PRESSURE SUPPORTED FREEZING PROCESSES. MODELLING AND NUMERICAL SIMULATION

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Abstract. *A model for the simulation of thermal exchanges in a high-pressure equipment prototype is developed. Good agreement between simulated and experimental time-temperature profiles is found during different tests. The model allows to study the effect of the different variables implied in it and its variation in order to have a better thermal control in the treatments performed. This work involves an important advance in optimization of high-pressure processes in food industry.*

1 INTRODUCTION

We present part of the work that is being developed under a research project (described in Section 4 below). Our aim is the overcoming of certain scientific and technological problems as the lack of knowledge about the behavior and the physical, chemical and biological properties of foods under pressure and low temperatures. These problems hinder a wider application of Pressure Supported Assisted Freezing processes in foodstuffs. Therefore, its study may aid in highlighting the benefits of these processes as in comparison to conventional ones (for example, regarding the quality of treated food). Nowadays, there is only a partial and ill-structured scientific knowledge of the phenomenon. One of the main technical drawbacks is the difficulty of applying suitable cooling rates because of the huge mass of High Pressure equipments.

It is intended to face the solution of important scientific topics such as modelling the nucleation process, determining the amount of instantaneous ice formed after expansion and modelling the whole freezing process. Also, it is aimed to design and optimize a system which will enable the use of higher cooling rates in the process. To design this system we have built a 1/3 scale prototype in order to simulate the process. The first goal is to be able to simulate the process without pressure.

The idea is as follows: By means of high-pressure-assisted-processes we can get two effects which can not be reached by classical freezing: An instantaneous nucleation in the whole sample volume, independently of its volume, and the instantaneous production of an initial percentage of ice. These two factors have an important role in the quality of frozen food.

The process consist of the following steps: 1) Before cooling the sample, we increase the pressure. 2) We cool the sample under pressure remaining in the liquid part of the Pressure-Temperature phase diagram. 3) Pressure is then released to a determined pressure for phase change or, more usually, down to atmospheric pressure.

We shall start the simulation without considering the change of pressure. We therefore shall be interested in simulating numerically the distribution of temperatures we shall get before releasing pressure, i.e. in the second step. We want to be able to predict the time we shall need to cool the sample to the desired temperature. We shall use as a sample a fluid that remains unfrozen for low temperatures.

2 DESCRIPTION OF THE COOLING PROTOTYPE

The prototype is a metallic cylinder with radius R and height $2L$ with an inside cavity to hold the sample that is going to be cooled. This cavity is cylindrical with radius r and height $2l$ where, obviously, $0 < r < R$ and $0 < l < L$. We shall suppose also that the mass center of the container is in the point $(x_1, x_2, x_3) = (0, 0, 0)$ and the axis of both cylinders is the x_3-coordinate axis, so that the container and the inside cavity are located between the values of x_3 corresponding to the intervals $(-L, L)$ and $(-l, l)$ respectively.

To cool the sample located in the cavity, there is an internal circuit in the container, through which a cooling fluid is circulating.

In Figure 1 we show a graphical representation of this prototype with the scale in millimeters.

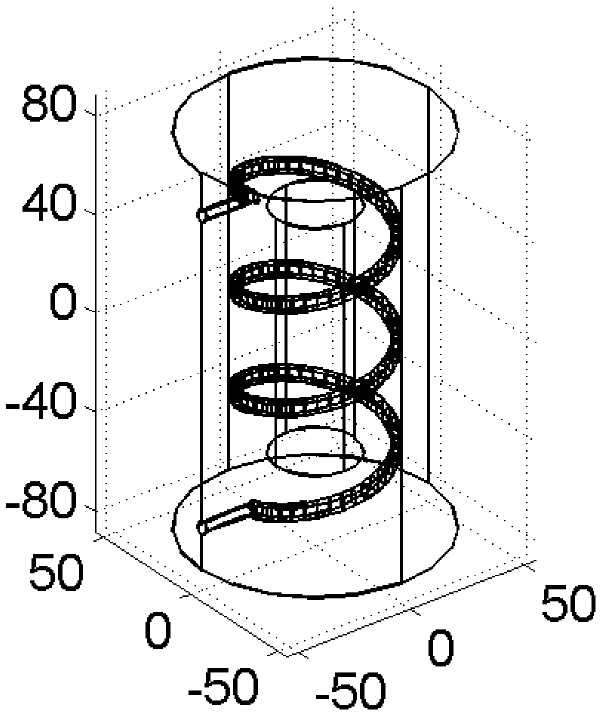

Figure 1: Graphical representation of this prototype with the scale in millimeters.

3 MODELIZATION OF THE PROCESS

We use the heat transfer equations in order to model the temperature distribution in the sample and its container. Thus, we have to solve a partial differential equation together with suitable boundary and initial conditions. This equation cannot be solved analytically on the domain of the prototype. Therefore we use finite element methods to numerically approximate its solution.

Figure 2 shows a mesh of the domain involved when solving the problem.

Numerical simulations together with experimental tests shall be presented for different cases.

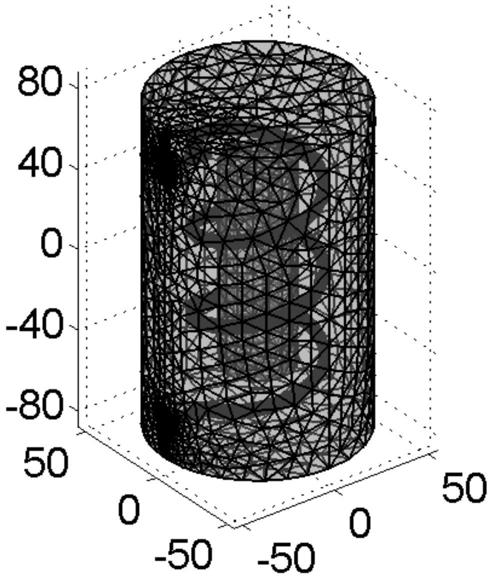

Figure 2: Mesh of the prototype.

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