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Friction Stir Welding of Wrought and Cast Al Alloys: Weld Quality Evaluation, Thermo-Mechanical Modeling and Microstructure Prediction

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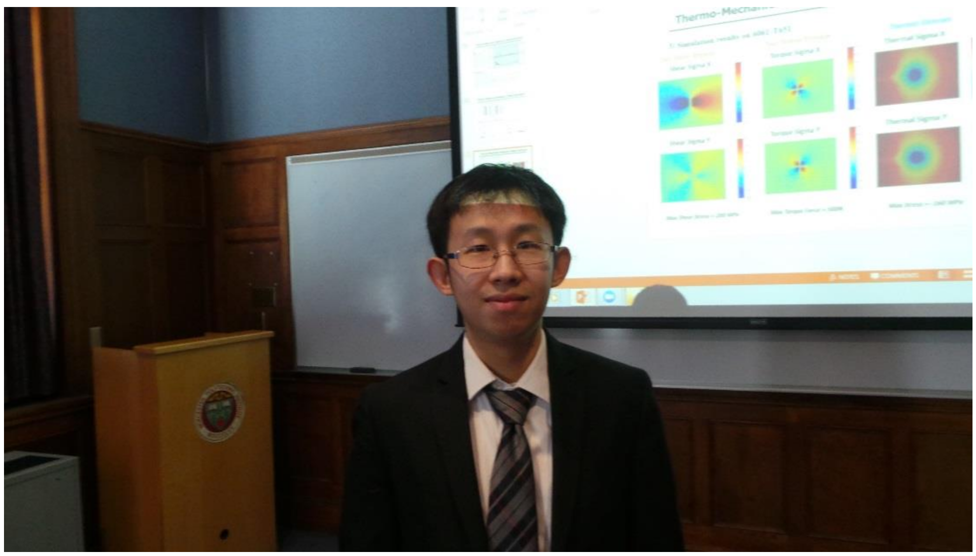

Abstract

Friction stir welding (FSW) is a solid-state technique widely used for joining and repairing in the transportation sector, and understanding its effects on static and dynamic properties is critical for structural integrity. In this study, four aluminum alloy systems (wrought 6061 and cast A356, 319, and A390) were processed using various controlling parameters in both as-fabricated and pre-weld heat treated conditions. The effects of processing and heat treatment on the resulting microstructures, macro/micro-hardness, and static properties were systematically investigated and mechanistically correlated. Optimum processing parameters that provide both defect-free welds and good mechanical properties were experimentally determined for each alloy. In addition, a thermo-mechanical model was developed for simulating and predicting temperature, stress, and material flow fields, as well as microstructure evolution during FSW, through a dynamic recrystallization and secondary phase fragmentation model, under different processing conditions. The results of these studies will be systematically presented and discussed from the perspectives of both process optimization and structural design.

Reuse Opportunities for Bauxite Residue

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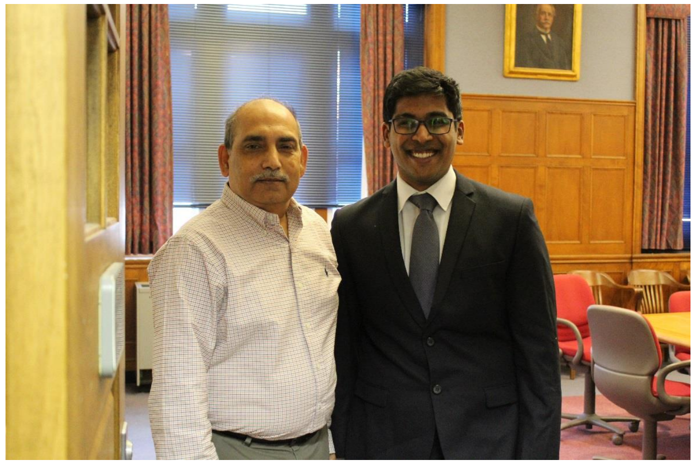

Abstract:

Bayer processing of bauxite employed for production of alumina yield a residue red-mud. The worldwide annual-rate of red-mud generation is approximately 120 million tons, and most of this is stockpiled. Red mud is rich in elements like aluminum, titanium and rare earths, in addition to the major iron-bearing constituents. The objective of this research is to explore such a strategy to extract Iron as magnetite. Pyrometallurgical reduction experiments using carbon mixtures and a novel hydrometallurgical route are experimented. Reduction experiments performed with petroleum coke as a reductant resulted in incomplete reduction. Gaseous reductants CO (g) and CO2 (g) are also used for reduction. Four temperatures: 475oC, 500oC, 550oC and 600oC, time-of-reaction10, 20 or 30 min, CO (g)-CO2 (g) 1:1.5 or 1:1 or 1.5:1 are varied to study the conversion. The 'optimal conditions' for the reduction are determined to be: a processing temperature of 540oC ± 10oC, partial pressures CO (g) and CO2 (g) each of 0.070atm (bar) ± 0.001atm.(bar)/ inert diluent-gas: N2 (g), for a conversion-time of 30min. A mathematical model was developed on the basis of unidirectional-diffusion of CO2 (g) within the CO2 (g)– CO (g)–N2 (g) gas-phase of the porous product-layer. Magnetic classification was performed, by employing (a Frantz) dry magnetic-separator as well as (a Davis-Tube) wet magneticseparator, on samples produced under optimal conditions by CO2 (g)–CO (g)–N2 (g) gasphase reduction. Magnetic separation in: obtaining a magnetic portion with high iron and non-magnetic portion containing nonferrous (Al, Ti) is not successful. This finding was subsequently attributed to the nanometer length-scales crystallites of the predominant iron-containing phase, hydrated ferric-oxide(s) as determined by STEM micrographs. In addition, the presence of substitution for Fe3+ by Al3+ and Ti3+/ 4+ are determined with the help of MÖssbauer spectrograms. A hydrometallurgical route involving selective leaching and precipitation of iron in red-mud is tried. Red-mud is leached in oxalic acid at: 95˚C, 15 % Pulp density, 2.5 h leaching time, 1.5 pH. Kinetic studies yielded the leaching mechanism to be predominantly fluid film control. Ferric oxalate in the leach liquor is reduced to insoluble ferrous oxalate selectively using Iron powder. The ferrous oxalate formed is ~98 % pure. The precipitated ferrous oxalate is magnetically separated and reduced in Nitrogen atmosphere to form fine particulate magnetite. Additionally an economic feasibility study was conducted for the hydro and pyro alternatives to produce magnetite using Monte Carlo Simulations by imparting uncertainties in various input cost components. A traditional process was also compared to the proposed approaches for Total Capital Investment (TCI), Total Product Cost (TPC), Net Present Value (NPV) and sensitivity analysis. ~52 % reduction in Total product cost, 46 % reduction in Total Capital Investment was achieved for the hydrometallurgical process when compared to the traditional approach.

Recycling of Passenger Vehicles: A framework for upcycling and required enabling technologies

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Abstract

The automotive industry is expected to transition from a net-consumer to a net-producer of aluminum scrap as aluminum-intensive vehicles (AIVs, i.e., Ford's aluminum-bodied F-150) begin to reach end-of-life (EOL). In the past, the industry has downcycled aluminum scrap to meet the consumption demands of the automotive sector. With the shift to having a large supply of this scrap in the near future, the industry needs to recover and reuse EOL Al by utilizing a circular economic model, create value via an upcycling paradigm (vs downcycling). This work establishes a platform as to how the recycling industry can be restructured to create value in our waste streams and is organized in three segments: First, an analysis of the flow of automobiles at EOL was carried out from the perspective of recovery and reuse; a recycling rate for Al has been determined, and the factors that go into the dynamics of the recycling rate have been identified. Secondly, the current state of the market was surveyed to evaluate where improvements could be made to affect material collection and recovery. The latter led to compositional characterization of aluminum auto-shred to identify the alloys in the mixture, and thereby the needed intelligent sorting systems for upcycling. Thirdly, these results were used in a dynamic material flow model to predict how the composition of auto-shred will change due to increased aluminum usage and as a function of various end-of-life processing scenarios. The outcome and impact of this work is that we have established a platform that enables the ELV recycling industry to upcycle the large amount of Al that will be available in the near future. These results will be discussed and reviewed during this presentation.

Sintered Ti6Al4V for Orthopedic Applications

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Abstract

Ti-6Al-4V alloy has been used as biomedical implants for decades because of its superior mechanical properties, good biocompatibility, lack of allergic problems and good corrosion resistance. It is widely used as the tibial components in total knee arthroplasty and hip cup in total hip replacement. However, mechanical properties of Ti-6Al-4V implant can be deteriorated due to corrosion pits. In the past decades, the rapid developments in additive manufacturing have broadened their applications in biomedical area due to the high geometrical freedom in fabricating customized implants. However, the high-localized thermal input and fast cooling rate during laser processing usually result in non-equilibrium phase with high residual stress. Therefore, it is necessary to apply proper post-treatments on the as-print parts to ensure better properties. In this work, various post-treatments (e.g. post-heat treatments, hot isostatic pressing) were applied aim to improve the corrosion behavior of direct metal laser sintered Ti-6Al-4V parts. The effect of post-treatment temperature on the mechanical properties and corrosion behavior were examined experimentally. Microstructure, phase fraction and residual stress are evaluated. A discussion on factors influencing corrosion rate was presented, and the corrosion mechanism on the Ti-6Al-4V part in simulated body fluid was proposed. Based on the electrochemical measurement results, enhanced corrosion resistance was observed in the samples after high temperature annealing treatment in the $\alpha+\beta$ region, and solution treatment in β region followed by aging.

Microstructure Evolution, Static and Dynamic Properties, and Fatigue Damage Mechanisms in Ti-6Al-4V and Inconel 718 Fabricated by Laser Engineered Net Shaping (LENS®)

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Abstract:

As the industry pushes for the implementation of Additive Manufacturing (AM) technology, a focus of efforts is now on the qualification and certification of AM processed materials. For critical applications in the field of aerospace, defense, medical etc., the fatigue and fracture resistance of materials are among the most important design criterions. Therefore, qualification of AM processed materials for such critical applications requires extensive examination of their fatigue and fatigue crack growth properties, and understanding of the fatigue failure mechanisms. This study investigates two important aerospace alloys, Ti-6Al-4V and Inconel 718, fabricated by the Laser Engineered Net Shaping (LENS®) technique. For each material, systematic evaluations of the tensile and fatigue crack growth properties are performed in both as-built and heat treated conditions. Post testing analysis reveals the contribution to damage from certain microstructural features, defining favorable as opposed to detrimental microstructural conditions. These observances provide important guidelines for further modification of processing and heat treating procedures. This study establishes the process – structure – property relationships for each investigated alloy, and demonstrates the application of such knowledge in design with AM.

Modeling and Verification of Simulation Tools for Carburizing and Carbonitriding

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Abstract

The Center for Heat Treating Excellence (CHTE) surface hardening simulation tools, CarbTool© and CarbonitrideTool©, have been enhanced to improve the accuracy of the simulation and to predict the microstructure and microhardness. These tools simulate both gas and low pressure processes. CarbTool© was enhanced by modifying the boundary condition. Carbon deposit and carbides formed during the boost step were studied. Nominate carbon potential was proposed for the simulation. Mass transfer coefficient was calculated. The microstructure and microhardness prediction were developed for both CarbTool© and CarbonitrideTool©. Retained Austenite fraction was predicted and used for input condition of hardness prediction. Magnetic Barkhausen Noise (MBN) was studied as an effective nondestructive testing method for surface hardness and case depth. The correlation between the MBN and the microstructure was well studied. Verification of the testing method was applied.

Life Extension of High Temperature Structural Alloys by Surface Engineering in Gas and Vacuum Carburizing Atmospheres

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Abstract

The heat-treating industry is in need of heat-treatment furnace materials and fixtures that have a long service life and reduced heat capacity. Based on microstructural analysis of components that were used until failure in carburization furnace application, it was found that the primary reason for failure was the excessive carburization that leads to “metal dusting” and subsequent cracking. Aluminizing is widely used to increase the high temperature oxidation and carburization resistance of nickel-based alloys. In this dissertation, RA330, RA602CA, 304L/316L, Inconel 625 alloys were selected to study their performance in an industrial carburization furnace for times up to two years. These alloys were exposed in both the as-fabricated and aluminized condition. The test samples were exposed to carburizing atmosphere at approximately 900℃ for 3 months, 6months, 12months, 18 months and 24months. The oxidation properties and oxide stability at high temperatures will be presented. In addition, the analysis of microstructural development during long term exposure experiments in an industrial carburizing furnace will be presented. These samples were characterized using optical and scanning electron microscope, EBSD, and x-ray diffraction. It was found that the aluminized alloys exhibited lower weight gain and carbon uptakes