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Corner Sealants for Tactical Shelters

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The University of Southern Mississippi

Corner Sealants for Tactical Shelters

by

Janine Nowak[*]

A Thesis
Submitted to the Honors College of
The University of Southern Mississippi
in Partial Fulfillment
of the Requirements for the Degree of
Bachelor of Science
in the Department of Polymer Science

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[*] This project was a team project, completed by Janine Nowak, Ryan Dufrene, Mark Norman, and Tyler Woldanski. All credit is shared among team members. Janine Nowak's main contributions, in order to fulfill the thesis requirements, were focused on the design concepts.

Approved by

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Abstract

The demand for a lightweight, easy-assembly tactical shelter is high for those faced with unexpected disasters and global conflicts. This project focuses on designing and prototyping the corner sealant for such a shelter. Two materials were chosen and tested: an in-house thermoplastic polyurethane (TPU) and Texin 950. Thermogravimetric Analysis (TGA) was performed on both of these materials. The in-house TPU showed initial degradation at 282.50 °C and sample degradation at 457.45 °C. Similarly, Texin 950 showed initial degradation at 293.68 °C and sample degradation at 453.26 °C. Differential Scanning Calorimetry (DSC) was then run. The crystallization temperature (T_c) was observed at 79.73 °C for the in-house TPU and 99.07 °C for Texin 950. The melt temperature (T_m) was observed at 182.91 °C for the in-house TPU and 182.24 °C for Texin 950. Dynamic mechanical analysis (DMA) was run. The storage modulus for the in-house TPU was 42.72 MPa, and the loss modulus peaked at 7.013 MPa. The storage modulus for the Texin 950 was 47.03 MPa, and the loss modulus was 7.492 MPa. Due to the similarity in the properties of the materials, the choice became the most economical of the two: Texin 950. The final design chosen was one with a rounded edge to exclude unnecessary stressors and a hollow spine to reduce weight. Using a non-standardized test method, the volume of each corner sealant using the Texin 950 was calculated to be 4806.63 cm^3. Using this value, the mass was calculated to be 5.52992 kilograms, or 12.19 pounds. Further research will have to be done to reduce this weight and further refine material selection and sealant design.

Dedication

To my parents, Rudy and Julie Nowak, for their constant and unwavering love and support. Thank you for never giving up on me and supporting my crazy ideas these last few years. And to my sister, Andrea Nowak, who kept a smile on my face through it all. Thank you for being my best friend and keeping me motivated to finish what I started. Without you all, this would not have been possible.

Acknowledgments

I would like to acknowledge my advisor, Dr. Jeffrey Wiggins. Thank you for your guidance and support throughout this project. Additionally, I would like to thank Dr. Olivia McNair, who also guided and advised this project. Finally, I would like to thank my team members, Ryan Dufrene, Mark Norman, and Tyler Woldanski. This was truly a team effort, and without their dedication, hard work, and knowledge, this project would not have been completed.

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I. Introduction

In the face of unexpected disaster and global strife, rapid and tactful response efforts are crucial in mitigating the resulting human casualties. The construction of reliable, weatherable refuge is a decisive factor in effectively aiding those displaced by disaster and those needing protective shelter in warzones. This results in a demand for lightweight tactical shelters that possess a high degree of structural integrity and may be deployed rapidly with simple assembly. The goal of this project is to develop a hard wall shelter system that provides refuge from the elements for both the soldiers and systems housed within the shelters. The hard wall shelter must perform either at or above the standards set by previous soft wall shelters while also proving to be a less costly alternative to current tactical shelter options.

The University of Southern Mississippi (USM) team is tasked with developing new polymer materials with reusable sealing capabilities to be utilized at the edges and corners between tactical shelter panels during assembly.[1] This project is a part of a larger project headed by the United States Army Natick Soldier Research, Development & Engineering Center (NSRDEC). The outcome of this project could potentially bring about a new era of tactical shelters for the United States Army, much like DHS Systems brought about when they developed the Deployable Rapid Assembly Shelter (DRASH) decades ago. The focus of this project is to design a locking system comprised of polymeric materials with the purpose of connecting and sealing composite material shelter panels together in the construction of a rapidly deployable tactical shelter.

II. Background

The United States' entry into World War I left a significant mark on history, and its involvement would turn the tides of the war in favor of the allies. However, World War I would also be the first major, non-domestic war that the United States would participate in. Up until its entry (April 6, 1917),[2] the United States had only been involved in conflicts domestic to the American continent, such as the American Revolutionary War, the War of 1812, and the American Civil War. Mobilizing troops across the Atlantic Ocean was simple for the United States because the United States Navy was well-developed by this time. However, the challenge was housing and caring for the troops once they arrived on the frontline. Housing and medical facilities were often established in vacant buildings, such as the abandoned chateaus of France.[3] These medical locations were for the wounded who did not require immediate medical attention or surgery to save their lives. Casualty clearing stations (CCS) took on the burden of the serious injuries, such as amputations and surgeries. CCS were either set up in abandoned structures closer to the frontlines of the war or in tents. **Figure 1** portrays the typical style of tents used in these field hospitals. The same operation was utilized in the European theater of World War II, due to the urban and suburban battlefields. However, soldiers fighting in the jungles were not so lucky.

Figure 1: Field hospital with nurses' tents.[4]

Soldiers fighting in the Pacific theater of World War II, as well as the Vietnam and Korean Wars, saw action in the jungles of Asia and the Pacific islands. These soldiers relied on tents to house themselves, their supplies, and field hospitals. However, much like the hospitals of the European theater of World War II, there were the CCS and then there were hospitals further from the action to house injured soldiers. These hospitals were located on ships such as the USS Samaritan (AH-10). She was tasked with transporting wounded soldiers away from islands and to establish hospitals around the Pacific islands. The Samaritan was involved in the capture of the islands of Saipan and Guam, as well as the assault on Iwo Jima.[5] While the hospital ships were up-to-date with the most advanced medical instrumentation and staffed with the best doctors and nurses in the United States Army, field hospitals were still operating with the bare minimum of supplies. The tents provided by the military did not meet the needs of the field doctors and nurses to adequately perform their lifesaving tasks. However, an advancement in tactical shelter technology was right around the corner.

DHS Systems, LLC (now owned by HDT Global, as of 2015)[6] developed the DRASH to be integrable with military technology, whether that be computer system, decontamination stations, or field hospitals. The DRASH were deployed as early as 1984[7] and soon became a key factor in the rapid deployment of soldiers around the globe. DRASH are also fully integrable with electrical systems, as well as air conditioning and heating systems to make a soldier’s life in the field more comfortable. These soft wall shelters were developed with the sole purpose of keeping everything within them safe from the elements. A recent experiment conducted by the United States Army Corps of Engineers in conjunction with the Engineer Research and Development Center (ERDC) focused on how much energy was lost from the shelters being tested (Airbeam Series 32 and Utilis TM60) and how two thermal barrier attachments affected the results.[8] The results of these experiments highlight the key roles of current soft wall tactical shelters, as well as set a benchmark for the development of alternative tactical shelter systems.

III. Design Concepts

The team brainstormed multiple iterations of the design, focusing on the functions of the tactical shelter, as seen in **Figure 2**.

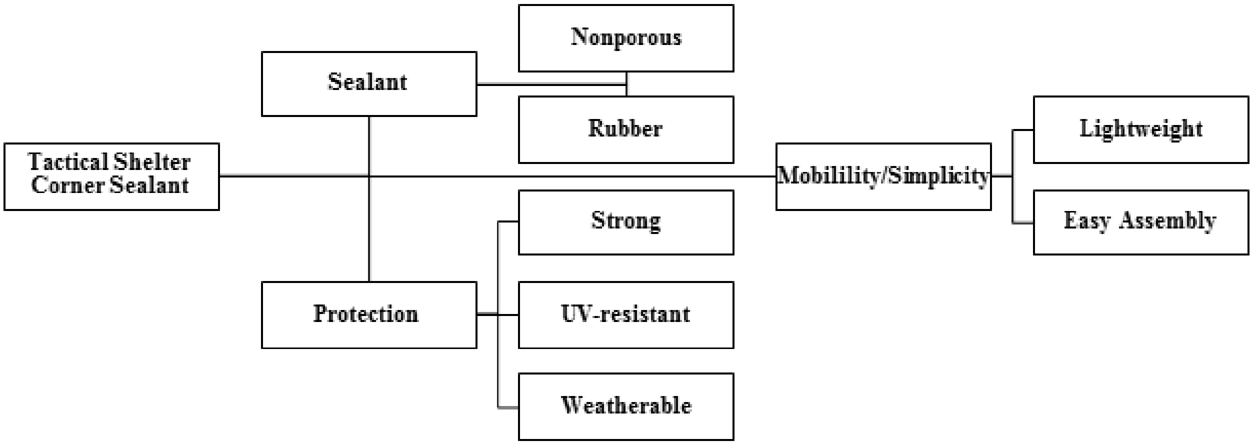


Figure 2: Function diagram for first design concept.

After careful consideration of all functions the corner sealant must possess, the team designed two joint piece designs, the first of which had multiple interior designs. The first proposed design consists of a corner piece by which two hard wall shelter panels are locked together in place, as depicted in **Figure 3.1**. Grooves have been purposely included on the outer surface of the joint piece for ergonomic design while simultaneously reducing part weight. **Figure 3.2.** displays variations of the joint piece interior design. These variations include a joint design by which two panels are connected by a hollow space, a joint design by which two panels are connected by a hollow space with a structural spine, and a joint design by which the connecting hollow space is omitted. This choice reflects the team's desire to produce a joint piece utilizing the lowest volume of material while maximizing part tensile strength. Additionally, a design with prongs positioned along the joint's surface in direct contact to the hard wall panel was proposed. This design represents the desire to select a locking piece geometry that provides the most stability to the compatible hard wall panels.

Figure 3.1: Joint piece initial design.

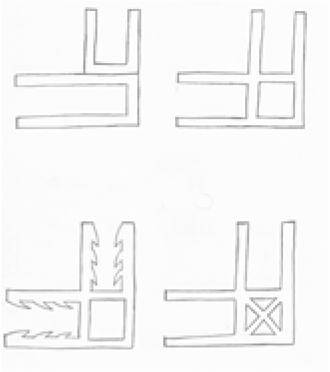


Figure 3.2: Top-down interior designs.

The second design iteration was conceptualized in order to eliminate potential stressor points while retaining the fundamental functionality of a polymeric corner joint by which two hard wall tactical shelter panels may be connected. **Figure 4.1** displays a similar design to the initial iteration while employing a rounded inner-edge and a rounded outer-edge. **Figure 4.2** shows the top-down perspective of this iteration.

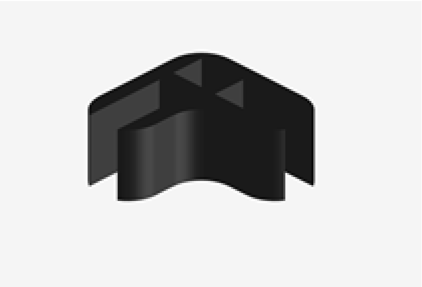


Figure 4.1 Joint piece second design.

Figure 4.2 Second design, top-down view.

VI. Material Selection

When considering polymeric corner sealants for composite panels in tactical shelters, the first objective is deciding what properties are vital to maintain the engineering design concept. One of the many goals is a fast assembly and disassembly when entering or leaving a territory. The sealant's ability to minimize size and weight is a key aspect in the assembly and disassembly process since it will reduce the energy consumption among soldiers. These sealants must also be nonporous when attached to the composite panels to eliminate any water, gas, or liquid permeation. Along with the sealant being nonporous, it must contain excellent thermal, moisture, chemical, and environmental stability. The sealant must be stable in any environmental condition it may be in, whether that may be in desert, arctic, or tropical conditions. The sealant must be durable, with excellent mechanical properties and a long lifecycle. Ultimately, the sealants must refrain from elastic deformation and be recyclable after the termination of their lifecycle. With these desired properties in mind, the best polymeric material to choose is a thermoplastic elastomer (TPE).

Thermoplastic elastomers are typically rubbery polymers that do not require drying, curing, or vulcanizing. Because the goal of this project is to design a corner sealant, there are plenty of materials that could make an excellent corner sealant. However, the team believes a TPE is the right choice due to its low friction characteristic and low-cost processability. TPEs are more suitable because the polymers can be melted and molded using conventional thermoplastic processing. Other benefits to TPEs are their low modulus and hardness with excellent shock absorption.

When taking these properties into consideration, property charts can be used to determine what material will ultimately be the best choice for the product. A key relation to examine is the comparison between Young’s modulus and density, as shown in **Figure 5**.

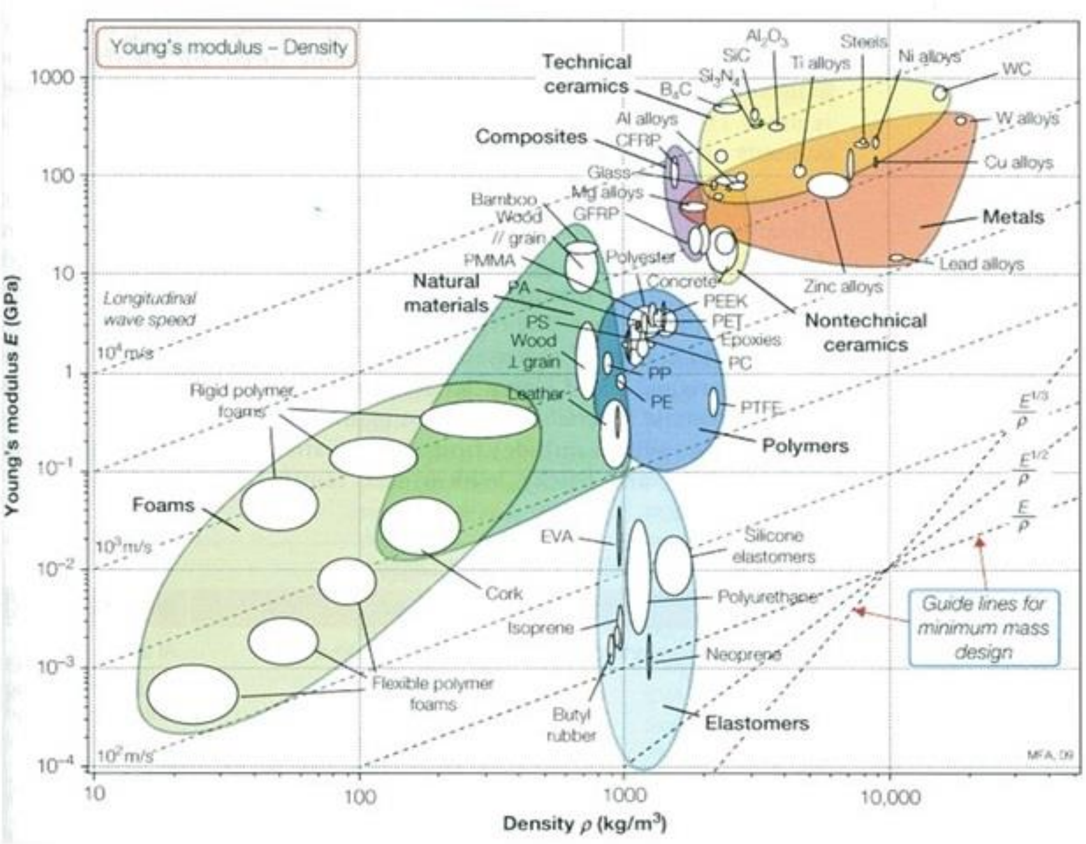


Figure 5: Young's Modulus vs. Density property chart.[9]

According to **Figure 5**, there are multiple elastomers that provide a reasonable density with a low modulus. The density is comparable to most polymer plastics and less than most metals used in the material world. The low modulus will provide that rubbery and elastic behavior which is vital in a corner sealant. The corner sealant must be able to shape and form around the composite tactical shelter and this is where the low modulus comes into effect. Looking at the property chart in **Figure 5**, some elastomers that may be a functional material for this corner sealant is isoprene, butyl rubber, neoprene, and polyurethane, among others.

Elastomers typically behave in the rubbery state, meaning a low modulus is a property always associated with such materials. One goal of the corner sealant is to not only perform in the rubbery state, but also be strong enough to withstand a variety of circumstances and conditions that may affect the shelters wherever they may be located. **Figure 6** shows the property chart comparing the Young's modulus relation to the strength of the material.

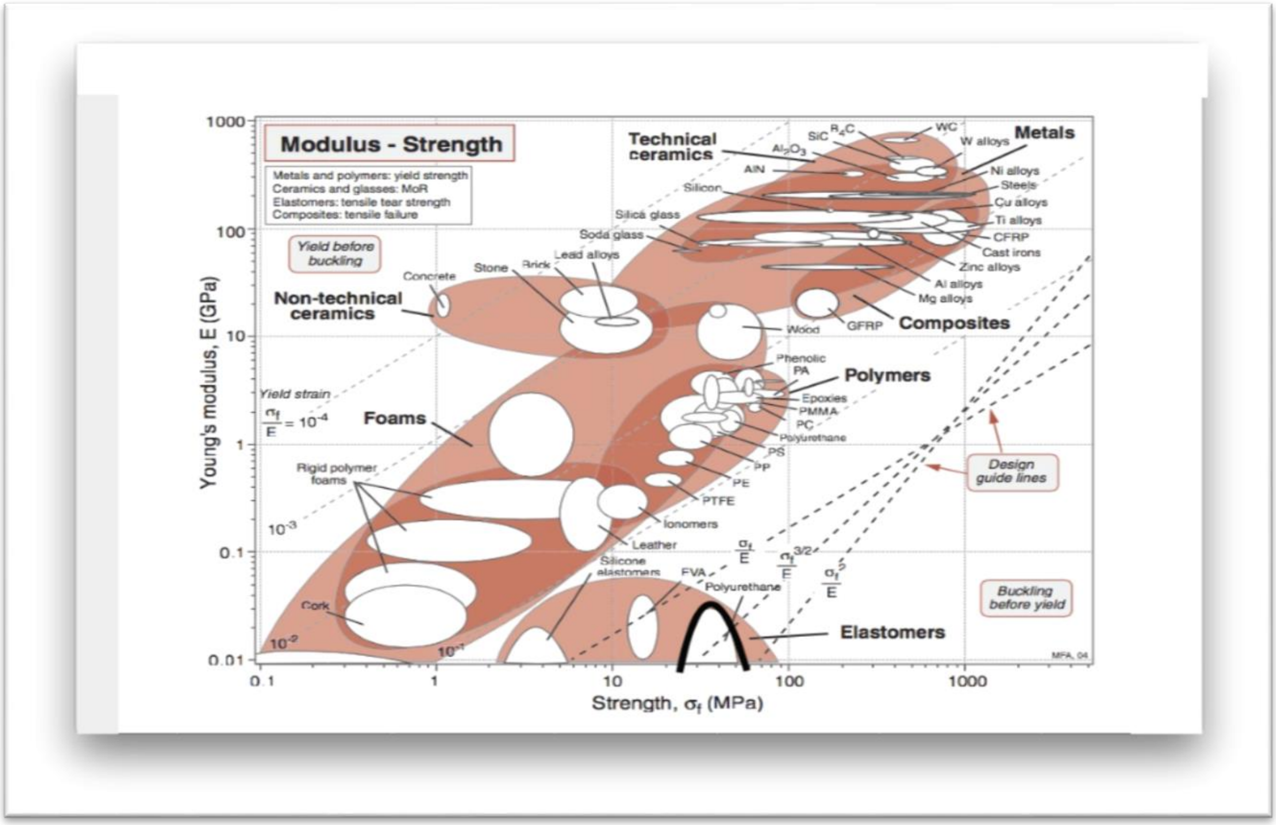


Figure 6: Young's Modulus vs. Strength property chart.[9]

A material that contains excellent strength is desirous for many applications, including a corner sealant. As previously stated, elastomers have a low modulus that gives the material its rubbery behavior. The elastomer section in **Figure 6** focuses on the tear strength of the material and how much stress it can undergo before it ultimately fails. Even with its low modulus, the tear strength of elastomers is proportional to the yield strength of polymers. Containing high tear strength is vital in a corner sealant because it will constantly undergo stresses and deformation as it upholds the tactical shelter. Like **Figure 5**, polyurethanes are situated in the elastomer group, as well as ethylene vinyl acetate and silicone.

Temperature is an intensive property, which means it does not depend on the amount of material that is in a system. A material’s performance can vary depending on the temperature conditions. **Figure 7** illustrates the strength plotted against the maximum service temperature of different materials.

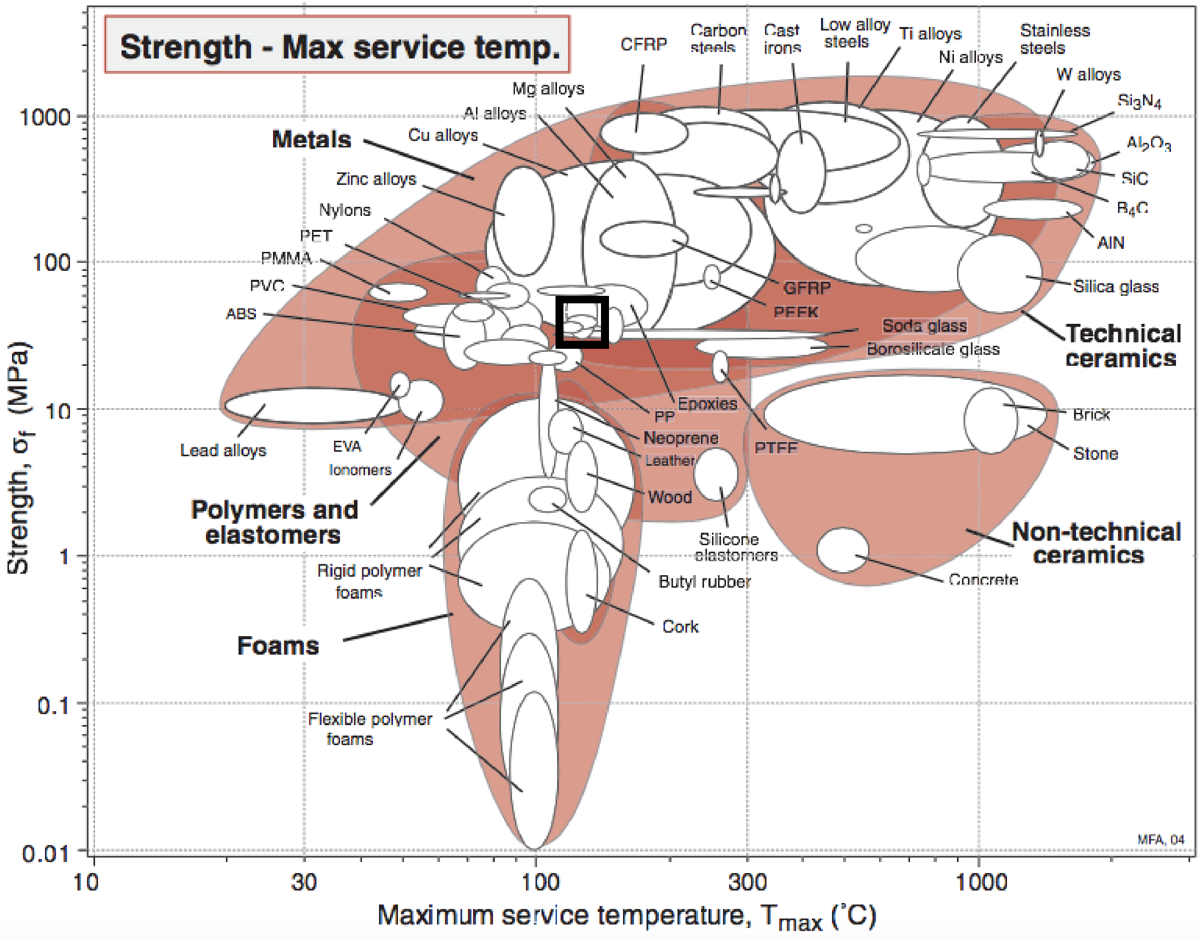


Figure 7: Strength vs. Maximum Service Temperature property chart.[9]

Maximum service temperature is a big factor when considering which material will be used as the corner sealant. Looking at the bigger picture, the Army needs sealants that will not deform or undergo any creep resistance when deployed in the field. These shelters will be used in extreme hot and cold temperatures, and failing properties should never be one of their concerns. According to **Figure 7**, elastomers and polymers mesh into one group but elastomers tend to have a slightly higher maximum service temperature. Elastomers have a 100-200 ^{o}C maximum service temperature which qualifies the material to be considered for the corner sealant. Thinking realistically, no place on this planet will reach above 100 ^{o}C, so choosing an elastomer is the right choice.

Observing all of the property charts and comparing different materials, ultimately TPEs qualify for all of the performance properties being asked by the United States Army. In a previous report, the Army mentioned a few materials in which they would like to examine closely and perform tests. These materials are thermoplastic polyurethane (TPU), styrene-isoprene-styrene (SIS), copolyamide (CPA), and copolyester (CPE). However, due to time constraints, the team analyzed and tested two different grades of TPU.

TPU is a flexible and elastic polymer that is melt-processable. **Figure 8** shows that TPU is a block copolymer that consists of diols and diisocyanates that can be vacuum-formed.[10]

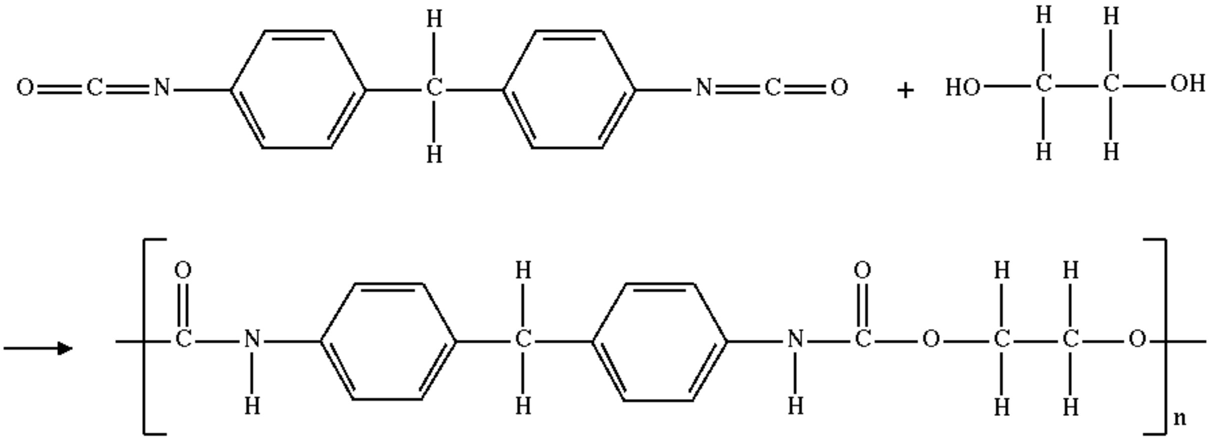


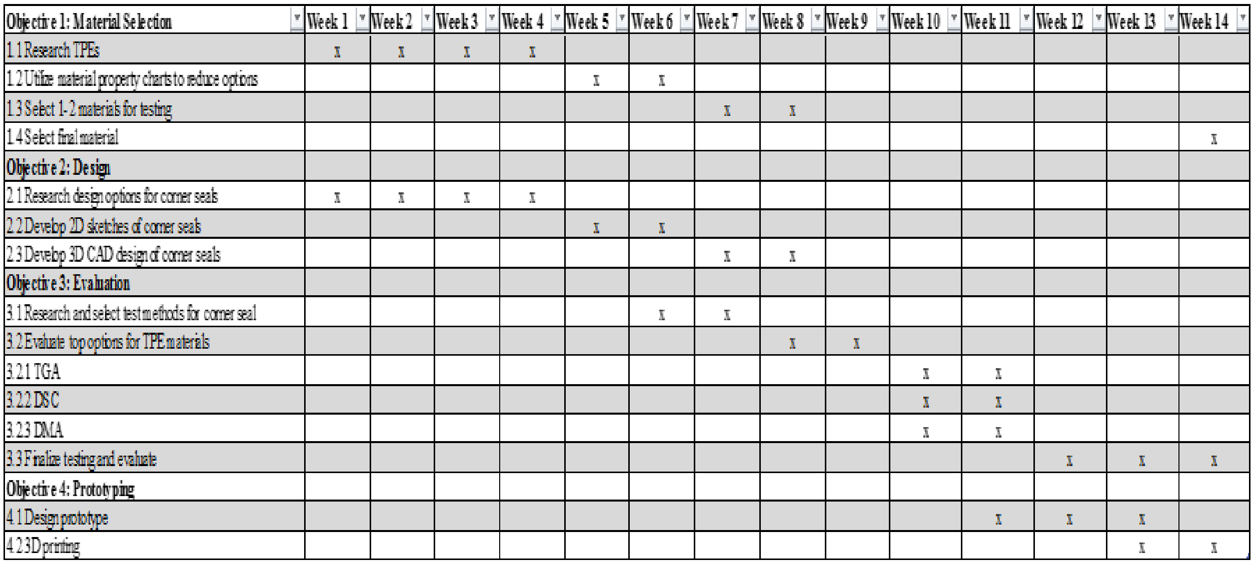
Figure 8: TPU is a block copolymer with the monomers of diols and diisocyanates.[10]

Within the TPU are hard blocks that can either be aromatic or aliphatic. Aromatic TPU has a hard block of methylene diphenyl diisocyanate (MDI), while aliphatic TPU has a hard block of H12 MDI. TPUs are flame-retardants and have excellent anti-static properties that could be very beneficial when designing a corner sealant.[10]

V. First Design Concept

Based on the information and research gathered, the corner sealant will be processed by a conventional thermoplastic processing method. By observing the desired properties proposed by NSRDEC, a thermoplastic polyurethane will be the optimal material, due to its excellent stability properties and low cost per raw material. When conceptualizing the design sketches, the goal of minimizing weight and aesthetics is the major discussion. Determining the specific dimensions and physical design of the corner sealant has been taken into consideration. Initially, a hollow spine is being chosen to reduce weight and add durability when the sealant is in effect.

Table 1 displays a GANTT chart for the project. The GANTT chart is a timeline that represents the steps that are being taken for the remainder of the project.



Objective 1: Material Selection	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
1.1 Research TPEs	x	x	x	x										
1.2 Utilize material property charts to reduce options					x	x								
1.3 Select 1-2 materials for testing							x	x						
1.4 Select final material														x
Objective 2: Design														
2.1 Research design options for corner seals	x	x	x	x										
2.2 Develop 2D sketches of corner seals					x	x								
2.3 Develop 3D CAD design of corner seals							x	x						
Objective 3: Evaluation														
3.1 Research and select test methods for corner seal						x	x							
3.2 Evaluate top options for TPE materials								x	x					
3.2.1 TGA										x	x			
3.2.2 DSC										x	x			
3.2.3 DMA										x	x			
3.3 Finalize testing and evaluate												x	x	x
Objective 4: Prototyping														
4.1 Design prototype											x	x	x	
4.2 3D printing													x	x

Table 1: GANTT chart for the corner sealant project

Research of TPEs to select the best material was studied for the first four weeks, followed by reducing the amount of options. Narrowing the selection down to a couple of materials occurred in the middle of the project, ending with the final material selection at the end of the project. Similarly, research of design options for the corner seals took place in the first four weeks, followed by developing 2D sketches and 3D CAD designs of these sealants. Evaluation of the materials occurred halfway through the project, starting with researching test methods for the sealants. By the middle to end of April, all tests were run and final evaluation took place. By the beginning of May, a final prototype of a thermoplastic corner sealant was processed and ready to display.

VI. Engineering Analysis

The two materials that were tested for the tactical shelter corner sealant were an in-house TPU made in the Wiggins lab and Texin 950. As deliberated, we believed TPUs were the correct choice when deciding on what material to choose because all property charts provided excellent data in the areas that we are desirous of. Covestro Texin 950 is an aromatic polyether-based TPU with a Shore D hardness of approximately 50. This material was chosen due to its excellent abrasion resistance, impact strength, toughness, and flexibility. The in-house material is also an aromatic polyether-based TPU with a Shore D hardness of approximately 50. This material was processed using polytetrahydrofuran (PTMEG) form 1,4-butanediol and MDI. These two materials underwent thermal and mechanical testing to ultimately observe which material had better performance and properties.

Thermogravimetric Analysis (TGA) is a thermal analysis technique, which alters the chemical and physical properties of a certain material when applied with increasing temperature. Both materials were tested using a TA Instruments Q50 with the temperature parameters set from 20 ºC to 600 ºC with a heating rate of 10 ºC per minute. **Figure 9** illustrates the instrument used to perform TGA on both materials.

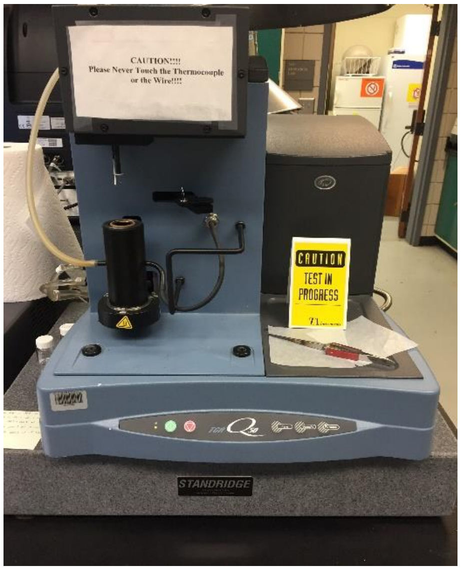


Figure 9: TGA Q50 instrument.

As observed in **Figure 10**, initial degradation of the in-house TPU was 282.50 °C, and its sample degradation was 457.45 °C. Similarly, **Figure 11** shows initial degradation for Texin 950 at 293.68 °C, and sample degradation at 453.26 °C. These two TPUs have similar degradation temperatures, both of which are high enough to withstand the high temperatures necessary for the tactical shelters.

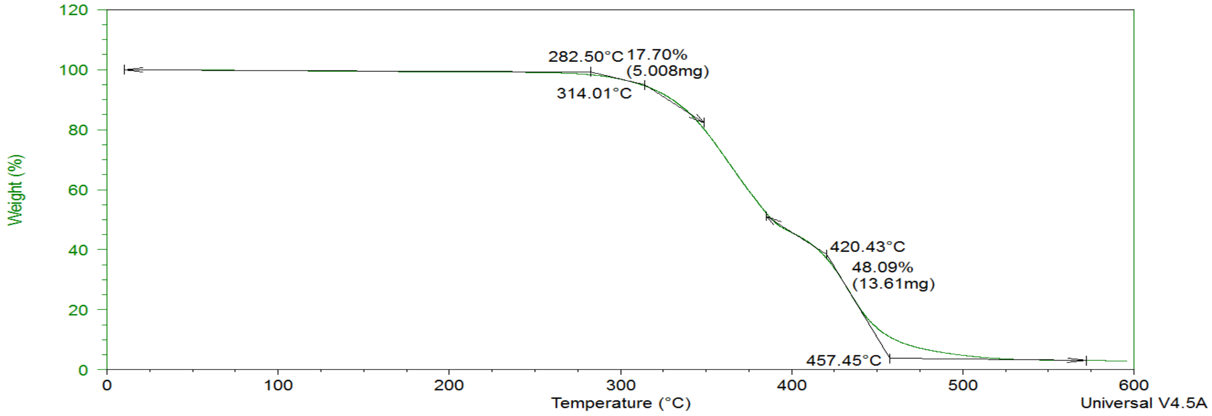


Figure 10 TGA of in-house TPU.

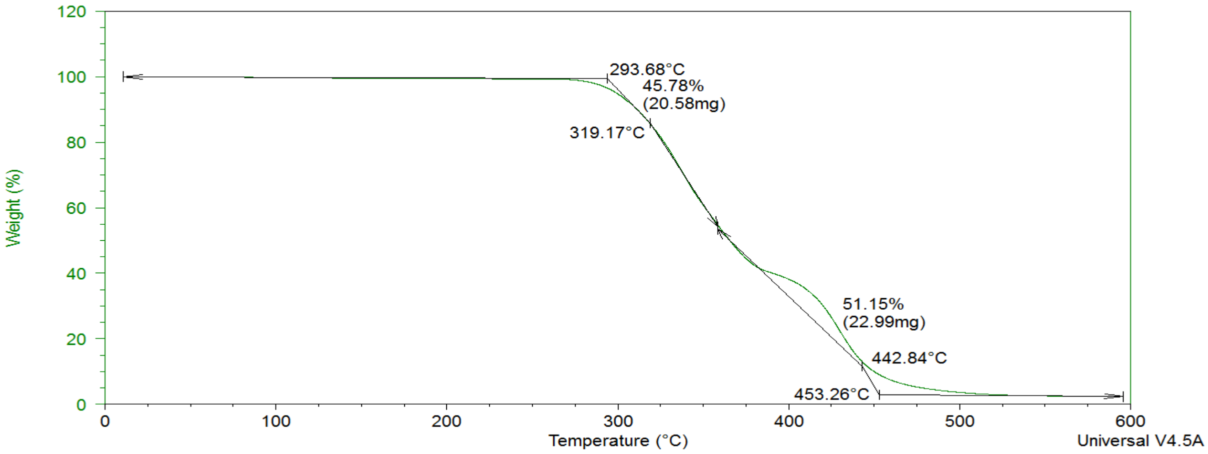


Figure 11: TGA of Texin 950.

Differential Scanning Calorimetry (DSC) is a thermal analysis technique that is used to measure how a material's heat capacity is changed by temperature. This test provides vital information when observing thermal analysis properties, including melt temperature (T_m), glass transition temperature (T_g), crystallization temperature (T_c), and degree of cure (DoC). DSC was performed using a TA Instruments Q200, as shown in **Figure 12**. The parameters were set from 30 ºC to 250 ºC using a heat-cool-heat cycle at 10 ℃ per minute. The sample mass was 4.1 mg for the in-house TPU and 3.4 mg for Texin 950.

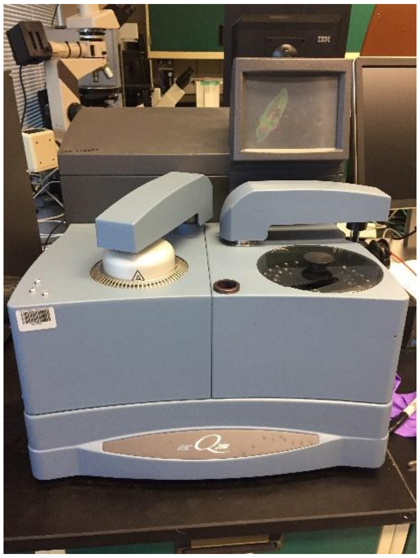


Figure 12: DSC Q200 instrument.

According to the Texin 950 product data sheet, the T_g was recorded at -27 °C. The T_c and T_m were measured. The DSC curves for the in-house TPU and Texin 950 can be seen on **Figure 13** and **Figure 14**, respectively. The T_c was observed at 79.73 ℃ for the in-house polymer and 99.07 ℃ for Texin 950. The difference in T_c could suggest that the in-house TPU is more susceptible to aging effects than the Texin 950. The T_m for the two materials was extremely similar, as the in-house TPU was observed at 182.91 ℃ and Texin 950 was observed at 182.24 ℃. Because the T_m is very similar, the difference in T_c was one of the ultimate deciding factors in the final material selection choice.

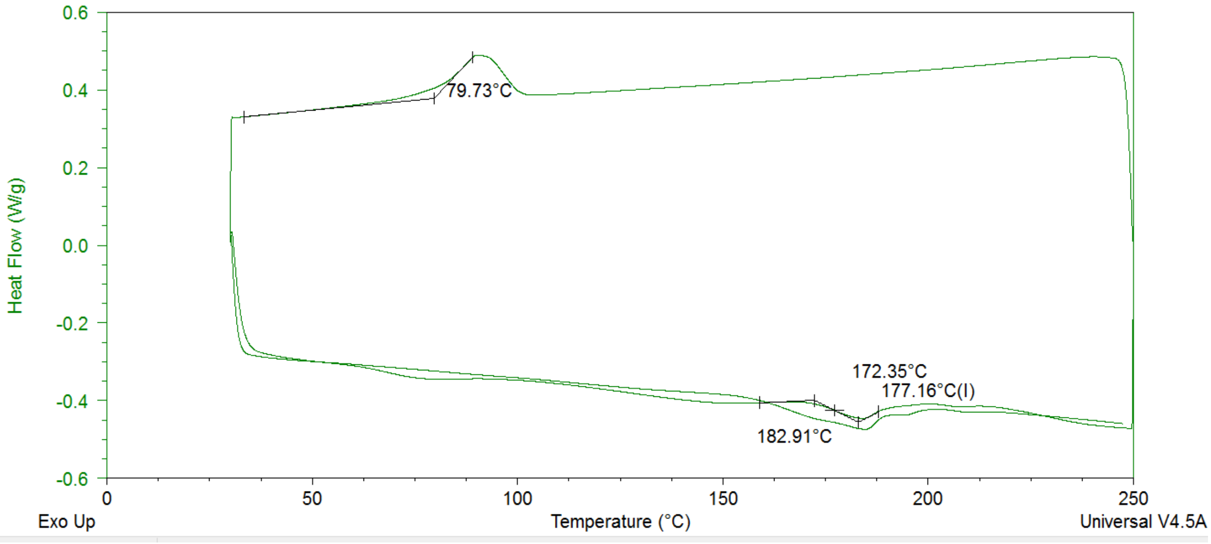


Figure 13: DSC of in-house TPU.

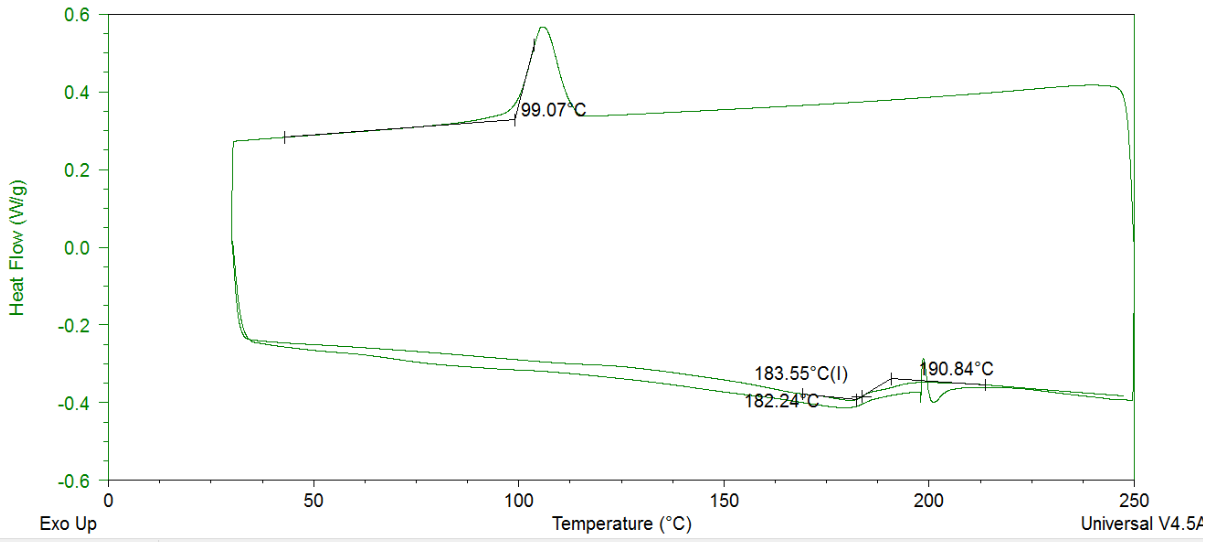


Figure 14: DSC of Texin 950.

From the TGA and DSC data, the materials are observed to be similar in terms of thermal degradation and analysis. According to the property data sheet, the melt temperature of Texin 950 is between 196-215 ^{o}C. Because the T_g of the Texin 950 is at 182.24 ^{o}C, it assures that the property data sheet and DSC run are correct. Because the in-house TPU was made within the Wiggins lab, there is no data sheet to compare our result to a standard. Both materials contain a degradation temperature higher than the melting temperature, meaning the materials can be applied up to very high temperatures before degrading.

Dynamic mechanical analysis (DMA) is a thermomechanical technique that focuses on the stress and strain a material undergoes within a range of temperatures. Storage modulus, loss modulus, and tan delta can be determined depending on the type of experiment being performed. Storage and loss modulus measure the stored energy in the elastic region and the energy as it is dissipated. Tan delta is the storage modulus divided by the loss modulus and is directly correlated to determining the T_g of a material. Before performing any mechanical testing on the TPUs, each material was required to be dried for 2-4 hours in a desiccant dryer. Because the in-house TPU and

Texin 950 have a Shore D hardness of 50, the temperature in the desiccant dryer was set between 85-90 ^{o}C. There was not a vacant desiccant dryer to dry these materials, so they were placed in a vacuum oven for 72 hours at 80 ^{o}C. Once the material was completely dry and purged of any moisture in the thermoplastic pellets, a melt compressor was utilized to make DMA bars. The two plates were set at 240 ^{o}C because that was well above the melting temperature for each material and compressed with 2000 psi. A silicon and metal mold were both used to determine which method was better to produce suitable DMA bars. Both of these methods failed and this resulted in switching from making bars for a three-point bend to a film for tension testing. Using the same parameters for the silicon and metal molds, a thin film was produced by layering two Teflon sheets with each material placed between the sheets. **Figure 15** shows the films that were processed for both the in-house TPU and Texin 950.

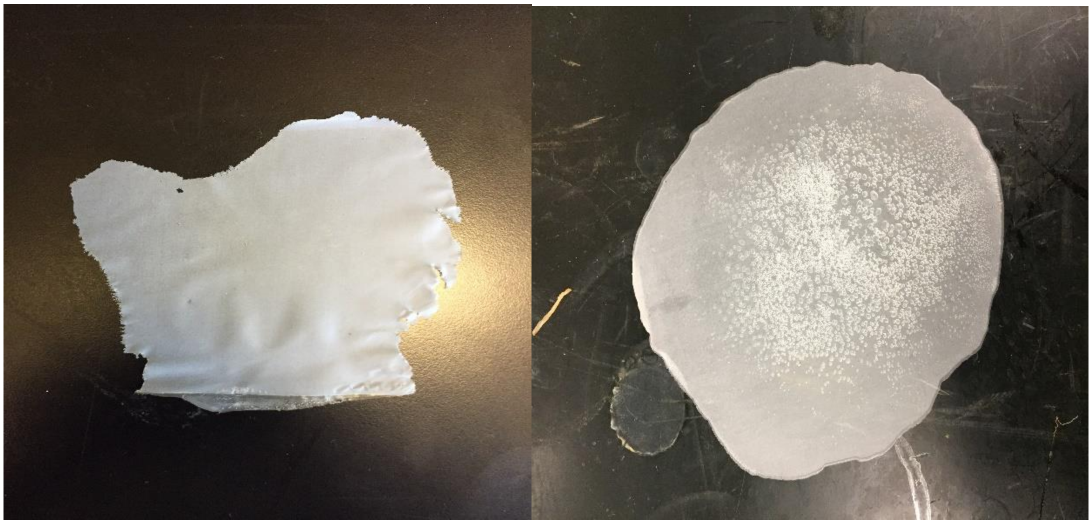


Figure 15: In-house TPU (left) and Texin 950 (right).

DMA was performed using a frequency-strain test on the TA Instruments Q80, as shown in **Figure 16**, using a ramp from 30 ^{o}C to 170 ^{o}C at a rate of 3 ^{o}C per minute. Each run was performed with a frequency at 1 Hz and an amplitude of 15 μm. The dimensions for Texin 950 were 15.8578 mm x 8.05 mm x 0.12 mm ($l \times w \times t$). The dimensions for the in-house TPU were 19.937 mm x 8.10 mm x 0.05 mm ($l \times w \times t$).

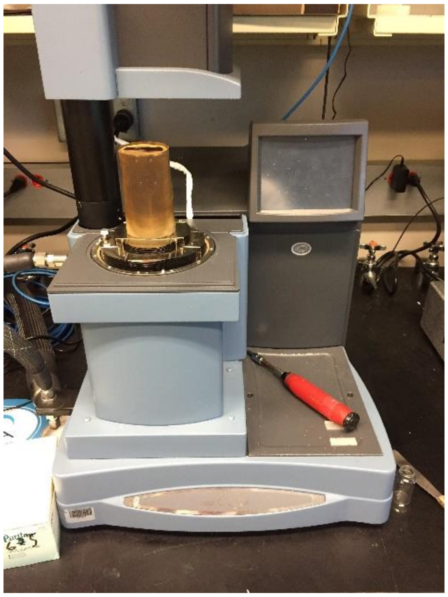


Figure 16: DMA Q80 instrument.

From the DMA curve for the in-house TPU, the storage modulus peaks at 42.72 MPa, while the loss modulus peaks at 7.013 MPa. For the Texin 950, the storage modulus was 47.03 MPa and the loss modulus was 7.492 MPa. These values occur at room temperature and the energy dissipates as the temperature is increased. As previously stated, the T_g of both materials is around -27 ^oC and because it is so low, there is no tan delta peak that is visible. There is plenty of noise that occurs around 170 ^oC because the material began to yield and started to melt while in the Q80 instrument.

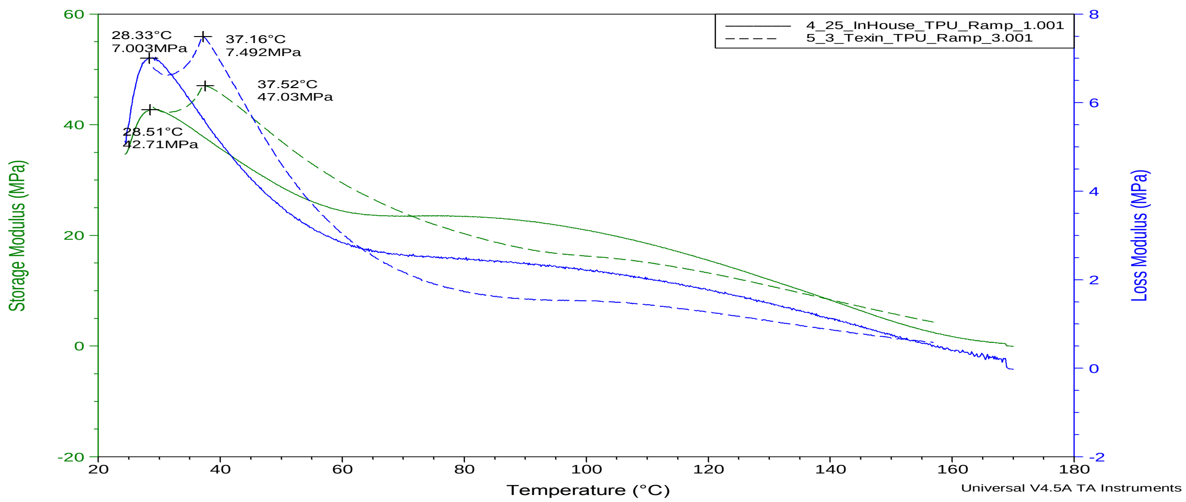
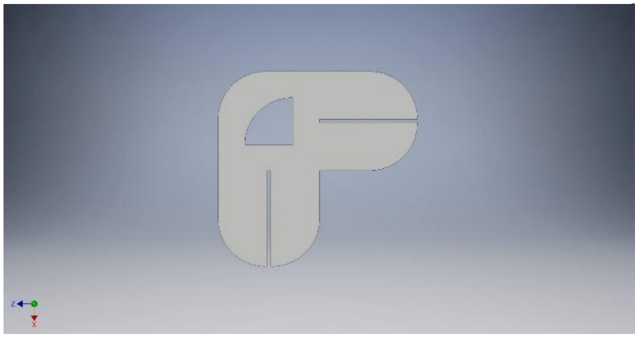


Figure 17: DMA overlay of in-house TPU and Texin 950.

Figure 17 indicates that the thermal and mechanical properties for the in-house TPU and Texin 950 are very similar. Texin 950 provides a higher T_c and higher modulus than the in-house TPU, but the differences are insignificant. From the results, the deciding factor is the more economical of the two choices.

VII. Final Design and Prototype Description

Figure 18.1 displays the tactical shelter corner sealant’s final design and prototype. In comparison to previous iterations, a rounded edge was maintained for our final design to exclude unnecessary stressors. Additionally, a hollow space in the spine of the corner sealant was employed in the final design similar to previous iterations for the purpose of corner sealant weight reduction. The hollow space geometry was selected to be a semi-circle and is displayed in **Figure 18.2**, the cross-sectional area for the final design. Furthermore, a much larger corner sealant wall-thickness-to-panel-gap ratio was chosen to improve the integrity of the corner sealant-panel connection.



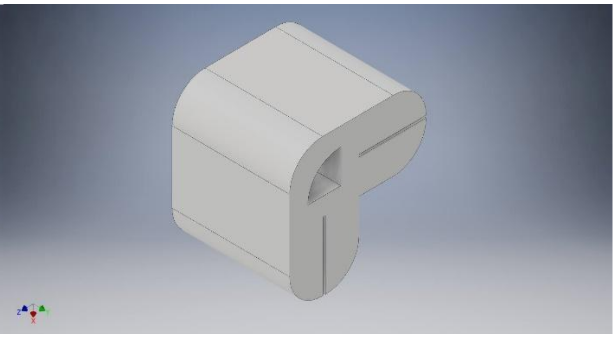


Figure 18.1: Joint piece final design. **Figure 18.2:** Final design cross-section.

VIII. Fabrication Plan

The cost of TPU pellets varies with the supplier, but they are still inexpensive compared to most types of materials. **Figures 19** and **20** show the average price ranges per mass and volume, respectively.

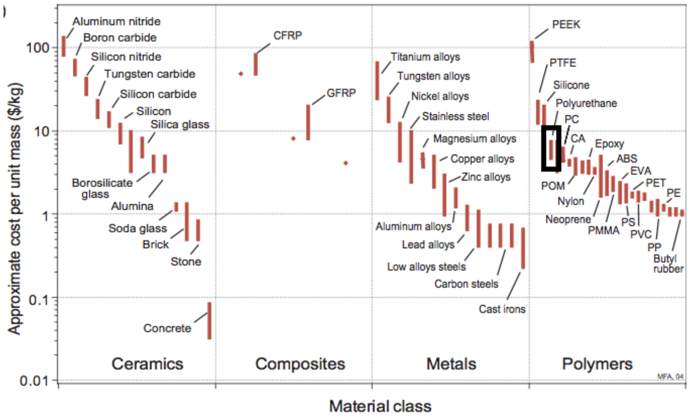


Figure 19: Cost per unit mass (kg).

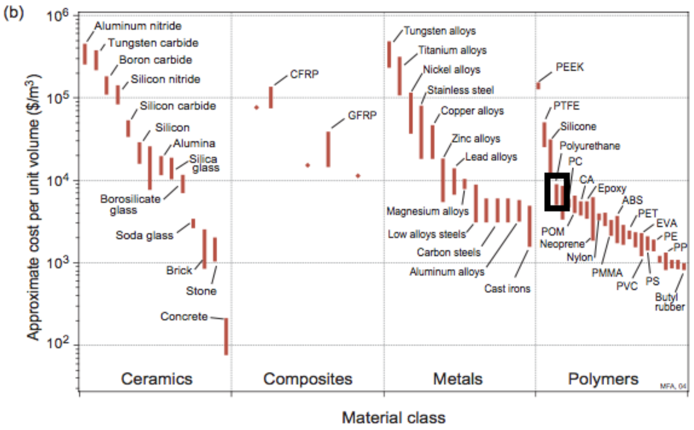


Figure 20: Cost per unit volume (m^3).

To commercially process thermoplastic polyurethane elastomers, injection molding and extrusion are the two methods for manufacturing the final design. TPUs can be injected molded on any commercial equipment that has a screw length-to-diameter (L/D) ratio of 20:1 with a compression ratio of 2.5-3.1. In order to obtain good optical clarity with the products, the material must be molded on highly polished chrome surfaces. When processing the TPU pellets by injection molding, the barrel temperatures will vary within the different zones of the barrel. Because the melt temperature ranges from 190-215 ^{o}C, each zone will be progressively increasing as the material is traveling down the barrel at a pressure of 6,000-15,000 psi. The TPU is injected at a moderate speed because it guarantees that all material will be processed without any discrepancies. Once the material is fully processed, it will enter the mold of the prototype. The mold temperature is set between 16-43 ^{o}C to ensure the rapid cooling of the processed material as it exits the barrel.

Another processing technique that can be used to produce the corner sealant is the process of extrusion. The preferred screw design should have a compression ratio of 3:1 and a L/D ratio of 24:1. Extruders have three zones that will vary between 182-205 ^{o}C with long and gradual transition and meter zones. These parameters are typically used for TPUs. However, every extruder is different and will vary when it comes to setting specific temperature ranges. Both Texin 950 and the in-house TPU are recyclable and can be regrinded into pellets. However, only 20% of these pellets can be mixed in with new material, provided that the material is not contaminated. A mixture of contaminated material with new material will ultimately lead to property failure in certain areas. Even though regrinding is plausible, it is not recommended when processing material that needs to have excellent impact strength.

Proto Labs is a manufacturing company that provides services that include 3D printing, CNC machining, and injection molding. This company can produce 25-10,000+ parts for any need, and the products can be delivered anywhere between 1-15 days. The molds for prototypes start at $1,495 and increase with the difficulty of the design. Because the corner sealant is a simple design, the mold cost will hover around that $1,495 and should not surpass $2,000.

IX. Validation Plan and Results

Analysis of the final design was done using non-ASTM test methods that the design team created. The first test determined the weight of the part, which is crucial for making any decisions for further weight reduction on the part as the project moves forward. This test was performed utilizing the calculated volume of the part using the virtual model generated in Inventor. The volume of the part was calculated by the software to be 4808.63 cm^3. This value can be used to calculate the mass of the part using density values for different grades of material that could potentially be used. The density of Texin 950 was found to be 1.15 g/cm^3.[11] The resulting mass of the part is 5.52992 kilograms, or 12.19 pounds.

Additionally, the part must be able to withstand being dropped repeatedly to ensure longevity in the field. A test that the design team has come up with for the part is to create a silicone mold of the final design, as well as a silicone mold of another design chosen, in order for the team to create some parts out of the chosen thermoplastic polyurethane (TPU) materials. These molded parts can then be dropped pre-determined distances numerous times. This will allow the design team to analyze how the material and part react to hitting the ground numerous times. This will also allow the team to determine certain stress points on the part that need to be reengineered for better load distribution.

Another test that can be performed utilizing these molded parts is a water submersion test. By submerging the part in water for different lengths of time (i.e. 1 hour, 12 hours, 24 hours, etc.), the design team can analyze the effects that water would have on the part, as well as highlight any porous areas of the part. Salt and fresh water could be used to account for different real world scenarios.

X. Design Critique and Discussion

Over the course of this project, challenges presented themselves with regards to prototype design, material choice, and fabrication. Outlying points of criticism were openly discussed by the project group to bring attention to negative and positive aspects concerning the engineering process. Regarding prototype design, the mass of the final prototype was calculated to be 12 pounds, a weight deemed too heavy for individual tactical shelter corner sealants. Additionally, prototype dimensions were limited by 3D printing, which caused difficulty in appropriately assessing the validity of past, as well as current, design iterations. Furthermore, the validation testing was not conducted as prototypes were not fabricated employing selected materials; this caused a lack of representative data. Despite shortcomings surrounding the final prototype, the design concept provides a good basis for possible functioning variations, such as a tactical shelter corner sealant with tunable angles or a three-pronged design with the purpose of supporting a dividing wall.

Further issues were met in prototype material analysis. DMA samples fabricated possessed visible bubbles caused by residual water due to samples not being fabricated through injection molding; a fabrication method was not available in-house. Additionally, the two selected materials for testing possessed similar properties which ultimately caused difficulty in determining the optimum material choice despite both materials possessing favorable properties for injection molding. Researching and testing a wider variety of materials would ensure the best material is chosen, potentially avoiding these unfavorable circumstances.

XII. Conclusion

From soldiers in war to those displaced by disasters, many individuals around the world could benefit from a rapid assembly tactical shelter. The University of Southern Mississippi team's focus of this project was to create a corner sealant for such a tactical shelter. In order to accomplish this task, multiple iterations of the sealant were created in order to find the best design, resulting in a rounded corner piece with a hollow center. This piece was decided upon due to less stressors and weight. However, the weight of the piece is still a concern, because the piece needs to be lightweight for mobility. The team chose TPUs as their materials, ultimately deciding on Texin 950 because of its excellent thermal and tensile properties, as well as being an established and inexpensive polymer. Due to time constraints, further testing of the corner sealant was not able to be accomplished. However, future progress can be made with this project. Developing a wider selection of materials to potentially select a better choice followed by further material testing, fine-tuning the design to overcome any outlying issues present in the final design, and fabricating further prototypes with the newly selected materials via injection molding would push this research further. If these next steps are met, the development of improved tactical shelters with the hope of becoming a lifesaving device could become a reality.

XIII. References

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[1] Wiggins, Jeffrey, Rawlins, James. “Tactical Shelters.” U.S. Army Natick Soldier Research, Development & Engineering Center. 8 Dec. 2016.

[2] “America Enters World War I.” *History.com*. A&E Television Networks, n.d. Web. 6 Dec. 2016.

[3] Anderson, Julie. “Wounding in World War One.” *The British Library*. The British Library. 17 Jan. 2014. Web. 6 Dec 2016.

[4] “WW1 Nurses.” *Kate Luard Unknown Warriors*. The History Press. N.d. Web. 6 Dec. 2016.

[5] Priolo, Gary P. “USS Samaritan (AH-10).” *NavSource Online: Service Ship Photo Archive*. N.p. 18 Dec. 2015. Web. 6 Dec. 2016.

[6] “HDT Global Announces the Acquisition of DHS Technologies’ Operations.” HDT Global. HDT Global. 9 Feb. 2015. Web. 20 Nov. 2016.

[7] Verge, Amy Soo. “RAPIDLY DEPLOYABLE STRUCTURES IN COLLECTIVE PROTECTION SYSTEMS.” N.d. Web. 20 Nov. 2016.

[8] Deru, Michael, Eric Bonnema, Greg Barker, Ed Hancock, and Ashok Kumar. “Energy Performance Measurement and Simulation Modeling of Tactical Soft-Wall Shelters.” United States Army Corps of Engineers. July 2015. Web. 20 Nov. 2016.

[9] Ashby, Michael F. Materials Selection in Mechanical Design. Amsterdam; Boston; Heidelberg...Butterworth-Heinemann, 2017. Print.

[10] "Polyurethanes." *Thermoplastic Polyurethane*. Web. 07 Dec. 2016.

[11] "Covestro Texin 950 Urethane Thermoplastic Elastomer." *Handbook of Plastics Joining* (1997): 485-86. *Look Polymers*. Songhan Plastic Technology Co., Ltd. Web. 26 Apr. 2017.