Plenary Lectures

PL-01

Bridging Science and Industry: Data-Driven Strategies for Reliable Operation in High-Corrosivity Environments

Matina Thammachart
Specialist, Corrosion and Manager, Materials and Corrosion Section, Facility Engineering Department, Engineering Technical Solutions Division, PTT Exploration and Production Public Company Limited

Operating in the energy industry means confronting corrosive species that threaten the reliability and integrity of pipelines and facilities. This presentation transforms that challenge into a journey of innovation, demonstrating how data-driven strategies and lessons learned can turn obstacles into opportunities for progress. Experience has shown that conventional corrosion management approaches are no longer sufficient - advanced, adaptive solutions are required to address real-world complexities.

Bridging academic research with industrial practice, the session highlights how insights into corrosion mechanisms under high-corrosivity conditions are translated into field applications through innovative strategies, i.e. data-driven analysis, chemical treatment optimization, and real-time monitoring dashboards. By connecting scientific understanding with operational experience, the discussion demonstrates how collaboration drives emerging applications and sustainable reliability - truly embodying the spirit of Academic-Industrial Linkage Towards Innovative Emerging Applications.

Bio: Dr. Matina Thammachart
Corrosion Specialist and Materials and Corrosion Section Manager
Facility Engineering Department, PTTEP

Matina Thammachart is a corrosion specialist and manager at PTTEP, where she leads the Materials and Corrosion Section within the Facility Engineering Department. She earned her PhD in corrosion from Heriot-Watt University, UK, before joining PTTEP in 2006 as a corrosion engineer.

With extensive experience across both engineering and operations, Matina has developed expertise in corrosion management, pipeline integrity, and materials engineering. She has played a key role in

major projects and responsible for corrosion related PTTEP Engineering General Specifications, while also contributing to cross-functional projects, technical reviews, and peer collaborations.

Actively engaged in technical conferences, workshops, and knowledge-sharing forums, Matina is recognized for driving innovation in corrosion mitigation, reliability and integrity improvement, and asset life extension, reinforcing her central role in PTTEP's technical community.

PL-02

Roles of the Metallurgist in Impacting Industries: from atomic diffusion kinetics to structural analysis, from pico-liter soldering to micro-liter additive laser manufacturing, from jewelry investment casting to Tesla giga-casting, and from thermodynamic simulations to AI- and machine learning driven alloy formulation and implants design.

Boonrat Lohwongwatana
Department of Metallurgical Engineering, Faculty of Engineering, Chulalongkorn University

As an academic, I have faced continual challenges in career growth as a professor: fine-tuning research interests to match industry needs, balancing scientific curiosity with existing knowledge bases, applying for research grants amid shifting government priorities, and managing time while holding executive positions in research institutes. This talk explores those struggles and the many pivots that emerged as opportunities along the way.

The journey began with the development of a novel soldering technique, a supercooled viscous liquid capable of atomistically dissolving solid metals to form intimate contacts observed through HRTEM, which was later patented and licensed to Intel. This concept was later applied to solder-jet bonding of pico-liter solder balls in the hard disk drive industry. Work on shape memory alloys such as Nitinol, initially envisioned as a "self-healing" material, led to a deeper understanding and control of martensitic transformation, which was later applied to delayed cracking in heavily deformed stainless steel wires and incorrectly quenched (and delayly exploded) automotive axles. Research into bulk metallic glasses and rapid solidification provided insights into solder joint microstructures, solidification fronts in various alloy compositions, and the reliability of solder systems under cyclic thermal loading in semiconductor applications.

Subsequent projects in semicontuctor industry readily expanded into MgO coatings deposited by PVD and diamond-like carbon (DLC) films. The adoption of synchrotron and neutron techniques, such as 3D tomography, EXAFS, and in-situ solidification studies, opened new windows into phenomena such as magnetic anomalies in semiconductors, porosity formation in additive manufacturing, and microstructural evolution during aluminum alloy solidification.

A substantial part of the research was devoted to the jewelry industry, where investment casting remains the dominant process. This archaic yet intricate technique relies on numerous metallurgical concepts: vulcanization of rubber molds, viscous wax flow, stereolithography, phase transformations amongst α-quartz, β-quartz, tridymite, and cristobalite, alloy granulation, dendritic growth, and solidification dynamics. Some students ventured further by reducing the conventional thirteen investment casting steps to five, leveraging thermodynamic simulations to design novel alloys suitable for direct injection into molds made of copper, aluminum, or silicone.

Current projects extend these principles into Tesla's giga-casting of truck chassis, scaling die-casting concepts from toy cars such as Hot Wheels into full vehicle chassis production, eliminating hundreds of welds and assembled parts. This leap demands entirely new aluminum alloys and advanced mold technologies capable of rapid cooling, high throughput, and minimized shrinkage and porosity. Additive manufacturing now plays a central role in fabricating conformal cooling molds, combining laser powder bed fusion with new mold steel formulations designed for selective laser melting.

Different research teams focuses on churning out intellectual properties such as novel titanium alloys with antimicrobial properties, and the 3D printing of ultrathin and superelastic implants. Insights into phase transformations and evolution during Ti-6Al-4V laser melting and rapid solidification have led to the development of USFDA-approved craniomaxillofacial and orthopedic implants, now improving the lives of thousands of patients. AI and machine learning have been applied to implant design, image processing, alloy formulation, and large-scale manufacturing.

The common thread across these projects lies in the four pillars of materials science and metallurgical engineering: processing-structure-properties-performance, reinforced by advanced characterization and by the flexibility to pivot research directions. This openness has allowed teams to address real-world industrial problems through collaboration, innovation, and cross-disciplinary impact.

PL-05

Corrosion control and passivation quality evaluation method for stainless steel rail vehicles

SUN Xiaoguang
CRRC Qingdao Sifang Co., Ltd.

Stainless steel is widely used in rail vehicle manufacturing due to its excellent mechanical properties and corrosion resistance. However, corrosion failures, such as pitting and crevice corrosion, still occur in harsh service environments, primarily influenced by chloride ions, humidity, surface contaminants, and microstructural defects. To enhance surface corrosion resistance, advanced surface treatment technologies have been developed. Electrolytic passivation improves the stability and integrity of the passive film through optimized electrochemical parameters, while laser surface treatment refines surface morphology and microstructure, reducing susceptibility to localized corrosion. Research on evaluation methods, particularly using ferroin testing, are also introduced to improving the corrosion control and passivation quality of stainless steel rail vehicles, extending service life and ensuring operational safety.

Keynote Lectures

KL-04

Multi-scale Assessment and Prediction of Metal corrosion —— Introduction of the Corrosion Assessment and Prediction Laboratory (CAPLab)

Ying Jin[a*], Lei Wen[a], Feifei Huang[a], Songtao Yan[a], Wenchao Li[a], and Min Liu[b]
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Keywords: Materials service safety, Corrosion behavior, Multiscale assessment, Cross-scale prediction

First, a brief introduction to the major national scientific research infrastructure - the Materials Service Safety Assessment Facility (MSAF, with an investment of 505.1 million yuan) is provided. This facility is a large-scale, coupled, extreme and serialized group of test facilities composed of six major test facilities and their supporting simulation and shared systems, which can reproduce the typical failure forms of materials to large/full-scale components/equipment in key industries. Among MSAF, the Corrosion Assessment and Prediction research group (CAPLab) has constructed a set of Atmospheric Environment Test Facility for Engineering Structures (AETFES) with the coupled control of seven environmental factors. In addition, it has accumulated multi-scale experimental evaluation, sensor and monitoring system development, modeling and simulation, as well as the prediction capabilities for the performance of materials/components/equipment. Relying on the national major scientific infrastructure, the CAPLab has provided support to various industries for the safe service and life extension of those key equipment. It has undertaken and completed high-quality reliability evaluation and life prediction of important equipment/key components in complex/extreme working conditions in key areas such as neutron absorption equipment for wet storage of spent nuclear fuel in nuclear power plants, dry storage tanks, high-pressure hydrogen transmission pipelines, and the hydrogen fuel system of the main torch for the 2022 Beijing Winter Olympics, etc.

Graphical Abstract

KL-05

Research and Application of Anti-Sand and Rain Erosion Coatings

GUI Taijiang
Aokang Quality Inspection Technology Co., Ltd.

Sand and rain erosion pose a significant threat to the structural integrity and safety of high-speed components, with helicopter rotor blades and wind turbine blades being prime examples. Coatings represent an effective strategy to mitigate this damage. This presentation will detail our development of a high-toughness coating system. Through rigorous evaluation in multiple environments, this coating has successfully resolved sand and rain erosion issues for helicopter rotor blades. Furthermore, the technology has been extended to applications in high-speed trains.

Invited Lectures

IL-02

Weathering Steel Exposure Test in Thailand: Long-term Corrosion Kinetics and Machine Learning on Bi-electrode Sensor Data

Wanida Pongsaksawad[a,*], Pranpreeya Wangjinaa, Piya Khamsuk[a], Warut Butratsamee[a], Benjawan Moonsri[a], Amnuaysak Chianpairot[a], Ekkarut Viyanit[a], and Junhua Dong[b]

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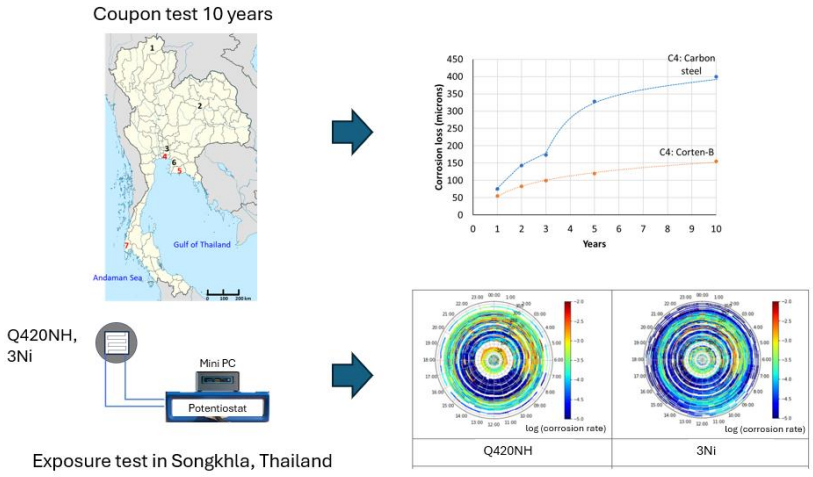
Keywords: Corten-B, weathering steel, atmospheric corrosion, bi-electrode sensor, and machine learning

Weathering steel exposed under proper wet-dry cycles can form patina or stable protective rust layer. Corten-B weathering steel had been tested at 7 test sites in Thailand from 2013 – 2023 to investigate the corrosion behavior of weathering steel in Thailand climate. The corrosion kinetics followed power law with exponential terms less than 0.5, indicating diffusion-controlled mechanism and compact rust layer. Corrosion loss of Corten-B was 70% lower than that of carbon steel after 10-year exposure in C4 environment. To understand the influence of weather parameters, electrochemical signals from a bi-electrode sensor made of Q420NH and 3Ni weathering steels obtained during 2022 – 2024 were investigated by machine learning. The results revealed different rust layer characteristics as a result of atmospheric parameters. The 3Ni weathering steel formed more compact inner rust layer that effectively inhibit chloride penetration.

Graphical Abstract



IL-04

Hydrogen Effects in Steels and SS Steels and Their Impacts on Service Safety of Hydrogen Pipings and Vessels

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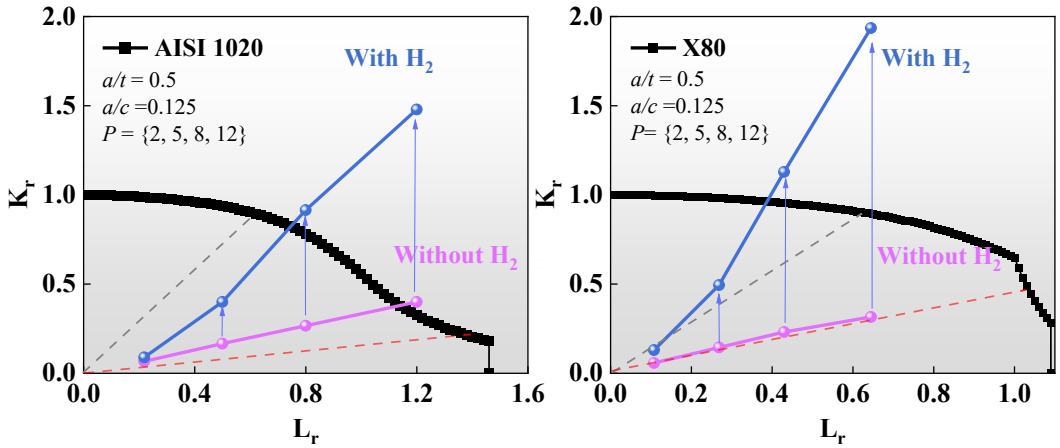
Keywords: Hydrogen embrittlement, Service safety, Hydrogen Compatibility

The effects of hydrogen on the mechanical properties of steels and stainless steels (SS) have been long recognized. However, when it comes to design and construction of specific components such as piping and vessels for high pressure hydrogen service, materials selection and validation need to be based on reliable, often using high-pressure hydrogen gas, testing results. Testing conditions such as loading rate and frequency, alloy composition and structure, the amount of hydrogen allowed to enter the test specimens, all affect test results.

Industry relies on hydrogen compatibility standards/requirements (such as tensile, fatigue and toughness) in their materials selection. However, current test conditions in national and international standards (such as ASME B31.12) were based on pressure-vessel designs of limited capacities. Therefore, some of the test results can be non-conservative when used for current hydrogen applications. An example will be the fracture toughness of hydrogen pipelines: Toughness property data is often relied on in service safety analysis using Failure Assessment Diagram (FAD), and non-conservative toughness data can lead to unreliable safety boundaries in FAD.

Graphical Abstract



The effects of hydrogen on the safety boundaries as defined using FAD

IL-05

Influence of High Temperatures and Off-Design Operating Conditions on the Degradation of Grate Blocks in a Refuse-Derived Fuel (RDF) Boiler

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Keywords: High-Temperature Oxidation, Chlorine-Induced Corrosion, Grate Block Degradation, RDF Power Plant

Grate blocks in a Refuse-Derived Fuel (RDF) boiler, designed for a five-year service life, experienced catastrophic failure after just one year of operation. The components, made of a heat-resistant cast steel, were intended to operate within a temperature range of 215°C to 280°C. However, post-mortem analysis revealed that localized temperatures significantly exceeded these design limits, accelerating material degradation. This study investigates the failure mechanisms of these critical components within Thailand's waste-to-energy infrastructure.

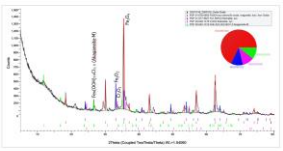
A comprehensive suite of analytical techniques was employed to identify the root causes of the premature failure. These included macroscopic visual inspection, chemical composition analysis, scanning electron microscopy (SEM) with energy-dispersive spectroscopy (EDS), X-ray diffraction (XRD) for phase identification of the oxide scale, and micro-hardness profiling.

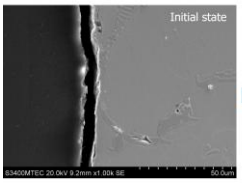
The primary failure mechanism was identified as severe high-temperature oxidation exacerbated by chlorine-induced corrosion. Prolonged exposure to temperatures well above the design range led to the formation of a thick, brittle oxide scale. This scale repeatedly spalled, causing a continuous loss of material. The presence of chlorine from the RDF further intensified this degradation by disrupting the protective oxide layer and promoting highly aggressive corrosion. This synergistic effect between thermal stress and a corrosive environment resulted in the premature and catastrophic failure of the components.

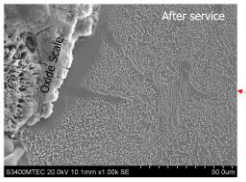
The findings demonstrate the critical effect of off-design operating conditions on the long-term durability of heat-resistant alloys in waste-to-energy applications. The results provide valuable insights for improving material selection, design, and operational control to enhance the reliability and service life of RDF boiler systems.

Micrograph of a degraded grate block surface, showing the effects of high-temperature exposure and chlorine-induced corrosion. This dual-mechanism attack disrupts the protective oxide layer, leading to its repeated spalling and a continuous reduction in component thickness.

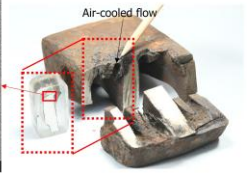
XRD spectrum of the oxide scale.







SEM image showing microstructural degradation of the material.



Physical appearance of the damaged grate block.

IL-06

Galvanized Reinforcing Steel and Sacrificial Anode Cathodic Protection to Prevent Corrosion of Reinforced Concrete Structure

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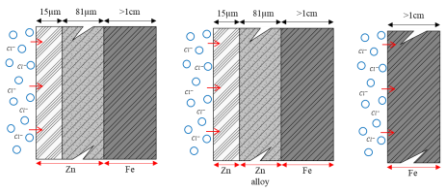
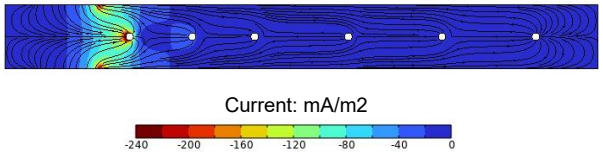
Keywords: Hot dip galvanized, Sacrificial anode, Reinforcing Steel, Durability

Corrosion of reinforcing steel adversely affects service life and maintenance cost of reinforced concrete structures especially in chloride rich environment. Hot dip galvanized (HDG) reinforcing steel is one of alternative reinforcing bars that show better resistance against corrosion due to chloride. This paper shows results of corrosion rate and service life of uncoated, corroded HDG and uncorroded HDG reinforcing steel. Moreover, bond strength of reinforcing steel and concrete is also studied. Different binders including hydraulic cement, coal fly ash and calcined clay are used as a binder of concrete. Different chloride contents are mixed initially into concrete to initiate different severity of reinforcing steel corrosion. The results show that corrosion current of uncorroded HDG is the lowest. And corrosion rate of corroded HDG is increased and comparable to uncoated steel due to zinc alloy layer is exposed. However, calculated corrosion cracking time of concrete using HDG reinforcing steel both corroded and uncorroded is longer than uncoated steel. Initial bond strength of HDG reinforcing steel is significantly reduced due to hydrogen evolution and should be concerned. Chromate treatment is recommended to minimize hydrogen evolution. Moreover, quality control of HDG thickness and zinc composition are very important for a good corrosion resistance. Also zinc sacrificial anode cathodic protection is widely used in corrosion damages repair work. Performance of embedded zinc anode and zinc tape anode is studied and compared. Different chloride contents are mixed initially to concrete to initiate reinforcing steel corrosion. Reinforcing steel is embedded 10cm to 75cm distance from anode. Potential decay shift results show that both embedded zinc and zinc tape can protect corrosion of reinforcing steel. However, corrosion properties such as potential and current flow of zinc anode and reinforcing steel significantly change in the long term due to many causes. Deterioration of anode and re-passivation of reinforcing steel are needed to be further studied to accurately predict service life of sacrificial anode protection system.

Graphical Abstract (mandatory)



Corrosion of HDG reinforcing steel



Current distribution of zinc sacrificial anode

IL-07

Stainless Steel Selection Tool For Water Application: Pitting Engineering Diagrams

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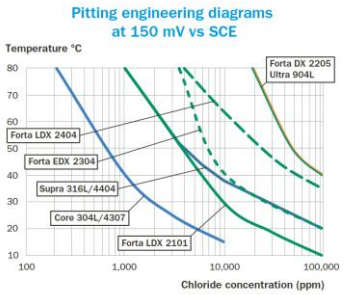
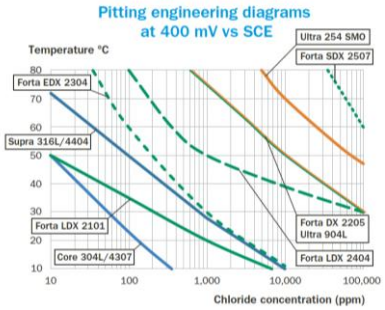
Keywords: STAINLESS STEEL, PITTING ENGINEERING DIAGRAM, ELECTROCHEMICAL MEASUREMENT, WATER APPLICATION

Stainless steel is known for its corrosion resistance, especially in chloride environments, making it essential for water-related applications. Its pitting resistance depends on alloy composition and service conditions, with higher alloy levels enhancing resistance. Key factors like chloride concentration, temperature, and oxidation potential influence pitting risk. Guidelines for pitting performance include the Pitting Resistance Equivalent Number (PREN) and Critical Pitting Temperature (CPT). PREN allows for quantitative comparisons of alloys, while ASTM standards and G48, method E, help determine CPT under standard conditions, though they may not predict specific performance accurately.

Stainless steels are widely utilized in water applications across a range of temperatures. To facilitate informed material selection, it is crucial to have comparative data on different grades of stainless steel under uniform environmental conditions. Pitting engineering diagrams serve as valuable tools, incorporating factors such as chloride ion concentration, temperature, and stainless steel grades. These diagrams effectively illustrate the critical conditions that can lead to pitting corrosion in stainless steel. The objective of this study was to develop a reliable method for constructing pitting engineering diagrams and to explore the interrelationships among various electrochemical techniques. Comprehensive electrochemical tests were conducted to deepen our understanding of the factors influencing the corrosion behavior of stainless steel, correlating with the boundaries established in the diagrams. The tests were performed in environments containing chlorides, with concentrations ranging from those typical of potable water to levels found in seawater and beyond. Diagrams were created at two distinct potentials, representing either more or less oxidizing conditions. The results are discussed in relation to existing knowledge regarding the critical levels of key parameters necessary for constructing pitting engineering diagrams.


Pitting engineering diagrams
at 150 mV vs SCE
Temperature °C
80
70
60
50
40
30
20
10
100
1,000
10,000
100,000
Chloride concentration (ppm)
Forta DX 2205
Ultra 904L
Forta LDX 2404
Forta EDX 2304
Supra 316L/4404
Core 304L/4307
Forta LDX 2101


Pitting engineering diagrams
at 400 mV vs SCE
Temperature °C
80
70
60
50
40
30
20
10
10
100
1,000
10,000
100,000
Chloride concentration (ppm)
Ultra 254 SMO
Forta SDX 2507
Forta EDX 2304
Supra 316L/4404
Forta LDX 2101
Core 304L/4307
Forta DX 2205
Ultra 904L
Forta LDX 2404

L-08

Corrosion behavior of metal materials in simulated high-temperature flue gas environment

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Keywords: Carbon steel, Stainless steel, High-temperature flue gas, Acid corrosion

Firstly, the failure analysis of an analytical tower that used for desulfurization and denitrification was conducted, heating zone, cooling zone, and SRG section/ segment. Based on the characteristics of their respective service environments, the failure mechanisms of each segment were analyzed, and thus the possible corrosion mechanism and its influence factors were clarified. Based on the severe problem of corrosion failure caused by high temperature flue gas, several materials are used for selecting the potential candidate for the analytical tower tube material. According to the results of failure analysis and the test factors that may affect corrosion, a special high-temperature flue gas corrosion test was designed. A self-built steam/ steam-gas environment simulation test equipment that could introduce as most as six kinds of polluting atmosphere simultaneously was used to carried out the high-temperature flue gas test, by using which, the corrosion behavior of two kinds of materials, ND and 2205 duplex stainless steel were investigated. With the prolongation of time, the corrosion of ND and 2205 duplex stainless steel was enhanced. By comparing the electrochemical results of the two kinds of metals, 2205 duplex stainless steel show better relative smaller electric current density and larger corrosion resistance, indicating its better corrosion performance. The unchanged semiconductor type, enrichment of Cr in the passive film are observed as the reason for its excellent behavior. While the time-environment induced variations of film structure and doping concentrations are responsible for the degradation of the protective passive film. Finally, the potential candidate material for analytical tower was determined.

IL-09

New Generation of Sacrificial Anodes for Reinforced Concrete

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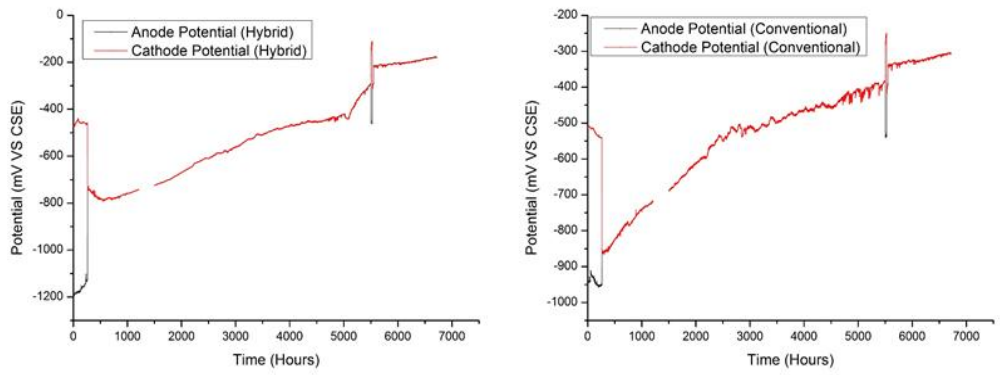
Keywords: Concrete, Cathodic Protection, Sacrificial Anode, New Generation

Corrosion of steel in reinforced concrete remains a major concern in the durability and maintenance of civil infrastructure. While traditional galvanic anodes offer a simple and maintenance-free solution, they are often limited by low current output and a relatively short service life. To address these limitations, a patented multi-stage sacrificial galvanic anode was developed—introducing a new generation of hybrid anodes capable of delivering both immediate and long-term corrosion protection without the need for external power sources or complex control systems.

This innovative system features an internal booster mechanism that can be activated either upon installation or at a later stage, depending on the specific needs of the structure. This activation phase delivers a strong polarization current, helping to displace aggressive ions and re-establish a protective alkaline environment around the steel reinforcement. As the high-output phase diminishes, the system naturally transitions into a long-term protection mode, supplying a stable, self-regulating galvanic current. The specially engineered backfill enables this multi-phase functionality by preserving ionic conductivity and preventing passivation, ensuring reliable performance over an extended service life.

Beyond this core design, ongoing long-term field and laboratory trials have introduced a transformative advancement: staged or delayed activation of anodes using integrated power boosters. These trials—now ongoing for over 30 months—demonstrated that anode activation can be programmed to occur in phases. Some anodes were activated immediately, others after a two-month delay, and a final group only recently—more than two years after installation. This ability to adjust the current over time allows the system to give the right level of protection as the structure changes, which helps the anode last much longer. This new generation of sacrificial anodes sets a precedent for high-performance, low-maintenance corrosion control in reinforced concrete applications.

Graphical Abstract



IL-11

The Evolution of Pipeline Top of the Line Corrosion Management: Leveraging VCIs for Pipeline Longevity

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Senior Engineer, Quality Assurance and Quality Control
PTT Exploration and Production Public Company Ltd.

Top-of-the-line corrosion (TLC) remains one of the most challenging integrity threats in wet gas pipelines, primarily driven by condensation and localized corrosive environments. Traditional mitigation strategies—such as material selection, coatings, and operational adjustments—often fall short in addressing TLC under dynamic flow and temperature conditions.

This paper explores the evolution of TLC management, emphasizing the role of Vapor Phase Corrosion Inhibitors (VCIs) as a transformative solution for pipeline longevity. VCIs offer a unique mechanism by forming protective molecular layers on steel surfaces in vapor spaces and under condensed water films, reducing corrosion rates without requiring continuous liquid-phase dosing. The discussion includes advancements in VCI chemistry, deployment techniques, and performance monitoring, supported by field applications and laboratory studies.

By leveraging VCIs, operators can achieve cost-effective, environmentally responsible corrosion control, extending asset life and enhancing reliability in complex pipeline systems.

IL-14

Comparison Between Existing Deep-Well Anodes and Distributed Anode Design with Multiple Controllers for Cathodic Protection Upgrade in Petrochemical Plant

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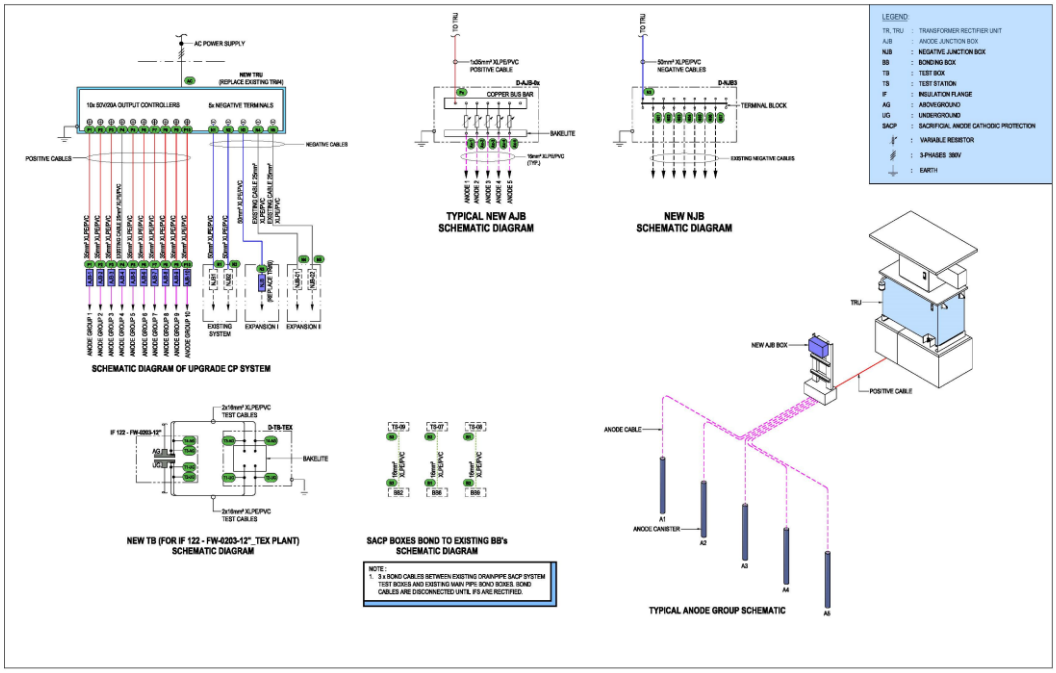
Keywords: Cathodic Protection (CP); Deep-well Anodes; Distributed Anode Beds; Multiple Output Controllers; Current Distribution.

Deep-well anodes have been a conventional design for cathodic protection (CP) systems in petrochemical plants. However, past projects have revealed significant limitations, including unbalanced protection, underprotection in central process areas which likely due to current shielding by underground structures such as reinforced concrete foundations and grounding grids—and overprotection near the deep-well locations leading to coating disbondment or hydrogen embrittlement. Furthermore, synchronized portable interrupters for CP monitoring are often impractical to install and operate. To address these problems, an alternative design was proposed using distributed anode beds entire the plant, powered by a single transformer rectifier unit (TRU) with multiple output controllers. Each controller enables to interrupt through built-in interrupter mode and fine-tuned current distribution by adjustable variable resistors for each anode bed in anode junction box as well. The design current was based on depolarization testing and current drainage test (CDT) equations to determine site-specific current requirements. Post-commissioning results demonstrated that the upgraded system achieved effective protection compliant with NACE SP0169 criteria at all test points with current outputting expected to achieve design life of 30 years. Fine-tuning remains necessary in some areas to correct minor overprotection.
This upgraded design improves CP current distribution and reliability while simplifying monitoring. However, this system still has some disadvantages, such as the lack of a backup TRU and the higher cost of installation. Overall, the distributed design provides a more suitable solution for complex underground pipeline networks in petrochemical facilities.


AC POWER SUPPLY
NEW TRU
(REPLACE EXISTING TR#)
10x SDV20A OUTPUT CONTROLLERS
6x NEGATIVE TERMINALS
POSITIVE CABLES
NEGATIVE CABLES
EXISTING SYSTEM
EXPANSION I
EXPANSION II
SCHEMATIC DIAGRAM OF UPGRADE CP SYSTEM
TO TRU
COPPER BUS BAR
BAKELITE
TYPICAL NEW AJB
SCHEMATIC DIAGRAM
TERMINAL BLOCK
EXISTING NEGATIVE CABLES
NEW NJB
SCHEMATIC DIAGRAM
LEGEND:
TR, TRU : TRANSFORMER RECTIFIER UNIT
AJB : ANODE JUNCTION BOX
NJB : NEGATIVE JUNCTION BOX
BB : BONDING BOX
TB : TEST BOX
TS : TEST STATION
IF : INSULATION FLANGE
AG : ABOVEGROUND
UG : UNDERGROUND
SACP : SACRIFICIAL ANODE CATHODIC PROTECTION
: VARIABLE RESISTOR
: 3-PHASES 380V
: EARTH
D-TB-TEX
BAKELITE
NEW TB (FOR IF 122 - FW-6203-12" _TEX PLANT)
SCHEMATIC DIAGRAM
SACP BOXES BOND TO EXISTING BB's
SCHEMATIC DIAGRAM
NOTE :
1. 3 x BOND CABLES BETWEEN EXISTING DRAINPIPE SACP SYSTEM
TEST BOXES AND EXISTING MAIN PIPE BOND BOXES. BOND
CABLES ARE DISCONNECTED UNTIL IPS ARE RECTIFIED.
TRU
NEW AJB BOX
POSITIVE CABLE
ANODE CABLE
ANODE CANISTER
A1
A2
A3
A4
A5
TYPICAL ANODE GROUP SCHEMATIC

IL-15

Atmospheric corrosion resistance of stainless steel: Result of Field Exposures in Marine Environments

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Keywords: ATMOSPHERIC CORROSION, MARINE ENVIRONMENT, STAINLESS STEEL

Corrosion can profoundly affect the service life of structures and their components in maritime coastal regions. One of the key reasons for choosing stainless steel for structural applications in marine environments is its exceptional corrosion resistance, which ensures long-term durability. Additionally, aesthetic considerations play a vital role in the selection of stainless steel for architectural purposes. The atmospheric corrosion resistance of stainless steel can vary significantly across different marine regions due to factors such as the concentration of sea salt aerosols and climatic conditions. These factors influence the risk of atmospheric corrosion, potentially leading to material degradation if unsuitable grades are selected.

International standards and guidelines, including ISO 9223, EN 1993-1-4 Annex A (Eurocode 3), the IMOA Site and Design Evaluation System tool (IMOA program), and a Corrosion Map, establish frameworks for material selection in structural applications. While these guidelines aim to simplify the material selection process and minimize testing duration, they must accurately depict the behavior of stainless steel under real-world environmental conditions. This study presents the findings from various field investigations into atmospheric corrosion in maritime coastal regions characterized by diverse climates: (1) Bohus-Malmön, Sweden; (2) Dubai, United Arab Emirates (UAE); and (3) Songkhla, Thailand. The selection of suitable material grades in these environments must align with performance requirements. The results underscore the considerable impact of environmental factors, particularly chloride ions, contamination, and rainfall, on localized corrosion and surface degradation. These findings are examined in the light of current understanding regarding the atmospheric corrosion of stainless steel, offering valuable insights for practical applications in the field.



IL-16

Crevice Corrosion Behavior of Rail Steel Grade U900A by Corrosion Monitoring Sensor and Coupons at Lampang Environment

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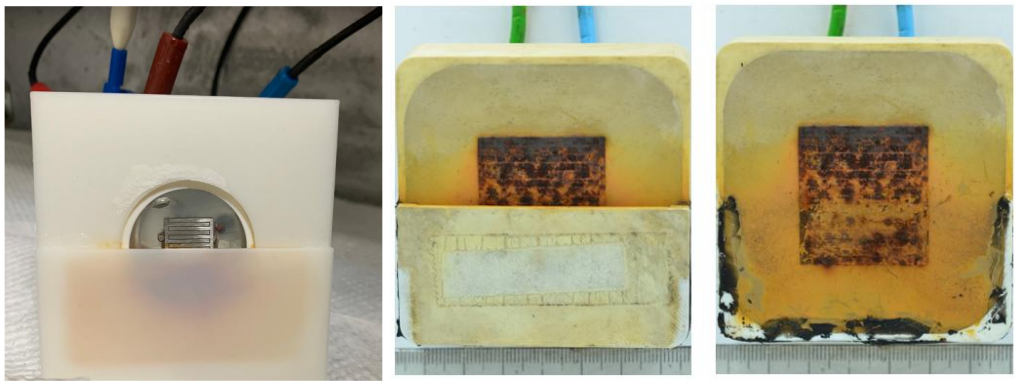
Keywords: Crevice corrosion, rail steel, bi-electrode sensor, accelerated corrosion test

The contact between the railway track and fastening systems often contains crevices at the interface. These areas are highly susceptible to severe and unpredictable crevice corrosion, posing significant challenges to long-term durability and maintenance. This project studied crevice corrosion behavior by rail steel grade U900A via crevice sensor and coupons. In the development of a laboratory-scale prototype of a bi-electrode sensor for crevice corrosion, the experimental results indicated that the corrosion data obtained from the crevice sensors showed good agreement with those from coupons under similar simulated conditions. Therefore, corrosion monitoring sensor can enhance the accuracy of corrosion prediction, as they enable detailed measurement of corrosion progression through electrochemical techniques.

Accelerated cyclic corrosion tests with exposure to synthetic ocean water salt-deposition process (ISO 16539) were simulated in accordance with the exposure test condition at Lampang station for 12 months. The corrosion rates were found to be consistent with each other. The corrosion classification (ISO 9223) was determined to be category C2. Under simulated condition at more severe corrosivity, the corrosion rate increased by 1 – 2 categories.

Corrosion map for rail steel and fastening system has been constructed based on crevice corrosion studies in accelerated corrosion tests and field test validation. The resulting data will support the selection of rail materials appropriate for specific environmental conditions, facilitate informed decision-making regarding rail infrastructure expansion, and contribute to the development of a corrosion map for rail materials across various regions of Thailand. The key finding can be applied to crevice corrosion in other industries as well.

Graphical Abstract (mandatory)



Title: Enhancing Corrosion Protection in Aboveground Storage Tanks with Vapor Phase Corrosion Inhibitors

Abstract:
Underside corrosion of aboveground storage tank (AST) bottom plates remains a critical integrity concern, particularly in cases where cathodic protection (CP) performance is compromised due to poor electrical continuity with the sand foundation or shielding by contaminants such as oily sand or bitumen. While CP and protective coatings are widely applied, their limitations in certain field conditions necessitate supplemental mitigation approaches. Vapor phase corrosion inhibitors (VpCI) have gained increasing attention as a viable solution, especially for complex tank bottom environments.

Recent industry standards, including API TR 655 and AMPP SP21474-2023, offer comprehensive guidance on the design, application, and performance validation of VpCI systems. These inhibitors can be deployed across various tank configurations using application-specific methods such as:

1) Slurry injection through under-tank dispensing systems during new construction,
2) Powder injection beneath existing tanks, and
3) Emitter placement around the tank perimeter for retrofitting scenarios.

Each method can serve as a standalone corrosion control strategy or complement existing CP and coating systems for enhanced protection.

Field implementations have demonstrated a minimum 70% reduction in underside corrosion rates, often achieving corrosion rates below 5 mils per year (MPY). These results support the effectiveness of VpCI in extending AST service life, reducing the frequency of internal inspections, and improving overall risk management. This paper will discuss corrosion mechanisms, design considerations, and performance outcomes associated with VpCI implementation in AST bottom protection.

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Keyword: Above Ground Storage Tank, Cathodic Protection, Vapor Phase Corrosion Inhibitor

Title: Difficulties in Achieving Electrical Isolation for Pipeline Cathodic Protection

Abstract:
Electrical isolation is essential for ensuring the effectiveness of cathodic protection (CP) systems in onshore pipeline networks. According to industry standards such as AMPP SP0286 ("Electrical Isolation of Cathodically Protected Pipelines") and AMPP SP0169 ("Control of External Corrosion on Underground or Submerged Metallic Piping Systems"), proper electrical isolation is critical to prevent current leakage, minimize stray current interference, and enable accurate monitoring of CP performance.

In practice, however, maintaining reliable isolation can be challenging—particularly when pipelines operate in environments with conductive media, such as moisture-laden soil or hydrocarbon residues. This paper presents a case study in which a conventional glass-reinforced epoxy (GRE) isolation gasket failed to maintain effective isolation due to intermittent conductive paths formed by fluid ingress. As a result, CP system performance was compromised, and fluctuating pipe-to-soil potentials were observed.

The issue was resolved by replacing the GRE gaskets with upgraded isolation kits featuring Teflon inner diameter (ID) seals, which provided superior sealing performance and resistance to conductive contamination. This solution restored effective electrical isolation and stabilized CP system performance.

The paper will discuss the root cause analysis, field testing techniques (in alignment with AMPP TM0107, "Field Testing of Electrical Isolators in Cathodic Protection Systems"), and best practices for material selection and installation. Emphasis will be placed on ensuring long-term isolation reliability in compliance with AMPP SP0286, as well as the broader CP system design principles outlined in AMPP SP0169 and API RP 651.

This case highlights the importance of integrating proper design, field validation, and material selection to overcome real-world isolation challenges in onshore pipeline cathodic protection systems.

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Keyword: Above Ground Storage Tank, Cathodic Protection, Vapor Phase Corrosion Inhibitor

IL-19

Advanced Remote Monitoring Solutions: Merging High-Frequency Data Logging with Edge Computing for Enhanced Cathodic Protection Analysis

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Keywords: Cathodic Protection, Remote Datalogger Unit, Edge Computing.

Recent technological advancements in cathodic protection monitoring have led to the development of next-generation remote monitoring devices that combine the capabilities of traditional Remote Terminal Units with high-frequency data logging features. These innovative devices address the growing challenges in modern infrastructure protection, particularly in environments affected by stray currents and telluric interference. By implementing continuous second-based sampling of critical parameters such as structure potential, coupon polarization, and current density measurements, these systems enable comprehensive analysis of time-variant effects on protected structures.

The integration of edge computing technology represents a significant breakthrough, allowing these devices to process vast amounts of collected data locally and generate condensed daily reports containing essential statistical information, including averages, extremes, and threshold violations. This approach dramatically reduces data transmission requirements while maintaining analytical depth and consent daily data transmission even operating on batteries.

Real field cases will be shown, demonstrating that this combination of high-frequency sampling and daily reporting capabilities significantly simplifies cathodic protection effectiveness assessment, providing unprecedented insight into protection system dynamics. Real-world applications reveal how this technology enables technicians to identify and analyze complex interference patterns and protection issues that were previously difficult to detect, marking a transformative advancement in infrastructure asset protection monitoring.

The Nautilus Robotic Solution: A Single Robot That Integrates Inspection, Maintenance, Repair Capabilities For Subsea Pipelines And Tubulars

Phongpat Binsomprasong[1], Thitikul Nagadhana[2]

S2 Robotics Company Limited

1 ABSTRACT

The Pipeline Inspection and Repair robot, "Nautilus", can deliver full pipeline Inspection, Maintenance and Repair (IMR) service with less time, less resources, and less risk. Delivering all tasks in a single robot represents a major achievement, and a significant reduction in CO_2 emissions since all the IMR activities are performed in a single trip of a vessel and with a single crew. By performing all repairs in a closed habitat, all debris from the repair is brought back to the surface for disposal.

In the Oil and Gas industry, subsea pipelines are the vital part of installed subsea infrastructures. As these pipelines age, they are subjected to different forms of degradation, including internal corrosion. In the worst cases, this degradation eventually leads to through-wall defects, leaks and production shutdown. Currently, underwater pipeline repairs are conducted by saturation divers to stop or prevent product leakage. The use of the Nautilus is a novel approach that integrates all the relevant tasks for pipeline spot repair into one single robotic system.

Comparing the workflow between the conventional approach and Nautilus. Clearly, deciding to perform remedy action for non-leak repairs can be made much faster as the operating cost is over 20% cheaper than a conventional repair by a saturation diver. As such, asset owners can resume full operations considerably faster when compared to the conventional approach.

The Nautilus has undergone testing and demonstration in the Gulf of Thailand in 2022, involving engineering calculation for testing inside the pool (Pit Test), Pit test demonstration, engineering calculation for first subsea operation, hazard and operation study (HAZOP) prior to the operation, world's first offshore operation and the final review and report with the customer acceptance.

Nautilus successfully completed the first ever operation in the Gulf of Thailand and It has been commercialized since in October 2022.

2 INTRODUCTION

The conventional method of subsea pipeline repairs has been relying on the availability of the fit-for-purpose subsea pipeline repair clamps. The clamp must be installed using divers and ROV. The long lead time, project cost, operating time, CO2 emission and fatality risk have always been the difficulties for oil and gas operators since it's involving defect analysis, design of the clamp, clamp manufacturing/transportation and storage and availabilities of the specialist (diver) and the diving support vessel.

The operation of the subsea pipeline inspection, repair and maintenance robot "Nautilus" is based on the use of an Offshore Support Vessel (OSV). Once the OSV is positioned at the known coordinates of a defective pipeline, the ROV operators will deploy a W-ROV to survey the working area and excavate the seabed thus preparing for Nautilus. The operator will deploy the Nautilus from the vessel to engage at the location of the defective pipeline. The operators onboard will control the Nautilus to perform the variety of tasks including;

- Draining seawater to empty the habitat.
- Verify the defected location by NDT (if no visible leak is found) using UT and TOFD.
- Removing anti-corrosion coating.

- Applying a 2-component epoxy coating.
- Apply the leak repair solution (Patching) on the defective area.
- Wrapping with a composite material (Carbon fiber wrap).
- Flooding the habitat and completing the repair.

The repair system using coating, leak repair solution (Patching) and wrapping has been certified by DNVGL and is able to last over to 10 years depending on operating pressure and temperature.

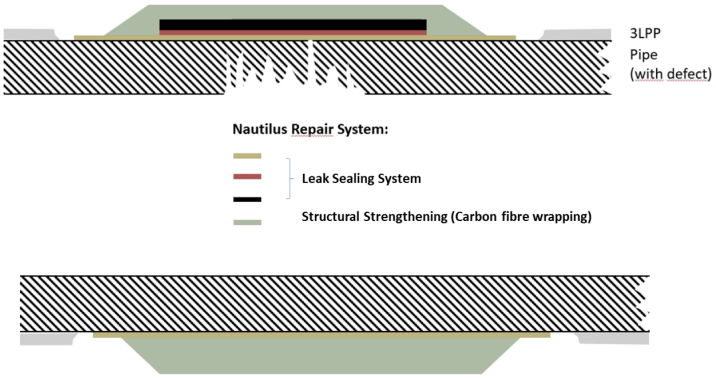

Fig. 1—Illustration of Composite Repair System for leaking flowlines performed by Nautilus

Function	Quality Standard
Surface prep	ST3 level cleanliness (ISO 8501 / ISO 8503)
Coating	2 comp epoxy (NACE / NORSOK M-501)
Structural Strengthening	Composite repairs for pipework (ISO 24817)

Table 1- Pressure Quality Standard

3 BACKGROUND, INFORMATION AND SPECIFICATION

The Nautilus has been originally developed with PTTEP since 2015 crafted from the needs that PTTEP would like to improve the offshore pipeline inspection and repair operation for both commercial and safety aspects.

As S2 Robotics is a subsidiary company under PTTEP, Thailand, we fully understand the pain points of current pipeline IRM solutions. Together with the Kongsberg Ferrotech, who demonstrate extensive expertise in subsea technology intervention, we have built Nautilus, a 100% joint designed robot. All the repair materials for patching and wrapping are selected, tested, and certified by international accreditation and classification societies.

As well as the integrated NDT techniques employ globally well-known and reliable methods. Nautilus is a cutting-edge solution for pipeline inspection repair and maintenance created by an E&P operator for other E&P operators.

Key Features

- Remote control robot for pipeline inspection and repair with no diver required
- NDT feature (over coating, 3LPP) using UT and TOFD
- Coating removal using mechanical tool and re-coating
- Pipeline repair feature (patching and wrapping)
- Non-stop operation
- No waste disposed into the water and less CO_2 emission
- Real-time monitoring and decision making from anywhere

Service Application

- Pipeline inspection (NDT over coating)
- Pipeline repair (patching and wrapping method)

Specification

- Working depth 1,000 m.
- Pipeline repair diameter 8”-20”
- Wrapping material: Composite material (NRI Viperskin)
- Max temp: 92 DegC
- Max pressure: 60 Bar (for thru-wall defect)

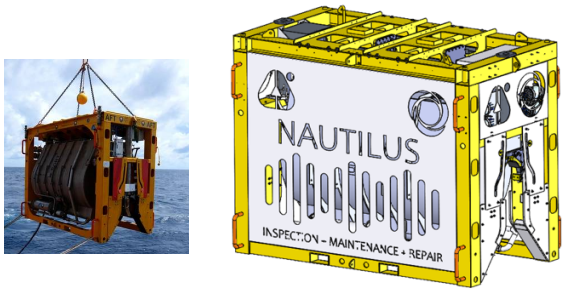

Fig. 2-Nautilus

4 SUCCESSFUL DEPLOYMENT OF IRM ROBOT

4.1 PIT TEST STAGE

A system test and demonstration (Pit test) of Nautilus was requested to be performed on a 16” thin-walled test pipe in a pit. The main objective was to demonstrate full Nautilus operation on a thin-walled test pipe to simulate a worst-case scenario verifying that Nautilus landing, clamping and all repair operation do not damage the pipe with 6 mm wall thickness. In addition, it was a validation of the NDT system.

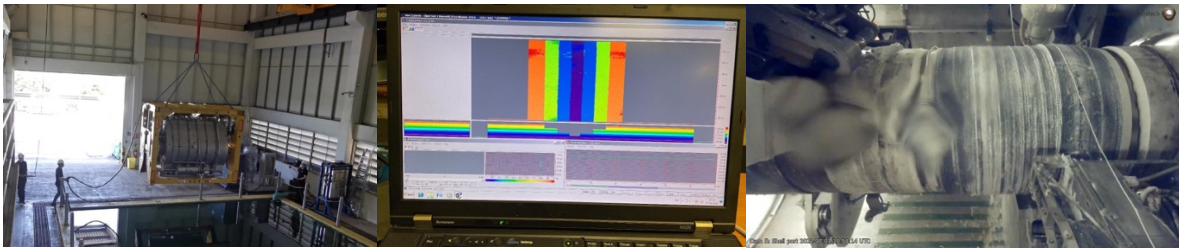

Fig. 3- Pit test and result

Pressure test: The test pipe with the repair was retrieved, and a pressure test was performed. DNV inspector witnessed the pressure test. See. Table below presents the result of the pressure test. table below presents the result of the pressure test.

Test pressure [bar]	Hold Time [min]	Result/Observations
10	1	OK. No leakage
20	1	OK. No leakage
30	1	OK. No leakage
40	1	OK. No leakage
50	1	OK. No leakage
60	1	OK. No leakage
70	1	OK. No leakage
85	60	OK. No leakage

Table 4- Pressure test result

Summary: The full Nautilus operation for this pit test was successfully completed. Demonstration has verified that Nautilus landing, clamping and all repair operation can be performed on a thin-walled pipe. The integrated NDT system demonstrated its capabilities. All steps and applications were carried out as intended and the full repair was completed in ahead the time schedule. The Nautilus Robot System worked as planned, and it has proven a stable and safe operation.

4.2 OFFSHORE DEPLOYMENT

Top of line corrosion (TLC) has been identified in customer's pipeline in the gulf of Thailand (GOT) by MFL pigging in 2020. The objective of this operation is for Nautilus to land on a defined area. Once the defect is verified, a repair system shall be applied over that area..

Pre-operation info	Details
Pipe Material Specification	Seamless API 5LX65
Size(OD)	16"
Nominal Wall thickness	19.1 mm
External Coating	2.7 mm of 3LPP coating
Design pressure and operating pressure	77 barg / 25 barg

Design temperature and operating temperature	120 degC / 27 degC
Nautilus scope	Verfity defect and perform repar near field joint
Vessel type	DP2 vessel

Table 5- Pipeline information

A repair system has been designed and prepared for the pre-identified defect. This defect was localized and identified during MFL pigging inspection in 2020. The details below were provided by customer prior to the offshore operation.

Defect details	
Defect location	Near field joint
Type of defect	Internal corrosion
Size and shape	37mm x 55mm, see figure below
Wall loss%	67% peak WL, 24% average WL (as per MFL pigging results from 2020)
Through-wall defect size and shape	Non-through-wall
Orientation on the pipeline	08:15
Obstacles within 2m each direction of the defect	Field joint 330mm from the defect center. Heat Shrink Sleeve (HSS) over field joint ~200mm each direction from the center of weld

Table 6- defect information

The operation schedule as per table below. The pipeline was one of the pipelines which were not shut down.

Activity	**Days**
Transit	1
Mobilization at port	2
Vessel departs from port to the field	1
Dredging preparation	3
Nautilus operation	2.5
Transit	1
Demobilization	2
Travel back to the base	1

Table 7- Planned Operation timeline

Dredging, High Pressure Water Jet and Area Marking

Total of 7 days were planned for the dredging activity. However, these activities were completed by ROV in 3 days which is well ahead of schedule.

Deployment and Installation

Nautilus deployment commenced as planned. The landing of Nautilus was carried out by the vessel crane. Nautilus was landed on the pipeline within the marked area observed by the ROV. The landing on the pipeline within the marked area was carried out efficiently.

Fig. 16—Nautilus landed on the marked area of the pipeline

Defect Verification

After the Nautilus shells were closed, an NDT scan of the defined area was performed. Based on the real-time result, the worst defect area was identified for patching application which has been agreed upon between the operator and Nautilus crew. Defect center is at approximately 12:30 o'clock position, and it is 437,5mm from the Field Joint.

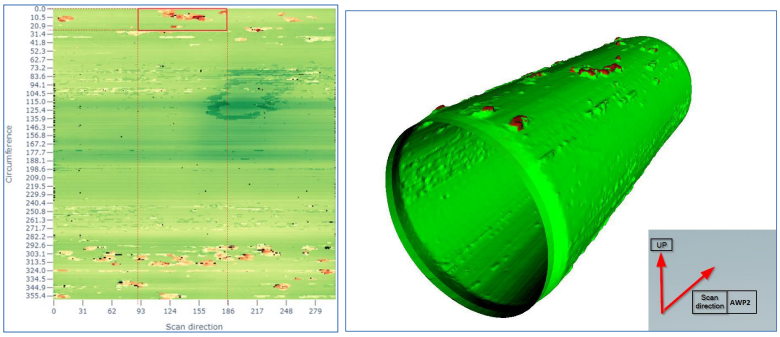

Fig. 17—NDT scan result performed by Nautilus

Surface Preparation

Following the NDT scan sequence, the habitat was established to provide the clean, dry environment. Nautilus then commenced the surface preparation operation to remove 3LPP coating of the pipeline. During the 3LPP removal process, the debris was flushed away and filtered in the shells' drainage system. Surface preparation operation continued until the pipe's bare steel.

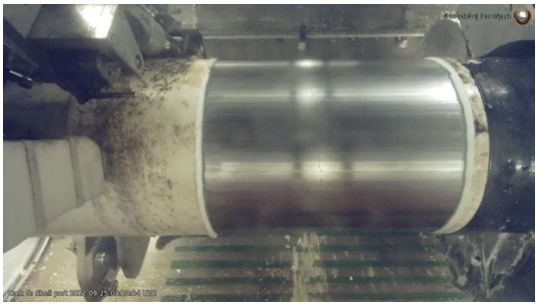

Fig. 18—Clean surface area inside the habitat after 3LPP coating was removed

Coating Application

Once the repair area was fully dry, the coating application was performed. All pipe's bare steel section in the repair area was fully coated and confirmed through the live-feed camera from different angles. The coating then was left to cure as per the pre-calculated curing time based on the ambient conditions.

Conclusion: Coating application completed. Coating has good coverage over the repair area according to procedure. All pipe bare steel sections in the repair areas are covered with coating. Nautilus can proceed to the next step, which is curing of coating, and followed by leak repair application.

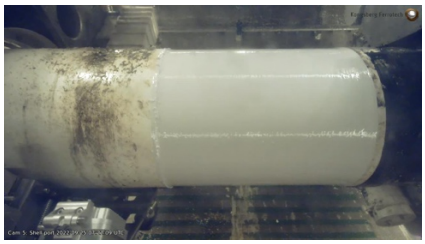

Fig. 19—Coated repair area

Leak Repair Application

Once the coating is cured, Nautilus proceeded to the leak repair application sequence. The patch was moved over to the agreed defect area following the NDT scan result and was pressed against the pipe. It was kept pressed during the heat treatment/curing. After the curing time, Nautilus crew removed the patch-holder.

Conclusion: Adhesive and patch applied over the defect correctly according to program. Heat treatment of the adhesive for 5 hours is completed. Some excessive adhesives at the edges, which indicates good coverage under the patch. Next step is wrapping application.

Fig. 20—Patch application

Composite Wrapping

The composite wrapping was applied according to the pre-programmed sequence. Fresh water mist was sprayed on and around in the habitat throughout the entire application to activate the curing process of the wrapping product. At the end of the wrapping program and during curing, the fiber cloth was kept with tension following the pre-defined time before it was released.

Conclusion: Wrapping application is finished, and it was applied completely with no flaws. Curing of wrapping with tension in the habitat. When it is cured, the system repair is completed. Habitat can be waterfilled and Nautilus retrieved.

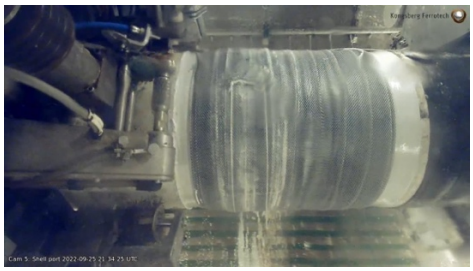

Fig. 21—Complete repair inside the habitat

Habitat Refill and Nautilus Retrieval

When the composite wrapping had cured for 4 hours, the tension was released. Thereafter, habitat was refilled with water, followed by opening of the shells. ROV hook reconnected to the Nautilus master link, and the Nautilus was then retrieved back to the vessel after a successful operation.

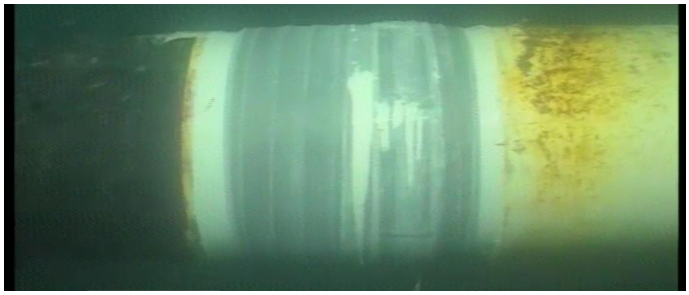

Fig. 22—Finished repair post Nautilus retrieval.

Repair System Result

The as-built repair system is based on the actual defect identified by the NDT inspection tool with Nautilus. The applied repair system is according to the standard Nautilus repair system which is DNV approved.

The 3D figure and diagram below show the actual applied repair at the location.

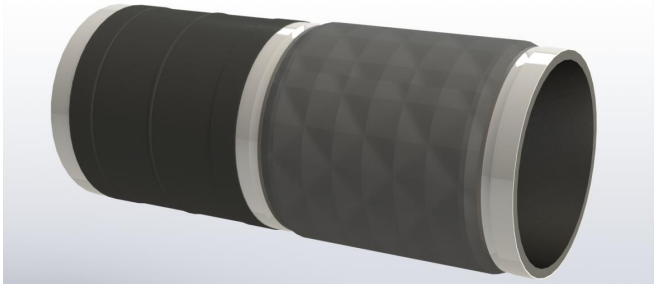

Fig 23- 3D figure of the repair.

Summary

All operations were carried out safely without any injury or damage to equipment. Efficient dredging and site preparation allowed for Nautilus repair operations to begin ahead of schedule. Some delay in asset owner decision making and slight malfunction of the Force NDT sensor meant that the Nautilus operation took longer than necessary. Nevertheless, all activities were completed well ahead of schedule and a quality repair executed for the first real world application of Nautilus.

5 BENEFITS OF NAUTILUS

5.1 NAUTILUS ROBOT VS CONVENTIONAL METHOD - PREPARATION

The conventional method has some difficulties for the preparation which involves long preparation times and high cost including.

1) Defect analysis
2) Design of the clamp and clamp manufacturing.
3) Clamp transportation time and clamp storage.
4) Availability of the specialist (diver).
5) Availability of the diving support vessel.

The preparation time of the conventional method could be up to 3 - 6 months. On the other hand, Nautilus can remove all the difficulties with all these reasons.

1) Same consumables for all pipe sizes.
2) The leak solution system and wrapping are on shelf and ready for the operation immediately.
3) It can perform the operation continuously. It can move to the next defect right after completion the previous one.
4) No diver and diver support vessel required.

5.2 NAUTILUS ROBOT VS CONVENTIONAL METHOD - OPERATION

According to the Nautilus operation during the thin wall offshore deployment which only took 2.5 days, we can estimate the cost comparison between Nautilus operation and the conventional method (Clamp installation by diver) as showing below.

Conventional Method	Nautilus Operation

Clamping, diver and supporting personnel	773,600	Nautilus and personnel	**259,404**
Support Vessel for diving emergency	223,520	Support Vessel for diving emergency	**0**
Main vessel	1,994,400	Main vessel	**1,249,654**
Others	10,450	Others	**4,666.67**
Total	2,701,970	Total	**2,253,804**

Table 9- operating cost comparison between conventional method and Nautilus operation

The main benefits of the Nautilus operation; firstly, the Nautilus operation does not require the support vessel for diving emergency since the operation has zero diver requirement. Secondly, the robot can complete the operation within 3 - 5 days while the conventional method could be completed by 7 - 14 days depending on the defect conditions. Finally, Nautilus operation does not require the diver which mean there will be zero fatality risk.

Moreover, Nautilus repair system can be used for prevention in case of the emergency (EPRS) which can reduced the unplanned shutdown that could lead to high loss of the production.

5.3 NAUTILUS ROBOT VS CONVENTIONAL METHOD - ENVIRONMENTAL EFFECT

The Nautilus operation functions as a closed system, wherein all debris, compressed air, and fluid are confined within the system or discharged at the surface. This process ensures that the environmental impact of the operation is kept to a minimum. Furthermore, the Nautilus method requires fewer auxiliary vessels, resulting in significantly reduced CO_2 emissions in comparison to the conventional operation.

	Category	Conventional Clamp	Nautilus
1	Weight of repair material	190 kg *	10 kg
2	Number of repairs per mobilisation	1 location	1 location
3	Inspection time	48 hrs	12 hrs
4	Repair time	120 hrs	36 hrs
5	Distance from warehouse to Port	1090 km	2180 km **
6	Vessel Transportation - port to operation site (round trip)	400 km	400 km
7	Vessel type	DSV	Std vessel ***
SUM	CO2 footprint (Tonnes of CO2 equivalents)	328 tCO2e	124 tCO2e

* Assuming std Plidco clamp or similar, 16in
** Roundtrip Pinthong – Songkla
*** Using data from MS Gunnerus – sufficient vessel for Nautilus operation

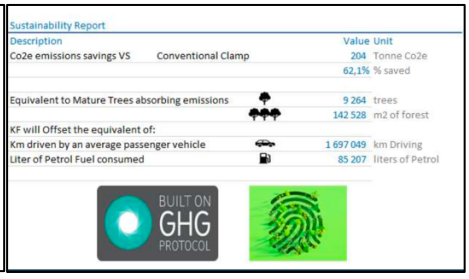

Table 10- CO_2 Emission comparison between conventional method and Nautilus operation

Waste and emission during Nautilus operation

Type	Amount (per repair)	Environmental Impact	Comment
PP	Pipe specific	None	Removed existing 3LPP coating from pipeline which is brought back to surface. No debris left in the sea.
FBE	Pipe specific	None	Removed existing 3LPP coating from pipeline which is brought back to surface. No debris left in the sea.
Corrosion Inhibitor	0,3 L	None	Applied on bare steel pipe during surface preparation to prevent corrosion. Emmision to sea.
IPA (Isopropyl alcohol)	4 L	None	Applied on pipe prior to coating applicaiton to clean the pipe from any oil and other contamination. Emmision to sea.
2 Epoxy Coating	ca 0,4 L	None	Coating remains in the coating roll, and minor spills inside the habitat. Cured to solid and brought back to surface.
Polyurethane resin	ca 0,1 L	None	Remains and spills of wrapping resin inside robot. Cured to solid and brought back to surface.

Table 11- Waste Emission comparison between conventional method and Nautilus operation

6 CONCLUSION

With the Nautilus robot, the pipeline Inspection, Maintenance and Repair can be carried out much faster than the conventional clamp method. The valuable detailed NDT scan can be provided to verify the defect area prior the execution of the repair ensuring the correct location as well as verifying the information received from the PIG operations. The DNV certified repair uses on-the-shelf consumables regardless of the pipe size and is performed in a controlled environment inside the habitat ensuring the quality of the repair. All the repair steps can be adjusted on-the-fly based on pipeline conditions faced during the actual repair. These steps are performed in a closed habitat wherein all debris, compressed air, and fluid are confined within the system and discharged at the surface ensuring the minimum environmental impact. Nautilus repair is done in a single dive with a smaller DP vessel without the needs of divers and the larger Diver Support Vessel (DSV) eliminating the fatality risk and resulting in significant reduction of CO_2 emission in the operation comparing to the conventional clamp operations.

IL-21

Next-Generation Boiler Water Management in Flexible Power Operations

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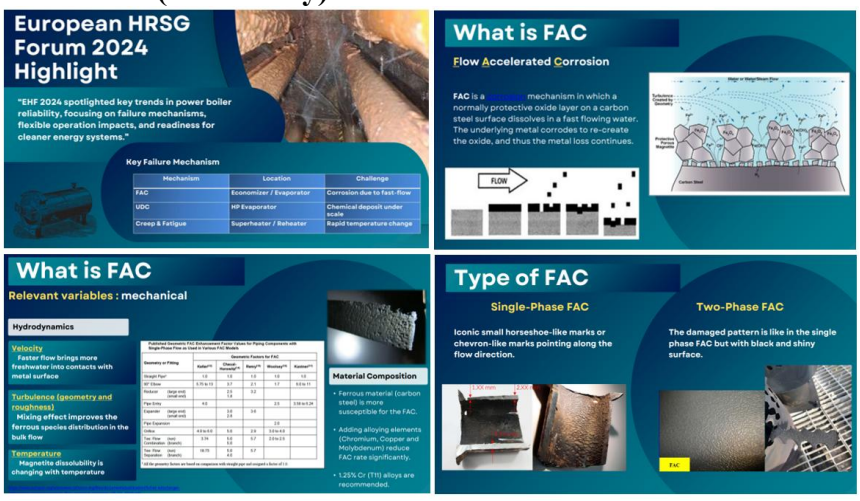
Keywords: FAC, HRSG Chemistry, Boiler Water Treatment, Flexible Operation

Flexible operation in modern power plants intensifies corrosion risks in boiler and HRSG systems, particularly Flow-Accelerated Corrosion (FAC). This presentation summarizes key factors influencing FAC, including flow conditions, temperature, material composition, and water chemistry variables such as pH, dissolved oxygen, and ORP. Treatment program options—AVT(R), AVT(O), OT, PT, and CT—are compared with emphasis on their suitability for different HRSG configurations and operating regimes. Case studies demonstrate that transitioning from High-AVT(R) to High-AVT(O) enhances oxide film stability, reduces iron transport, and mitigates operational issues. Effective shutdown preservation methods are also highlighted. These practices represent next-generation boiler water management approaches that improve reliability under flexible, cyclic operation.

Graphical Abstract (mandatory)



IL-22

Development and engineering application of MXene-based anti-corrosion/wear resin coating

FAN Xiaoqiang
Southwest Jiaotong University

The waterborne epoxy resin coatings suffer from drawbacks such as high porosity in spatial structures, poor resistance to the spread of corrosive media, and unsatisfactory tribological properties, significantly hindering their further application in practical engineering. Two-dimensional (2D) nanofillers can significantly enhance the protective performance of epoxy coatings due to its small size effect, high mechanical properties, easy interlayer shear, and impermeability. Among them, 2D Ti3C2Tx MXene, with high specific surface area, excellent mechanical properties, high electrical conductivity, and abundant surface functional groups that are easily tunable, demonstrates immense potential in improving the protective properties of waterborne epoxy resin coatings. However, to fully leverage the anti-corrosion and wear-resistance advantages of Ti3C2Tx hybrid epoxy coatings in harsh environments and meet the comprehensive protective performance requirements of anti-corrosion/wear for modern and future equipment, there are still a series of challenges to overcome. Currently, we primarily focus on enhancing the protective performance of Ti3C2Tx-based polymer coatings from the following aspects: (1) Enhancing the dispersion stability and compatibility of Ti3C2Tx nanosheets with the polymer matrix; (2) Inhibiting/utilizing the high electrical conductivity of Ti3C2Tx nanosheets; (3) Achieving oriented arrangement of Ti3C2Tx nanosheets in the resin matrix; (4) Intelligentizing Ti3C2Tx MXene. Design principles for functionalized Ti3C2Tx-based resin coating systems are established and the interaction between Ti3C2Tx-based composite resin coatings and multiple environmental factors are explored. The protective performance of Ti3C2Tx composite epoxy resin coatings are systematically investigated and the protection and failure mechanisms of the composite coatings are elucidated.

IL-23

Research on Ultrasonic Method for Online Monitoring of Corrosion Status in High-Speed Train C-Type Grooves

JIN Junjun
Southwest Jiaotong University

The corrosion thickness detection system of C-type groove of high-speed train realizes the real-time online detection of the corrosion thickness of C-type groove by laying a multi-channel ultrasonic transducer array on the C-type groove structure, using the ultrasonic signal propagation characteristics to measure the thickness, and combining the functions of signal acquisition, digital processing, corrosion judgment, data transmission and alarm prompt. The system has the characteristics of high precision, high reliability, strong anti-interference, visual monitoring and intelligent analysis, and can be widely used in the safety inspection of high-speed trains and rail transit vehicles

IL-24

The behavior of hydrogen absorption into high-strength steel sheet under atmospheric corrosion environment

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Keywords: Hydrogen embrittlement, Atmospheric corrosion, Hydrogen absorption, Ultra-high-strength steel(UHSS).

These days, ultra-high-strength steel sheets are applied to automobile bodies to reduce body weight and improve crash safety. However, one of the problems associated with such applications is hydrogen embrittlement (HE). The factors contributing to the occurrence of HE include steel strength, stress, and the amount of absorbed hydrogen. In our previous study, a hydrogen monitoring system was developed to measure the accurate amount of absorbed hydrogen based on the electrochemical hydrogen permeation method.

In this presentation, the hydrogen absorption behaviors of Ultra High Strength Steel (UHSS) were investigated in a corrosive atmospheric environment using a developed system. In the automotive sector, UHSS is utilized after undergoing press processing; therefore, steel sheets subjected to strain were employed in laboratory dry-wet corrosion test cycles to examine the effects of temperature and salt load. The results indicated a tendency for amount of absorbed hydrogen to increase with higher temperature and larger salt load. This trend was consistent with that observed in mild steel; however, the amount of absorbed hydrogen was significantly larger in UHSS. Furthermore, it was demonstrated that the amount of absorbed hydrogen increased with the level of strain applied. Additionally, the results of exposure tests conducted in Thailand will be compared, and the relationship between absorbed hydrogen and environmental factors will be discussed.

Graphical Abstract

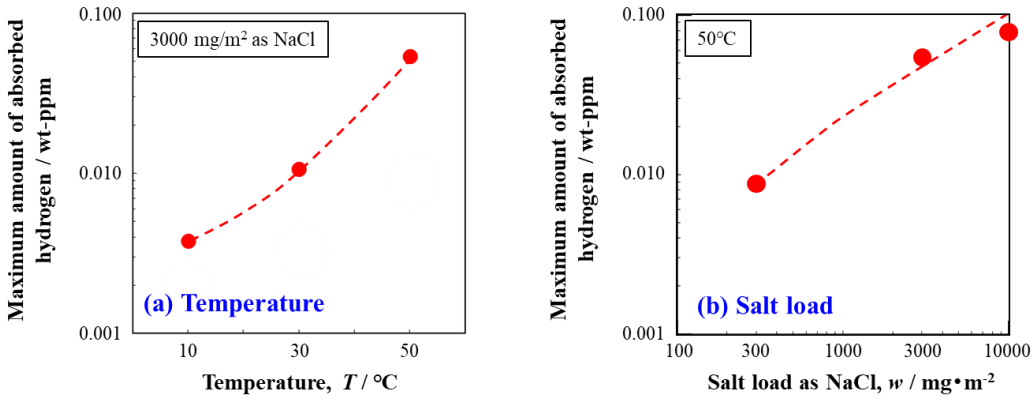

Figure Relationship between amount of absorbed hydrogen and environmental factors (a) Temperature (b) Salt load

IL-27

Recommendations for New Rail Inspection and Storage

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Keywords: Rail inspection, Rail storage, Decarburization, Standardization

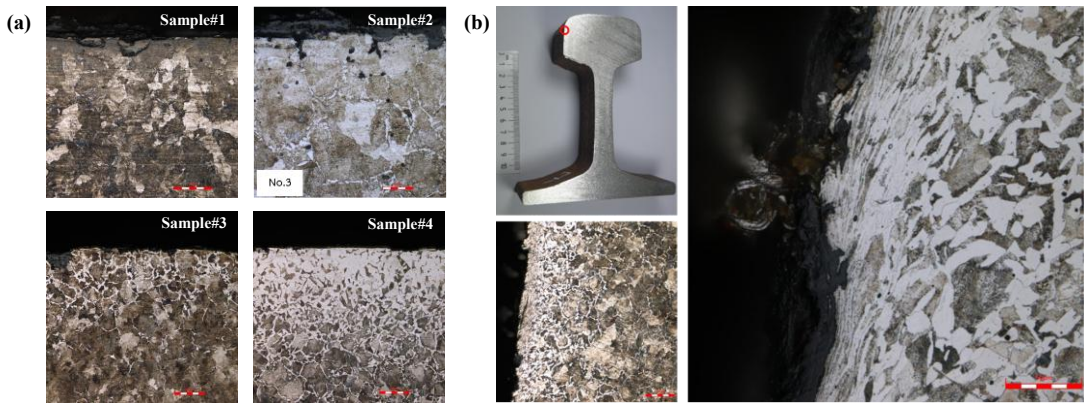
Rails are critical components in railway infrastructure, providing load-bearing capacity, directional guidance, and safe train operations. However, during service, rails are subjected to severe contact stresses, thermal effects from friction, and cyclic loading, which can cause plastic deformation, microstructural alterations, wear, rolling contact fatigue, and surface defects such as shelling and galling. Furthermore, decarburization layers formed during manufacturing may accelerate surface degradation. These issues compromise riding comfort, increase vibration and noise, and raise maintenance costs.

This study emphasizes the need for standardized acceptance and inspection procedures for new rails in Thailand. Metallurgical analyses of unused rails revealed that additional inspection requirements are essential to ensure safety and service life. Recommended procedures include microstructural examination of the running surface and cross-section, hardness profiling across the rail head, chemical composition analysis, and assessment of decarburization depth.

Based on these findings, a comprehensive inspection and storage standard has been developed in collaboration with the Department of Rail Transport and the State Railway of Thailand. The proposed standard defines technical guidelines for sampling, testing, corrosion protection, and storage, with reference to internationally recognized practices. Complementary measures include drafting manuals for rail head maintenance, corrosion risk mapping, and material selection for high-risk environments.

The outcomes are expected to enhance acceptance quality, reduce premature rail failures, and improve the efficiency, reliability, and safety of Thailand's railway system.

(a) Micrograph of a new rail showing corrosion attack and a decarburized zone with pro-eutectoid ferrite at the surface; (b) rolling contact fatigue cracking associated with the decarburized layer on the running surface after only 8 months in service. These results underscore the importance of sampling inspections of new steel rails to ensure long-term reliability and operational safety.



Oral Presentations
Energy Industry Session

The effect of temperature on corrosion of bismuth-40tin alloys in 3.5 wt.% NaCl solution

Chanin Tangpongkitjaroen[a], Tachai Luangvaranunt[a], Patama Visuttipitukul[a], Suwin Sompopsart[b], Wararit Toempromaraj[b], Passaworn Silakorn[b], Kittithuch Hnuruang[b], and Pitichon Klomjit[a,c,*]

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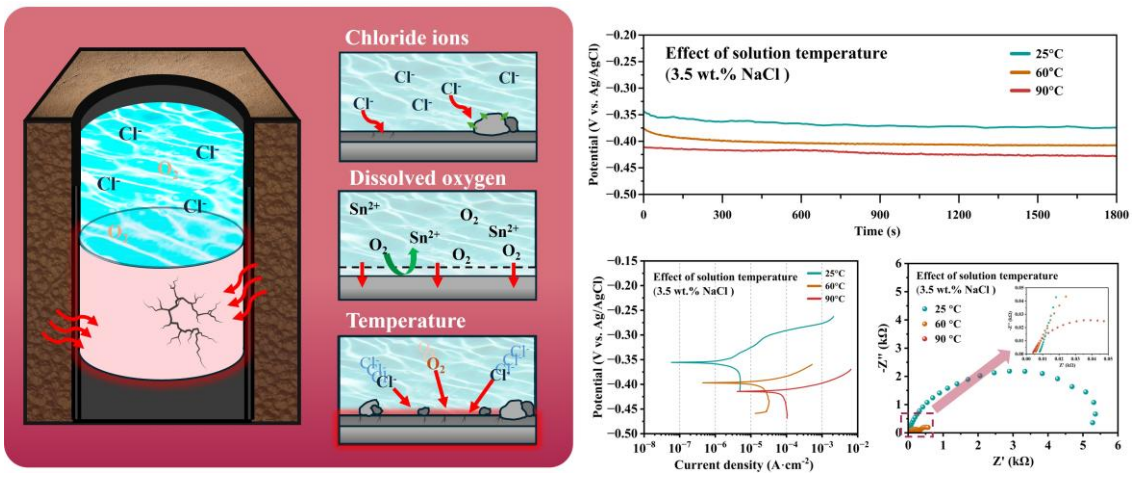
Keywords: Corrosion; Bismuth alloys plugs; Plugging and abandonment

The alternative plugging and abandonment (P&A) protocol utilizing thermite technology has attracted considerable attention in the oil and gas industry. By employing a thermite heater, low-melting-point alloys can be melted to seal the wellbore upon solidification, thereby preventing the leakage of chemical substances from the downhole. Bismuth–40 wt.% tin alloy (Bi-40Sn) is a promising candidate for P&A applications due to its low melting point, good castability, and expansion upon solidification, which enhances the sealing performance of the alloy plug. However, the corrosion of the alloy may significantly affect its mechanical properties, limiting its long-term use as a plug material. Furthermore, temperature and chloride ions are known to have a substantial influence on the corrosion rate of such alloys. In this study, the effect of temperature on the corrosion behavior of Bi-40Sn alloy in a 3.5 wt.% NaCl solution was investigated. The result from electrochemical method revealed that the corrosion resistance of Bi-40Sn decreased significantly with rising of temperature, indicate the critical role of temperature in the corrosion degradation of Bi-40Sn alloy in chloride-containing environments.



A-O-13

Implementation of High Velocity Thermal Spray for Reliability Improvement of Asset Critical Equipment

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Keywords: Corrosion, Protective barrier, Cladding

Thermal Spray has been around for 100 years, but only in recent years has it been developed into a robust internal protective barrier. There are several factors that need to be considered when considering options for upgrading metallurgy of internal surface of process equipment to improve the performance and extend asset life. The factors are not limited to material development, the delivery system, method of application, and time frame.
In Brownfield application, the speed of application is additional scope need to be considered with alternative protective coating system. It is important to understand the differences in how the system is implemented and produced. The seemingly insignificant differences in technology can lead to issues in application and in performance of protective barrier.
It is also noted that utilizing one solution provider is highly important to the users, therefore we aim to look what support work should be combined together to implement a permanent solution.
This paper addresses how High Velocity Thermal Spray (HVTS) overcomes the additional requirements that other systems require to rapidly apply a barrier which is now considered the most reliable protective system on the market.

A-O-23

Stabilizing Zinc Anodes in Zinc-Air Batteries Through Optimized Operating Parameters

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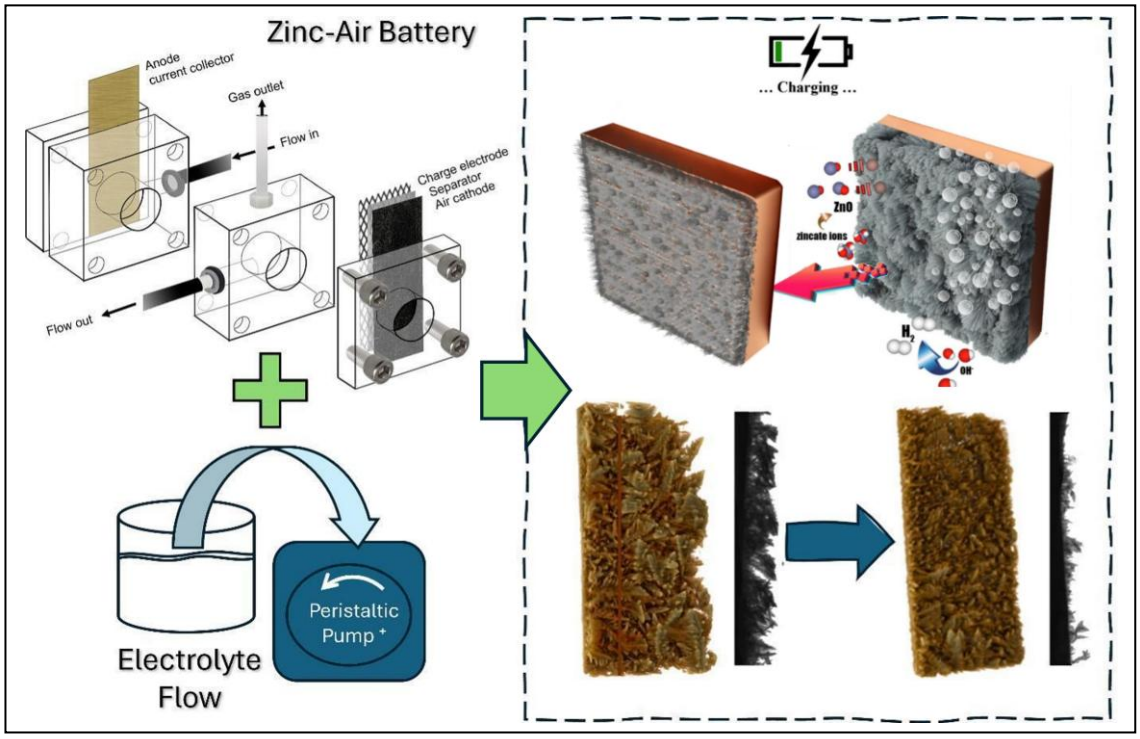
Keywords: zinc-air flow battery, zinc electrodeposition, current density, electrolyte flow rate, dendrite suppression, cycling stability, alkaline battery.

Zinc-air batteries (ZABs), are gaining attention as cost-effective and environmentally friendly energy storage systems due to their high energy density and inherent safety. However, their long-term performance is hindered by instability at the zinc anode, including dendrite formation, hydrogen evolution, surface passivation, and the memory effect, which lead to capacity fading and reduced cyclability. This work presents a detailed investigation into the influence of operating parameters, specifically current density and electrolyte flow rate, on zinc electrodeposition behavior and surface morphology in alkaline zinc air flow batteries (ZAFBs). Through in-situ synchrotron X-ray tomography, microscopic imaging, and electrochemical analyses, we show that regulating flow velocity and charging current significantly alters mass transfer characteristics, suppresses dendritic growth, and minimizes ZnO accumulation on the anode. Moderate current densities (50–60 mA/cm²) combined with optimized electrolyte flow promote smoother, more uniform zinc deposition and reduce charge-transfer resistance and overpotentials during cycling. These operating conditions also mitigate gas bubble accumulation and associated overpotentials, improving the reversibility of the zinc redox process and enhancing overall battery durability. Our findings highlight that engineering the operating environment can substantially improve zinc utilization and extend the lifespan of ZAFBs, offering a practical approach toward their commercialization and large-scale energy storage deployment.



A-O-31

Microstructural Characterization and Electrochemical Performance of Fine-Grained Aluminum Anodes Processed by Friction Stir for Aluminum-Air Batteries

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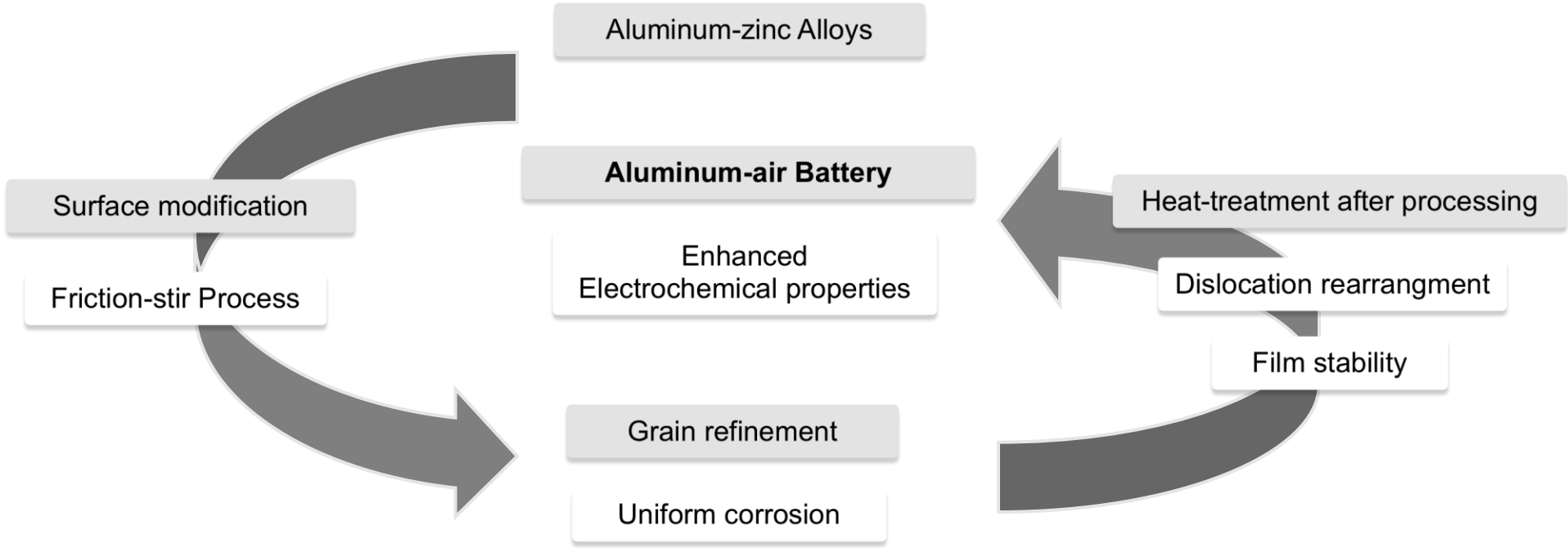
Keywords: Microstructure Characterization, Electrochemical Behavior, Aluminum Anodes, Aluminum-Air Batteries

This research explores the application of aluminum-zinc alloy anodes in aluminum-air batteries, focusing on optimizing their microstructure and electrochemical performance through solid-state processing and post-heat treatment. Aluminum alloys were produced using a modified Friction Stir Process, offering an alternative route for microstructural refinement. The modified surfaces were extensively characterized using ex-situ Electron Backscatter Diffraction and Transmission Electron Microscopy. Post-heat treatment was employed to examine changes in crystal orientation, revealing that preferred orientation can be altered to improve electrochemical properties. Electrochemical performance was evaluated through discharge behavior under stable current density in a cell assembly. The results highlight how microstructural refinement and heat treatments enhance anode performance. Post-heat treatment influenced recrystallization, enabling it to occur without significant grain growth due to the relatively low temperature. Low-temperature heat treatment promoted recrystallization without significant grain growth, with orientation contrast attributed to changes in dislocation density. These findings demonstrate that fine-grained aluminum-zinc alloys produced via Friction Stir Processing offer promising potential as high-performance anodes for aluminum-air batteries, with refined grain structures significantly enhancing their electrochemical behavior.

Graphical abstract: Microstructural Characterization and Electrochemical Performance of Fine-Grained Aluminum Anodes Processed by Friction Stir for Aluminum-Air Batteries



A-O-38

The Impact of Sulphate-Reducing Bacteria on Corrosion and Reservoir Souring in Hydrocarbon Systems

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Keywords: Microbiologically Influenced Corrosion (MIC), Sulphate-Reducing Bacteria (SRB), Hydrogen Sulfide (H_2S), Sulfide Stress Cracking (SSC)

Bacteria associated with oilfield environments are commonly observed in any context where water is present within the hydrocarbon production process. These microorganisms are key contributors to microbiologically influenced corrosion (MIC) in both wells and production facilities. Additionally, they may promote reservoir souring through the metabolic activity of sulphate-reducing bacteria (SRB), which produce hydrogen sulfide (H_2S) as a by-product. Reservoir souring may also result from shifts in the fluid phase distribution and partitioning of H_2S which change though present from the onset of production life, may initially remain undetected. A sudden increase in H_2S levels during production poses a significant risk of material failure due to sulfide stress cracking (SSC), particularly when the facility's materials were originally selected under the assumption of an H_2S-free environment.

Therefore, it is imperative to undertake comprehensive analysis and evaluation of the reservoir souring potential to identify the underlying causes and to formulate effective management and mitigation strategies for souring root cause and corrosion in the context of ongoing field development.

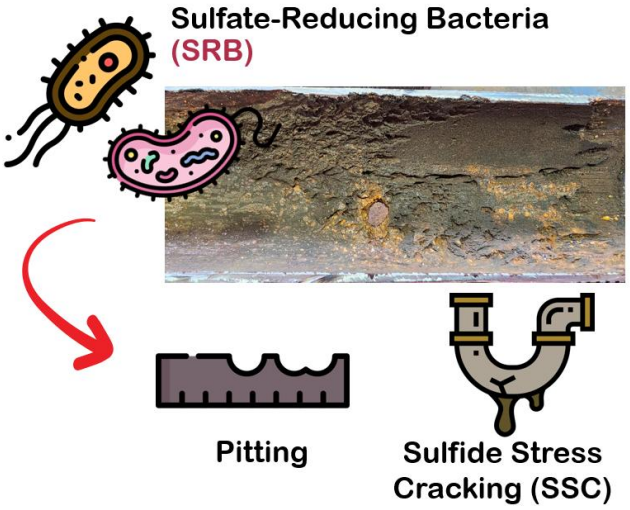
This study presents a reservoir souring risk analysis, along with an H_2S forecast for an onshore oilfield in Thailand. Data was collected from over 40 distinct well and production sites, incorporating on-site sampling, bacteria analysis, historical data review, and 2D reservoir souring modeling.

The findings revealed a high degree of bacterial diversity, with mature biofilm-forming colonies and significant populations of corrosive species. The injection water system was shown to be contaminated with bacteria, resulting in microbial growth and biofilm accumulation in reservoir system. In combination of the abundance of carbon sources which utilized by SRB suggests that the reservoir environment is conducive to microbially mediated souring. However, the progression of souring was found to be largely constrained by sulfate concentrations within the water system, highlighting the need for stringent management of injection water quality to maintain sulfate levels below 20 ppm.

The findings from this study were implemented to address operational challenges at the site. Raised H_2S concentrations were detected in the field, cause well service tools unable to access the well due to a shift in the sour service—from Zone 0 to Zone 2—

posing a risk of SSC. Based on the study's recommendations, biocide was directly injected into the well. This intervention yielded favorable results, with H_2S levels reduced to within Zone 0 limits within one day post-injection.

Graphical Abstract (mandatory)



Oral Presentations

Infrastructure & Construction Session

Innovative Titanium Applications In Chlor-alkali - Balancing Cost And Durability For Industrial Success

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Keywords: Titanium, Chlor-Alkali, Corrosion Resistance, Cost Optimization

In the challenging Chlor-Alkali industry, Prolog Titanium Corporation stands at the forefront of innovation, delivering titanium-based solutions that strike an optimal balance between cost and durability. This presentation will delve into Prolog Titanium's expertise in designing and implementing titanium equipment, including tanks, pipes, and machinery, that withstands the demanding corrosive conditions unique to Chlor-Alkali processes. With a vision to make high-performance materials accessible, Prolog Titanium has pioneered applications that reduce long-term maintenance costs and extend equipment lifespan for clients both domestically and internationally. Attendees will gain insights into successful case studies showcasing how Prolog Titanium's solutions help clients meet industry demands with enhanced operational efficiency and sustainability.

Oral Presentations

Manufacturing & Process Industries Session

C-O-04

Fabrication of Aluminium Foams Using Coated and Uncoated Oyster Shell Foaming Agents

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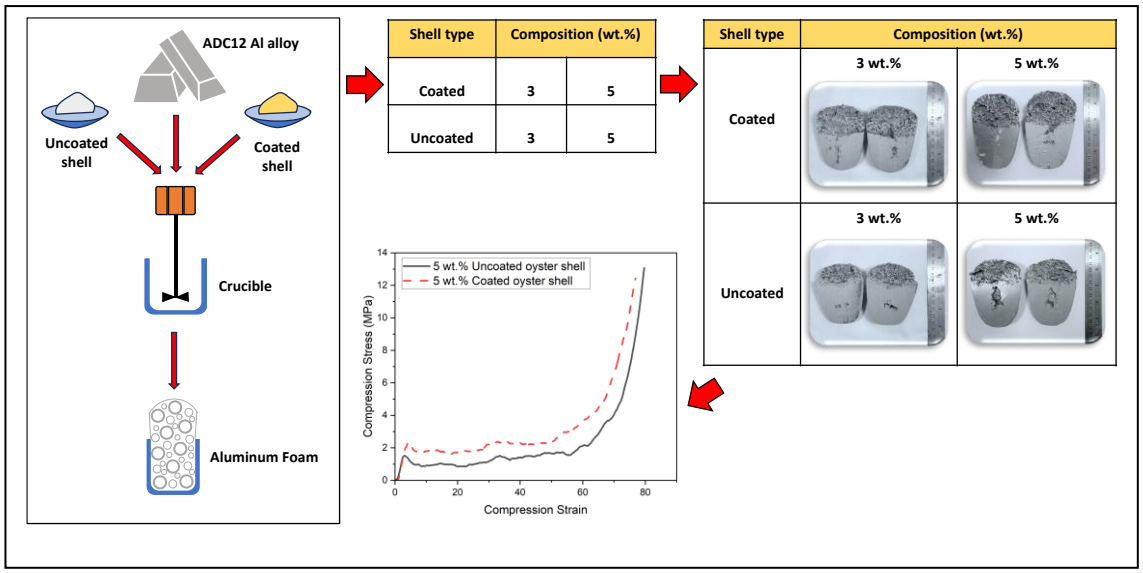
Keywords: Aluminium foam, Foaming agent, Oyster Shell, Porosity, Mechanical property

Closed-cell aluminium foam has garnered significant attention for structural applications due to its low density, high strength-to-weight ratio, excellent stiffness, and superior energy absorption capacity. Traditionally, such foams are fabricated using foaming agents like metal hydrides or carbonates. Among these, carbonate-based foaming agents are favored for their lower toxicity, ease of handling, cost-effectiveness, and ability to produce foams with fine and uniform cell structures. In this study, oyster shell powder, rich in calcium carbonate ($CaCO_3$), was employed as a sustainable and low-cost foaming agent at concentrations of 3 wt.% and 5 wt.% to produce ADC12 aluminium foams. The influence of surface modification of the oyster shell powder with sodium fluoride (NaF) on foam expansion behavior was systematically investigated. Axial compression tests were conducted to evaluate the mechanical performance of the resulting foams. The experimental results indicate that the use of 5 wt.% NaF-coated oyster shell powder yields the highest foam expansion and leads to the formation of a more homogeneous and refined pore structure. This finding highlights the potential of modified biogenic carbonate sources as effective and eco-friendly alternatives for aluminium foam production.



C-O-06

Investigating the plastic deformation mechanisms of a twinning-induced plasticity steel using advanced transmission electron microscopy

Jesada Punyafu[a,b,*], Sukyoung Hwang[c], Nobuhiro Tsuji[c], and Mitsuhiro Murayama[b,d]

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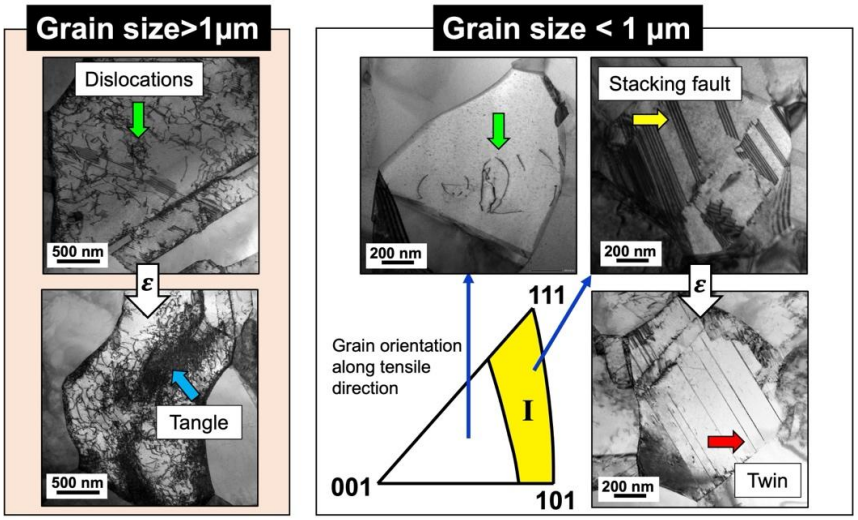
Keywords: TWIP steel; Ultrafine-grained materials; Deformation mechanism; Transmission electron microscopy

Twinning-induced plasticity (TWIP) steels exhibit superior strain hardening capability. With grain refinement, their yield strength can be further enhanced with minimal compromise in ductility. However, when the grain size falls below 1 µm, distinct changes emerge in the stress–strain curves, such as yield drops and less pronounced serrations, indicating alterations in the deformation behavior. To date, the underlying mechanisms responsible for these phenomena have been explained based on limited micro- to nanoscale observations. In this study, the plastic deformation mechanisms of an Fe-22Mn-0.6C (wt.%) TWIP steel were investigated using both ex-situ and in-situ transmission electron microscopy (TEM). The results revealed that, in grains under 1 µm in size (ultrafine grains), the dominant plastic deformation mechanisms shift from dislocation glide and tangling to stacking fault formation and deformation twinning. This transition also strongly depends on the correlation between grain orientation - loading direction, which modulates the maximum resolved shear stress for both perfect and partial dislocation slip. The impact of this shift in deformation mode on the mechanical behavior will be discussed.


Grain size>1μm
Dislocations
500 nm
ε
Tangle
500 nm
Grain size < 1 μm
200 nm
Stacking fault
200 nm
111
Grain orientation
along tensile
direction
I
001
101
ε
200 nm
Twin

C-O-08

Advanced Zn-Al-Mg Protective Coating for PV Mounting Structures in Harsh Atmospheric Environments

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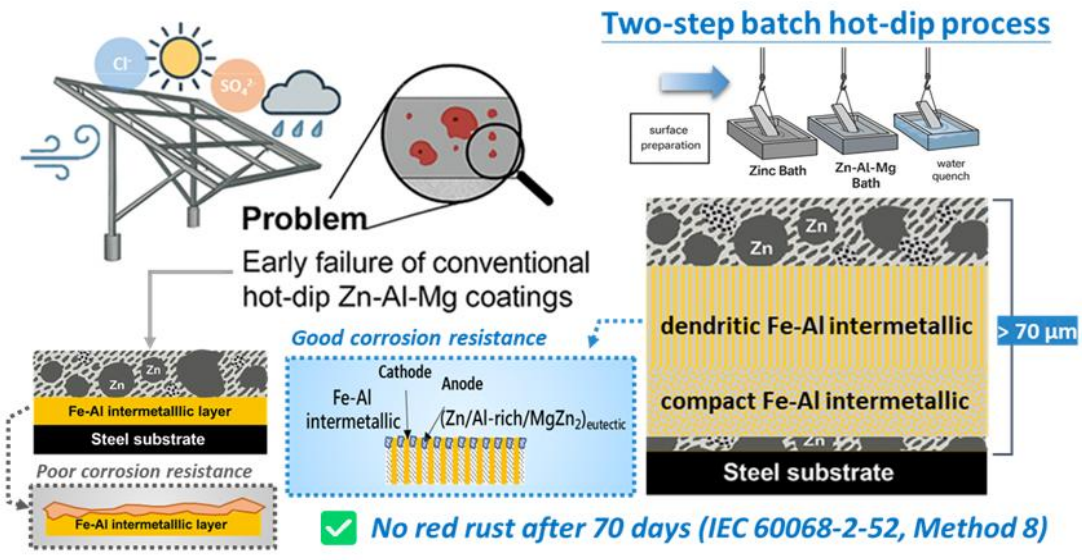
Keywords: A: Photovoltaic support structures, B: Corrosion protection, C: Two-step hot-dip coating, C: Multilayer coating microstructure

This study presents the development of a Zn-Al-Mg protective coating for photovoltaic (PV) mounting structures exposed to harsh atmospheric environments. Conventional hot-dip Zn-Al-Mg coatings often suffer from insufficient thickness and uneven microstructure, leading to premature failure in CX-class corrosion conditions. To overcome these issues, a two-step hot-dip process was developed, involving immersion in pure Zn, followed by a Zn-5Al-2Mg alloy bath and water quenching. The resulting multilayered coating (>70 µm) consists of a Zn-Al-Mg alloy top layer, a corrosion-resistant Fe-Al intermetallic region with a dendritic structure, and a compact intermetallic sublayer. A thin Zn-Al-Mg layer was also observed near the steel substrate. The optimized structure exhibited excellent corrosion resistance, showing no red rust after 70 days of IEC 60068-2-52 Method 8 testing, offering enhanced durability for PV systems in aggressive environments.

Graphical Abstract (mandatory)



C-O-16

Comparative study of Frictional Behavior of Cr-doped and Al:Ti-doped DLC coatings on AISI 4140

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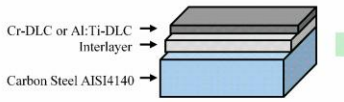
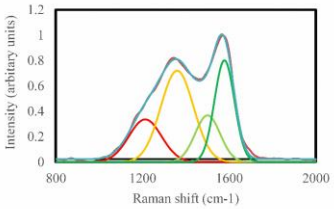
Keywords: TRIBOLOGY, DIAMOND-LIKE CARBON, FRICTION BEHAVIOR, BALL ON FLAT

Diamond-like carbon (DLC) coatings have attracted significant interest for applications requiring low friction and high surface durability. As a result, various DLC formulations have been developed to meet different tribological demands. In this study, the frictional behavior of AISI 4140 carbon steel—commonly used as a high-strength structural material—was investigated following surface modification with two distinct DLC coating systems. Specifically, chromium-doped DLC with a chromium interlayer (Cr-DLC/Cr) and aluminum/titanium co-doped DLC with an Al/Ti interlayer (Al:Ti-DLC/Al:Ti) were compared. Wear tests were conducted using the ball-on-flat method.

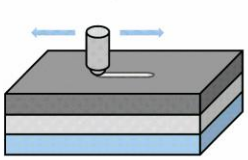
The results show that the Cr-DLC/Cr coating exhibited a lower coefficient of friction (0.26) than the Al:Ti-DLC/Al:Ti coating (0.30). Raman spectroscopy revealed a higher sp^2 bonding ratio in the Cr-DLC/Cr coating, as indicated by the increased I_D/I_G ratio, which contributed to its lower friction behavior. Post-wear analysis was performed using scanning electron microscopy (SEM) to examine wear tracks, and energy-dispersive X-ray spectroscopy (EDS) to assess material loss. EDS mapping indicated a higher concentration of Fe on the worn surface of the Al:Ti-DLC/Al:Ti sample, suggesting more severe wear and reduced wear resistance compared to Cr-DLC/Cr.

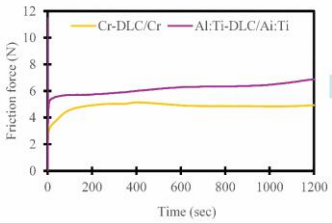
In conclusion, the Cr-DLC/Cr coating demonstrated superior tribological performance and wear resistance, making it a more promising surface modification for enhancing the durability of AISI 4140 carbon steel.



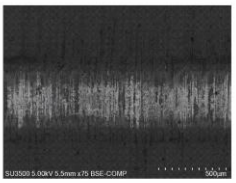


Sample	I_D/I_G Ratio
Cr-DLC/Cr	1.67
Al:Ti-DLC/Al:Ti	1.51





Sample	Friciton Force (N)	CoF
Cr-DLC/Cr	5.03 ± 0.06	0.26 ± 0.03
Al:Ti-DLC/Al:Ti	6.00 ± 0.17	0.30 ± 0.05



C-O-18

Silicon Carbide Effects on the Microstructure and Mechanical Properties of Sintered Diffusion-Bonding Alloyed Fe-Mo-Cu

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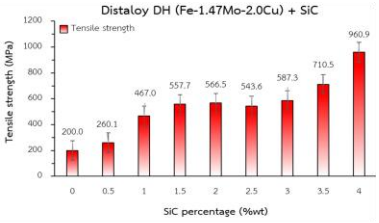
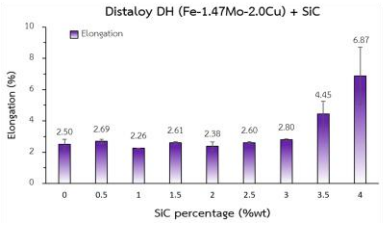
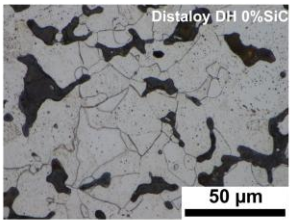
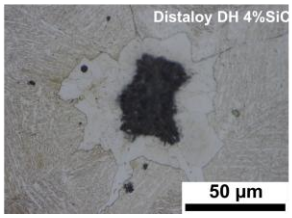
Keywords: Diffusion-Bonding Alloyed Fe-Mo-Cu, Sintered steels, Silicon Carbide, Microstructure, Mechanical Properties

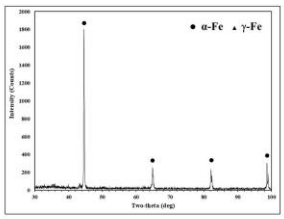
Recently, silicon carbide (SiC) has been utilized as a silicon and carbon source to produce sintered steels by adding them into the Fe or Fe-based matrix. The addition of SiC has a significant impact on microstructure and mechanical properties of sintered steel. This work explored the SiC addition effects on microstructural evolution, and mechanical properties of sintered diffusion alloyed. In this experiment, sintered Fe-Mo-Cu-Si-C alloys were prepared from mixtures of diffusion-alloyed Fe-1.47Mo-2.0Cu (Distaloy DH) and varied SiC content from 0.5-4.0 wt.%. The tensile testing specimens were compacted and subsequently sintered in vacuum furnace at 1250 ºC for 45 minutes with furnace cooling rate of 0.1 ºC/s. Results indicated that with 0.5 %SiC addition, the microstructure of sintered alloys showed the polygon ferrite with upper bainite phase. With increased SiC to 2%, the sintered alloys displayed the fully granular bainite. At 2.5 %SiC addition, the sintered alloys illustrated the fully ausferrite phase. When the SiC was increased to 3, 3.5, and 4.0wt.%, the microstructure included black particles embedded with ferrite and ausferrite matrix phase. The observed microstructure resembles that of austempered ductile iron (ADI). Furthermore, the mechanical properties of this sintered steel exhibited a high strength, and elongation with increasing the SiC content

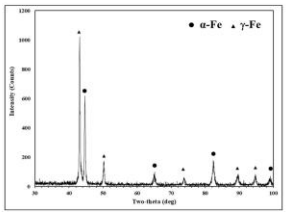

Distaloy DH (Fe-1.47Mo-2.0Cu) + SiC
Tensile strength
Tensile strength (MPa)
200.0
260.1
467.0
557.7
566.5
543.6
587.3
710.5
960.9
SiC percentage (%wt)


Distaloy DH (Fe-1.47Mo-2.0Cu) + SiC
Elongation
Elongation (%)
2.50
2.69
2.26
2.61
2.38
2.60
2.80
4.45
6.87
SiC percentage (%wt)


Distaloy DH 0%SiC
50 µm


Distaloy DH 4%SiC
50 µm


α-Fe
γ-Fe


α-Fe
γ-Fe

C-O-19

Effects of Pre-Treatment and Leaching Parameters on the Dissolution of Valuable Metals from Cathode Active Materials of Li-ion Batteries

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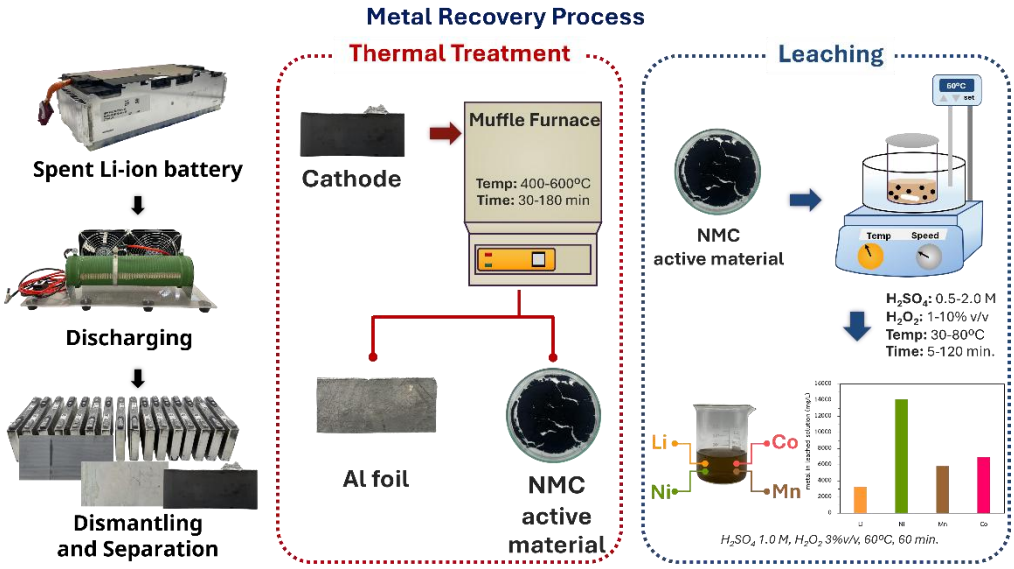
Keywords: Spent Li-ion Battery, Cathode Active Materials, Thermal Treatment, Leaching.

End-of-life lithium-ion batteries require proper management procedures to prevent adverse environmental impacts. Furthermore, since lithium-ion batteries contain economically valuable metals as constituents, it is essential to implement recovery and extraction processes to recover these metals for reutilization in manufacturing applications. This study explores the dissolution of valuable metals from cathode active materials contained in spent Li-ion batteries type NMC 523 ($LiNi_{0.5}Mn_{0.2}Co_{0.3}O_2$) through a combination of thermal pre-treatment and acid leaching processes. Initially, the battery cells were discharged and dismantled to isolate the cathode material. Thermal treatment of the cathode material was conducted in an air atmosphere to remove the polyvinylidene fluoride (PVDF) binder, with roasting temperatures of 400°C, 500°C, and 600°C for durations of 30 to 180 minutes. The roasted material was subsequently leached using sulfuric acid (H_2SO_4, 0.5–2.0 M) in conjunction with hydrogen peroxide (H_2O_2, 1–10%) in a controlled water bath. Leaching parameters, including temperature (30–80°C) and duration (5–120 minutes), were systematically varied. The concentrations of lithium (Li), nickel (Ni), manganese (Mn), and cobalt (Co) in the leachate were quantified using inductively coupled plasma optical emission spectrometry (ICP-OES). Optimal recovery was achieved under roasting conditions of 500°C for 60 minutes, resulting in 97% PVDF removal and recovery efficiencies exceeding 99% for all target metals.


Metal Recovery Process
Spent Li-ion battery
Discharging
Dismantling and Separation
Thermal Treatment
Cathode
Muffle Furnace
Temp: 400-600°C
Time: 30-180 min
Al foil
NMC active material
Leaching
NMC active material
Temp
Speed
H2SO4: 0.5-2.0 M
H2O2: 1-10% v/v
Temp: 30-80°C
Time: 5-120 min.
Li
Co
Ni
Mn
H2SO4 1.0 M, H2O2 3%v/v, 60°C, 60 min.

C-O-20

Green Synthesis of Tin Oxide Nanoparticles from Soldering Waste using Orange Peel Extract

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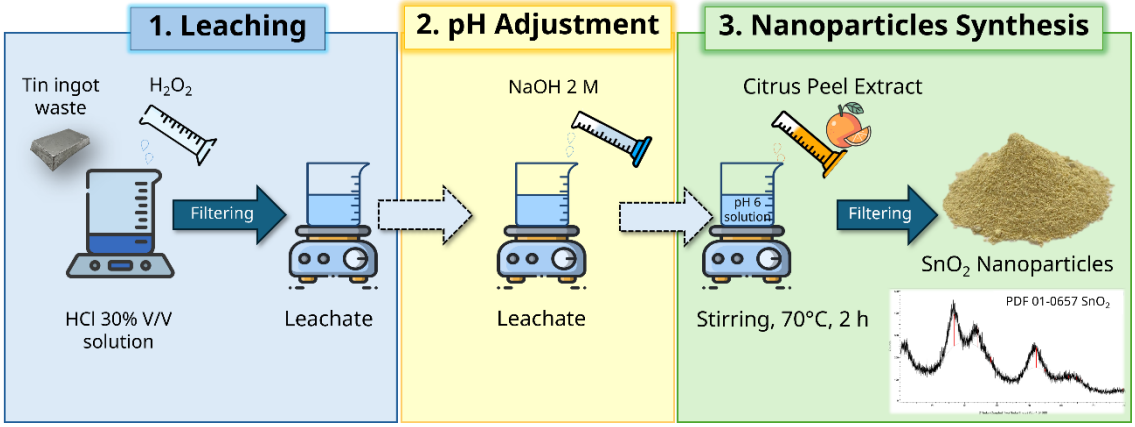
Keywords: Tin Solder Waste, Tin Oxide Nanoparticle, Green Synthesis, Orange Peel Extract

This study presents a sustainable method for recovering tin from lead-free soldering waste into tin oxide nanoparticles through a green synthesis process. Tin ingot waste was leached in hydrochloric acid associated with hydrogen peroxide to accelerate oxidation, achieving tin concentrations exceeding 60,000 mg/L. The leachate was adjusted to pH 6 using 2 M sodium hydroxide. Nanoparticles were synthesized by adding orange peel extract (rich in antioxidants and phytochemicals) to the leachate and stirring at 70°C for 2 hours. The product was filtered and dried at 90°C. Results showed that orange peel extract promoted uniform particle formation and prevented agglomeration. This green synthesis valorizes industrial waste while utilizing biodegradable plant materials, providing an eco-friendly alternative to conventional nanoparticle production.



C-O-21

Development of an Optimized Medium for Bioleaching of Lithium Cobalt Oxide Cathode Powder using *Penicillium* sp. Strain JMET 24

Thanapon Chandakhiaw[a,*], Phanuphan Mareo[a], Thanachot Chomnawang[a], Natthicha Ma-Ud[a], Tapany Patcharawit[a], Tanongsak Yingnakorn[a], and Sakhob Khumkoa[a]

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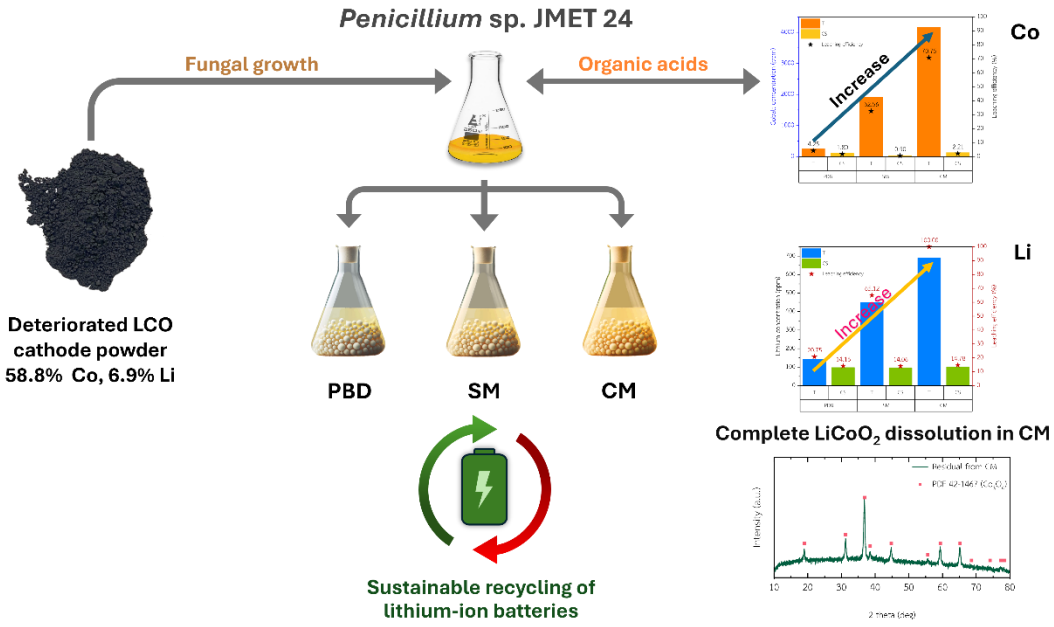
Keywords: Bioleaching, Penicillium, Spent Li-ion Battery, Lithium Cobalt Oxide (LCO)

This study investigates the enhancement of bioleaching efficiency for cobalt (Co) and lithium (Li) from deteriorated lithium cobalt oxide (LCO) cathode powder using *Penicillium* sp. strain JMET 24. The LCO powder, containing 58.8% Co and 6.9% Li by weight, was subjected to bioleaching in various nutrient media, including potato dextrose broth (PDB), sucrose medium (SM), and a newly developed composite medium (CM). The CM formulation, enriched with sucrose, KH_2PO_4, yeast extract, and PDB, was formulated to enhance fungal growth and organic acid biosynthesis. After 30 days of incubation, the CM significantly improved leaching performance, increasing Co recovery from 32.56% to 70.75% and Li recovery from 65.12% to 100%, compared to the standard sucrose medium. XRD analysis of the leaching residue confirmed complete dissolution of $LiCoO_2$, with cobalt partially precipitating as Co_3O_4. These findings demonstrate that medium optimization can substantially enhance the bioleaching potential of *Penicillium* sp. JMET 24 offers a promising approach for the sustainable recycling of spent lithium-ion batteries.



C-O-22

Surface quality and wear performance of 316L stainless steel fabricated by MIM and MEX: effects of shot peening

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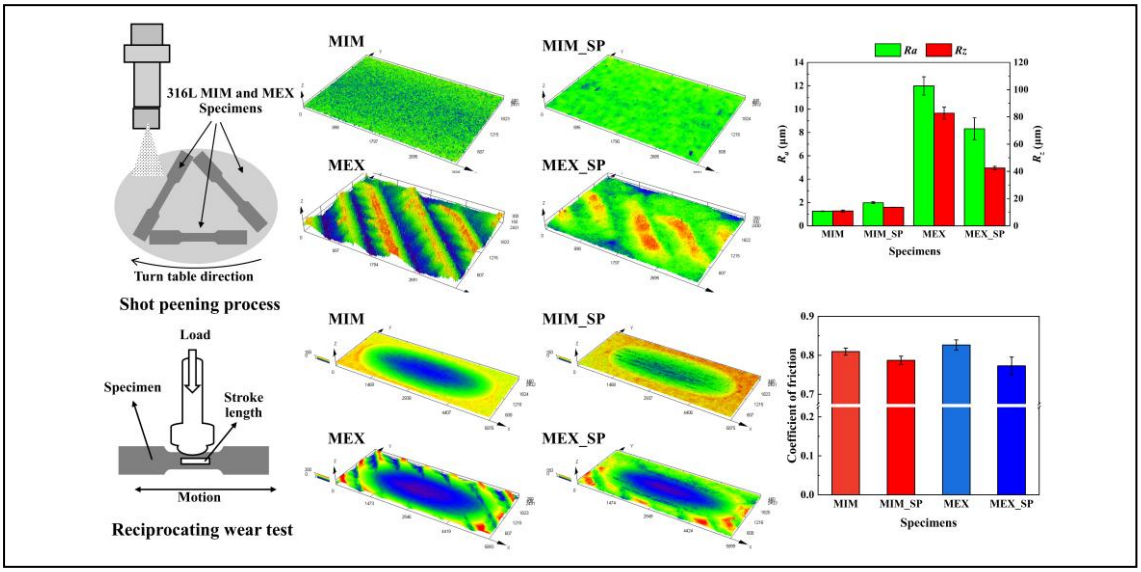
Keywords: Metal injection moulding; Material extrusion additive manufacturing; 316L stainless steel; Shot peening; Wear performance; Surface roughness

Metal injection moulding (MIM) is a near-net-shape manufacturing process that typically produces parts with high surface quality and reliable mechanical properties. In contrast, material extrusion additive manufacturing (MEX), which builds parts through layer-by-layer extrusion, often results in surface defects such as striping or staircase patterns inherent to the printing process. Shot peening is a widely used surface treatment that enhances surface integrity and mechanical performance by introducing compressive residual stress and refining the surface microstructure. This study investigates and compares the effects of shot peening on the surface quality, microstructure and wear performance of 316L stainless steel fabricated by MEX relative to MIM. Surface roughness and topography of MIM and MEX specimens, both with and without shot peening, were characterised using 3D surface profilometry. Microstructural changes were examined via X-ray diffraction (XRD) and electron backscatter diffraction (EBSD). Surface and subsurface hardness were evaluated using Vickers microhardness testing, and wear behaviour was assessed through a linear reciprocating wear test using an Al_2O_3 ball as the counterpart. The results show that shot peening can either improve or degrade surface quality, depending on the initial surface condition. The treatment induces plastic deformation and promotes strain-induced martensite formation in both MIM and MEX specimens. Notably, shot peening was found to enhance the wear resistance of both.



C-O-24

Effect of Heat Treatment on Multi-Material Additive Manufacturing (MMAM) Fabricated by Selective Laser Melting (SLM) via Non-Destructive and Destructive Test

Farhana Mohd Foudzi[a,b*], Nabiha Muhammad Zulkifli[b], Ramaniswaraan Velayuthan[b], Fathin Iliana Jamhari[a,b], Nabilah Afiqah Mohd Radzuan[a,b], Abu Bakar Sulong[a,b], Norhamidi Muhamad[a,b] and Muhammad Nur Farhan Saniman[c]

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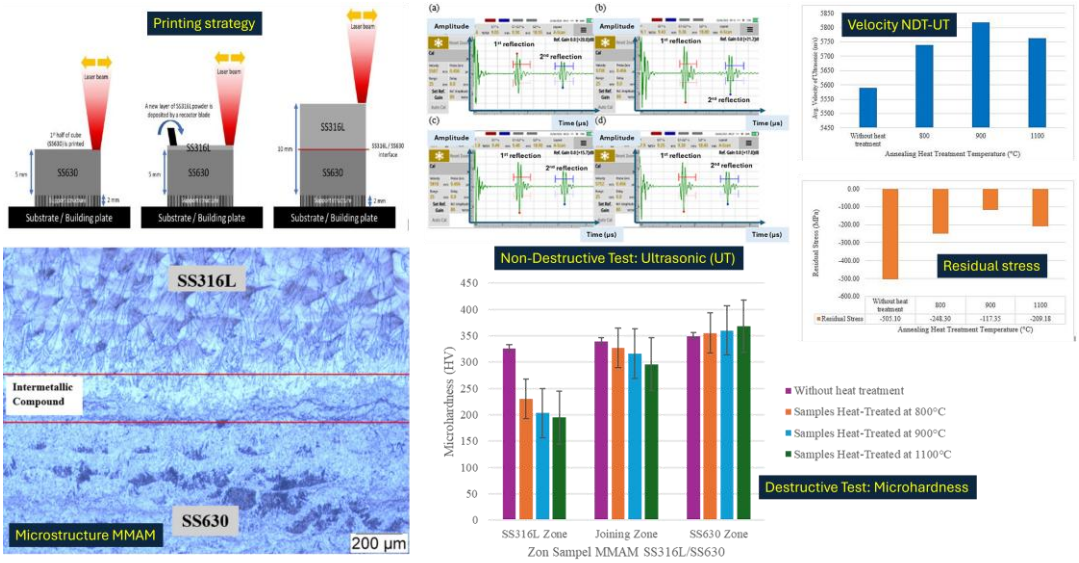
Keywords: Multi Material Additive Manufacturing (MMAM); Selective Laser Melting (SLM); Residual Stress; Annealing Heat Treatment

Multi-Material Additive Manufacturing (MMAM) is a technology combining two or more different metals in a single part via Selective Laser Melting (SLM) process. In this study, two types of stainless steel; SS316L and SS630 were printed in a single MMAM part using several printing strategies. For metals in SLM, formation of residual stresses occurred during the printing process due to repetition of heating and cooling processes. Such stresses affecting the mechanical properties and may lead to warping and cracking of MMAM parts. To overcome this, annealing heat treatment is commonly employed to reduce the stresses. In this study, non-destructive (ultrasonic) and destructive (microhardness) test were used to evaluate the effect of heat treatment based on the residual stresses. It was found that heat treatment temperature at 900°C is suitable in eliminating residual stresses based on the velocity of ultrasonic waves and microhardness compared to MMAM parts heat treated at 800°C and 1100°C.



Corrosion Behaviors of Thermally Sprayed Nickel Alloy Surface Coatings for Use in Maintenance Industry

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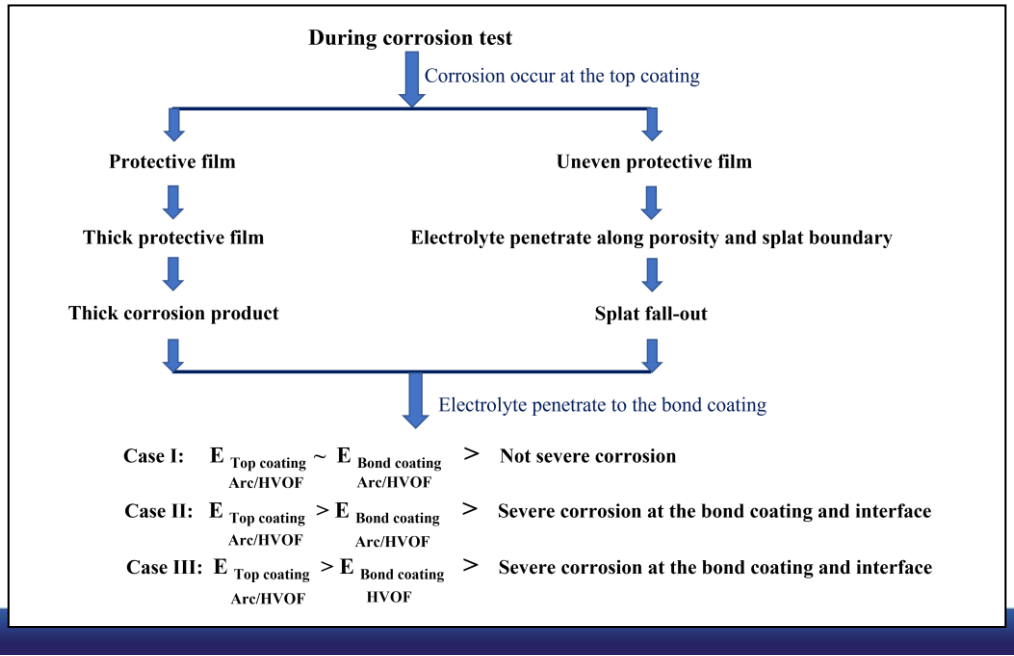
Keywords: Thermal sprayed coating; Corrosion behavior; Microstructure

This study examines corrosion behaviors of single-layer and double-layer thermally sprayed nickel alloy coatings, consisting of bond and top coatings. Ni-5wt.% Al, PMET 866, and Ni-20wt.% Cr were selected as bond coatings, while the top coatings included highly alloyed Ni-based materials such as Hastelloy C276 and Inconel 625. The coatings were produced using arc spraying (Arc) and high-velocity oxy-fuel (HVOF) techniques on a 304 stainless steel substrate. The corrosion behavior was assessed using potentiodynamic polarization tests and immersion tests in a 20 vol% H_2SO_4 solution at ambient temperature. Scanning electron microscopy (SEM), along with energy dispersive X-ray spectroscopy (EDS), was employed to analyze the microstructure and chemical composition of the coatings. The arc sprayed coatings are composed of a lamellar\ microstructure with low porosities, unmelted particles, and high oxides at the intersplats. A uniform and compact coating with minimal oxides and porosity was achieved for all coatings via HVOF technique. In single-layer coatings, Inconel 625 coating shows better corrosion resistance compared to that of Hastelloy C276 coating owing to its Cr oxide passive film. For double-layer coatings, the Ni-20wt.% Cr bond coating by HVOF yields the best corrosion resistance, due to its highly densed microstructure with low oxide and porosity content compared to arc-sprayed coatings. Among the arc-sprayed coatings, the PMET 866 bond coating shows the best corrosion resistance, followed by Ni-20wt.% Cr and Ni-20wt.% Al, respectively. Although the PMET 866 bond coating has a high open circuit potential and good corrosion resistance, its arc coating has higher oxide content and porosity than the HVOF coating, which allows the electrolyte to penetrate the substrate more easily. These findings can be used as recommendations for maintenance industry in the future.



C-O-34

Optimizing Recycled Hypereutectic Al-4Fe Alloys for Superior Mechanical and Corrosion Properties through Ultrasonic Melt Processing

Tawatchai Tangsuksan[a], Phromphong Pandee[b, c], Chaowalit Limmaneevichitr[b], Dmitry G. Eskin[d], and Suwaree Chankitmunkong[a,*]

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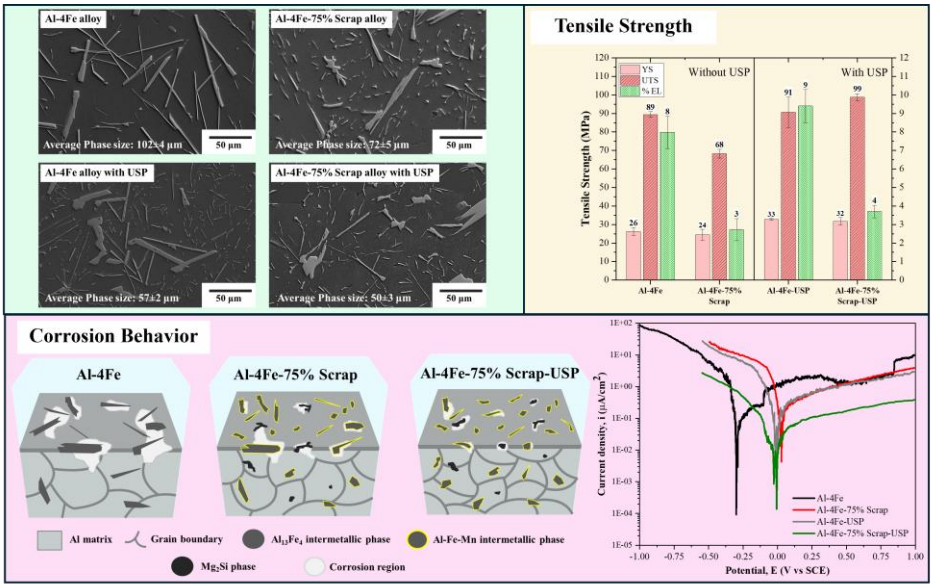
Keywords: Recycled aluminum alloy, Hypereutectic Al-Fe alloy, Ultrasonic melt treatment, Tensile strength, Corrosion resistance

The production of eco-friendly recycled aluminum alloys has gained significant attention in the aluminum manufacturing industry due to its ability to reduce energy consumption and greenhouse gas emissions. However, the use of aluminum scrap introduces limitations, especially with iron, which impacts alloy properties. This study develops a hypereutectic Al-Fe alloy using 75wt% recycled aluminum beverage cans. This new alloy grade is of particular interest as a high-iron aluminum alloy due to its potential to enhance mechanical properties, thermal stability, and electrical conductivity. Nevertheless, an increase in iron content often leads to the formation of coarse, elongated Fe-rich intermetallic compounds, which can adversely affect fluidity, strength, and corrosion resistance. To address these limitations, ultrasonic melt processing (USP) was employed to improve the microstructure. The results showed that the recycled Al-4Fe alloy contained increased amounts of alloying elements such as Mg, Mn, Si, and Cu. Phase analysis revealed $Al_{13}Fe_4$ (containing Mn) and Al_6(Fe, Mn), which improved corrosion resistance but did not enhance tensile strength, likely due to the increased number of intermetallic phases and oxide impurities from scrap. However, USP treatment significantly refined the microstructure, enhancing both tensile strength and corrosion resistance. This research offers a promising approach for developing environmentally friendly, high-performance aluminum alloys for industrial applications.


Al-4Fe alloy
Average Phase size: 102±4 µm
50 µm
Al-4Fe-75% Scrap alloy
Average Phase size: 72±5 µm
50 µm
Al-4Fe alloy with USP
Average Phase size: 57±2 µm
50 µm
Al-4Fe-75% Scrap alloy with USP
Average Phase size: 50±3 µm
50 µm
Tensile Strength
YS
UTS
% El.
Without USP
With USP
Tensile Strength (MPa)
26
89
8
24
68
3
33
91
9
32
99
4
Al-4Fe
Al-4Fe-75% Scrap
Al-4Fe-USP
Al-4Fe-75% Scrap-USP
Corrosion Behavior
Al-4Fe
Al-4Fe-75% Scrap
Al-4Fe-75% Scrap-USP
Al matrix
Grain boundary
Al13Fe4 intermetallic phase
Al-Fe-Mn intermetallic phase
Mg2Si phase
Corrosion region
Current density, i (µA/cm2)
Potential, E (V vs SCE)
Al-4Fe
Al-4Fe-75% Scrap
Al-4Fe-USP
Al-4Fe-75% Scrap-USP

C-O-35

Microstructural Evolution and Property Enhancement in ADC12 Aluminum Alloys by Mn and Ce Additions

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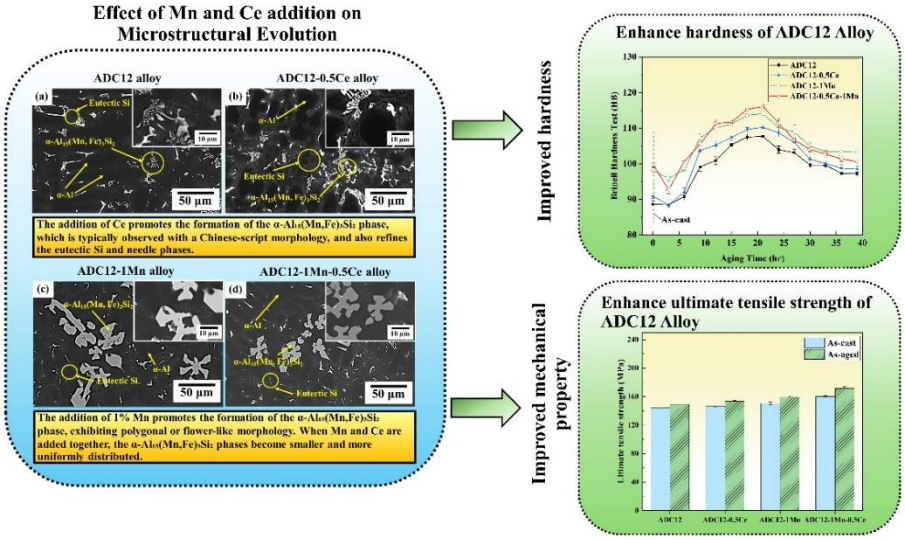
Keywords: ADC12 ALLOY, MICROSTRUCTURAL EVOLUTION, AGING, MECHANICAL PROPERTY

The effect of 1% Mn and 0.5% Ce addition to ADC12 alloy was investigated through microstructural evaluations and mechanical properties, including hardness and tensile tests, for both as-cast and as-aged specimens (Aging temperature at 175 °C). This study indicates that the addition of 0.5% Ce promotes the formation of the α-$Al_{15}(Mn,Fe)_3Si_2$ phase, typically observed in a Chinese-script morphology, which contributes to strengthening the Al matrix in ADC12 alloys. The addition of 1% Mn leads to the formation of a polygonal or flower-like phase. When both 1% Mn and 0.5% Ce are added together, the microstructure exhibits a more refined and uniformly distributed polygonal or flower-like phase within the Al matrix. These microstructural changes enhance the hardness and mechanical properties of the alloy. Furthermore, microstructure evolution confirms that the combined addition of Ce and Mn significantly improves the hardness of ADC12 alloys in both as-cast and aged conditions. Specifically, the ADC12-1Mn-0.5Ce alloy exhibited the highest hardness values, reaching 99.9 ± 0.88 HB in the as-cast condition and 116.08 ± 1.27 HB after aging. Additionally, the combined Ce and Mn additions improved the tensile properties, particularly by enhancing the ultimate tensile strength.



Special Session
TCMA Awards

The effect of temperature on corrosion of bismuth-40tin alloys in 3.5 wt.% NaCl solution

Chanin Tangpongkitjaroen[a], Tachai Luangvaranunt[a], Patama Visuttipitukul[a], Suwin Sompopsart[b], Wararit Toempromaraj[b], Passaworn Silakorn[b], Kittithuch Hnuruang[b], and Pitichon Klomjit[a,c,*]

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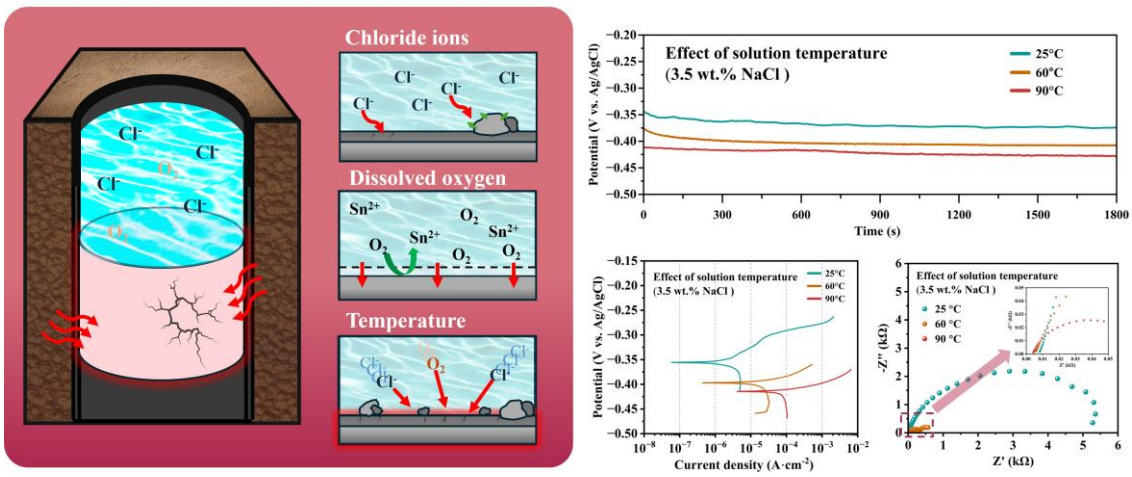
Keywords: Corrosion; Bismuth alloys plugs; Plugging and abandonment

The alternative plugging and abandonment (P&A) protocol utilizing thermite technology has attracted considerable attention in the oil and gas industry. By employing a thermite heater, low-melting-point alloys can be melted to seal the wellbore upon solidification, thereby preventing the leakage of chemical substances from the downhole. Bismuth–40 wt.% tin alloy (Bi-40Sn) is a promising candidate for P&A applications due to its low melting point, good castability, and expansion upon solidification, which enhances the sealing performance of the alloy plug. However, the corrosion of the alloy may significantly affect its mechanical properties, limiting its long-term use as a plug material. Furthermore, temperature and chloride ions are known to have a substantial influence on the corrosion rate of such alloys. In this study, the effect of temperature on the corrosion behavior of Bi-40Sn alloy in a 3.5 wt.% NaCl solution was investigated. The result from electrochemical method revealed that the corrosion resistance of Bi-40Sn decreased significantly with rising of temperature, indicate the critical role of temperature in the corrosion degradation of Bi-40Sn alloy in chloride-containing environments.



"A Natural Approach to Preventing Aluminum Corrosion: Role of Clitoria Ternatea (Shankhpushpi) Plant Extract in Acidic Environments"

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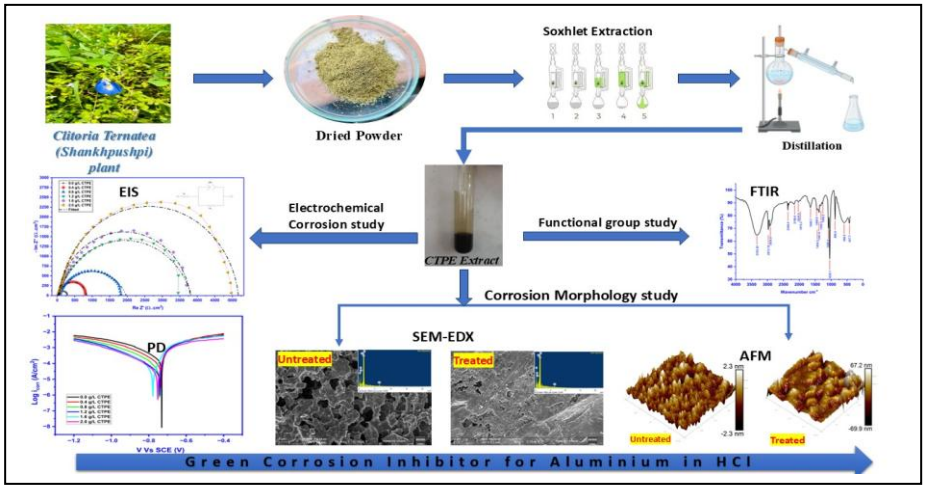
Keywords: Clitoria Ternatea Plant, EIS, SEM-EDX, AFM

Aluminum is widely used in industrial applications due to its light weight, strength, and natural corrosion resistance; however, its performance is significantly compromised in highly acidic environments such as hydrochloric acid (HCl), where it undergoes rapid degradation. Conventional corrosion inhibitors often pose serious environmental and health risks due to their toxic and non-biodegradable nature, prompting the search for green and sustainable alternatives. In this study, the corrosion inhibition performance of *Clitoria Ternatea* (Shankhpushpi) plant ethanolic extract (CTPE) was investigated as an eco-friendly inhibitor for aluminum in HCl solutions ranging from 0.2 M to 0.4 M. Weight loss experiments demonstrated excellent inhibition efficiency, with the plant extract achieving 95% protection at a concentration of 2.0 $g \cdot L^{-1}$ after 24 hours of immersion at 25°C in 0.2 M HCl. Electrochemical impedance spectroscopy (EIS) data revealed a significant increase in charge transfer resistance (Rct) from 800.07 $\Omega.cm^2$ to 5113.0 $\Omega.cm^2$ as the concentration of the extract increased from 0.4 g/L to 2.0 g/L, indicating an inhibition efficiency of approximately 93.44% at 303 K in 0.2 M HCl for 3 hours. Adsorption studies indicated that the inhibitor molecules adhered to the aluminum surface according to the Langmuir isotherm model, with a high correlation coefficient (R^2= 0.9958), suggesting monolayer coverage. The negative Gibbs free energy of adsorption (ΔG^{o}_{ads}= –16.42 $kJ \cdot mol^{-1}$) confirmed that the adsorption process was spontaneous and physical in nature. Further surface characterization using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX) revealed significantly reduced surface damage in the presence of the plant extract, supporting the formation of a protective barrier on the metal. These findings suggest that CTPE can serve as a highly effective, low-cost, and environmentally benign corrosion inhibitor for aluminum under acidic conditions. The use of CTPE aligns with global efforts toward sustainable and eco-conscious industrial practices.



Advanced Zn-Al-Mg Protective Coating for PV Mounting Structures in Harsh Atmospheric Environments

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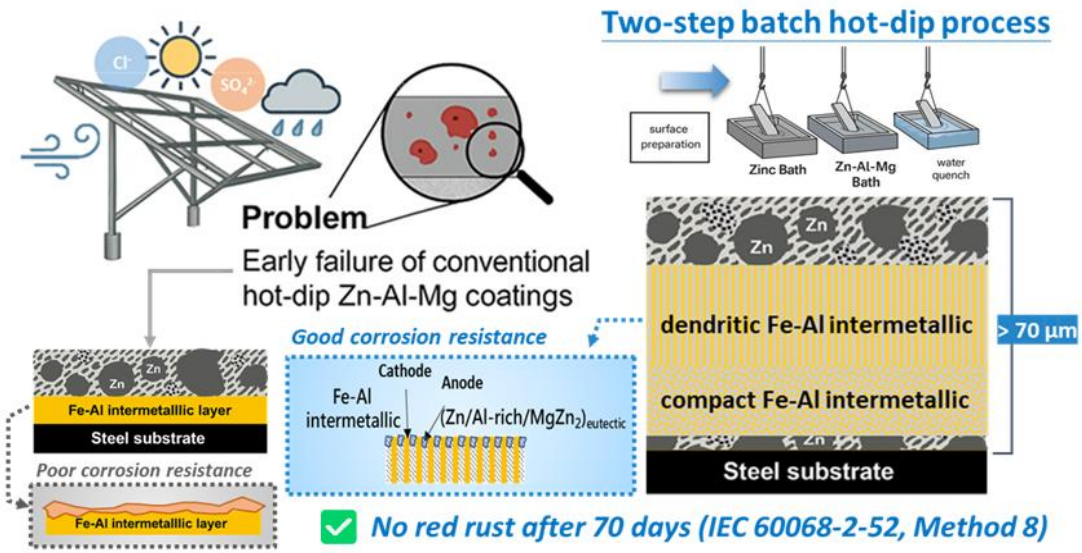
Keywords: A: Photovoltaic support structures, B: Corrosion protection, C: Two-step hot-dip coating, C: Multilayer coating microstructure

This study presents the development of a Zn-Al-Mg protective coating for photovoltaic (PV) mounting structures exposed to harsh atmospheric environments. Conventional hot-dip Zn-Al-Mg coatings often suffer from insufficient thickness and uneven microstructure, leading to premature failure in CX-class corrosion conditions. To overcome these issues, a two-step hot-dip process was developed, involving immersion in pure Zn, followed by a Zn-5Al-2Mg alloy bath and water quenching. The resulting multilayered coating (>70 µm) consists of a Zn-Al-Mg alloy top layer, a corrosion-resistant Fe-Al intermetallic region with a dendritic structure, and a compact intermetallic sublayer. A thin Zn-Al-Mg layer was also observed near the steel substrate. The optimized structure exhibited excellent corrosion resistance, showing no red rust after 70 days of IEC 60068-2-52 Method 8 testing, offering enhanced durability for PV systems in aggressive environments.

Graphical Abstract (mandatory)



Optimizing Recycled Hypereutectic Al-4Fe Alloys for Superior Mechanical and Corrosion Properties through Ultrasonic Melt Processing

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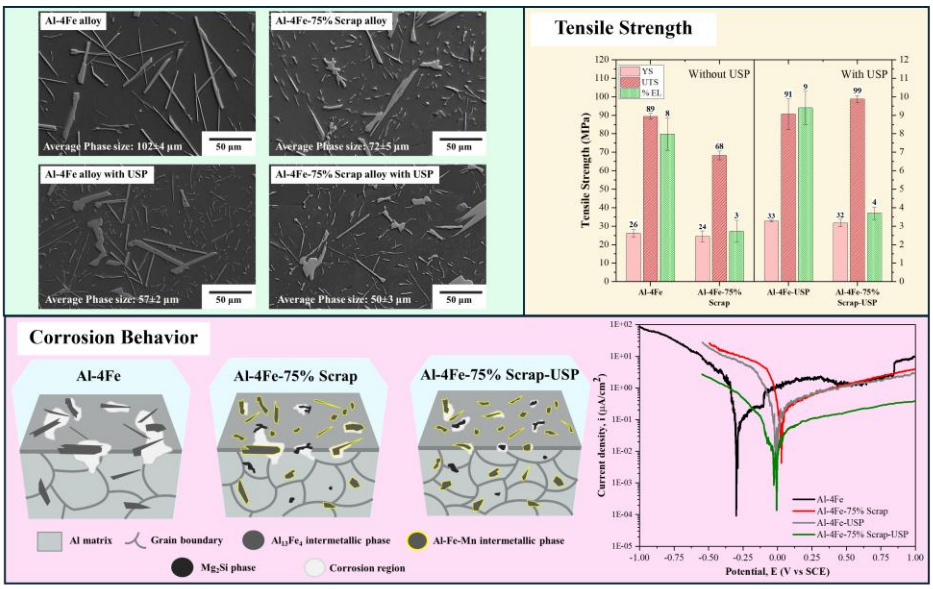
Keywords: Recycled aluminum alloy, Hypereutectic Al-Fe alloy, Ultrasonic melt treatment, Tensile strength, Corrosion resistance

The production of eco-friendly recycled aluminum alloys has gained significant attention in the aluminum manufacturing industry due to its ability to reduce energy consumption and greenhouse gas emissions. However, the use of aluminum scrap introduces limitations, especially with iron, which impacts alloy properties. This study develops a hypereutectic Al-Fe alloy using 75wt% recycled aluminum beverage cans. This new alloy grade is of particular interest as a high-iron aluminum alloy due to its potential to enhance mechanical properties, thermal stability, and electrical conductivity. Nevertheless, an increase in iron content often leads to the formation of coarse, elongated Fe-rich intermetallic compounds, which can adversely affect fluidity, strength, and corrosion resistance. To address these limitations, ultrasonic melt processing (USP) was employed to improve the microstructure. The results showed that the recycled Al-4Fe alloy contained increased amounts of alloying elements such as Mg, Mn, Si, and Cu. Phase analysis revealed $Al_{13}Fe_4$ (containing Mn) and Al_6(Fe, Mn), which improved corrosion resistance but did not enhance tensile strength, likely due to the increased number of intermetallic phases and oxide impurities from scrap. However, USP treatment significantly refined the microstructure, enhancing both tensile strength and corrosion resistance. This research offers a promising approach for developing environmentally friendly, high-performance aluminum alloys for industrial applications.



Mechanistic Investigation of the Corrosion Behavior of Oil Casing Steel Governed by Microstructural Features

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Keywords: P110 oil casing steels, CO_2- corrosion, Microstructure, Inclusions

Oil casing steels are frequently exposed to high-temperature, high-pressure underground environments containing corrosive species such as CO_2 and brine, leading to localized corrosion, perforation, and even fracture, thereby threatening the safety and efficiency of oil and gas extraction. Understanding the localized corrosion mechanisms under CO_2-rich conditions is therefore critical for extending service life and ensuring wellbore integrity. Among various influencing factors, microstructural characteristics play a crucial role in determining corrosion behavior. Even for steels with similar compositions, differences in processing history can lead to significant variations in grain size, phase structure, elemental segregation, and inclusion morphology. In this study, two commercially sourced P110 oil casing steels were comparatively investigated. Detailed microstructural characterization and inclusion analysis were performed, followed by immersion and electrochemical tests in high-temperature, high-pressure CO_2-containing environments over different exposure times. The morphology, composition, and depth profile of corrosion products were analyzed, and correlations between microstructural features and corrosion severity were established. The findings provide mechanistic insight into microstructure-controlled corrosion in oilfield environments and offer guidance for quality control and material selection to mitigate casing failure risks.

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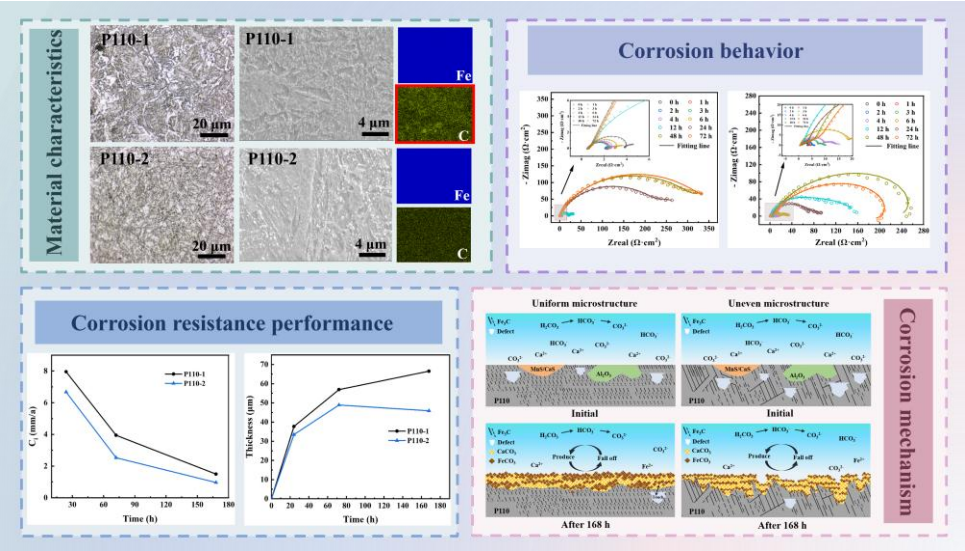

Study on The Influence of Surface Microstructure and Chemical Configuration of Ni-Zn-P Coating on Its Hydrogen Permeation Behavior

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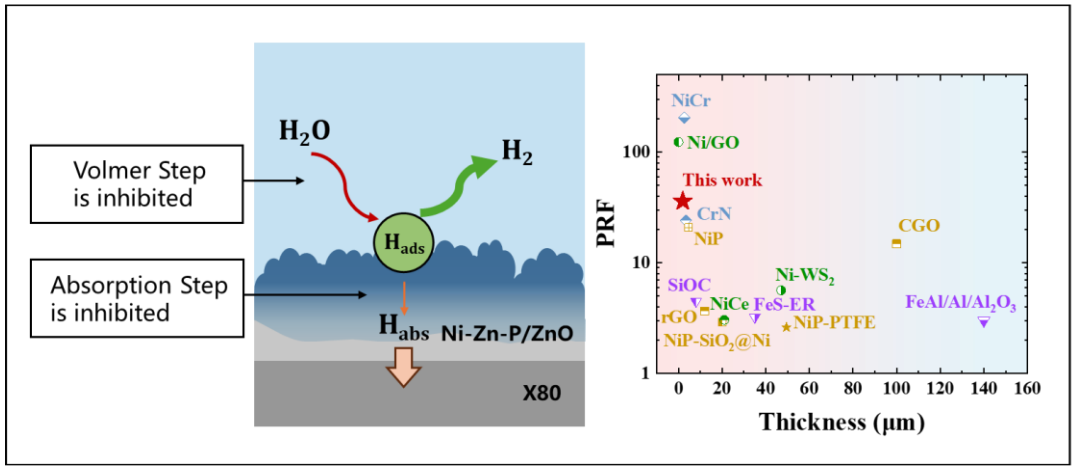
Keywords: X80 pipeline steel, Ni-Zn-P, HER kinetics, hydrogen barrier.

A cauliflower-like Ni-Zn-P/ZnO composite functional layer was successfully synthesized on X80 steel via in-situ co-deposition of ZnO/$Zn(OH)_2$ particles, induced by adding SDS to the electroplating bath. Electrochemical tests demonstrated that this composite coating significantly reduces hydrogen permeation current and apparent diffusivity compared to the baseline Ni-Zn-P. This outstanding performance is primarily attributed to a comprehensive kinetic inhibition mechanism at the coating-electrolyte interface. Detailed kinetic analysis (Tafel, EIS, IPZ model) revealed that the composite surface establishes a dual kinetic barrier: it alters the hydrogen evolution reaction (HER) kinetics to suppress the generation of adsorbed hydrogen, and simultaneously strongly inhibits the fundamental hydrogen absorption step into the bulk. This work clarifies that the coating's efficacy is dominated by kinetic suppression, offering a new strategy for designing advanced hydrogen barrier coatings via interfacial engineering.

Graphical Abstract (mandatory)



Special Session
POSCO-Thainox Metallurgy Awards

Manufacturing Pathways and Peening Synergy: Effects of Initial Surface Quality, Shot Media, and Peening Parameters on MIM and MEX 17-4PH Stainless Steel

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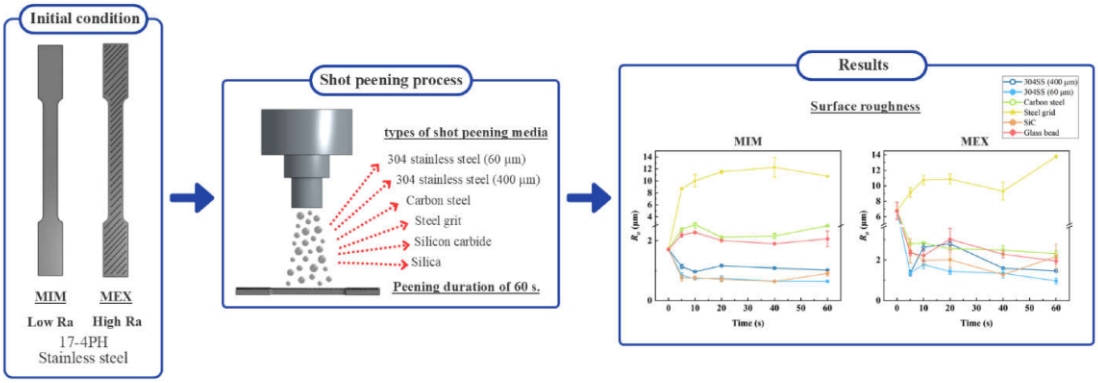
Keywords: Metal Injection Moulding; Material Extrusion Additive Manufacturing; Shot Peening; Mechanical Surface Treatment

It is well known that shot peening can either improve or deteriorate surface quality, depending on the initial surface condition and the processing parameters. Nevertheless, a systematic investigation on this interplay remains limited. This research therefore aims to investigate the effects of shot peening parameters on the microstructure, surface properties, and mechanical properties of 17-4PH stainless steel fabricated by metal injection moulding (MIM) and material extrusion additive manufacturing (MEX), which inherently provide distinct initial surface qualities. Various types of shot peening media were employed, including 304 stainless steel particles with the average sizes of 60 and 400 µm, carbon steel, steel grit, silicon carbide and silica, with a constant peening duration of 60 s. Surface quality and characteristics before and after shot peening were examined using laser confocal microscopy (LCM) and scanning electron microscopy (SEM) equipped with energy-dispersive X-ray spectroscopy (EDS). Deformation behaviour was analysed by electron backscatter diffraction (EBSD) and X-ray diffraction (XRD). Mechanical properties were evaluated via Vickers microhardness as a function of depth from the surface. The results indicate that the initial surface quality plays a significant role in determining the final surface state. Specimens with poor initial surface quality (MEX specimen) exhibited a notable reduction in surface roughness after shot peening, while those with better initial surface quality (MIM specimen) experienced surface roughening. Furthermore, both surface characteristics and hardness were found to be influenced by the type of peening media. These findings provide insights into the influence of shot media type and peening parameters on the surface and mechanical performance of components produced by MIM and MEX. This study offers practical guidance for optimising surface modification strategies for additively manufactured metal parts.



The Influences of Steel Matrix and Composition on The Behavior of Nitrocarburizing White Layer

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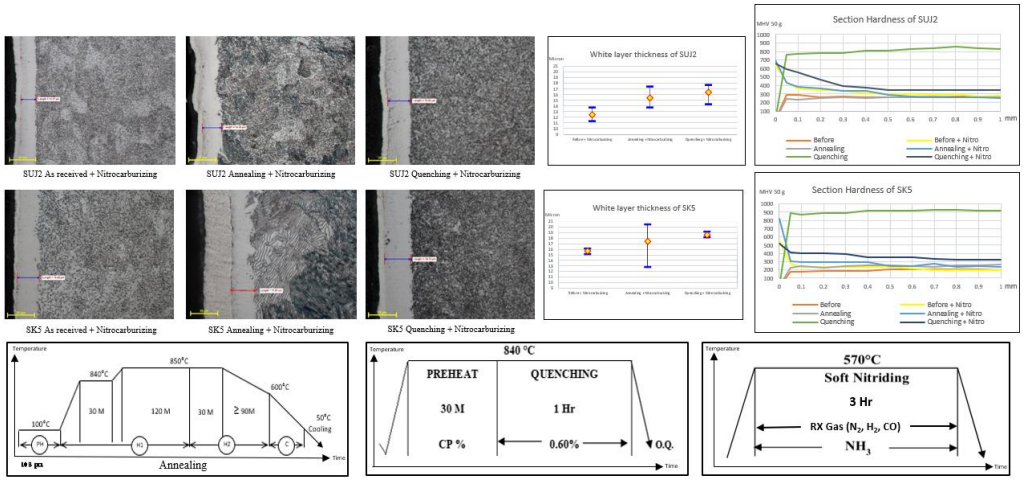
Keywords: Nitrocarburuzing, Base Microstructure, White Layer

Depending on heat treatment steel can exhibit a variety of matrix, such as bainite, ferrite, martensite, and pearlite. This research investigates the behavior of white layer formed during the nitrocarburizing process in steels with three different matrix, including ferrite, pearlite, and martensite. The two types of carbon steel selected for this research are SUJ2 and SK5. Both steels possess a ferrite matrix containing spheroidal carbide under research conditions. To prepare specimens with different matrix for comparison, the steels were subjected to different heat treatment processes. Annealing process produces the pearlite matrix and quenching process produces the martensite matrix. Subsequently, specimens were subjected to the nitrocarburizing process under identical condition to introduce nitrogen and carbon gases into the surface of the specimen. This treatment results in the formation of white layer that can increase the strength and wear resistance. After surface treatment, the specimens were examined using an optical microscope to observe microstructure, and surface hardness was examined using a Micro-Vickers hardness tester. Experimental results indicate that finer structures, such as martensite, result leads to in a formation of a thicker white layer and more uniform white layer compared to coarser structures, such as ferrite and pearlite. Additionally, the presence of alloying elements also affects the thickness of the white layer and the hardness of the diffusion zone. Observation indicates that SUJ2 steel, which contains a higher amount of chromium compared to SK5, shows a thinner white layer and higher hardness in the diffusion zone. The results from this research demonstrate that the chemical composition and its microstructure significantly affect the nitrocarburizing process and the characteristics of the white layer, particularly the thickness of the white layer.

Graphical Abstract (mandatory)



Hybrid Interface Effect of g-C_3N_4/ZnO Nanocomposites on the Protection of 304 Stainless Steel in Corrosive Aqueous Solution

Htet Yadanar Soe [a], Gasidit Panomsuwan [a], Oratai Jongprateep [a], Thanate Na Wichean [b], and Ratchatee Techapiesancharoenkij[a*]

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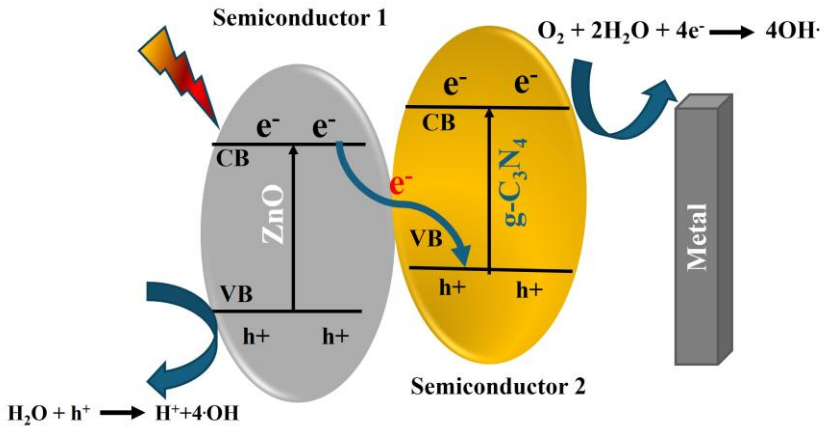
Keywords: Metal corrosion, photoelectrochemical cathodic protection, g-C_3N_4, ZnO, composite materials, 304 SS.

The development of efficient and environmentally friendly corrosion protection systems for metals in aggressive environments has become a critical area of research, particularly for stainless steel used in marine and industrial applications. In this study, a series of graphitic carbon nitride (g-C_3N_4) and zinc oxide (ZnO) composites with varying g-C_3N_4 weight ratios (10 wt%, 20 wt%, 30 wt%, 40 wt%, and 50 wt%), which are integrated to form heterojunction structures with enhanced charge separation and interfacial activity. The composites were prepared using a facile thermal mixing method and were characterized using XRD, SEM, BET, FTIR, UV–Vis, and PL to confirm their structural, morphological, and optical properties. Electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization measurements revealed a substantial reduction in corrosion current density and an increase in charge transfer resistance for stainless steel protected by g-C_3N_4/ZnO nanocomposites compared to the bulk one. The open circuit potential (OCP) of the steel shifted negatively under illumination, confirming the generation of photogenerated cathodic protection. The results revealed that the incorporation of g-C_3N_4 significantly enhanced the visible-light absorption and charge separation efficiency of ZnO. These findings demonstrate the potential of g-C_3N_4/ZnO composites as promising photoanode materials for solar-driven corrosion protection applications.



Behavior of compound layer formation in nitrocarburizing process on gray cast iron standards JIS G5501 FC150

Chairerk Pinukram [a,b,*], Nithi Saenarjhan[b], Patama Visuttipitukul[b], Jatupon Opapaiboon[b], Prasonk Sricharoenchai [b]

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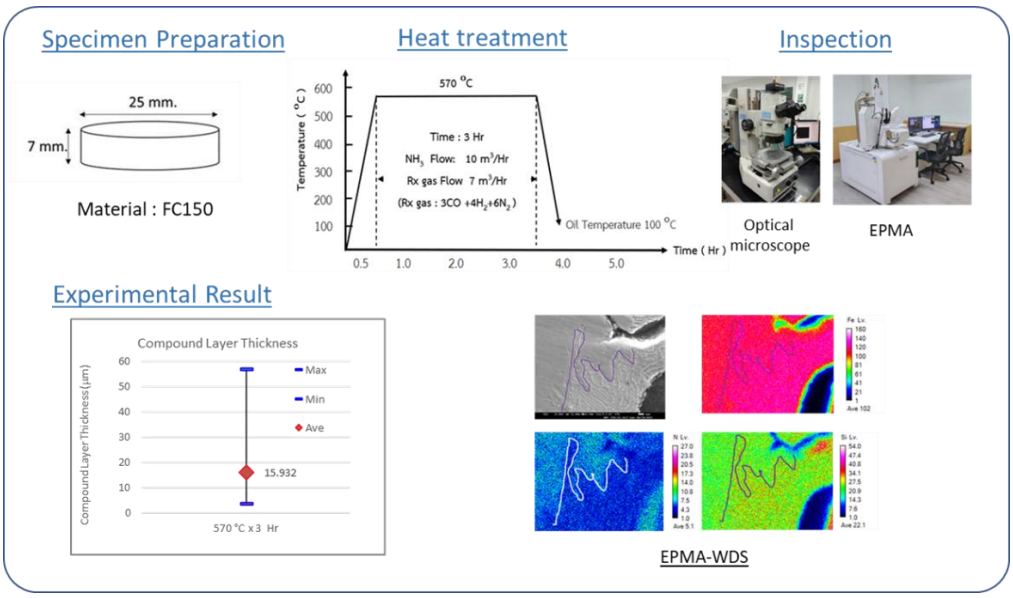
Keyword: FC150, Nitrocarburizing , Compound layer

Gray cast iron grade FC150 is common used in automotive components such as brake discs due to its good castability. However, during service, brake discs made from FC150 often suffer from wear and generate micro particles, indicating limitations in its wear resistance. To enhance this property without altering the base microstructure, nitrocarburizing treatment is considered a suitable surface modification technique. The base microstructure of FC150 consists mainly of pearlite and flake graphite, with its chemical composition comprising 3.5–3.8% carbon, 2.3–2.8% silicon, and 0.50–0.80% manganese. In this study, the nitrocarburizing process was carried out at 570 °C for 3 hours under atmosphere content NH_3 and Endothermic gas ($CO+H_2+N_2$) by batch type furnace. The microstructure of the treated surface was observed using optical microscopy, revealing a compound layer thickness from 3.8 to 57.0 microns, with a range of maximum and minimum 53.2 microns. The element distribution analyzed using Electron Probe Micro Analyzer with Wavelength Dispersive Spectroscopy (EPMA-WDS) showed that areas with high silicon concentration tended to exhibit thinner compound layers, while regions with lower silicon content exhibited thicker compound layers. This indicates a significant influence of silicon on the growth of the compound layer during nitrocarburizing of cast iron grade FC150.



Influence of Gas Nitrocarburizing and Solution Nitriding on the Microstructure and Mechanical Properties of SUS430 Stainless Steel

Tanabodee Praditja[a, b*], Nipon Taweejun[a], Nithi Saenarjhan[b], Patama Visuttipitukul[b], Jatupon Opapaiboon[b], Prasonk Sricharoenchai[b]

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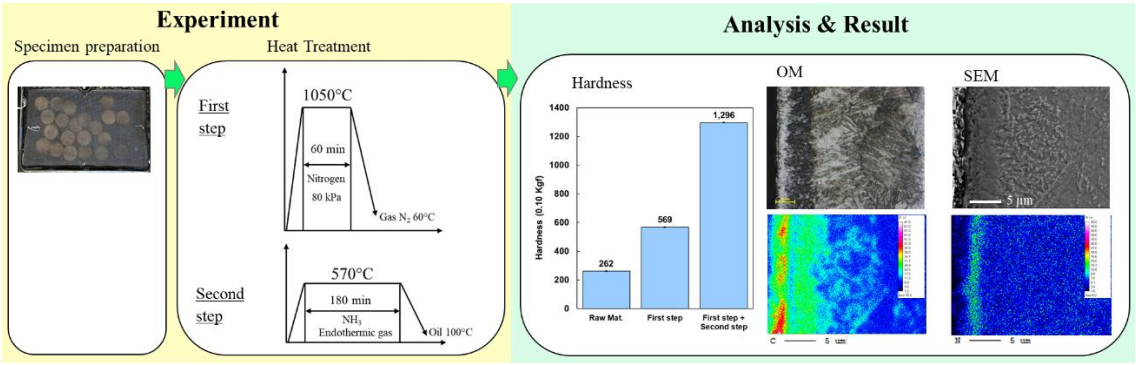
Keyword: Gas nitrocarburizing, Solution nitriding, SUS430 stainless steel

Stainless steel SUS430 is a famous material used in various industries regarding its high corrosion resistance. However, it has a limitation in the mechanical properties, which is its hardness, that makes it unsuitable for the process relevant to friction. To overcome these limitations, this research aims to improve mechanical properties, focusing on increasing surface hardness through the heat treatment process. This experiment uses specimens with a diameter of 22 mm and a thickness of 10 mm, applied in a two-stage heat treatment process. The first step is the solution nitriding process under a controlled atmosphere of nitrogen gas at 80 kPa, at a temperature of 1050 °C for 1 h. This is followed by the second step, which is the gas nitrocarburizing process using ammonia gas and either endothermic or exothermic gas, at a temperature of 570 °C for 3 h. Then, the surface hardness will be inspected using a micro-Vickers hardness tester at 100 g load, the microstructure will be examined with an optical microscope (NIKON DS-Ri, NIS-Elements software), and a scanning electron microscope (JOEL, JXA-ISP100). The experimental results showed that the nitrocarburizing process significantly increased surface hardness to HV(0.1) 1296, compared to HV(0.1) 569 after solution nitriding and HV(0.1) 262 in the untreated specimen. Moreover, from the microstructure, it was found that the compound layer formed on the surface of the specimen is uniform and continuous throughout the surface area, which has a direct effect on the significant increase in hardness. From the experimental results, it can be concluded that the solution nitriding process followed by the gas nitrocarburizing process is an alternative option for improving the surface hardness in order to make it suitable for use in industries that require materials which has high hardness and friction resistance.



Adhesion Performance of DLC Coating on SUJ2 Steel Hardened by Atmosphere controlled and Vacuum Controlled Process

Manusavee Taksadej[a, b*], Nipon Taweejun[a], Nithi Saenarjhan[b], Patama Visuttipitukul[b], Jatupon Opapaiboon[b], Prasonk Sricharoenchai[b]

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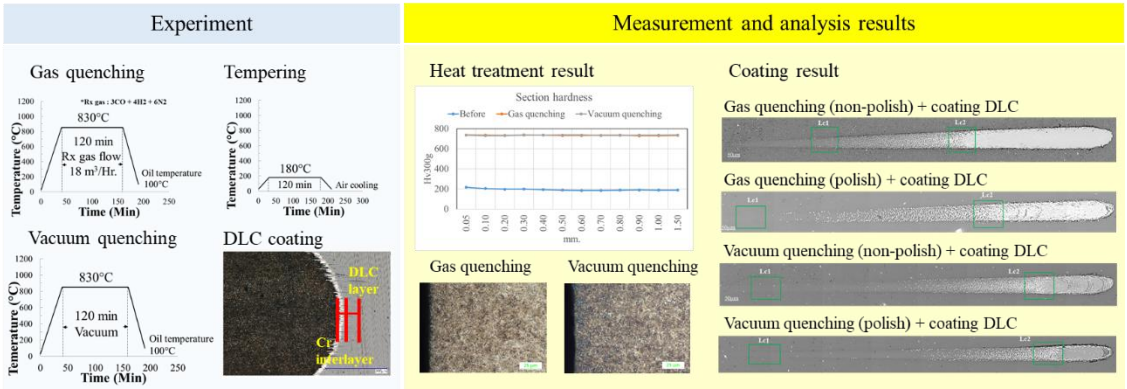
Keyword: SUJ2 steel, Quenching & Tempering, Micro crack, DLC coating

In modern surface engineering, diamond-like carbon (DLC) is among the most widely used coating techniques because of its exceptional hardness and low coefficient of friction. Apart from the design of the DLC coating process, the surface preparation of the substrate material is also critically important. To ensure the suitability of the substrate, surface machining is commonly performed to remove micro-cracks formed during quenching and to reduce surface roughness prior to coating. The objective of this study is to investigate the effects of surface roughness on the DLC coating process, as well as to explore methods for minimizing micro-cracks formed during the quenching process. In this study, SUJ2 material was quenched using two types of heat treatment furnaces: a controlled atmosphere furnace and a low-pressure atmosphere furnace. After quenching, the specimens were polished to adjust the surface roughness and subsequently subjected xto DLC coating. Following the DLC coating process, the specimens were evaluated to compare hardness by Vickers hardness tester, coating thickness by calo tester, and adhesive force by scratch tester, respectively. It was found that the hardness of both is similar. However, the low-pressure atmosphere furnace resulted in no microcracks at the surface. Furthermore, the adhesion performance of DLC coating on process low-pressure controlled specimens was better than atmosphere-controlled with and without polish process prior to coating.



The Effects of Aging on Microstructure and Corrosion Resistance of AISI 201 J1 Stainless Steel

Putthipong Namwol, Gobboon Lothongkum, Pitichon Klomjit, Nithi Saenarjhan,
Department of Metallurgical Engineering, Faculty of Engineering, Chulalongkorn University

Keywords

Austenitic stainless steel, Isothermal aging, Microstructure, Corrosion

Abstract

This research studies the effects of isothermal aging on microstructure and corrosion resistance of AISI 201 J1 stainless steel (high-manganese austenitic stainless steel) at 800°C with various durations. The microstructure was characterized using an optical microscope (OM), a scanning electron microscope (SEM), an electron probe micro-analyzer (EPMA) for elemental distribution analysis, and an X-ray diffractometer (XRD) for phase identification. The corrosion resistance was characterized by potentiodynamic polarization test. The microscopic results showed that after aging, precipitates formed at grain boundary and their size increased with increasing aging duration. EPMA results showed aggregation of Cr and C with depletion of Fe at the same region when aging duration increased, indicating the formation of precipitates containing Cr and C, which aligns with microscopic images. Potentiodynamic polarization results showed a significant decrease in corrosion potential, a slight increase in corrosion current density, and poorer stability of passive film as the aging duration increases. In summary, aging at 800°C deteriorates corrosion resistance of AISI 201 J1 stainless steel because of the formation of Cr-rich precipitates. The longer aging duration promotes corrosion due to an increase size of precipitates.

Poster Presentations

Dismantling and Cathode Pretreatment of End-of-Life Prismatic Cell Lithium Iron Phosphate Battery

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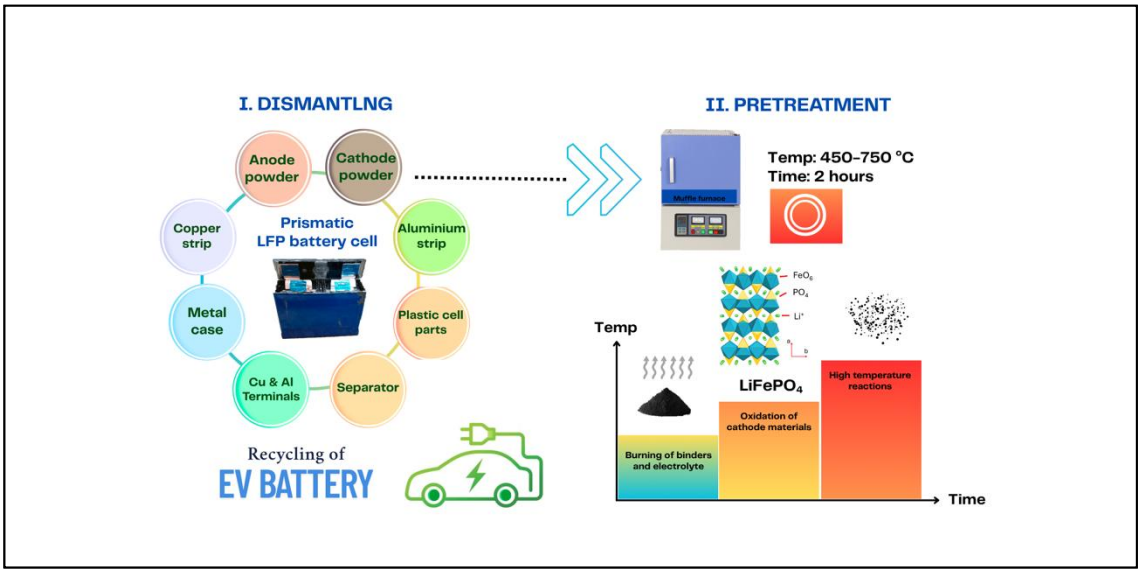
Keywords: cathode, dismantling, lithium iron phosphate battery, prismatic cell, thermal pretreatment.

Lithium-ion batteries have gained great attention due to their high energy density and long cycle life. Lithium iron phosphate (LFP) is one of the most comment types of cathode materials, owing to safety, extended life cycle, and good high temperature performance. Increasing end-of-life of the LFP batteries has also raised awareness towards zero waste and resource conservation. Apart from repurpose, recycling is an important opportunity to recover valuable materials. This research aimed to investigate safe dismantling and pretreatment of cathode materials from prismatic cell typed LFP batteries in order to obtain suitable input materials for the next step of metal recovery via hydrometallurgy. Discharging was via resistive load battery discharger prior to dismantling to obtain cathode and anode powders, copper and aluminum strips, metal case, copper and aluminum terminals, separator, and plastic cell parts. It was found that the cathode materials accounted for approximately 44.37 wt.% of the total LFP prismatic cell battery weight while the anode was 28.21 wt.%. Subsequently, the cathode materials were subjected to pyrometallurgy process via thermal pretreatment at 450, 500, 550, 600, 650, 700 and 750 °C for 2 hours in ambient condition to dispose binder and electrolyte. The cathode materials prior to and after pretreatment were subjected to XRD, SEM+EDS, and TGA, for phase identification and thermal analysis. Upon thermal pretreatment, burning of binders and electrolyte, oxidation of the cathode materials occurred followed by high temperature reactions.



Synthesis and Tribological Evaluation of 2D Ni-MOF Additives for Enhanced Lubrication Performance

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Keywords: Metal Organic Framework (MOF); 2D Nanomaterials; Lubricant Additives; Four-ball test; Tribological Properties

Lubricants play a crucial role in mechanical systems by reducing friction and wear, thereby extending the service life of machinery. In this study, three types of two-dimensional nickel-based metal–organic frameworks (2D Ni-MOFs)—Ni-BDC, Ni-ABDC, and Ni-BPDC—were synthesized via a sonication method in a DMAC medium using benzene dicarboxylic acid (BDC), amino benzene dicarboxylic acid (ABDC), and biphenyl dicarboxylic acid (BPDC) as organic linkers, respectively. These MOFs were incorporated into 150SN base oil at a concentration of 0.1 wt%. Structural and morphological characterizations were performed using PXRD, TGA, FT-IR, and SEM, while dispersion stability was evaluated via zeta potential and UV–visible spectroscopy. Among the synthesized materials, Ni-ABDC exhibited the highest surface charge and superior dispersion stability.

Tribological performance was investigated using a Bruker four-ball tester under two load conditions (147 N and 392 N) at 1200 rpm for 1 hour. Ni-ABDC effectively reduced the coefficient of friction at both loads, achieving comparable results to commercial semi-synthetic 5W30 and fully synthetic 10W40 oils. Although the Ni-MOF-based formulations exhibited larger wear scar diameters (0.6–0.7 mm) than commercial oils (0.3–0.4 mm) under low load, the semi-synthetic oil suffered thermal degradation at higher load, evidenced by welding scars and discoloration. This sign was also found in Ni-BPDC, attributed to its bulky structure and low dispersion. In contrast, Ni-ABDC maintained stable friction and wear behavior across conditions.

These findings highlight Ni-ABDC as a promising, thermally stable, and efficient lubricant additive for next-generation tribological systems.

Effects of N_2 Flow Rate on the Microstructure of Nanocrystalline TiAlN Films Prepared via Reactive DC Magnetron Co-Sputtering

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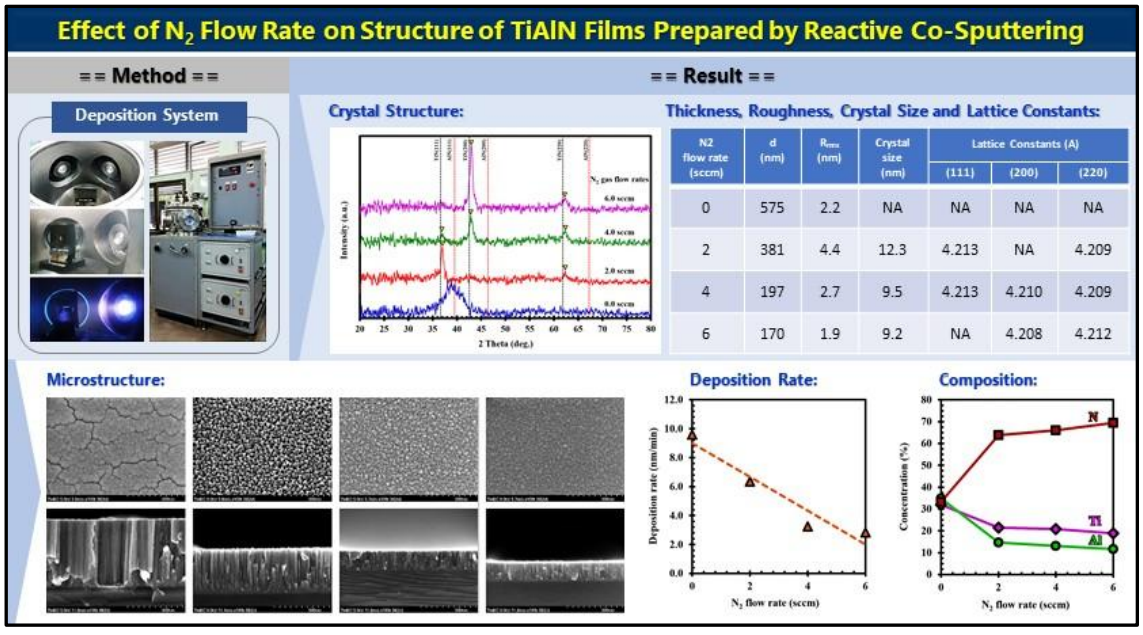
Keywords: TiAlN, Thin Films, N_2 Flow Rates, Reactive Magnetron Co-Sputtering.

Nanocrystalline TiAlN thin films were deposited on Si (100) substrates using a co-target reactive magnetron sputtering, with nitrogen (N_2) flow rates varied from 0 to 6 sccm under identical deposition conditions. The influence of nitrogen gas flow rates on the crystal structure, surface morphology, microstructure, and chemical composition of the as-deposited films was systematically investigated. Structural, morphological, and chemical composition characterizations were conducted using grazing-incidence X-ray diffraction (GI-XRD), atomic force microscopy (AFM), field emission scanning electron microscopy (FE-SEM), and energy-dispersive X-ray spectroscopy (EDS), respectively. The results revealed a strong dependence of film characteristics on the nitrogen flow rates. A preferential (111) orientation was observed at a low flow rate (2 sccm), whereas higher flow rates (4–6 sccm) promoted a (200) preferred orientation. Average crystallite sizes, estimated by Scherrer's equation, decreased from 12.3 nm to 9.2 nm. Surface roughness values (R_{rms}) decreased from 4.4 to 1.9 nm with higher nitrogen flow. FE-SEM analysis showed the presence of nanocrystalline columnar structures in all samples, accompanied by a decrease in film thickness from 575 nm to 170 nm. Variations in chemical composition were also observed as a function of nitrogen gas flow rates. These findings highlight the critical role of nitrogen gas flow rates in tailoring the structural and morphological features of TiAlN thin films for advanced coating applications.



Biosynthesis of Silver Nanoparticles Using Clove, Cinnamon and Star Anise as Reducing Agents

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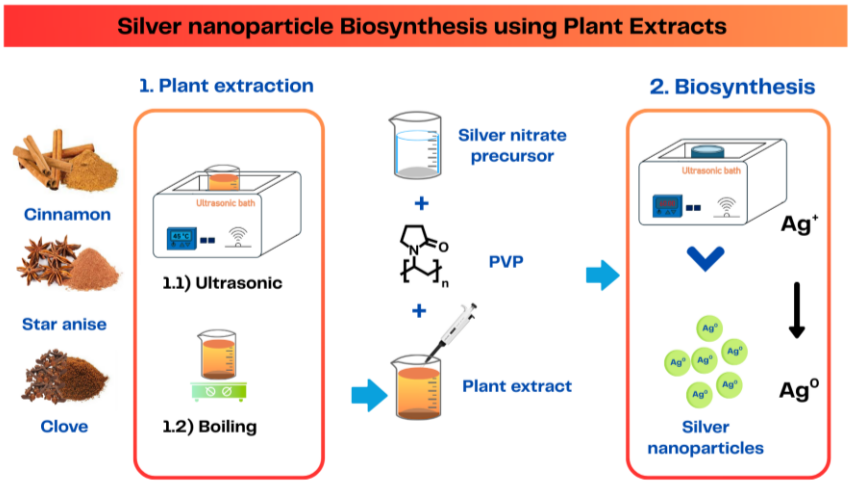
Keywords: biosynthesis, silver nanoparticles, clove, cinnamon, star anise

Siver nanoparticles have gained attention due to their antibacterial properties over 650 types of bacteria. This research investigated silver nanoparticle synthesis by applying environmentally friendly biosynthesis using plant extracts such as clove, cinnamon and star anise as the reducing agent, whilst their therapeutic effects of pain and inflammation relief are also of interest. Plast extraction was carried out in two routes: i) under ultrasonic at 45 ºC for 1 hour, followed by filtering and ii) boiling at 90 ºC for 1 hour. The plant extract was prepared at S:L ratio of 20 g.:100 mL and grinding effect to receive a particle size of < 210 micron was investigated. It was found that the boiled plant extract appeared dark brown whereas the ultrasonic ones exhibited a paler extract solution. Grinding, however, did not offer differences in extract solution's color while clove extract solutions provided the darkest color of the extract solution. Moreover, grinding led to liquid oil mixed with the extract solution that made it difficult to be used in the synthesis. During the biosynthesis using 25 mL of 0.01 M silver nitrate precursor at room temperature under ultrasonic for 2 minutes, effect of capping agent addition using polyvinylpyrrolidone (PVP) was studied. It was found that without PVP, micro-sized silver particles were observed while PVP addition offered encapsulation and resulted in smaller size of silver nanoparticles. Clove extract provided better reducing effects in comparison to cinnamon and star anise, which might be due to phenol such as gallic acid and 4-p-hydroxybenzoic acid obtained in clove.

Graphical Abstract



Comparative Study of Silver Recovery from X-Ray Film Fixer via Cementation, Chemical Precipitation and Electrowinning

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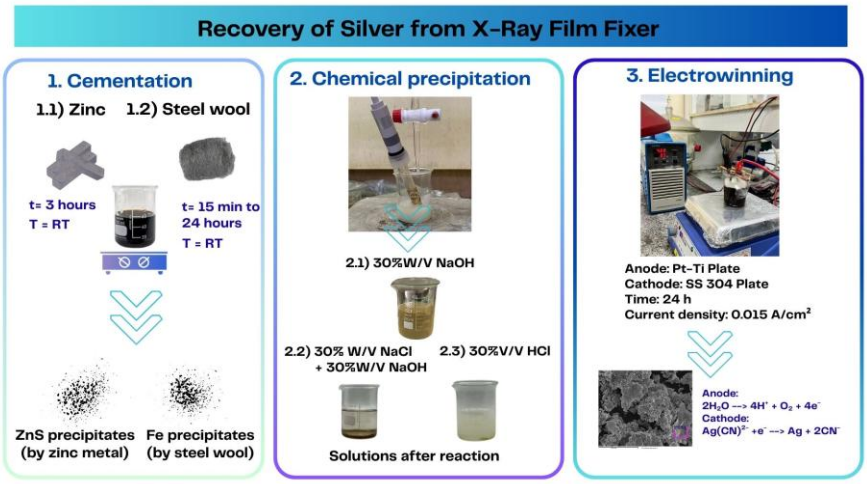
Keywords: cementation, chemical precipitation, electrowinning, silver, X-ray fixer.

Spent X-ray film fixer contains valuable sources of silver, and its recovery is considered economically and environmentally beneficial for resource conservation. Following the film developing, the fixer is used to dissolve the unexposed silver halide crystals into the fixer solution in the form of silver-thiosulfate complexes. The initial amounts of Ag in the spent fixers obtained varied from 49.7-1,531 mg/L. This research objective was to investigate comparative study of the recovery of silver from spent fixer solutions from dental clinics via i) cementation, ii) chemical precipitation and iii) electrowinning. First, cementation was carried out by using zinc, studied at S/L ratio of 30 g Zn metal/30 mL fixer for 3 hours. Alternatively, steel wool was used to at S/L of 4.5 g/ 100 mL for 15 minutes to 24 hours. Secondly, chemical precipitation was utilized using 30%W/V NaOH or 30% W/V NaCl + 30%W/V NaOH or 30%V/V HCl. Thirdly, electrowinning was employed using Pt-Ti and 304 stainless steel plates as the anode and cathode respectively. The fixer of 100 mL was used as the electrolyte for 24 hours at the current density of 0.015 A/cm^2. It was found that zinc cementation resulted in ZnS compounds with 5.22 wt.% Ag found. For steel wool cementation, ICP-OES result showed that Fe was dissolve while Ag was still in the solution at 1.2-1.3 mg/L. For chemical precipitation, all three processes provided precipitates of low Ag contents. Precipitated by 30% W/V NaCl + 30%W/V NaOH gave 4.70 wt.% Ag. Electrowinning, however, showed higher Ag purity of 82-98 wt.% by SEM-EDS results, but ICP-OES result indicated low % recovery of 23-33%. Therefore, electrowinning allowed higher silver purity when compared with other recovery methods, but with low % recovery.

Graphical Abstract



Wear Mechanisms of Ni-Based Coatings Produced by High Velocity Oxy-Fuel (HVOF) Spraying and Arc Spraying

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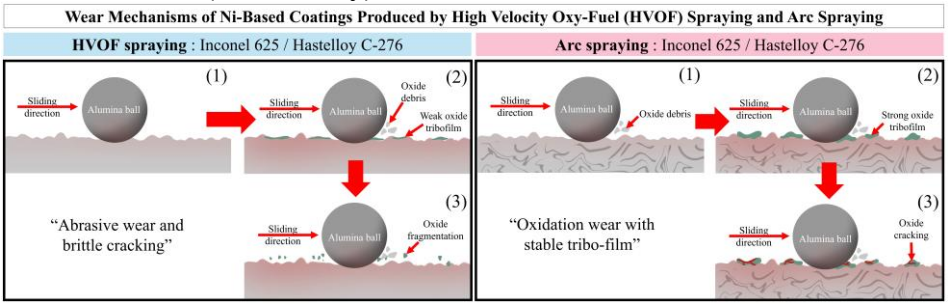
Keywords: Ni-Cr coatings, High-velocity oxygen fuel spraying, Arc spraying, Wear.

Thermal spray coatings are extensively used in industry to enhance surface properties, particularly improving wear and corrosion resistance. Ni-based coatings, Inconel 625 and Hastelloy C-276 are widely used due to their good mechanical properties and corrosion resistance. This study investigates and compares the microstructure and mechanical performance of Inconel 625 and Hastelloy C-276 coatings, produced by high velocity oxy-fuel (HVOF) spraying and arc spraying. Microstructural analysis, conducted using scanning electron microscopy (SEM), revealed that HVOF-sprayed coatings possessed a denser structure with lower oxide content and porosity than arc-sprayed coatings. These differences resulted from the higher particle velocities and reduced oxidation during the HVOF process.

Mechanical properties were evaluated using Vickers microhardness tests, scratch tests, and ball-on-disk wear tests. Results indicated that HVOF-sprayed coatings had significantly higher hardness than arc-sprayed coatings. Specifically, for HVOF, Inconel 625 exhibited an average hardness of 464.29 ± 40.65 HV, and Hastelloy C-276 showed 439.91±45.76 HV. In contrast, arc-sprayed coatings of Inconel 625 had an average hardness of 291.1 ±38.15 HV, while Hastelloy C-276 measured 266.45±44.48 HV. This represents a hardness increase of approximately 59% for Inconel 625 and 65% for Hastelloy C-276 when sprayed using HVOF compared to arc spraying, due to their denser microstructure and better splat bonding. Scratch tests confirmed that HVOF coatings provided superior scratch resistance, with lower penetration depths, compared to arc-sprayed coatings, which exhibited splat debonding and cracking under load. However, ball-on-disk wear tests demonstrated a trade-off between hardness and wear resistance. Despite the higher hardness of HVOF coatings, arc-sprayed coatings showed better wear resistance, attributed to the formation of protective oxide tribo-films during sliding wear. HVOF coatings exhibited higher wear rates primarily due to abrasive wear mechanisms. In summary, HVOF-sprayed coatings demonstrate superior hardness and scratch resistance, whereas arc-sprayed coatings achieve superior wear resistance via tribo-film formation, emphasizing the importance of process and material selection for optimal surface performance.

Graphical Abstract (mandatory)



Study of Chromium Influence to Properties of 9K White Gold

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Keyword: 9K White Gold, Chromium, Gallium

Due to the rising price of gold, manufacturers have increasingly turned to producing 9-Karat gold jewelry, which offers a more affordable alternative. However, achieving a white color in gold alloys typically requires the addition of nickel, a metal known to cause allergic reactions. This has led to restrictions on its use, especially under European regulations. Palladium, while hypoallergenic and effective in whitening, is expensive and unsuitable for low-karat gold. This study proposes the use of chromium and gallium as alternative alloying elements for producing hypoallergenic white 9K gold with improved mechanical properties and reduced cost. The proposed alloy composition consists of 37.5 wt% Au, Ag, Ga, and Cr. The alloys were cast using a flame-melting method, then poured into a metal mold and quenched in water. Sample were investigated properties including Vickers microhardness, colorimeter, tarnish resistance and microstructure. The highest hardness was found to contain 0.05 wt% Cr, 180 Hv and a yellowness index 22.56 within the range of standard white gold. Additionally, increasing the concentrations of Cr and Ga to 0.05 wt% led to improve the alloy's tarnish resistance significantly.