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MATHEMATICAL MODEL USED FOR SIMULATION OF HEAT TRANSPORT IN SOLID FOOD PARTICLES HEATED IN A CONTINUOUS LIQUID FLOW

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BACKGROUND

In the design and development of a continuous heat treatment process for a fluid food containing particles the microbiological safety as well as the quality of the product have to be considered.

It is, however, difficult to predict these factors, i.a. due to the fact that it is difficult to measure the temperature in a moving particle "on-line".

A computer program has been developed at SIK, which allows for predicting the time/temperature distribution in the liquid and the particle heat-treated in a continuous flow.

Using the calculations we can predict the length of the holding tube required to reach a desired F-value after the holding tube. The program can also calculate a value for the quality attained a so-called Cook-value.

The program can also indicate how the flow conditions in the heat exchangers or the holding tube influence the process. The influence of the heat transfer from the liquid to the particle can also be studied.

A brief discription of the program follows below.

SIMULATIONS IN GENERAL

Simulators and simulationtechnique have traditionally been used in connection to education and training of pilots in the aircraft and for operators in the nuclear power industry and in some cases for ships.

The development of simuators increases at the same time as the devlopment of the automation of processes. Better computers and grafhic capabilities will give better opportunities to use simulators for different operations in the process industry.

The simulation program like the one that has been developed at SIK can be used for education of the staff but it can also be used for tests to find out how different changes of the process parameters like temperature, particle density, particle geometries and flow conditions influence the lapse of the process. It can also be a valuable tool to get support in different decision oppotunities.

DESCRIPTION OF THE SIMULATED PROCESS AND THE PRODUCT

The simulated process consists of a given number of exchangers for heating of the product, a given number of exchangers for cooling of the product and a holding tube between the heating and the cooling units. (See figure below).

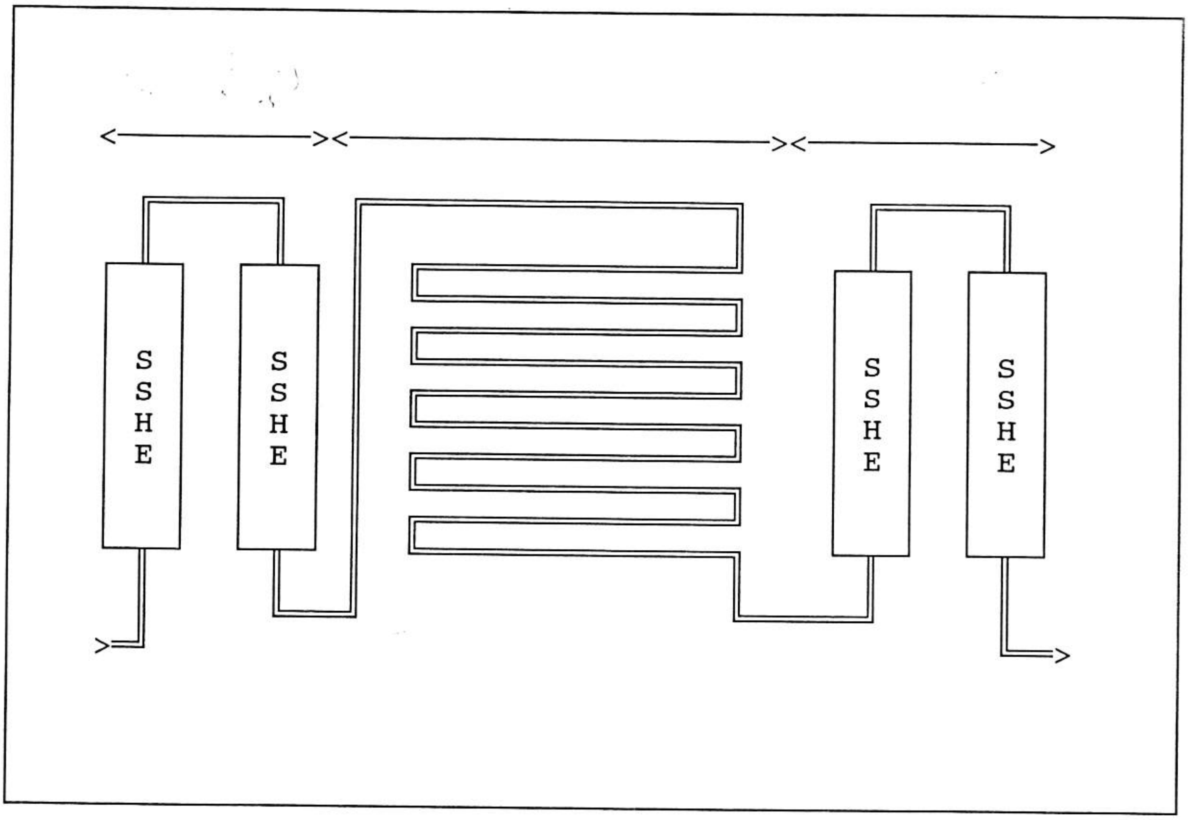

Figure 1 The simulated process

The product, that consisting of a fluid containing particles, is heated in the heat exchangers before the holding tube. The temperature profile in the exchanger depends on the flow conditions in the heat exchanger, the steam temperature and the design of the exchangers. The temperature development in the holding tube, including the temperature drop due to loss of heat from the liquid to the particles is calculated by the program. The holding tube is used to allow the product to reach the required F-value in the centre of the fastest moving particle at the sterilization temperature. The geometry and the size of the particles are input variables in the program. The relationship between the weight /volume of the particles and the fluid must also be entered.

RESULTS FROM THE CALCULATIONS

The computer program calculates the temperature distribution in the heated food by solving the equations in the mathematical model. The numerical method used is based on the finite difference technique.
The hardware requirements are a personal computer (IBM AT or PS/2), a plotter (HP 7550) and a printer (IBM Proprinter).

The program consists of three main parts:

I. Initiation of the calculations
II. Calculations
III. Results of Calculations

Initiation of the calculations

In the first part of the program various parameters are entered. These parameters are:

A. System
Heat Exchangers

Number of heat exchangers
Internal diameter
Length
Shaft diameter
Equipmentmaterial
Heating or cooling medium

Holding tube

Internal diameter
Thickness of material
Holding tube material
Insulation and thickness of insulation

B. Product

Temperature at heat exchanger inlet
Flow rate
Percentage of particulates
Minimum target F-value at end of holding tube
Size and geometry of the particles

Calculations

Using the output data the computer program calculates the following values:

* The temperature of the fluid
* The temperature of the particles
* The F-value of the particles
* The cook value of the particles and the fluid

Results of the calculations

The graphic capabilities give different kinds of figures and curves that can be plotted on the screen, the printer or the plotter.

The calculation gives:

- The required length of the holding tube in order to get the targeted minimum F-value in the centre of the fastest moving particle.

Other results from the calculations are:

Fluid:

- Temperature/time relationship the total lapse of the process
- Volume-average cook value/time relationship

Particle:

- Temperature/time relationship in the centre of a given particle
- F-value/time relation in the centre of a given particle
- Volume-average cook-value/time relationship.

DESCRIPTION OF THE MATHEMATICAL MODEL

The general approach for modeling of the heat transfer involves two parts:

- determination of the fluid temperature profiles over the heat exchangers and the holding tube;

- determination of the temperature and the F-value at different points of an individual representative particle.

The approach used here involves calculation of the liquid tempera-ture by use of energy balances which include energy input from steam and energy loss to the particles. The temperature profile of the fluid is used as an input variable in the subsequent calculation of the particle temperature.

The heat transfer coefficient between the fluid and the particle is used as an input variable and gives in combination with the calculated fluid temperature, the surface temperature of the particle.

Fluid temperature predictions. Within the heat exchanger, the fluid is heated by steam and loses energy to the particles. It is assumed that the particles have equal size. It is also assumed that the fluid medium is perfectly mixed in the radial direction of the heat exchanger. The process is divided into a finite number of time increments and the program calculates the temperature in the fluid at each incremented step time.

Particle temperature. It is assumed that the heat is transported into the particle by conduction. At each time step, the position of the particle is determined by use of the information about the flow rate and the residence time distribution. Heat is transferred from the liquid to the particle surface by convection heat transfer. The temperature is calculated at three different positions in the particles

* on the surface
* in the particle
* at the centre