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EEGRC Poster: Experimental Design and Measurement of Internal and External Flow Convection Coefficient Using 3D Printed Geometries

Mr. Michael Golub, Indiana University Purdue University, Indianapolis

Michael Golub is the Academic Laboratory Supervisor for the Mechanical Engineering department at IUPUI. He is an associate faculty at the same school, and teaches part-time at two other colleges. He has conducted research related to Arctic Electric Vehicles. He participated and advised several student academic competition teams for several years. His team won 1st place in the 2012 SAE Clean Snowmobile Challenge. He holds a M.F.A. in Television Production, a B.S. in Mechanical Engineering, and a B.S. in Sustainable Energy.

Experimental Design and Measurement of Internal and External Flow Convection Coefficient Using 3D Printed Geometries

Joseph Derrick, Michael Golub, Samuel Attoye,
MD Minal Nahin, Vaibhav Shrivastav
Purdue School of Engineering & Technology
Indiana University-Purdue University Indianapolis

IUPUI
DEPARTMENT OF MECHANICAL ENGINEERING
SCHOOL OF ENGINEERING AND TECHNOLOGY
A Purdue University School
Indianapolis

Abstract

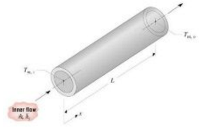
The convection heat transfer is explored for a new academic laboratory experiment to help address the lack of practical experimentation due to the continued integration of technology. A cost-effective design is generated with three core principles: 1) Low Cost, 2) Low Maintenance, and 3) Concept Visualization. This is achieved through the following description of the apparatus. The plexiglass chamber has a square base with a designated height. At the bottom of the chamber, there is a rectangular section removed to act as an inlet to the chamber. A high powered mini turbine fan is located at the top of the chamber. The fan acts as the driving force that pulls in the surrounding air from the inlet to generate a flow within the chamber. A door is located on the front of the chamber to allow for interchanging of different test geometries. The geometries being used are 3D printed to components either in the form of a fin (External Flow) or a hollowed channel parallel to the flow (Internal Flow). The components are mounted to the door with cylindrical heater connecting the two. The components are heated until steady state, where the average temperature along the surface is calculated. The velocity, surface temperature, and ambient temperature are record using a data acquisition system. The resulting convection coefficients are then determined.

Introduction

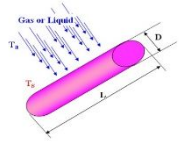
Convection Heat Transfer Coefficient:

- $h(T_s, T_\infty, V, \rho, \mu, Geomtery, Flow\ Regime, Flow\ Type)$
- Large number of dependencies
- Type Types of Flow: Internal vs External
- $h = \frac{Nuk}{D}$, where Nu is the Nusselt Number, k is the film conduction coefficient, and D is the diameter.

Internal Flow



External Flow



Design and Methodology

Design

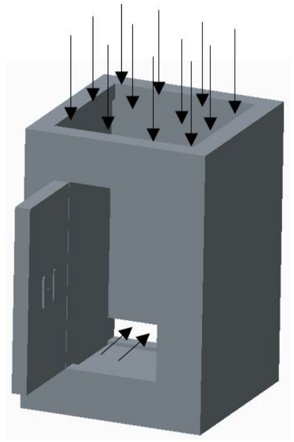


Figure1: Conceptual Design

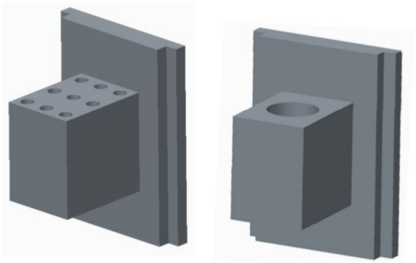


Figure 2: Internal Flow
(Left: Tube Array and Right: Single Tube)

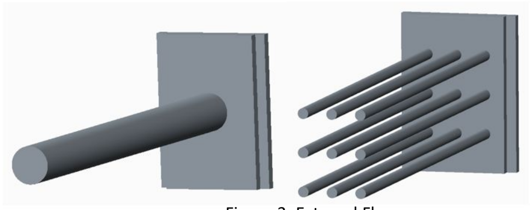


Figure 3: External Flow
(Left: Single Fin and Right: Fin Array

Methodology

(1) Set the velocity on the Fan to a desired value.

(2) Place a cylindrical heater inside the component (heater is wired through door) and set the input.

(3) Wait until steady state is achieved and then record the temperature using thermocouples placed along the component and ambient temperature of fluid as well.

(4) Using empirical formulations provided in several texts, determine Nusselt formulation.

(5) Calculate the convection coefficient for the given conditions.

Benefits

Educational Advantages

1. Practical, hands on approach
2. Allows for design, build, and test opportunities for students
3. Can be incorporated into multiple laboratory experiments

Cost Advantages

1. 3D printing inexpensive to make
2. Total production cost is just under $300 dollars
3. Savings obtained from multipurpose use of apparatus

Conclusion

Recommendations

- Incorporate an Infrared Camera to monitor temperature distribution for steady state
- Develop more complex geometries for testing
- Design a more accurate, cost effective system of surface temperature measurement

Next Steps

- Construct the apparatus for testing.
- Test standard well-known geometry components to verify functionality and usability.
- Determine additional experimental laboratory uses for apparatus.