DIMENSIONLESS CORRELATIONS FOR CONVECTIVE HEAT TRANSFER TO CANNED LIQUID PARTICLATE MIXTURES UNDER AXIAL AND END-OVER-END ROTATION PROCESSING

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Outline

- Introduction
- Objectives
- Materials and Methods
- Results and Discussion
- Conclusions

Introduction

Thermal Processing

- Most efficient method of food preservation
- Principles of thermal processing:
  - Safety and shelf stability
  - Reduce the number of microorganisms of public health concern
  - Create an environment to suppress the growth of spoilage microorganisms

Introduction

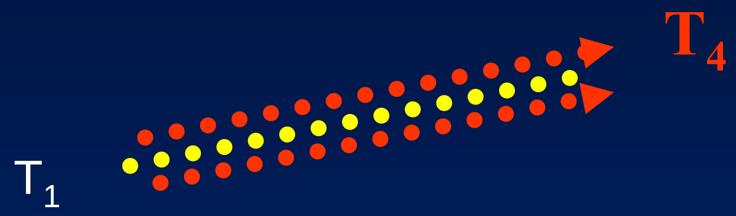
- ➢Today the Consumer demands more than safe and self stable product

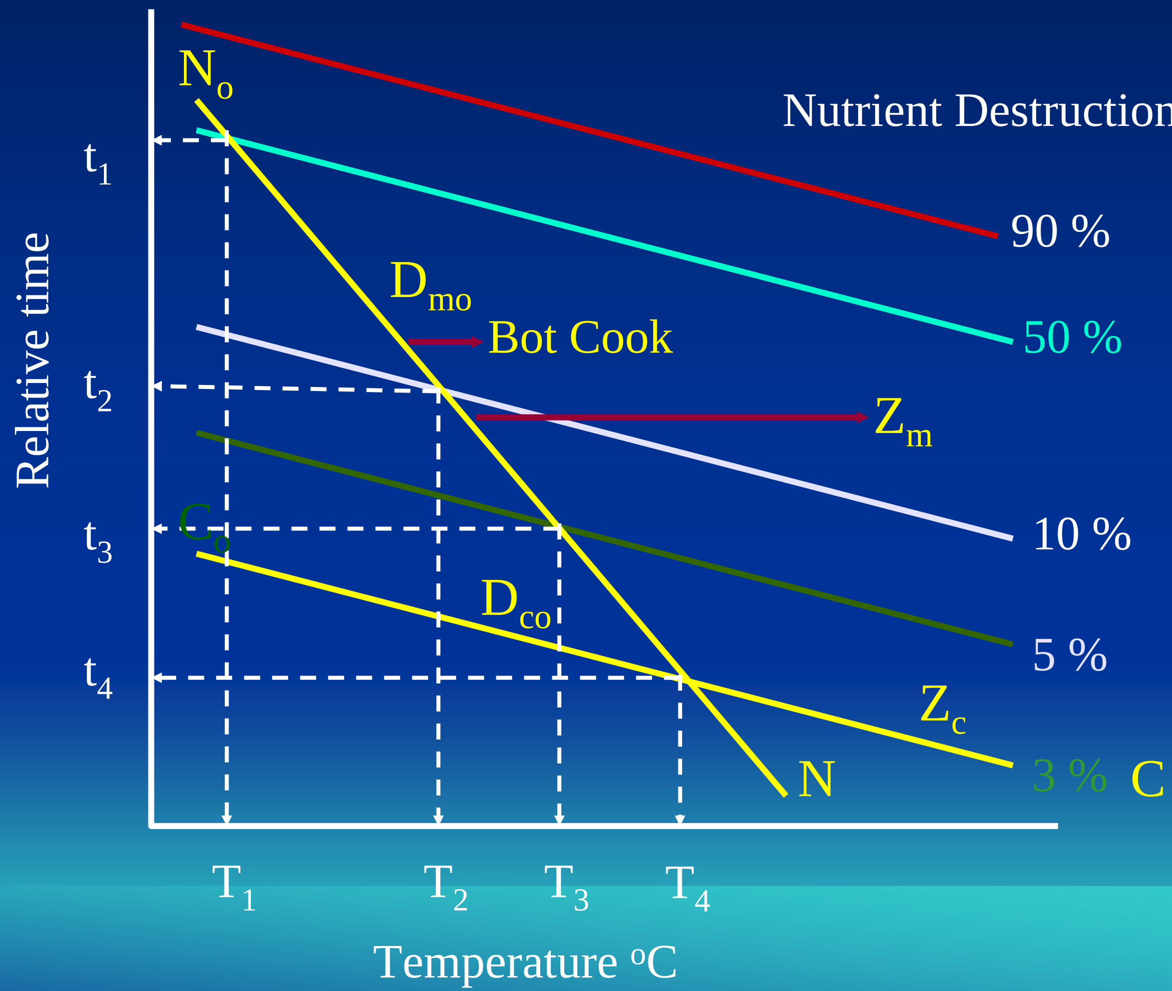
- ➢Processors demand technology which is
- ➢More efficient
- ➢Cost effective

➢**HTST** process is designed to meet the aforementioned processors and consumers demand

- ❖Minimizing the severity of heat treatment
- ❖Promoting product quality

HTST Principles



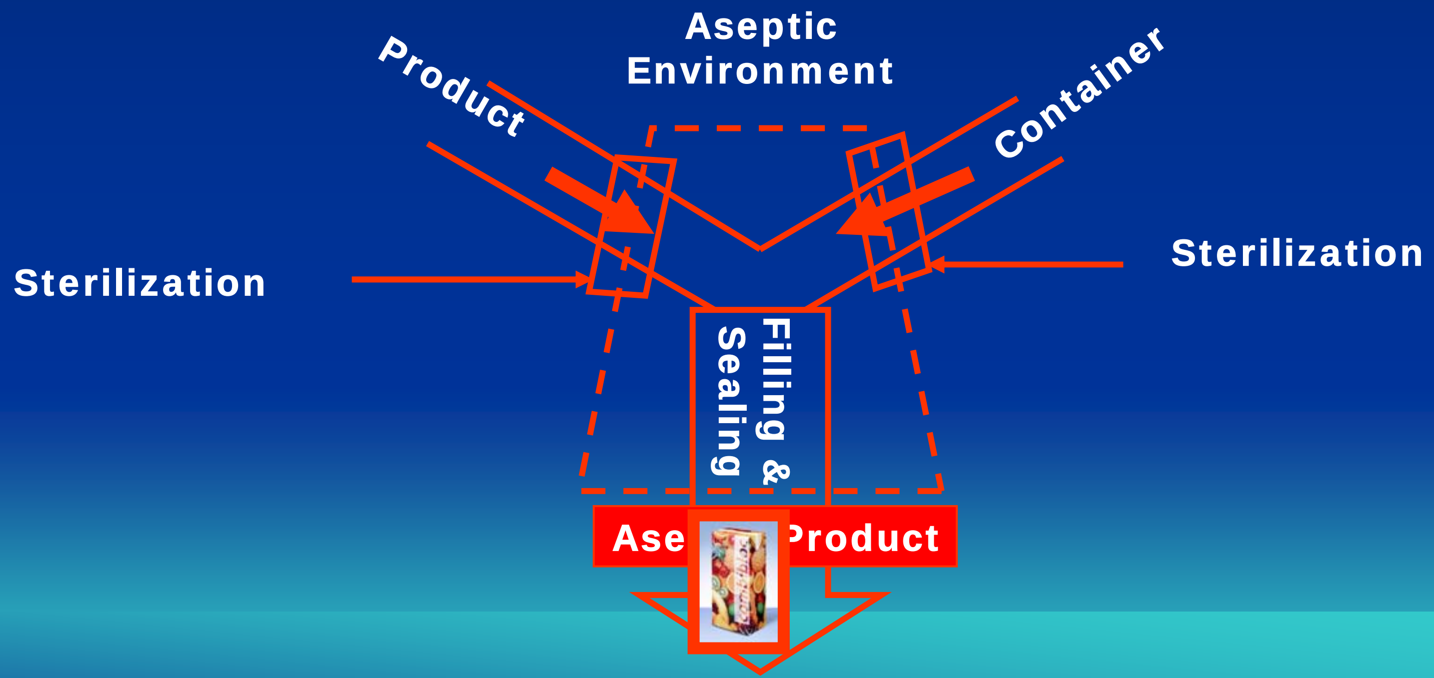


Three Major developments in HTST processing

Aseptic processing and Packaging (1)

➢What is Aseptic processing?

Process in which commercially sterile products are filled into pre-sterilized containers and sealed hermetically in a sterile environment.



Three Major developments in HTST processing

Thin Profile Packaging and Processing (2)

➢What is thin profile packaging?

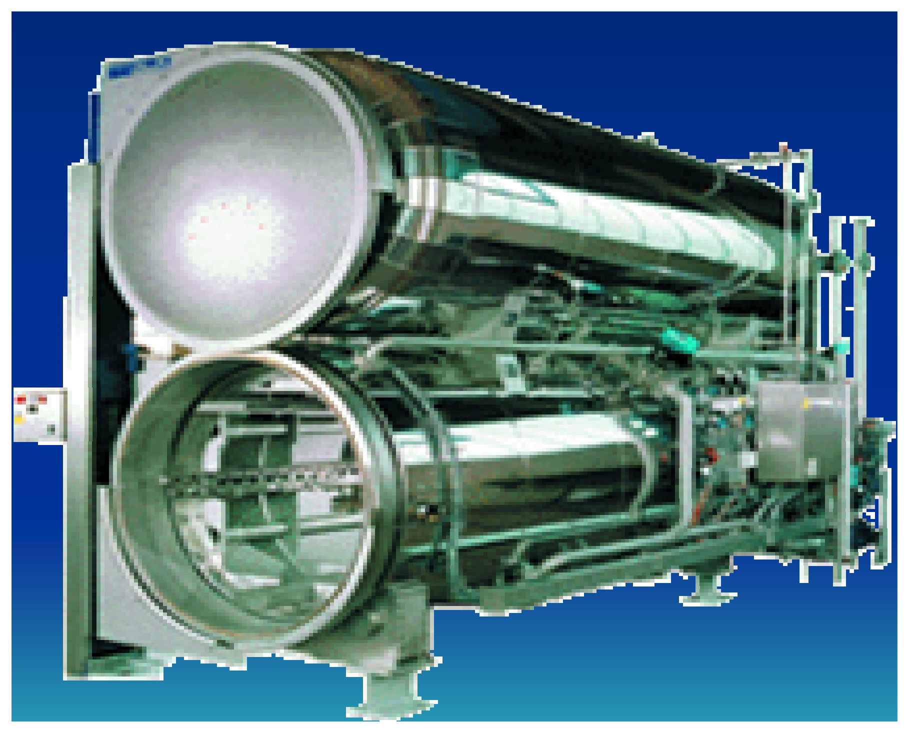
- ❖ Thin profile semi rigid containers,
- ❖ Large surface area
- ❖ Faster heating and cooling
- ❖ Promotes better quality retention

➢Applications:

- ❖Liquid, Semi solid & Solid products

Three Major developments in HTST processing

Rotational retorts Processing (3)

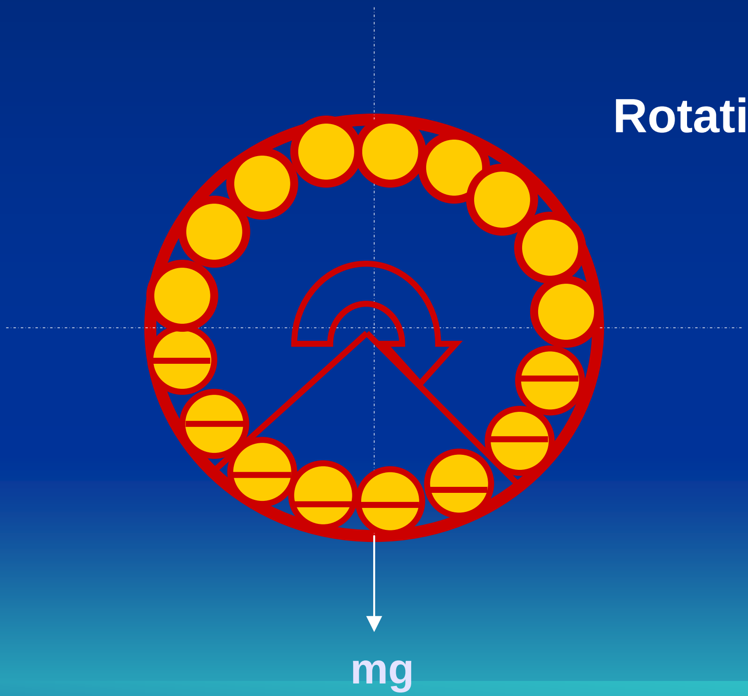


Technological Improvements (3)

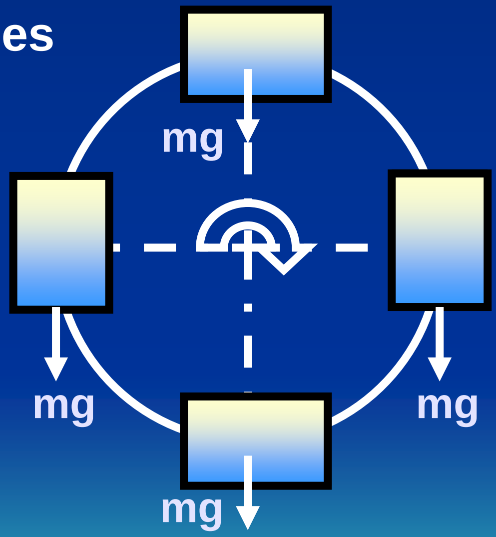
- Rotational /Agitation Processing
- Filled containers are subjected to agitation during process
- Agitation helps to induce mixing and improve heat transfer
- Achieves faster heating and cooling
- Better product quality

Different Modes of Rotation in Agitation retorts

Rotational Modes



Axial Rotation (Continuous Operation)



End over end rotation
(Batch Operation)

Introduction Cont..

- Rotational retorts either in end-over-end or axial modes can enhance the heat transfer to products
- Particulate/liquid canned foods are mostly processed in rotational retorts

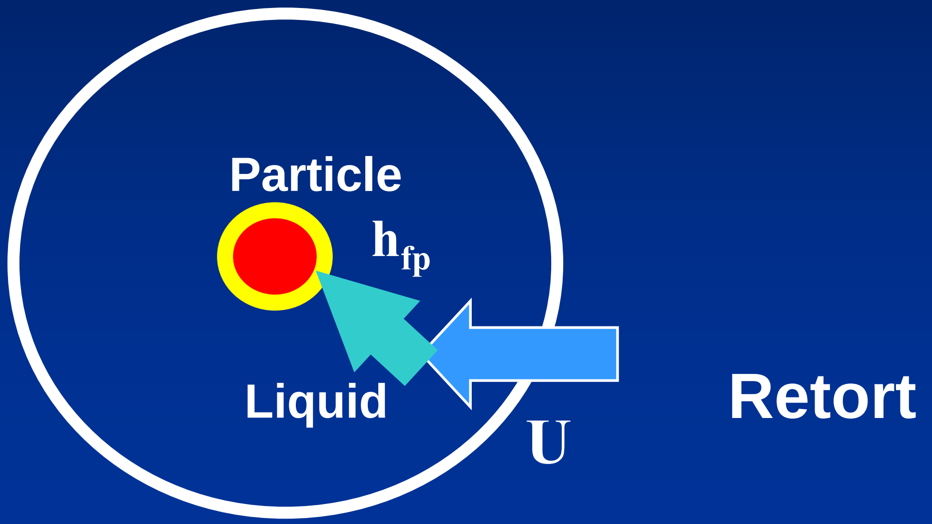
Process Parameters

U and h_{fp}

are commonly used

to quantify the heat

transfer process.



U : **Overall heat transfer coefficient**

h_{fp}: **Fluid to particle heat transfer coefficient**

➢ Why is it difficult to study heat transfer in free axial agitation?

- **Evaluation of (U and h_{fp}), are challenging :**
  - **Attaching temperature sensors**
  - **Collection of data**

- **Knowledge of U and h_{fp} is important in predicting the particle center lethality**

A new method was developed to measure U and h_{fp} associated with canned liquid/particle mixtures, subjected to axial agitation processing

Presented in IFTPS Annual meeting - 2007

Dimensionless correlations

- Dimensional analysis is a preferred and widely used Technique to quantify a heat transfer process (predicting heat transfer coefficients)

- It permits the grouping of physical variables that affect the process of heat transfer in terms of dimensionless numbers

- These dimensional numbers give a better understanding of the physical phenomenon and can also be easily used for scale-up purposes.

Objectives

To develop the dimensionless correlations for overall as well as fluid to particle heat transfer coefficients for liquid-particle mixtures in cans subjected to

To compare the correlations between end over end mode and free axial mode using only liquid in the cans.

General Methodology

Parameters	Experimental range
Retort Temperature	111.6,115,120, 125,128.4 ^{0}C
Rotation speed	4,8,14,20,24 rpm
Can headsp	
Test liquids	00 % glycerin
Test particle	Teflon
Particle Size	0.019, 0.02225 and 0.254 meters
Particle concentration	20 %, 30 % and 40 %

Retort temperature :
111.6, 115, 120, 125 and 128.4

Dimensionless correlations set up

Parameters	Experimental range
Retort Temperature	111.6,115,120, 125,128.4^{0}C
Rotation speed	4,8,14,20,24 rpm
Can head	[illegible]
Test liqui	,100 % glycerin
Test part	nd Teflon
Particle Size	0.019, 0.02225 and 0.254 meters
Particle concentration	20 %, 30 % and 40 %

Rotational Speed :
4, 8, 14, 20 and 24 rpm

Dimensionless correlations set up

Neural network models set up

Parameters	Experimental range
Retort Temperature	111.6,115,120, 125,128.4^{0}C
Rotation speed	4,8,14,20,24 rpm
Can head	
Test liqui	,100 % glycerin
Test part	nd Teflon
Particle Size	0.019, 0.02225 and 0.254 meters
Particle concentration	20 %, 30 % and 40 %

Glycerin Concentration : 80,84,90,96,100 %

Dimensionless correlations set up

Neural network models set up

Parameters	Experimental range
Retort Temperature	111.6,115,120, 125,128.4 ^{0}C
Rotation speed	4,8,14,20,24 rpm
Can heads[illegible]	[illegible]
Test liquids	[illegible]00 % glycerin
Test particl[illegible]	[illegible] Teflon
Particle Size	0.019, 0.02225 and 0.254 meters
Particle concentration	20 %, 30 % and 40 %

Test Particle :
Polypropylene, Nylon and Teflon

Dimensionless correlations set up

Neural network models set up

Parameters	Experimental range
Retort Temperature	111.6,115,120, 125,128.4^{0}C
Rotation speed	4,8,14,20,24 rpm
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Particle Size :

0.019, 0.02225 and 0.254 meters

Dimensionless correlations set up

Neural network models set up

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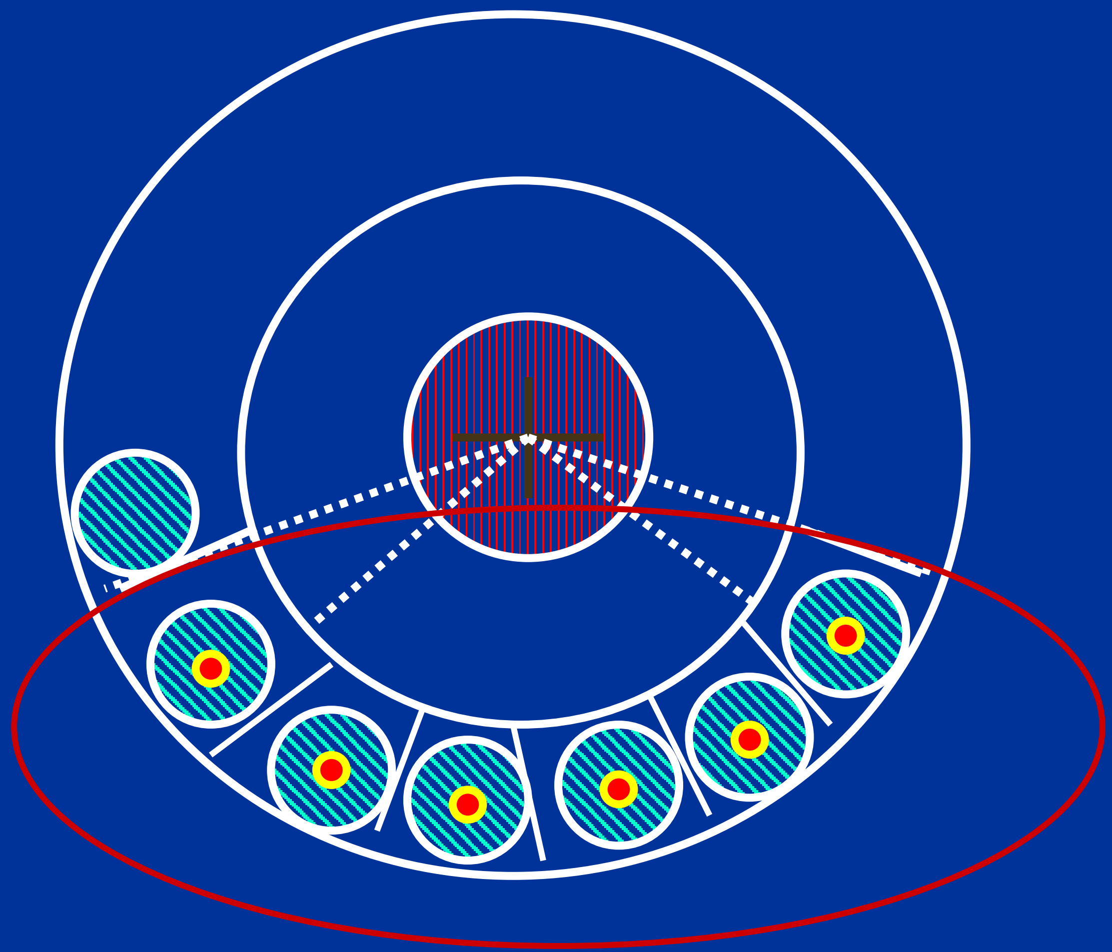
Particle Concentration : 20 %, 30 % and 40 %

Dimensionless correlations set up

Neural network models set up

DC in steritort -Formulated – on the basis; heat transfer -complex combination natural and forced convection ;Rotate only in lower 1/3rd part



Dimensionless Groups

Description	Relationship	Significance
Reynolds number	$\mathrm{Re} = \dfrac{\rho u d_{ch}}{\mu}$	Visualize the flow characteristics of a liquid
Prandtl number	$P_r = \dfrac{\mu c_p}{k}$	Thickness of hydrodynamic to thermal boundary layer (ν/α)
Nusset Number	$Nu = \dfrac{h d_{ch}}{k}$	Heat transfer caused by convection
Froude number	$Fr = \dfrac{d_{ch} N^2}{g}$	Resistance of an object moving through liquid
Grashof Number	$Gr = \dfrac{g\beta(T_s - T_\infty) d_{ch}^3}{\nu^2}$	Flow characteristics over an object

Characteristic length

$$RR + R_p + R_c$$

RR: Reel Radius;
Rp: Radius of the particle
Rc: Radius of the can

for both Fixed and Free Axial Mode

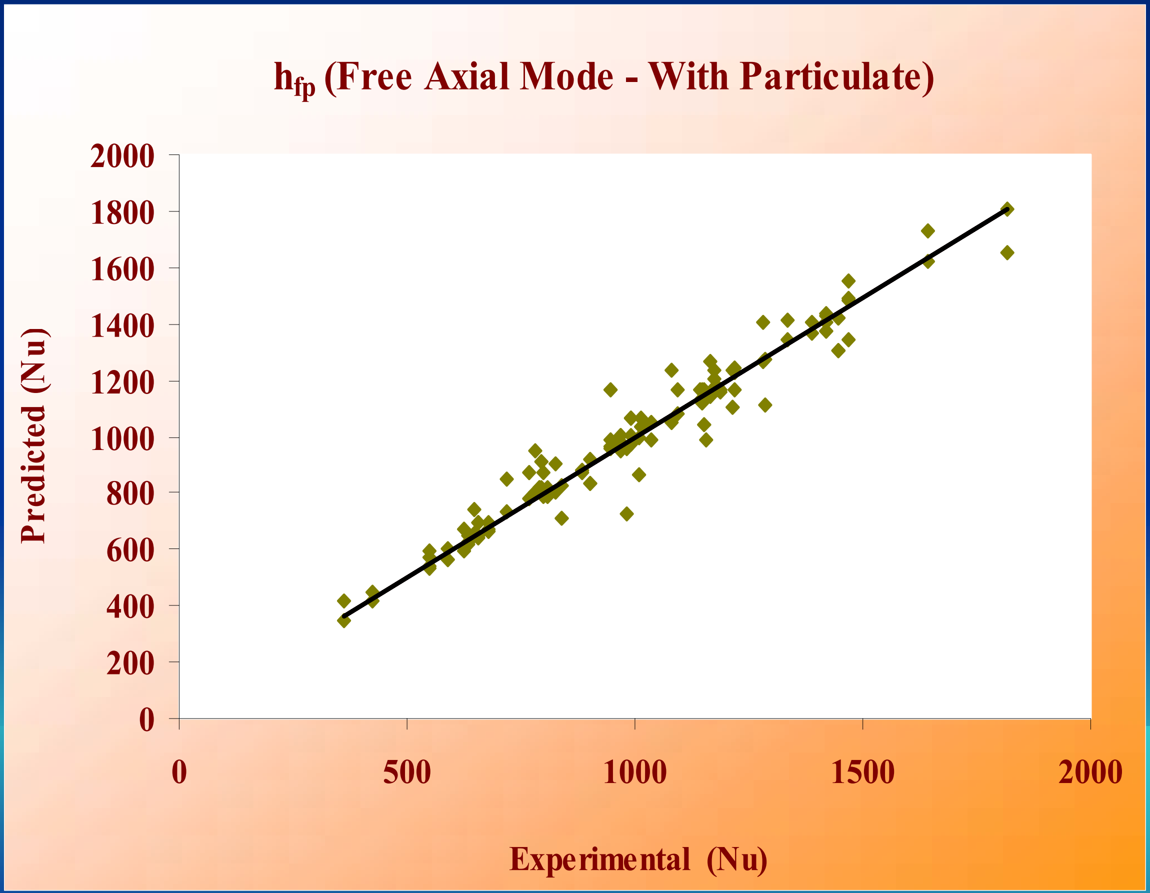
Regression Analysis used

A multiple linear regression analysis for developing forced convection correlations

A step-wise multiple non-linear regression analysis was used to develop the mixed convection dimensionless correlations

h_{fp} in a canned liquid/particulate mixture

$$N_u = 20\left(G_rP_r\right)^{\ldots} + 0.0095\left(R_e\right)^{0.72}\left(P_r\right)^{\ldots} \times \left(F_r\right)^{.195} \times \left(\frac{\rho_p}{\rho_l}\right)^{1.165} \times \left(\frac{e}{100-e}\right)^{.022} \times \left(\frac{d_p}{D_c}\right)^{-1.05} \left(\frac{k_p}{k_l}\right)^{2.26}$$



$$Nu = A_1 (G_r P_r)^{A2} + A_3 (\rho_p/\rho_l)^{A5}, (d_p/D_c)^{A6}, R_e^{A7}, F_r^{A8}, P_r^{A9}, PC^{A10}$$

Free Convection ←→ $A_1 (G_r P_r)^{A2}$

Forced Convection ←→ $A_3 (\rho_p/\rho_l)^{A5}, (d_p/D_c)^{A6}, R_e^{A7}, F_r^{A8}, P_r^{A9}, PC^{A10}$

Description	Pure Forced		Mixed Convection	
	R^2	SS	R^2	SS
Free Axial U, with particle	0.85	213947	0.92	175873
Fixed Axial U, with particle	0.84	115585	0.93	84388
Free Axial h_{fp}, with particle	0.80	180504	0.90	99453
Fixed Axial h_{fp}, with particle	0.81	247587	0.95	126434
Free Axial U, without particle			0.96	39132
EOE, U without particle	0.81	577.57	0.97	224

Conclusions

Dimensionless correlations for mixed and pure forced convection were developed with and without particulates in Newtonian fluids during all modes of agitation

Higher coefficients of correlations showed that in all forced convection situations, the natural convection phenomenon continues to operate because of buoyant forces.

Thank You

Dr. H.S. Ramaswamy

all of you for your kind attention

"End"

Academic studies

Industries focus

Heat penetration studies

Calculate:

Heat penetration parameters:

Fh, jch, Lethality (General method)

Mathematical models: To predict time temperature profiles for conduction, convection or combined conduction and convection heating products using finite difference or element methods.

1. Regression models
2. Dimensionless correlations
3. Neural network