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Investigation of Descaling Techniques for Naturally Oxidized Iron Based Alloy

Abstract:

To meet the future demand for sustainable and environmentally friendly "green" chemical cleaning solutions for rust removal from naturally oxidized iron alloys, this study showed how an optimized DES (Deep Eutectic Solvents) can enhance descaling performance. A series of experiments were conducted using different combinations of acetic acid, malonic acid, and choline chloride in aqueous solutions. Bicycle chain components with naturally formed rust layers were used as representative samples. The samples were immersed in chemical solutions for varying durations to evaluate the influence of composition and exposure time on rust removal performance. Surface characterization was performed using optical microscopy, and quantitative analysis was carried out using a Python-based image processing method. Rust-covered areas were identified through HSV (Hue, Saturation, Value) color thresholding, allowing calculation of rust coverage percentage before and after treatment. Descaling efficiency was determined based on the reduction in rust coverage. The results demonstrate that the presence of choline chloride along with malonic acid significantly enhances the oxide dissolution capability of organic acid solutions. This study highlights a **greener way to remove rust from iron-based alloys** with the potential for environmentally favourable chemical systems and provides a quantitative framework for evaluating descaling performance using image-based analysis.

Popular Abstract:

Rust damages everything from bicycle chains and bridges to industrial machines. However, cleaning rust usually requires harsh chemicals that can harm both people and the environment. In this degree project at Lund University, a more environmentally friendly method for removing rust from steel was investigated using organic acids and a common biodegradable salt called choline chloride. Most people have seen rust spread across metal surfaces. Over time, this corrosion weakens steel, reduces product lifetime, and increases maintenance costs. Industries often use strong mineral acids to remove rust, but these chemicals can be dangerous to handle and create environmental problems. The goal of this project was therefore to explore whether safer chemical mixtures could effectively clean rust without relying on aggressive industrial acids.

The study focused on naturally rusted bicycle chain components made of iron-based alloy. Different cleaning solutions were prepared using water, organic acids, and choline chloride. The two acids tested were acetic acid, which is found in vinegar, and malonic acid, an organic acid commonly used in chemical research, which is a naturally occurring substance found in many fruits and vegetables. Choline chloride is used as a dietary supplement for humans. The rusted metal samples were placed into the solutions and observed over time using microscope imaging.

One of the most interesting findings was that the cleaning performance improved significantly when malonic acid and choline chloride were combined. Surprisingly, choline chloride alone removed very little rust, but together with the malonic acid it helped create a much more effective cleaning system. The best-performing solution containing 2.5 wt% malonic acid and 4 wt% choline chloride achieved the most effective rust removal performance while also producing a more stable and uniform cleaning process. Instead of measuring weight loss like in many traditional corrosion studies, this project used digital image analysis to calculate how much rust remained on the surface. A Python-based program identified rust-coloured areas in microscope images and measured the percentage of rust coverage over time. This approach made it possible to follow the cleaning process visually and quantitatively at the same time.

The results of this project show that environmentally favourable cleaning systems based on organic acids could become an alternative to more hazardous industrial descaling methods. Such systems may help reduce chemical waste, improve workplace safety, and support more sustainable maintenance of steel components in the future.

Although this was a laboratory-scale study, the work demonstrates how relatively simple chemical systems can contribute to greener engineering solutions for corrosion treatment and metal maintenance.