Proposal for a MINISYMPOSIUM ECMI 98

RADIATIVE HEAT TRANSFER

This minisymposium is a part of the Glass-Symposium organized together from the Scientific Computing Group of the Eindhoven University of Technology and the Institute of Industrial Mathematics Kaiserslautern. It will be devoted to the modelling of radiative heat transfer during glass production and processing. There will be the following talks:

Mathematical aspects of conductive and radiative heat transfer

M. Laitinen and T. Tiihonen

University of Jyvaskyla
Department of mathematics
P.O. Box 35, FIN-40351
Phone: (+358) 14 602741 Fax: (+358) 14 602731
e-mail: `tiihonen@math.jyu.fi`

In this lecture we consider models that describe heat transfer by conduction and radiation. Due to non-local character of radiative transfer on the one hand and non-linear dependency between temperature and emissive power on the other hand, these models are mathematically non-trivial. We propose a mathematical framework that covers at least the most important radiation models for gray materials. Results on existence, uniqueness and boundedness of solutions are given. Furthermore, the implications of the well posedness results to the theory of numerical approximation of conduction-radiation models are discussed.

Numerical methods for radiative heat transfer and applications

Norbert Siedow

Institute of Industrial Mathematics
Erwin-Schrödinger-Straße
D-67663 Kaiserslautern

Phone: (+49) 631/205-4126 Fax: (+49) 631/205-4139
e-mail: `siedow@itwm.uni-kl.de`

The knowledge of the exact temperature distribution in glass or other semitransparent materials is of utmost importance to control the production process and the final quality of the products. Heat transfer is not only accomplished by conduction but also by radiation. While conduction is a local phenomenon thermal radiation is a global one. The avarage distance a photon travels before interacting with a molecule may be very short (e.g. absorption in a metal), but can also be very long (e.g. sun rays).

Since the coupling between the energy equation and the equation of radiative transfer is highly nonlinear, it is of great importance to use efficient and accurate solution procedures to the radiation part. Heat transfer problems by conduction can be solved routinely using commercial software packages. For the calculation of radiative transfer, these packages use only the simplest approximation methods, so that it is not possible to simulate real three-dimensional problems with good accuracy in realistic computing times. The intensified interest in the treatment of radiative transfer encouraged the development of a number of methods devoted to this subject. We will give a short overview of such methods and applications for real problems.

Radiative Heat Transfer During Cooling of Glass

Frank Zingsheim

Institute of Industrial Mathematics
Erwin-Schrödinger-Straße
D-67663 Kaiserslautern

Phone: (+49) 631/205-4087 Fax: (+49) 631/205-4139
e-mail: `zingsheim@itwm.uni-kl.de`

The temperature distribution during the cooling process has a great influence on the quality of the glass. Large gradients in temperature causes stresses inside the material which may cause breakage. Even if the glass does not break the stresses decrease the quality of the glass and make it useless for optical purposes. A slow cooling of the glass reduces the temperature gradient, but is very time consuming. Therefore, the glass producing industry wants to achieve an optimal cooling which is as fast as possible, but as careful as necessary. For that purpose a simulation of the cooling process is required.

A simulation of the cooling process has to include the heat transport by conduction and thermal radiation. A particularity of radiation in glass is that glass is a semi-transparent medium, i.e. radiation is emitted as well as absorbed in the whole volume of the glass. This requires special methods to handle the radiation. Methods used to calculate the radiation are on the one hand methods based on spherical harmonic expansions or discrete ordinates. The later one is very popular in academic purposes. Those kinds of methods are very accurate, but also very calculation time consuming and for real problems in general not practical on workstation class computers. On the other hand diffusion approximations, i.e. Rosseland type approximations, are used which are very fast in calculation and frequently applied in industries, but not accurate for the temperature rang arising in the cooling process.

Therefore, a new method has been invented which overcomes the model problems of the Rosseland Approximation and keeps its great advantage of fast computation. The fast computation time in the Rosseland Approximation is achieved by including the thermal radiation as a correction in the heat transfer equation. This is done in a way which looses all geometric information of the glass solid. By making use of geometrical information which are achieved by apriori calculations of special radiative problems, while including the radiation in the heat transfer equation a new diffusion like approximation is formulated.

This diffusion like approximation combines the advantage of the fast computation time which is known from the Rosseland Approximation, with an accuracy which is comparable to that of the discrete ordinate method.

Simulation of Heat Transfer in an Axisymmetric Parison

Bas van der Linden

Eindhoven University of Technology
Scientific Computing Group
NL-5600 MB Einhoven

e-mail: `linden@win.tue.nl`

The assumptions needed for the Rosseland Approximation to make sense are severely violated in most forming processes. Because most glass products are thin, the assumption of optical thickness does not hold anywhere in the geometry. In this lecture we treat actual implementations of various methods to achieve higher order accuracy. Comparing the speed and accuracy a study is made of the forming and cooling of a parison - a half product in the production of glass bottles. The considered geometry has rotational symmetry but can have an arbitrary geometry.