Control of Impregnation Processes

Dr. K. Velten
Institute of Industrial Mathematics (ITWM)
Erwin-Schrödinger-Str. 49
D-67663 Kaiserslautern, Germany
Phone: ++49-631-205-4138
Fax: ++49-631-205-4139
Email: velten@itwm.uni-kl.de

D. Schattauer
Siemens AG
KWU WM EG5
D-45466 Mülheim a.d. Ruhr, Germany
Phone: ++49-208-456-2660
Fax: ++49-208-456-2275

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Many composite materials manufacturing processes involve the impregnation of porous materials with a fluid. Examples are the resin transfer molding process, which is used to produce fibre-reinforced materials, or the impregnation of endless fibre bundles which are used as a raw material in injection molding [A]. Also, there are several applications in the electro industry, where insulating materials have to be impregnated with resins in order to work well. Typical problems include incomplete impregnation or dry spot formation. In many cases, these deficiencies are hard to detect but can severely affect product quality. Thus, improved process control is of great importance in impregnation processes.
We have investigated a case where continuous electrical capacitance measurements had been used to monitor the process. The problem was the interpretation of these data. The process engineers had experience and ideas as to how the measurements relate with process performance. However, only

a few points of the measurement curves were used. The information content of these curves remained largely unexploited.
We used an inverse problems approach to evaluate the process data. Based on the standard porous medium flow equations, we developed one- and twodimensional models of the impregnation process. The twodimensional model was used to simulate the capacity measurement and to identify the internal flow pattern from the data (figure 1). In the onedimensional model, we used this information to estimate important process variables such as permeability K and porosity ϕ (figure 2).

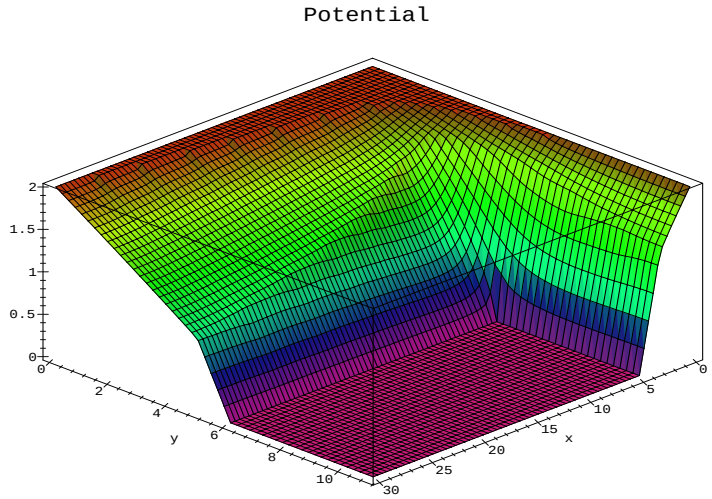

Figure 1: Simulated electrical potential for a twodimensional impregnation process. The flow front started at coordinate lines $x = 0$, $y = 0$. Its actual position is where the potential surface meets the zero-level.

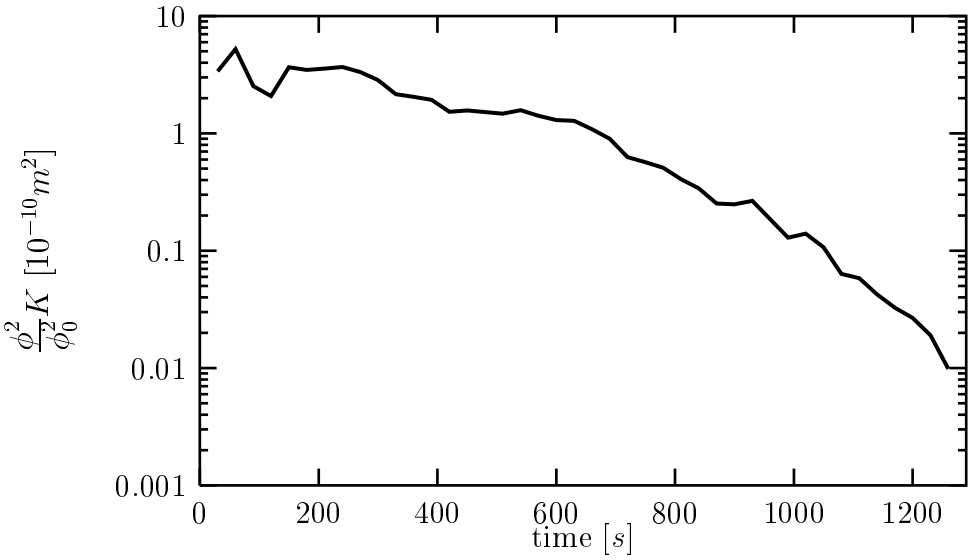

Figure 2: Time development of $\frac{\phi^2}{\phi_0^2}K$ (where ϕ_0 is the initial porosity) at the impregnation flow front as derived from electrical capacity measurements.

References

[A] S.G. Advani, ed. 1994. *Flow and Rheology in Polymer Composites Manufacturing.* Elsevier Science.