Simulation of the Molten Glass Sheets Flow

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Introduction: Thin glass sheets have nowadays a lot of commercial applications, i.e. screens, mobile phones. In this study a glass trough as part of a glass sheet production process was built in Comsol Multiphysics in order to simulate a molten glass flow.

In this process the molten glass flow fills the reservoir then overflows the longer sides of the trough, cascading down the wall and meeting on the downside, building a single sheet Fig.1.

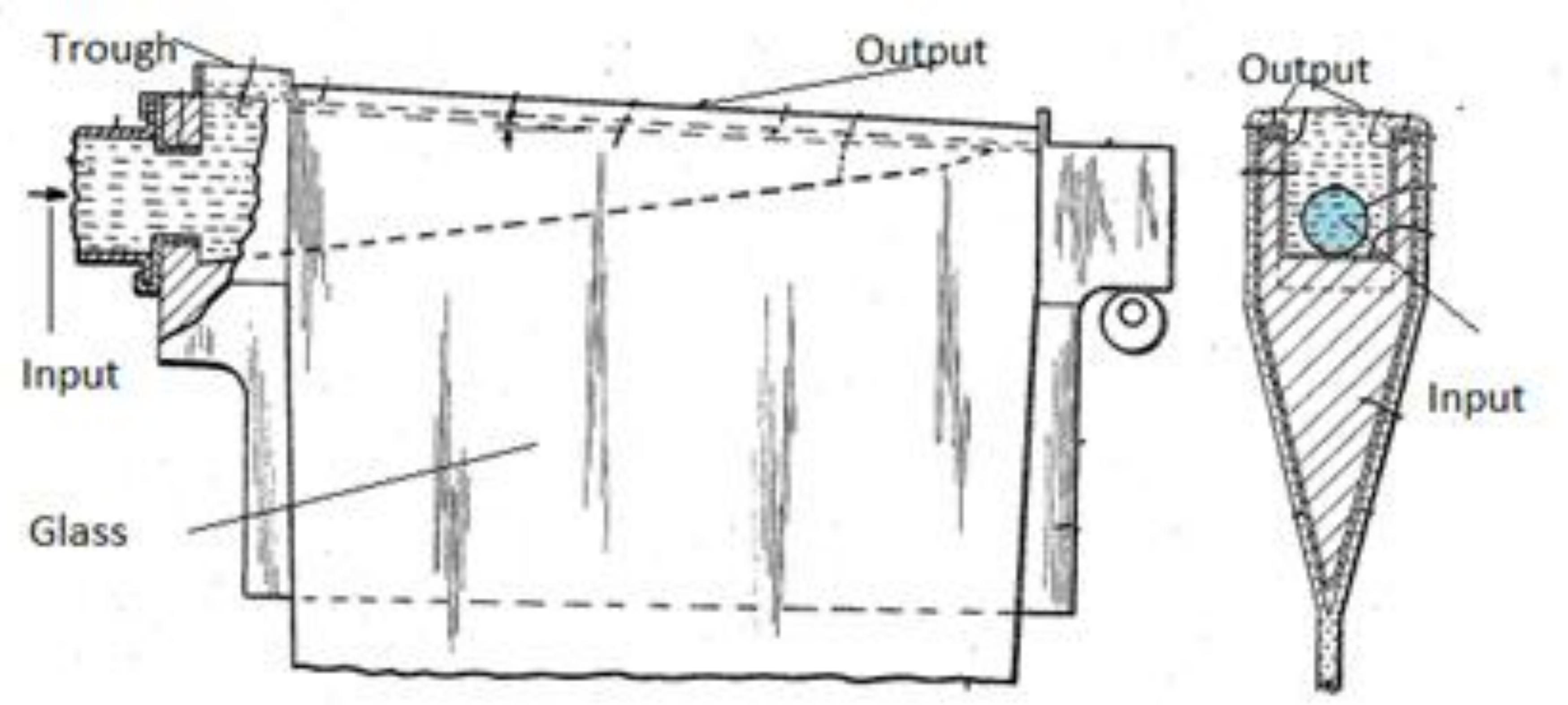

Figure 1. The glass trough after Stuart M. Dockerty& Corning [1]

Computational Methods: In this study a model was built in order to simulate the flow of the glass over the outer boundaries of the trough. For the simulation of the fluid dynamics the Laminar Two Phase Flow- Level Set mode was chosen. To incorporate the effects of gravity a volume force was added as a term on the right-hand side of the incompressible formulation of the Navier-Stokes equations:

$$\rho\frac{\partial u}{\partial t} + \rho(u\cdot\nabla)u = \nabla\cdot[-p\mathbf{I} + \mu(\nabla u + \nabla u^T)] + \boldsymbol{F}_g + \boldsymbol{F}_{st} + \boldsymbol{F}_{ext} + \boldsymbol{F}$$

$$\nabla\cdot u = 0$$

$$\frac{\partial\varphi}{\partial t} + u\cdot\nabla\varphi = \gamma\nabla\cdot\left(\varepsilon\nabla\varphi - \varphi(1-\varphi)\frac{\nabla\varphi}{|\nabla\varphi|}\right)$$

For glass the relevant material constants at 1273.15 K were used, assuming isothermal conditions. A simplified geometry representing the involved fluid (glass and surrounding air) is shown on Fig. 2

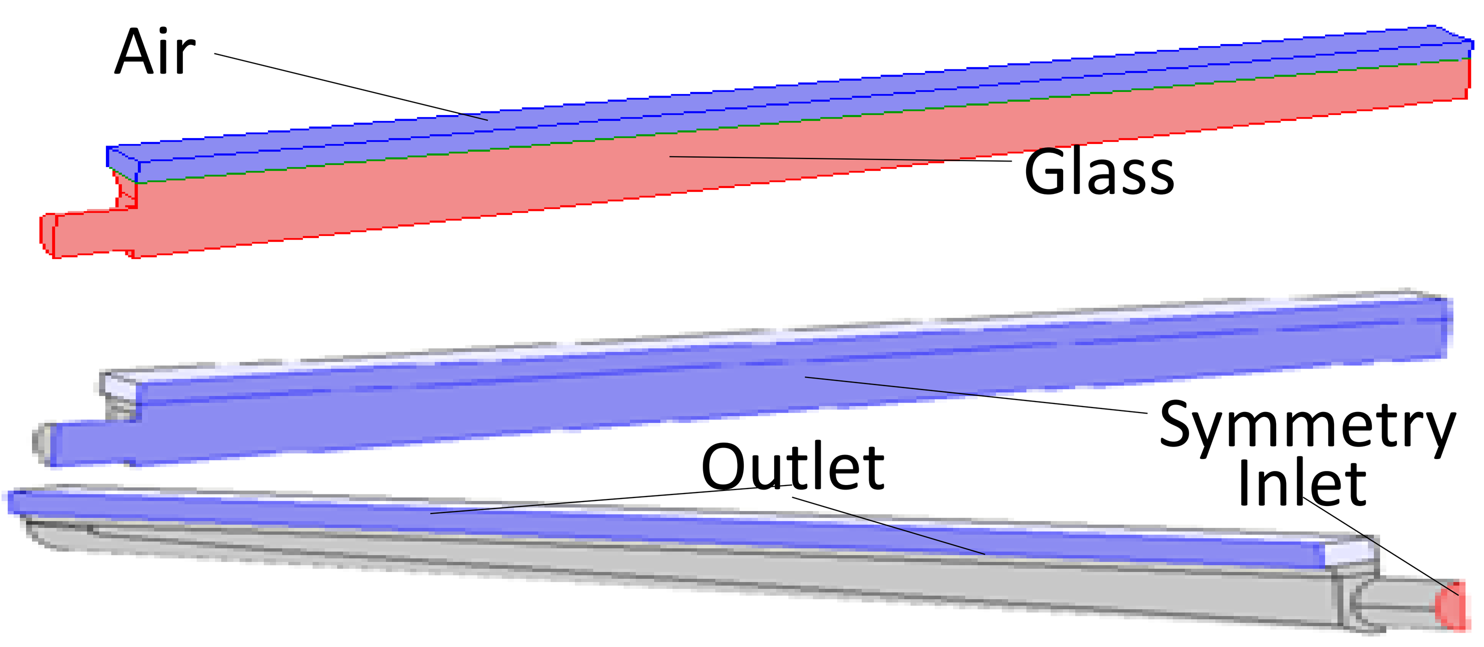

Figure 2. Geometry of the Fluids and Boundaries

Results: In Fig. 3 the results for a 0° inclination are represented as 3 D plots of the mass flow rate over the outflow boundary at different time steps. The colour range distribution of the plot represents the non-uniformity of the glass distribution in Fig. 4.

Fig. 5. shows a comparison of the resulting contours of the flow at t=1800s. Here the influence of the 7° inclination is clearly visible in the shape of the contour. It changes towards a more homogenous contour which is commonly better for the production process.

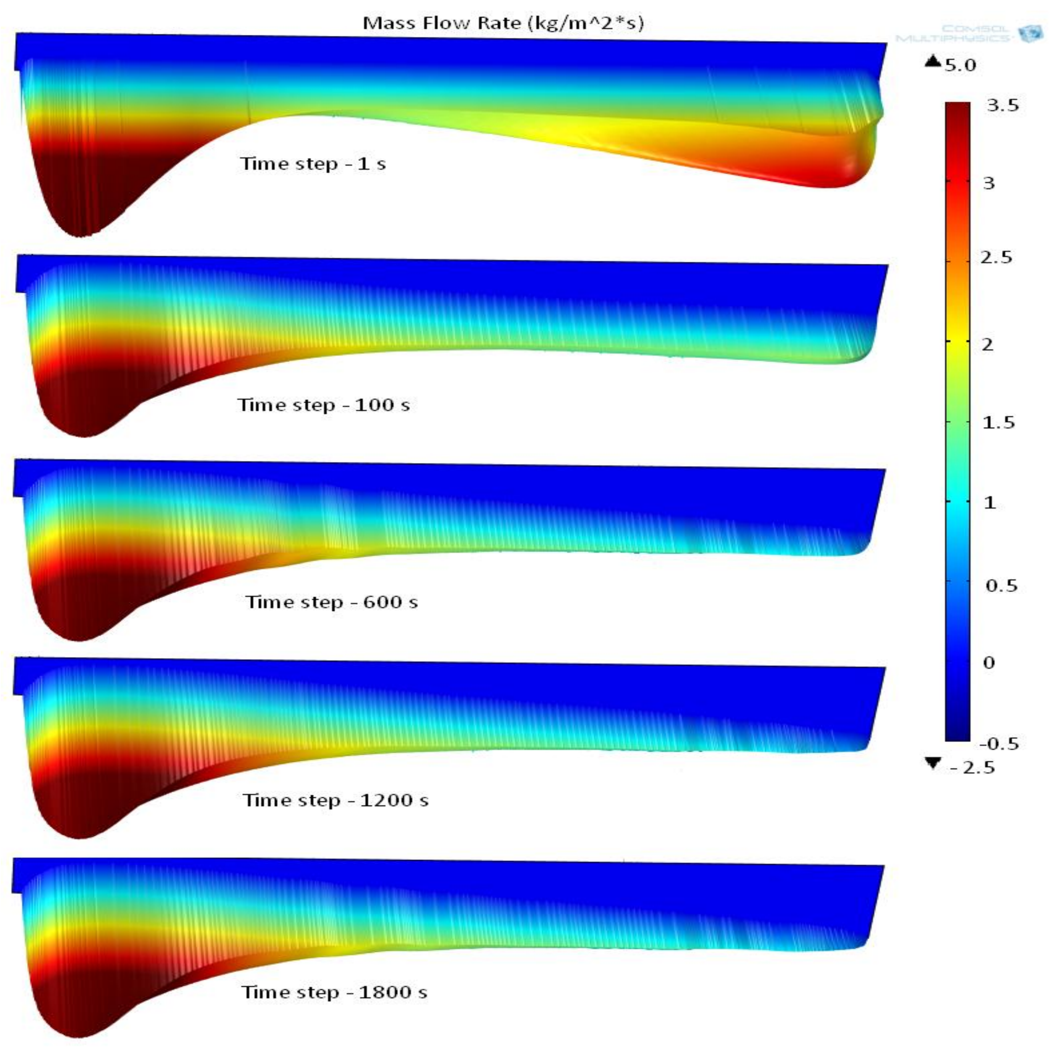

Figure 3. Flow profile for 0°

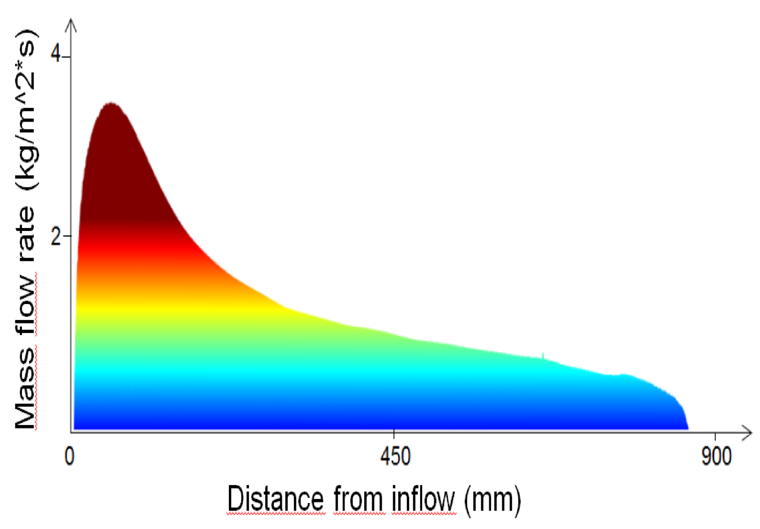

Figure 4.Mass flow rate distribution at 1800s for 0°

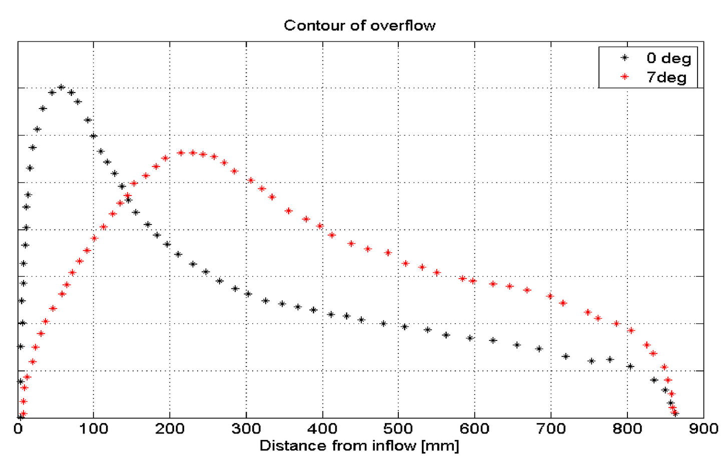

Figure 5. Contour of outflow at outlet for 1800s for 0° and 7°

Conclusions: In this study it was shown that the model is able to simulate the overflow of molten glass flow. We were able to introduce a parameterized model in order to investigate different influences on the contour of the glass outflow.

References:

1. S.M. Dockerty. *Sheet Forming Apparatus*. U.S. Patent 3,338,696, (1967)