Refrigeration Modeling of a Frozen Carbonated Beverage Dispenser

November 5, 2018

Presented by:
Anthony Behe
FBD Partnership, LP

• Privately Held Limited Partnership
  – Based in San Antonio, TX
  – In business since 1996
  – Expanding operations in Asia

• Industry Leaders
  – Innovation
  – Technology
  – Market Share (>80% for FCB)
Who We Are

• Beverage Dispensing Machines
  – Frozen Carbonated Beverages (FCB)
  – Slush & Granita
  – Shakes & Smoothies

• Markets Served:
  – Convenience Stores
  – Movie Theaters
  – Resorts
  – Restaurants...
Why GT SUITE?

• Refrigeration Modeling
  – Entering new industries: shakes & smoothies, coffee, mixed drinks, etc.
  – Responsiveness to customer requests & customization
  – Adapting to regulatory requirements
  – Meeting changing customer expectations

• Product-Refrigerant Interaction
  – Dramatically varying load conditions
  – Alternative expansion gases
  – Improved control systems
Project Introduction

• Our Company’s First Introduction to GT SUITE
  – Learning how to use the software
  – Achieving a model that attains numerical convergence
  – Target: 5% correlation for suction & discharge conditions during initial pull-down and defrost cycles
Approach

- **Assumptions**
  - Calibration to Test Data
  - Parameters Tuning
    - FCB properties
    - Heat transfer properties of evaporator
    - Condenser air flow rate
    - Internal friction head loss multipliers in pipes
  - Calculated Values
    - Mass flow rates
    - Heat transfer in condenser during IPD
    - Discharge temperatures during defrost
    - Pressure drop in defrost loop
Approach

• Design and Simulation Process
  – Develop models of major components.
  – Calibrate individual components with test data.
  – Create open-loop subassemblies with controlled boundary conditions.
  – Adjust unknown, assumed parameters as necessary to get the best possible results.
  – Create a full, closed-loop assembly.
  – Continue adjusting unknown parameters until the best possible results are reached.
Challenges

• Unconventional Evaporator Design
  – Similar to a scraped-surface ice slurry generator
  – Heat ‘sink’ is limited in size, and capacity and temperature vary

• Pre-Existing Test Data
  – Non-ideal sensor placement
  – Potential setup errors

• Modes of Operation:
  – Initial Pull-Down (IPD)
  – Cyclic Freeze / Thaw
  – Defrost
Results - IPD

- Short-Range Fluctuations
  - PWM valve & overshoot
- Spike in Mass Flow Rate Early:
  - Possible condenser blockage or malfunction
  - Suspect data
Results - Defrost

- Temperature Match Issues
  - Heat transfer in the evaporator
  - Measurement issues
    - Sensor location
    - Calibration
- Pressure Match Issues
  - Pressure drop uncertainty
Observations & Takeaways

• **Modeling Challenges**
  - PWM Valve vs. TXV
  - Control issues (re: superheat target)
  - Mass flow rate and correction calculations
  - Condenser heat transfer values and air flow rates
  - Accurate modeling of FCB and its interaction with the barrel
  - Defrost system pressure drop

• **Results**
  - Questionable observations in test data
  - Overall results are not bad – generally within the target 5%
  - Velocity in barrel insufficient to push compressor oil up the channel
Next Steps

• Evaporator Modeling
  – Capture phase dynamics of 3 phase mixture
    • Expansion / “foaming” when ice forms
    • Changing solution concentration & properties due to ice formation
      – Freezing point, specific heat, latent heat, density...
    • CO2 dissolution & effervescence
  – Encompass product draw, solution injection, and syrup / FCB mixing
  – Model temperature gradient along the axis
  – Include dynamic heat transfer characteristics through ice film layer
Questions?