Understanding chemomechanical interactions during hard surface cleaning processes

Perrakis Bistis
Hard surface cleaning
Hard surface cleaning – Aim of the project

<table>
<thead>
<tr>
<th>Factors</th>
<th>Name</th>
<th>Formulation Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mechanical force</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>Chemistry</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Substrate or cleaning material</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>Soil or Stain</td>
<td>Modelling</td>
</tr>
<tr>
<td>5</td>
<td>Hard Surface</td>
<td>Modelling</td>
</tr>
</tbody>
</table>
Hard surface cleaning – Aim of the project

• **Challenge**
  Lack of knowledge about Chemical + Mechanical interactions with surface

• **Aim**
  Understanding factors that affect cleaning → Produce Mathematical Models:
  cleaning rate=f(?)
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Background
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• Cleaning → Hard surface cleaning / Soft surface cleaning

• Tribology → Study of friction, wear and lubrication

  - Key tool to study mechanical interactions during cleaning

• Previous Projects → Developed a soil → **Main outcome 1**: Surfactants achieve to weaken cohesive strength more than adhesive strength **Main outcome 2**: Hydration main cleaning factor\(^1\)
Background

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Factors affecting cleaning

• Main Factors that affect Cleaning:
  - Temperature (T),
  - Applied Pressure (P),
  - Substrate Surface (A),
  - Hardness of soil (H),
  - Shear rate (γ),
  - Chemistry:
    1. Detergent Concentration (C)
    2. Surfactant Action

Cleaning rate = f(T,P,A,H,γ,C)
H= f(viscosity, adhesive cohesive strength, Young's modulus)
Equipment used to obtain these parameters

- **Mini Traction Machine** → measures **Traction Coefficient**
- **Micromanipulation** → measures **Adhesive & Cohesive strength**
- **Indentation** → measures **Young’s Modulus**
- **Rheometer** → **Viscosity**

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Mini Traction Machine

• Measures traction coefficient
• Main parts: Rotating ball – Rotating disc
• Controlled Factors: Load W, speed U, Slide Role Ratio SRR, Temperature T
• Frictional force F measured by transducer → traction coefficient $\mu = \frac{F}{W}$
Mini Traction Machine

Why MTM?

• Friction coefficient values, while using mechanical force and changing various parameters

• Prove that MTM can be used for cleaning experiments

• An effort to correlate traction (friction) coefficient with cleaning rate
Sample preparation + Experimental procedure

<table>
<thead>
<tr>
<th></th>
<th>Mass (g)</th>
</tr>
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<tbody>
<tr>
<td>Water</td>
<td>~75</td>
</tr>
<tr>
<td>Fat</td>
<td>~0.5</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>17.1</td>
</tr>
<tr>
<td>Fibre</td>
<td>2.6</td>
</tr>
<tr>
<td>Protein</td>
<td>4.4</td>
</tr>
<tr>
<td>Salt</td>
<td>0.38</td>
</tr>
</tbody>
</table>
Sample preparation + Experimental procedure

- (1,2) Position puree around disc with a spatula and sample loader (picture 2-3) (~1.5 g), measure weight and place in the oven (110°C 1h)
- (3) After oven, measure weight (picture 5)
- (4) Disc in MTM chamber (parameters: Load, Speed, Mass, Detergent Concentration)
- (5) During the experiment (liquid samples for UV-Vis measurements)
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Cleaning rate

- Cleaning rate calculations

\[ m_o = m_2 - m_1, \ m = m_3 - m_1 \]
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60° C, 1 day
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Dry \[ 60^\circ C, 1 \text{ day} \]
Cleaning rate

- Cleaning rate calculations

\[ m_0 = m_2 - m_1, \quad m = m_3 - m_1 \]

- 60°C, 1 day
- Dry
UV-Vis calculations

• Calibration curve for tomato puree ($\lambda=480$ nm)

• Liquid samples with syringe filters during the experiment

• UV-Vis measurements
Visual observation of the experiment
Visual observation of the experiment
Visual observation of the experiment
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Visual observation of the experiment
Cleaning mechanisms in MTM – Cleaning rate

Tomato fragments
Cleaning mechanisms in MTM – Cleaning rate

UV-Vis to measure cleaning mechanism contribution
Cleaning mechanisms in MTM – Cleaning rate

• 2 main cleaning mechanisms
  no chemistry:
  - Dissolution
  - Mechanical Removal

• **Cleaning rate** = \( \frac{d\left(\frac{m}{m_0}\right)}{dt} \)

UV-Vis to measure cleaning mechanism contribution

\[
y = -0.0046x + 1
\]
\[
R^2 = 0.9931
\]
Hydration vs Mechanical removal

- **Hydration**
  Removed 20% in 5 min

- **+Mechanical force**
  Should coexist → 100% removal in less than 5 min
Parameter variation

• 1. Mass of the tomato puree

• 2. Normal Load/Applied Pressure

• 3. Rolling Speed

• 4. Detergent Concentration
1. Mass of the tomato puree

- Slope = Cleaning rate (constant)
- Different masses \(\sim\) cleaning rates \(\rightarrow\) Mass does not affect cleaning rate

![Graph showing the relationship between mass and time for different masses with slopes of -2.4 mg/s and -2.2 mg/s.](image_url)
2. Normal Load/Applied Pressure

- Different load (1, 2.5, 5N or 260, 350 and 440 kPa)
- Increase of load → Increase of cleaning rate
3. Rolling Speed

- 200 mm/s → Not linear behaviour
- Increase of speed → Increase of cleaning rate
3. Rolling Speed

- 200 mm/s $\rightarrow$ Not linear behaviour
- Increase of speed $\rightarrow$ Increase of cleaning rate
4. Detergent Concentration (1)

- Better cleaning rate for detergent was expected but it was not the case.
- Lubrication effect seems to hinder cleaning rate for detergent cases.

![Graph showing the effect of detergent concentration on cleaning rate over time.](chart.png)
4. Detergent Concentration (1)

- Better cleaning rate for detergent was expected but it was not the case
- Lubrication effect seems to hinder cleaning rate for detergent cases
4. Detergent Concentration (2)

1. Water traction coefficient > Fairy traction coefficient values
2. Traction coefficient decreases after the removal of tomato puree

Lubrication effect
Conclusion

Parameters

**Mass**: No effect on cleaning rate

**Load, Speed**: load/speed increase $\rightarrow$ earlier traction coefficient increase and better cleaning

**Detergent**: Lubrication hinders cleaning efficiency of detergent for the experiment in MTM for tomato puree
Thank you for your attention