Feedback Control of Microstate to Control Macrostate Properties of Controllable Fluids

by

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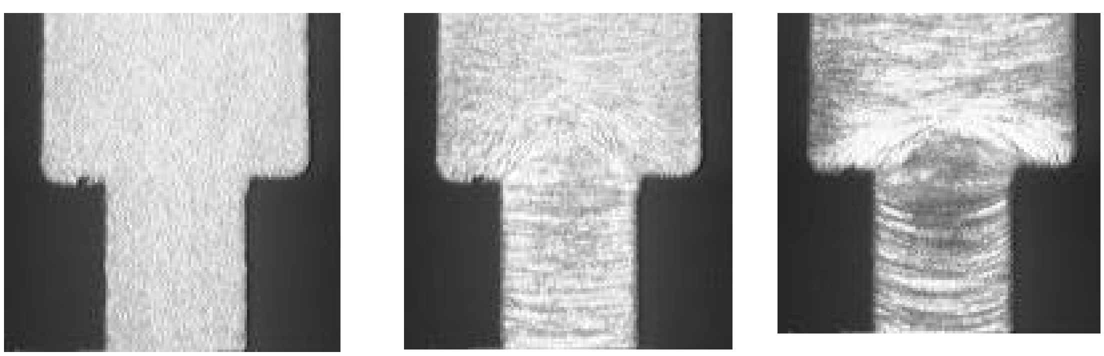
ABSTRACT

Controllable fluids are those fluids whose properties can be controlled through the application of an externally applied field. Many types of fields may be used including electric, magnetic, pressure, or other field types. Of particular interest in the present presentation are those fluids whose properties are controlled by electric fields. These fluids are made of micron sized dielectric particles suspended in a liquid of low dielectric constant and are called electrorheological fluids. Electrorheological fluid applications are typically based upon control of fluid viscosity and stiffness. Recently our attention has been on thermal process control through control of thermal transport properties. Specifically, the radiative transmittance, the thermal conductivity, and the convective heat transfer process have been of interest. The concept is to control the organizational state of the particle laden electrorheological fluid and thus to control the mechanism for thermal energy transport.

Thermal property control can be accomplished through the following mechanism. When the fluid is exposed to the electric field, chains of micron sized particles will form into small or even macro chains (Fig. 1). These chains provide for preferred pathways for thermal energy transport. Further, the directionality of the transport is controlled since the particle chains follow the



Unexcited and Fully Dispersed | After 1 minute at 1000VDC | After 10 minutes at 1000VDC

Figure 1: Photographs show both the time and field dependence of the internal chaining state of electrorheological fluid microstructure. 1000v applied across a 2 mm (top) and 1 mm (bottom) section.

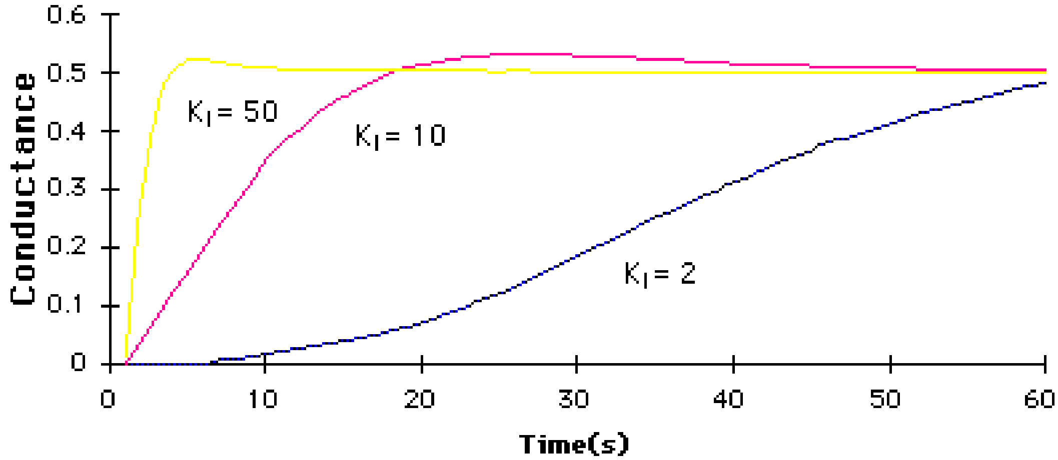


Figure 2: Proportional-Integral Control generates precise transient to desired material state with speed controlled by feedback control gain, K_I.

field lines. Thus it is possible to have the preferred path curve relative to the thermal field, if indeed we can create curved electric field lines). When the particle chains are subjected to fluid shearing forces, the particles still attract even though they may be pulled away from each other. Higher electric field strength increases polarization and causes the particle chains to pull together tighter and to lengthen the chains through the addition of more particles. These longer, stronger particle chains result in higher fluid viscosity and an alteration in composite fluid thermal transport properties.

Current ER fluids typically do not react quickly or precisely enough to meet needs of the applications. When low particle volume fluids are used to control transport of thermal energy by a feed-forward control method, and they have very slow ER fluid response. Response time was several minutes as compared to fractions of seconds with high particle volume concentrations. Greater control of the speed and precision of ER fluid response is the objective of our feedback control study (Fig. 2). Laboratory and analytical comparisons have been made between state feedback and conventional open-loop control of a low particle volume concentration ER fluid. Empirical models have been developed and an analytical model is under current investigation for ER fluid and control systems that predict ER fluid responses to the application of both conventional feedforward and state feedback control of the fluid. Effective and efficient control of an ER fluid is necessary for successful application of their controllable properties for thermal process control applications.

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