Ultrasonic Measurement of the Reaction Kinetics of the Setting of Calcium Sulfate Cements Using Implicit Calibration

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Cements based on calcium sulfate and calcium phosphate are being used as synthetic bone replacement surgery. For both developers and end users, the properties of the material need to be known. Apart from material properties regarding biocompatibility, mechanical strength, porosity, etc, it is important also to know the setting time of the cement. Ideally, one would like to follow the chemical setting reaction of the cement, since this would provide information on both mechanical strength and to what degree the reaction is finished. The existing standards for setting time measurement do not provide any information about the underlying chemical reactions. Methods based on X-ray diffraction that do, are not suitable for on-line use, since they require samples to be removed and prepared.

Previous work using ultrasound shows that acoustic properties will vary as the chemical reaction progresses. Studying some of these properties, it is then possible to determine the setting time of the cements. However, no physical knowledge of the underlying setting reaction is exploited, and no obvious connection to the mechanical strength of the material can be found.

There are physical models, describing to which degree the chemical reaction has finished. However, the parameters of these models are not known. Using X-ray diffraction the parameters can be readily calculated, but with ultrasound we only get observations that are correlated with the model.

In this paper, a general methodology for combining soft multivariate statistical methods with hard physical models is described in terms of direct and indirect implicit calibration.

We then show with experiments how this can be used for the specific case of monitoring the reaction kinetics, i.e. time constants and delay parameters, in the setting reaction of calcium sulfate cement. The experiments show that mapping observed data onto to a physical model, the accuracy and the repeatability of the method is increased compared to non-parametric methods.
