Rotary Arm Design for U.S. Roaster Corp.

Prepared by CoolRoast Engineering Design Group

Drew Sutterfield, Jonathan Lim,
Cameron Buswell, Sibongile Hlatywayo
MISSION STATEMENT

• We are committed to working with clients throughout the design process to understand their needs so that we can provide practical engineering solutions that exceed customer expectations.
Sponsor Information

- Based in Oklahoma City, OK.
- Fabricate and sell Coffee Roaster machines to clients.
  - Primarily U.S. cliental
- Repair of Coffee Roaster machines manufactured by other companies
- Sell fresh-roasted coffee beans
• Cliental Survey results showed that cooling system of machines could be improved.

• Preferable to maintain some traditional aspects of past rotary arms, while modernizing them as well.

• The rotary arm in the cooling bin is the most
Background Information

• Rotary arm mixes freshly-roasted coffee beans after they empty into cooling bin.
• Rotary arm can affect several key factors.
  • Uniformity of bean cooling.
  • Bean cooling speed.
  • Bin emptying speed.
• NSF standards.
Problem Definition

Design Objectives & Goals
CoolRoast Design Goals

• Work closely with U.S. Roaster Corp to design a rotary arm that will enhance the quality of their coffee roaster machines.

• New rotary arm design should perform better than the current rotary arm currently used in the U.S. Roaster Corp’s coffee roasters.

• Rotary arm design should help preserve the traditional design aesthetic of U.S. Roaster Corp’s coffee roasters.
CoolRoast Design Objectives

• Improve the uniformity of cooling of coffee beans in the cooling bin.
• Improve the rate of cooling of the roasted coffee beans.
• Improve the flow of air in the cooling bin as it mixes.
• Minimize the amount of coffee beans that are destroyed (crushed or ground) by the rotary arm in the cooling bin.
• Adhere to NSF International standards if possible.
CoolRoast Design Constraints

• Cost of materials for each prototype design should not exceed $650.

• Prototype rotary arms will be designed to fit and rotate within the current 12 kg coffee bean roaster cooling bin

• Rotary arm design should not cause coffee roaster machines to stray too far from “traditional” look.

• Final product (not prototype) should be tested and approved before April 2013.
Scheduling of Project

Gantt Chart

- Main tasks in 2012: brainstorming about testing procedures and design concepts, testing of current rotary arm, development of prototypes
- 2013: Testing and evaluating prototypes, constructing final design, completing reports.
CoolRoast
Investigations
Main Competitor

• Probat

• Founded in 1868.

• Foremost competitor for U.S. Roaster Corp.

• Represented in over 60 countries worldwide.

• Roasters for coffee beans, cocoa beans, nuts, and cereal grains.
Patent Search

• Most of the patents filed for coffee deal with commercial production of coffee, not small batch roaster machines

• Kando, M., Kishimoto, A., Katsuragi, Y. “METHOD AND DEVICE FOR ROASTING/CoolING BEAN”

• Smith JR., H.L. “METHOD FOR COOLING ROASTED COFFEE”.

• Ginn, I. M. “COFFEE-STIRRER”.
  • U.S. Patent #513179. January 23, 1894
Patent Search

- Song, E. “Coffee Roaster and Controlling Method of Same”.
Location of Testing

- Carried out in the Robert M. Kerr Food and Agricultural Products Center (FAPC).
  - Wet processing lab

- FAPC resources made testing easier
  - Ovens to heat beans
  - Sanitary area to set up cooling bin
Testing Equipment

- Cooling Bin
  - Detachable Rotary Arm
  - Fabricated by U.S. Roaster Corp
- Coffee Beans for testing
  - Donated by U.S. Roaster Corp.
- Infrared Camera
  - Visual aid of heat distribution on surface
- Industrial Ovens
Testing: Thermal Imaging

- Infrared Camera
  Provided by Dr. Frazier

- Shows uniformity of cooling on the surface of the beans
Thermal Imaging

Beans exiting oven

30 seconds
Thermal Imaging

60 seconds

90 seconds
Thermal Imaging

120 seconds

150 seconds
Mixing Test

• Visual aid test developed to look at the ability of rotary arm designs to effectively mix coffee beans
  • Compare and analyze original and prototype designs.
Mixing Test

- Originally thought that candy may imitate coffee beans
  - Testing disproved this theory
  - 3 tests
    - 2 with Jelly Beans
    - 1 with Red Hots
Mixing Test

Performed with Red Hots
Mixing Test

• Visual Area Determination method (VAD method)
  • Measuring mixing of colored material vs. roasted coffee beans.
  • Intermittent snapshots of coffee bean surface
  • Statistical distribution programs and algorithms.
  • % brown (roasted coffee beans) vs. % colored material (other material) over time.
VAD Method

- Colored Material mixed with coffee beans
- Snapshots of coffee bean surface
- Colored Material Provides contrast for snapshots
  - Material consideration list: jelly beans, Red Hots candies, white spray-painted coffee beans, different colored beans (non-coffee)

- Determine color fraction of surface beans
  - Observe distribution of colored material in coffee bean surface over time
  - Extrapolation: colored material distribution as coffee is mixed.
  - Quantify mixing ability of rotary arms
Engineering Specifications

Equations/Formulæ, Calculations, etc.
Important Factors

• Initially considered performing force and weld analysis of the current design.
• Through inspection of design with Dr. Hardin we learned that a machinery analysis wasn’t needed.
• Decided to focus on heat transfer aspect of project.
• Coffee beans encounter convective heat transfer by the air flow as well as conductive heat transfer between the beans and metal walls.
Heat Transfer Equations

- Convective: $q = h A (T_1 - T_2)$
  - Due to external argent (air)
- Conductive: $q = -k A (T_2 - T_1)$
  - Due to the transfer of energy from rotation arm to the beans.

Where:
- $q$ = heat transfer, W
- $h$ = convective heat transfer coefficient, W/m$^2$K
- $k$ = conduction heat transfer coefficient, W/m K
- $A$ = Normal area to the direction of heat flow
- $T$ = Temperature, Kelvin

- $T_1 = 450^\circ$ C
- $T_2 = 90^\circ$ C
Future Testing Plans

• From the literature we found that coffee beans have similar physical properties to that of softwood.
• Use temperature probes or to provide temperature data at different depths in the cooling bin over time.
Design Considerations

• Believe that better coffee bean circulation vertically will improve cooling rate.
• Inclined pieces of metal to help move beans upward from the bottom of the bin.
• Prevent beans from collecting in piles as they are moved.
Generation of Design Concepts
Design Criteria

• Cool coffee beans from a temperature of 450°F to 90°F within 3-5 minutes.
  • Ambient air temperature not greater than 90°F
• Improve circulation of beans throughout cooling bin
• After cooling is completed, proposed designs should reduce the time taken to remove beans from bin
• Number of broken or warped coffee beans should be minimized.
Future impacts of new design

- Successfully designed rotary arm may:
  - Increase customer satisfaction by producing a more consistent product
  - Boost sales of U.S. Roaster Corp’s coffee roaster machines
  - Reduce fabrication costs of roaster machines.
  - Provide a competitive advantage for U.S. Roaster Corp’s against competitors
Plastic Modeling

• Consulted with Doug Enns about using 3D printer to construct plastic rotary arm models.
  • 3D printing is better suited for complex, small objects

• Concluded that 3D printing would be inefficient for our applications.
Brainstorming and Conceptual Design
Brainstorming and Conceptual Design
Default Rotary Arm Design

- Current design used by U.S. Roaster Corp
Prototype 1

- Advantages
  - Easy to fabricate
  - Reduces bolts and other joint fasteners
  - Increases aeration of beans in cooling bin due to blade design

- Disadvantages
  - Does not clean sidewalls of bin
  - Currently the design is not flush between the inside plate and center piece of the bin.
Prototype 2

• Advantages
  • Increase lift caused by rotary arm, increase aeration
  • Reduction of crevices and bolts, easier to get NSF certified
  • Easier to clean than current design

• Disadvantages
  • Greater torque on motor, due to greater surface area pushing the beans
  • More metal in design, leads to higher cost of fabrication than current design
Design Project

Budget

Predicted Budget, Other Constraints
Proposed Budget for Rotary Arm

• NSF standards require 304 stainless steel for food machinery.
• Surface Finish

No. 4 Polished
  ➢ First Prototype ( $100.00)
  ➢ Second Prototype ( $200.00)

2B Unpolished
  ➢ First Prototype ( $80.00)
  ➢ Second Prototype ( $160.00)

➢ Sr. Design Budget $650.00
Other Concerns

• Need more coffee beans for testing purposes

• Mixing tests & VAD Method
  • Use colored coffee beans, or use different non-coffee bean for proof-of-concept test?
  • No hard and fast way to quantify mixing capability
  • Consult with professors & research past mixing experiments.
Acknowledgements

- U.S. Roaster Corp
  - Dan Joliff, Dean Oldham, and staff involved in model cooling bin construction.
- Dr. Paul Weckler
- Dr. James Hardin
- Dr. Scott Frazier
- Dr. Timothy Bowser
- Dr. Yu “Jessie” Mao
- Oklahoma State University Food and Agricultural Products Center (FAPC)
- Jake Nelson
- Doug Enns
References

• Ginn, I. M. “COFFEE-STIRRER”. 513179. January 23, 1894


