# Filmboiling studies with CFD

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## 1 Introduction

Filmboiling is a phenomenon, which occurs when liquid is brought into contact with a considerably warmer solid surface. Then on top of the metal surface a thin vapour film is formed due the vaporization of the liquid. Because the heat transfer effectiveness of vapour is much smaller than that of liquid, more water is needed to cool the metal plate. This has a significant impact on the process energy economy.

Computational fluid dynamics (CFD) can help to gain essential information about the properties and behaviour of the film layer in the case of metal cooling. This can be used in the design of new generation steels. By investigating film layer properties with different initial conditions one can have valuable information, which can be used in the design of the cooling process, for example in the water usage expenses.

## 2 Objectives of the research

The goal of this research is to develop a model, which would give some insight into the filmboiling in extreme conditions. The temperature of the wall varies from 400 K to 1300 K and the jet velocities from 1 to 5 m/s. The values to monitor are the heat transfer coefficient of the liquid side of the wall and vapour volume fractions. The heat transfer coefficient is of special interest, since the model will be used in further studies in the Department of Mechanical Engineering regarding to the new generation steels.

Because of the high velocities, a turbulence model has to be used in simulations. The different phases have to be modelled with a multiphase model, where the temperature dependent interaction between the phases has to be taken into account.

## 3 Results

Simulations have been performed with Fluent 6.3.26 CFD-software. The turbulence has chosen to be realizable $k-\varepsilon$ and multiphase model has been 2-phase VOF models. The mass transfer between the liquid and vapour phases has been included with source terms to the energy and VOF-equations.

The calculation domain is 800 mm in width and 60 mm high. The origin is under the inlet jet, which is in this symmetric domain 10 mm width, which corresponds to the inlet diameter of 20 mm. The relevant features to monitor are the overall volume of the fluid fractions and the heat transfer coefficient h, which describes elegantly the effectiveness of cooling.

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### *3.1 Volume of fluid fractions*

Figure 1 illustrates the vapour volume fractions at different wall temperatures and inlet velocities. Value 1 represents the full vapour phase and 0 the pure liquid phase. One can see that under the inlet the film layer is very thin. This corresponds to the fact, that the water hits to the wall with a very high speed and vapour film is not formed.

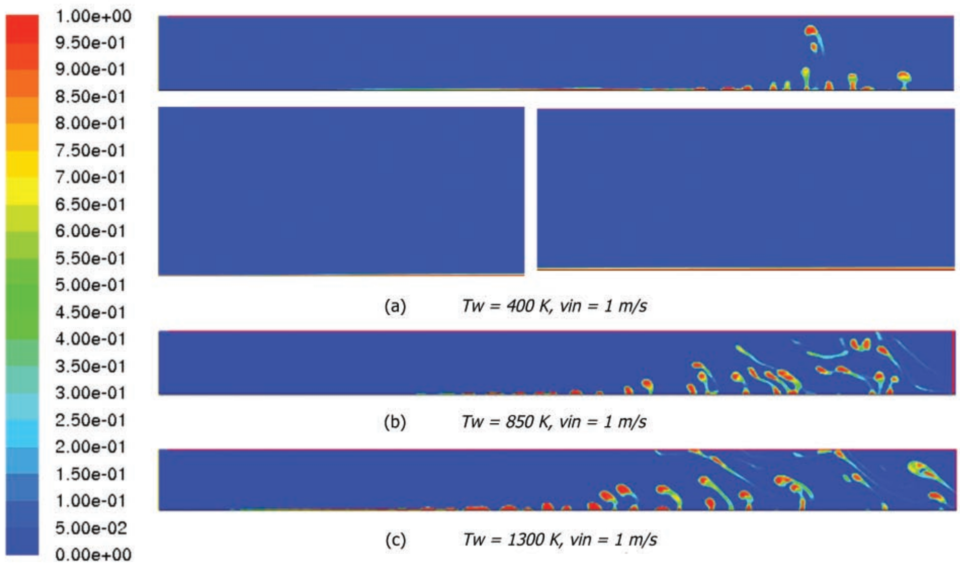


**Figure 1** Film layers at low velocity cases with different wall temperatures

### *3.2 Heat transfer coefficients*

In Figure 2 the time averaged heat transfer coefficients at different temperatures and input velocities are shown. Under the inlet the film layer is very thin, which corresponds to the high heat transfer coefficients. After the impact region h decreases, which corresponds to the growth of the film layer until the film boiling region is reached, where the heat transfer coefficient starts a rapid time-dependent oscillatory motion.

One thing that can be seen from Figure 2 is the temperature dependence of heat transfer coefficients peak at impact region. The higher the temperature, the lower the peak is.

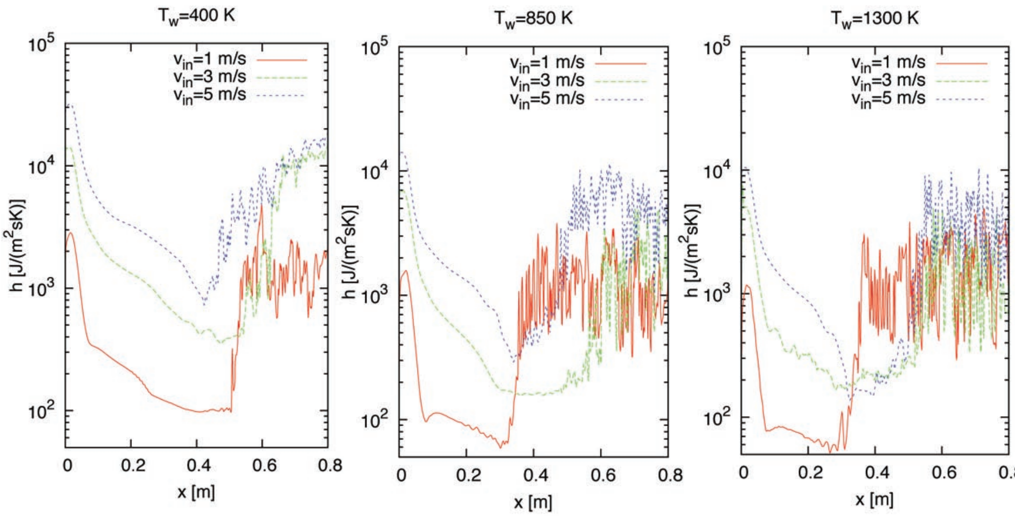


**Figure 2** Heat transfer coefficients at different temperatures and inlet velocities.

## 4 Relevance of the research

The task of this project was to develop a model to describe the film-boiling process at the vicinity of hot metal plate. The model to describe the film layer was chosen to be turbulent VOF-model, turbulence was modelled with realizable k–εmodel, mass and heat transfer was modelled with source terms found in the literature (Welch & Wilson 2000, Yuan et al. 2007, Incropera & DeWitt 1981). The results were found to correspond quite well the expected overall heat transfer coefficients (Silverman et al. 2005), at least in order of magnitude. As the plate is stationary, the left boundary can be taken as a symmetry plane. In reality, when the plate is moving and it has a thickness, one should consider a full calculation with dimensions $x \approx \pm 0.5$ m from the center and let the inlet be 20 mm. As the width of the area has been shown to be crucial, for further studies with moving plate one should calculate also some of the cases with a larger domain.

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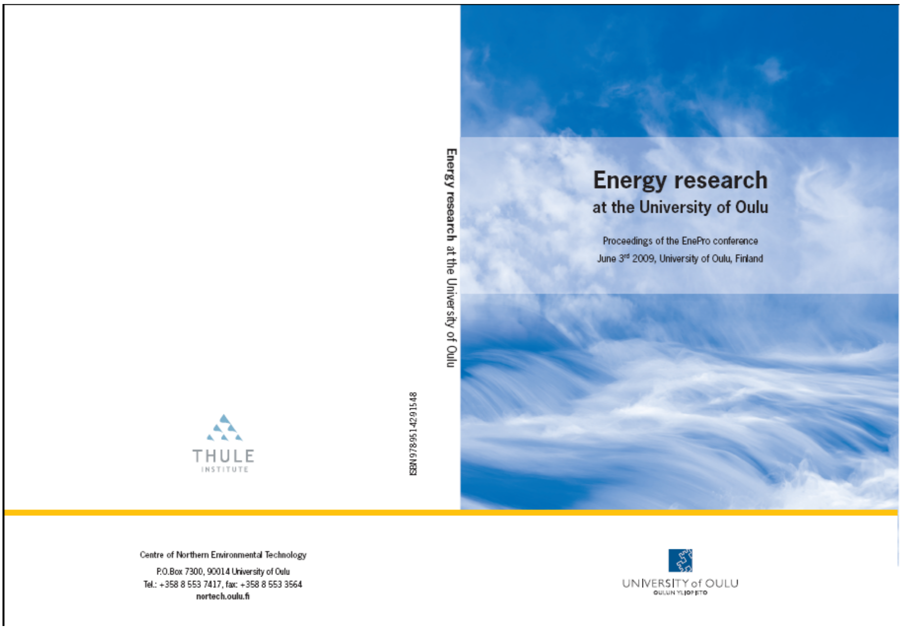


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