Cooling and Hardening During Injection Molding of Field Joint Coatings for Deep Sea Pipelines

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Abstract

Carbon steel pipelines to transport hydrocarbons installed in the sea need not only to be protected against corrosion, but also to be insulated to maintain the temperature of the pipe contents and to assure the flow. Therefore a multilayer polymer coating is applied. After the individual pipe sections are coated with a factory-applied coating along their full length, the coating is cut back at the ends before welding them together during the offshore installation. After welding, a field joint coating is applied over the welded area by injection moulding (Figure 1).
Several requirements need to be met for field joint coatings, among which an easy applicability in the field, the possibility to cure or crystallize optimally (hence as quickly and completely as possible) in the mould, and the prevention of the formation of internal cavities.
Regarding the adhesion onto the steel pipe and the factory applied coating, the interfacial stresses due to differential thermal, cure-induced, and crystallization-induced shrinkage during both coating application and pipe usage are the prime cause for failure. As a consequence, ensuring optimal application conditions for the application of the field joint coating during an offshore installation is far from straightforward.

For field joint coatings, both thermosets (like polyurethane) and semi-crystalline thermoplastics (like polypropylene) are commonly used. For this case study on PP field joint coatings, a temperature-dependent crystallization kinetics model, consisting of a set of ordinary differential equations (ODEs), was developed using Matlab based on experimental data. To predict the temperature and crystallinity of the PP during the cooling and hardening of the field joint coating in the injection molding application process, a 2D axisymmetric model was developed in COMSOL Multiphysics, including the crystallization model using Domain ODEs which are linked to temperature using the Heat Transfer Module. The computed temperature and crystallinity profiles as a function of time (Figure 2) were in good agreement with industrial test results. In a next step not only heat transfer and crystallization were taken into account, but also thermal and crystallization shrinkage and the resulting interfacial thermal stresses were implemented. In a final stage, the filling of the mould will also be built in into the model.

Figures used in the abstract

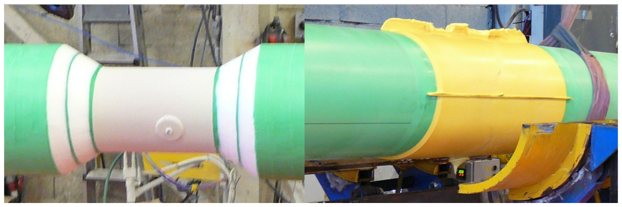

Figure 1: Welded pipe section, (left) after application of the corrosion protection layer, clearly showing the chamfers and (right) after application of a PP field joint coating.

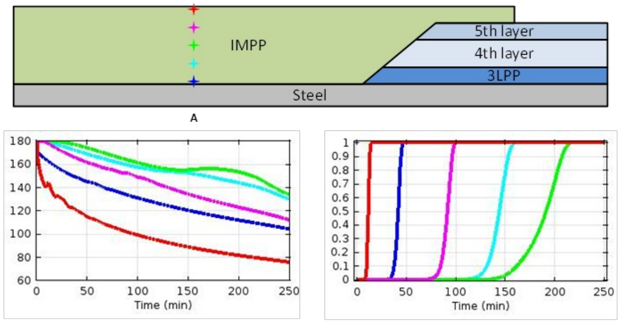

Figure 2: 2D axisymmetric geometry of the Comsol model of a PP field joint coating (top) with corresponding computed temperature (bottom left) and crystallinity profiles (bottom right).