Virtual Prototype Evolution by COMSOL Multiphysics® of a Continuos Flow Animal By-Products (ABP) Ohmic Sterilization Unit

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Ohmic Heating

Ohmic heating (joule heating) was first developed as a viable processing option (for food processing) by ECRC (now C-Tech Innovation) in the 1980s. Ohmic heating is a method which offers the advantages of being: highly responsive; volumetric and efficient and offering low maintenance costs. In heating a highly viscous and inhomogeneous product as is animal by-products (ABP), ohmic is a good choice.

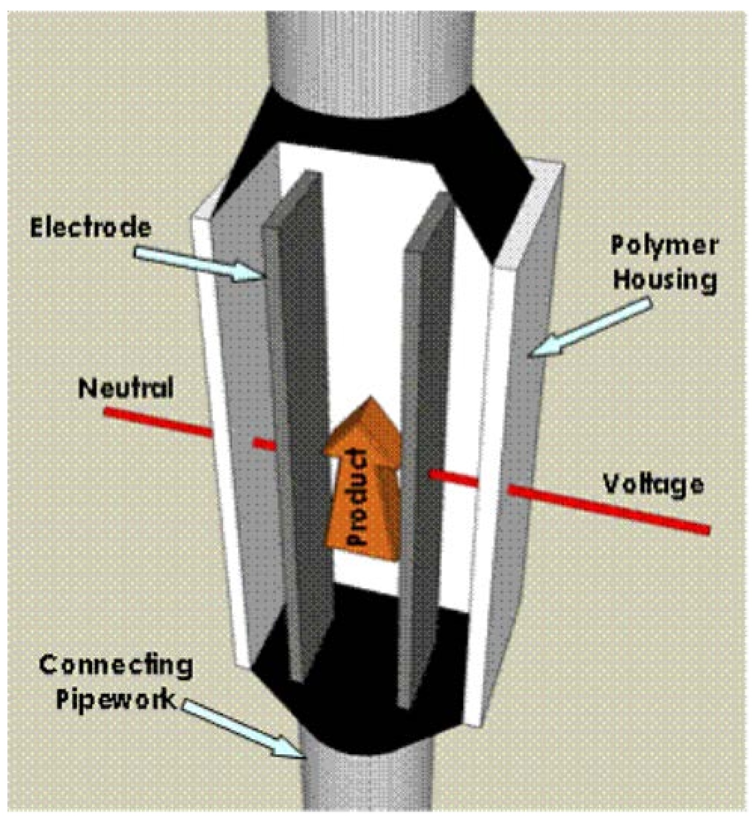

Figure 1: Ohmic heater conceptual diagram

The operation of an ohmic heater involves application of AC Voltage (typically 50 Hz) across the product using electrodes. Current passes through the conductive path of the product and heating occurs. Power dissipation (dP) at a small volume $d\tau_i$ is given by:

$$dP_i = \sigma_i |E_i|^2 d\tau_i$$

where σ_i is the electrical conductivity and $|E_i|$ the electric field strength.

The nature of the heating is expected to be dependent on multiple system parameters including, voltage applied, geometry of electrodes, temperature dependence of product electrical conductivity and localised temperature. When there is a temperature dependence to the heating, computational modelling therefore commands a simultaneous Multiphysics approach involving CFD, heat-flow and joule heating which for which our initial investigation showed COMSOL Multiphysics® to be up to the task.

Investigation objective

The system is required to have an outflow of minimum temperature 180ºC to enable sterlization in a later holding section and good uniformity of heating to keep down maintenance costs. The initial investigation was centered around a serpentine (meandering) design. Our previous investigation (COMSOL 2013, Rotterdam) showed the original meander design to be functional for the objective.

Initial design

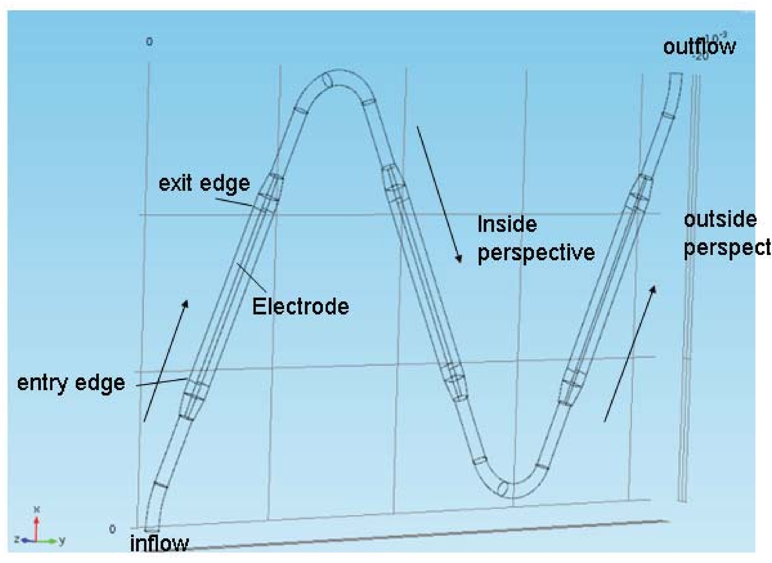

Figure 2: Original meander design

Our previous investigation pointed to the following possible evolutions of the system system:

i) significant reduction in equilibration zones (pipeline after each heater section)

ii) removal of bend sections

iii) multiple heating voltages/zones

COMSOL Multiphysics® approach

As before we employed simultaneous solution of CFD, joule heating and heat conduction to achieve a steady state (stationary) solution whilst incorporating a linearly increasing temperature dependence of electrical conductivity:

$\sigma_i = 0.07$ S/m For $T_i < 25$ºC

$\sigma_i = 0.01T_i - 0.18$ S/m For $T_i \geq 25$ ºC

Feature of model	Combined fluid
Material	Macerated raw chicken, bones and offal
Dielectric constant ε'_r	66
Density kg/m³	1050
Thermal conductivity κ (Wm⁻¹K⁻¹)	0.5
Heat capacity C(JK⁻¹)	3500

Table 1. Material properties used in the model

In this investigation, manual optimisation was used, whereby the voltage dependence of outflow temperature at each electrode was determined by means of parametric sweeping.

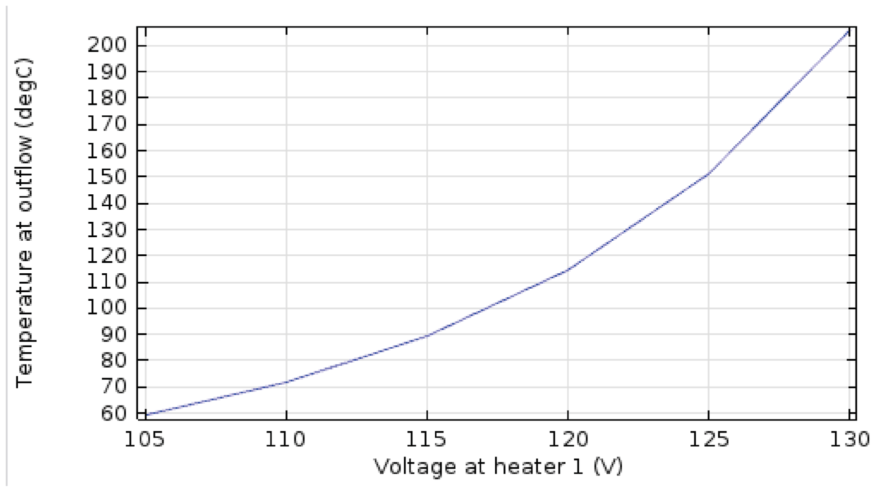

Figure 3: Dependence of outflow temperature on heater voltage - representative of the manual optimisation approach adopted

Outcome of the investigation

By means of the COMSOL Multiphysics® investigation we were able to greatly reduce the equilbration lengths of the system and incorporate appropriate voltage specification to maintain a good uniformity of temperature in the system.

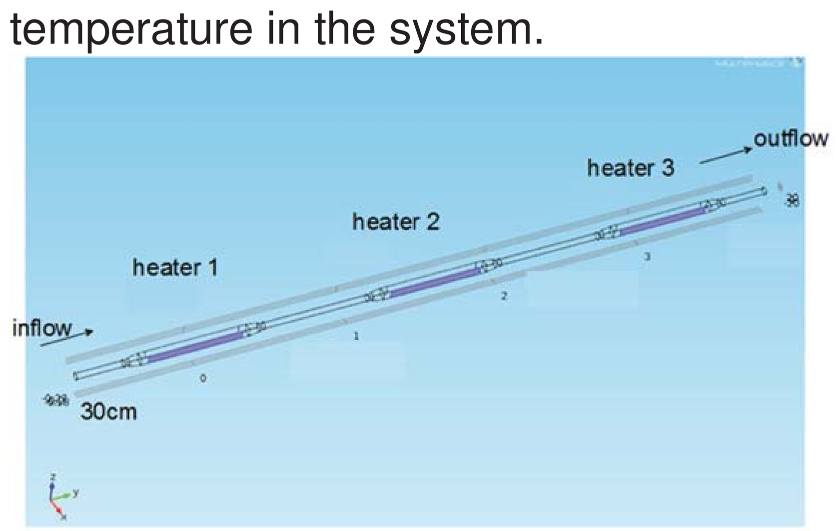

Figure 4: Evolved linear setup for triple heater section

On the basis of modelling, ohmic heating looks like it is a viable heating method for difficult, particulate containing materials.

Ongoing work

The evolved ohmic heater design has been constructed successfully in house by C-Tech Innovation and our scientists are currently conducting preliminary trials with low viscosity fluids before moving to the target ABP.

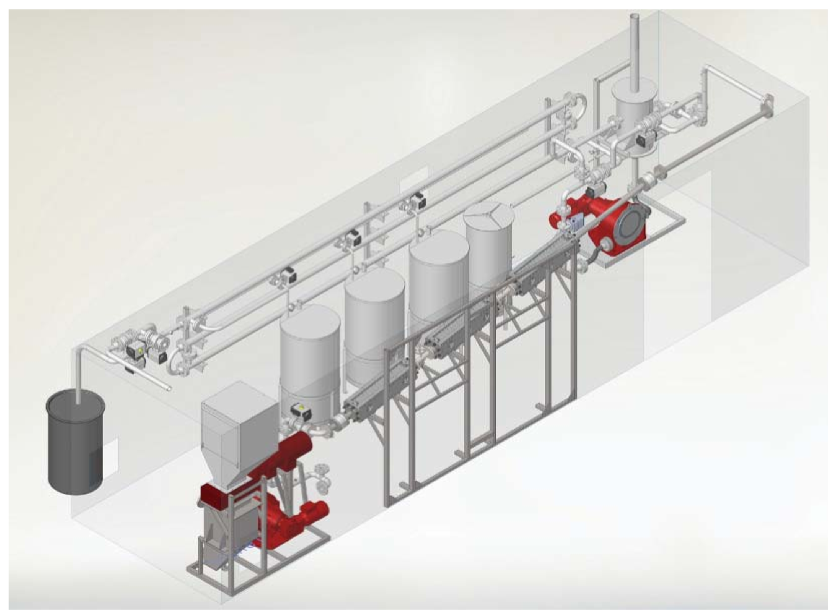

Figure 5: CAD representation of the C-Tech Innovation in house ohmic heater sterilization unit which is shown below.

Figure 6: Ohmic heater element design by C-Tech Innovation for this project.

It is our ongoing approach at C-Tech Innovation to combine our in house prototyping and experimental testing facilities symbiotically with our in house Multiphysics modelling capability. We would be happy to hear from any other parties who would like to take advantage of our in house combined modelling, prototype build and lab testing capability.