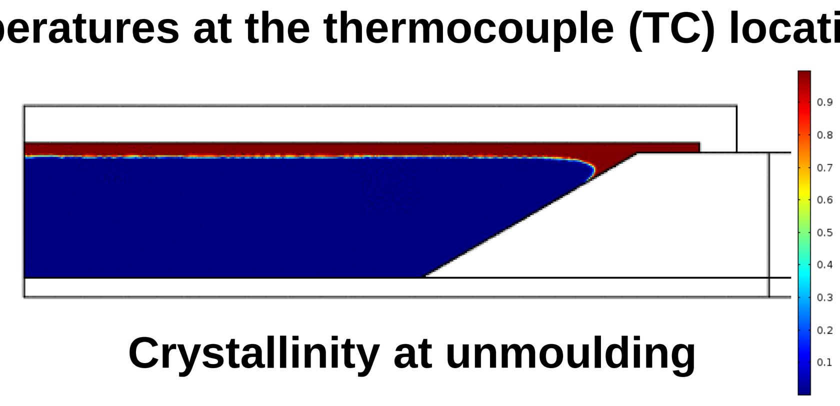




Experimental (solid line) and modeled (dashed line) temperatures at the thermocouple (TC) locations



Temperature at unmoulding



Crystallinity at unmoulding

Temperature profiles collected during the industrial FJC application process are compared with the computed profiles. Optimization of the boundary conditions resulted in a good comparison between model and tests.

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