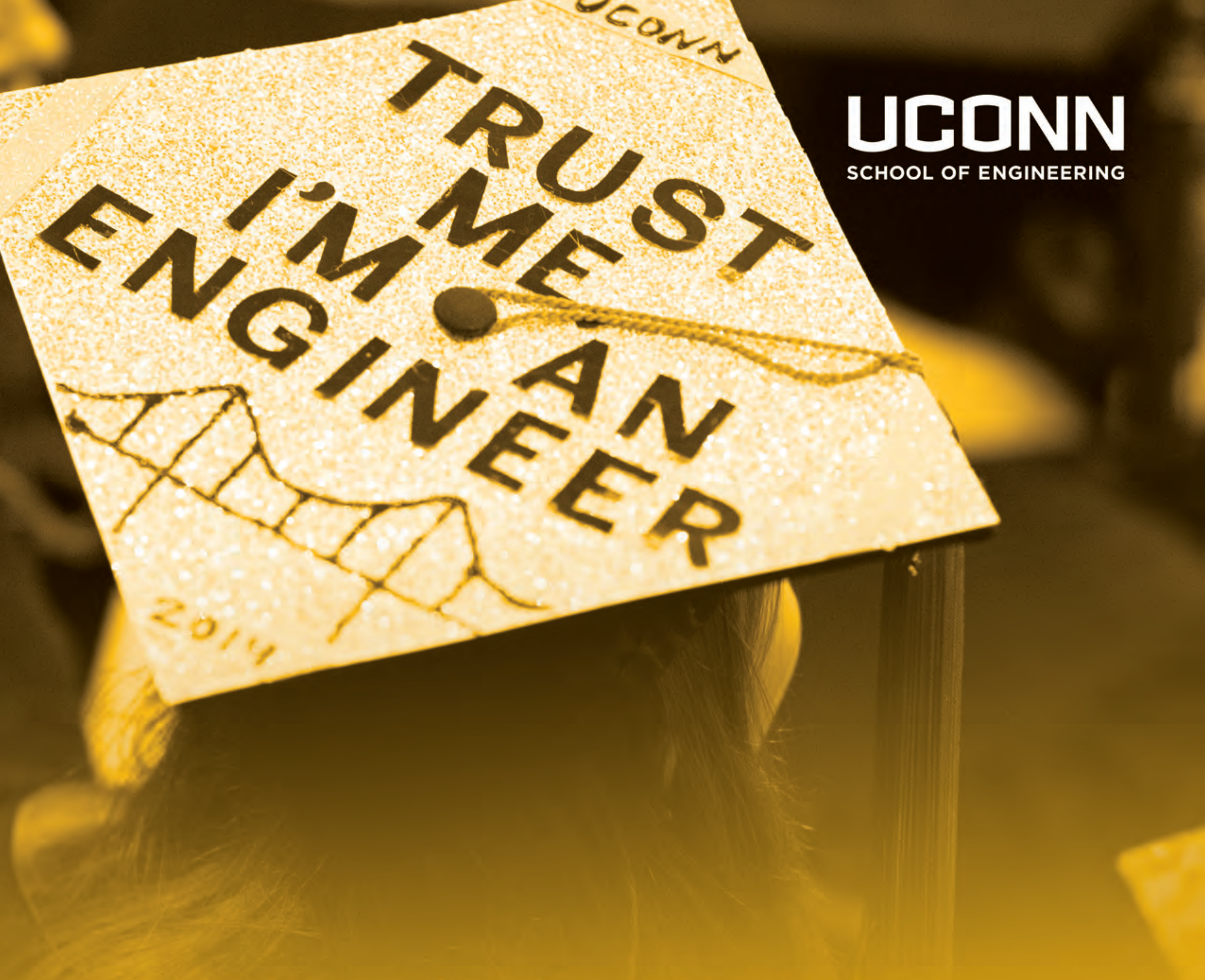

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Team 1: Additive Metal Processing for the Production of Surgical Device Components

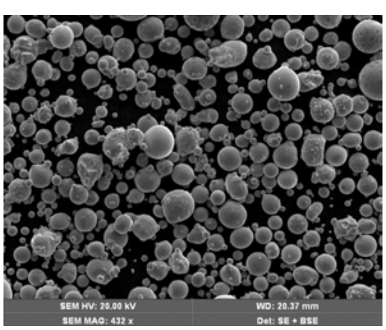
Sponsored by: Covidien
Sponsor Advisor: Dr. William Powers

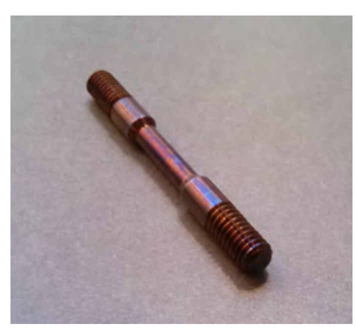
Andrew Fasano & Pamela Dyer

Covidien, a global medical device company, is focused on creating innovative devices for surgeons that provide better clinical outcomes for their patients. Additive Metal Processing has the potential for producing complex components for advanced surgical instruments. Specifically, Direct Metal Laser Sintering (DMLS) is a relatively new additive manufacturing technique and Covidien is seeking to investigate laser processing variables and understand their effect on resulting component properties. This project focused on the analysis and improvement of the mechanical properties of Alloy 17-4 PH stainless steel. The objectives of the project were to design and analyze a process that maximizes the build speed for DMLS 17-4 PH steel without a significant loss in tensile strength and to provide a greater understanding of the capabilities and limitations of DMLS.

The initial experimental analysis for this project consisted of imaging 21 samples of 17-4 PH stainless steel that were manufactured by DMLS at Linear Mold & Engineering. These samples were produced by an EOS M280 machine using a variety of laser power outputs as well as differing laser scan speeds. The volume fraction porosity in each sample was calculated using optical metallography and ImageJ software. These results were used to define the laser process parameters for the subsequent experimental portion of the project.

The final part of the project involved analyzing differences in mechanical properties between traditionally manufactured 17-4 PH stainless steel bar stock samples and DMLS 17-4 PH material. Cylindrical tensile samples were machined from the bar stock material by Covidien and 54 samples of the same design were produced using DMLS by Linear Mold & Engineering. The samples were produced to a final precipitation hardened condition of H900 using appropriate heat treatments prior to mechanical testing. The DMLS samples required solution heat treatment prior to the subsequent H900 age-hardening heat treatment. The 54 DMLS-produced cylindrical tensile samples consisted of 6 samples at each of 3 different settings of laser process parameters and 3 different build orientations. The mechanical properties measured included yield strength, ultimate tensile strength, and % elongation to failure. In addition, Scanning Electron Microscopy (SEM) was used to analyze resulting fracture surfaces. The results from the two different processing methods (conventional bar stock and DMLS 17-4 PH) were compared and contrasted.





Team 2: Salt Penetrometry for Design of Reduced Defect Filters

From left to right: Jason Monnes, Marc Bennett, and Noveen Delaram

Sponsored by: KX Technologies
Sponsor Advisor: Bruce Taylor, William Li

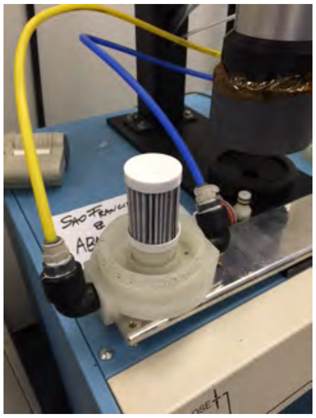
KX TECHNOLOGIES
The Science Behind Better Water

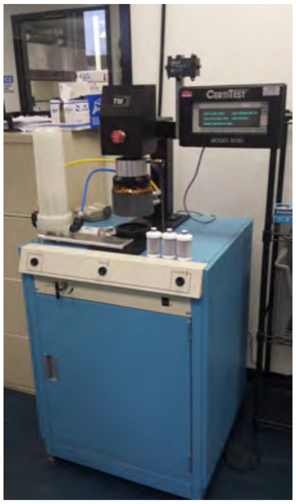
Water is possibly the most valuable resources on the planet. All over the globe, people suffer from a lack of access to clean water. Contaminants like viruses, bacteria, and heavy metals all can affect how clean water is. KX Technologies produces pleated and extruded carbon water filters that can filter out these contaminants. To ensure the filters are defect free, KX Technologies tests their filters. Current testing methods destroy filters that are being tested which prevent each filter from being sold. A non-destructive testing method needs to be developed so a greater number of filters can be tested and then can be sold.

This project focuses on the creation and evaluation of a non-destructive testing method for the water filters made by KX Technologies. Creating a faster testing method that is more consistent and reproducible was also an important goal for this project. The method of testing that was explored is known as salt penetrometry. Salt penetrometry is a non-destructive filter testing method that is commonly used to test air filters. The goal of this project is to develop a testing method using salt penetrometry that will work to identify large in water filters while being non-destructive.

Initially, the project started with oil penetrometry, which uses the similar principles for testing as salt penetrometry, but oil penetrometry was still destructive to the filters. After successful testing with oil penetrometry the project transitioned to salt penetrometry once the testing machine was ready for use. The testing parameters that were developed when using oil penetrometry were applied to the testing with salt penetrometry. Both testing methods easily identify a variety of defects that can be present in the filters.

Developing a testing procedure for KX Technologies using salt penetrometry was the goal of this project. The procedure developed accurately identifies defects and is non-destructive. This effective procedure will eventually lead to KX Technologies testing most if not all of their filters with salt penetrometry as part of the production line. This represents yet another innovation by KX technologies.





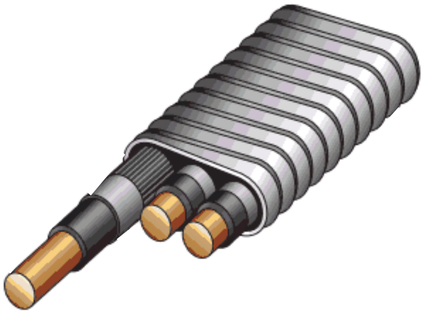
Team 3: Marmon Utility ESP Cable Systems

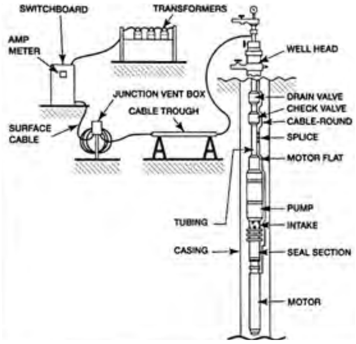
Sponsored by: Marmon Utility-Kerite Pump Cable
Sponsor Advisors: Michael Norton, Mohamed Alameh

From left to right: Cody Andelin and Jackson MacMillan.

Marmon Utility is a leading producer of electrical submersible pump (ESP) cable systems. The cable is designed for performance, durability, cost, and effectiveness. Because of the depth and geographic locations of some wells, specific high temperature, and high corrosion resistant cables must be used. High temperatures and aggressive oil conditions can cause unexpected cable failure. Currently, there are multiple layers intended to protect the copper conductor (see figure below). The polymeric EPDM layer is the first to be added to the copper conductor. Its purpose is to insulate electricity. Next, a lead layer is added to increase corrosion resistance. Then, a fabric tape is wrapped around the cable to prevent mechanical damage from the last layer, a steel wrap. If the EPDM insulation layer is compromised, then the resistance will be lowered, arcing occurs, and the cable fails. The goal of the project is to improve Kerite's high temperature cable by investigating and testing the limitations of the current layers. Another important aspect of this project is to deliver useful results pertaining to the material properties of the cable.

Testing the mechanical properties of the materials used in the cable is important in understanding the limitations of each layer. Some of the tests include tensile test, hardness test, fatigue test and swell test outlined by IEEE and ASTM standards. The insulation layer of EPDM has electrical properties that are also tested. The EPDM is tested against a new EPDM in accelerated conditions. The electrical conductivity will change in varying oil chemistries. Volume change, hardness change and the resulting structure are also investigated. All of these tests are useful in understanding how and why oil penetrates the cable. Using background knowledge as well as results obtained, the root cause of the failure is determined. Ultimately, this knowledge is used to design or recommend better material choices for the high temperature ESP cable.





Team 4: Al-Li Alloy Peening and Impact on HCF Behavior

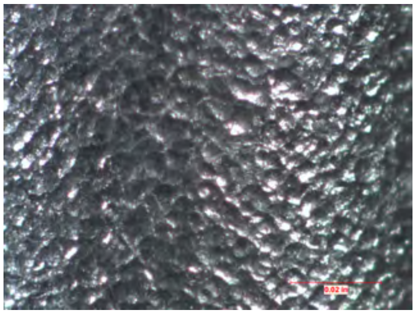
Timothy James

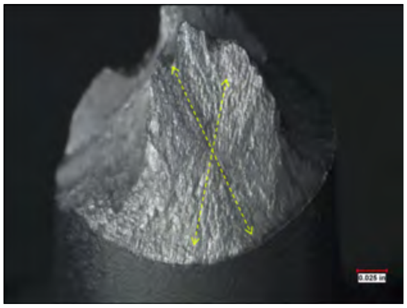
Sponsored by: Pratt & Whitney
Sponsor Advisor: James Hansen

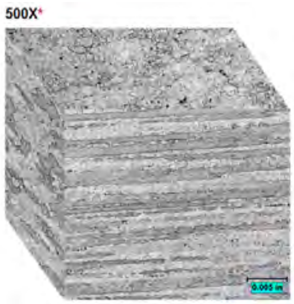
Recent fatigue testing of aluminum-lithium (Al-Li) alloy by Pratt & Whitney (P&W) has shown diminished or no benefit in high cycle fatigue (HCF) capability from shot peening. This result is unexpected given prior P&W experience with peening of legacy aluminum alloys. Since the Al-Li alloy in the forged state is anisotropic, i.e., the elastic and yield properties change relative to the forging frame of reference, it is believed that residual stress effects from peening may vary depending on orientation. The first major objective of the design project is to understand the relationship between surface treatment process parameters and Al-Li material behavior with respect to residual stress and fatigue life. The second major objective is to optimize the peening process so that it provides an HCF benefit over the baseline Al-Li material while generating a sufficient amount of damage tolerance against corrosion pitting.

Two studies were completed in parallel. First, residual stress effects from peening at different intensities and at different angles relative to the forging direction were quantitatively measured via X-ray diffraction (XRD) on test blocks machined from an extruded Al-Li forging. The longitudinal-longitudinal transverse (L-LT), longitudinal transverse-short transverse (LT-ST), longitudinal-short transverse (L-ST), and 45 degree-short transverse (45°-ST) surfaces were peened at 11N, 15N, or 20N intensities. Stress versus depth profiles for each were plotted to compare the residual stress effects of different peening intensities in a given orientation, and the effects a given intensity imparts in different orientations.

The second portion of the design project involved machining axial fatigue test specimens with standard specimen geometry from an extruded Al-Li alloy forging and peening them at 11N, 15N, and 20N intensities. Fatigue testing was then completed to generate an S-N curve out to 3.0E+07 cycles. All testing was performed with an R-ratio of -1, indicating fully reversed loading during each load cycle, and at a temperature simulating the expected engine operating temperature. Test data showed a minor benefit in HCF capability associated with the 11N peening intensity versus baseline (no peen). Post-mortem analyses of failed specimens, such as fractography, metallography, and orientation image mapping (OIM), were completed to characterize fracture morphologies and microstructural effects relative to peening intensity.







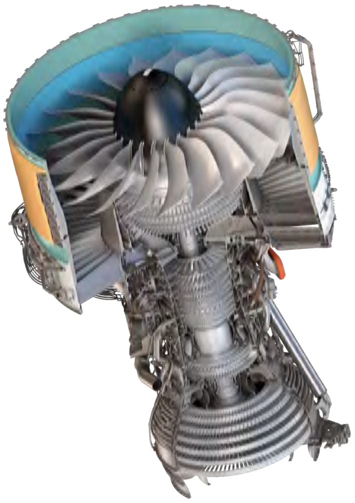
Team 5: Impact of Alloy Overageing on Mechanical Properties

Sponsored by: Pratt & Whitney
Sponsor Advisor: Dr. Max A. Kaplan

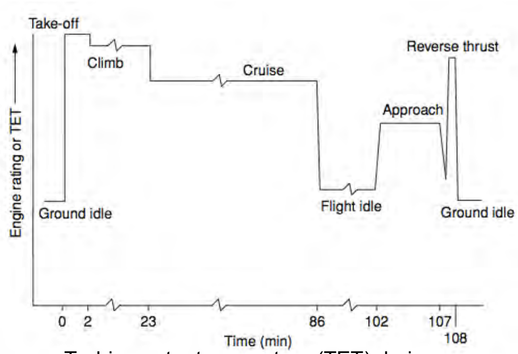
Group members James Lee and Riordan Hoffman

Project Description: Pratt & Whitney produces aerospace materials that are used in gas turbine engine applications. The material considered in this study is ME16, a powder metallurgy Nickel-based superalloy that is commonly used to produce critical rotating components, specifically turbine disks. Because of the nature of turbines, the disks are exposed to high stresses, high temperatures and aggressive environments. In rare instances the Ni-based superalloy can be exposed to temperatures that unintentionally exceed the designated operating temperatures, known as "overtemp" events. These events can occur as either short transient excursions to metal temperatures that are above the material's intended design space or as long continuous rises in metal temperatures that are narrowly greater than predicted. Pratt & Whitney asks for deeper investigation as to how overtemp events affect the properties of this Ni-based superalloy.

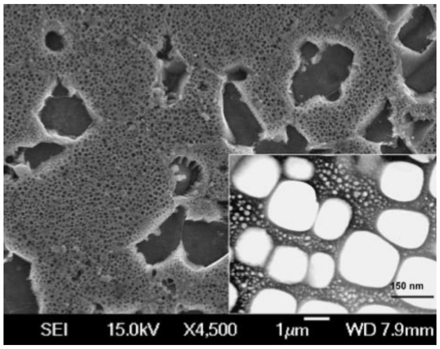
The study will analyze how different overtemp events affect the mechanical properties and microstructure of a Nickel-based superalloy specimen. The overtemp events are recreated by using heat treatment ovens in the temperature range of 1400-2000° F and a duration from 1 to 100 hours. A mathematical model of precipitation hardening, via Matlab, is used to predict the critical precipitate size for the maximum strength. The model outputs the trending curve of the property deterioration due to the effects of the exposures to extreme environments and the microstructural changes that follows it. The change in specimen microstructure due to overtemp events is found using Scanning Electron Microscope (SEM) imaging to measure the volume fraction of secondary phase particles, known as γ'. The change in specimen hardness due to overtemp events is found using Rockwell C Hardness testing. Our intention is to find a correlation between specimen hardness value, volume fraction of γ' and overtemp conditions.



Illustrated Diagram of Pratt & Whitney GP7200



Turbine entry temperature (TET) during a typical flight cycle of a civil aircraft, The Superalloys Fundamentals and Applications, pg. 5, Reed, 2006



SEM image of Ni-based Superalloy, pg 2656, J. Mater. Res., Vol. 18, No. 11, Nov 2003, Wusatowska-Sarnek, Ghosh and Olson, Blackburn and Aindow

Team 6: Temperature and Time Limitations on PTFE Material

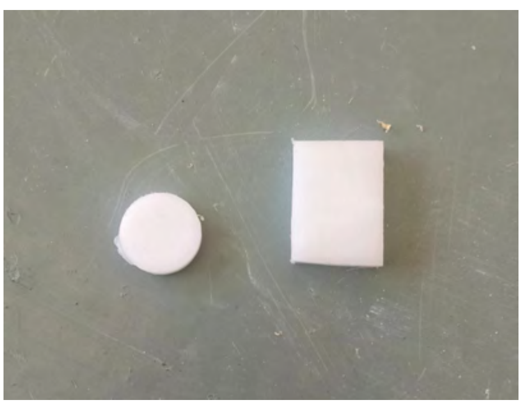
Sponsored by: Pratt & Whitney

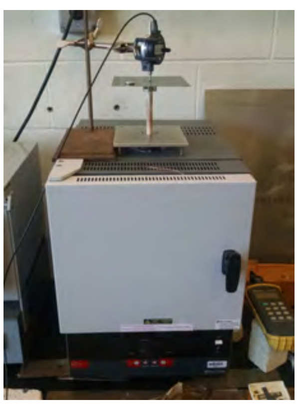
Luke McCarthy (left); Samuel Wentworth (right)

The purpose of this project is to investigate the compressive creep behavior of polytetrafluoroethylene (PTFE) when it is heated to high temperatures, ultimately determining an equation which accurately models PTFE creep as a function of temperature, time, and mechanical stress. This will be accomplished through analysis of deformation when the material is held at specific loads and temperatures over extended periods of time. (As there are two potential suppliers of PTFE for practical application, materials from both suppliers will be investigated and compared.) By modeling PTFE creep behavior, it will be possible to select the more desirable of the two materials and more accurately predict the useful lifespan of PTFE components.

Testing will be performed over two primary stages. The first stage of testing will be a preliminary test using simple weights and ovens. The deformation of several PTFE samples will be observed over the course of several hours, determining what combinations of temperatures and stresses will cause the material to deform significantly. Based on initial results, the second stage of testing will focus on closely measuring PTFE deformation over a range of temperatures and stresses deemed during preliminary testing to be most significant. These tests will be performed using thermomechanical analysis (TMA) apparatus, which measure deformation, temperature, and applied stress with high precision. X-ray diffraction will also be performed, before and after testing, to determine whether crystallinity is affected by deformation under the conditions in question.

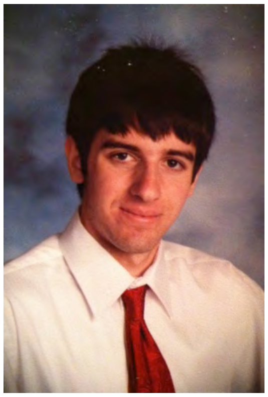
Data obtained through TMA testing will be used to extrapolate an equation governing the creep behavior of each material as a function of applied stress, heating temperature, and duration of stress and heat application. These equations should make it possible to predict creep behavior under conditions beyond those applied during testing.





Team 7: Oxidation Effects on Nickel Base Superalloys at Intermediate Temperatures

Sponsored by: Pratt & Whitney
Sponsor Advisor: Dr. Mario Bochiechio



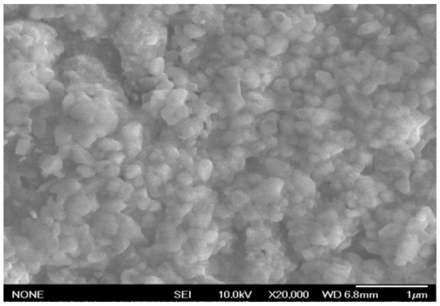
Benjamin Bedard, primary student investigator.

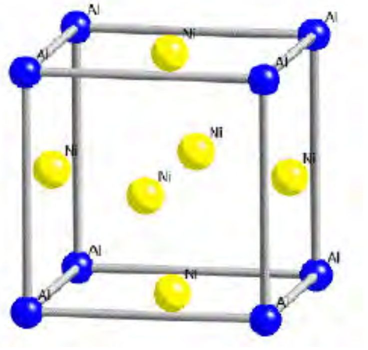
Pratt & Whitney
A United Technologies Company

Nickel-based superalloys are a category of high-temperature structural materials whose development has revolutionized the world of aerospace and power generation. These alloys exhibit strength, creep resistance and oxidation resistances that are far superior to those of traditional ferrous structural alloys. These properties have been achieved as a result of extensive metallurgical engineering. Modern nickel base superalloys contain a complex mixture of alloying elements such as aluminum, titanium, cobalt and chromium. The resulting microstructures are carefully controlled through thermal mechanical processing routes. The major strengthening phase in Ni-based superalloy is an intermetallic compound with the chemical formula Ni_3Al, which is more commonly referred to as the γ' phase. The γ' phase is coherent with the surrounding nickel matrix, resulting in a strong, tough microstructure that efficiently bears the loads applied to the material.

The exceptional strength, creep resistance and oxidation resistance of these alloys at temperatures above 800˚C has led to them being a key enabling technology in modern gas turbine engines; such engines are the centerpieces of contemporary commercial aircraft and power-plants. There is significant interest in leveraging the extensive investments that have been made in superalloy development by extending the range of applications and environments in which these materials are applied. With that goal in mind, the aim of this project is to explore the intermediate temperature oxidation behavior of two types of nickel-based superalloys: a single crystal alloy and a powder metallurgy alloy.

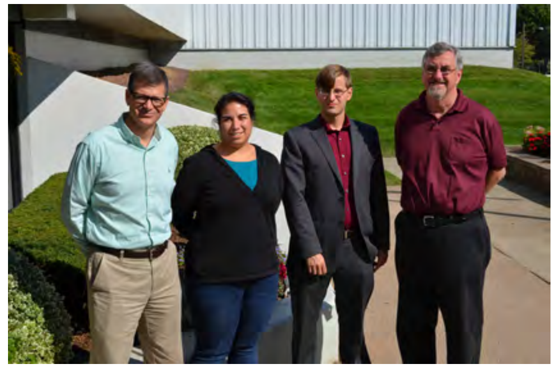
The main objective of this study is the quantification of the oxidation properties for these two alloys between 760˚C and 872˚C. The characteristics of interest include: sample weight gain; oxide scale thickness, morphology and composition; and the character and thickness of any depletion zone in the alloy at the interface. This will be accomplished through the use of a series of isothermal oxidation heat treatments for various times at temperatures within the range of interest. The alloy samples will be held at the desired temperatures for times of 2 - 168 hours to capture both the initial transient rapid growth and the longer-term steady-state growth of the oxide scale. Once the oxidation treatments have been completed, the resulting oxide will be analyzed using a combination of scanning electron microscopy and x-ray diffractometry.





Team 8: Local Heat Treatment

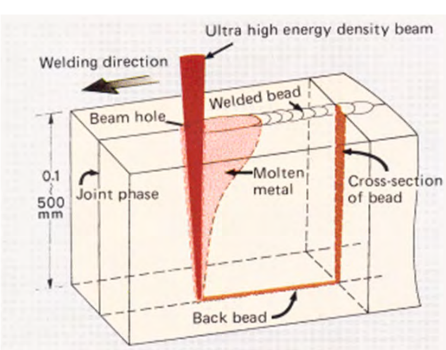
Sponsored by: PTR Precision Technologies
Sponsor Advisor: Dr. Amber Black, John Rugh

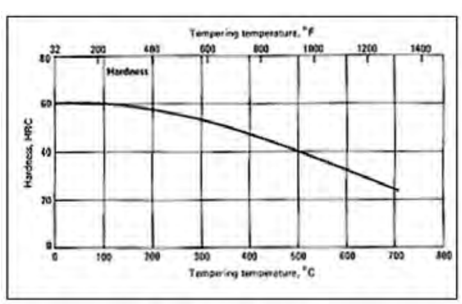


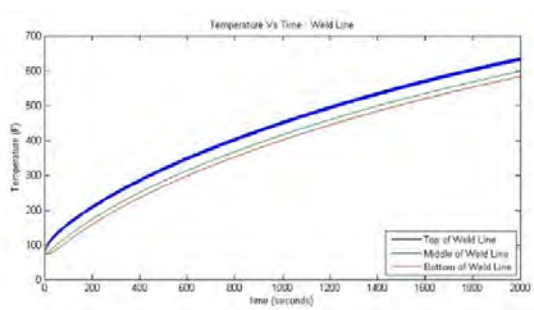
John Rugh, Amber Black, James Kos, Gary Laflamme.

PTR Precision Technologies is investigating the effectiveness of a localized heat treatment performed with an electron beam. This is a solution intended for the problem posed by parts with a low weld volume compared to the overall volume of the part. A traditional heat treatment of such parts would apply the heat treatment to an unnecessary volume of material. A localized heat treatment performed by a dispersed electron beam would be a cheaper and more efficient alternative to a furnace heat treatment. PTR Precision Technologies aims to develop a heat treatment to achieve an effective and efficient heat treatment process with the rapid electron beam reflection technology utilized by PTR. This heat treatment must effectively relieve the internal stress as well as homogenize the precipitated phases that can result from the self-quenching process of high mass parts. To achieve this, the dispersed electron beam will be run in repeated scans along the weld line to hold the weld line and heat affected zone (HAZ) at the temperature required for the time designated by the standard heat treatment for the material.

To test the effectiveness of the heat treatment, a computation model was developed using ANSYS as well as a MATLAB program utilizing finite deferential method. These goal of these models is to calculate the temperature distribution of a weld line as a function of time, grid power, scan speed and periodicity, and the material properties. The accuracy of this model will be tested by applying the same heat treatment to a sample of SAE 4140 steel, with the variables tested in the model. The test piece has a 1” x 1” dispersed electron grid scanned repeatedly along a weld line previously performed. To simulate the self-quench of larger parts, the edges of the test piece are held against copper chills. To test the effectiveness of the heat treatment, the test piece is sectioned, and hardness values of the weld bead and HAZ are taken at various depths. This is compared against a test group that has been furnace heat treated. The effectiveness of the local heat treatment will be determine by the heat treatments ability to lower the hardness of the weld bead and HAZ to match the furnace heat treatment.







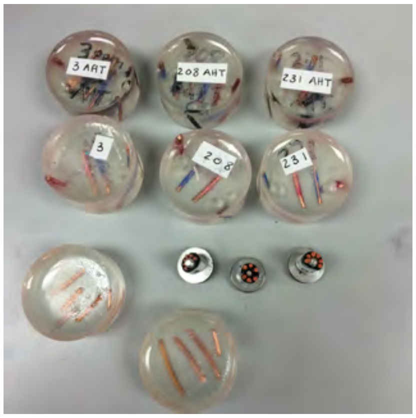
Team 9: Hydrogen Embrittlement in High Purity Copper Conductors

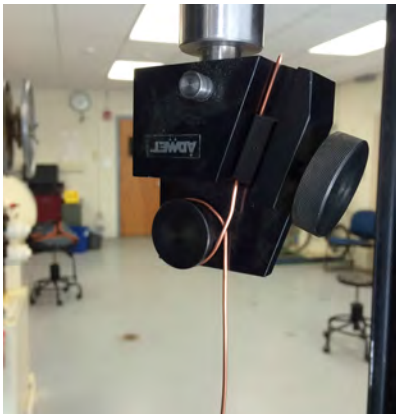
Sponsored by: Rockbestos-Suprenant Cable Company
Sponsor Advisor: Ivan Stannard, Daniel Masakowski

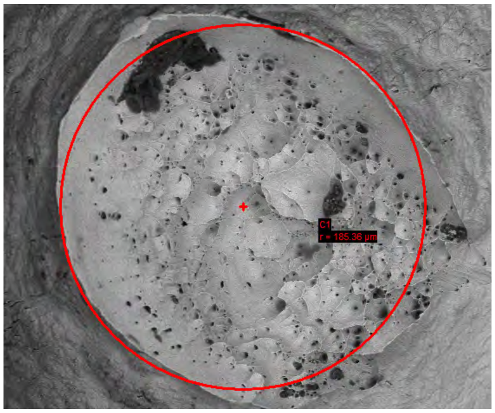
Wieslaw Kapalczynski (left) Samantha Brantley (right)

R-SCC is investigating the effects of hydrogen embrittlement on two high purity copper conductor grades that vary in oxygen concentration. In order for a cable to be certified for fire safety it needs to establish circuit integrity in a fire scenario. At elevated temperatures starting at 400°C, hydrogen diffuses through the surface of the cable and reacts with pre-existing oxygen to form cuprous oxides at the grain boundaries. The fire responsive conductors experience a ductile to brittle transition as intercrystalline cracks lead to vertical strength failure. A comparative analysis of Electrolytic Tough Pitch (ETP) and Oxygen Free High Thermal (OFHC) conductors that vary in copper purity will be conducted to determine which will subdue hydrogen embrittlement and thus prolong failure time. The experimental design requires a hydrogen gas environment during heat treatment to simulate fire development – this can be dangerous as hydrogen flames are nearly invisible and explosive in nature. An effective testing environment is required to obtain accurate experimental and numerical data exhibiting the brittle transition.

Mechanical tests were performed using tensile testing techniques on one OFHC and two ETP conductors that consist of 3, 208, and 231 PPM oxygen. Admet Wire grips ensured that the cylindrical samples were properly elongated until fracture. These tests were conducted for samples as received and after heat treatment, where they were exposed to two varying hydrogen atmospheres. The conductors prior to heat treatment were predicted to have a higher percent elongation than samples after heat treatment, as they demonstrate ductile properties as received. A representative grain boundary and fracture surface for each conductor type was imaged via Visual Light and Scanning Electron Microscopy to see how oxygen, intergranular cracks, and cuprous oxide affect sample exposed to hydrogen. Results show that both conductor types experience an increase in cuprous oxides, but more so in ETP than OFHC. It is understood that the lower concentration of oxygen that OFHC conductors provide allow for favorable mechanical properties that subdue embrittlement and prolong failure time.







Team 10: Tooling and Processing Optimization for Complex Geometry, Nonferrous Castings

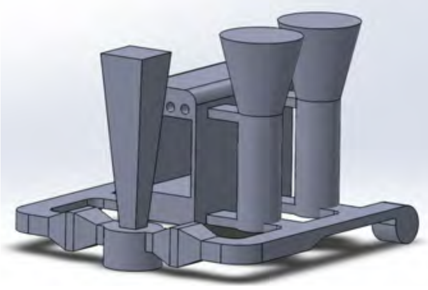
Sponsored by: Sikorsky Aircraft Corporation
Sponsor Advisor: Paul Inguanti, Dr. William Fallon

Group Photo: Kevin La and Lauren Salisbury.

Sikorsky
A United Technologies Company

When casting complex geometries, the formation of defects during the pouring of metal and during the solidification process is very common. Currently Sikorsky Aircraft Corporation is having a low yield of their complex castings due to various defects being found in each of the castings. Casting defects affect the appearance and structural soundness of the product. The castings being produced are not of acceptable quality and cannot be applied to the final product. Many components require post pour weld repair or are scrapped due to extensive defect concentrations. These issues result in a long qualification period and long delivery times for good castings. Sikorsky would like to evaluate a casting simulation program, called ProCAST, and its effectiveness at determining expected defects in the casting ahead of time. The goal is to determine whether or not ProCAST will accurately predict the defects of interest which are microporosity and oxide skins. By using a simulation to study fluid flow and cooling methods in the casting, Sikorsky hopes to increase efficiency in the casting process in terms of material and time use.

To determine ProCAST's abilities, an experimental procedure was created so that both ProCAST simulations and actual castings were run concurrently. Since this was a continuation project, the first step was to redesign last year's model in order to promote the previously mentioned defects. Once that was done, the design was sent to the Institute of Materials Science Machine Shop to be made into a pattern board for real castings. The pattern boards provide a model for sand molds to be created with and then cast into. With the castings poured, analyses of defects commence using non-destructive and destructive testing methods. A Scanning Electron Microscope (SEM) is capable of evaluating both porosity volumes and oxide concentrations. While the castings are being made and analyzed, ProCAST is also running casting simulations of the same design. Defects are evaluated using ProCAST's analyzers and the results are compared against the metallurgical lab results of the real castings. The last stage of the project is to repeat the procedure with a modified design that is optimized by iterative modeling to reduce or eliminate casting defects. The success of this project is based on ProCAST's ability to accurately predict defects in the original model and effectively aid modifications made for the new model.



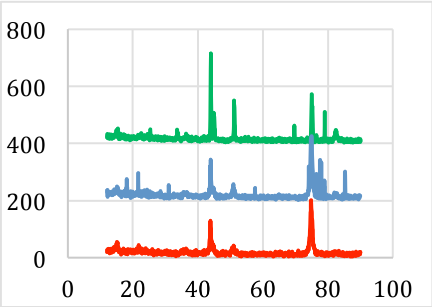
Team 11: Design of Stress-relief Heat Treatments of Austenitic Stainless Steels

Sponsored by: Ulbrich Stainless Steels & Special Metals Inc.
Sponsor Advisor: Sean Ketchum

Jennifer Heiser (left) and Allie Clark (right)

The purpose of this capstone project is to design a method of heat-treatment depending on how time and temperature affect the performance of temper rolled austenitic stainless steel. Ulbrich Stainless Steel and Special Metals treats their grade 302 austenitic stainless steel for customers that favor its properties for their specific applications. The steel is treated via a very time consuming method of heat-treatment, where it is passed through a continuous annealing furnace. This stress-relief heat-treatment alters the mechanical properties of the metal in order to improve the condition of the material for the specific applications the customers need it for. The relief of internal stresses improves the bending performance of the material. This is a benefit when using the material to create complicated part geometries. Saving time for production will speed up the heat-treatment process and therefore increase productivity in the Ulbrich mill. Increasing the efficiency of the heat-treating process can be accomplished by determining the optimal temperature and minimum time at which the steel can be heated while obtaining comparable mechanical properties gained by the steel through Ulbrich's current heat-treatment method.

The first objective of this project is to determine the processing parameters that satisfy the customer's needs in a more energy and time efficient manner. The second objective is to design a quality control technique in order to verify that the desired material condition is achieved. The third objective is to determine the properties and microstructure of heat-treated steal that makes it more workable. The steel that has been treated by Ulbrich's heat treatment method is being tested for stress-relief using X-ray Diffractometry (XRD). The material is being tested via XRD both before and after heat-treatment in order to identify changes to the spectra. A faster heat-treatment method is being designed by determining the maximum temperature of the furnace and minimum time the stainless steel will be heat-treated in order to achieve the optimal change in mechanical properties. A plethora of data is being gathered via mechanical testing, visual light microscopy (VLM), and XRD before and after heat-treatment at a range of temperatures under one minute to uncover a quicker (and therefore, more efficient) stress-relief method as well as enhance Ulbrich employees' knowledge and understanding of this material and its behavior.



Tensile	185,000 psi min
Yield	*180,000 psi min*
Elongation	*2% min (critical)*
Hardness	*40 HRC min*
Thickness	*0.00400in*

Team 12: Impact Testing of Circuit Breaker Enclosures to Simulate Short Circuit Conditions

Sponsored by: GE Energy Management

Sponsor Advisor: Dr. Haritha Namduri

Nicholas DeMello and Douglas Hendrix

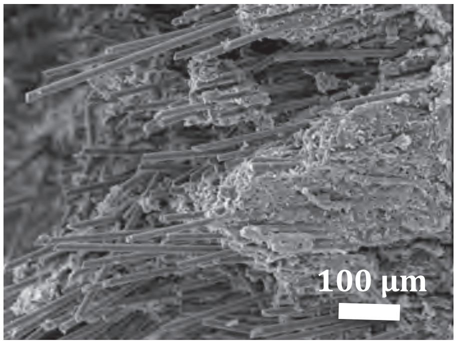
GE Energy

GE Energy produces many types of residential and commercial circuit breakers in very high volumes. Circuit breakers protect an electrical circuit from damage by interrupting the current flow when a fault condition is detected. One such fault condition is a short circuit. When a short circuit occurs, by design, arcing occurs within the circuit breaker plastic enclosure. This arcing produces temperatures up to 5000 K in a very short amount of time. As a result of outgassing, there is a significant pressure wave that is built up. It is very important that the plastic enclosure can contain the effects of this explosion-like arcing. Currently, all enclosure designs must undergo short circuit testing. This is an expensive test and requires many safety measures.

This project aims to develop a test that will act as a filter for the short circuit testing. This test will simulate the expansion of gas seen in a short circuit event. The goal is to reach 200 psi in 5-7 ms within the enclosure. This new test method is very important to the design process of circuit breakers. It will increase efficiency since the new method will not use high currents, reducing energy consumption. It will also increase the speed of redesigning enclosures, as this test will be quick to implement. This new test will also be safer than short circuit testing because there will be no combustion or current. However, it is important that materials failure is similar in both short circuit testing and the new test method.

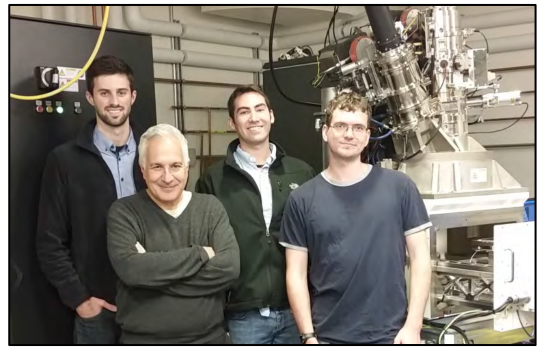
A main goal of this project is to develop a test method that has the ability to be used over a range of pressures and volumes. Since GE produces many circuit breakers of all shapes and sizes, it is important that this test method can be used on a wide range of enclosures. The test that is currently being designed is for use on smaller residential circuit breakers.

Our current test method will use nitrogen as the source gas. The gas will be pressurized to about double the desired pressure in a plenum. An electronic solenoid valve will release the gas very quickly into the enclosure. To ensure the correct pressure and time within the enclosure, pressure sensors will be used. National Instruments modules and LabView will be used to control the valve and acquire data from the pressure sensors.



Team 13: Zeiss MultiSEM Sample Mount

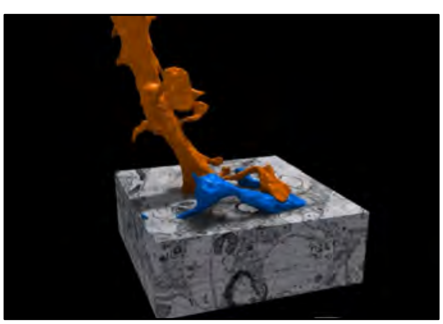
Sponsored by: Zeiss
Sponsor Advisor: Pascal Anger, Kyle Crosby

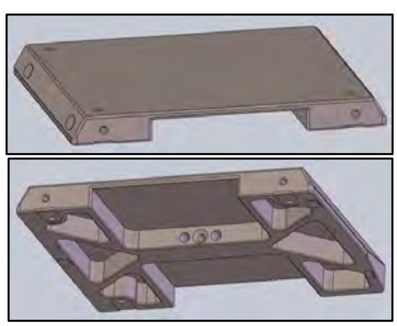


Senior design group standing in front of the MultiSEM microscope at Harvard. From left to right: Stephen Ecsedy, Jeff Lichtman, Kyle Keeley, and Eric Bousfield

Carl Zeiss has built a multi beam scanning electron microscope (MultiSEM) to be used by a research team, led by Dr. Jeff Lichtman, at Harvard University. The team is using the 61 beam MultiSEM to image small sectional slices of a mouse brain, which are then layered upon each other to create a three dimensional map of neurons and their synapses. This process involves taking thousands of SEM images and subsequently processing them, therefore a major obstacle the team faces is the time required to image the brain slice samples. The advantage of the MultiSEM is that it uses 61 electron beams to image the sample, instead of just one beam which would be found in a conventional SEM, which allows for a much larger area to be captured in each image, greatly reducing the time required to build the three dimensional map of the mouse brain. The Harvard research team processes the samples by adhering them to 4 in diameter silicon wafers, which are then imaged using a visible light microscope (VLM), followed by the high-magnification high-resolution (4nm) image capture using the MultiSEM. The current system and mount used by the research team allow for relatively fast image capture; however the process flow and mounting system still need to be optimized. The goal of the senior design group is to design a new sample mount for the MultiSEM that can be used in both the VLM and the MultiSEM to increase the accuracy and the reproducibility of the images taken.

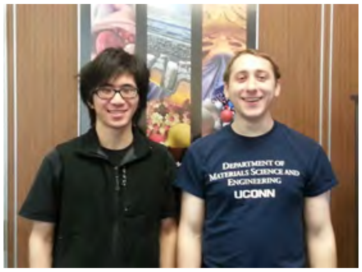
Initial work on the project consisted of materials research to determine the optimal material to be used for the sample mount. The current mounts use nickel plated aluminum, as aluminum is cheap and conductive but will produce a water absorbent oxide when exposed to atmospheric air, and a nickel coating will stop this oxide growth. This material choice works well and is one of the most cost effective options. A new sample mount will be designed and prototyped using SolidWorks. This design will incorporate an adapter mount and permanent mount per wafer, both using a dovetail mounting system. This will allow for each wafer sample to have a designated mount, increasing the reproducibility of the images taken. Additional alternatives were investigated, including using pre-machined aluminum plates for use as the permanent wafer mounts.





Team 14: DMLS In718 Heat Treatment

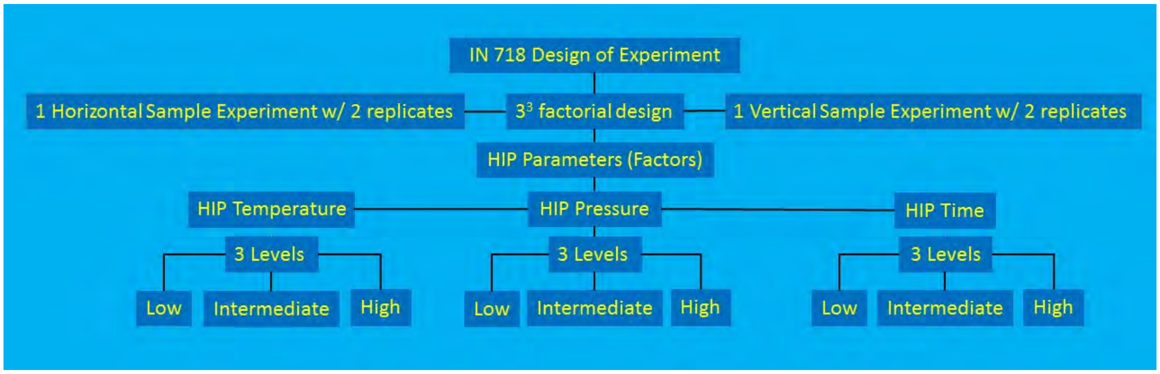
Sponsored by: UTAS
Sponsor Advisor: Sergey Mironets

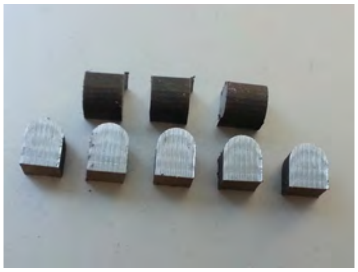

Timothy Siu, Jordan Parley

Inconel alloy 718 is widely used in manufacturing for high temperature applications due to is super-alloy properties and corrosion resistance. UTAS desires to improve upon the current fatigue life of its current In 718 check valves through refining the HIP'ing parameters used for heat treating the alloy.

It is a well-known fact that the HIP operation heals isolated voids and internal porosity of additively manufactured components. On the other hand, elevated HIP temperatures lead to excessive grain growth that has adverse effects on fatigue properties. The goal of this project is to improve the mechanical properties of a common alloy used by UTAS, Inconel 718, by using different HIP'ing parameter combinations. This will yield an understanding of HIP'ing variable interactions and heat treatment on the microstructure and mechanical properties of In718.

The chosen design of experiment will be a 3^3 full factorial experiment. This experiment will be done once for In 718 samples grown in the vertical direction. Another separate experiment with identical process will be done for horizontally grown samples. The three factors under study will be the HIP'ing parameters: Pressure, Temperature, and Soak Time. Each of these factors will be tested at three levels; low, intermediate, and high level. The experiment will be performed with two replicates of each combination. Results are expected to show an increase in grain size as temperature rises and a decrease in grain size as pressure rises. The optimal parameters for HIP'ing In718 are expected to be at a lower temperature and higher pressure.





Team 15: Evaluation of Electric Discharge Machining (EDM) of Aerospace Alloys

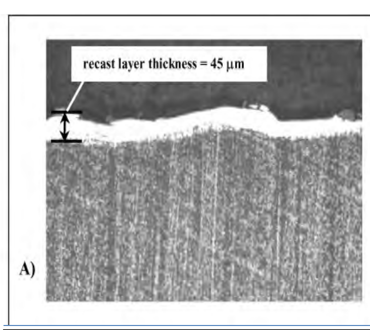
Sponsored by: UTC Aerospace Systems
Sponsor Advisor: Stephen Pasakarnis

From left to right: David Twohill, Eric Anderson

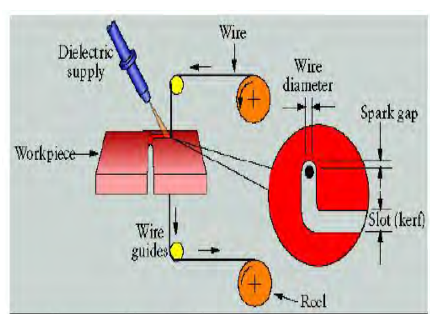
Electric Discharge Machining (EDM) is a precision manufacturing technique, commonly used to fabricate aerospace alloys. Highly concentrated electrical discharges (sparks) are used to create erosion at the surface of a material. EDM is capable of producing parts with complex geometries, which would otherwise be impossible by means of conventional machining. United Technologies Aerospace Systems (UTAS) is one of the world's largest suppliers of advanced aerospace products and regularly uses EDM to manufacture their aerospace alloys. The high temperatures present during the erosion process, lead to rapid re-solidification at the material's surface. As a result, formation of an undesirable Heat-Affected Zone (HAZ) and recast layer becomes present. Micro cracks within the recast layer lead to strength reductions for a given material. UTAS currently bases their strength reductions on 30 year old EDM technology. This study will evaluate the performance of two different aerospace alloys (Al 6061-T6, IN-718) which are machined via EDM. Each alloy will be subjected to an aggressive, and moderate, EDM cutting rate. The goal is to provide UTAS with an up-to-date understanding between the initial EDM parameters and the resulting material's performance. This proposal will enable Materials Science & Engineering to reset design allowable levels for both fatigue and static properties.

Experimentation will consist of mechanical testing and the characterization of EDM cut tensile and fatigue specimens. Fatigue testing will be performed off-site by the part manufacturer, while tensile testing will be performed on campus. Data collected from tensile testing will include various mechanical properties, including ultimate tensile strength, yield strength, percent elongation and percent reduction in area. Light microscopy will be used in order to determine the effects of current EDM technology on the cut surface. This includes measuring the thickness of HAZ and recast layers, as well as identifying the presence of microcracks on the cut surface. In addition, the fracture surfaces of failed specimens will be imaged in order to determine the fracture mechanics present in the different sample and parameter types. Scanning Electron Microscopy (SEM) will be used in order to determine the composition and phases present in the HAZ.

(1) EDM Machined Parts



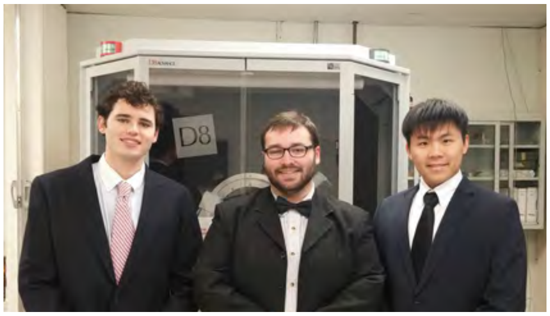
(2) AISI P20 Steel Recast Layer, HAZ



(3) Wire EDM Diagram

Team 16: Mechanical Properties of Al6061 with Al4043 Welds

Sponsored by: UTC Aerospace Systems
Sponsor Advisor: Callie Benson



Benjamin Bilancieri, Nicholas Poulos, and Terry Ng

UTC Aerospace Systems is developing new technology for its projects all over the world. Aerospace technology requires materials that are light, strong, and widely applicable. Alloys of aluminum, in combination with cold working or heat treating, is a widely used material because it fits these properties of low density and high strength. This project specifically investigated the properties of Al6061, an alloy of aluminum with magnesium, silicon, and copper in small amounts, and Al4043, a weld filler of aluminum and silicon.

Gas Tungsten Arc welding (GTAW) is a form of fusion welding that results in favorable post-weld qualities for aluminum. Fusion welding allows for limited heat-affected zone (HAZ) formation and greater weld consistency due to the high arc temperature.

The purpose of this project was to investigate aluminum and GTAW properties for variable quality, namely sample thickness, sample length, and weld geometry. These three variables were to be analyzed by characterization. Visual microscopy, hardness testing, and tensile testing were to be completed by a factorial design of the variables in a two level test: Thick and thin for the width, short and long for the length, and a butt weld versus a v-groove weld.

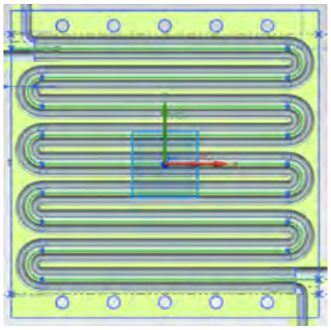
Team 17: UTAS Additive Manufacturing of a Cold Plate

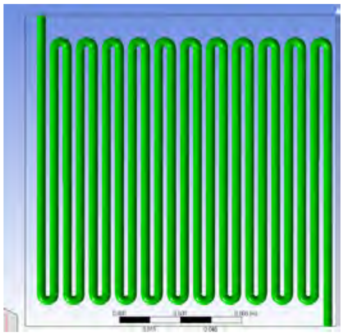
Sponsored by: UTC Aerospace Systems
Sponsor Advisor: Colette Fennessy

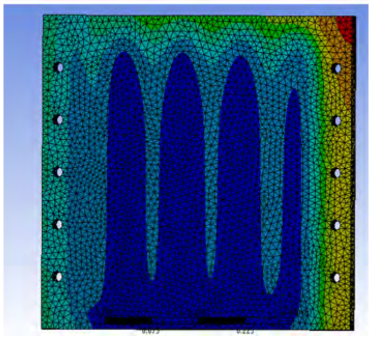
Gabrielle Charno and Spencer Lambrecht

Cold plate heat exchangers are commonly used in aerospace applications to cool high energy density electronics. There is a significant potential to reduce the overall foot print of these heat exchangers by innovative designs incorporating straight and curved cooling circuits. However, current conventional manufacturing method of brazing and welding of multiple plates and heat exchanger fins are not suitable for fine three dimensional channels and cooling designs. By virtue of layer by layer building of a part, 3D printing or additive manufacturing eliminates the need for joining operations and can accommodate complex internal geometry.

As a continuation of the 2014 senior design project, the team was tasked with designing and fabricating a cold plate heat exchanger using additive manufacturing to maximize the heat rejection from an electrical box. Based off the previous results, preliminary research was conducted to understand the fabrication limits of various additive technologies such as laser sintering, electron beam melting, and ultrasonic additive while comparing as-built chemistry and microstructure to the bulk material. The heat map and test rig from the 2014 project were provided as well as the physical loading and fluid flow requirements. In order to optimize fluid flow in the passageways, small scale testing coupons were designed and manufactured, using direct metal laser sintering, DMLS, to determine construction and loading limits as well as material properties and thermal analysis. A full scale cold plate was constructed based on the preliminary findings of the coupons and adjustments to structural geometry design and thermal properties were implemented.







Team 18: Bimodal HDPE Resin Grades for Bottle Weight Reduction and Equivalency

Alexandra Merkouriou

Sponsored by: Unilever
Sponsor Advisor: Warren Kleeman and Julie Zaniewski

With over 400 different brands in 190 different countries, Unilever is a global company whose products are used by over two billion people every day. Such widespread impact drives a need for sustainability and environmental awareness which Unilever has outlined in the Sustainable Living Plan. The goal of this initiative is to reduce environmental imprint while doubling the size of the business and continuing to inspire positive social impact. One way to reduce the overall impact on the environment is to reduce the amount of material needed to make the bottles many Unilever products are packaged in. Specifically, reducing the amount of material used by 10% is an efficient way to work towards the overall goal of reducing the environmental footprint by one third.

Currently, Unilever has an extensive resin portfolio. However, in order to increase the economic value by way of harmonization throughout brands, it is necessary to use the same kind of resins for each brand in all regions. High density polyethylene (HDPE) resin is one such material that often comes in many forms. Typically, Europe uses bimodal HDPE while North America historically uses unimodal HDPE. The main difference between the two is that bimodal HDPE undergoes a two reactor process in polymerization while unimodal HDPE undergoes a single reactor process. The two reactor process is said to increase the strength to weight ratio of the resin, thus allowing for lighter weight bottles and improved environmental stress crack resistance.

This project focuses specifically on the interchangeability of common unimodal and bimodal resins by confirming the bottle strengths and functional features of each. To determine the equivalency of the resins, extrusion blow molding will be used to create bottles at three different weights for each resin being tested. During the blow molding process, all parameters are diligently recorded for an assessment of how the resins respond to changes during manufacturing. The finished bottles will then undergo a number of functional mechanical tests, including impact and compression tests, to determine the overall performance consistency among each of the three gram weights.

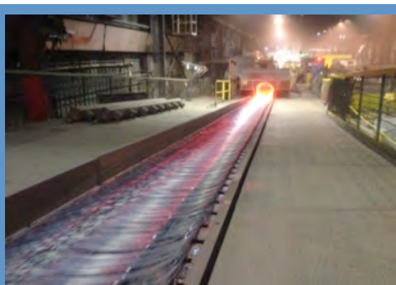
Team 19: Improving Tensile Strength Consistency Around High Carbon Steel Rings

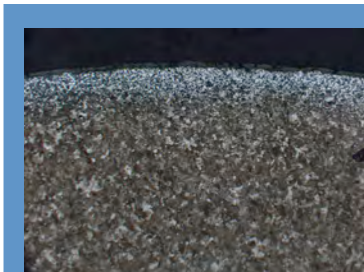
Sponsored by: Nucor Steel Connecticut
Sponsor Advisor: Charlie Hyatt

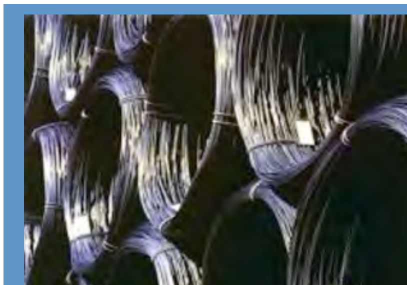
Team 19 Photo: Brenden Mil-Homens (right) and Joseph Pacheco (left)

Project Description:
Nucor Steel Connecticut (NCST) is branching out into the High Carbon Steel Industry to increase their product diversity and profitability. HCQ Rod offers higher selling prices which in turn gives them a better product margin and increases their overall profitability. NCST uses a Stelmor cooling deck, which takes rings of plain carbon and alloy wire-rod steel at temperatures between 1550 and 1750°F, and lays them in an overlapping pattern. This allows them to cool off at a controlled rate. The cooling rate, which is the key for controlling the tensile strength around the rings of steel, is controlled by three parameters. First, the deck has five cooling fans underneath, which blow air over the rings as they are pulled up the length of the deck. The cooling rate increases with more air usage. Next, the variable deck speed allows for control over the ring spacing. Faster deck speeds lead to greater ring spacing, yielding faster cooling and higher tensile strengths. Lastly, the laying head temperature, or the temperature at which the steel rings exit the rolling part of the process, can be controlled. Hotter laying head temperatures allow for a faster cooling rate, leading to higher tensile strengths.

Currently, the tensile strength around the high carbon steel rings is somewhat variable, which is due to the inconsistent cooling between the top and bottom of the rings relative to the overlapped side portions of the ring. We must improve tensile consistency to ensure customer satisfaction. This consistency will be measured by performing tensile tests at various points around the ring and finding the standard deviation. Cooling profiles along the Stelmor cooling deck will also be gathered during the cooling process. After finding the relationship between Stelmor parameters, temperature profiles, and tensile strength around the ring, we will search for ways to improve cooling control, with the ultimate goal of increasing tensile consistency to world class standards.

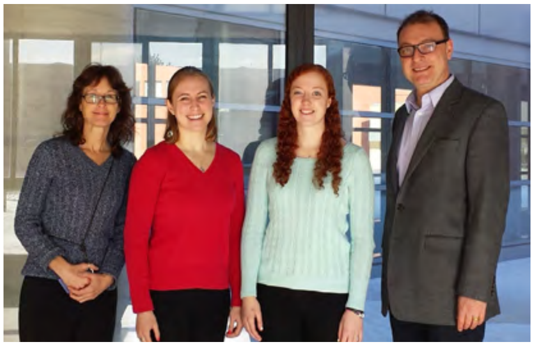






Team 20: Non-Destructive Test for Incoming Nylon Fabrics Prior to Metalizing

Sponsored by: Swift Textile Metalizing
Sponsor Advisor: Tony Luna



From right to left: Dr. Fiona Leek, Rheanna Ward, Kacie Wells, Dr. Pamir Alpay

Swift Textile Metalizing takes various types of nylon fabrics and metallizes them for military, medical, and commercial applications. The metalized fabrics are used in to provide protection for people and equipment from electromagnetic interference, radio frequency interference, and static discharge. Swift is in need of a non-destructive test to analyze their incoming fabrics. This test must be cost-effective, rapid and must be performed in house to grade contamination levels that could adversely affect the coating process.

Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM) were initially performed because the contaminants on the materials are unknown. The destructive tests concluded that processing contaminants were on the fibers from the weaving process. Background research on types of non-destructive tests has been done throughout the length of the project in order to find the best standardized test for the company.

One promising method is electrical conductivity testing. By measuring the volume resistivity of the fabric, a difference between clean and dirty fabric can be determined. After plasma treating samples to ensure cleanliness, electrical conductivity measurements of both cleaned and uncleaned fabrics were tested. To then determine the volume resistivity. Significant differences in resistivity were observed.

Success of this project will be determined by finding a standardized test the company will be able to use for the nylon fabrics of different weaves. It was recommended that existing standardized tests for contaminants be considered first in order to have rapid acceptance of the testing method. This will allow STM to hold their suppliers to a higher standard and produce better products.

Team 21: Improved Methods of Pretreating Polymer Fiber Prior to Metalizing

Sponsored by: Swift Textile Metalizing LLC
Sponsor Advisor: Antonio Luna

Team#21: Alexander Westlund (Left), Bartek Wojciechowski (Right)

Swift Textile Metalizing LLC (STM) is a manufacturing company based in Bloomfield, CT that specializes in the production and fabrication of metalized fabrics. These products are used in a variety of industries including aerospace, military, and medical fields. STM uses a proprietary metalizing process to coat nylon fibers with conductive metals. Through the use on an intermediate layer, applied by a specific pretreatment method, metalizing agents adhere to the fabrics. STM is investigating improved pretreatment methods to improve adhesion performance. The objective of this project is to explore an alternative pretreatment method in order to improve the adhesion between a silver film on a nylon fiber. The proposed method must be easily integrated into the existing metalizing process in a cost effective manner. In order to validate silver adhesion, an appropriate adhesion test will need to be determined.

STM's metalizing process cannot be changed, although, the pretreatment process may be modified to accommodate the alternative pretreatment. The alternative pretreatment must fall within the constraints of being commercially available, cost-effective, and adhere to environmental and safety regulations. Success will be measured by how well the silver will adhere to the nylon fabric after alternative pretreatment methods have been used. Samples will be tested to ensure the integrity of the metalized silver in aggressive environments. The major experimental task in this project is the testing of the adhesion of the silver to the nylon fabrics after alternative pretreatments have been applied. The current pretreatment method, and factors that affects adhesion will be primarily evaluated prior to testing alternative pretreatments. This includes the examination of a number of samples that have undergone metallization, samples that have not been coated, and samples that have shown signs of wear after being exposed to aggressive environments. Then, samples will be fabricated using determined alternative pretreatments and tested by an appropriate adhesion test method.