UCONN
SCHOOL OF ENGINEERING

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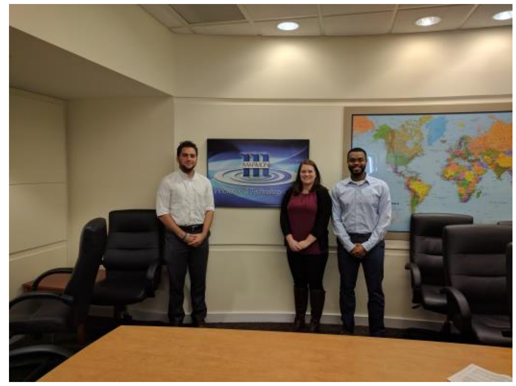
MATERIALS SCIENCE & ENGINEERING

Team #1: Characterization of Homogeneity in Polyethylene Cable Insulation

Sponsored by Marmon Innovation and Technology
Sponsor Advisor: Dr. Dan Masakowski

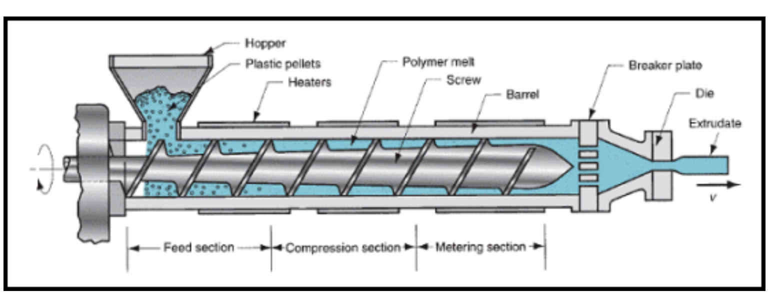


Owen Casey, Ashleigh Scahill, Josiah Morgan, and Tochukwu Njoku (not pictured)

Polyolefin-based cables are fabricated by Marmon Innovation and Technology. These cables are used in industrial applications, where they are exposed to harsh environments. The cables are made from a blend of high-density polyethylene (HDPE) and low-density polyethylene (LDPE). LDPE has long chain branches comprising ethyl and butyl groups at concentrations that negatively affect crystallization. HDPE has mainly linear chain branches, very few flaws, and a high degree of crystallinity. Blends of LDPE and HDPE are used in cable applications because of their balanced mechanical properties and ease of processing.

However, due to differences between the structures of LDPE and HDPE, separation of the HDPE/LDPE blend occurs almost immediately upon cable fabrication. In addition, due to thermal and radiation exposure, degradation of the polymer cable jacket occurs, and ultimately results in underperformance relative to industry standards. When used in the nuclear power plant industry, the standards require that the cable maintain a minimum of 250% elongation to be considered satisfactory.

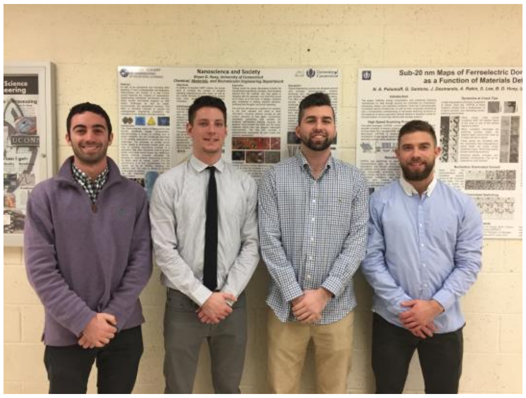
This project examines a model cable formulation, consisting only of an HDPE/LDPE blend and antioxidants, in order to identify relationships between the structure of the blend and the mechanisms of degradation. An experiment is designed to quantify the homogeneity of a series of samples prepared under controlled aging conditions. Characterization of the aged specimens by density measurements, x-ray diffraction and differential scanning calorimetry is used to establish a correlation between the blend structure and the onset of thermo-oxidative and thermomechanical degradation leading to brittleness and reduced time-to-failure during elongation. To observe and understand this degradation, various sets of samples were used. The sets were either aged for approximately 65 days or newly manufactured, then half of these samples were radiation crosslinked. The ultimate goal is to develop a concrete understanding of the degradation mechanism and a method to quantify homogeneity through various processing parameters.



Team #2: Alpha Case in Commercially Pure Titanium

Sponsored by: Ulbrich

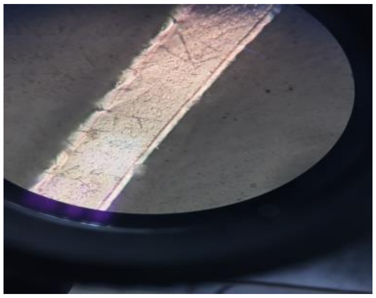
Sponsor Advisor: Sean Ketchum



Sam Guerra, Matt McKenna, Zach Florio, Andrew Boucher

Alpha case is a metastable phase of titanium that forms during the annealing of commercially pure titanium. It is an oxygen-enriched phase that causes embrittlement at the surface of the sample. This can cause premature failure during creation of a part, such as deep drawing, or later, when the part is in use and under mechanical pressure. Testing must be completed in order to learn the temperature range at which alpha case is achieved, as well as identifying alpha case growth at all on specific grades of commercially pure titanium. If alpha case can be proven to grow or not grow on certain grades of titanium, than preventative measures will not have to be taken in order to combat said growth.

Testing will be done by first heat treating different samples of commercially pure titanium, in order to identify the range at which alpha case grows. In addition, this will also yield results on if alpha case growth is even achievable on certain grades of titanium. Once heat treated, samples are mounted, polished, and etched in order to locate differences in grain structure, indicating the formation of alpha case. Different etchants are used in order to identify the best chemical reagent in identifying differences in grain structure at the surface. Results have thus far shown that alpha case is forming on grade 9, commercially pure titanium, while no growth has been identified on grades 1 and 2. This is hypothetically caused by the differences in phase presence between grades, as grade 9 is an alpha-beta alloy, whereas grades 1 and 2 are commercially pure titanium.



Team #3: Recrystallization During Continuous Annealing of 300 Series Stainless Steel

Sponsored by: Ulbrich Stainless Steels and Specialty Metals
Sponsor Advisor: Will Keenan + Sean Ketchum

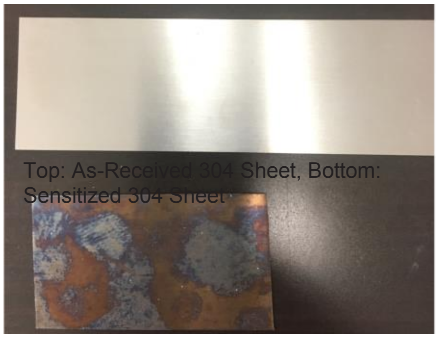
Group Members from Left to Right: Eric Jonsson, Josh Motley, and Matthew Kall

We Deliver Precision®

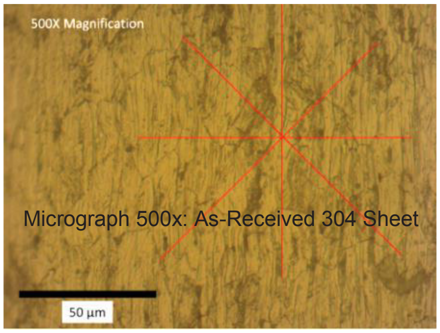
Ulbrich Stainless Steels and Specialty Metals are a precision re-roller and distributor of stainless steel strip, along with many other alloys. They maintain several annealing furnaces in order to heat-treat cold rolled metal sheets. Heat-treating metal alloys is a fundamental secondary processing technique that increases properties like ductility and toughness lost during the cold work process. This senior design project is centered on designing a test to verify that Ulbrich's continuous annealing furnaces function according to ISO standards. Austenitic stainless steels are often annealed to alter their properties for specific applications. Ulbrich has provided grade 304 stainless steel samples to establish a proper test method for the annealing process. Currently, a thermocouple is tacked onto the steel samples and the temperature vs. time curve is recorded as it travels through the furnace. However, this risks damage to the machine from the thermocouple wire. It would be much easier if a piece of steel with known properties were passed through the furnace. Final examination of the microstructure and fraction of recrystallized grains could be used to complete the test. This will save production time and provide further evidence to Ulbrich's customers that the furnaces are operating correctly.

This project will consider two methods. The first is that the sole criterion for determining the desired recrystallized grain structure is the peak temperature the samples reach. However, the other idea is that the amount of time the samples are held at a temperature below this peak temperature may also yield the proper grain size. The end goal is to determine which process gives comparable properties to the current heat treatment technique used at Ulbrich. If the difference in recrystallization is larger over the range of max temperatures than the range of times above the recrystallization temperature, temperature can be deemed the more important variable.

The most important tasks involved in this project are the annealing process and post heat treatment characterization techniques. Furnaces at UConn provide the necessary temperature range for the experiments. Visible light microscopy can image and measure the fraction of recrystallized grains in the steel. Hardness measurements pre and post heat treatment yield data that verify the annealing process.



Top: As-Received 304 Sheet, Bottom: Sensitized 304 Sheet



Micrograph 500x: As-Received 304 Sheet

Team #4: Surface Readiness for Adhesion

Sponsored by: Sikorsky, Lockheed Martin
Sponsor Advisor: Dr. Xiaomei Yu

Group Members (from left to right): Leopoldo Valencia, Alexander Berry, Andrew Jeffery, Zachary Thatcher

The need for a fast acting, reliable, easy to use, and low cost characterization method to determine surface readiness for adhesion is required. Adhesion is important in the aerospace industry for structural bonding and coating applications. These bonding failures can result in expensive costs if they happen during the manufacturing process, and a lack of customer satisfaction should they occur in the field. The current test being used by industry standards is the water break test, which tests for the cleanliness of the material surface, yet ignores several important factors and occasionally provides false readings because of factors that could affect the readiness level for adhesion. Aside from the water break test, the other existing method used to determine surface readiness is analyzing how well the instructions for surface preparation were followed. This has led to many surface failures, especially when samples with prepared surfaces are left on a shelf for an undetermined period before the adhesive coating or paint primer is applied. This problem is found commonly on anodized aluminum, composite, and Plexiglas substrates.

The goal of this project is to develop a characterization technique for the determination of the adhesive readiness of three broad types of materials: anodized aluminum, acrylic glass, and epoxy thermoset composites. Adhesion failures are costly and time consuming issues; current test methods for determining adhesion readiness can result in false positives. This project's methods must be quick, easy-to-use, low cost, and reliable. There are three primary parameters that must be quantified, surface topography (roughness), surface energy, and surface composition. Surface roughness will be quantified by taking R_a and R_z measurements in profilometry and AFM, surface energy will be calculated through goniometry, and surface composition will be measured using GC/MS and XRD. The overall objective is to determine a quantifiable pass/fail criterion for adhesion readiness for the three substrate types.

Sikorsky MH-60 SEAHAWK Helicopter

Sikorsky UH-60 Black Hawk Helicopter

Sikorsky Advanced Composite Cargo Aircraft (ACCA)

Team #5: Performance Testing of Tubing Encapsulated Cables

Sponsored by: Rockbestos Suprenant
Sponsor Advisor: Scott Magner, Jason Vilakis

From left to right: Ryan Chapman, Emily Shallo, Michael Martin, and Brendan McLarty

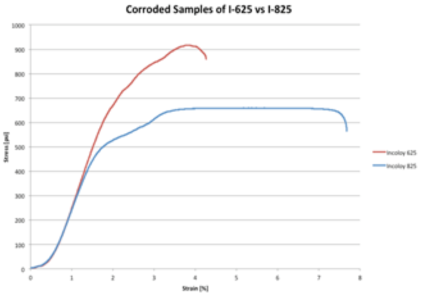
RSCC®
World Class Engineered Cable

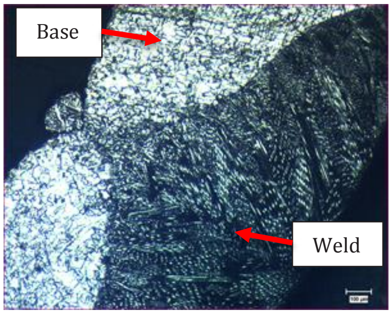
Downhole drilling is the practice of extracting materials locked deep below the Earth's crust. In most cases this is used to recover crude oil which is then refined into the petroleum products we use every day. The depths of oil wells can reach as far down as 40,000 feet below sea level where temperatures can be as high as 500˚F, pressures can reach 16,000 psi, and the harsh environment can contain highly corrosive chemicals like hydrogen sulfide (H_2S).

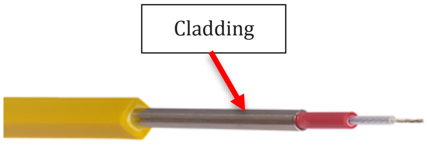
RSCC manufactures electrical wire products that can resist such forbidding oil well conditions and provide an electrical connection all the way down to the drill head. Such a feat is possible because of the protective metal cladding surrounding the electrical current carrying core. RSCC usually uses a cladding made of a nickel-based superalloy in the Incoloy family of alloys, chosen for its high corrosion resistance. But RSCC would like to increase wire strength so a stronger grade of Incoloy cladding will be used. This particular Incoloy has seldom, if ever, been used for such an application and little is known about its corrosion characteristics in oil well conditions. The goal of this project is to identify the major mode of chemical attack so recommendations can be made to RSCC on product handling to improve the product's lifespan.

Initial experiments were conducted by cutting samples of both grades of Incoloy and soaking them in sulfuric acid (H_2SO_4) to see what forms of corrosion dominated. Sulfuric acid was used due to the dangers associated with handling a gaseous, corrosive, flammable and toxic chemical like hydrogen sulfide along with the theory that sulfuric acid would attack the metal in a similar way. Scanning Electron Microscopy (SEM) was used to analyze the fracture surface of the samples. It is thought the interface between the TIG weld bead and the base metal is where corrosion is most likely to occur due to microstructural differences so careful analysis of this region was conducted.

Based on current literature research and testing, it is believed the major form of chemical attack this new wire may experience in the environmental conditions is stress corrosion cracking. Further testing is being done to see which factors are the most influential to stress corrosion cracking and what practical steps can be taken to prevent it from occurring in the field.







Team #6: Characterization of Tensile Mechanical Properties of Biodegradable Polymers

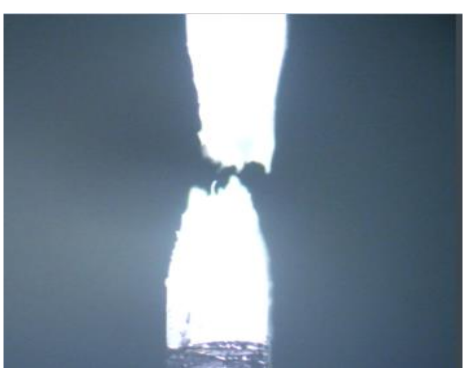
Sponsored by: Medtronic

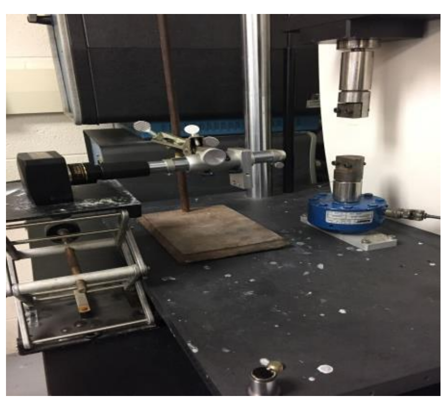
Sponsor Advisor: Darlene Nebinger and Michael Morsches

From left to right: Jarred Correira, Zachary Kerschner, Alexis Jensen, Jessica LeClerc, and Michael Murelli

As one of the leading companies in biomedical engineering, Medtronic is constantly developing new polymers and improving upon existing ones. As such, they have asked the UConn team to perform mechanical tests on four new polymers: L1, L4, L11, and L21. These polymers are composed of polylactide and polyglycolide, which are safe and suitable for internal implantation and are currently being used as hernia mesh clips. This blend of polymers is very efficient as it is both biodegradable and adaptable; the rate of degradation can be changed by modifying the ratio between the two component polymers. The purpose of this study is to test the tensile properties of each composition, and to study their behavior and mechanical properties after undergoing in vitro testing in Sorenson's buffer solution. However, the small size and nature of the samples makes obtaining accurate measurements difficult using conventional tensile testing methods.

To conduct these tests, the UConn team needs to develop a working homemade extensometer. The current setup uses a traveling microscope and digital camera to capture the movement of two marks on the sample. Each pixel of movement is converted into microns, generating a displacement vs. time curve. Compiling this data with the load vs time data from the tensile tester will allow the creation of accurate stress/strain curves. These curves will change as the samples degrade, allowing for the development of strength loss curves for the polymer samples. These data will allow Medtronic, vendors, and clients to accurately predict when products made from these polymers will fail, and select them accordingly. Medtronic has asked the student team to develop this test method in the hopes of using it to characterize further polymers in collaboration with the University of Connecticut.





Team 7: Cryogenic Processing of EBM Ti -6Al-4V

Left to right: Jordan Kovacs, Brendan Hans, Alexander Kinstler, Kevin Tran, Amanda Giroux

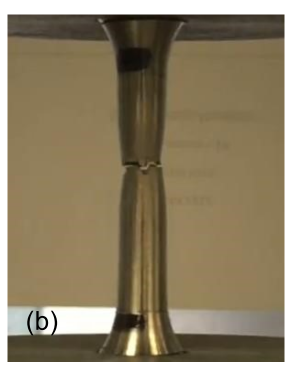
Sponsored by: UTC Aerospace Systems

Sponsor Advisor: Mr. Sergey Mironets

UTC Aerospace Systems

Additive manufacturing is poised to have a transformative impact on the aerospace industry. Additive manufacturing offers increased precision, flexibility, and efficient material use compared to traditional metal manufacturing techniques. UTC Aerospace Systems (UTAS) has investigated electron beam melting (EBM) as an additive manufacturing process for Ti-6Al-4V, an α+β titanium alloy used pervasively in the industry because of its excellent properties, such as high specific strength and corrosion resistance. Its other mechanical properties, specifically ductility and fatigue life, are two limiting factors of its potential applications. It is necessary to develop a post-process for EBM Ti-6Al-4V to produce desirable mechanical properties. Recent studies have suggested that processing with cryogenics conditions can improve the mechanical properties of Ti-6Al-4V. The goal of this study is to determine the relationship between cryogenic treatment and the microstructure of the EBM Ti-6Al-4V alloy. This will yield an understanding of how control and optimization of the morphology and phase ratios of the α and β phases affects its mechanical properties, allowing guidelines for an optimal thermomechanical process to be developed. If such a process is practically implemented, the additively manufacture alloy can be considered as a competitive material choice for a wide variety of aerospace applications.

An experiment to investigate the effects of cryogenic treatment, ageing treatment, Hot Isostatic Pressing treatment, and a combination of such on the mechanical properties and microstructure of EBM Ti-6Al-4V was set up using eight different tensile test groups, each with a different combination of processing treatment conditions. Cylindrical dog-boned specimen samples used in tensile testing were machined to ASTM E8/E8M16a and ISO 898-1 standards. Investigation of fatigue life involved one test group, of which the samples were subjected to the processing conditions found optimal in tensile testing. Success was determined by an improvement of Percent Elongation (E%), Percent Reduction in Area (RA%), and High Cycle Fatigue (HCF) with minimal reduction of Ultimate Tensile Strength and Yield Strength at ambient and elevated temperatures. Scanning Electron Microscopy was used to examine and characterize the microstructures of samples in the different test groups. It is expected that a reduction in the β phase improves the mechanical properties of EBM Ti-6Al-4V.



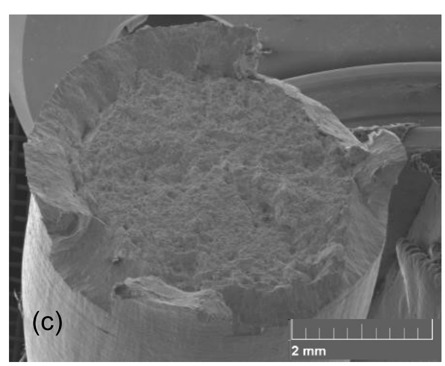


Figure. (a) Billet and tensile specimen
(b) Uni-axial tensile test
(c) Fracture surface

Team #8: Ceramic Membrane for Partial Reduction of Total Dissolved Salts

Sponsored by: KX Technologies LLC
Sponsor Advisor: Dr. Frank Brigano
William Li

Group Photo: Benjamin Thieken, Fresia Morales, Jonathan White.

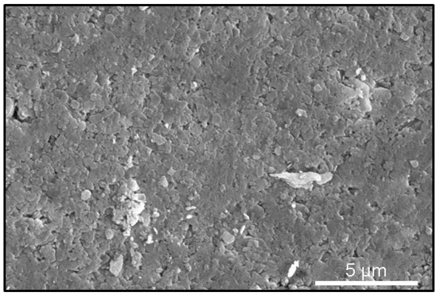
KX TECHNOLOGIES
The Science Behind Better Water

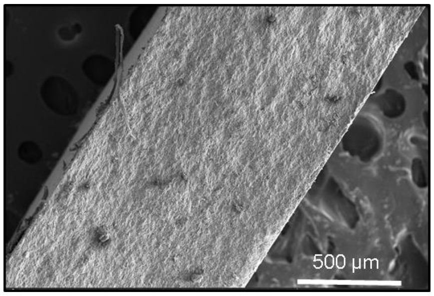
Project Description:

Water; a necessity for life on Earth. However, it's capability to dissolve broad arrays of substances can often pose issues. A simple example of this are basic salts. High concentrations of total dissolved salts (TDS) cause issues not only with personal water usage, but commercial and industrial usages as well. The capability to control TDS in water is thus a very important and useful trait for water treatment facilities. By creating cost-effective methods for reducing TDS we can make water treatment easier and more affordable, allowing for cleaner cheaper water around the globe.

One potential path that shows promise for TDS reduction is ceramic membranes composed of zeolites. Zeolites are nano-porous ceramics, much like clays, which are highly configurable both chemically and structurally. Due to their chemical and nano-porous nature, Zeolites have found applications as absorbents, catalysts and molecular sieves. Extensive work has been done on the synthesis of a variety of different zeolites for specific applications within these three fields. Our group aims to investigate the viability of a zeolite molecular sieve that can effectively block salt ions in water without hindrance to the water molecules themselves.

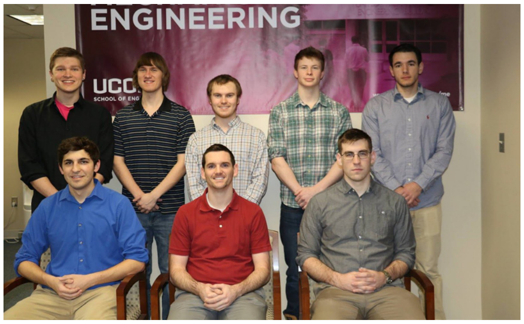
In this project we have tested sponsor supplied zeolite membranes and explored 3rd party samples for their ability to reduce TDS in a simple water filtration system. These membranes are then characterized to identify crystallography, microstructural features and constituents present. From this information, investigation on different synthesis methods for ceramic zeolite membranes can be done. This includes both the creation of zeolite seed crystals from the modification of fly ashes and clays as well as the analysis and synthesis of substrates for the hydrothermal growth of zeolite membranes.





Team #9: In Space Recycling & Reclamation via Additive Manufacturing

Sponsored by: NASA
Sponsor Advisor: Tracy Gill

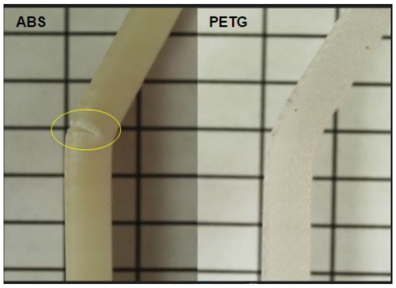


Back: Stephen Hawes (ME), Tyler Young (EE), Asa Army, Beau Teatreault, Alex Kadow
Front: Jon Rasimas, Adam Wentworth, Spencer Palmer

As one of NASA's partners for the eXploration Systems and Habitation (X-Hab) Academic Innovation Challenge 2017, UConn's multidisciplinary team was tasked with designing and building an integrated Additive Manufacturing Center with the capabilities of 3D printing and recycling engineering thermoplastics in a single unit. NASA has identified this system as key to the success of future missions to Mars. One of the main objectives for NASA is to reduce the weight of raw filament being transported to space. Recycling waste plastic from food packaging, tools, and waste support material will allow for a sustainable product life cycle and give astronauts increased flexibility in their experiments and missions. In addition to design and fabrication of the unit, another objective of ours is to study the properties of various plastics through the process of printing and recycling.

The team has used a systems engineering approach, purchasing a commercially available, open-source 3D printer as well as a newly developed recycling unit. We chose a Lulzbot Taz-Mini for our 3D printer, which we have outfitted with a custom automatic part removal system, and a linear actuator controlled drive gear. We have also purchased the RedeTech Protocycler,a recycling unit that will consistently grind the plastic, melt, extrude, and spool the new filament. The goal is for the process to be as automated as possible to guarantee repeatable parts with minimal astronaut interaction with the system. In addition to the mechanical automation upgrades we have made to the system, we have also developed a webpage using Octoprint that will act as the control interface for astronauts and engineers on earth.

Nasa has specified certain criteria to determine a successful end result. The complete system of the printer and recycler needs to fit in a locker with four cubic feet of space, and meet certain power consumption and weight limits. Various mechanical tests have been performed to determine the characteristics of ASA, Ultem, PETG, and ABS. We used ABS as our baseline, however PETG has displayed the best overall properties so far. We also believe that PETG will hold its properties the best after multiple recycling cycles compared to the other plastics.



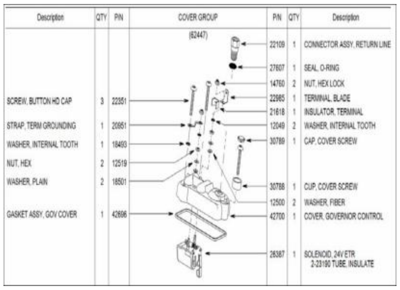
Team #10: Pump Cover & Solenoid Assembly Design

Sponsored by: Stanadyne
Sponsor Advisor: Fred Golja

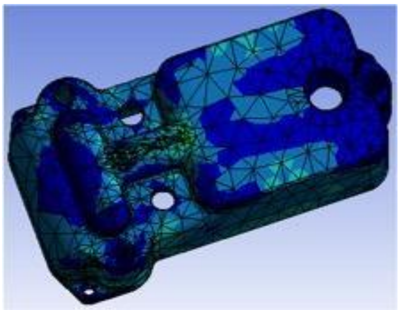
The main objective of this project is to redesign the cover and electric shut-off (ESO) assembly for Stanadyne diesel fuel injection pumps in order to reduce the number of parts and assembly time required for Stanadyne to produce the cover. In order to accomplish this, the material selection of the cover casing is imperative. Researching and selecting a new material to replace the Cast Aluminum A-380 as well as redesigning the ESO solenoid mechanism dictates much of the project. The current cover assembly consists of three subcomponents that include a total of 18 various parts that are assembled by a worker. The gasket is made up of 5 components, the ESO Solenoid Assembly is made up of 9 components, and the return line has 4 components. Dealing with the numerous small parts required to produce the assembly results in a large amount of time needed to produce one assembly.

The new cover assembly must be simplified and consolidate all of the current components and their functions. It must be able to withstand all of the current functional demands as the existing cover in addition to utilizing the same fasteners since the new cover has to be backwards compatible, as the pump itself is not being redesigned. Additional requirements include a tamper proof feature, and cost effectiveness. The part would ideally be a material that can be either cast or molded in order to retain the ease of manufacturing of the assembly housing in large quantities. Utilizing a plastic material for the casing would allow several components used for electrical isolation of the solenoid leads to be eliminated from the assembly. The material must also have the ability to function properly within the conditions listed above. From these design constraints the candidate materials for the redesign include Teflon FEP, PTFE, Nylon 6/6 and Nylon 6/6 GF30.

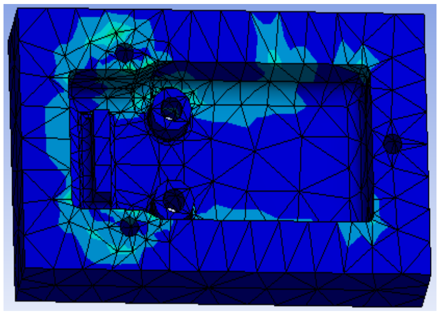
CAD software will be used to model the new design as well as software to analyze the effects of the stresses, strains, and vibrations that the new design will undergo. The final product will go through numerous part validation tests which include: Functional Test, Durability Test, Fuel Compatibility Test, Vibration Tests, Thermal Cycle Tests, Temperature Rise Test, Salt Spray Test, and Torque to Failure Test. Stanadyne will be responsible for these tests as they take months to years to complete.



Cover assembly schematic



CAD analysis of current pump cover



CAD redesign of new cover

Team #11: Materials Selection in Sustainable Product Design

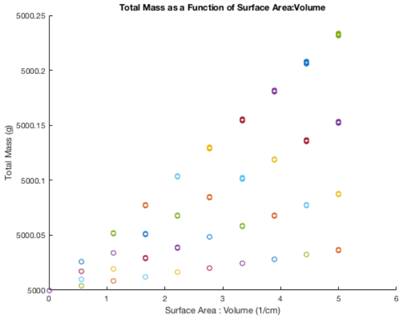
Sponsored by: Pratt & Whitney
Sponsor Advisor: Dr. Amra Peles

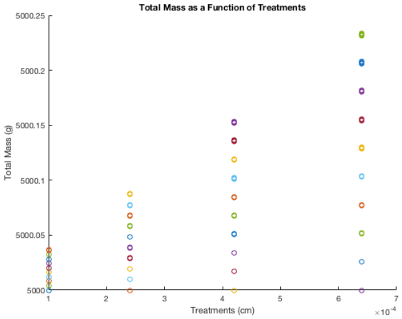
Project Team: Jack Persico, Brian Keane, Kevin Gryk, and Mohamad Daeipour

Material selection in product design is essential in ensuring a product is safely functional for the duration of its life cycle. Sustainable design entails solutions that keep in mind the health of both the public and the environment. This project examines design process, as well as identifies and evaluates use of materials in design specifications. In particular, materials whose specifications include the use of chemicals in violation of REACH regulations have been surveyed, and methodology that identifies chemical state and amount of regulated material present has been developed. REACH is a regulation of the European Union implemented in order to help improve the protection of human health and the environment from risks that may be imposed by substances of very high concern (SVHCs). These regulations affect products both imported and manufactured within the EU’s jurisdiction. In addition to the identification of materials in violation of REACH regulations, this project examines possible alternative material solutions and input on possible materials development and replacement has been provided.

This project involved the development of a MATLAB program that can survey and categorize previously identified design specifications. The program executes computations of restricted substance content in design specifications. Formulas have been derived for materials weight percent computations using specification data and specific object geometries. Trends relating quantities such as surface area, aspect ratio, and coating thickness were established to provide a better idea of how these properties are related, and were used to inform decision making in the program design. The program is capable of accommodating a number of user-defined inputs and outputs depending on the needs of the operator. Materials were categorized according to weight percent of a given SVHC, and materials were identified as being either always, never, or sometimes in violation of REACH standards. GRANTA CES Selector software was then used to generate Ashby charts and identify possible viable alternative materials.

Pratt & Whitney imposes the highest quality criteria for engine performance and responsible energy consumption. Product designs must meet both performance and sustainability criteria to provide the best, safest, and most efficient product. This project plays in essential role in helping Pratt & Whitney achieve their goals.





Team #12: Effect of Thermal Exposure on Chromium Conversion Coatings

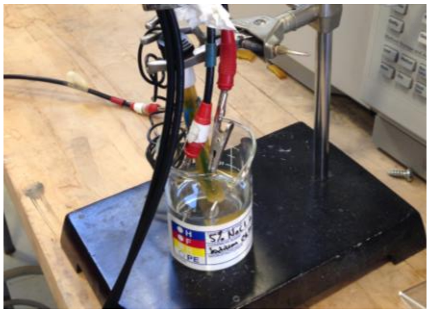
Sponsored by: Pratt & Whitney
Sponsor Advisor: Dr. Promila Bhatia
Faculty Advisor: Dr. Prabhakar Singh

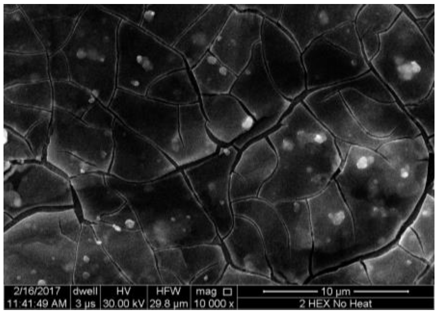
Ben Hyde, Ryan Shiring, Alyssa Denno, Jack Morley

Project Description:

The application of chromium conversion coatings (CCC) is a commonly used industrial practice that provides excellent corrosion protection for a wide range of aluminum alloys. CCCs contain hexavalent and trivalent chromium, where hexavalent chromium is a known carcinogen that can leach into the environment. The coatings are also prone to degradation at elevated temperatures. Due to the hazardous nature of these coatings and their propensity for degradation, many industries are currently engaged in developing an in-depth understanding of the degradation mechanisms as well as alternative coatings including trivalent chromium formulations for replacing CCCs. The goal of this study is to compare the performance of a recently developed trivalent chromium coating with a widely-used coating containing hexavalent chromium. There is specific interest in the study of the relationship between exposure to elevated temperature and the corrosion inhibiting performance of these two coatings.

The student team conducted numerous experiments to study the structure and performance of these coatings on an aluminum 2024 substrate. Samples were prepared and coated according to industrial standards prior to testing. To test the performance of these coatings after exposure to elevated temperature, coated samples were subjected to a 24-hour heat treatment at 125°C and 175°C. These heat-treated samples were compared with samples that were not heat treated. Samples were tested using a 500-hour Salt-Spray (SS) test according to ASTM B117 and by Electrochemical Impedance Spectroscopy (EIS). These methods allowed the team to compare the corrosion resistance of the two coating types. Scanning Electron Microscopy (SEM) was used to examine the surface of the samples before and after performing any treatment or testing. SEM was used to better understand the relationship between coating breakdown and surface morphology. Energy dispersive x-ray spectroscopy was used to examine the chemical composition of surface features that might contribute to the performance of these coatings.





Team 13: Accelerated Aging and Failure Analysis of Polyurethane Adhesive

From left to right: Christopher Didero-Gonzalez, Dion Buterbaugh, Aaron Gladstein, and Jay Latimer

Sponsored by: Pratt & Whitney
Sponsor Advisor: Dr. John Harner

Pratt & Whitney
A United Technologies Company

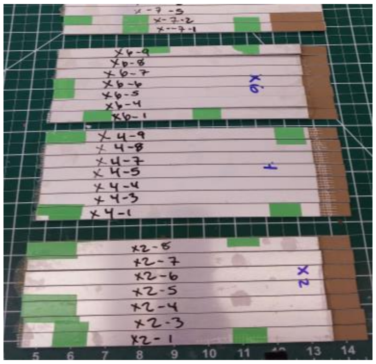
Pratt and Whitney (P&W), a leader in jet engine technology, is on the forefront of creating new methods to reduce engine weight and fuel consumption associated with engine runtime. Fuel efficiency continues to be a major criteria driving competition and research in the jet airplane market. Many advanced lightweight materials solutions have the potential of replacing current technologies to reduce engine weight without compromising required mechanical properties of the overall structure. Incorporating polymer-based structural adhesives is currently being investigated by P&W. However, since they are relatively new to the industry there is limited data and methodologies available to predict behavior of adhesives over a full 20+ year lifecycle. Existing methodologies which predict adhesive behavior, oxidation, and degradation over time are insufficient and unreliable for polymeric materials due to their lengthy runtimes, inability to incorporate the multitude of potential adhesive failure pathways, and their limited description of overall polymer behavior.

Every year, millions of lives depend on the proper functioning of aircraft engines and parts made by P&W, so accurately predicting how structural adhesives age in an appropriate time frame is of the utmost importance for the future uses of structural adhesives. Developing a reliable methodology which better describes polymer behavior and more accurately predicts adhesive failure is crucial to the success and eventual incorporation of polymer-based adhesives into P&W engines and components.

The focus of this research was on aging through oxidation of a given polyurethane adhesive. Multiple rapid aging models were tested and compared to long-term aging results that were held in common aircraft conditions. Traditional oven aging, as well as more efficient and advanced methods such as Thermogravimetric Analysis and Differential Scanning Calorimetry were used to artificially age samples. Each process was scrutinized to determine its overall predictive capability, strengths and weaknesses, ability to predict adhesive failure pathways, and a reliable predictive window of use. In addition to the main investigation, additional research and experimentation was done to evaluate potential processes for future exploration. These include but are not limited to utilizing ultra-violet light to accelerate oxidation as well as using Fourier Transform Infrared analysis to quantify degradation from oxidation.

Polyurethane dog bone sample comparison: As-received (L) and Aged (R)

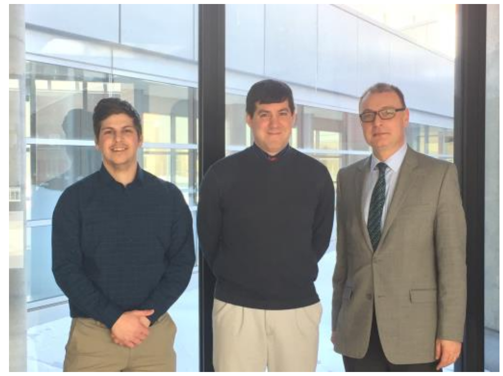
Polyurethane dog bone under tensile stress



Layout of as-received aluminum peel test samples

Team #14: Advanced Adhesive Bonding Optimization

Sponsored by: ASML
Sponsor Advisor: Dr. Andy Judge
Faculty Advisor: Dr. Pamir Alpay



Nathaniel Santos, Justin Webster, Dr. Pamir Alpay

ASML

Glass to metal bonding via two part epoxy adhesives and its wicking phenomenon were investigated and optimized through numerical modeling and experimentation. ASML is the global-leading producer of photolithography machines. The precise, glass optics inside these machines are bonded to steel or titanium mounts by epoxy injected into miniscule wells in the metal surface. Occasionally, the surface energies of the glass, metal, and epoxy may cause the epoxy to wick away from the injection site and into less desirable locations. While the bonds are still strong with wicking, they could be stronger without it. The ability to control wicking of the time reacting non-Newtonian epoxy fluid through various barrier methods is highly desirable for manufacturing processes where consistent high strength glass to metal bonds are necessary. Thus, the physics behind wicking, ways to control it, and new well designs were investigated.

This extensive investigation aided in the construction of superior bonding techniques and epoxy deposition well (bottom right picture) construction. Three phases of experimental materials testing were conducted concurrently with computational analysis. Phase I of the experimental regime was performed to evaluate liquid epoxy wicking on currently used materials in the glass to metal bond (bottom left picture). Phase II explored wicking with respect to more complex geometries using methodology similar to Phase I. Phase III experimentation encompassed surface property and adhesive well geometry evaluation. Finite element analysis pertaining to wicking modeling was explored, however, due to the time and resource constraints on this project, the analysis is intended to be complementary to the empirical results. A two-dimensional MatLab model of a single drop of polymer spreading in between two dissimilar surfaces was created to predict the behavior of the epoxy (bottom middle picture).

A set of tunable parameters and their effects was created from the computational and experimental analysis completed. This includes surface treatments for the metal and geometric barrier designs for the adhesive wells. These adjustments will allow ASML to optimize their adhesive bonds in their state of the art Ultra Violet lithography machines.