Effect of Droplet Size and Microstructure on Contact Angle of Ductile Iron with Water

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Introduction
- Ductile iron, a mild steel alloy, is widely used for piping in the water industry due to its flexibility, durability, and mechanical properties.
- However, this piping often corrodes, leading to the accumulation of unwanted buildup, which is costly and difficult to remove.
- The wastewater industry has relied on hydrophobic alloy coatings for their pipes, in the attempt to reduce corrosion.
- However, these coatings are expensive and prone to damage.
- With the ultimate goal of finding a corrosion resistant ductile iron alloy, experimental work was done to study the contact angle of ductile iron with water, since higher contact angles imply reduced corrosion.
- Factors which could influence the hydrophobicity of a surface were studied.
- It was hypothesized that an increase in droplet size would result in an increase in contact angle.
- Furthermore, it was hypothesized that samples containing higher amounts of graphite would have a higher contact angle.

Methods
For this experiment:
- Four different Ductile Iron samples were tested with varying phase percentages of graphite.
  - Sample designations: DI 1, DI 2, DI 3, DI 4
- Samples were polished to the appropriate grit with sand paper of different grit sizes.
- A Ramé-Hart goniometer was used to measure the contact angle of the water droplet on the samples.
- The contact angle of a sessile droplet of water with varying volumes on samples of ductile iron was measured.
  - Droplet size: 2 µl, 4 µl, 6 µl, 8 µl
  - Roughness: 400 grit, 800 grit, 1200 grit

Results
Microstructure:
- Samples were fully polished with 1 micrometer of Alumina prior to taking microstructural images.
- Using an optical microscope, 3 images were taken at each magnification for every sample.
- Afterwards, each image was analyzed using an image processing program for phase percentages of graphite, and averaged to find the amount of graphite in each sample.

Table 1: Phase percentage of graphite nodules
<table>
<thead>
<tr>
<th>Sample</th>
<th>% of Graphite Nodules</th>
</tr>
</thead>
<tbody>
<tr>
<td>DI 1</td>
<td>10.13%</td>
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<td>12.68%</td>
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<td>16.34%</td>
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<td>DI 4</td>
<td>25.84%</td>
</tr>
</tbody>
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Discussion
- Previous studies have concluded with droplets small enough to disregard the effect of gravity, an increase in contact angle is seen as droplet size increases.
- The Young equation for quantifying the wettability of a solid surface is stated as:
  \[ \cos \theta = \frac{s_v - s_{lv}}{s_{ls}} \]

Contact Angle Data:

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Contact Angle of Ductile Iron with Water

Theoretical Calculations
- Cassie’s law for calculating the contact angle of a liquid on a composite surface is stated as: \( \cos \theta = f_1 \cos \theta_1 + f_2 \cos \theta_2 \) where \( f_1 \) is the fraction of component 1 in the composite, \( \theta_1 \) is the theoretical contact angle of component 1, \( f_2 \) is the fraction of component 2 in the composite, and \( \theta_2 \) is the theoretical contact angle of component 2.
- Ductile iron is composed of graphite and a mild steel matrix.
- The theoretical contact angle of graphite is 90º.
- The theoretical contact angle of mild steel is 40º.
- So by Cassie’s law,
  \[ \cos \theta = [(0.8642) \cos (40º) + (0.1358) \cos (90º)] \]
  \[ \theta = 46.81º \]
- Using an optical microscope, 3 images were taken at differing droplet volumes.
- Figure 1. Contact angle of a droplet, as seen through goniometer.
- Figure 2. Ramé-Hart goniometer, used to take contact angle measurements.
- Figure 3. Micrographs of unetched samples showing the distribution of graphite nodules (a) DI 1, (b) DI 2, (c) DI 3, (d) DI 4.
- Figure 4. Variation of Contact Angle with Droplet Volume
  - 400 Grit
  - 800 Grit
- Figure 5. Variation of Contact Angle with Phase percent of Graphite

Bibliography

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