Energy Saving Improvements for Industrial Ovens
Simulation and Experimental Validation of Oven Air Seal Performance
William DeKam and Jim Martlew (Undergraduate Research Assistants)
Claudia M. Fajardo (Advisor)

1. Project Overview

The objective of this project is to reduce energy consumption in industrial curing ovens by increasing hot-air containment within the oven. The proposed solution will be derived from a systematic study of the oven and its sealing mechanism using experimentally-validated computer simulations.

Background
“Curing” refers to the industrial process by which polymer-coated parts are heated until the polymer forms cross-links and hardens. Cured surfaces are used in a variety of consumer products ranging from small sheet metal parts to large outdoor furniture components.

A large percentage of the energy supplied to ovens for curing processes is lost through the door due to sub-optimal design of the oven door sealing mechanism. Buoyancy causes an uneven top-to-bottom temperature distribution near the oven exit. Fuel consumption is thus increased to achieve minimum curing temperature throughout the oven. Heat lost also tends to increase the temperature of the plant to uncomfortable levels during the summer months.

Project Benefits
1. Significant reductions in energy consumption will be attained by increasing hot air containment, producing an optimum temperature profile within the oven.
2. Increased rate of production will be made possible by this larger, more uniform region of high temperature, allowing for higher product throughput while ensuring adequate curing.
3. Substantial improvement in worker comfort during the summer months will result from the reduced amount of hot air escaping from the oven to the plant area.

2. Current Solution

Air seals provide a barrier between air masses using thin rectangular nozzles which create a “sheet” of high velocity air. These thin jets are directed across the opening of the oven to prevent the escape of hot air.

The air seal system at Rapid-Line was installed on an ad hoc basis. It is expected that improved performance is possible with an analytical approach taken toward system design and implementation.

3. Modeling the Oven

Computational fluid dynamics (CFD) software was used to simulate air motion and heat transfer characteristics within the oven and to the surroundings.

4. Model Validation

Multi-point thermocouple testing used to validate the exit profile and lengthwise temperature distributions.

A wire frame was attached to oven conveyer and used for mounting thermo-couples for end-to-end temperature measurement (pictured right).

An adjustable test stand (left) was used to make temperature measurements at points shown below in black.

5. Lengthwise Temperature

Illustration of the method for comparison between modeled and measured values of temperature taken between the entrance and the exit of the oven. Modeled results in white. Measured data in black.

6. Exit Temperature Profile

Illustrated below are the measured and model-derived exit temperature profiles. Model refinement is needed.

Discrepancy between actual and modeled temperatures result from inaccurate boundary conditions in the model; namely incorrect turbulence intensity and jet outlet velocity assumptions. The usefulness of the model depends on the realistic determination of these characteristics.

References:

7. Next Steps

1. Determine oven CFD model boundary conditions with experimentally measured velocity data using non-intrusive diagnostic instrumentation.
2. Conduct a parametric study to identify factors critical to effectiveness of air seal operation.
3. Implement the optimized seal design and quantify natural gas savings.

Thank You
Dr. John Patten, WMU
Dr. David Meade, WMU
Mark Lindquist, Rapid-Line, Inc.
Office of the Vice President for Research