Department of Biosystems and Agricultural Engineering
MICHIGAN STATE UNIVERSITY

BE 487 - Spring 2022
Biosystems Design Projects

BE 487 - Residual Product Recovery From Manufacturing Tanks for Unilever

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(Under NDA)

Unilever

Background

Understanding the Justification

- Unilever strives to make living more sustainable.
- Successfully recovering residual results in higher product yield and a reduction in the cleaning process
- By reducing the amount of product left in the tanks, Unilever can continue their journey to a "waste free world" by tackling manufacturing waste at the source

Understanding the Project Background

- The plant worked with manufactures personal car products with large viscosity ranges, as listed in table 1, with gels being the most viscous and others being the least.

Table 1: Product Categorization from Viscosity

Categories	Viscosity (cP)
Gels	Redacted
Scrubs	Redacted
Conditioners	Redacted
Shampoos	Redacted
Others	Redacted

- Gels are the top priority for removal, as they account for the most residual product due to their high viscosity and resulting difficulty in removal.
- Unilever wishes to implement a design solution that works for all large tanks in their manufacturing plant. These include:
  - Portable
  - Relay
  - Mixing tanks
- Portable and relay are similar in size and components, but portable tanks can be moved throughout the plant
- Mixing tank internal elements can vary, with some mixing tanks having two impellers, both an anchor and hydrofoil impellers, whereas some have one anchor impeller
- All mixing tanks have a baffle that is attached from the top of the tank to aide in product mixing

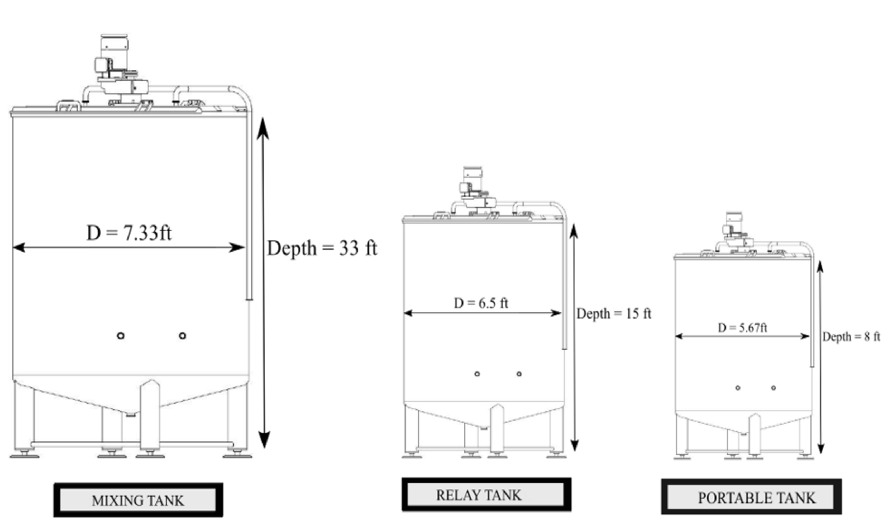

Figure 1: Tank dimensions of the mixing tank, the relay tank, and the portable tank utilized by the client

- All tanks have a conical shape at the bottom which helps completely drain the product from the tank using gravity
- The product is then pumped through a 3 in diameter pipe at the bottom of the cone where it exits
- The conical bottom and 3 in exit pipe are where the client is experiencing the most residual product sticking, which is where the team focused the solution

Objectives

The team has established objectives for the design and implementation of the chosen solution. These objectives are product specific and may vary depending on the type of tank.

- Gels
  - 62% reduction in residual product
- Conditioners
  - 50% reduction in residual product
- Scrubs
  - 25% reduction in residual product
- Minimize the environmental impact of the manufacturing process
- Establish a universal process for relay, portable, and mixing tanks

Constraints

When producing a design solution, several factors impacting the integrity of the design had to be considered, including:

- Non-removable tank additions
- Mixing impellers
- Scraping mechanisms
- Baffles
- Product exit and entry points within the tank
- Product specifications
- Temperature

In addition to physical constraints, several standards and regulations had to be maintained with the implementation of the final design, including:

- Standards
  - ISO 22716:2007 Cosmetics – Good Manufacturing Practices
  - ISO 18312-1:2012 Mechanical vibration and shock – Measurement of vibration power flow from machines into connected support structures – Part 1: Direct method
  - ISO/TR 19664:2017 Human response to vibration – Guidance and terminology for instrumentation and equipment for the assessment of daily vibration exposure at the workplace according to the requirements of health and safety
  - SAE AMS3400: Fluid, Reference for Testing Polyalphaolefin (PAO) Resistant Material
- Regulations
  - FDA Federal Food, Drug, and Cosmetic Act, Title 21, Subchapter IV- Cosmetics

Design Parameters

Table 2 identifies the most important parameters for the final design. Each parameter was ranked according to priority as specified by the client, with 1 being the highest and 6 being the lowest priority.

Table 2: Design parameters ranked by importance

Priority Level	Design Parameter
1	Safety
2	Product Recovery Rate
3	Scalability
4	Time
5	Cost
6	Change in Current Operations

Design Alternatives

The team identified three viable design alternatives that were guided by the identified design parameters, including:

1. Installation of mechanical scraping blade to the existing anchor impellor (Figure 2)
2. Application of vibrations to the tank walls (Figures 3 and 4)
   a. Vibrational sheath
   b. Vibrational plate
3. Application of an antistick agent to the interior tank walls via existing clean-in-place equipment (Figure 5)

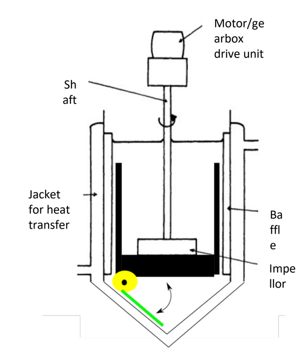

Figure 2: Blade Attachment

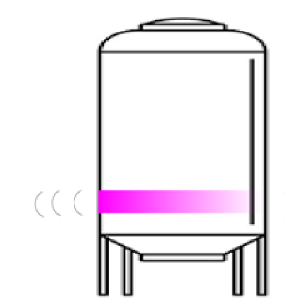

Figure 3: Vibrational Sheath

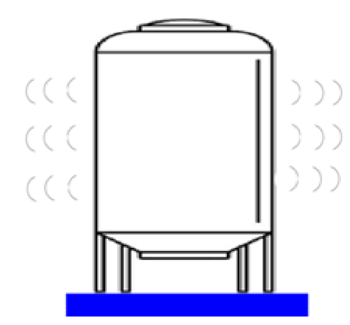

Figure 4: Vibrational Plate

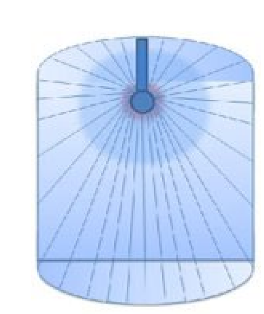

Figure 5: Antistick Application

Final Design

After analyzing the decision matrix that ranked each design alternative's performance for each design parameter, the team decided to further evaluate the antistick approach and concentrated vibrations individually and combined.

Vibrational Motor

Core Concept: Addition of microforces to the tank

- Utilizes a heavy-duty vibrational motor
  - Attaches to the side of the tank using a metal bracket
  - Often used for aiding in the removal of grain from hoppers/bins and shaking bubbles from concrete
  - Has the ability to adjust frequency of vibrations according to application

Design schematic is shown in Figures 6 and 7.

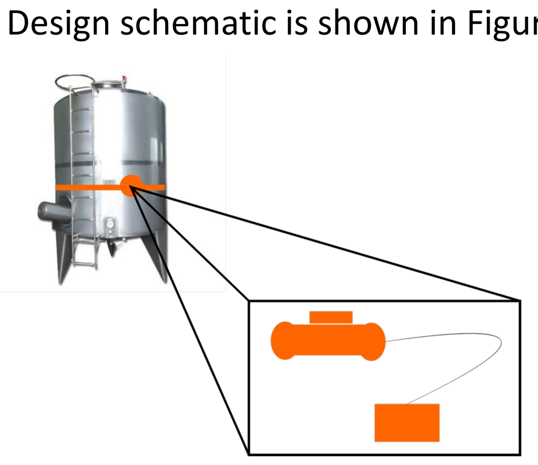

Figure 6: Vibrational Schematic

Figure 7: Example of Vibrating Motor

Antistick Solution

Core Concept: Application of a lubricant to tank walls using existing spray balls

- Polyalphaolefin (PAO)- common synthetic based oil lubricant
  - Hydrogenated poly C6-C14 olefins
  - Commonly used in cosmetics as an emollient
  - Nontoxic, nonirritating, and biodegradable
  - Products made with hydrogenated poly C6-C14 olefins can still be classified as oil free

Figure 5 displays design schematic.

Economics

Antistick:

- Estimated cost of client testing: $100,000
- Cost of PAO: ~$8,000/55-gal drum

Vibrations:

- Estimated cost of client testing: $100,000 based off calculated total product loss
- Cost of heavy-duty vibrational motor: ~$1,000/unit
- Installation: ~$80/unit

Experimentation

The team conducted small-scale experimentation on both proposed solutions and their combination. Four different rounds of testing were conducted, including:

- Control
- Polyalphaolefin only
- Vibrations only
- Vibrations and polyalpholefin

Experimental Materials

- Large stainless-steel funnel
  - Cone angle of inclination 33 degree
- Synthetic polyalphaolefin lubricant oil
  - Viscosity: 68 ISO, 20W SAE; 65 cSt at 40°C
  - Density: 0.0313 lb/in³
- 30 W concrete vibrator motor with speed controller (Figure 8)
- Dove Nutritive Solutions Daily Moisture Shampoo with Pump
- Dove Nutritive Solutions Daily Moisture Conditioner
- St. Ives Soft Skin Avocado Honey Face Scrub
- Laboratory stand with two-prong clamp
- Scientific scale
- Spray bottle

Figure 8: Experimental apparatus depicting vibrational motor, controller, and laboratory stand.

Experimental Methods

Weigh out 200 g of product and distribute throughout the funnel
↓
Place funnel into clap and allow to drain into a beaker for 3 minutes
↓
Weigh and record mass of product drained
↓
Measure and record viscous torque of the product at 20,30, 50,70,90, and 200 rpm

- Repeat this process 3 times for each product and testing method
- For antistick and combination tests, weigh out 2 g of PAO and coat the funnel prior to the addition of the product
- For vibrational and combination testing, secure the vibrator motor to the base of the clamp and operate at level 5 during draining

Results

From the experimentation, several important results were found.

- Combination testing resulted in the lowest residual for conditioner and scrub
- Vibrational testing resulted in the least residual for shampoo
- PAO only testing left small bubbles of oil in the drained product

These results are reflected in Figure 9.

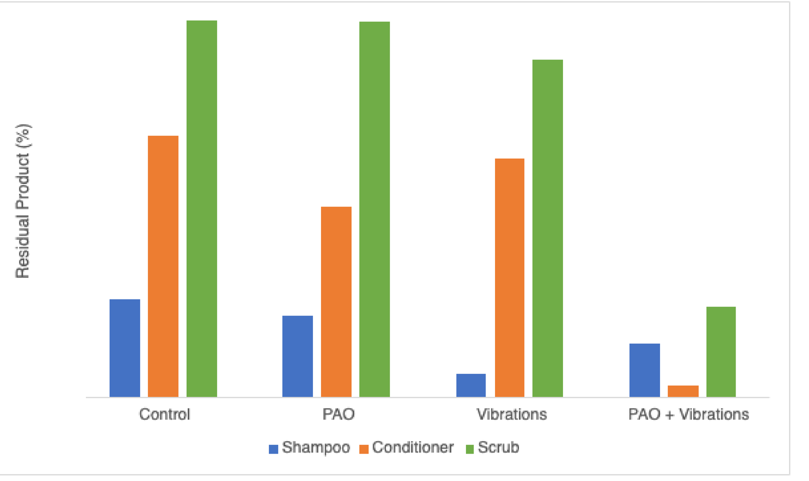

Figure 9: Residual product remaining in funnel after draining for 3 minutes

Limitations

There were limitations regarding the team's ability to replicate Unilever's tank design when scaling down the experimental setup.

- Increased amount of PAO mixed with product due to a higher surface area to product ratio
- The motor was unable to be directly attached to the side of the funnel
- The conical bottom was assumed to be the place where all product stuck, whereas some product sticks to the sides of Unilever's tanks as well as to the bottom
- The team was not able to replicate the pump connected to the outlet pump

Recommendations

A few key observations were made from bench-scale testing that led the team to the following recommendations.

1. Combination of PAO and vibrations
   a. Resulted in the lowest residual for more viscous products
   b. More costly than a single solution
2. Vibrations only
   a. No added materials to the products
   b. Less costly than combination solution
   c. Resulted in more residual than combination for more viscous products

If the client has concerns about PAO causing product adulteration, vibrations will provide a safe option. The vibrational motor is attached to the outside of the tank and will not touch the product.

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