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Batch Heating of Liquids

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Introduction

Batch heating and cooling of liquids belongs to very important industrial processes. Not all the cooling and heating processes, particularly in food industry, are implemented as continuous, so modelling of batch heating or cooling is important to a design of technological equipments. Modelling of batch cooling or heating time can significantly reduce energy consumption, it can also help to develop a suitable technological technique with a considerable impact on the quality of products, microorganism growth, etc.

A time behaviour prediction of batch cooling or heating to a given temperature in technological equipments is influenced by many factors: vessel geometry (mostly cylindrical vessel with a bottom of various shapes - ellipsoidal, conical, flat), method of heating or cooling (heating by a condensing steam, cooling or heating by a medium flowing in a vessel jacket or tube coil inside the vessel), agitator parameters, thermophysical properties of the batch, ... All these factors affect thermal design parameters, in particular heat transfer coefficients on internal and external surface areas of the vessel and its jacket or the tube coil. A significant contribution to an overall heat balance can also form a dissipation of an agitator mechanical energy inside a viscous batch as well as a reaction heat.

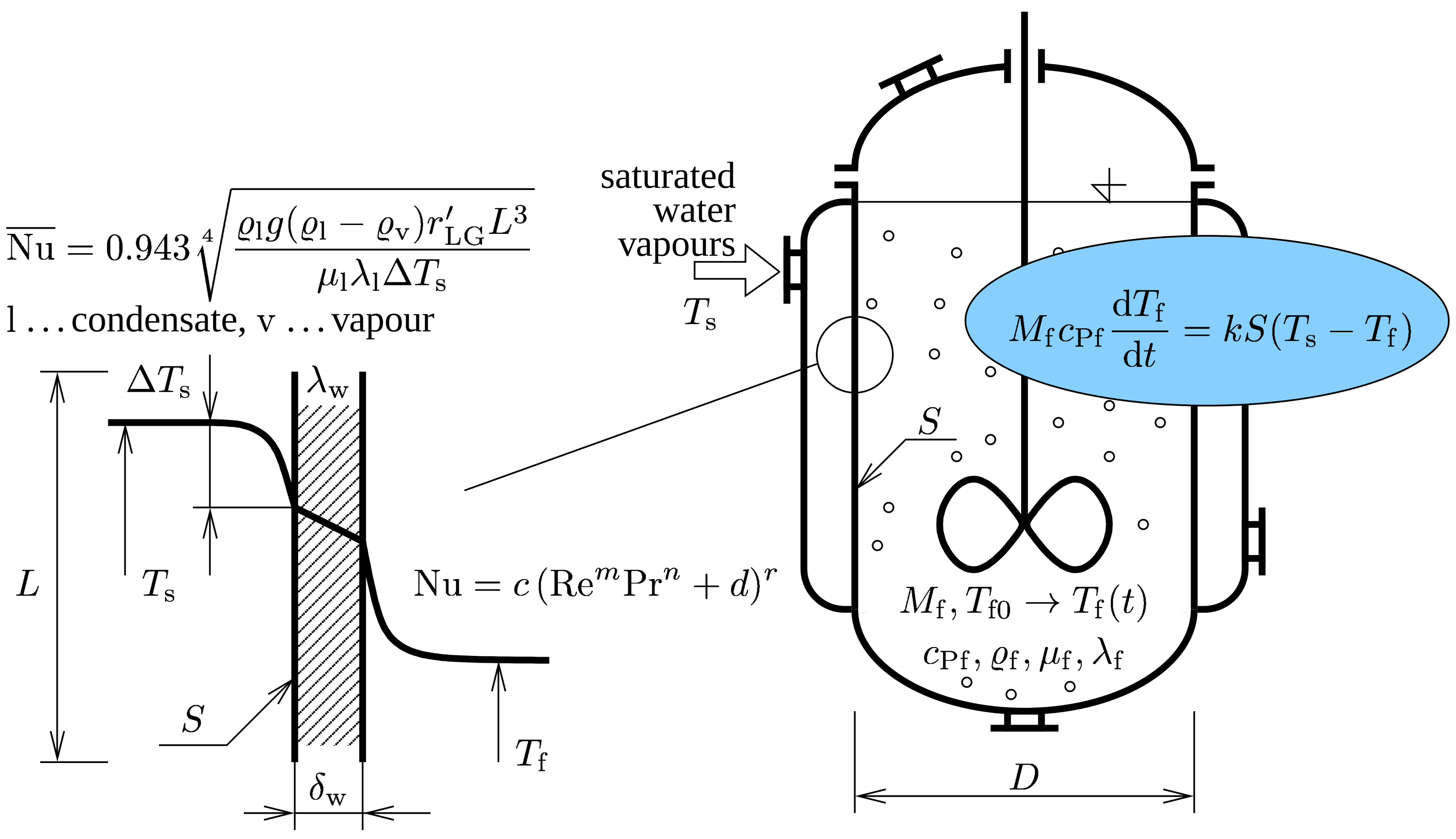

Figure 1: Scheme of the batch equipment with liquid heated by a condensing steam. Basic parameters and equations are depicted here.

Program

It is obvious that the time behaviour of batch cooling or heating depends on many parameters which are often difficult to determine accurately. BatchHeating program has been developed to simplify the design of process equipments. This program allows a numerical simulation of batch heating or cooling in equipment of a given size and it enables to examine effects of individual parameters on a heating or cooling rate.

Program BatchHeating 1.0 simulates numerically heating of an ideally mixed batch. The heat energy is supplied by a steam condensing at the outer surface of the cylindrical vessel, which is the method very frequently used in industry. Heat transfer coefficient at the outer cylindrical surface of the vessel is calculated here as for the case of condensation at a vertical flat wall, see Šesták and Rieger (1998). The calculation of heat transfer coefficient at the inner surface of the vessel is based on the relation $\mathrm{Nu} = c\,(\mathrm{Re}^m \cdot \mathrm{Pr}^n + d)^r$, where Nu is Nusselt number, Re is Reynolds number and Pr is Prandtl number, and the experimentally determined values of the constants c, d, m, n, r can be found in literature, see for example Šesták and Žitný (1997). The difference between the bulk liquid viscosity and the viscosity at the wall is respected by Sieder-Tate correction.

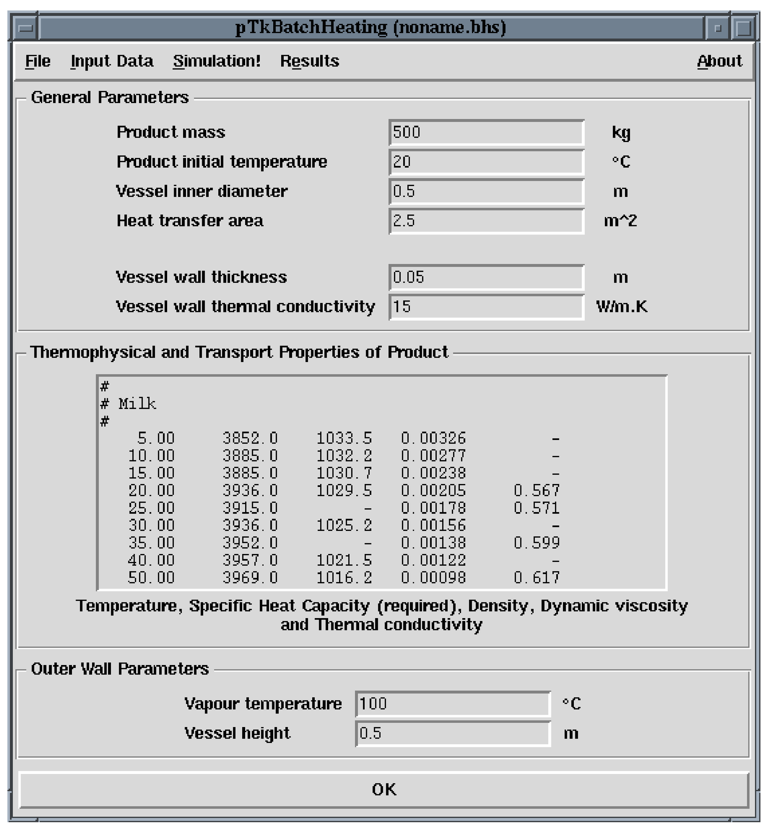

Figure 2: Input box of BatchHeating 1.0 program where basic geometrical parameters and thermophysical parameters of the heated liquid can be specified. The program has been written with the help of Perl programming language and graphical libraries Perl/Tk. All parameters can be entered interactively and numerical results of the simulation can be presented graphically by Gnuplot program. The BatchHeating program uses public free tools and can run under operating systems UNIX, GNU/Linux or Windows 9x/NT/XP (basically it can run on any platform where Perl with Tk libraries and Gnuplot are available).

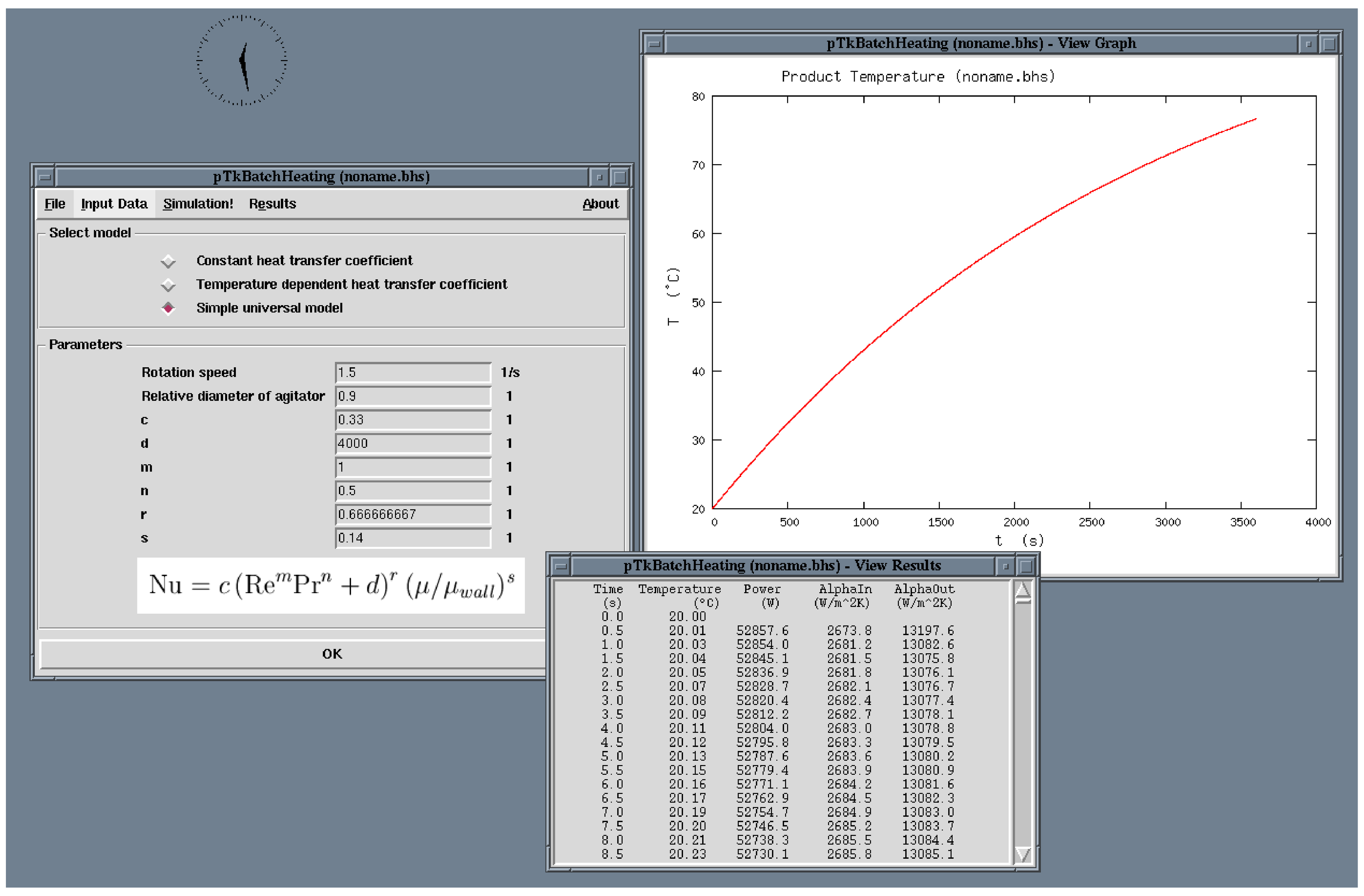

Figure 3: Input box with heat transfer parameters at the inner surface of mixed vessel and results of numerical simulation in graphical and numeric form.

Conclusion

The second version of the program BatchHeating 2.0 is developed at present. In contrast to the first version where only constant temperature of a condensing steam inside the vessel jacket is considered, the second version includes a temperature change of the heating or cooling medium which flows inside the vessel jacket. This also implies that the heat transfer coefficient inside the vessel jacket must be calculated. For the case of an annular cross-section relations based on Schlünder (1994) are used.

Acknowledgements

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