NUMERICAL APPROACH FOR THERMAL STERILIZATION OF CANNED FOOD PRODUCTS IN A STILL RETORT

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ABSTRACT

Thermal Sterilization of canned food products involves heating up the canned food products in a closed chamber to certain temperature and maintaining it for certain duration of time, so that all the micro-organisms and bacteria are killed. Once the micro-organisms are killed they are cooled by water by sprinkler to less than the atmospheric temperature. Computational fluid dynamics (CFD) analyses provide insight on the natural convective processes occurring during the sterilization of canned liquid food. The definition and estimation of heat transfer coefficients pertaining to the transient heat transfer occurring in cylindrical food cans is presented. The present study involves about modeling out the Thermal Sterilization procedure using CFD technique. A Transient turbulence flow is modeled out using the ANSYS FLUENT. Temperature variation inside and outside canned food products are to be captured so as to know the sterilization temperature. The Macro and micro level approach is followed in order see the temperature distribution over the entire volume. Conjugate heat transfer modeling approach is incorporated to find the solid surface interfaces at the wall. A realizable K-epsilon model is used to determine the turbulence inside the volume. The results are validated with respect to the standard tests.

Keywords: CFD, Conjugate Heat Transfer, K-epsilon model.

I INTRODUCTION

Sterilization (or sterilisation) is a term referring to any process that eliminates (removes) or kills all forms of life, including transmissible agents (such as fungi, bacteria, viruses, spore forms, etc.) present on a surface, contained in a fluid, in medication, or in a compound such as biological cultural media. Sterilization can be achieved by applying heat, chemicals, irradiation, high pressure, and filtration or combinations thereof. Thermal sterilization is applicable in foods, medicine and surgery.

1.1 Quantification of sterilization

The aim of sterilization is the reduction of initially present microorganisms or other potential pathogens. The degree of sterilization is commonly expressed by multiples of the decimal reduction time D denoting the time needed to

reduce the initial number N_o to one tenth (10^{-1}) of its original value. Then the number of microorganisms N after sterilization time t is given by

$$\frac{N}{No} = 10^{(-\frac{t}{D})}$$

D is a function of sterilization conditions and varies with the type of microorganism, temperature, water activity, pH etc. For steam sterilization typically the temperature (in degree Celsius) is given as index.

For sterilization a reduction by one million (10^{-6}) is minimally required with six times of D. For transfusion or other venous injections 10^{-05} is typically required to reduce infection risks. For disinfection 10^{-05} is sufficient. Theoretically, the likelihood of survival of an individual microorganism is never zero.

1.2 Heat sterilization

A widely used method for heat sterilization is the autoclave, sometimes called a converter. Autoclaves commonly use steam heated to 121–134 °C (250–273 °F). To achieve sterility, a holding time of at least 15 minutes at 121 °C (250 °F) at 100 kPa (15 psi), or 3 minutes at 134 °C (273 °F) at 100 kPa (15 psi) is required. Additional sterilizing time is usually required for liquids and instruments packed in layers of cloth, as they may take longer to reach the required temperature (unnecessary in machines that grind the contents prior to sterilization). Following sterilization, liquids in a pressurized autoclave must be cooled slowly to avoid boiling over when the pressure is released. Modern converters operate around this problem by gradually depressing the sterilization chamber and allowing liquids to evaporate under a negative pressure, while cooling the contents.

Proper autoclave treatment will inactivate all fungi, bacteria, viruses and also bacterial spores, which can be quite resistant. It will not necessarily eliminate all prions.

For prion elimination, various recommendations state 121–132 °C (250–270 °F) for 60 minutes or 134 °C (273 °F) for at least 18 minutes. The prion that causes the disease scrapie (strain 263K) is inactivated relatively quickly by such sterilization procedures; however, other strains of scrapie, as well as strains of CJD and BSE are more resistant. Using mice as test animals, one experiment showed that heating BSE positive brain tissue at 134–138 °C (273–280 °F) for 18 minutes resulted in only a 2.5 log decrease in prion infectivity. (The initial BSE concentration in the tissue was relatively low). For a significant margin of safety, cleaning should reduce infectivity by 4 logs, and the sterilization method should reduce it a further 5 logs.

To ensure the autoclaving process was able to cause sterilization, most autoclaves have meters and chart that record or display pertinent information such as temperature and pressure as a function of time. Indicator tape is often placed on packages of products prior to autoclaving. A chemical in the tape will change color when the appropriate conditions have been met. Some types of packaging have built-in indicators on them. Biological indicators ("bio-indicators") can also be used to independently confirm autoclave performance. Simple bio-indicator devices are

commercially available based on microbial spores. Most contain spores of the heat resistant microbe Geobacillus stearothermophilus (formerly Bacillus stearothermophilus) among the toughest organisms for an autoclave to destroy. Typically these devices have a self-contained liquid growth medium and a growth indicator. After autoclaving an internal glass ampule is shattered, releasing the spores into the growth medium. The vial is then incubated (typically at 56 °C (133 °F)) for 24 hours. If the autoclave destroyed the spores, the medium will retain its original color. If autoclaving was unsuccessful the *G.* sterothermophilus will metabolize during incubation, causing a color change during the incubation.

For effective sterilization, steam needs to penetrate the autoclave load uniformly, so an autoclave must not be overcrowded, and the lids of bottles and containers must be left ajar. Alternatively steam penetration can be achieved by shredding the waste in some Autoclave models that also render the end product unrecognizable. During the initial heating of the chamber, residual air must be removed. Indicators should be placed in the most difficult places for the steam to reach to ensure that steam actually penetrates there.

For autoclaving, as for all disinfection or sterilization methods, cleaning is critical. Extraneous biological matter or grime may shield organisms from the property intended to kill them, whether it physical or chemical. Cleaning can also remove a large number of organisms. Proper cleaning can be achieved by physical scrubbing. This should be done with detergent and warm water to get the best results. Cleaning instruments or utensils with organic matter, cool water must be used because warm or hot water may cause organic debris to coagulate. Treatment with ultrasound or pulsed air can also be used to remove debris.

II. METHODOLOGY

All fluid flow problems starts with the construction of geometry, the generation of the mesh on the surfaces or volumes. This stage is done with the software Hyper Mesh, linked to FLUENT. The geometry can be also imported from other CAD software's like CATIA. For creating the mesh there are different options that Hyper Mesh provides. For 3D there are structured meshes of quadrilateral faces and other faces easier to develop like the triangles. Transporting the problem to 3D, hexahedral and pyramidal (tetrahedral) volumes can be carried out.

2.1 Geometric Model Creation

The Geometry of computational domain from the analysis point of view can be created top-down or bottom-up. Top-down refers to an approach where the computational domain is created by performing logical operations on primitive shapes such as cylinders, bricks, and spheres. Bottom-up refers to an approach where one first creates vertices (points), connects those to form edges (lines), connects the edges to create faces, and combines the faces to create volumes. Geometries can be created using the same pre-processor software that is used to create the grid, or created using other programs (e.g. CAD, CATIA, etc). Geometry files are imported to HM to create computational domain.

Table1: Dimensions of retort and cans placed

Specification	DIMENSTION
Length of retort	720 mm
Diameter of retort	600 mm
Length of can	110 mm
Diameter of can	100 mm

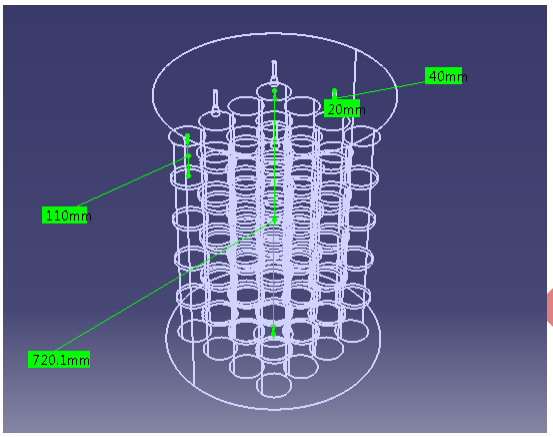


Fig1. Retort model with cans placed

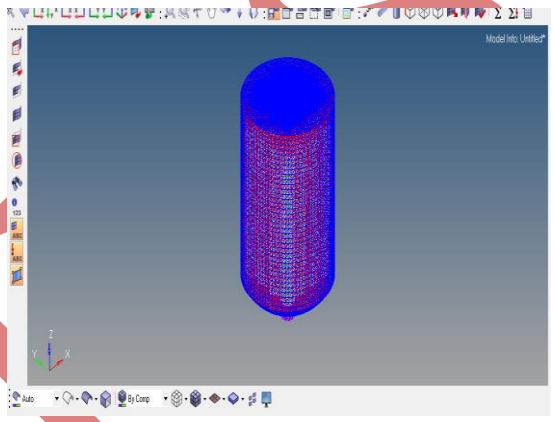


Fig2. Meshed model with 4 nozzles

2.2 Mesh generation

For the present work the meshing is done by using Hyper Mesh software. Many different cell/element and grid types are available. They are 2D (Triangle, Quadrilateral), 3D (Tetrahedron, Hexahedron, Pyramid, Wedge…) Choice depends on the problem and the solver capabilities. In boundary layers, quad, hex, and prism/wedge cells are preferred over tri's, tets, or pyramids. For the same cell count, hexahedral meshes will give more accurate solutions, especially if the grid lines are aligned with the flow. The mesh density should be high enough to capture all relevant flow features. The mesh adjacent to the wall should be fine enough to resolve the boundary layer flow.

2.3 Boundary Conditions

- Bottle fluid- select fluid on the other side and click set and from material dropdown list, select milk for case1 and ginger for case2. Click ok.
- Bottle wall- select wall on other side and click set. In thermal tab select coupled thermal conditions and turn on the shell conduction. The material for the bottle wall is aluminum. The wall thickness is given as 0.0005m.
- Fluid- select fluid on the other side and click set and from material dropdown list, select water-vapor. Click ok.

- Inlet- for inlet boundary condition, click the mass flow inlet and click set. And then give the mass flow rate of 0.2 kg/s and select intensity and viscosity ratio and give intensity and viscosity ratios as 10. Click on thermal tab and give the value of temperature 394K.
- Outlet- for outlet I impose outflow boundary condition because there is no reversed flow at the outlet of the domain. And the flow rate weighting is set as 1.
- Retort Wall- I use wall boundary condition for the retort wall. And use the stationary wall with no slip boundary conditions. No slip conditions are used because of, at the wall surfaces velocity is zero. The material for the retort wall is steel. Selected from material drop down list.

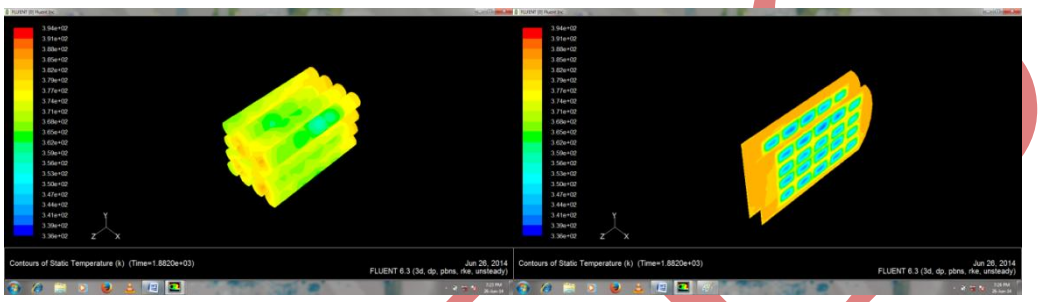


Fig3. Temperature contours on tin walls **Fig4. Temperature contours on X surfaces**

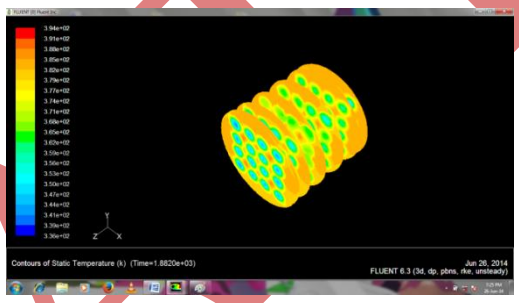
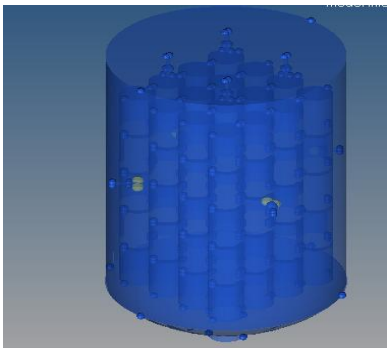


Fig5. Temperature contours in Z surfaces

The above fig3 shows that temperature distribution on the tin wall. From the figure it is clear that the corner side tins are not heating properly. The temperature contours on center tins are almost same but the outer is quite low. The fig4 shows that the temperature contours on the x surfaces. From the figure it is clear that the temperature on the top side cans are more and it decreases as go towards the bottom. At the middle region the temperature is much lesser. The fig5 shows that the temperature contours on the z direction iso-surfaces. From the figure it is clear that the temperature on the top side cans are more and decreases as we move towards the bottom. At the middle region the temperature of the can is lesser. And this place we identified as the short heating zones.

That's why put the nozzles on corner sides of the retort wall and at the centre can position. At the middle length of the retort place another 4 nozzles on the diagonal sides of the retort.



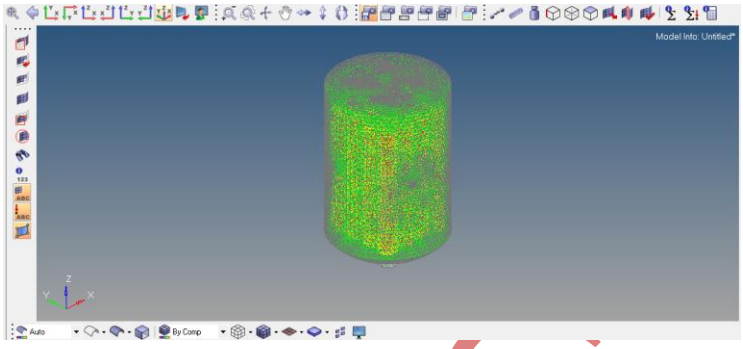


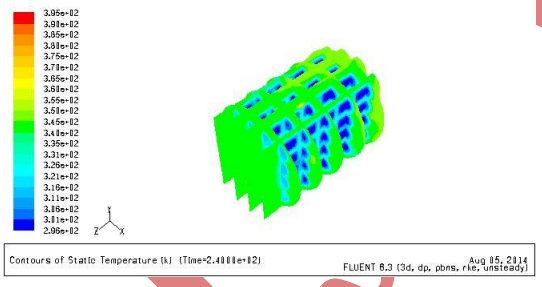
Fig6. Retort with 8 nozzles. **Fig7. Meshed model of 8 nozzle retort.**

III. RESULTS AND DISCUSSION

Here in this project discussion on the temperature distribution at various times is done. Here the temperature contours at the planes perpendicular to x-coordinate is observed the shortest heating zones if any. There is no such a short heating zones, because, we have added the extra nozzles to minimize the short heating zones. The temperature distribution in each of the cases is above the 60^0 C. At this temperature the microorganisms and bacteria or other fungus present in the canned food are killed at this high temperature.

3.1 Milk

Milk is a major canned food. It may be placed in the pouches also. But the pouches are not able to capture that much of temperature. That's why this uses the cans. The material used for the can is aluminum. The milk is pasteurized at the temperature of 60^0 C. All the viral organisms present in the milk are killed at that temperature. Some of the temperature contours at different times are identified from the contours



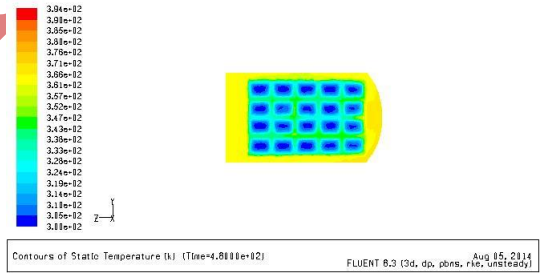
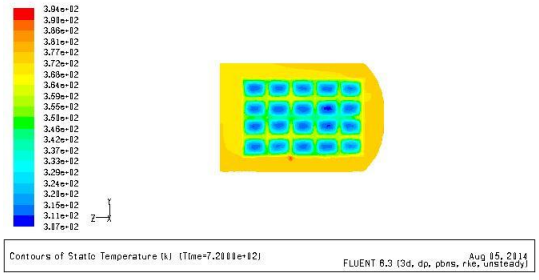


Fig8. Temperature on X and Z surfaces at 240s. **Fig9. Temperature contour at 480s**



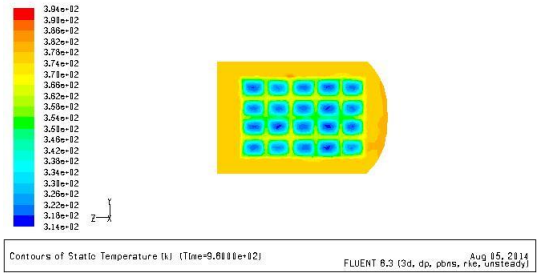


Fig10. Temperature contours at 720s **Fig11. Temperature contours at 960s**

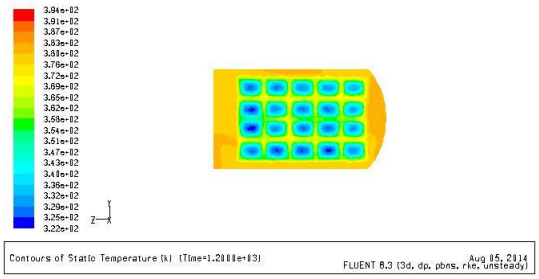


Fig12. Temperature contours at 1200s

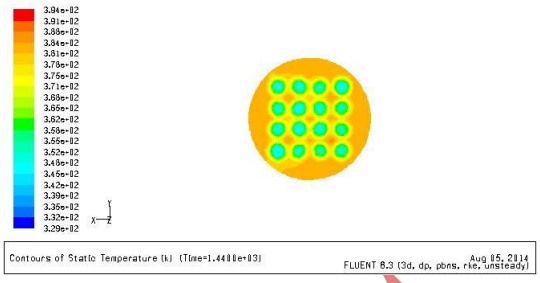


Fig13. Temperature contours at 1440s

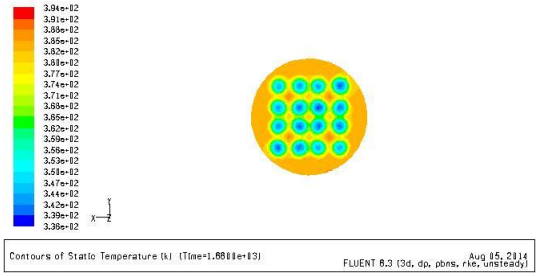


Fig14. Temperature contours at 1680s

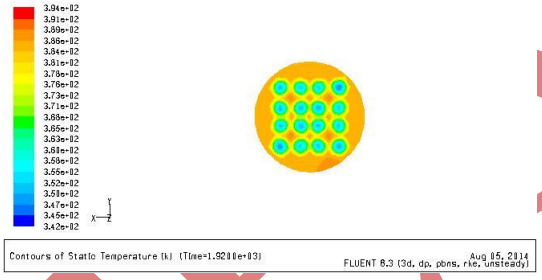


Fig15. Temperature contours at 1920s

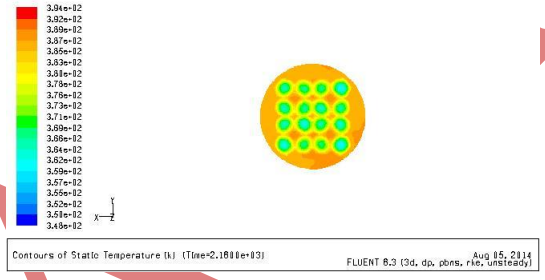


Fig16. Temperature contour at 2160s

From the above 9 figures the minimum temperature inside the can that is minimum temperature of milk inside the can is noted for the different intervals of time in reaching the sterilization temperature.

Table2. Minimum temperature at different time intervals

Time in sec	Minimum temperature for milk
240	296.0307
480	300.19
720	306.6794
960	314.0526
1200	321.5828
1440	328.8735
1680	335.7426
1920	342.0622
2160	347.8205

3.2 Ginger paste

Ginger is a new canned food. It may be placed in the pouches also. But the pouches are not able to capture that much of temperature. That's why we go for the cans. The material used for the can is aluminum. The milk is pasteurized at the temperature of 60^0 C. All the viral organisms present in the milk are killed at that temperature. Some of the temperature contours at different times are identified from the contours.

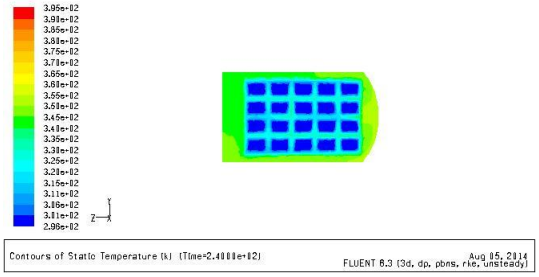


Fig17. Temperature contour at 240s

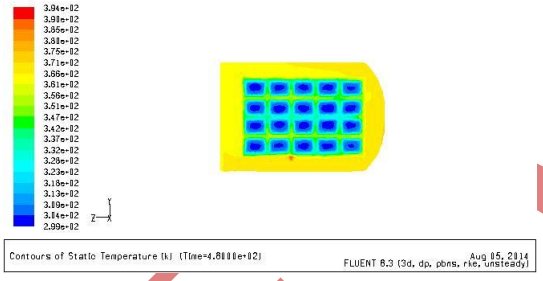


Fig18. Temperature contour at 480s

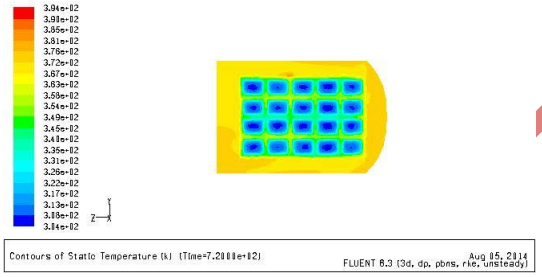


Fig19. Temperature contour at 720s.

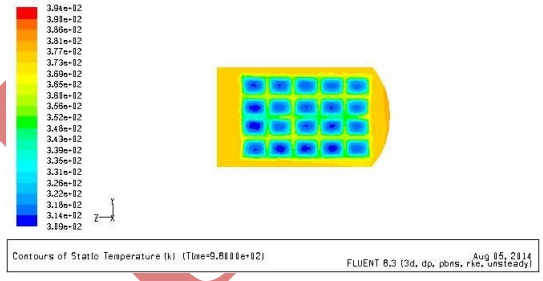


Fig20. Temperature contour at 960s

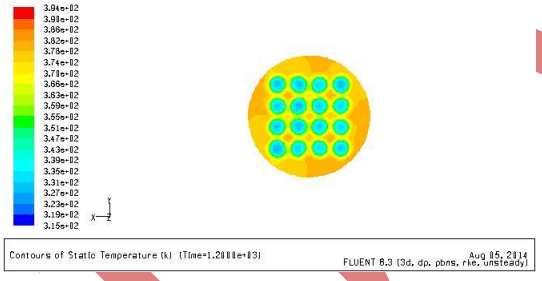


Fig21. Temperature contour at 1200s

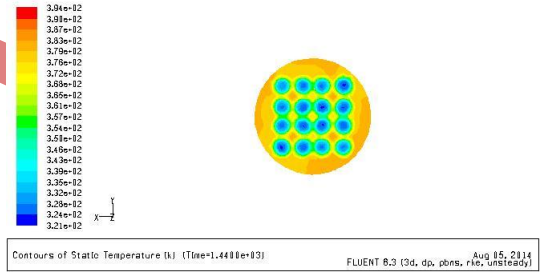


Fig22. Temperature contour at 1440s

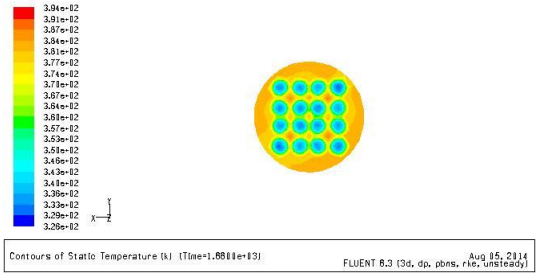


Fig23. Temperature contour at 1680s

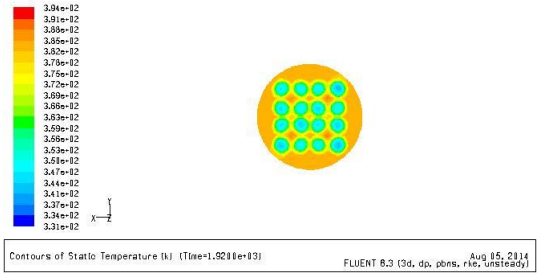


Fig24. Temperature contour at 1920s

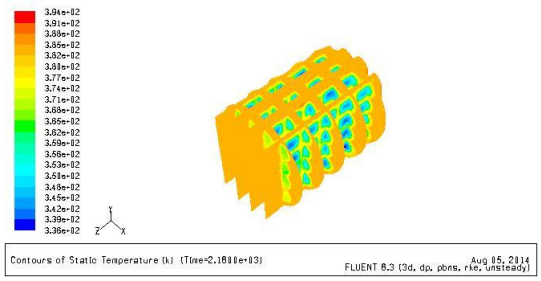


Fig25. Temperature contour at 2160s

From the above 9 figures the minimum temperature inside the can, that is minimum temperature of milk inside the can is noted for the different intervals of time in reaching the sterilization temperature.

Table3. Minimum temperature at different intervals of time

Time in sec	Min. temperature for ginger
240	295.6656
480	298.9982
720	303.7914
960	309.3061
1200	315.0234
1440	320.6413
1680	326.037
1920	331.1238
2160	335.8893

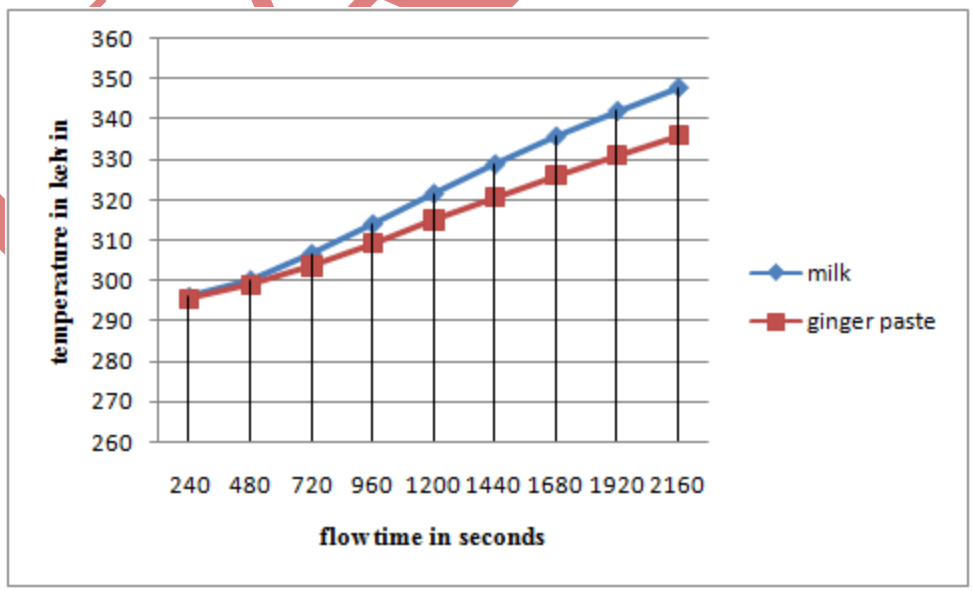


Fig26. Temperature v/s flow time

The above graph shows the variation of temperature as the time proceeds. And also it shows hoe the temperature varies as the can fluid is changed. And also it shows the time of steam spray required to heat the can fluid to a required temperature.

IV CONCLUSION

This project can be concluded that,

- Four nozzle retort is not sufficient to heat the entire cans at the same time. There are much short heating zones. At the corner of the arrangement the cans are not heated to the temperature of 60^0 C. but in the center gaps the temperature is more. That's why these corners are regarded as the short heating zones.
- By applying another four nozzles to the corners where cans are not heated to that much of temperature the temperature at the outer wall of the retort is almost uniform. And also the time taken for the heating of cans is reduced.
- Eight nozzle retort is more accurate and heat distribution is more uniform. We achieve required temperature more quickly than the four nozzle retort.
- The heating of can fluid inside the retort is from the can walls towards the center. That's why the temperature at the center is less and increases as moving towards the wall of the cans.
- For milk sterilization the temperature of 60^0 C is achieved at around 1680 seconds. That is at the center of the can the temperature is 60^0 C. and the whole temperature is maximum than the 60^0 C.
- For the sterilization of zinger paste the temperature of 60^0 C is achieved at around 2160 seconds. As same as the case for the milk.
- Ginger paste takes most time to heat up to the thermal treatment. But the milk takes less time to heat up to the thermal treatment.

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