



Transient Conduction-Convection

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About the Experiment

- The experiment studies natural and forced convection methods of heat transfer via a water bath respectively.
- The heat transfer coefficient of the various shapes of metals at specific conditions was obtained. The Biot number was used to prove which geometry shape satisfies the lumped heat capacity model.
- This simulation was to understand and solve the design problems, relating to control fluids of varying geometries, which are heated and cooled to temperatures of 120°C and 0°C respectively.



Schematic and Procedural Information

- Dimensions for the solid were measured with a caliper. The temperatures for the two hot water baths were maintained using hot plates.
- Thermocouples were embedded in all the solids.
- Temperature was recorded via LabVIEW, data2d.
- The forced convection trials were done in triplicate for the solids at three initial temperatures: +50°C, +40°C, and +30°C. The time it took to reach a temperature difference of -5°C was recorded.
- For the forced convection trials, the agitator was set to 400 RPM.

Basic Dimensions		
Shape	Diameter (mm)	Height (mm)
Cylinder	50.76	151.29
Sphere	50.8	...

Maximum Dimensions			
Object	Diameter or Length (mm)	Height (mm)	Width (mm)
Cylinder	50.81	151.33	...
Sphere	50.74
Rectangle	151.21	11.01	25.51

Introduction

- Convection:** heat transfer process between a solid object and a moving fluid.
 - Forced convection:** fluid flow caused by external means, i.e. fan blowing wind, agitator stirring water.
 - Natural convection:** fluid flow caused by density differences occurring fluid temperature variations.

For this experiment to determine the convection heat transfer coefficient the lumped heat capacity model (LHCM) approximation was assumed. This means that the temperature within a solid object is assumed to be spatially uniform at any instant throughout the cooling process. This theory implies that the temperature gradient within the solid is considered negligible in comparison to that across the solid fluid interface. Therefore, the heat transfer equation may be written as:

$$hA_s(T - T_\infty) = \rho V c_p \frac{dT}{dt} \rightarrow \text{regular heat transfer equation}$$

$$\frac{dT}{T - T_\infty} = -\frac{hA_s}{\rho V c_p} dt \rightarrow \text{LHCM}$$

h : convection heat transfer coefficient $\frac{W}{m^2 \cdot K}$ + non dimensional temperature difference
 ρ : density V : volume c_p : heat capacity t : time
 A_s : surface area of the solid



- The Biot number (Bi) is the ratio of the thermal resistance of the solid by conduction and the fluid by convection if the Bi number is greater than 0.1 it does not satisfy the LHCM.

$$Bi = \frac{hL_c}{k_s} \quad L_c = \frac{V}{A_s}$$

Raw data sample

Forced Convection Trials at 120°C				
Object	T _{in} (°C) ± 1	T _{out} (°C) ± 1	T _{avg} (°C) ± 1	Time (sec) ± 1 s
Al Bar	1	102	5	19
Al Bar	1	102	6	33
Al Bar	1	99	5	33
Al Cyl	1	99	4	43
Al Cyl	1	99	4	41
Al Cyl	1	97	4	43
Al Sphere	1	99	5	23
Al Sphere	1	97	4	27
Al Sphere	1	95	4	26

Tabulated Data

Forced Convection Trials at 120°C		
Object	Mean h (W/m²K)	Mean Bi
Al Bar	1744	0.00022
Al Cyl	1905	0.00004
Al Sphere	2219	0.00071
Al Cyl	896	0.00029
Al Sphere	871	0.000

Natural Convection Trials at 0°C		
Object	Mean h (W/m²K)	Mean Bi
Al Bar	914	0.00185
Al Cyl	117.2	0.00093
Al Sphere	114.9	0.00082
Al Cyl	57.9	0.00043
Al Sphere	105.4	0.00121

Design Problem solution

T _{in} (°C)	T _{out} (°C)	Time (sec)
Shape		
Cylinder		110.4
Sphere		283.6
Rectangular		111.3

Results and Conclusions

- The design problem and experimental results, follow a similar trend.
- As the surface area decreases, h increases, therefore Bi increases.
- The time taken for the solid to reach the desired temperature increases as the value of Bi decreases.
- Decreasing the total thermal resistance of the solid, allowing for maximum heat transfer.
- It is for laminar flow, normally seen in natural convection is lower than it is turbulent flow, which was observed during forced convection processes.
- Turbulent flow has a thin stagnant fluid film layer on the heat transfer surface.

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underline the antecedent twice if the antecedent is a relative

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