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Viscosity Determination from Rise Profiles and Pressure Data

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In foaming processes a large variety of chemical reactions simultaneously take place, which leads to dramatic changes of the physical properties, e.g. the viscosity of the system. This key parameter, however, determines important material properties such as flowability, demolding time etc. Monitoring the change in viscosity during the reaction offers the possibility to gain insight into the fundamental cross-linking and polymerization behavior of these reactions.

The knowledge of the reaction kinetics during the foaming process has an essential impact on the choice of raw materials and the reaction parameters. The reaction parameters can be optimized for the respective application (e.g. refrigerator or sandwich panels with PU rigid foams) by choosing suitable raw materials and reaction conditions, leading to tailor-made systems.

We have made a new approach to determine the increase in viscosity from experimentally available rise height and the pressure progression data. In recent work, we have been able to verify the viscosity data obtained by using a FOAMAT instrument with data gained from a conventional viscosimeter (rotation mode) using a modified PU rigid foam system.
The new method is based on the tube model of Hagen-Poiseuille, which defines the viscosity η by the force needed to move a liquid element of a unit length with a unit velocity through a tube of circular cross section.

$$F = 8 * \pi * \eta * s * v$$ Hagen-Poiseuille's equation (1)

This model can easily be applied to the geometry of the Foam Pressure Measurement Device FPM[1] which is part of the FOAMAT system manufactured by Format Messtechnik GmbH, Karlsruhe, Germany: The test cylinder is regarded as part of a tube in which the foam expands with the rise rate **v**. The force is then evaluated from the pressure **p** measured with the pressure gage at the bottom of the FPM, and the rise height **s** is taken as the length element of the foam. Because of zero velocity at the bottom plate, a factor 1/2 is introduced to the formula, which then reads:

$$\eta = p * A / (4 * \pi * s * v)$$ Viscosity formula (2)

The time dependent data p, s and v are continuously recorded during a test cycle, which spans from the liquid to the solid phase. From this data a time dependent viscosity curve is calculated.

[1)] Patent DE 19730891

- Viscosity calculation using FOAMAT pressure and rise height curves
- Evaluation model avoids slip effects and gives continuous viscosity / time curves
- No additional testing equipment needed

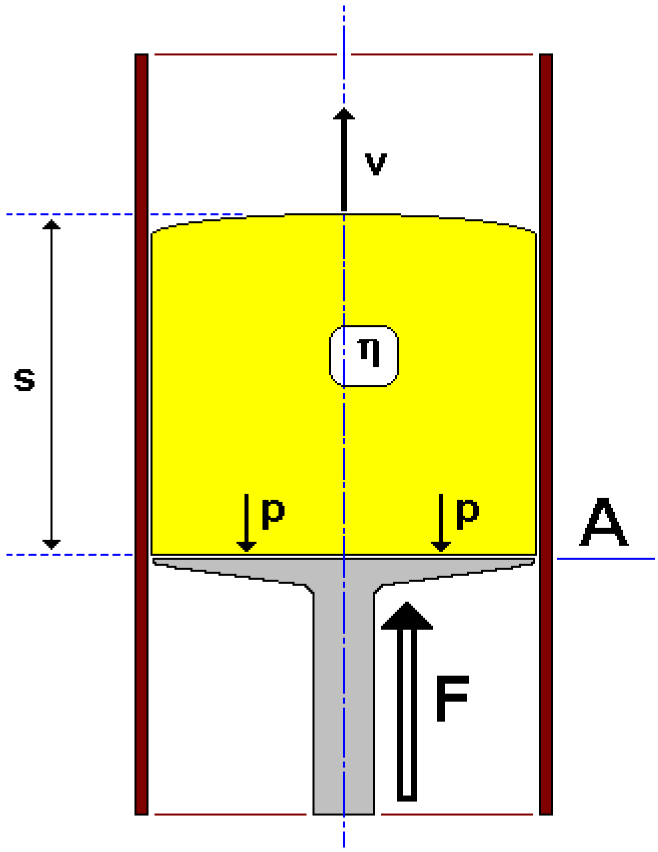

Figure 1: Physical model of Hagen-Poiseuille's equation

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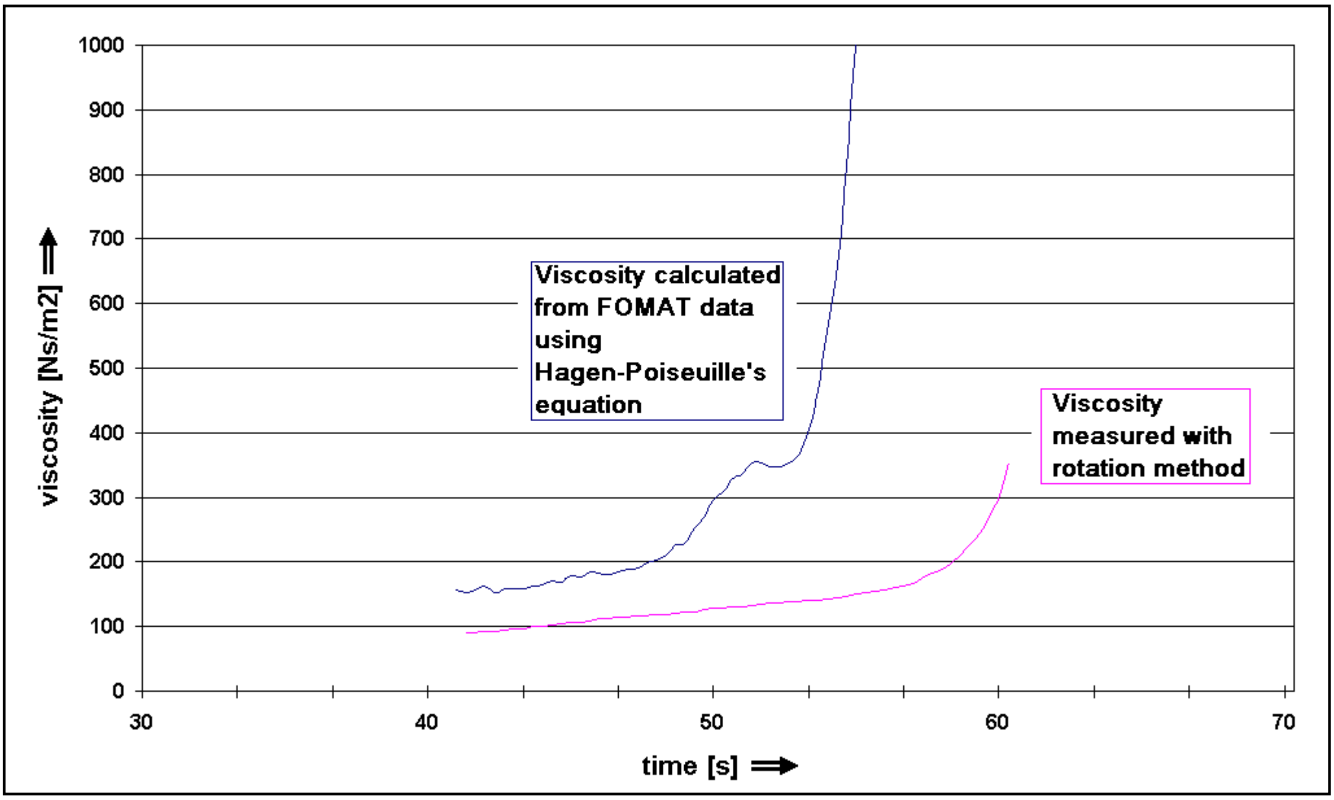

Figure 2: Comparison of calculated and experimentally determined viscosity data for a rigid foam system

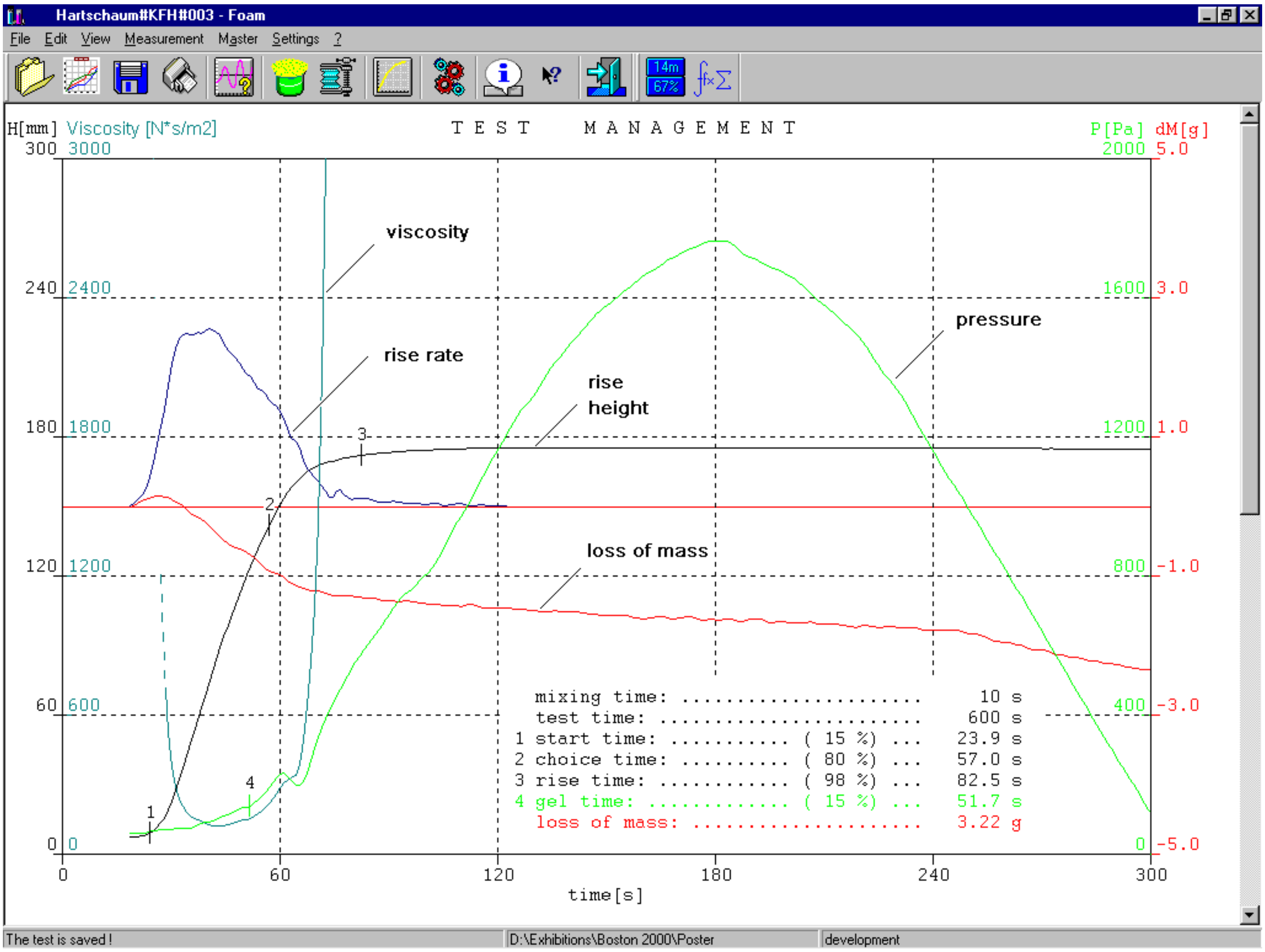

Figure 3: FOAMAT measurement data and calculated viscosity displayed with the software FOAM

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