Energy Saving Improvements for Industrial Ovens

Oven Air Seal

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Background

• Continuous oven uses
  – Curing
  – Drying
  – Annealing
  – Baking

• Energy sources
  – Natural gas
  – Electricity

Problem Description

- Hot air escapes through oven door openings due to buoyancy effects

- Cold air infiltrates oven interior lowering average temperature
Implemented Solution – Air Seal

- Modest improvements achieved with trial-and-error approach
- Need better understanding of the problem to optimize solution

Photo courtesy of Rapid-Line Manufacturing, taken using a FLIR ThermaCAM™
Goal and Objectives

• Goal:
  – Optimize implementation of air seals to reduce energy consumption in industrial ovens

• Objectives
  – Develop an analytical approach to predict oven performance
    • Computational tools
  – Validate the proposed model with field data
    • Experimental results
  – Evaluate changes to oven configuration
    • Minimize energy use and cost of implementation
    • Increased production via higher throughput
Benchmarking

• Focus areas
  – Ovens
    • Types, operation, heat loss mechanisms and solutions
  – Theory of turbulent buoyant jets
  – Experimental measurement techniques

• Methodology
  – Literature reviews
  – Site visits
Baseline Measurements

- Energy consumption
  - Invasive Natural gas meter well suited to low line pressure conditions
  - Provides quantitative measurement of energy use
Model Simulations

- Model capable of reproducing physical trends
  - Buoyancy and non-uniform temperature distribution
  - Energy loss out door opening
- Model requires experimental validation to ensure accuracy

Modeled Temperature Profile
Experimental Validation
Profile Temperature Measurement

- Multi-point thermocouple test
  - Requires specialized data acquisition tools
  - Setup built for 6” spatial resolution
Experimental Validation
Temperature Profile Results

Air Seals OFF

Air Seals ON
Experimental Validation
Profile Comparison, Air Seals OFF

Experimental data
Model results
Conclusions

• Designed and built test setup for accurate measurement of oven temperatures

• Quantified effects of current air seal solution:
  – Raised temperatures in lower regions of exit by as much as 20°F
  – Decreased peak temperatures in upper region of exit by around 10°F
  – Reduced temperature gradient across lower 75% of oven exit

• Present model requires refinement

• Boundary condition assumptions must be studied and reevaluated to improve accuracy
Future Work
Investigation of Boundary Conditions

• Hot air nozzle velocity and turbulence
  – Affects heat diffusion throughout oven
  – Difficult to measure directly

• Particle image velocimetry (PIV)
  – Utilizes high speed photography to gather images of illuminated particles entrained in flow
  – Statistical analysis of particle positions between images provides local fluid velocity vectors

• Laboratory model
  – Build a physical model representative of actual oven nozzle to side step difficulty of direct measurement issue
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Future Work

Investigation of Boundary Conditions

Example of PIV test setup for determining field flow characteristics

Image courtesy of www.dlr.de
Experimental Validation

End-to-End Temperature Measurement

- Lengthwise temperature through oven
  - Datapak DAQ system – provides temperature vs. time measurements
  - Experimental data compared with simulation results

Temperature probe orientation; attached to product conveyor system
Energy Consumption Measurement

• Natural Gas Metering
  – Provides quantitative results of energy use

• Methods
  – Non-invasive
    • Convenient and portable
    • Low gas pressure limits use
  – Invasive
    • Single station use
    • Suited for current application

Photos courtesy of sierrainstruments.com and omega.com