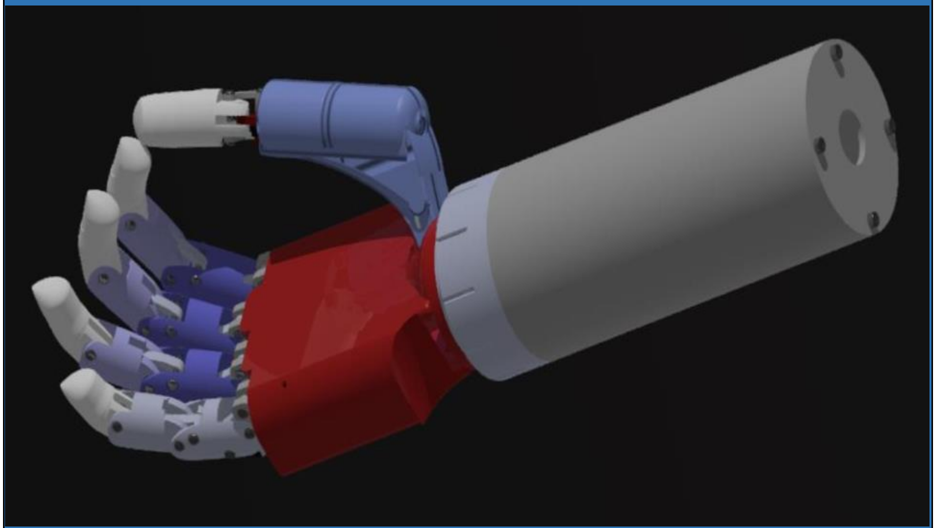
Prosthetic Hand



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Mechatronics Engineering,

Graduation Project Report

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DECLARATION

We hereby certify that this Project submitted as part of our partial fulfilment of BSc in ***(Mechatronics Engineering)*** is entirely our own work, that we have exercised reasonable care to ensure its originality, and does not to the best of our knowledge breach any copyrighted materials, and have not been taken from the work of others and to the extent that such work has been cited and acknowledged within the text of our work.

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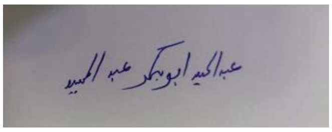
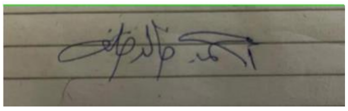
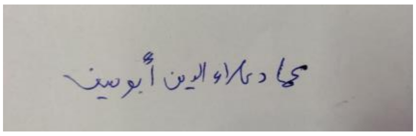
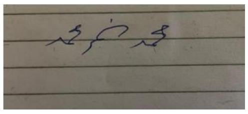
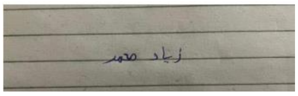
Abdelhamed Abubakr Abdelhamed	18T6373	
Ahmed Khaled Khalaf	1700059	
Emad Alaa El-din	1807013	
Mohamed Nemr Mohamed	1701301	
Zeiad Mohamed Mohamed	1801058	

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ABSTRACT

Many patients with upper limb defects want myoelectric prostheses, For some reason it's not used much. One of the most important reasons is its appearance. There is discomfort due to the difference in joint structure between human hands and robots. The structure should be based on human anatomy to create a more natural looking prosthesis. this Research using bones and multiple muscles to design a biomimetic prosthetic hand Based on the human musculoskeletal system. We reviewed the proposed hand prostheses using the EMG sensor to take signals from muscles.

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1 CHAPTER ONE: INTRODUCTION

Advances in science and technology are pushing prosthetics with promising functional capabilities and aesthetic appearance toward practical application in the research field. Prosthetic hand design is a multidisciplinary and essential knowledge of physiology, anatomy, electrical and electronic systems, mechanical design, software, etc., depending on the type of control. Still, most research is done in the laboratory, and the problem is the lack of integration with technology due to its multidisciplinary nature and lack of funding. There are different types of prosthetic hands, ranging from neural interface-based prosthetics that have been tested. The choice of prosthetic hand depends on the user's requirements. When it comes to fittings that provide “requirements” for arm amputees, there are choices for body-powered prostheses (which provide great function and are lightweight) and electric prostheses.in this project we concentrate on myoelectric arms, the most common electric fittings. First, we look at how a myoelectric arm works and later explain how an amputee learns to use it.

Myoelectric prostheses have motors and batteries to power the movement of the device. Ultimately, it is controlled by inputting electrical signals generated by the muscles of the stump. Where training is provided by an occupational therapist and/or orthopedic technician. When a muscle contracts, it emits an electrical signal. In the prosthesis, electrodes attached to the skin in sockets capture these muscle signals and send them to a controller that initiates movements consistent with the user's intention. When you want to close your hand, contract your muscles as you close, and your hand will close. There are now technologies that make this even more intuitive, allowing individuals to control multiple functions with one hand. B. Grip patterns for one hand, wrist rotator, elbow, and even shoulder.

The advantages of myoelectric prostheses over body-powered devices include a reduction of harnessing, access to effortless strength and multiple grip patterns, more natural hand movements. An often-stated limitation of myoelectric is that they cannot get wet. That too has been overcome with recent advancements in waterproofing technologies for some terminal devices and elbows.

2 CHAPTER TWO: RESEARCH AND HISTORICAL OVERVIEW

2.1 PROBLEM DEFINITION

Hands are an integral part of the human body and have incredible capabilities. In addition to providing gross and fine motor skills essential for bodily survival, hands are fundamental to social conventions and enable greetings, grooming, artistic expression, and syntactic communication.

Losing one or both hands is therefore a devastating experience and requires significant psychological support and physical rehabilitation.

Most hand amputations occur in working-age men, most commonly as a result of work-related trauma or as victims during fights. For thousands of years, people have used cutting-edge technology to create ingenious devices that facilitate the reintegration of hand amputees.

Exploration of the early iron hands intended primarily for combat use, to today's physical power and myoelectric prosthetic hands, to the revolutionary advances in targeted innervation and restoration of sensorimotor control through hand transplantation. Provides a historical overview of progress in replacing lost hands.

From grasping and manipulating objects to nurturing and communicating, the versatility of the human hand is essential to both physical survival and social conventions.

Losing one or more hands is therefore a devastating experience and requires significant psychological support and physical rehabilitation.

The majority of upper limb amputations occurs in working-age men and is most commonly caused by occupational or combat injuries.

Birth defects, cancer, and vascular disease are also leading causes of amputation. For thousands of years, people have used cutting-edge technology to help amputees reintegrate into society. Despite remarkable progress in this field, developing an ideal functional and cosmetic replacement for the lost hand remains a challenge for clinicians and researchers.

2.2 RESEARCH

Background investigation was done to make sure we were making informed decisions before jumping right into the development phase. We looked into the following areas to achieve this:

- Prosthetic devices
- Non-anthropomorphic prosthetic devices
- Prosthetic hand with myoelectric sensor
- Human Hand Anatomy

2.2.1 PROSTHETIC DEVICES

In medicine, a prosthesis is defined as an artificial device that replaces a lost

A part of the body lost due to trauma, disease, or congenital disease. prosthesis that replaces part of

The arm between the elbow and wrist is called a transradial prosthesis, also known as a "BE" prosthesis.

for lower extremities. These devices can be functional or simple looking, depending on their intended use. Physically challenged individuals who require a device that is durable, reliable, and strong due to manual work

A simpler prosthesis such as a hook may be selected. On the other hand, ready individuals

Sacrifice functionality for a more natural-looking prosthesis can opt for cosmetics.

A prosthesis (also called cosmesis) as shown in (Figure 1)

Figure 1: Personalized Cosmetic Prosthetic Hand by Sophie de Oliveira Barata

There are her two main types of functional trans radial prostheses: body-fed and external.

Driven. Body-powered prostheses are controlled by cables connected to harnesses or straps.

Attached elsewhere on the user's body. Move forward when the user moves their body in a certain way.

A cable causes the movement of the prosthesis. The simple nature of these devices makes them extremely lightweight.

But it also means you can't usually do complex tasks. common terminal z

A body-powered prosthesis is a scissor-like mechanism called a split hook, as shown in the diagram.

However, many other tasks exist for more specific tasks such as fishing and cooking.

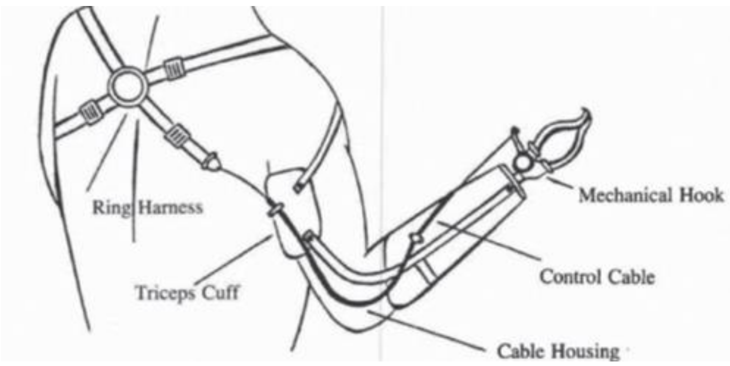


Figure 2: Typical Body Powered Trans radial Prosthesis

An externally powered prosthesis is a device that draws energy from some other source.

user's body. Most modern devices that are electrically powered can utilize multiple electric motors.

Other electrical components to achieve more complex grips and functions than achievable.

With a simple body-powered device. Allows additional use of onboard microcontrollers and sensors.

Allows you to control these prostheses in different ways. A common technique for controlling an externally powered prosthetic device is a switch.

control method. This procedure allows the user to toggle a switch or move the prosthesis.

Key. The user can toggle the switch on different parts of the body.

With the remaining muscle of the shoulder or stump. These devices usually support this, so

To perform such a wide variety of grips, users often use different shift knob sequences to

Toggles between different grip modes. Another advanced way to control an externally powered prosthesis is:

By using electrodes. When these sensors are placed on the surface of the skin,

It detects small electrical signals produced by muscle contractions in the user's stump. of

Most applications use additional software and circuitry to operate these analogy devices.

The user can control the device in a way like the switch control method. Devices that use this technology are called myoelectric prostheses. Some examples of commercials

Myoelectric prostheses available are Be bionic Hand and i-Limb. Each device is advanced.

An externally driven prosthesis currently considered the top product in the industry.

trans radial prosthesis

2.2.2 NON-ANTHROPOMORPHIC PROSTHETIC DEVICES

One of the most commonly used non-anthropomorphic terminals on the torso

Today's prosthesis is a split hook. A simple device consists mainly of two hooks connected to each other.

Hinged together at the base. This design allows the hook to open and close like pliers.

Enables basic grip functionality. The curved shape of this prosthesis offers several functions

Also, as long as there is a hole, handle or indentation where the hook fits. These devices are usually.

It is powered by the main unit, but an externally powered version is also available. More versatile than others

Prosthesis Compensates for functionality lacking in split hooks with durability and low cost

Figure 3:Common Split-Hook Terminal Prosthetic Devices

Custom Non-anthropomorphic prostheses are also developed for more specific tasks such as

cooking or fishing, or even for sports like basketball, climbing, or golf. It is not uncommon for an individual to own several functional prostheses intended for different tasks as well as a cosmesis for

social events.

2.2.3 Anthropomorphic Prosthetic Devices

At the opposite end of the trans radial prosthetic spectrum are I-LIMB and

baby ionic hand. This new generation of externally powered robotic prostheses combines functionality.

Natural and anthropomorphic appearance. Include opposite thumb and four.

Independently actuated fingers not only allow for more human-like movements, but also a wider reach.

of the grip pattern. Sensors within the device enable system feedback to improve performance.

In some cases, they even use lights, vibration motors, or other interfaces to provide user feedback. Prostheses are typically myoelectric. To operate the device, the user performs a combination.

A muscle contraction that triggers one of the preloaded grip patterns. number available

The pattern may vary from 14 to 24 depending on the model.

Figure 4:: Anthropomorphic Prosthetic Hands Showing bebionic (left), i-LIMB Ultra Revolution (center), i-LIMB Cosmetic Cover

These devices have many advantages over previous simpler prostheses, but additional.

Due to the weight caused by the on-board electronics, it can be uncomfortable when used for a long time.

from time. Another drawback of these devices is their high price. Adjusted peak around $100,000

Many potential users find it difficult to buy, even with insurance.

2.2.4 Human Hand Anatomy

Our arm is designed to be anthropomorphic and requires a fairly comprehensive understanding.

I needed the anatomy of the human hand. Here we will discuss various bone and muscle terms.

Groups and their main functions and physical aspects. The human hand consists of his 29 large and small bones, of which there are quite a few.

The wrist has 29 major joints and 34 muscles, 18 of which are in the forearm. Hand

There are only 22 degrees of freedom. 3 flexions and 1 abduction and 1 adduction for each finger and thumb

There are two more between the 4th and 5th digits of the metacarpal bones, allowing the palm to bend. all these

The joint is shown in (Figure 5) below

The wrist and forearm add three more degrees of freedom. Rotation about x, y, z axes

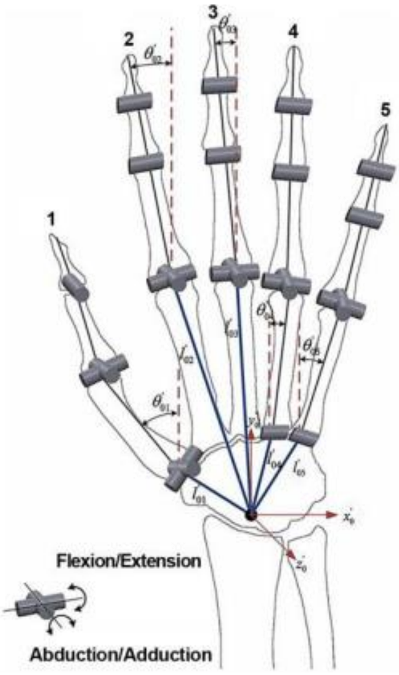


Figure 5: Hand Joint Diagram

from the middle of your wrist. The naming scheme for these bones follows a fairly simple naming convention. those bones

What forms the compound wrist is known as the carpel. bones that make up the palm

called the metacarpal bone. The bones that make up the fingers are known as phalanges. Phalanx

The base of the finger that connects to the knuckle is more accurately called the proximal phalange. Then follow the intermediate or intermediate links and finally the end links form the tip

of fingers. The thumb differs in that it has no intermediate links.

Connect the terminal link directly to the base link (“Hand.”, 2014). Each finger can flex, extend, abduct and add by flexing and relaxing.

some muscle groups. Fingers themselves don't have muscles, but are connected by tendons.

The muscles that give them strength are in the palms and forearms. The muscles located in the palm are called.

Consists of the ball of the foot (the muscle that moves the thumb) and hypomyasthesia as intrinsic muscles.

(Muscles that drive little fingers), dorsal and palmar interosseous (muscles between little fingers)

9

metacarpals, abduction, and adduction of the middle three fingers respectively) and psoas muscles

(Muscles that flex the metatarsophalangeal joints and extend the interphalangeal joints). muscle

Those with a belly on the forearm are called extrinsic and include large.

A strong muscle that allows you to flex and extend your three middle fingers.

2.3 HISTORICAL OVERVIEW

a historical overview of approaches to replace lost hands, from early iron hands to today's standard prosthetic hands to revolutionary advances in sensorimotor restoration was researched and came as follow.

FROM ANTIQUITY TO THE MIDDLE AGES: IRON HANDS

One of the earliest records of a prosthetic hand is described in AD 77 by the Roman scholar Pliny the Elder in his encyclopedia Naturalis Historia. After losing his one arm in the Second Punic War (218 BC-201 BC), the Roman General Marcus Sergio’s received his prosthetic arm and was able to rejoin battle.

“Sergius in his second campaign lost his right hand… He had a right hand of iron made for him and going into action with it tied to his arm, raised the siege of Cremona…”

One of the most famous examples of early prosthetic hands is the iron hand of the German knight Goetz von Berlichingen.

After Goetz lost his hand at the Siege of Landshut in Bavaria (c. 1505), the craftsmen passively flexed the metatarsophalangeal joints, proximal and distal interphalangeal joints, interphalangeal joints and made him iron hands with outstretching fingers.

With the prosthesis tightened, Goetz was able to grip the reins, grab the weapon, and return to battle. The device was modeled as an extension of his battle armor rather than a human arm, and due to its weight, had to be attached to Goetz's armor with thick leather straps.

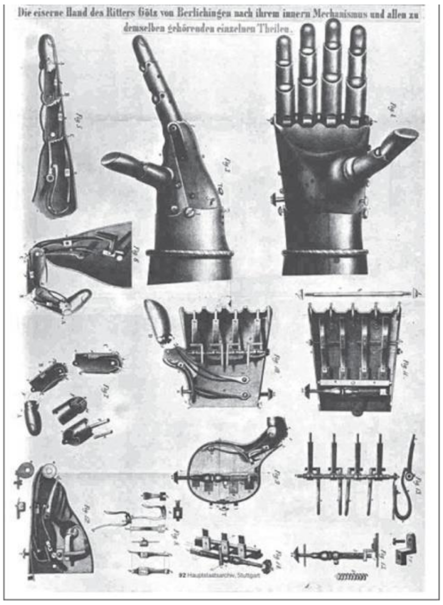


Figure 6: Illustration of the numerous components of Götz’s medieval hand prosthesis

ITALIAN HISTORIAN AND PHYSICIAN PAOLO GIOVIO

reports that the Turkish pirate Horc Barbarossa lost his right hand in the Battle of Bugia with Spain (c. 1517) and received an iron replacement so he could continue the fight. Another example of an iron hand was that of a Dutch craftsman of Christian, Duke of Brunswick, who lost his left hand at the Battle of Fleury (c. 1622).

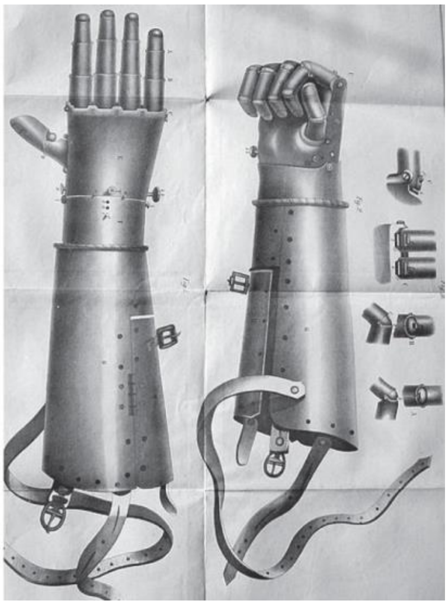


Figure 7: “The iron hand of Götz von Berlichingen featured articulations at the

One of his first descriptions of a non-combatant prosthetic hand was by Italian surgeon Giovanni Tommaso Minadoi in the 1600s, who could take off his hat, unbuckle his purse, and even write with a quill.

IN THE 16TH century, French military surgeon Ambroise hisparais drew the first detailed design of a spring-loaded prosthetic hand, called "le Petit-Rolin" after the craftsman who made it (figure 9).

Paré also donned his prosthetic arm for a humerus amputation (figure 8)

Figure 9 Ambroise hisparaisspring loaded prosthetic hand

Figure 8 : Paré s prosthetic arm for a humerus amputation

Although heavy and requiring control by the intact hand opposite the amputee, early prosthetic hands successfully restored a knight's ability to hold a shield or weapon during combat.

BODY-POWERED PROSTHESES, TWO WORLD WARS AND THE CREATION OF DEDICATED PROSTHETICS ORGANIZATIONS

IN 1818, the concept of “automatic” body-powered upper limb prosthesis was developed by the German dentist Peter Buriff.

By transmitting tension through leather straps, Barif's device allowed the intact muscles of the trunk and shoulder girdle to initiate movement at terminals attached to the amputated stump.

For the first time, an amputee was able to manipulate prosthesis with fluid body movements rather than as a foreign object in itself. it changed. Shoulders with straps buttoned to pants

His harness was threaded through loops to the opposite armpit and to the missing limb. Stretch with fused fingers

IN 1916, German surgeon Dr. Ferdinand Sauerbruch published the design of a prosthetic limb that controlled the fingers by transmitting the movement of the muscles of the upper arm.

Figure 10 : Sauerbruch’s prosthetic hand design in the early 20th century

WORLD WAR I (1914-1918) caused an unprecedented number of casualties. In the United States (USA), the Amputee Rehabilitation Program was created to help more than 4,400 amputees, most (54%) of whom have upper extremities, regain their ability to work on farms and factories. it was done. The distribution of prostheses with sockets and universal attachment devices allowed attachment of a variety of working tools.

In 1917, the U.S. Army's Surgeon General issued a groundbreaking invitation for limb manufacturers to meet in Washington, DC.

This resulted in the formation of the American Limb Manufacturers Association, now the American Association of Prosthetics and Orthotics. In Canada, a national charter in 1920 recognized the need to support amputees, leading to the formation of the World War I Amputee Society, now known as War Amps.

DURING WORLD WAR II (1939–1945), improved shock management and antibiotics saved lives, but 3,475 upper limb amputees occurred in the United States. The enormous demand for prosthetic limbs led to the formation of the US Prosthetic Limbs Research and Development Committee in 1945 and the Canadian Association of Prosthetics and Orthotics in 1955. The thalidomide tragedy (1958-1962), which produced many children with short limbs, further fueled demand and investment in improved prostheses.

In 1948, the body-powered Bowden Cable Prosthesis was introduced, replacing the bulky straps with slim, robust cables. Despite new materials and improved craftsmanship, today's body-powered prosthetic legs are essentially adaptations of Bowden's design.

Durable, wearable, and relatively affordable, body-powered prostheses use terminal devices (most commonly two hooks) to change cable tension with sustained shoulder and body movements.

It provides users with impressive range of motion, speed and power when manipulating the Rather than requiring a healthy hand to control the prosthesis, both hands can be used simultaneously, allowing users to complete their tasks more efficiently.

Additionally, sensing cable tension allows the amputee to anticipate and adjust prosthesis position without visual feedback. Prolonged wear can be uncomfortable, complex motor tasks are restricted, and body-powered prostheses are widely used, although not human-like in appearance.

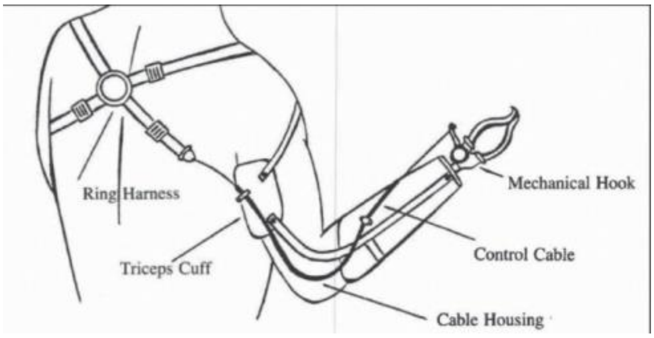


Figure 11: schematic of Bowden cable prothesis

ROBOTIC TECHNOLOGY MYOELECTRIC PROSTHESES

In 1919, a German book titled *Ersatzglieder und Arbeitshilfen* (*Limb Substitutes and Work Aids*) contained conceptual designs for the first externally powered prostheses, using pneumatic and electric power sources. Unfortunately, these revolutionary designs were too complex to be feasible with contemporary technology.

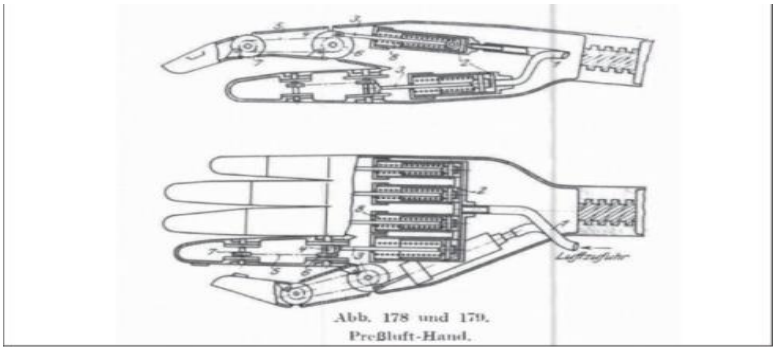


Figure 12: Early compressed gas-powered prosthetic hand from 1919

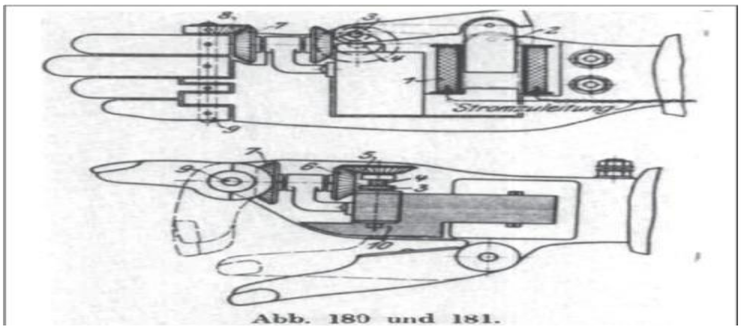


Figure 13: Electromagnetic hand prosthesis from 1919

IN 1948, Reinhold Reiter, a physics student at the University of Munich (Munich, Germany), created the first electromyographic prosthesis, a device that amplifies surface electromyographic (EMG) potentials to drive motorized parts. Did. Reiter published his work, but it was not widely accepted, and this potentially groundbreaking invention was not commercially or clinically accepted.

The first clinically significant myoelectric prosthesis was presented in 1960 by Russian scientist Alexander Kobrinsky. The use of transistors reduced bulk and made the device portable, and the battery and electronics were attached to a belt and wires connected to the prosthetic leg. The prosthesis was also fitted with flesh-colored rubber cosmetic gloves. This "Russian hand" was marketed in England and Canada, but had many problems: heavy, slow, weak clamping force, easily damaged cable connections, and electrical interference affecting reliability.

In the 1980s, myoelectric prostheses were used in rehabilitation centers around the world and are now a popular choice for amputees.

Improvements in materials have enabled lighter and more ergonomic designs, and power has evolved from compressed gas to rechargeable nickel-cadmium batteries.

Compared to body-powered prostheses, myoelectric prostheses offer superior comfort and aesthetics, no unsightly cables, and a wide variety of lifelike silicone palms and skin pad options. Moreover, signal detection is non-invasive to the skin surface and the surgical effort is comparable to that of normal limbs.

Control muscles vary according to the amputation level of the patient. For example, most sub-elbow (trans-radial) amputees use the preserved wrist flexors and extensors to control the prosthesis, whereas supra-elbow (trans-brachial) amputees also use the biceps and triceps. Incorporate and control the prosthetic leg.

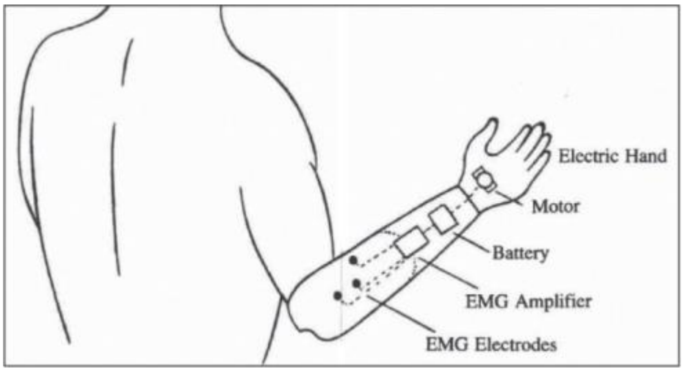


Figure 14: Myoelectric below-elbow prosthesis, controlled by electromyographic (EMG) potentials

However, unlike body-powered prostheses, myoelectric prostheses are externally powered and require regular charging. Learning to isolate muscle signals can be cumbersome, require multiple phases of training, and may not be possible for complex movements that require simultaneous joint movement in fingers, wrists, and elbows.

There is a delay between the initiation of the motion command and the mechanical response, with small variations of: For example, electrode displacement or changes in skin conditions (such as perspiration) can disrupt the EMG signal.

Without sensory feedback, visual input must be constant, which is tedious, error-prone, and unnatural.

Cosmetic overlays are impressive for their realism, but durability is an issue, with users complaining of frequently changing gloves due to wear, cuts, and stains.

Osseointegration, the direct attachment of titanium attachments to living bone, eliminates the need for a cup and improves stability and comfort at the prosthesis-stump interface.

Osseointegration was developed by Swedish surgeon Per-Ingvar Brånemark in his 1950s, but it was his son Rickard Brånemark who pioneered its application to prosthetic limbs.

By providing stable fixation, Osseo-integrated prostheses increase the range of motion of amputees while eliminating socket-related problems such as chafing and sweating.

Due to the close connection between the prosthesis and the skeleton, users can also experience improved pressure and vibration sensations.

Between 1990 and his 2010, Brånemark's team fitted his 10 trans-radial and his 16 trans-humeral osseo-integrated prostheses. Only three patients failed to use the prosthesis later because of implant fracture, traumatic injury, or incomplete integration. It is a major constraint for more adoption of the integration.

Despite its widespread use, myoelectric technology is expensive and may not be covered by insurance plans. In the 1990s, terminal-equipped myoelectric prostheses for forearm amputees cost approximately six times as much as body-powered prostheses.

In Canada, a trans-radial electromyographic hand costs him $7,500 to $29,500, and a trans-brachial electromyographic prosthesis is up to $80,000. By comparison, a traditional body-powered prosthesis costs about $5,500.

INTUITIVE MYOELECTRIC CONTROL WITH TARGETED REINNERVATION

A major advance in intuitive control of prosthetic limbs is the technique of Targeted Motor Reinnervation (TMR), first developed in 2004 by Dr. Todd Kuiken and Dr. Gregory Dumanian, of America.

By rerouting severed (i.e. severed) peripheral nerves from the amputated limb to an intact surrogate (target) muscle, the EMG signal obtained from the target muscle is transferred to the muscle of the missing limb by the movement of the muscle. Provide input.

For example, when the median nerve is conveyed to the abdomen of the central pectoralis major muscle, given that the amputee "bends the fingers", the central part of the pectoralis major muscle is contracted, giving him a robust edge to close the prosthesis. An EMG is generated. Unlike traditional body-powered myoelectric prostheses, TMR is intuitive and allows patients to move multiple joints simultaneously.

Opening and closing the prosthesis while bending and extending the elbow increases the speed of execution of the task from 2 to 6 times his.

In addition to improved motor control, a recovery of sensation was noted in the skin overlying reinnervated muscles in early TMR patients. When the reinnervated skin was stimulated, sensations were experienced in the area of the body that the severed nerve had used for innervation. That is, amputees felt touched to specific parts of the missing limb.

This knowledge has extended the technique of targeted reinnervation to reattach sensory nerves to the main trunks of peripheral nerves.

A multidisciplinary team at the University of Alberta (Edmonton, Alberta) identified, isolated, and rerouted individual sensory nerve fibers from the median and ulnar nerves to target sensory skin areas away from reinnervated muscles. We have developed a variation of this surgical technique. This technique, known as fascicular target sensory reinnervation, creates individualized handheld spatial sensory maps over selected areas of receptor skin remote from the prosthetic interface. By incorporating a sensory feedback device, the patient can feel and regulate the amount of force exerted by the myoelectric prosthesis when manipulating objects. Preliminary results show discernible pressure sensation (up to 4 discrete levels of force with 75% to 85% accuracy), ability to grasp and release objects, and ability to discriminate size (mean [±SD] 93) have shown effective recovery. ±6% accuracy) and density (100% accuracy) without visual or auditory stimulation

Reported complications of targeted reinnervation procedures include increased cellulitis, seroma, and transient phantom limb pain. Surgery, hospitalization, prosthetics, and rehabilitation costs range from $150,000 to $250,000.

Although still in the early stages of development, more than 40 of her patients have undergone targeted reinnervation worldwide since 2011.

3 CHAPTER THREE: IMPLEMENTATION

A systems engineering approach identified stakeholders and needs. those needs

Combine these into a general, step-by-step process called a goal. of

The achievement of the following goals represents a complete need within the framework of our project.

3.1 OBJECTIVES :

1.) Design and create a prosthetic device for anthropomorphic actuation

2.) Design an electrical system with all components and controllers integrated with it

3.) Design and create a control scheme to tie all systems of the arm together

3.2 MECHANICAL DESIGN

3.2.1 Finger Design

A key element in the design of our anthropomorphic prosthetic hand was the development of five human-like fingers. To maintain an anthropomorphic appearance, the fingers had to not only look human, but also move naturally and humanly. After carefully observing the movement of the hand, Using everyday object-grabbing methods and anatomical restraints, we discovered a common curling motion that allowed fingers to tightly close around objects of various sizes and shapes. The challenge, however, was to design a mechanism that replicated this movement and fit into a housing no larger than the average man's finger. We also needed a tough design that could withstand the rigors of everyday use. Before doing any major design work, we explored several options for achieving the desired finger movements. Based on our own considerations and some preliminary research, we have developed two possible methods. The first method is Fixed to finger segments and tips. The cable is routed so that it curls when one of his fingers is pulled. This is similar to how muscles and tendons operate in a natural finger. The second method used a series of inverted fournode linkages embedded in the finger.Segment itself to create the same curling method. Below is a table of the pros and cons we have Discovered for each method

Cable system	Linkage system
Pros: • Fewer necessary moving parts • Simpler design • Fewer Materials • Low Cost Cons: • Cable can stretch over time • Routing may be difficult • Possibly more friction	Pros: • Low friction • Rigid bodies will not stretch • More accurate position control • Simple design Cons: • Lots of moving parts allows for more points of failure • Could take a while to find the ideal link length • Link length will differ in every finge

Table 1 Cable vs linkage system

After considering each option, we decided that wed use the linkage connection system. It's relatively elaborate and a bit pricey, but I figured the cable routing would be too difficult to manage and the friction created by the system would cause problems when moving my fingers. We thought that it would be possible to approximate the position more accurately, which would improve motion control. Yes, I was worried that it might break. A basic illustration of the linkage system is shown below in (Figure 15)

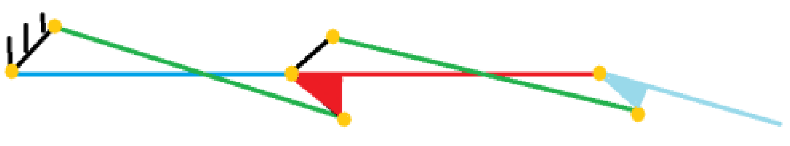


Figure 15 : Finger Serial Inverse Four-bar Kinematic Linkage System Diagram

the linkage system was constructed on (SAM the simulation software)taking in consideration the design parameters :

- length of the links
- mass of the links and the finger

to analyze the mechanism and calculate all required parameters, the simulation was ran and the following results were obtained

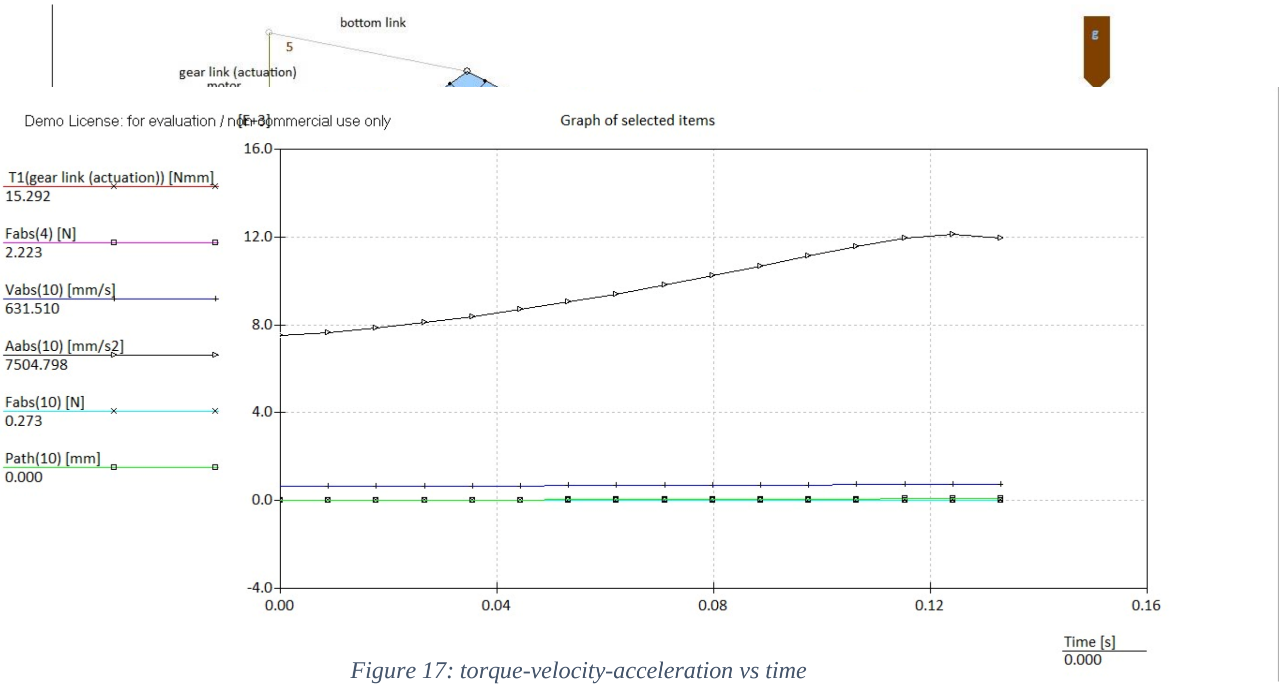


Figure 17: torque-velocity-acceleration vs time

Nr	Time	T1(4)	Fabs(4)	Vabs(10)	Aabs(10)	Fabs(10)	Path(10)
[-]	[s]	[Nmm]	[N]	[mm/s]	[mm/s2]	[N]	[mm]
0	0.000E+00	1.529E+01	2.223E+00	6.315E+02	7.505E+03	2.728E-01	0.000E+00
1	8.867E-03	1.481E+01	2.135E+00	6.365E+02	7.652E+03	2.839E-01	5.618E+00
2	1.773E-02	1.425E+01	2.042E+00	6.425E+02	7.853E+03	2.964E-01	1.129E+01
3	2.660E-02	1.357E+01	1.938E+00	6.493E+02	8.096E+03	3.100E-01	1.701E+01
4	3.547E-02	1.275E+01	1.818E+00	6.565E+02	8.376E+03	3.242E-01	2.280E+01
5	4.433E-02	1.175E+01	1.679E+00	6.640E+02	8.689E+03	3.388E-01	2.865E+01

6	5.320E-02	1.058E+01	1.517E+00	6.716E+02	9.034E+03	3.535E-01	3.456E+01
7	6.207E-02	9.210E+00	1.329E+00	6.792E+02	9.409E+03	3.681E-01	4.055E+01
8	7.093E-02	7.640E+00	1.112E+00	6.868E+02	9.812E+03	3.823E-01	4.660E+01
9	7.980E-02	5.868E+00	8.633E-01	6.942E+02	1.024E+04	3.959E-01	5.272E+01
10	8.867E-02	3.895E+00	5.805E-01	7.014E+02	1.069E+04	4.083E-01	5.890E+01
11	9.753E-02	1.729E+00	2.615E-01	7.083E+02	1.114E+04	4.190E-01	6.515E+01
12	1.064E-01	-6.180E-01	9.498E-02	7.149E+02	1.158E+04	4.272E-01	7.145E+01
13	1.153E-01	-3.134E+00	4.898E-01	7.211E+02	1.194E+04	4.314E-01	7.781E+01
14	1.241E-01	-5.819E+00	9.249E-01	7.265E+02	1.213E+04	4.295E-01	8.422E+01
15	1.330E-01	-8.737E+00	1.411E+00	7.308E+02	1.194E+04	4.173E-01	9.068E+01

Table 2: simulation results

We also made calculations for the forces acting upon the fingers with and without the rubber band.

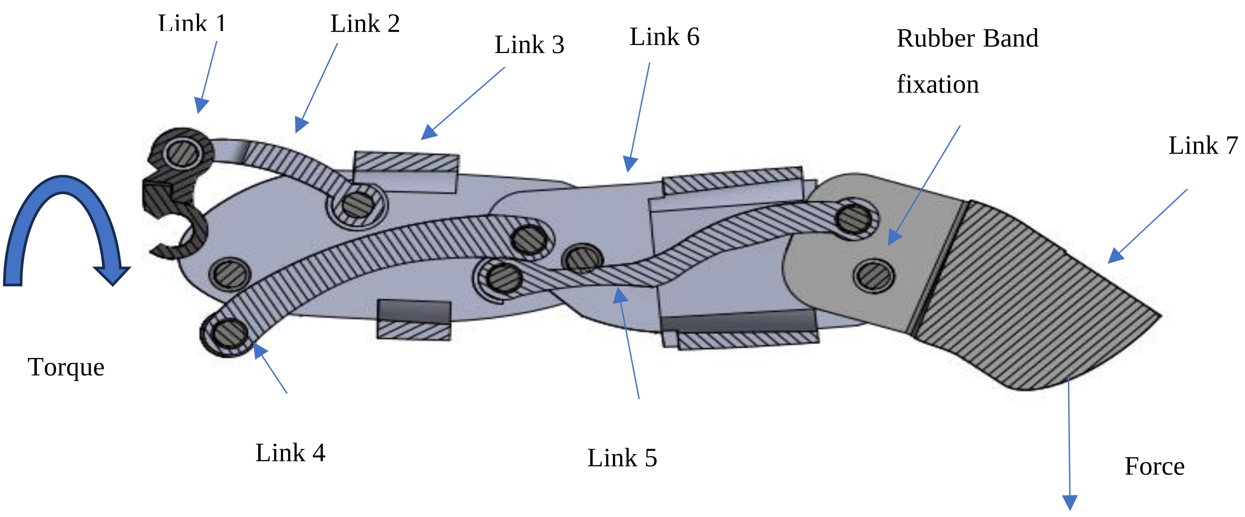


Figure 18 Finger detailed links

The maximum force is the force that makes the mechanism in equilibrium state, so that any task should the finger handle must be lower than the maximum force.

<u>Using static analysis.</u>

Case (1); without the rubber band and neglecting loses and friction.

Link 1

$$\theta_1 = \tan^{-1}\left(\frac{6.015}{06.965}\right) = 19052214°$$

$$\sum M_G = 0 \therefore T = (1.082 sin\theta_1 + 8.935 cos\theta_1) f_{21}$$

$$f_{21} = \frac{100}{8.783} = 11.386\ N$$

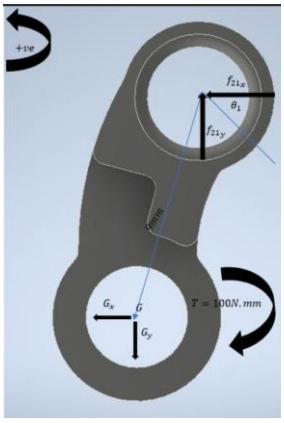


Figure 19 Link 1

Link 2

$$f_{12} = f_{21}$$

$$\sum f_x = 0$$

$$\therefore f_{12} cos\theta_1 = f_s \cos(90 - \theta_2)$$

$$f_s = \frac{f_{12} cos\theta_1}{f_s \cos(90 - \theta_2)} = \frac{11.386\cos(19.52214)}{\cos(90 - 32.81)}$$
$$= 19.81\ N$$

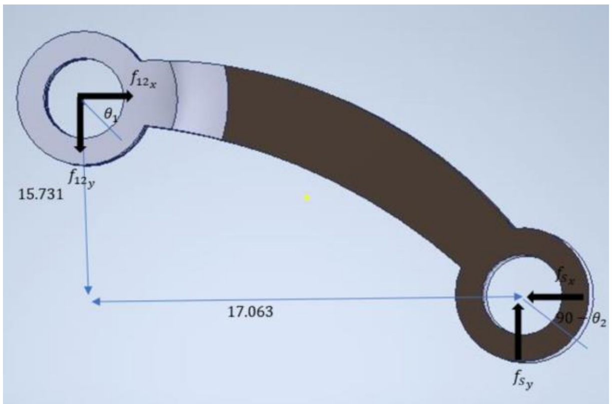


Figure 20 Link 2

Link 3

$$\theta_2 = \tan^{-1}\left(\frac{8}{12.41}\right) = 32.81°$$

$$\delta = \tan^{-1}\left(\frac{5.762}{34.015}\right) = 9.6°$$

$$\gamma = \tan^{-1}\left(\frac{2.018}{7.609}\right) = 14.8536°$$

$$\sum M_A = 0$$

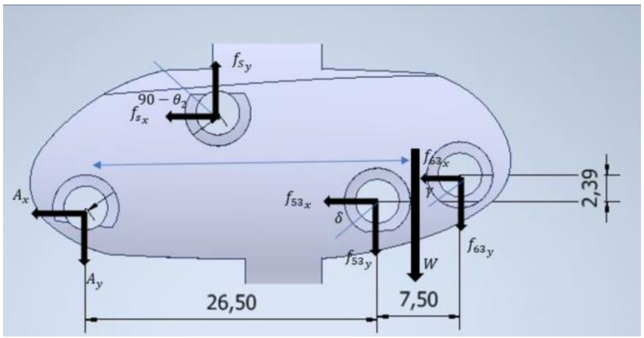


Figure 21 Link 3

$$\therefore f_{63x} = f_{63x}\cos(14.8536)\,, f_{63y} = f_{63y}\sin(14.8536)$$

$$f_{53x} = f_{53}\cos(9.6)\,, f_{53y} = f_{53}\sin(9.6)$$

$$1.321f_{63x} - 34.107f_{63y} + 8f_{sx} + 12.41f_{sy} - 0.7f_{53x} - 26.498f_{53y} - 27.711\omega = 0 \dots\dots\dots\dots (1)$$

Link 5

$$\theta_3 = \tan^{-1}\left(\frac{6.727}{1.732}\right) = 75.562°$$

$$f_{75x} = f_{75}\cos(75.562)$$

$$f_{75y} = f_{75}\sin(75.562)$$

$$f_{35x} = f_{35}\cos(9.6)$$

$$f_{35y} = f_{35}\sin(9.6)$$

$$f_{35x} = -f_{75x} \dots\dots (2)$$

$$f_{35y} = f_{75y} \dots\dots (3)$$

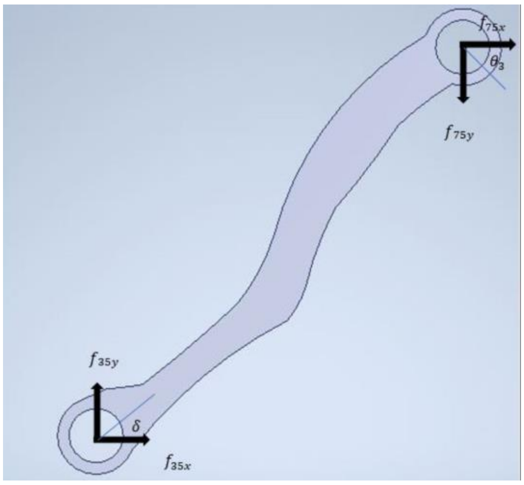


Figure 22 Link 5

Link 6

$$\theta_4 = \tan^{-1}\left(\frac{6.727}{1.732}\right) = 75.562°$$

$$\sum M_o = 0$$

$$\therefore \left(5.107f_{36y} + 2.635f_{36x} - 33.246f_{76y} + 5.618f_{76x}\right) = 0 \dots\dots (4)$$

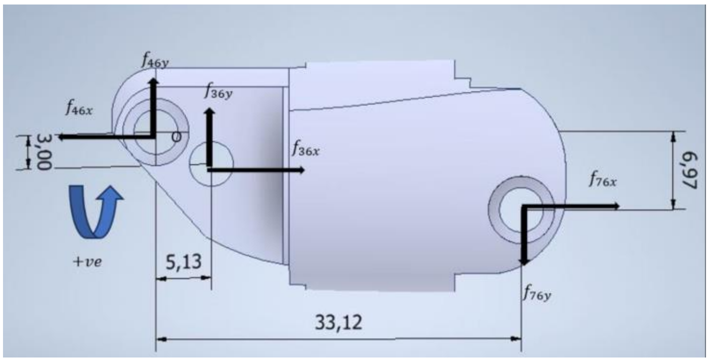


Figure 23 Link 6

Link7

$\sum f_x = 0$

$f_{75x} = -f_{76x} \dots \dots .. (5)$

$\sum f_y = 0$

$f = f_{76y} + f_{75y} \dots \dots \dots . (6)$

$f_{75y} = f_{75} sin\theta_4$

$f_{75x} = f_{75} cos\theta_4$

$f_{76y} = f_{76} \sin\theta_4$

$f_{76x} = f_{76} cos\theta_4$

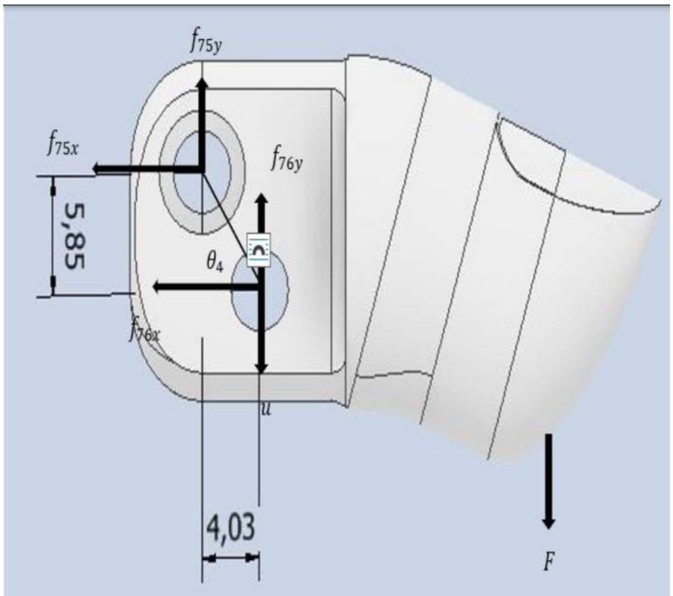


Figure 24 Link 7

From (4,5,6)

$$f = f_{75y} + \left(5.107 f_{36y} + 2.635 f_{36x} + 5.618 f_{76x}\right) * \frac{1}{33.246} \dots \dots \dots (7)$$

From (2,3,7)

$$f = f_{35y} + \left(0.1536 f_{36y} + 0.07926 f_{36x} + 0.168983 f_{35x}\right)$$

$$\therefore f = 0.333385315 f_{35} + 0.10704 f_{36} \dots \dots (8)$$

$$\omega = mxg = 50 * 10^{-3} * 9.81 \qquad m = 50g$$

$$\omega = 0.7905N$$

$$8f_{sx} + 12.41 f_{sy} - 13.592 - 4.42 f_{53} - 0.69 f_{53} - 8.743 f_{63} + 1.27686 f_{63} = 0$$

$$8f_{sx} + 12.41 f_{sy} = 5.11 f_{53} + 7.46614 f_{63} + 13.592$$

$$(14.7651 f_s = 5.11 f_{53} + 7.46614 f_{63} + 13.592)$$

$$f_s = 19.81\ N$$

$$\therefore 5.11F_{53} + 7.46614F_{63} = 278.9 \ldots \ldots \ldots (9)$$

$$asume\ f_{53} = f_{63} = N$$

$$N = 22.17728\ N$$

$$f = 9.7674\ N, \quad m = 0.99566\ kg$$

Case (2); with the rubber band the only force that will affect the calculations are the forces affecting link 7.

Link 7

$$\sum f_x = 0$$
$$f + u = f_{76y} + f_{45y} \ldots \ldots \ldots \ldots (10)$$
$$f + u = 0.333385315 f_{35} + 0.10704 f_{36}$$

For pinky finger

The minimum force of the rubber band is u which was calculated experimentally using the graph in Fig.18.

$$L_o = 165\ mm\ , L_s = 253\ mm$$

$\Delta L = 253 - 165 = 88\ mm$…….from the graph in fig.18.

$u = 2.8\ N$

$\therefore f = 0.333385315 f_{35} + 0.10704 f_{36} - 2.8$

$\therefore f_{MAX} = 9.76747 - 2.8 = 6.967\ N$

$\therefore Max\ Mass = \dfrac{6.967}{9.81} = 0.71\ KG = 710\ g$

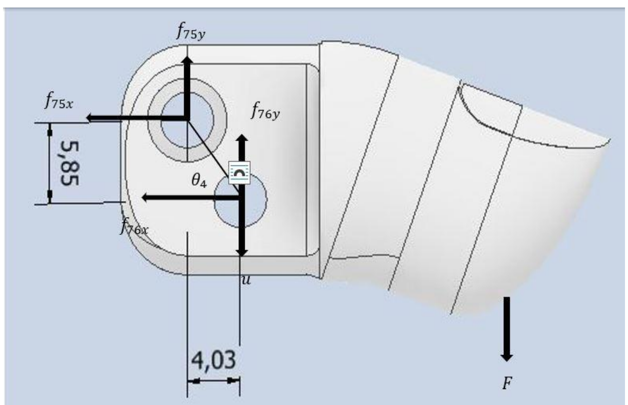


Figure 25 Link 7

The maximum force which makes the finger in equilibrium state is 6.967N, now let's make the motor is not actuated and lets see what is the spring needed to make the spring get back to the previous or zero position.

So now $f = 0, and \qquad u = 0.333385315 f_{35} + 0.10704 f_{36}$

$$N = f_{35} = f_{36} \;\; \& \;\; 2.8 = 0.440N$$

$$\therefore N = 6.36 \text{ Newton}$$

$$\because 14.7651 f_s = 5.11 f_{53} + 7.46614 f_{63} + 13.592$$

$$f_s = 6.34 \text{ Newton}$$

So, the needed torsional spring stiffness $K = \frac{f_s * r}{\gamma}$

Where γ is the angle rotated by the finger, and r is the distance between the force and the center of the spring, so to determine the angle of bottom knuckle we need to calculate it,

Firstly, we measured a point on the link relative to a constant point in the default mode of the finger (zero mode), then measured the same point relative to the same constant point at the maximum rotation mode.

Let's start with the actuation link (link 1):

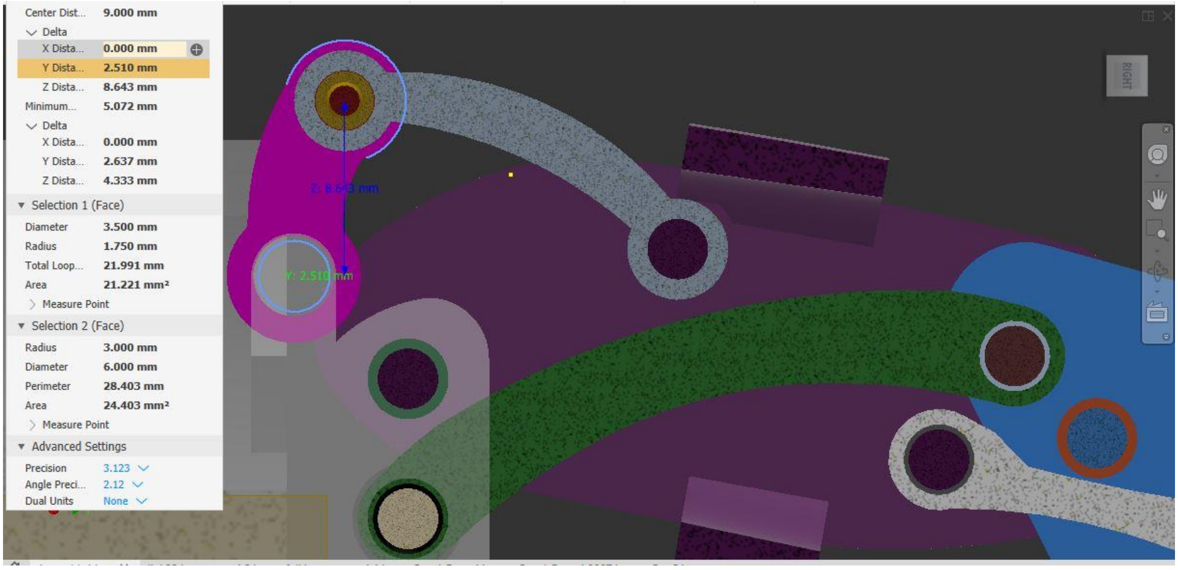
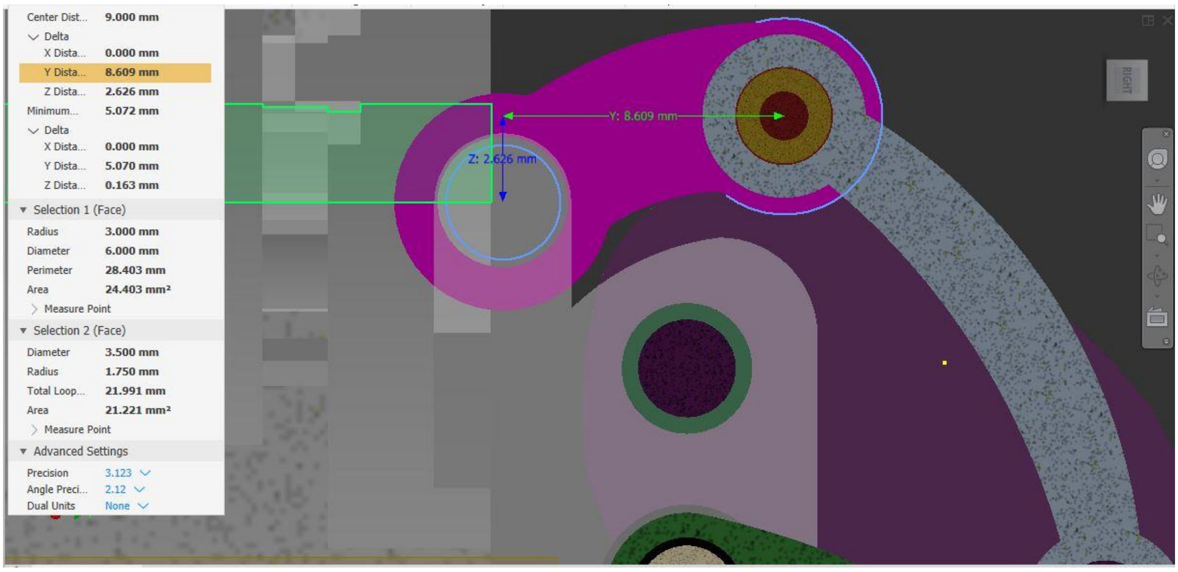


Figure 26 Link 1 dimensions

The angle made with the positive x-axis direction at zero position is:

$$\theta_1 = tan^{-1}\left(\frac{8.649}{2.51}\right) = 73.1°$$

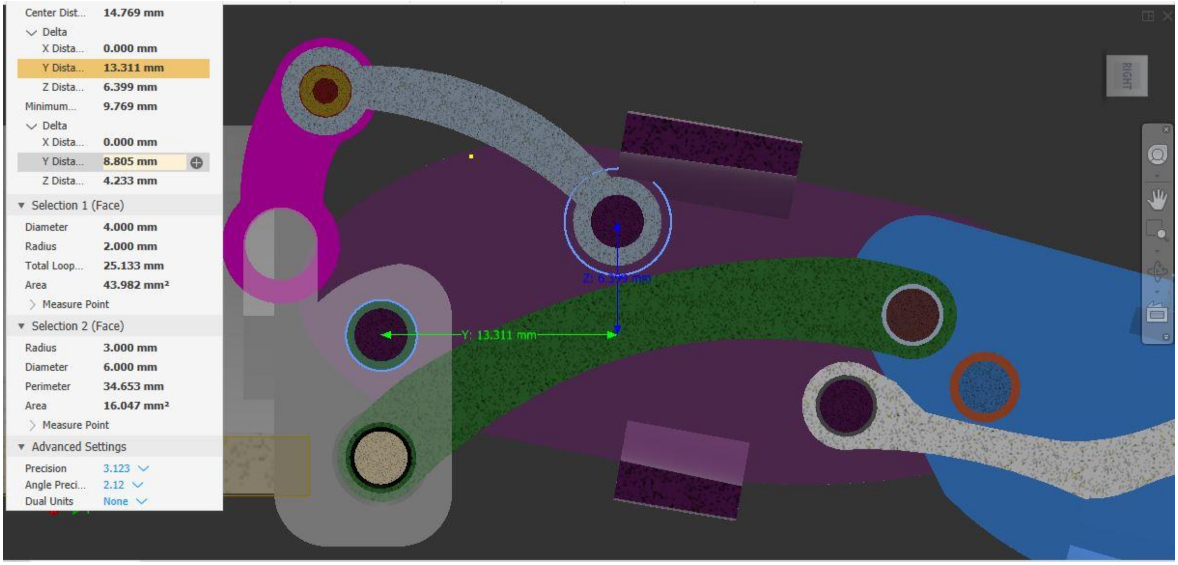


The angle made with the positive x-axis direction at maximum position is:

$$\theta_2 = tan^{-1}\left(\frac{2.626}{8.609}\right) = 16.96326°$$

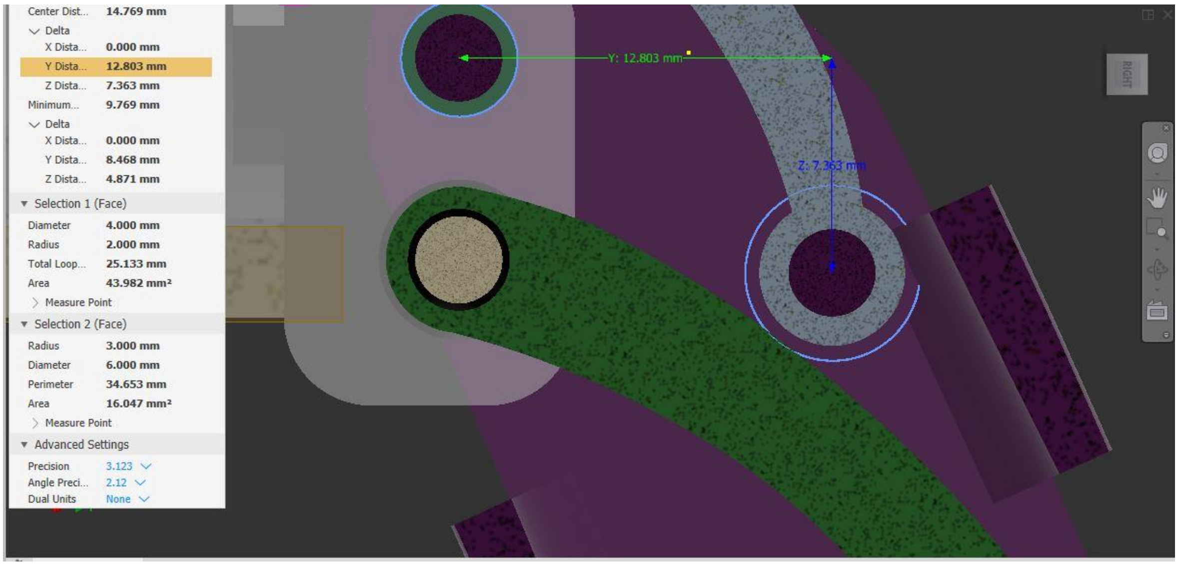
So, the angle rotated by the first link is: $\gamma_{Link\ 1} = \theta_1 - \theta_2 = 56.84674°$

For the bottom knuckle we need:



The angle made with the positive x-axis direction at zero position is:

$$\theta_1 = tan^{-1}\left(\frac{6.399}{13.311}\right) = 25.675°$$



The angle made with the positive x-axis direction at maximum position is:

$$\theta_2 = tan^{-1}\left(\frac{-7.363}{12.803}\right) = -29.9°$$

So, the angle rotated by the first link is: $\gamma_{bottom\ Knuckle} = \theta_1 - \theta_2 = 55.575$

$\gamma_{bottom\ Knuckle}$ is the max save travel for the spring.

Back to the spring design:

From design we have: $D_i = 3.5mm$

the needed spring stiffness must be: $K = \frac{19.81*14.796*10^{-3}}{55.575*\frac{pi}{180}} = 0.3\ \frac{N.m}{rad}$

Using stainless steel road grade 302 of diameter $d_{wire} = 1mm$ and modulus of elasticity

$E = 197\ GPa$

$D_{mean} = D_i + d = 3.5 + 1 = 4.5$

$$K = \frac{E * d_w^4}{10.8 * Dmean * 2\pi N} = \frac{197 * 10^9 * (1 * 10^{-3})^4}{10.8 * D_{mean} * 2\pi N}$$

Where N is the number of coils.

So $N = 2.15\ \approx 2\ loops$

The length of the spring is $L = d_{wire} * (N + 1) = 1 * (2 + 1) = 3mm$

The outer diameter of the spring is $D_{outer} = D_i + 2d = 3.5 + (2 * 1) = 5.5mm$

The mean diameter is $D_{mean} = D_i + d = 3.5 + 1 = 4.5mm$

The index number is $I = \frac{D_{mean}}{d_{wire}} = \frac{4.5}{1} = 4.5$

The correction term $K_i = \frac{4I^2-I-1}{4I(I-1)} = \frac{(4*4.5^2)-4.5-1}{4*4*(4.5-1)} = 1.198$

The stress on the material is $s = \frac{32T}{\pi d_{wire}^3} * k_i = \frac{32*19.81*14.769*10^{-3}}{\pi(1*10^{-3})^3} * 1.198 = 3.57\ GPa$

So we need a spring made of stainless steel 302 with diameter 1mm, internal diameter 3.5mm, length 3mm.

So, the mechanism has these features:

The tip path from zero mode to the maximum mode as shown in the next graph of the simulation using SAM simulation environment is about 147.589mm, it reaches this position in a maximum velocity about 176.300 mm/s and a max acceleration of 4934.253 $mm\ per\ sec^{2}$. All these calculations are for the tip of the finger.

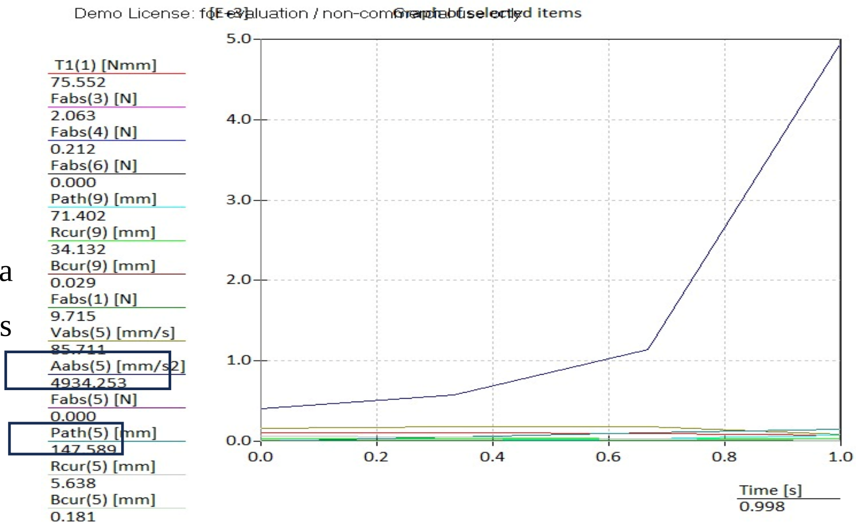


Figure 27 SAM Simulation 1

Note: all the previous calculations and analysis are made on the pinky finger and the stress analysis for each joint is in the appendix.

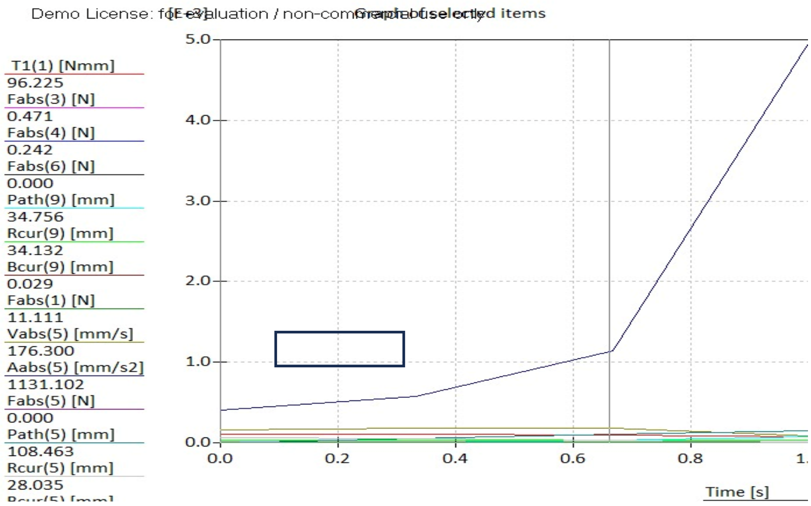


Figure 28 SAM Simulation 2

After the correct link length was determined, the finger mechanism could be designed It consisted of six main parts. tip, two intermediate segments, base A segment that completes the 4-bar mechanism and two cross-bar segments

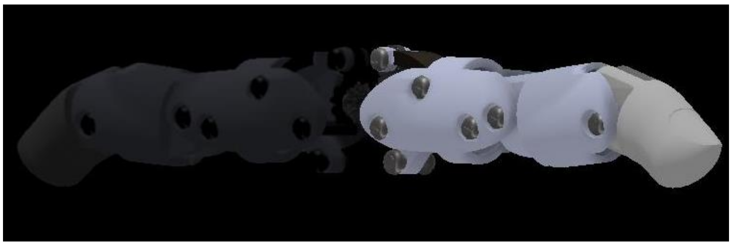


Figure 29: finger design

Safety mechanism:

The theory of the safety mechanism is the use of positive connection between bevel gear and the actuation link which transmits the force to the finger, if the motor is actuated by the user, then the gear will actuate the link in the direction to hold something or handling the task. But if the finger accidently collided with an obstacle, it would move and back to the previous position before collision without any contact with the motor.

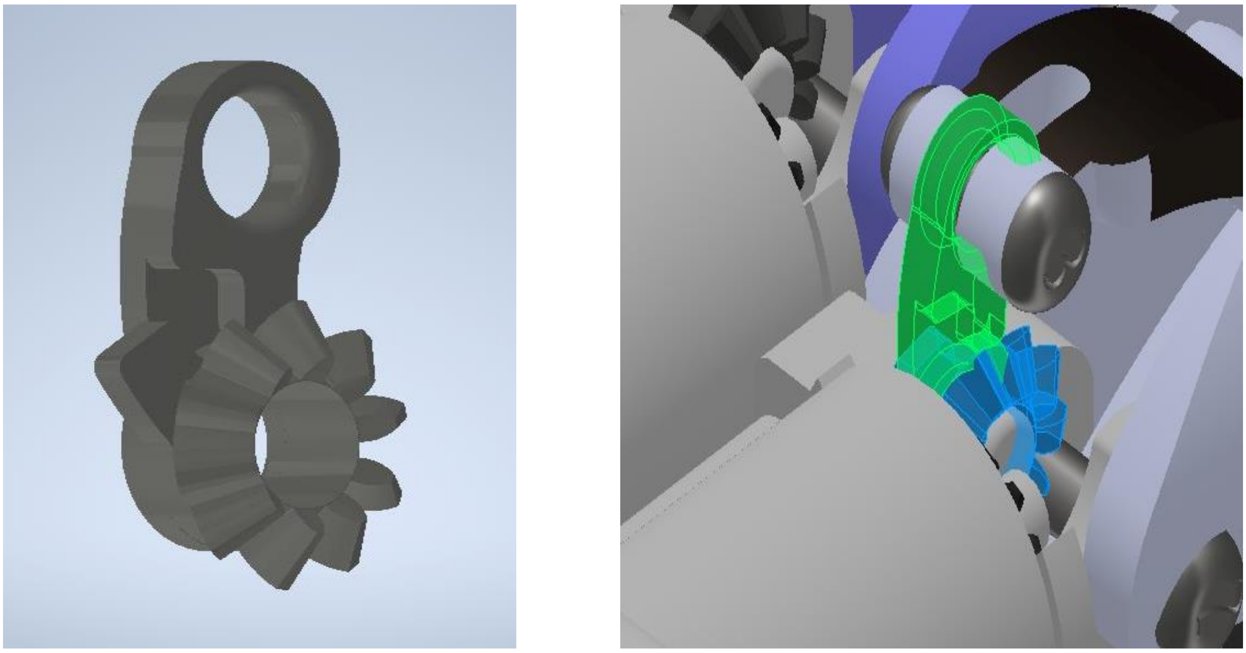


Figure 30 safety mechanism

Gears:

The gears have the following data which designed based on it.

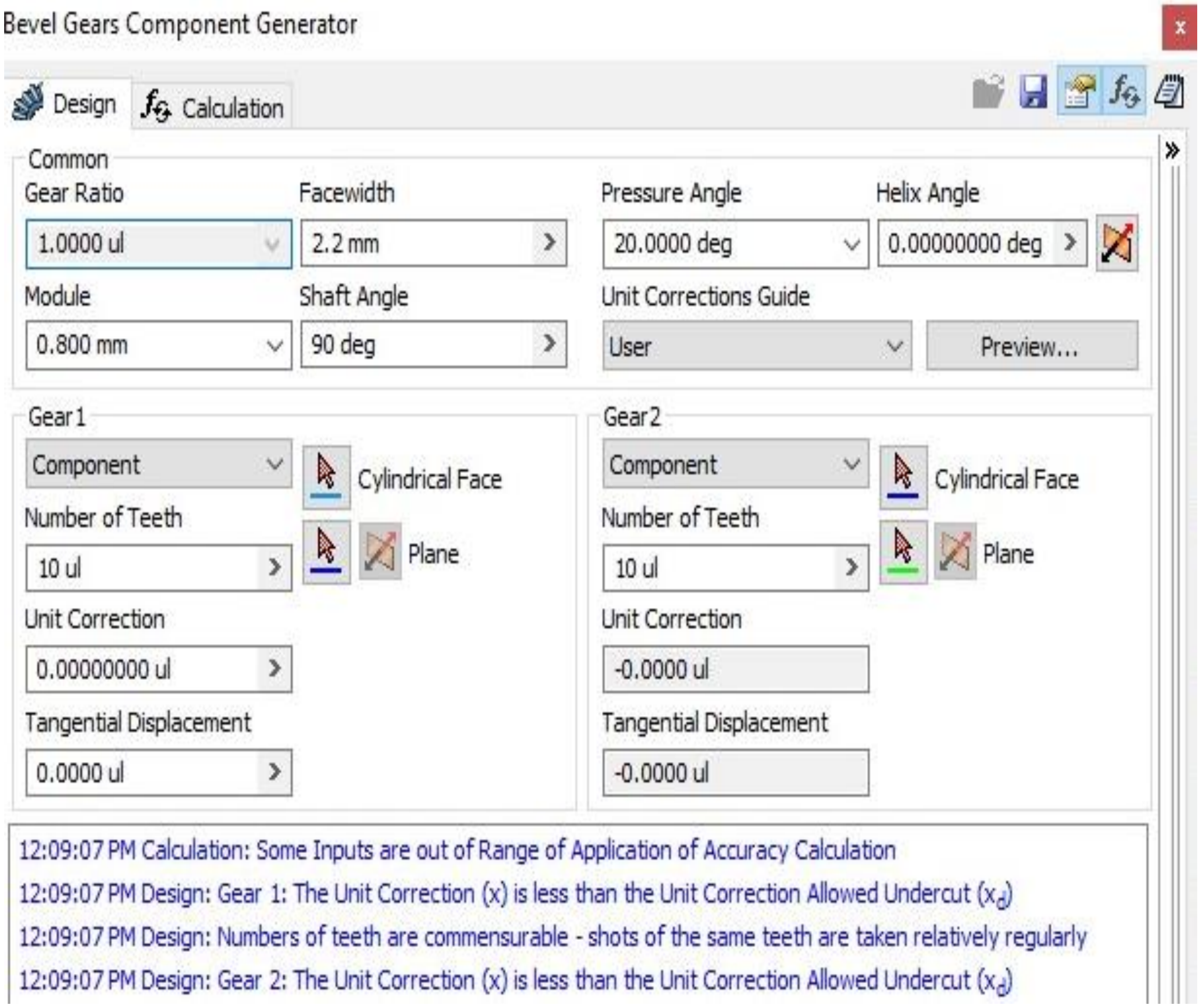


Figure 31 Gears Data

With the first finger already done the implementation of the other fingers followed through but an important part that had to be looked through was the palm and thumb design Fortunately, the linkage we developed to give the fingers a natural curling motion could be incorporated into the thumb with minor modifications. Problems with the thumb evolved into the design of a compound-powered joint at the base of the thumb, allowing it to flex and move relative to the fingers. Considering the limited space for motors in the palm of the hand, we designed the joints so that the motors driving the opposite motions of the thumb reside within the joint segment.

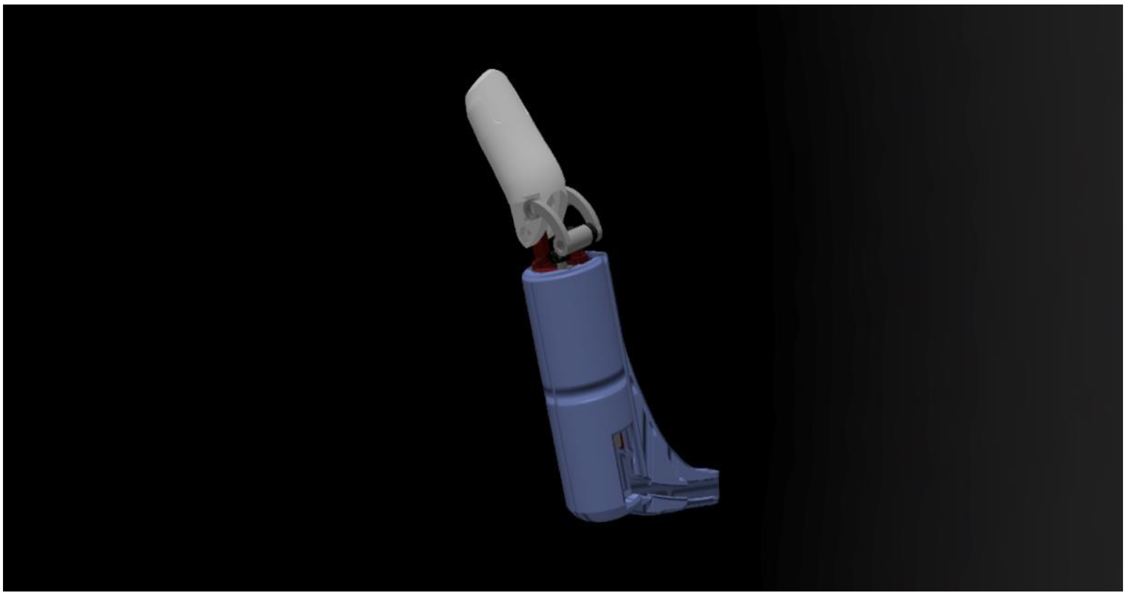


Figure 32 thumb design

3.2.2 Palm design

This was primarily to house the motors and to connect the whole hand together just like the human hand including the thumb.

All the electrical connections are also housed in the palm such that power can go through all the motors housed inside the palm, also, note that the servo motor of the thumb is also housed inside the palm.

The inner part of the motor holder is fixed on the part on the back of the palm, and the part on the front is connected to the part on the back holding them all together.

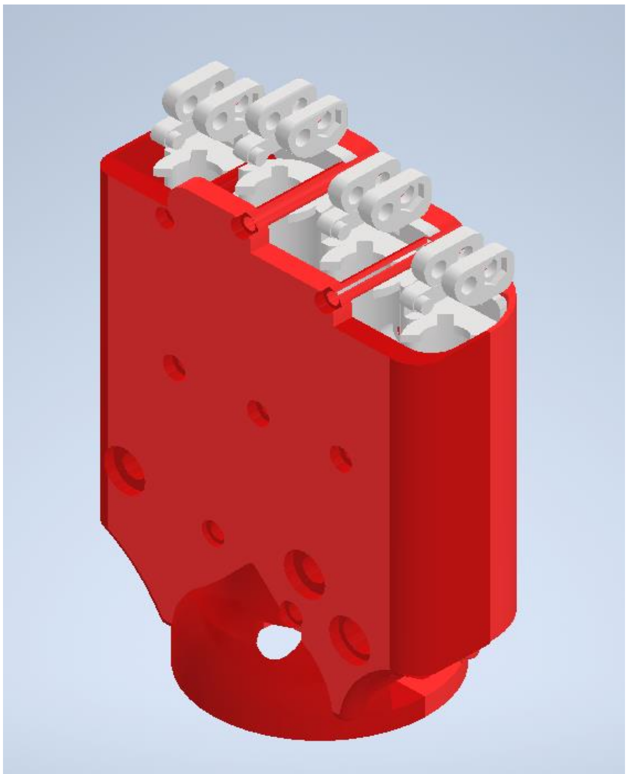


Figure 33 palm

3.2.3 The forearm design.

In this part we designed a forearm in a way to hold all the necessary components for the hand's operation including; the batteries, the PCB, the microprocessor….and so on.

The forearm was divided into four main parts as follows.

The Main container

This is the part that will hold most of the control components alongside with the batteries. It holds the PCB, the battery and connected to the part which attached to the socket of the hand.

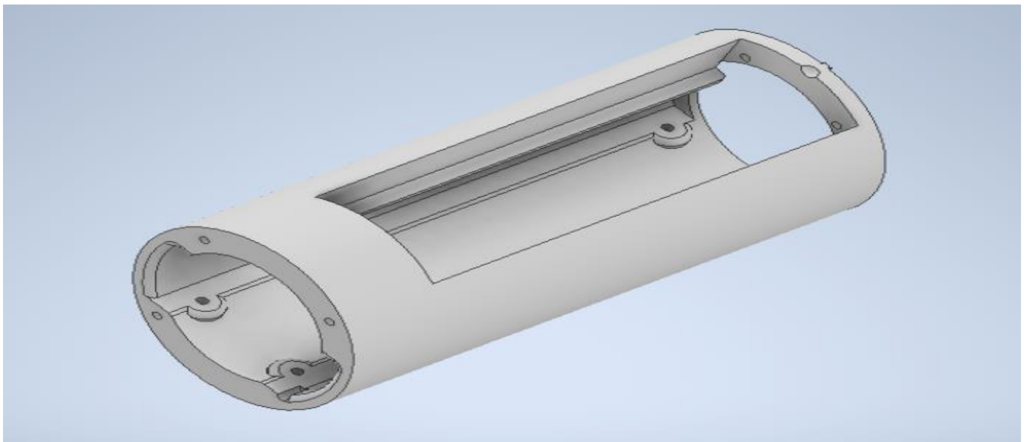


Figure 34 The main container

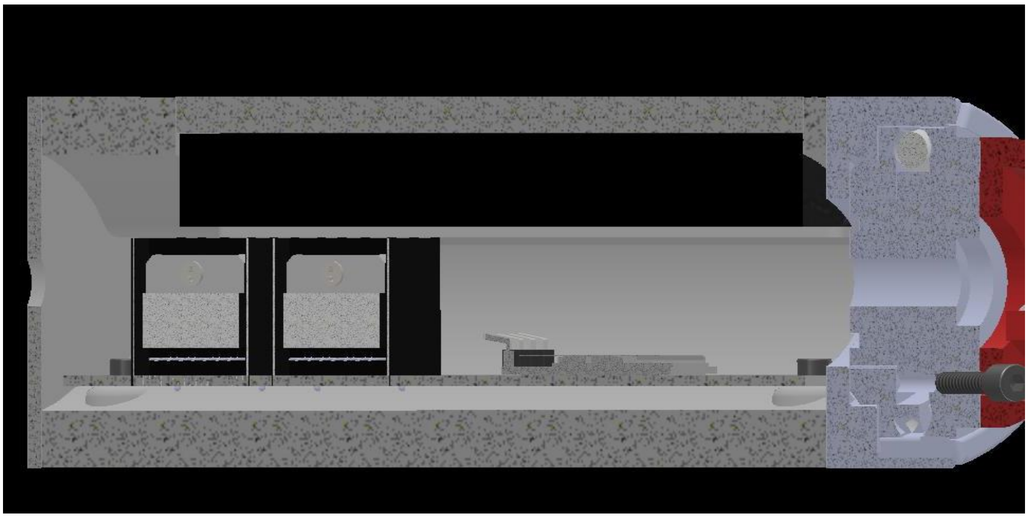


Figure 35 Forearm Section

The battery cover.

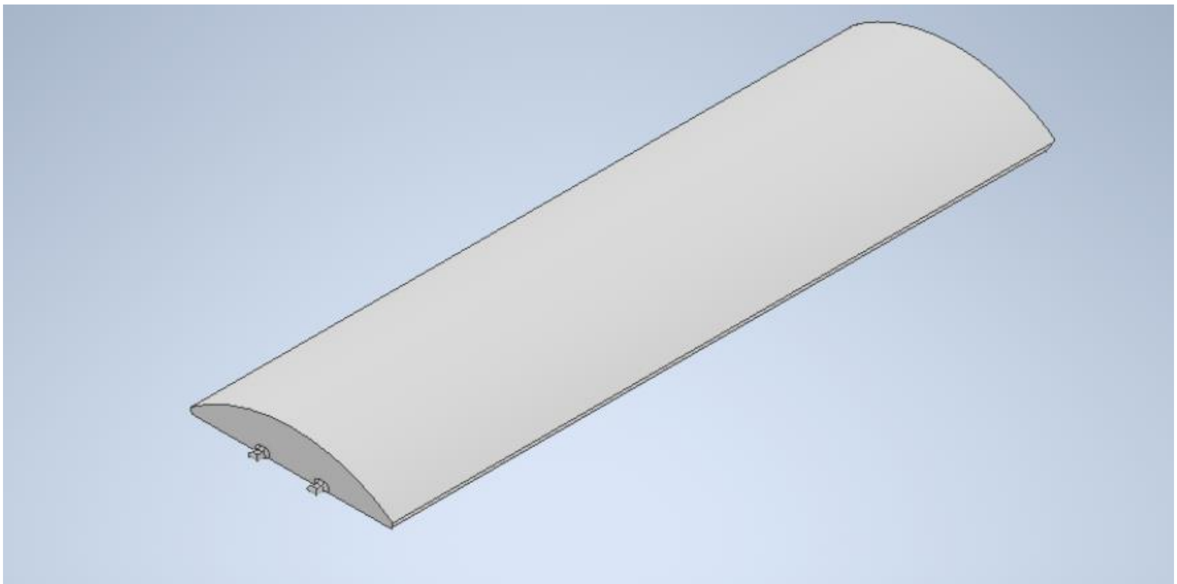


Figure 36Battery cover

The end cover.

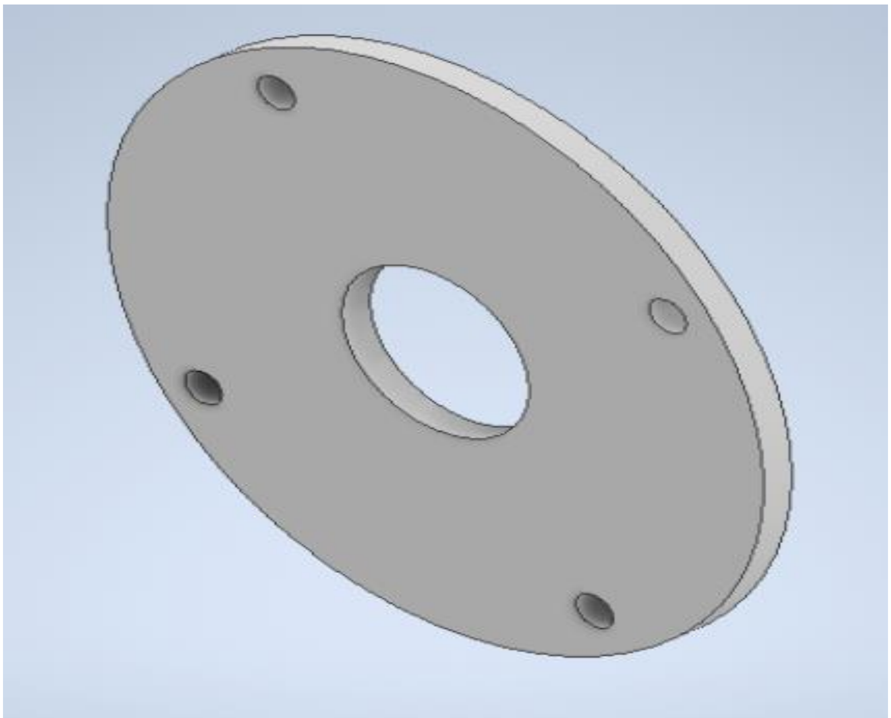


Figure 37 End cover

The forearm connector

This part is what we used to connect the forearm with the main hand and palm.

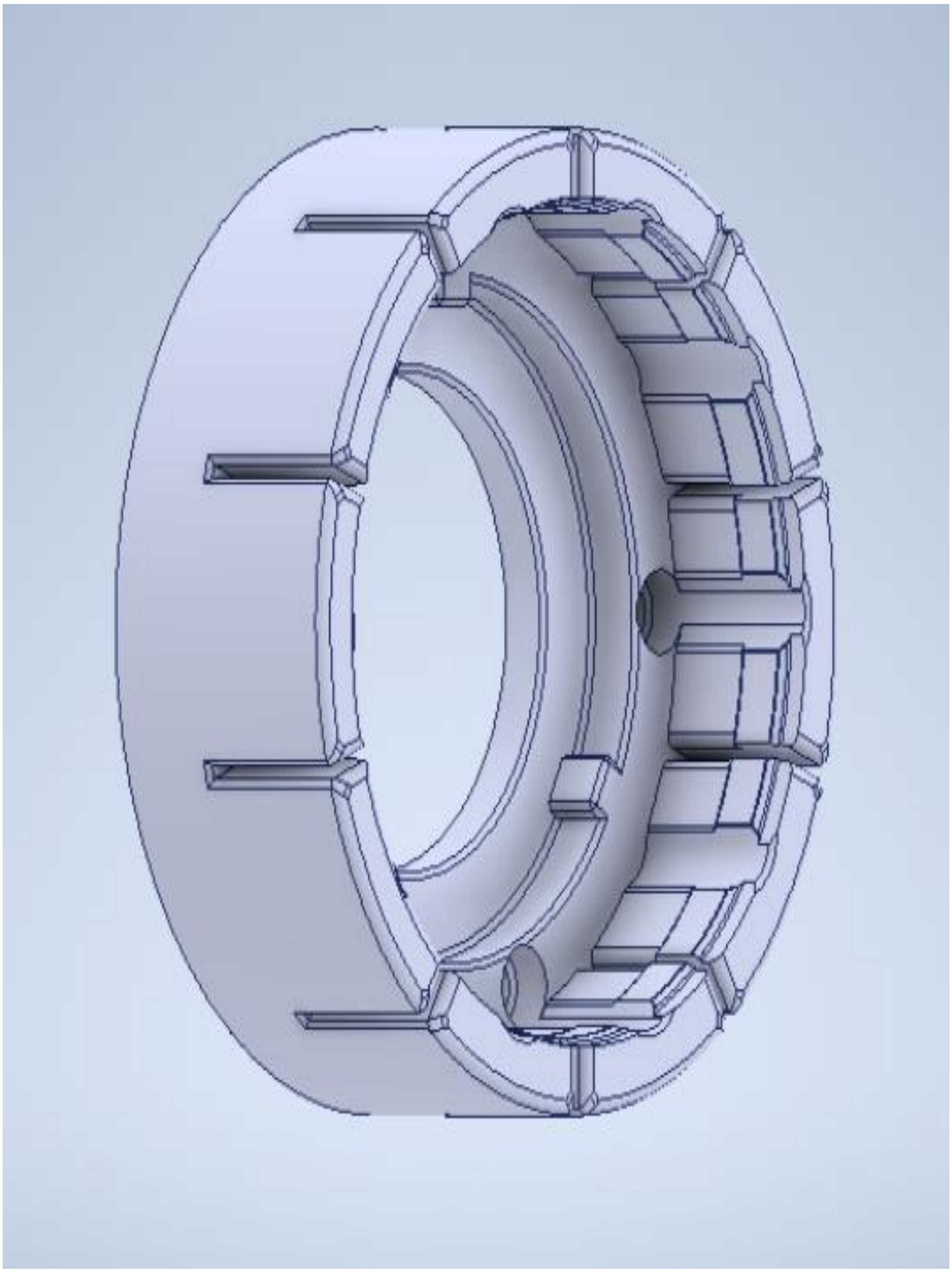


Figure 38 Forearm connector1

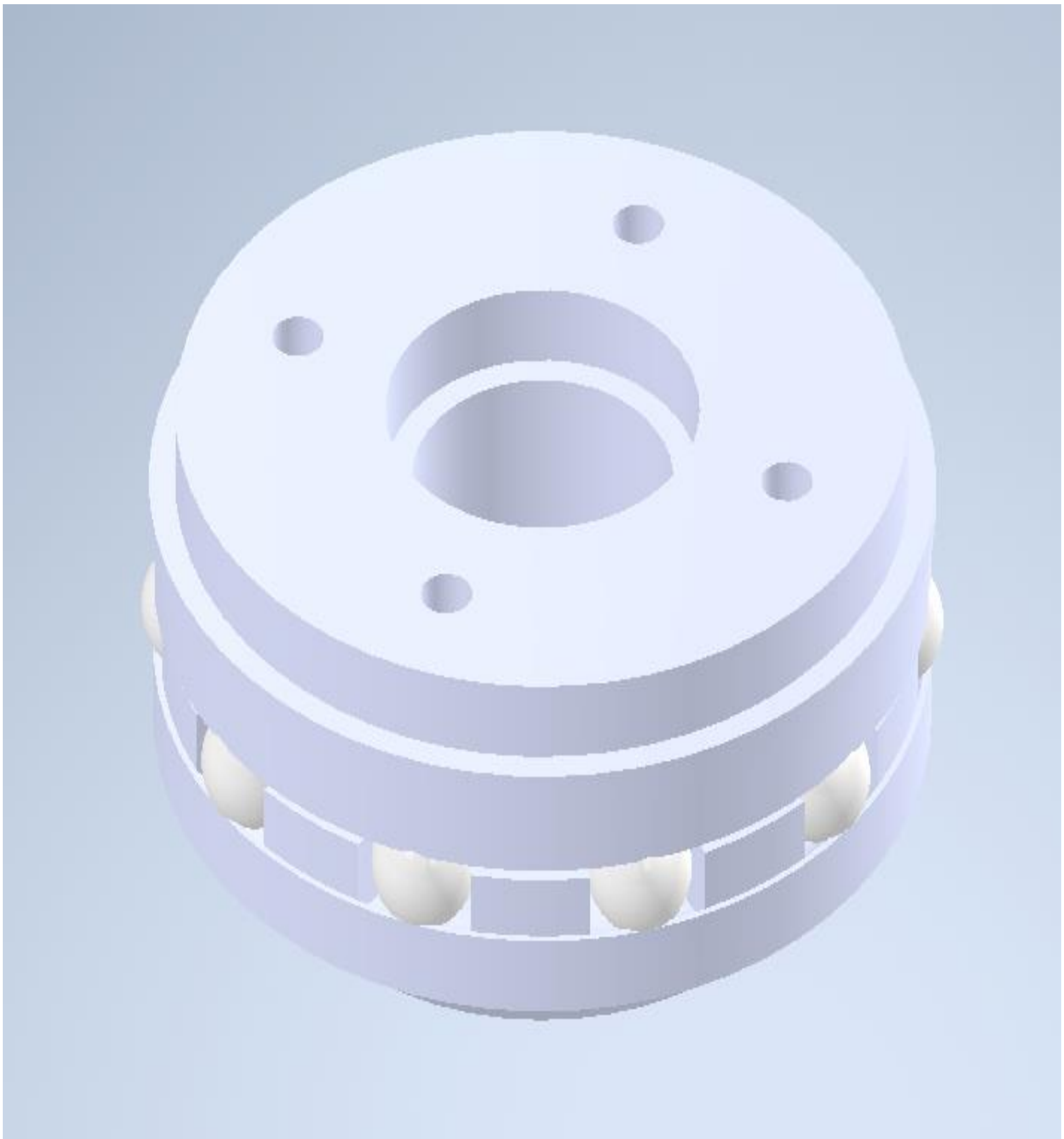


Figure 39 Forearm connector2

The part in Fig.24 and the part in Fig.25 are the main parts that connect the hand to the forearm, where the bearings shown in Fig.25 sinks in the groves in Fig.24 till the forearm connector 2 is fully housed inside the forearm connector 1, then the hand is rotated to the right meshing the forearm and hand completely without any clearances, the wires is then pulled through the hole in the middle of the forearm connector 1 and 2 to the main container of the forearm where all the electrical components and the PCB will be present and covered in an eye pleasing manor making the whole design compact, elegant and very easy to dismantle it for repairs, making it a very efficient design.

3.2.4 The full hand

After we successfully designed the different main parts we assembled them to introduce to you our Prosthetic hand

The term "DOF" stands for "Degrees of Freedom." In the context of the hand, the DOF refers to the number of independent movements or articulations that the hand can perform. It represents the flexibility and range of motion of the hand's joints and allows for various grasping and manipulation actions.

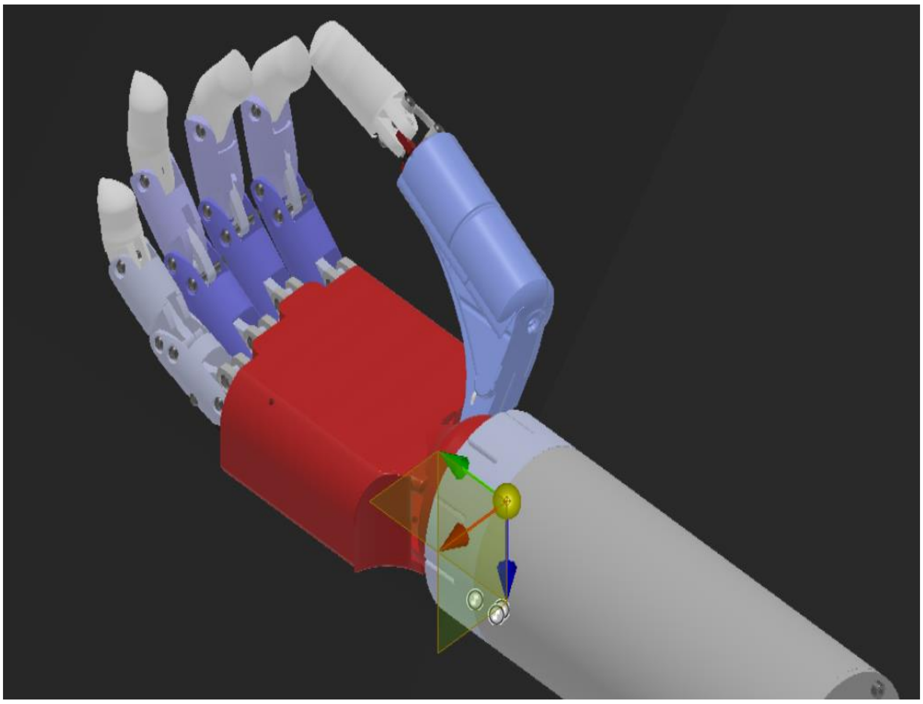


Figure 40 Full Hand Assembly

The human hand is a highly complex structure with multiple joints that enable a wide range of movements and dexterous control. The hand's DOF includes the movements of the fingers and the thumb, as well as the wrist joint. The specific number of DOF can vary depending on how the

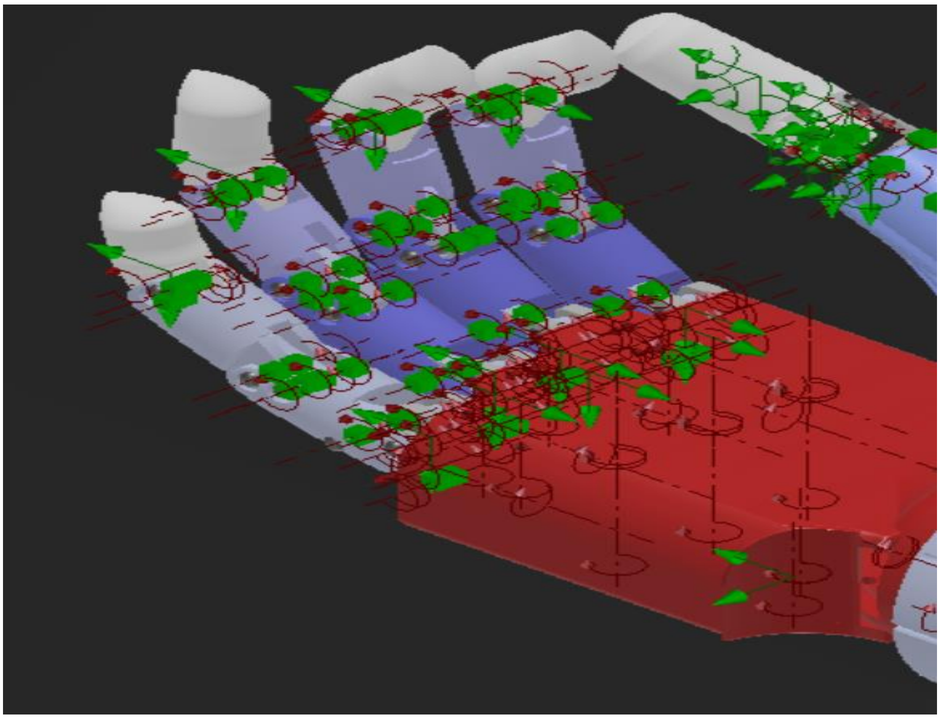


Figure 41 Fingers degrees of freedom

hand is defined, but typically, the hand is considered to have around 27 DOF.

Figure 42 Full hand

3.3 ELECTRICAL DESIGN

The system level electrical design was integrated in order to:

1) Actuate the fingers

2) Control the fingers

3) Integrate the system together

3.3.1 ACTUATUION LEVEL

After calculating the required torque and speed for the finger, we used a commercial motor compare in final selection. The main goal was to find a motor that didn't require a gear box design. Which would accommodate smaller motors but require additional hand space Provides the torque and speed you need. Additional factors were: cost, voltage requirements and lead time and weight.

The FAULHABER Mini Motor: SA Gearhead: 15/5 ratio 141:1 K832 was chosen as the fingers motor because it is powerful enough to meet the requirements even though the motor is very small.

Where The motor, gearhead, and encoder have a 16 mm diameter and a combined length of 57.65 mm not counting the 4 mm long shaft The total length is about 72 mm. The total mass is approximately 55 grams .so the size of the motor played a huge role in the selection procedure as a fairly larger motor would've made a bulkier unnatural looking hand, The FAULHABER mini motor gives a huge advantage due to its size to torque ratio.

Figure 43 The FAULHABER Mini Motor size demonstration

Additionally, the availability of these motors in our university lab made it an amazing and inexpensive choice

The next step was to power the motor. The currents and voltages required to run these motors are much higher than a typical microcontroller can supply, so a motor driver is required to interface between the microcontroller and the motors. After Comparing drivers available commercially weve found drivers that have many options for industrial applications such as: For example, serial communication options, various packaging options, low power options, sleep modes, etc. However, the main priority is given to the output voltage and current levels as they are the requirements for driving the motor. There was also a driver with a low pin count Considered to simplify wiring in the system. Based on the mentioned points the driver selected was the **L298N** chip from STMICRONTROLLERS

Figure 44 l289n IC

With a fairly small but enough number of pins, availability to supply the required current and voltage the l298n IC was enough to derive and control the motors.

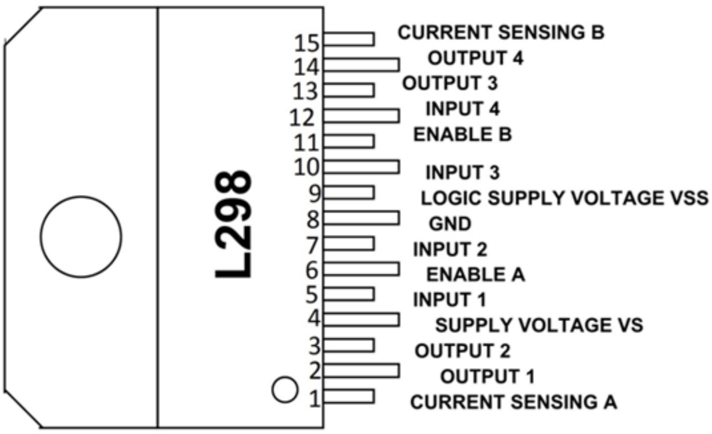


Figure 45 L298N pinout

3.3.2 CONTROL LEVEL

3.3.2.1 Sensors and feedback

The system needs joint angle information to control position and velocity. The most convenient way to do this is to attach the encoder or rotary potentiometer directly to the shaft of the rotary joint. Encoders are digital sensors and provide incremental data. The main advantage of using encoders is that you can perform a full 360 degree rotation without physical limitations. On the other hand, they can be difficult to calibrate as they do not provide absolute joint angles for an external encoder an example of the piece of electronic used is the Hollow Shaft Rotary Potentiometer.

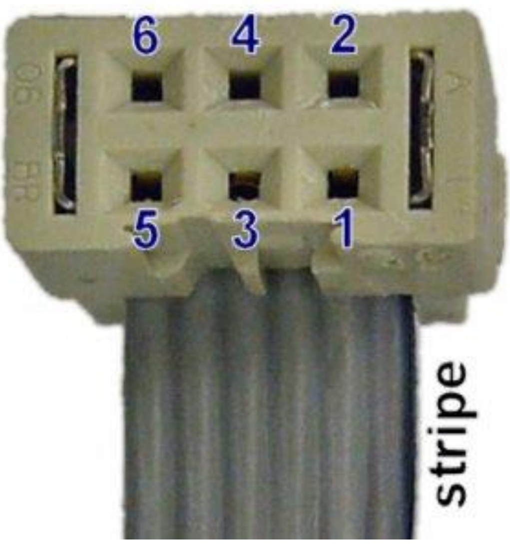
However, thankfully the motor selected has an integrated incremental potentiometer that would provide position and speed of the motor at all times so there will be no need for an external encoder the encoder is HES164A:

Figure 46 hollow shaft rotary encoder

- 'HE' stands for Hall Effect, which is a magnetic sensor.
- 'S' is the series? Or does it stand for “sensor”?
- 16 is the outer diameter in millimeters.
- 4A is the special order number?

Although I couldn’t find the datasheet for the HES encoder, it is likely similar to the HEM encoder. The HEM encoder accepts 4.5V to 15V, but I'll just use 5V.

The encoder is connected via a 6 wire ribbon cable to a 2x3 0.1-inch spaced female-socket connecter. The pinout is:



1. Motor positive. Connect to GND or 3V-to-9V. Pin 1 is nearest the side of the ribbon cable with the stripe.
2. Encoder Vcc. Connect to 5V.
3. Channel A digital output. Pulled up to Vcc through a 10 kilohm resistor. Switches between GND and Vcc.

4. Channel B digital output. Pulled up to Vcc through a 10 kilohm resistor. Switches between GND and Vcc.
5. Encoder GND. Connect to GND. You can use the same GND for the motor and the encoder or you can use a separate ground if you’re using a different power source for the motor.
6. Motor negative. Connect to GND or 3V-to-9V.

Figure 47 encoder pinout

Another sensor that was essential for our project is the EMG sensor, where it incorporates the sensor to to read muscle signals. Users select grips, open and close hand by flexing and relaxing their muscles in the arm.

ELECTROMYOGRAPHIC SENSORS, also called EMG sensors, measure the small electromyographic signals that muscles produce when they move. Muscle movements also include clenching a fist, raising an arm, and moving a finger. EMG sensors are a valuable asset in the medical field for diagnosing a variety of neurological and muscle degenerative diseases.

EMG sensors work by placing electrodes or sensations near muscle groups. These sensors are more effective against superficial muscles because they cannot bypass action potentials in superficial muscle tissue. It is powered on and its length is reduced during signal processing. In addition, muscles, skin and electrodes move in opposition to each other. Fundamentally, EMG signals arise from the electrical activity or potentials of muscle fibers active during contraction.

TYPES OF EMG SENSORS

Two types of EMG sensors are available for application. The first is a surface EMG sensor and a non-invasive technology, and the next is an intramuscular EMG sensor. While both types of EMG differ in the sensor placement, they do share some similarities in the procedure

SURFACE EMG SENSOR

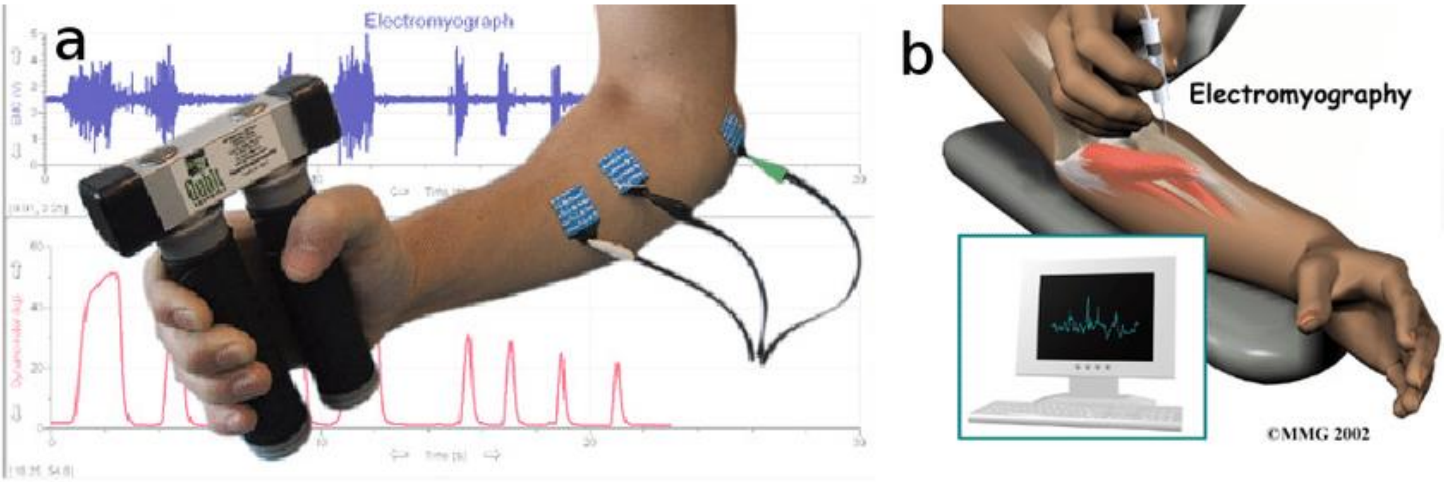


Figure 48 Surface vs. intramuscular emg sensor

- **Placement**: Surface EMG sensors are attached directly to the skin over the muscle or muscles of interest. The placement depends on the specific application and the muscles being monitored. The sensors are typically positioned parallel to the muscle fibers for optimal signal detection.
- **Signal Detection**: EMG sensors detect the electrical potentials generated by muscle fibers during contraction and relaxation. These signals are very small and typically require amplification to be accurately recorded and analyzed.
- **Signal Processing**: Once the electrical signals are captured by the surface EMG sensors, they are processed and analyzed to extract relevant information. This can include parameters such as muscle activation levels, timing of muscle contractions, and muscle fatigue.
- **Applications**: Surface EMG sensors have a wide range of applications. They are commonly used in sports an
- d rehabilitation settings to assess muscle function, monitor muscle activity during exercise, and evaluate movement patterns. EMG sensors are also used in prosthetics and robotics to control artificial limbs and exoskeletons based on muscle signals.

- **Advantages**: Surface EMG sensors offer several advantages. They are non-invasive and relatively easy to use compared to invasive EMG techniques that require needle electrodes. Surface sensors are also more comfortable for the individual being monitored. They can provide real-time feedback, making them useful for biofeedback and training purposes.
- **Limitations**: While surface EMG sensors are widely used, they have some limitations. The signals detected by surface sensors may be influenced by factors such as skin impedance, tissue thickness, and sensor placement. Cross-talk from adjacent muscles can also affect signal specificity. Interpretation of EMG data requires expertise to distinguish between meaningful muscle activity and noise.

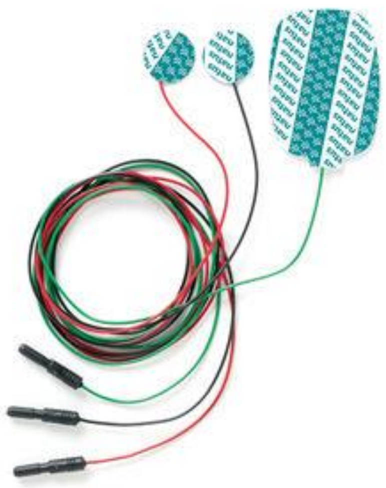


Figure 49 surface electrodes

For the muscle sensor board a schematic diagram was developed as shown in (figure 32)

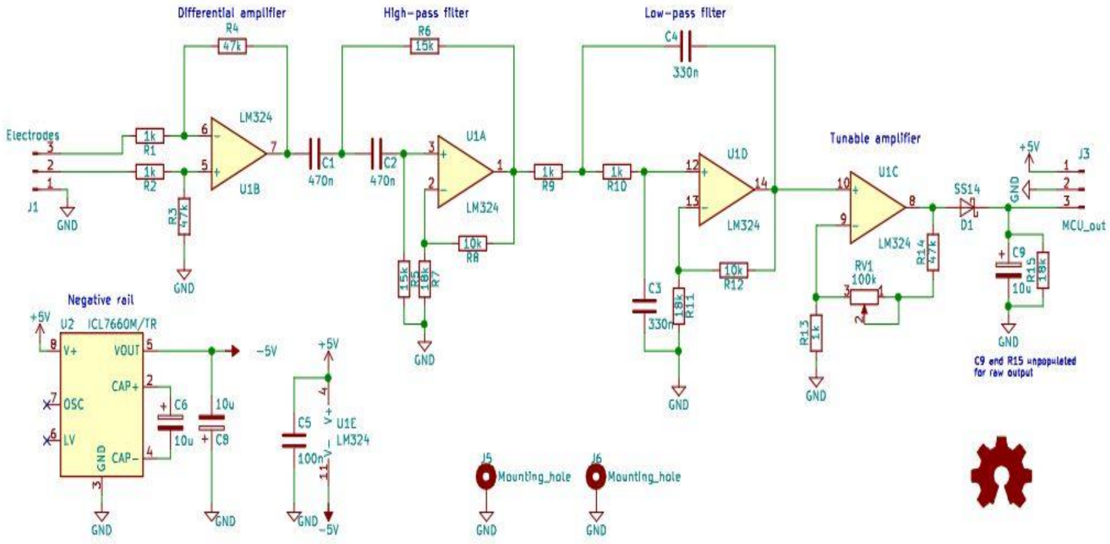


Figure 50 muscle sensor board schematic

We tested the EMG surface sensor and the results we relatively accurate as follows;

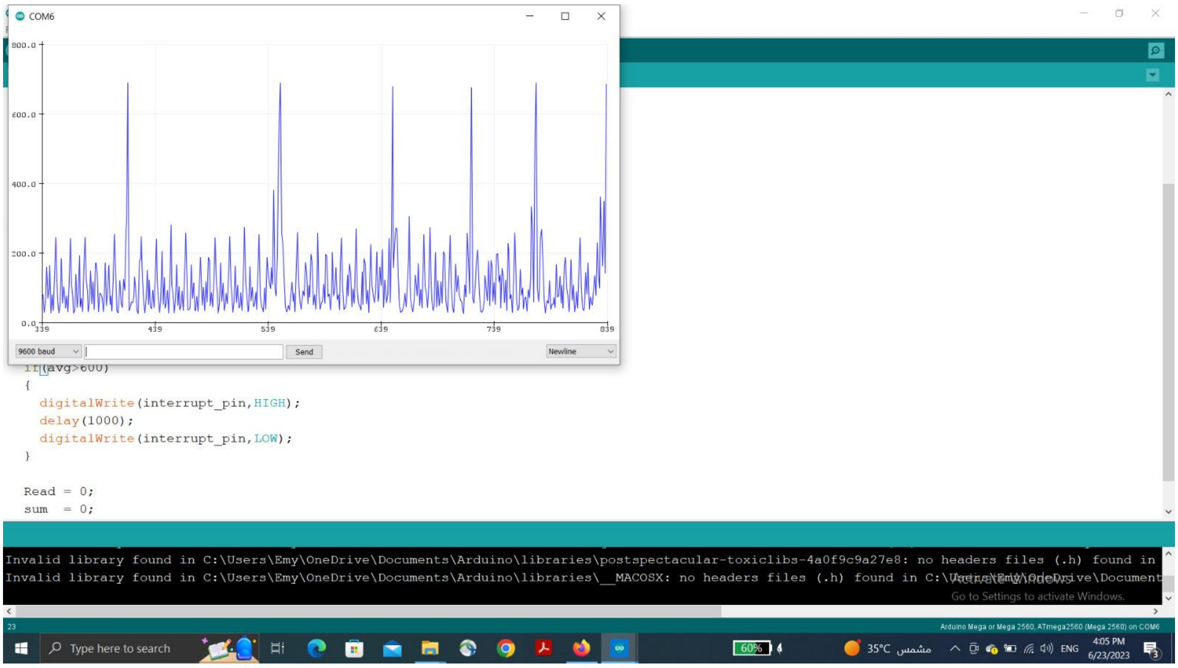


Figure 51 first EMG surface sensor test

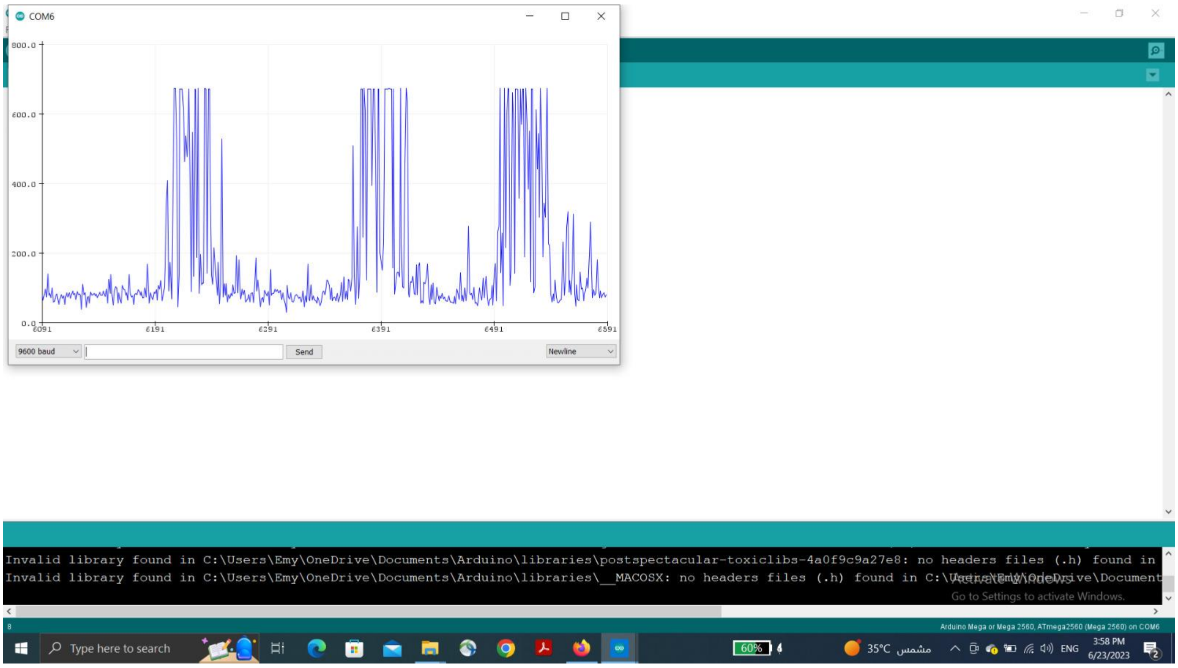


Figure 52 final EMG surface sensor test

A PCB is then generated which a size almost as equal to the boards had sold commercially and with much lower cost .

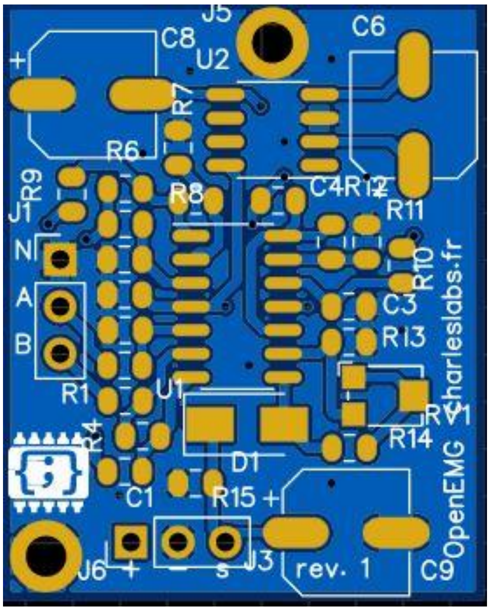


Figure 53 muscle sensor board PCB

3.3.3 MICROCONTROLLER SELECTION

The Arduino Mega is a microcontroller board based on the ATmega2560 microcontroller. It is an upgraded version of the popular Arduino Uno board, offering more digital input/output pins, more memory, and additional features compared to its smaller counterpart.

- The Arduino Mega is powered by the ATmega2560 microcontroller, which runs at 16 MHz and has 256 KB of flash memory for storing your program.

- One of the major advantages of the Arduino Mega is its extensive set of digital input/output pins. It has a total of 54 digital pins, of which 15 can be used as PWM (Pulse Width Modulation) outputs.

- The Mega provides 16 analog input pins, allowing you to connect analog sensors or read analog voltages.

- The Mega has 8 KB of SRAM (Static Random Access Memory) for storing variables and data during program execution. This larger memory capacity makes it suitable for more complex projects that require a significant amount of data storage.

- The Mega supports various communication protocols, including UART (Universal Asynchronous Receiver-Transmitter), I2C (Inter-Integrated Circuit), and SPI (Serial Peripheral Interface). This enables you to interface with other devices such as sensors, displays, and wireless modules.

- The Arduino Mega has some additional features compared to the Uno, including a larger board size and more power pins for providing voltage to external components. It also has a built-in LED connected to pin 13, which can be used for basic visual feedback.

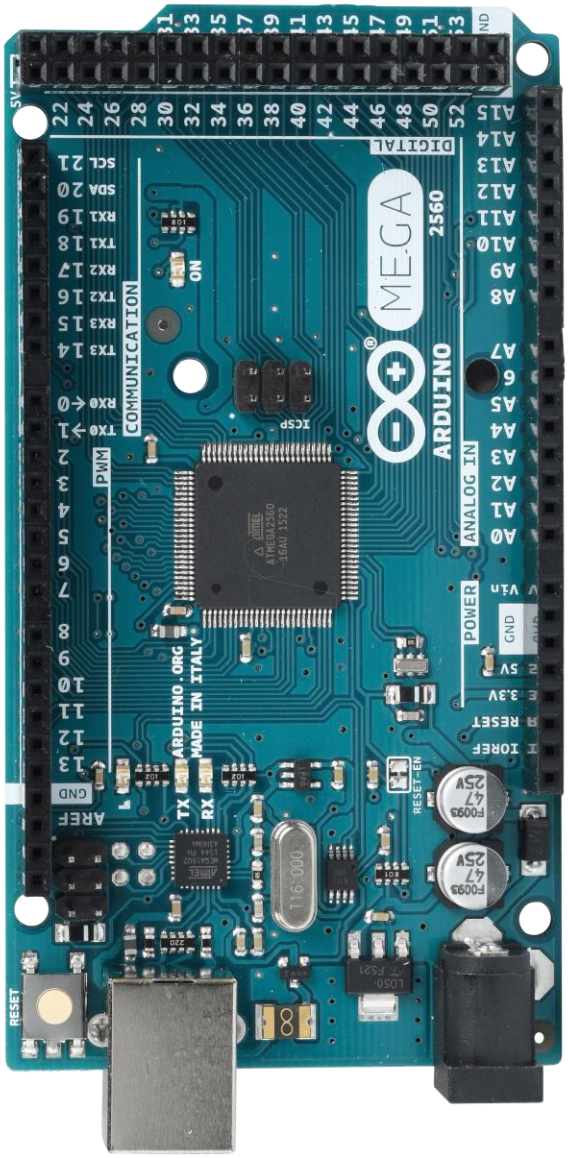


Figure 54 Arduino Mega

- The Arduino Mega is compatible with the Arduino software and libraries, making it easy to write, compile, and upload code. It can also be programmed using various integrated development environments (IDEs) that support Arduino, such as the Arduino IDE, Atmel Studio, or PlatformIO.

3.3.4 INTEGRATION LEVEL

In order to bring all the components together electrically and under software, a PCB was designed for that objective,

Firstly a schematic diagram was constructed with the following under consideration :

- All components must be taken in consideration in the schematic

  1) Arduino Mega
  2) 3 motor driver ICs
  3) Voltage regulator
  4) Required number of IO pins and pin headers
  5) Current flowing through tracks

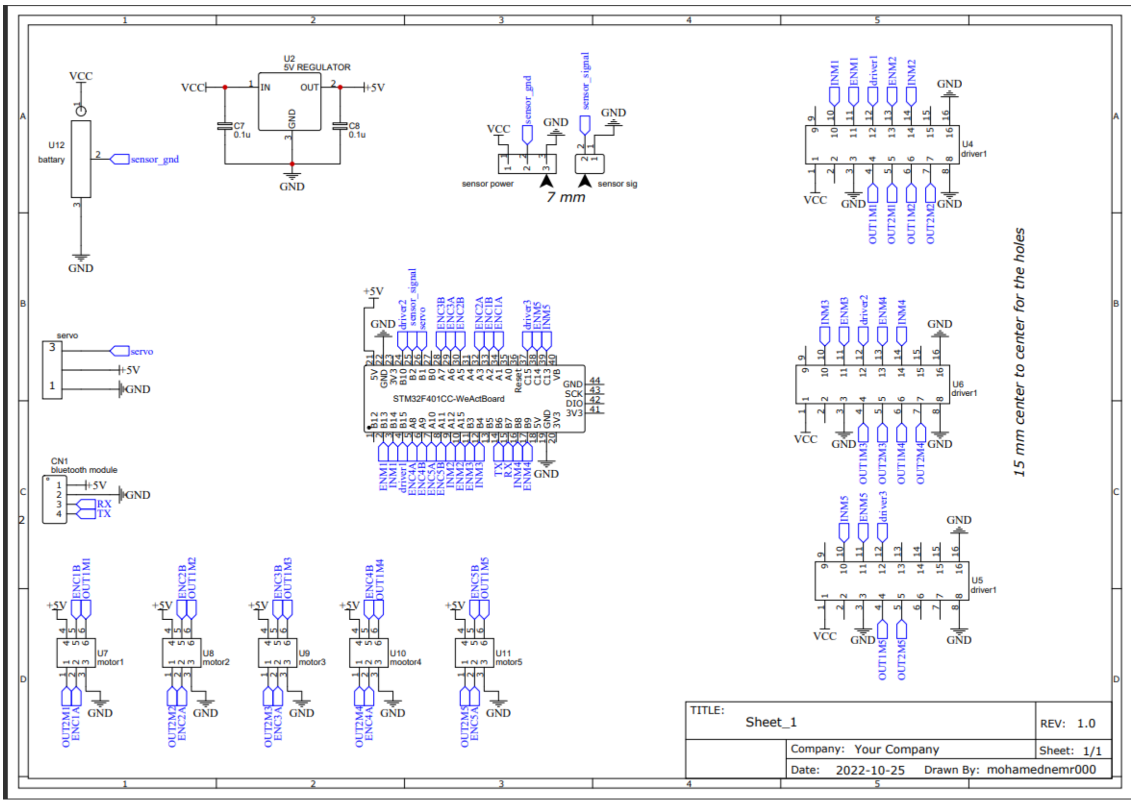


Figure 55 Electrical Schematic

3.3.5 Application

We made an application in order to control the different modes of the hand, the application is user-friendly and very easy to use making the use of the overall product very convenient for the people who needs it.

The application was tested thoroughly to troubleshoot all the bugs and malfunctions that might be found within the application's coding.

In this next section we will explain how to use the application so that we don't cause trouble for the users of our product.

Step 1:

After installing the application open the Bluetooth then launch the application, after you have done that press on the "Pick Bluetooth Device" button as shown in fig.57.

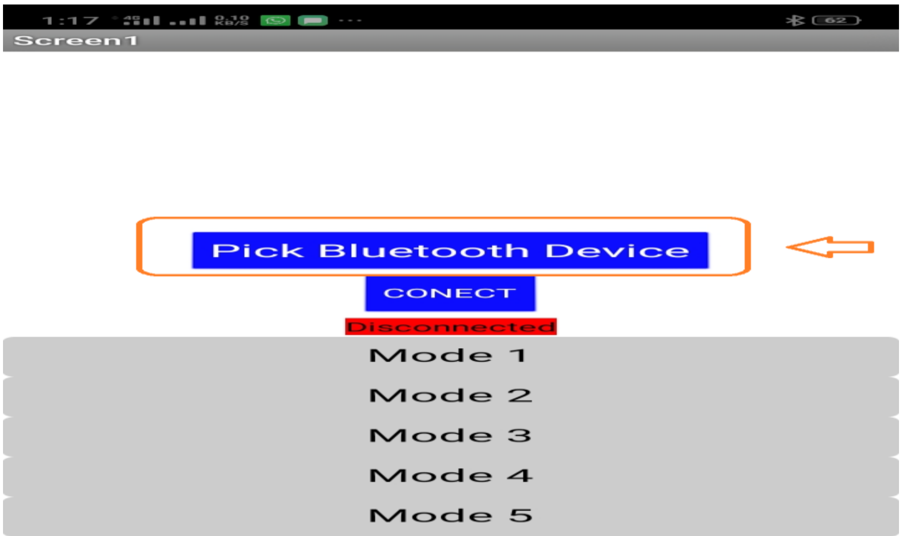


Figure 56 Application First Step

Step 2:

In this step the user should pick the Bluetooth device of the hand in order to choose the desired modes afterwards.The Bluetooth address of hand is as the highlighted in fi.58.

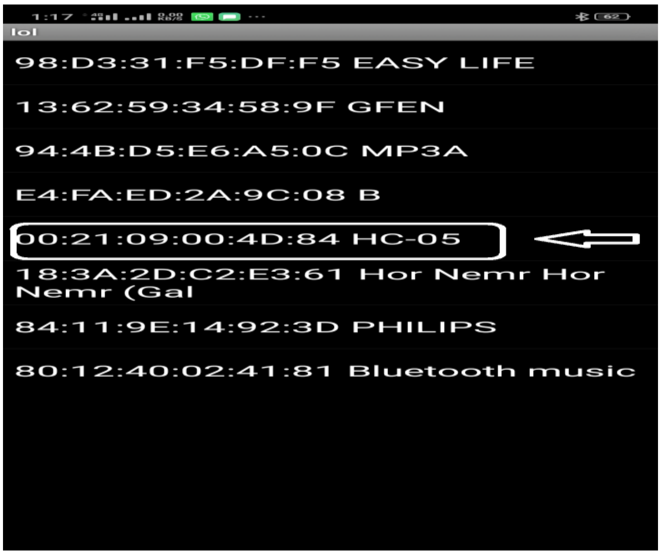


Figure 57 Application second step

Step 3:

After picking the correct address of the hand, now you press on connect, and when the "Disconnected" label changes to "Connected", then the device will be ready to use.

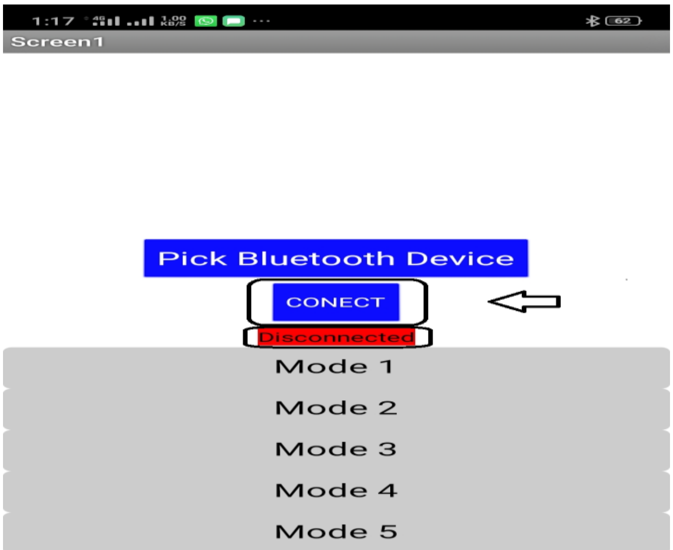


Figure 58 Application Last Step

4 CHAPTER FOUR EVALUATION

With the finger is assembled the team began to test the function of the finger

4.1.1 Aesthetic design

It is difficult to quantify whether the finger looks like human finger, but we designed the device based on the height of an average adult male. For this reason, we conclude with a clear conscience that we have indeed achieved our goal of having a design with anthropomorphic base

4.1.2 movement

We believe finger movements look natural and like human, but we can improve this in the next stage by collecting data from individuals.

4.1.3 electrical hardware

Submodules are individually tested to ensure their performance before system integration. All components were consistent with the datasheet specifications.

- the motor can provide the required torque
- The motor driver was tested at the input voltage specification and was able to deliver the required current to the control output.
- The STM has been tested and reprogrammed many times with no problems.

5 CHAPTER FIVE RESULTS

After evaluating each subsystem, we integrated these parts into one device. This integration includes mechanical connections for the fingers, palm, and controller (STM) communication.

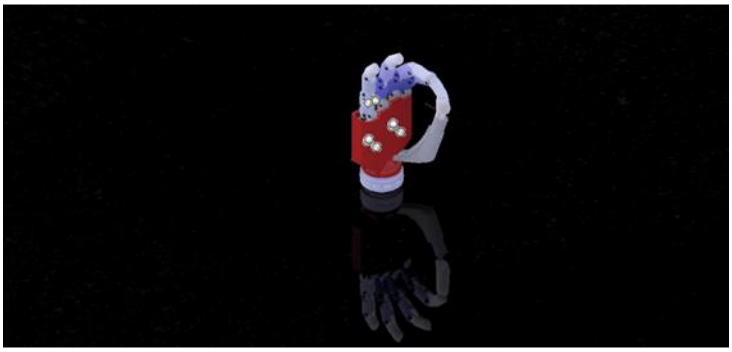


Figure 59 full hand

The finger is capable of performing a whole movement successfully, All unique parts, like the fingers, palm and forearm, will be 3D-printed .

Hand prototype

The electrical components communicate effectively with each other, allowing the motors to operate and control properly, All components are modular and easily replaced.

Figure 60 hand prototype

PID trial&error

For Kp = 20 , Kd= 1, Ki=0.001

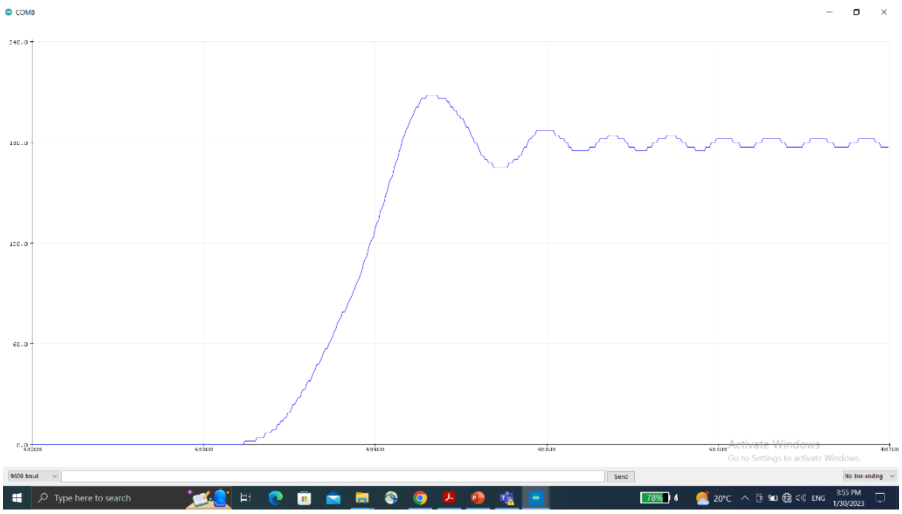


Figure 61 first PID results

For Kp = 20, Kd = 1, Ki= 0

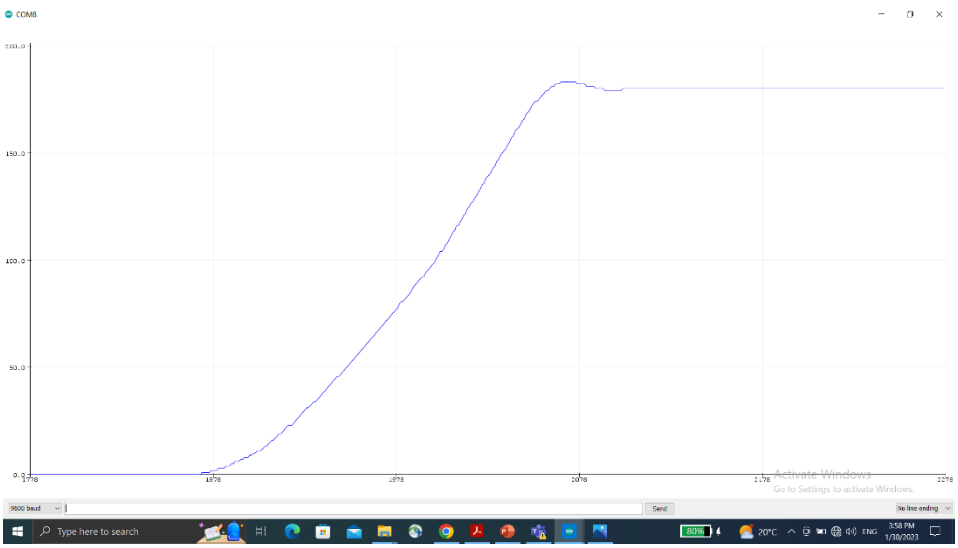


Figure 62 final PID results

6 CONCLUSION

The hand is designed to fit within the hand size limits of an average adult male. System functionality has been checked to the best of our knowledge and belief. If the recommendations we have made for future improvements are implemented, this device has the potential to provide thousands of people with a highly functional and easy-to-use transradial prosthesis.

7 APPENDIX

1. Construction drawings

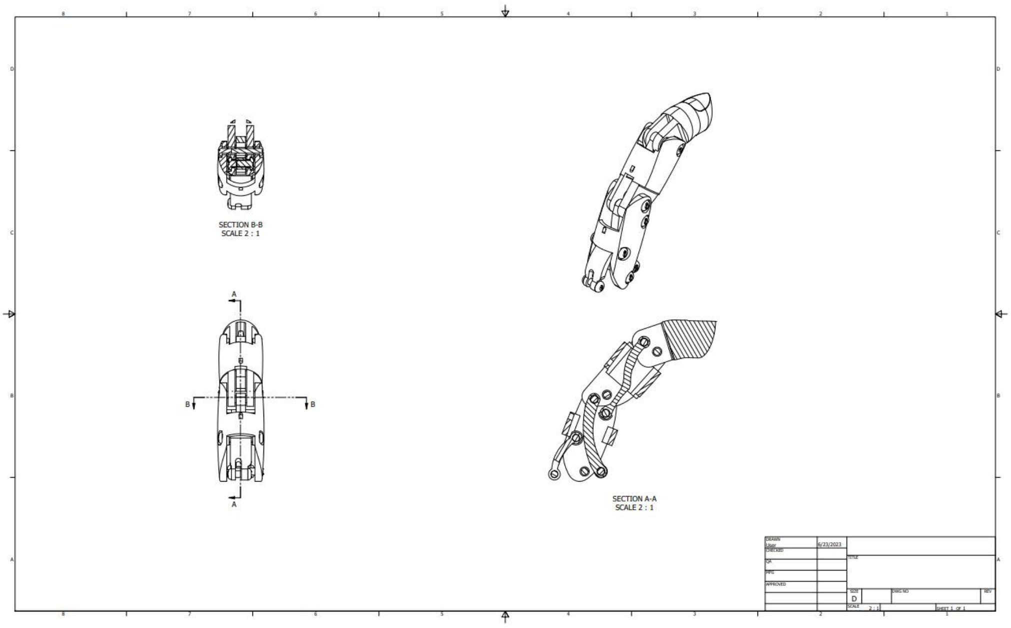


Figure 63 Finger

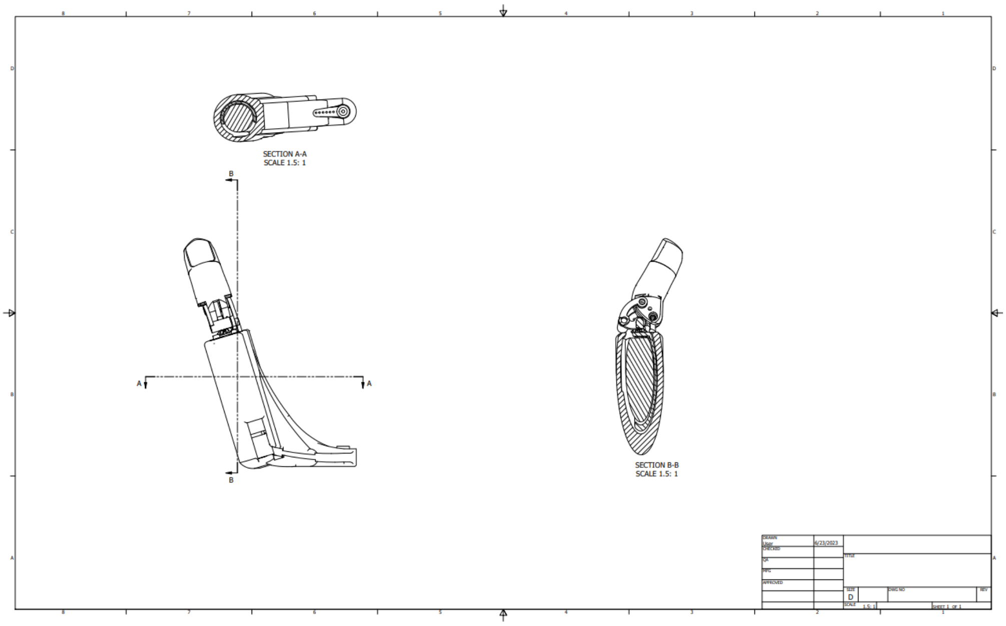


Figure 64 Thumb

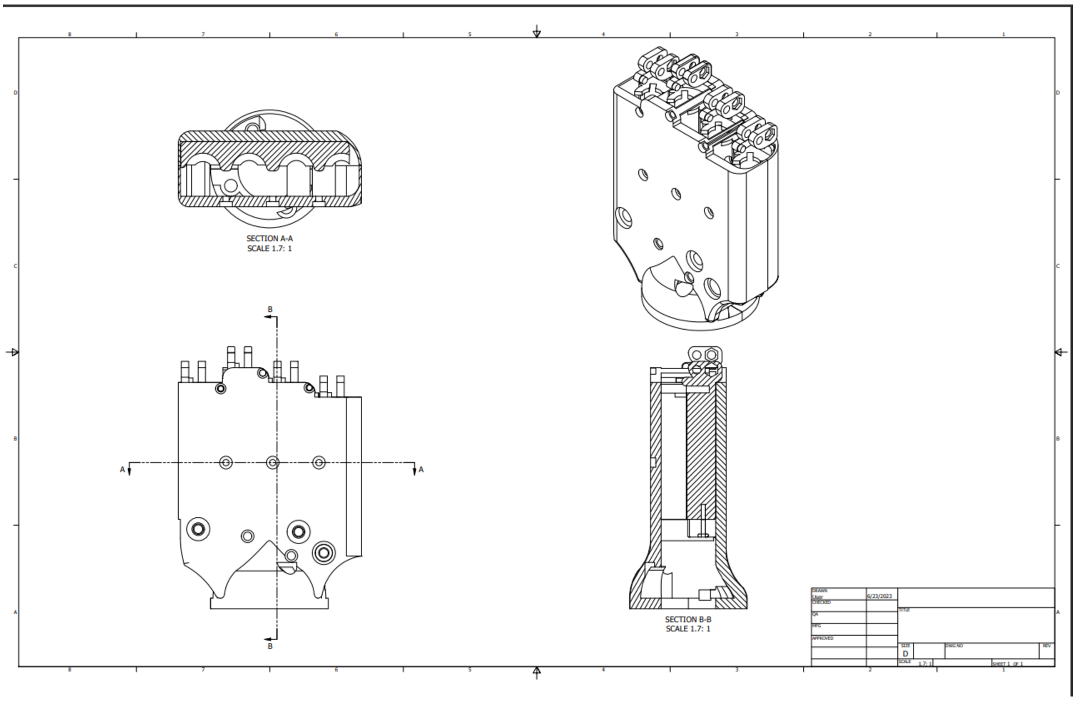


Figure 65 Palm

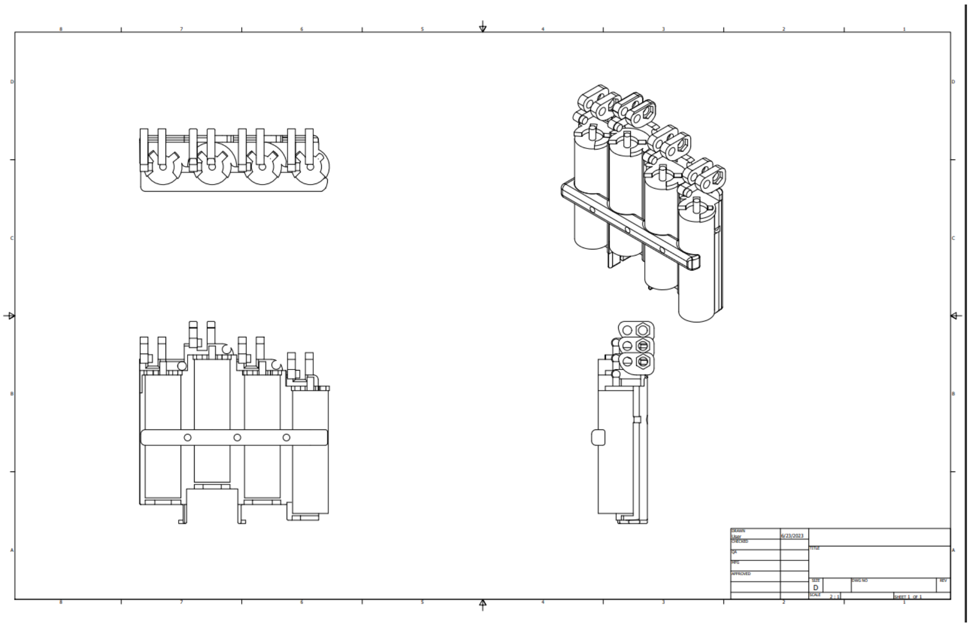


Figure 66 Motor Holder

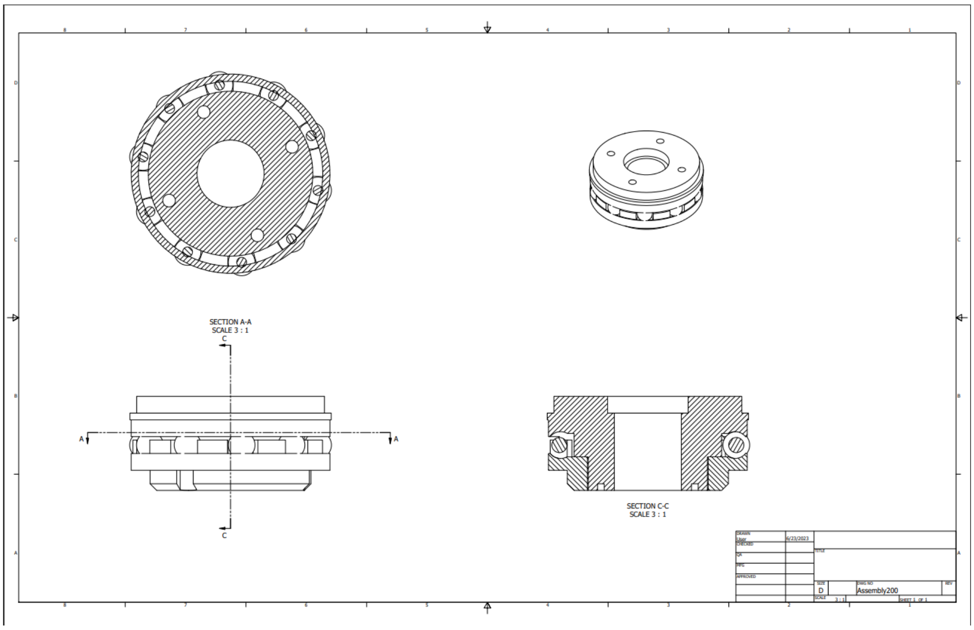
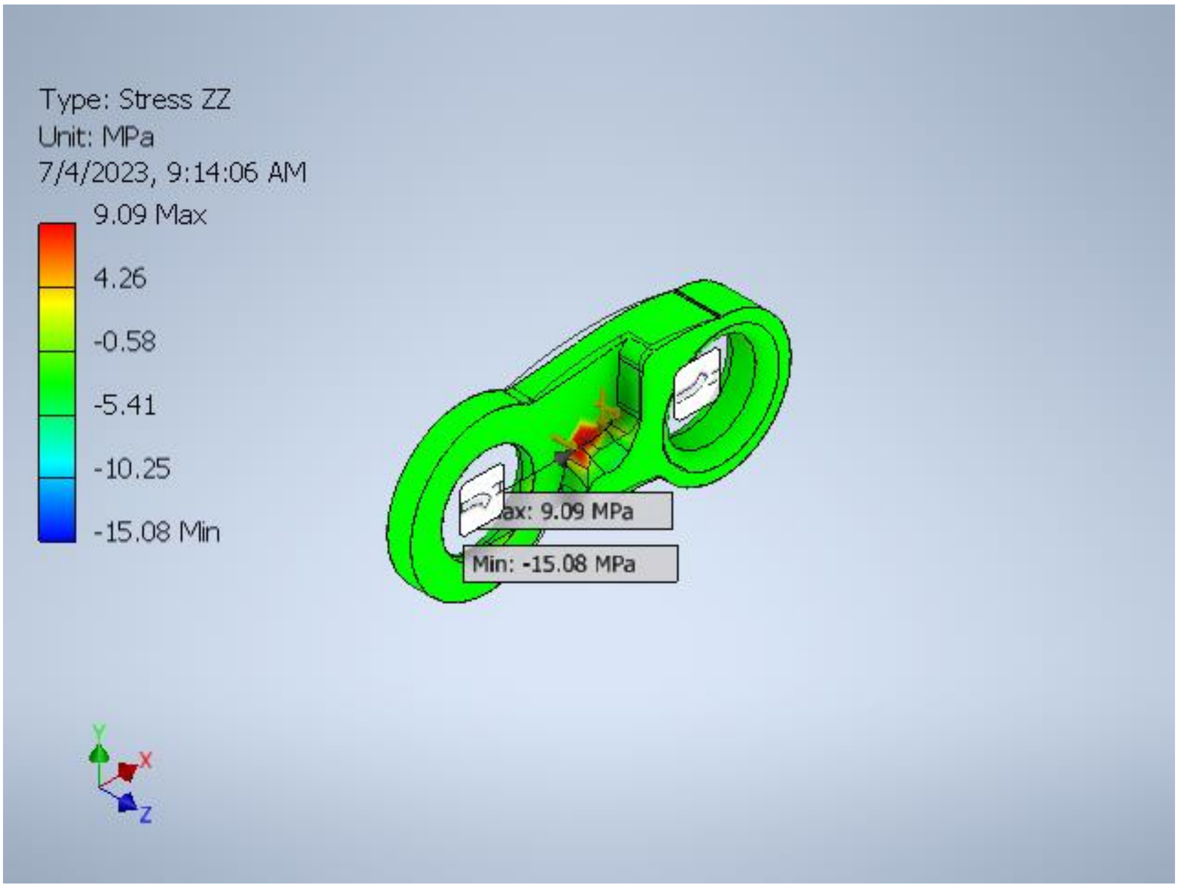
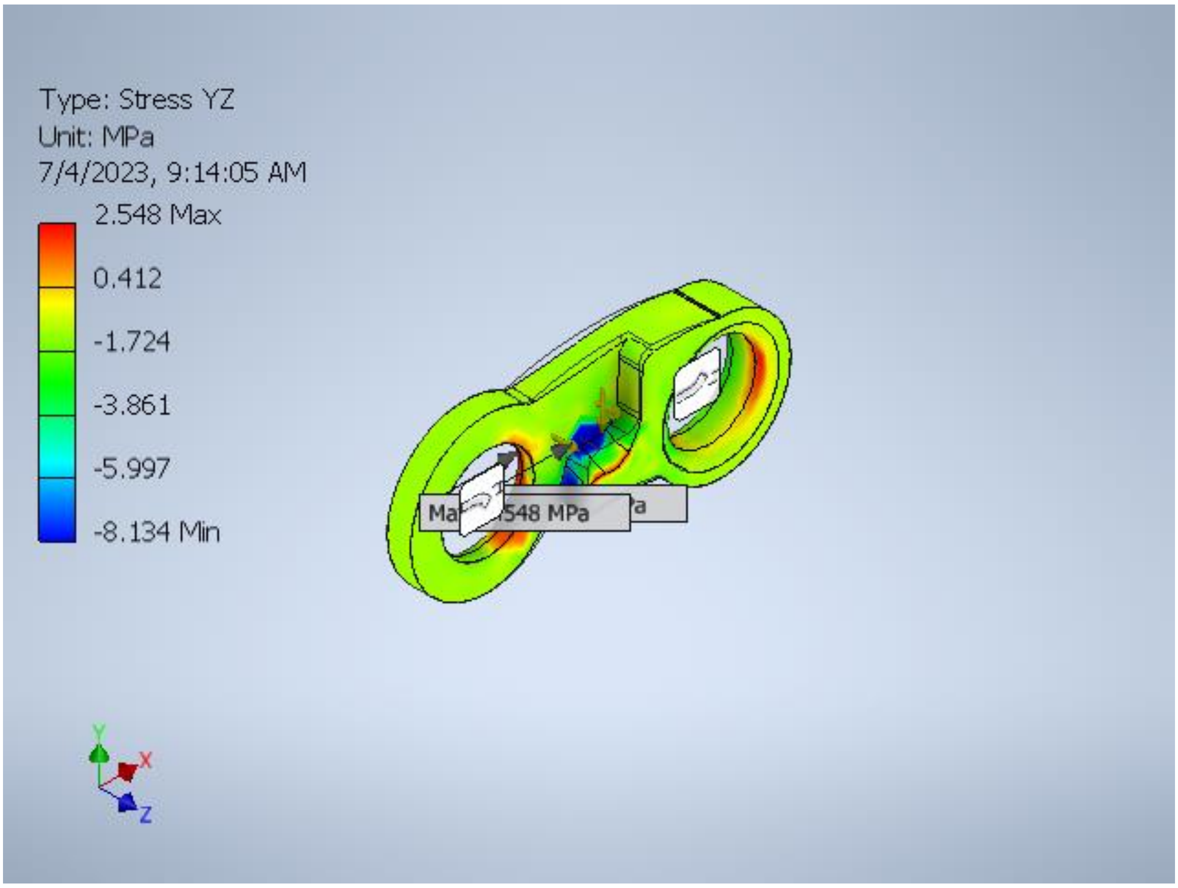


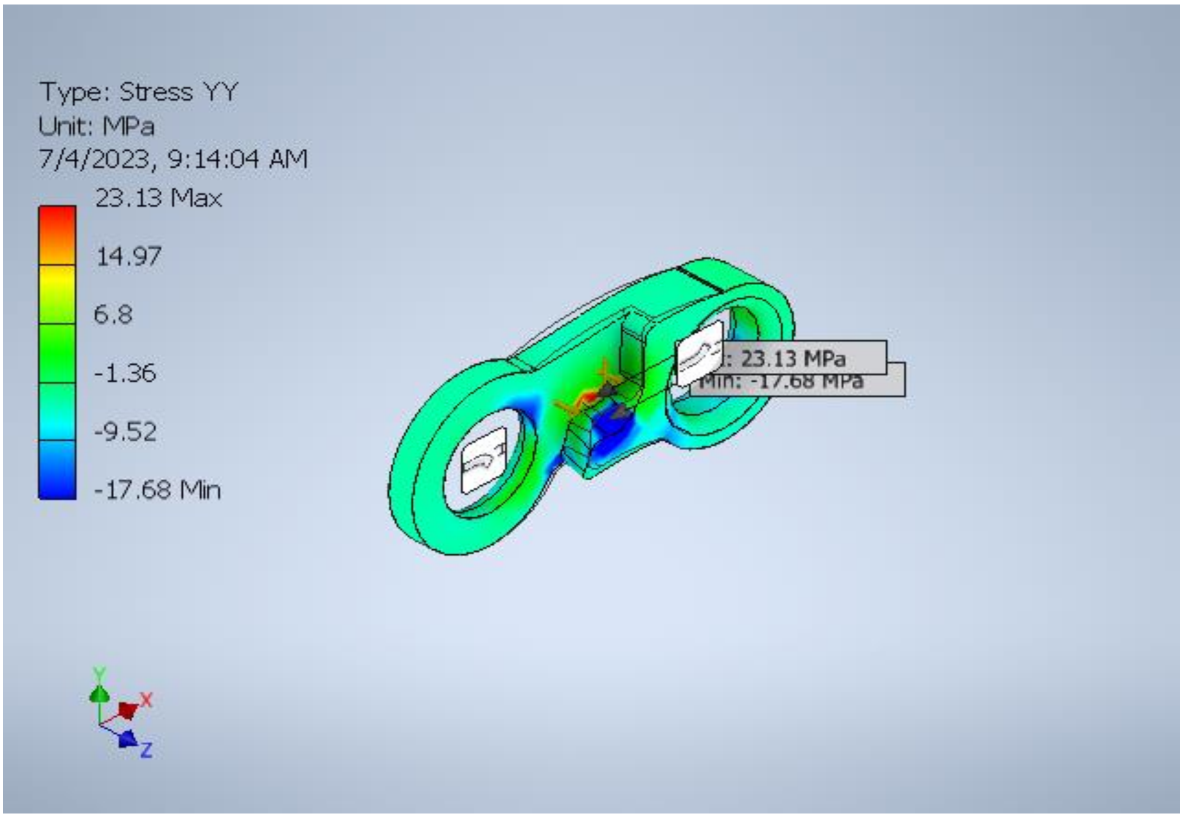
Figure 67 Forearm Connector

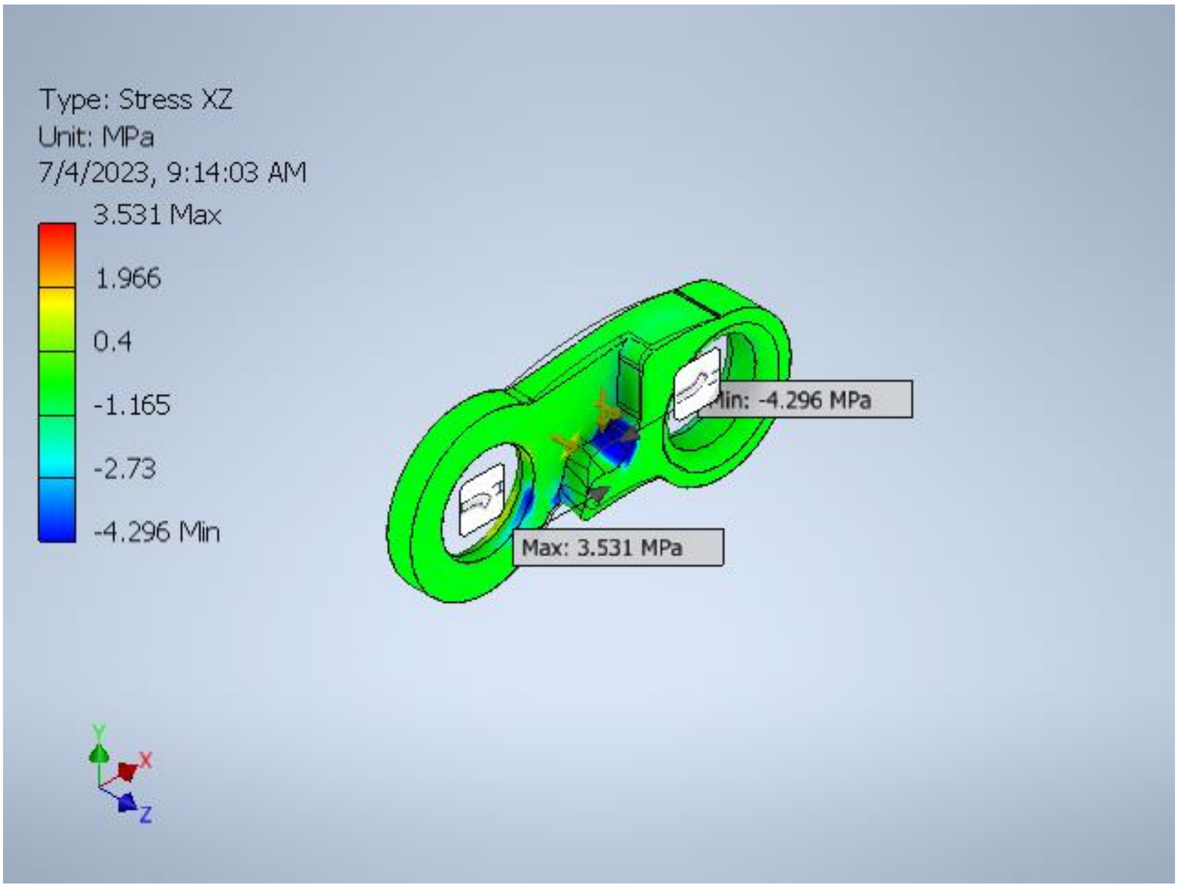
2.Stress analysis results on for each links:

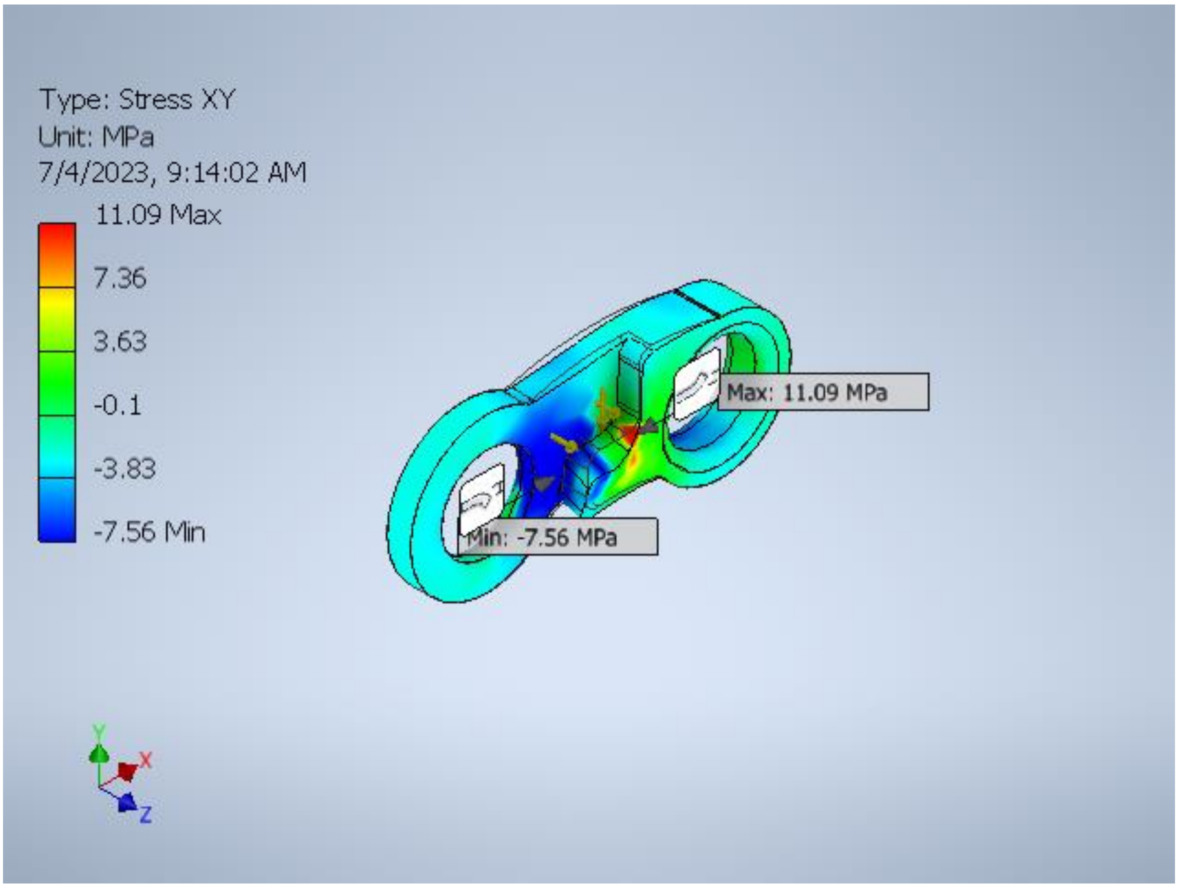
Link 1:

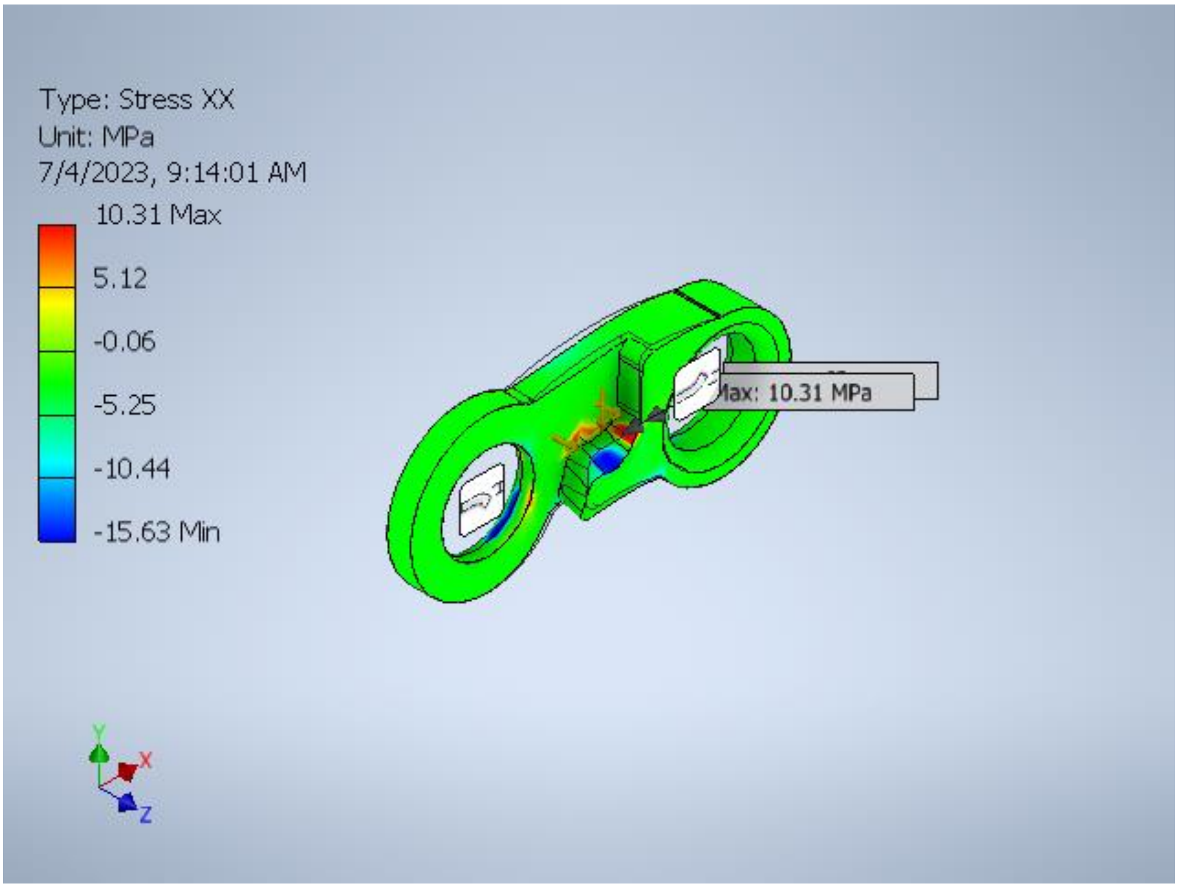


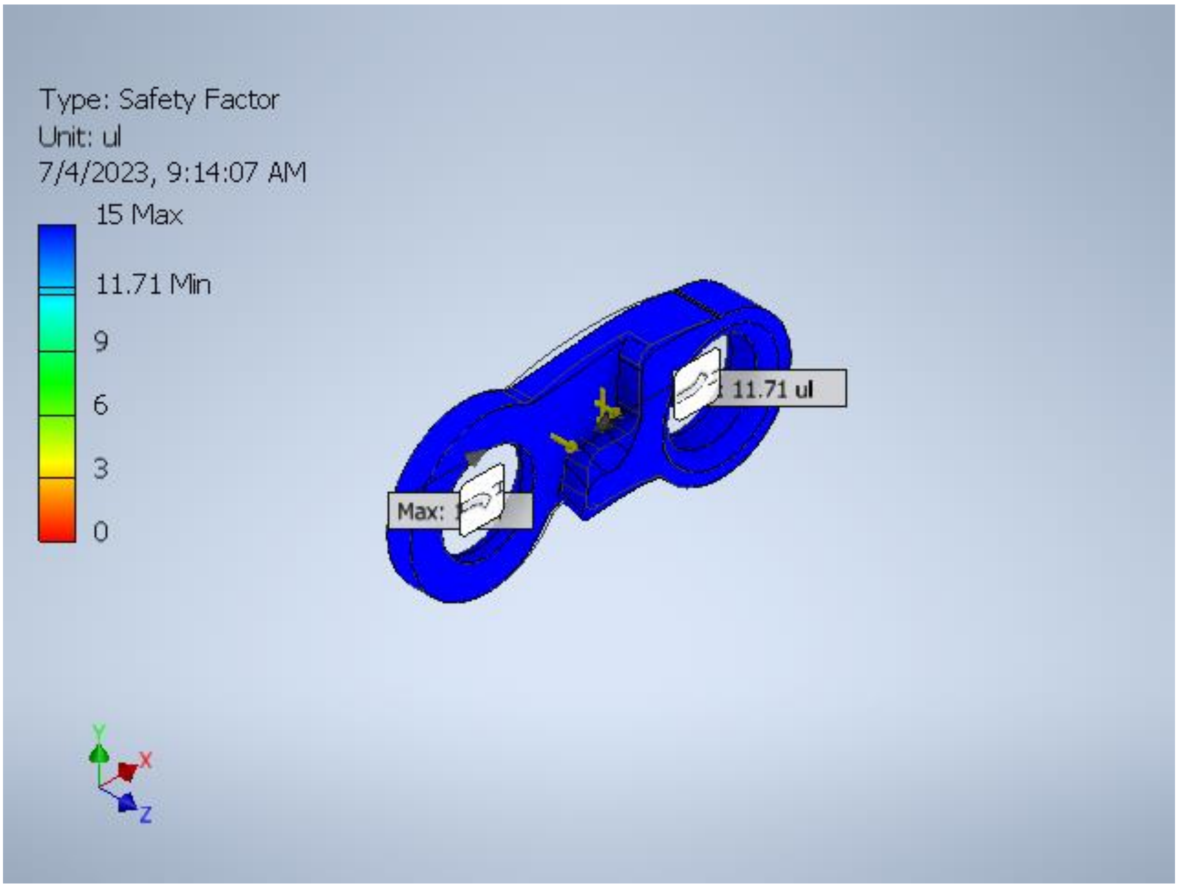

Type: Stress YZ
Unit: MPa
7/4/2023, 9:14:05 AM
2.548 Max
0.412
-1.724
-3.861
-5.997
-8.134 Min

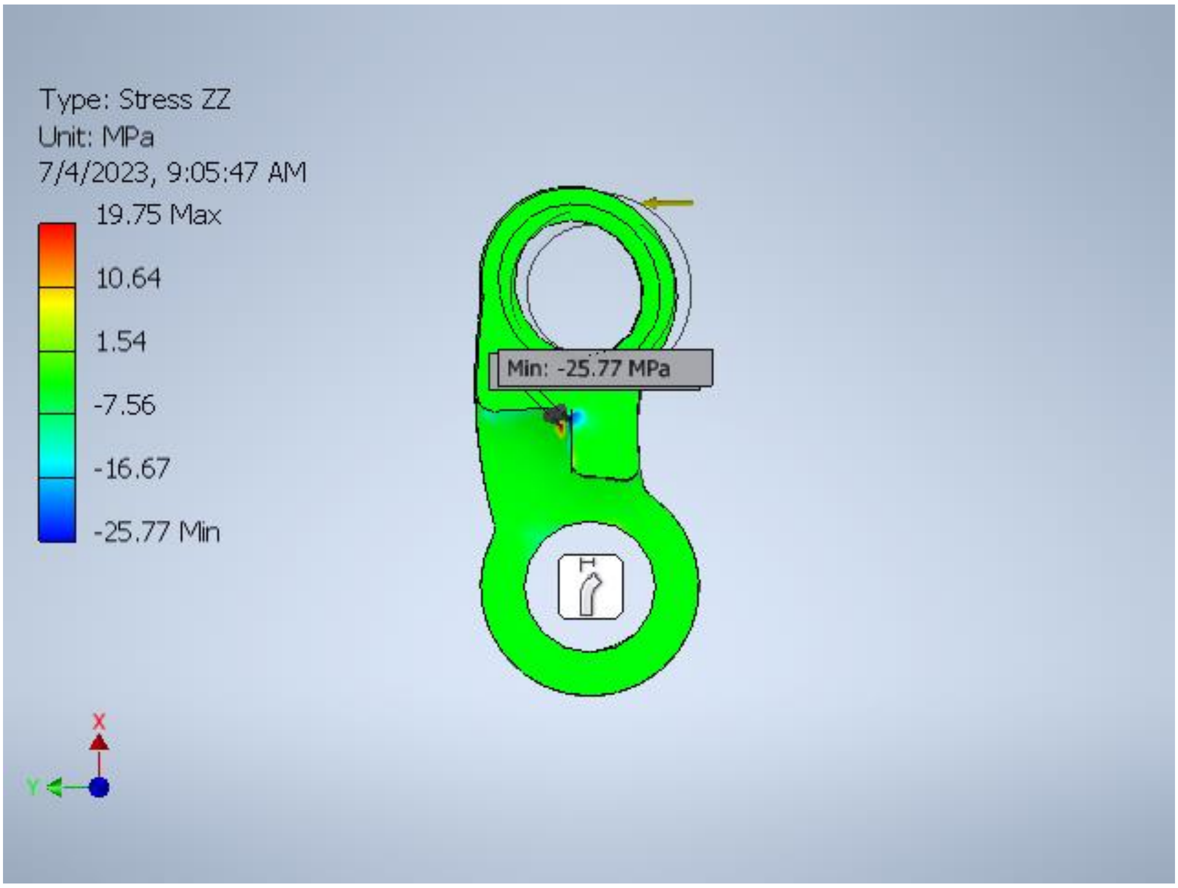

Type: Stress YY
Unit: MPa
7/4/2023, 9:14:04 AM
23.13 Max
14.97
6.8
-1.36
-9.52
-17.68 Min

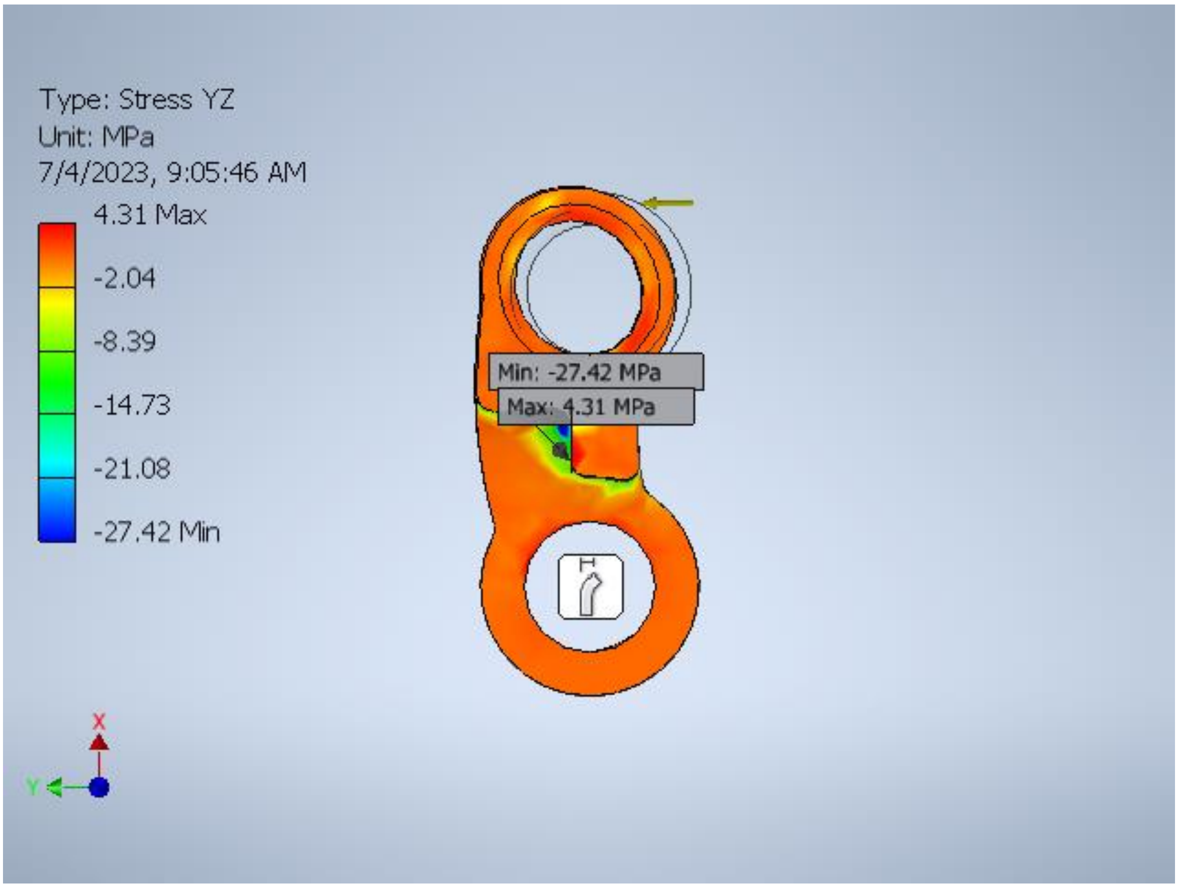

Type: Stress XZ
Unit: MPa
7/4/2023, 9:14:03 AM
3.531 Max
1.966
0.4
-1.165
-2.73
-4.296 Min
Min: -4.296 MPa
Max: 3.531 MPa
Y
X
Z

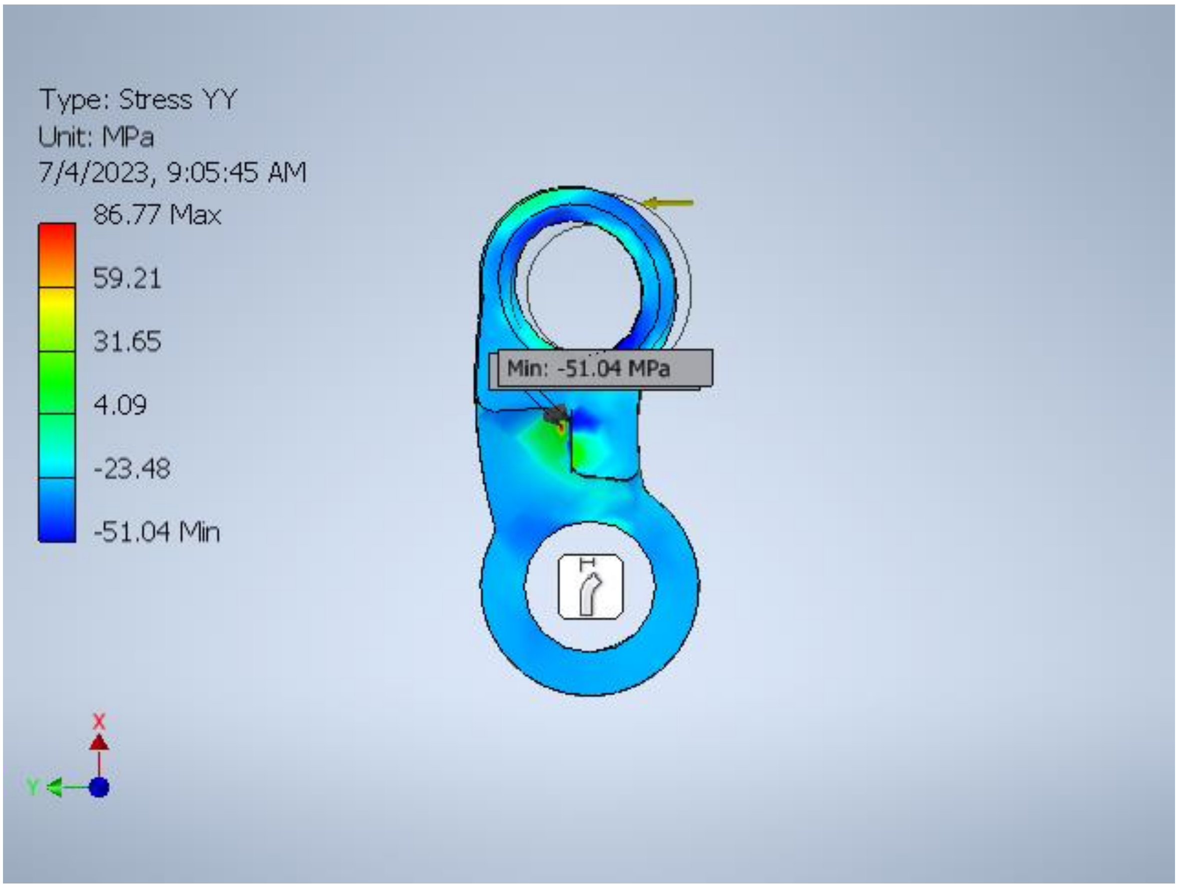

Type: Stress XY
Unit: MPa
7/4/2023, 9:14:02 AM
11.09 Max
7.36
3.63
-0.1
-3.83
-7.56 Min
Max: 11.09 MPa
Min: -7.56 MPa
Y
X
Z

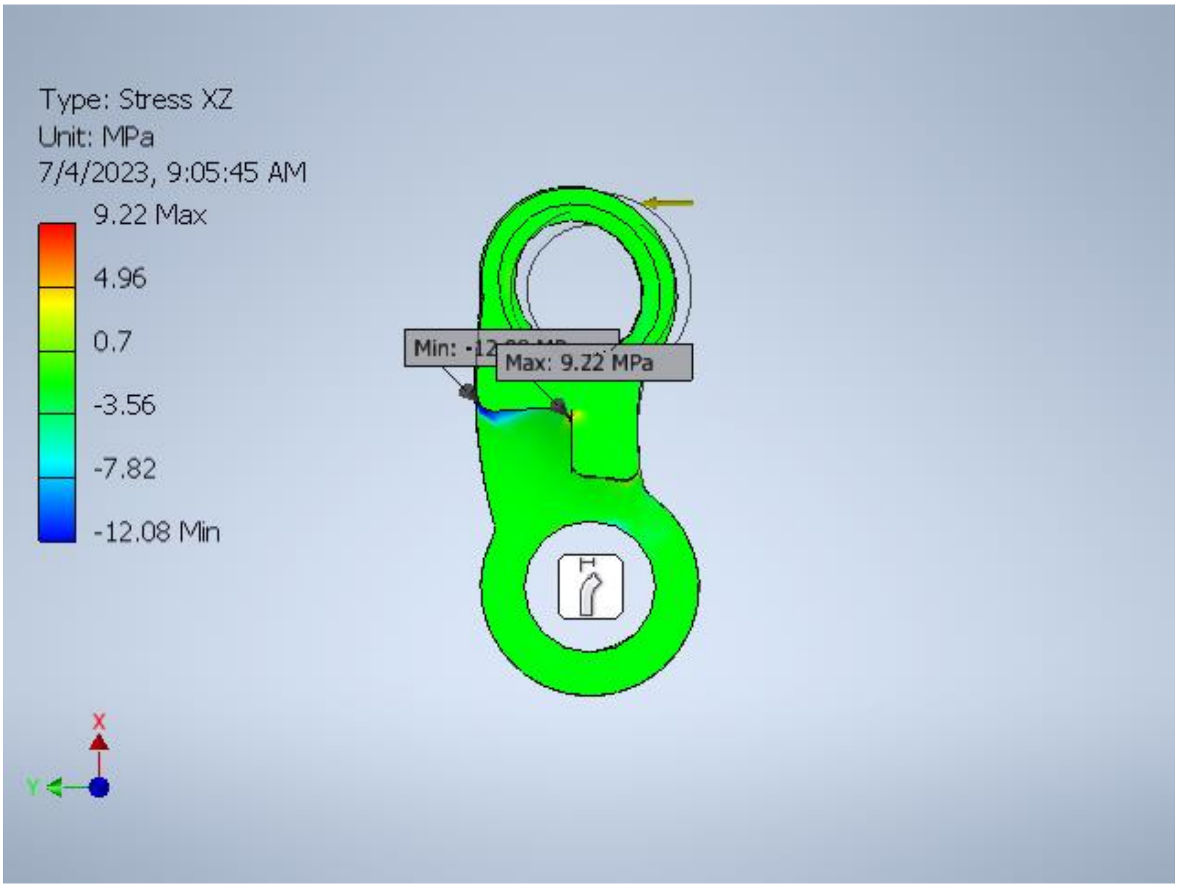

Type: Stress XX
Unit: MPa
7/4/2023, 9:14:01 AM
10.31 Max
5.12
-0.06
-5.25
-10.44
-15.63 Min
Max: 10.31 MPa

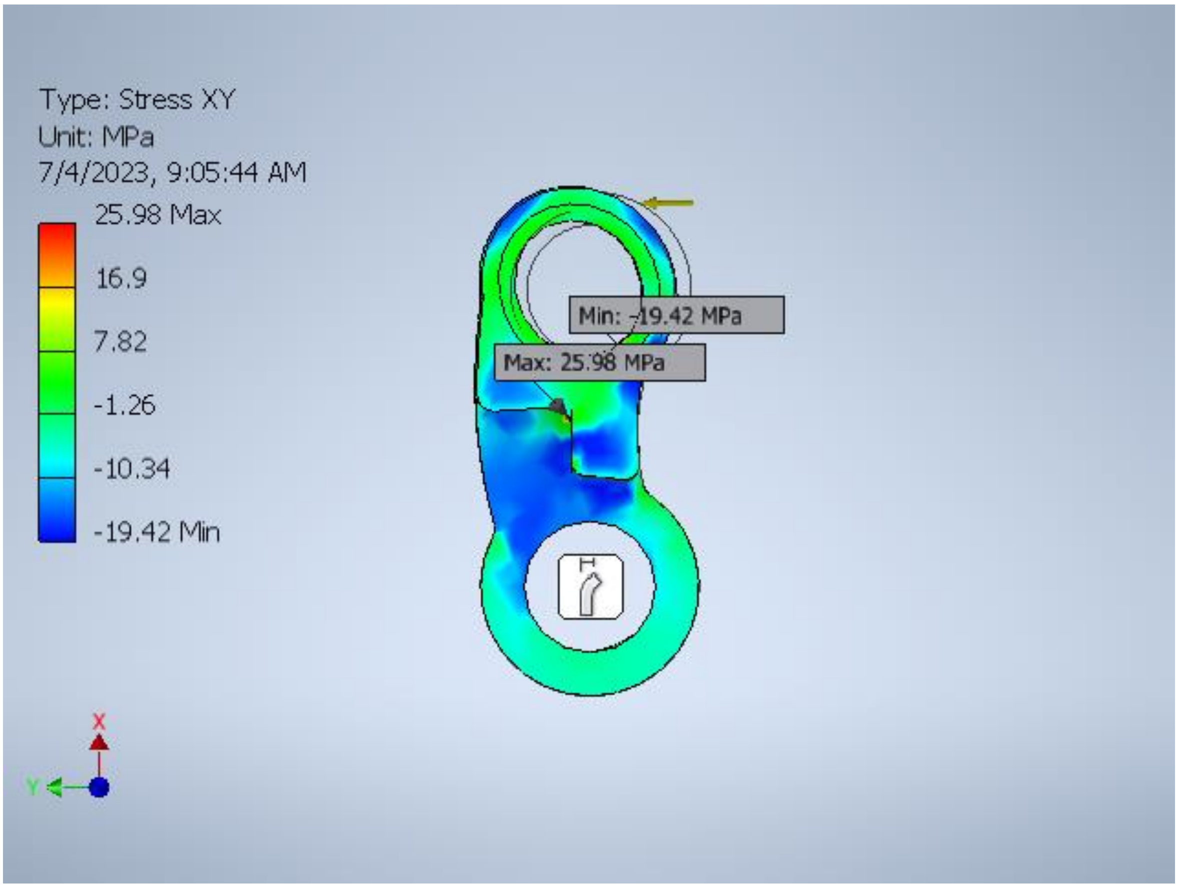

Type: Safety Factor
Unit: ul
7/4/2023, 9:14:07 AM
15 Max
11.71 Min
9
6
3
0
11.71 ul

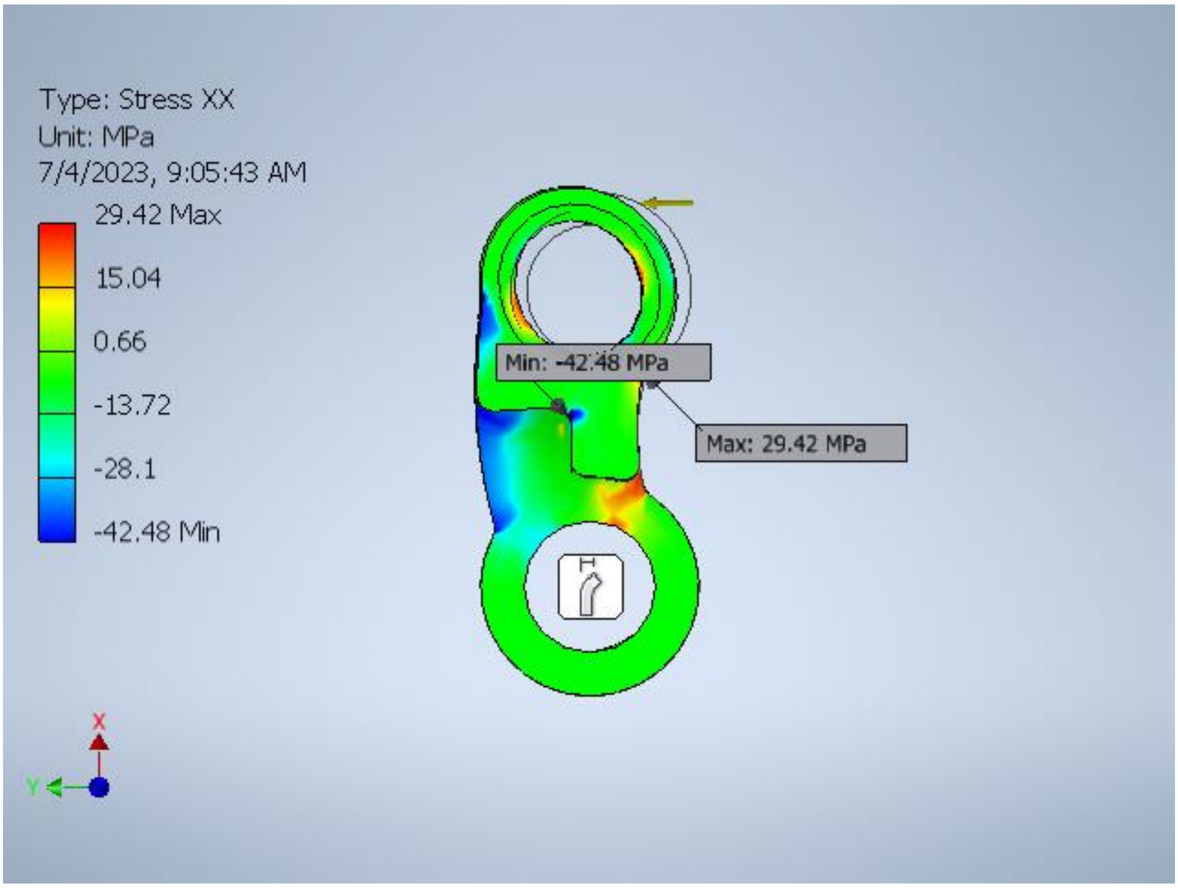

Type: Stress ZZ
Unit: MPa
7/4/2023, 9:05:47 AM
19.75 Max
10.64
1.54
-7.56
-16.67
-25.77 Min
Min: -25.77 MPa
X
Y

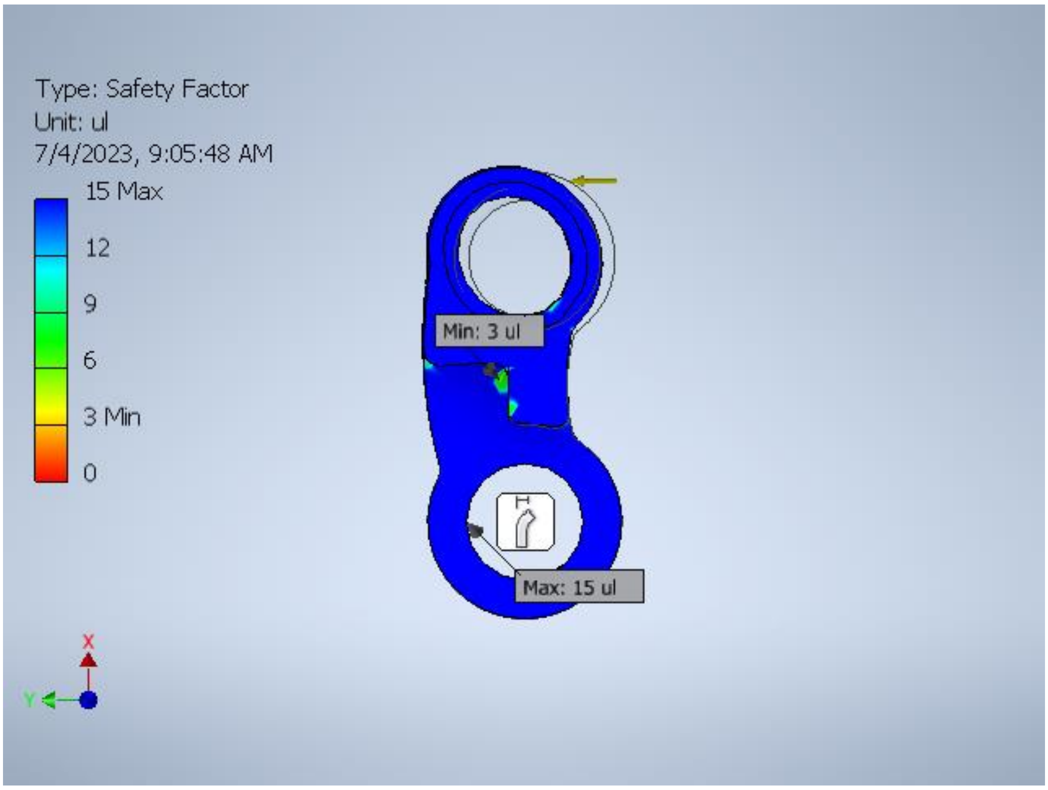

Type: Stress YZ
Unit: MPa
7/4/2023, 9:05:46 AM
4.31 Max
-2.04
-8.39
-14.73
-21.08
-27.42 Min
Min: -27.42 MPa
Max: 4.31 MPa
X
Y


Type: Stress YY
Unit: MPa
7/4/2023, 9:05:45 AM
86.77 Max
59.21
31.65
4.09
-23.48
-51.04 Min
Min: -51.04 MPa
X
Y

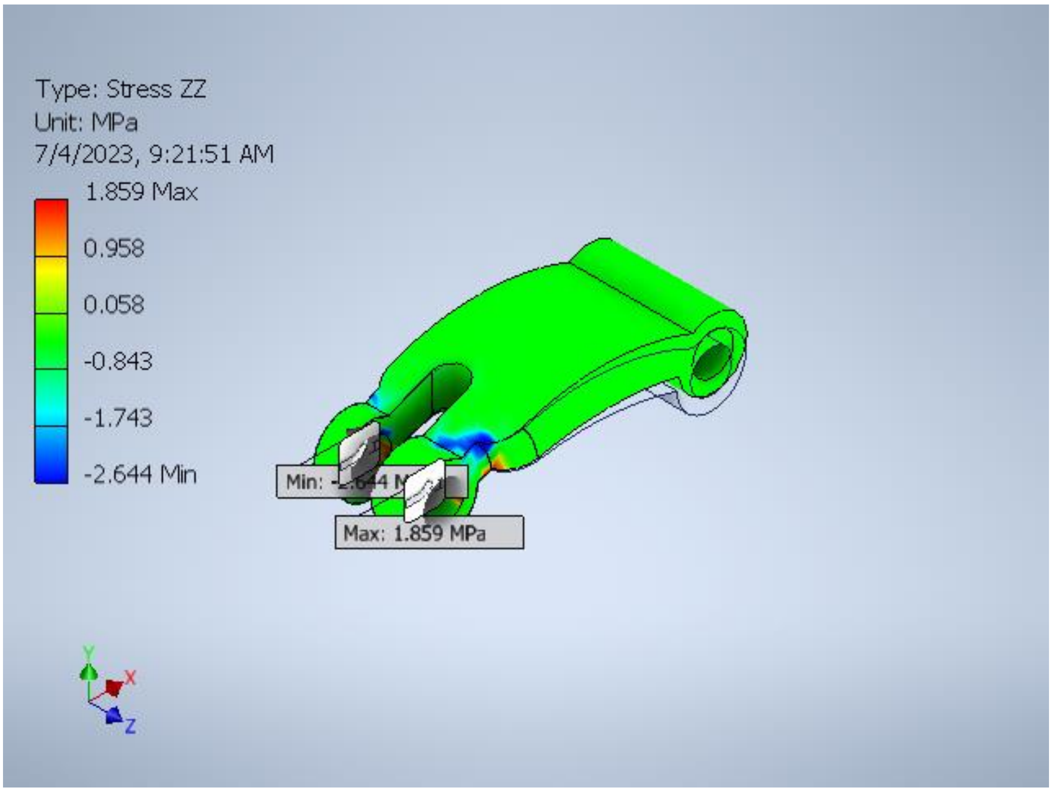

Type: Stress XZ
Unit: MPa
7/4/2023, 9:05:45 AM
9.22 Max
4.96
0.7
-3.56
-7.82
-12.08 Min
Max: 9.22 MPa
X
Y

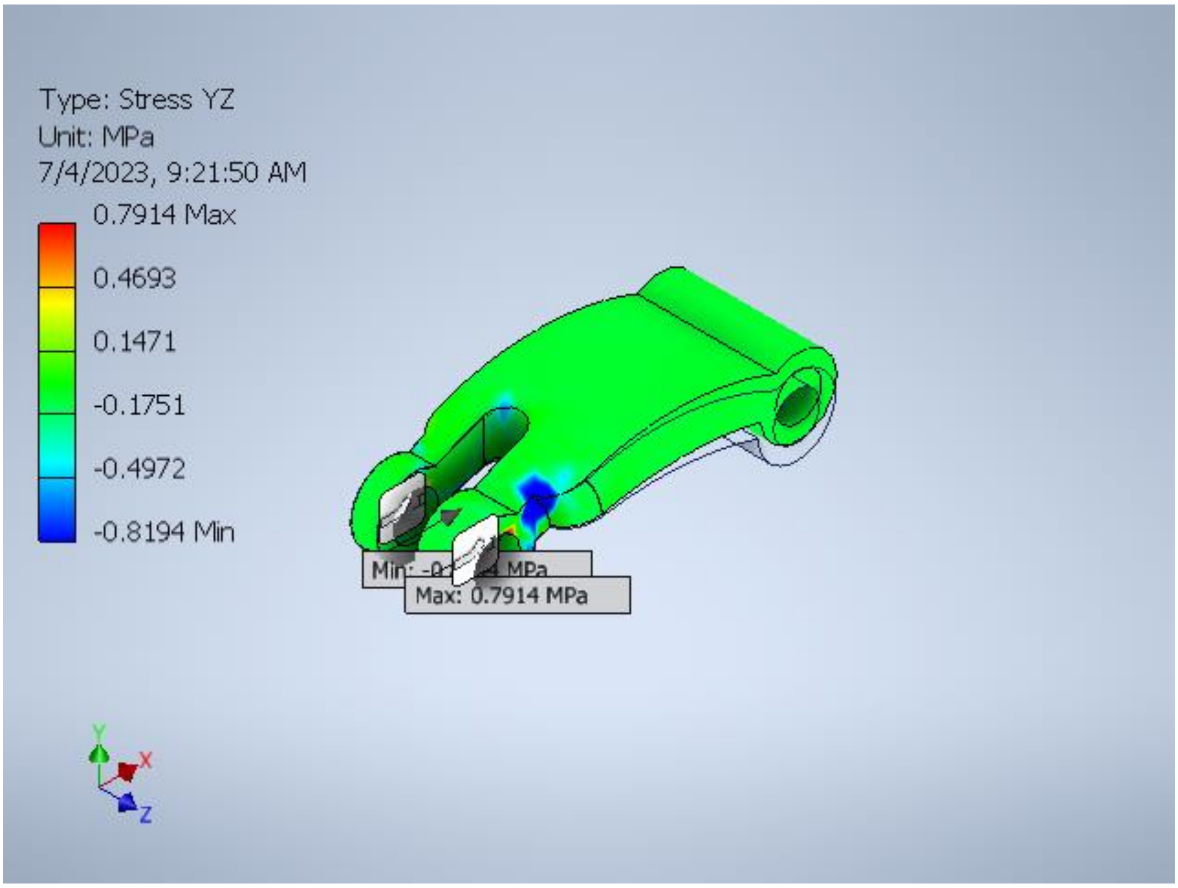

Type: Stress XY
Unit: MPa
7/4/2023, 9:05:44 AM
25.98 Max
16.9
7.82
-1.26
-10.34
-19.42 Min
Min: -19.42 MPa
Max: 25.98 MPa
X
Y

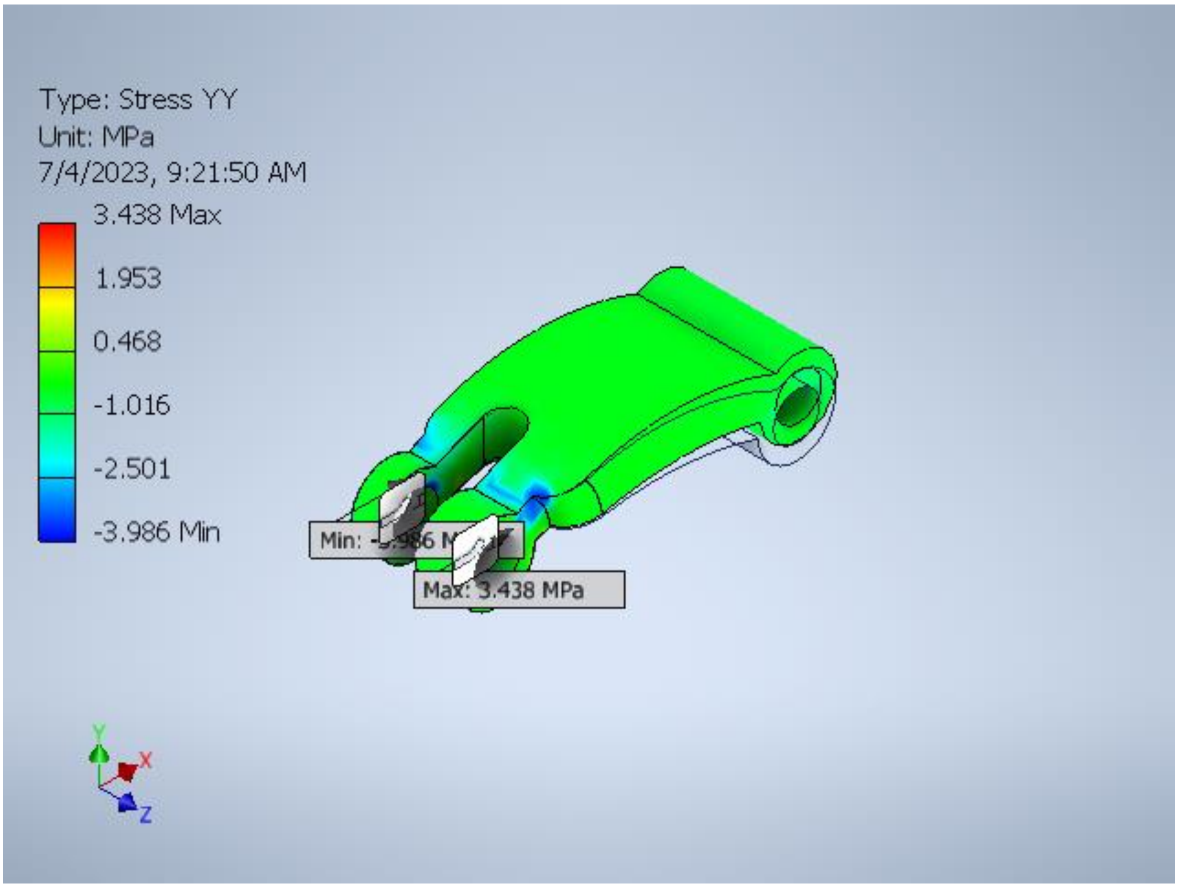

Type: Stress XX
Unit: MPa
7/4/2023, 9:05:43 AM
29.42 Max
15.04
0.66
-13.72
-28.1
-42.48 Min
Min: -42.48 MPa
Max: 29.42 MPa
X
Y

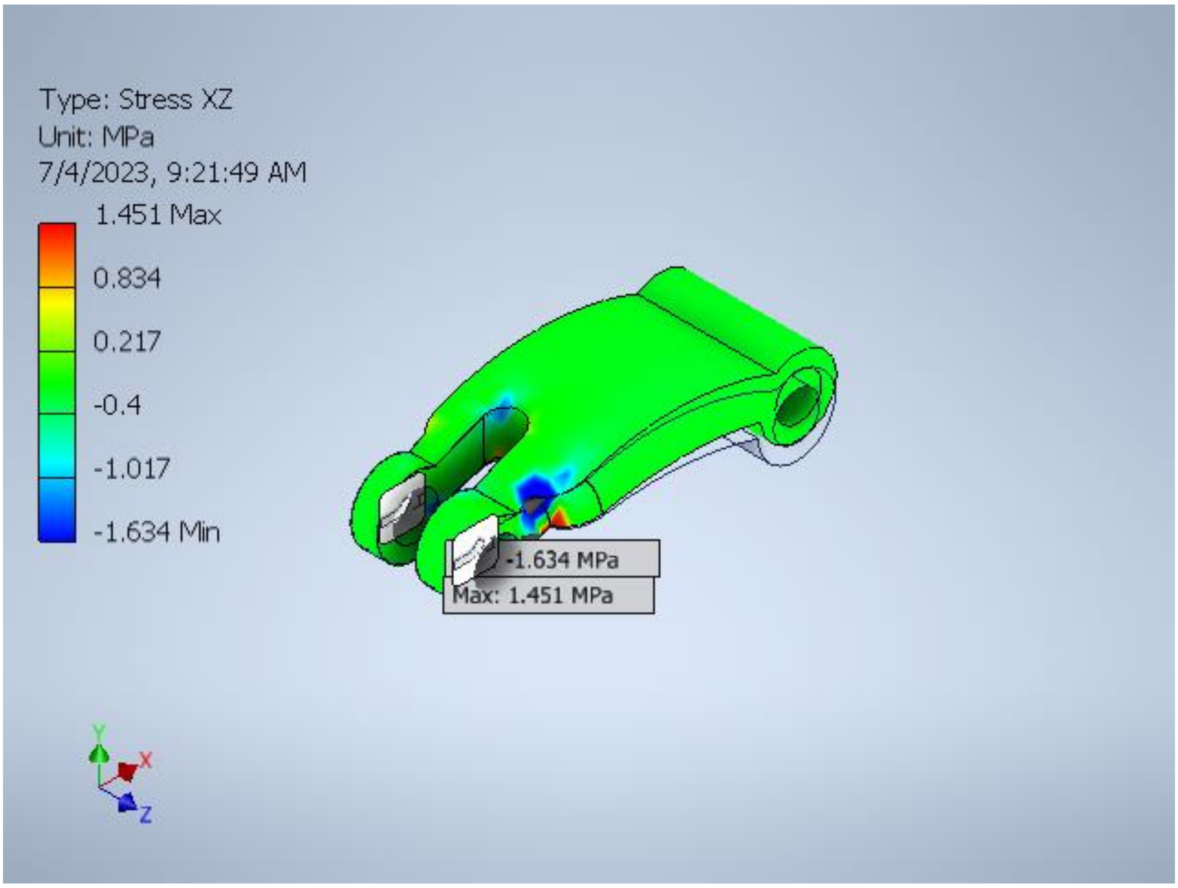

Type: Safety Factor
Unit: ul
7/4/2023, 9:05:48 AM
15 Max
12
9
6
3 Min
0
Min: 3 ul
Max: 15 ul
X
Y

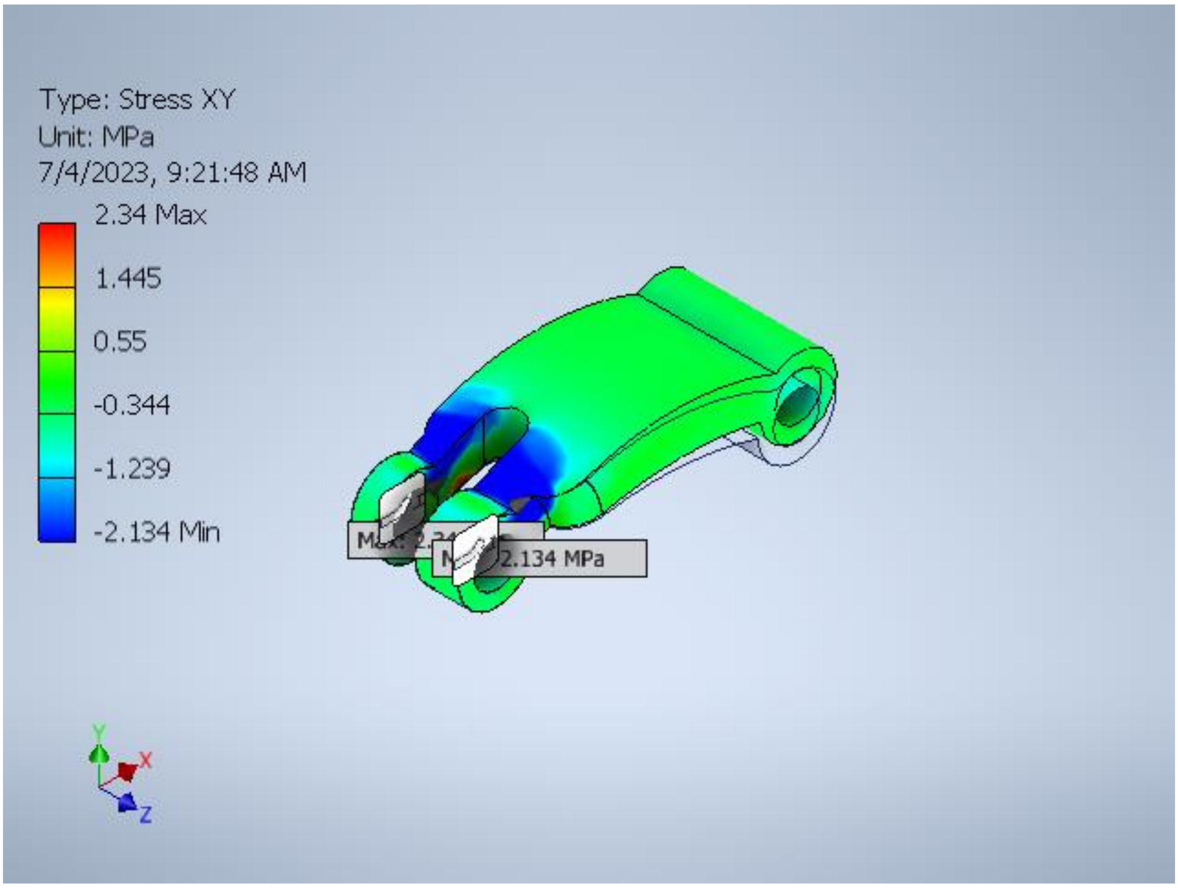
Link 2:

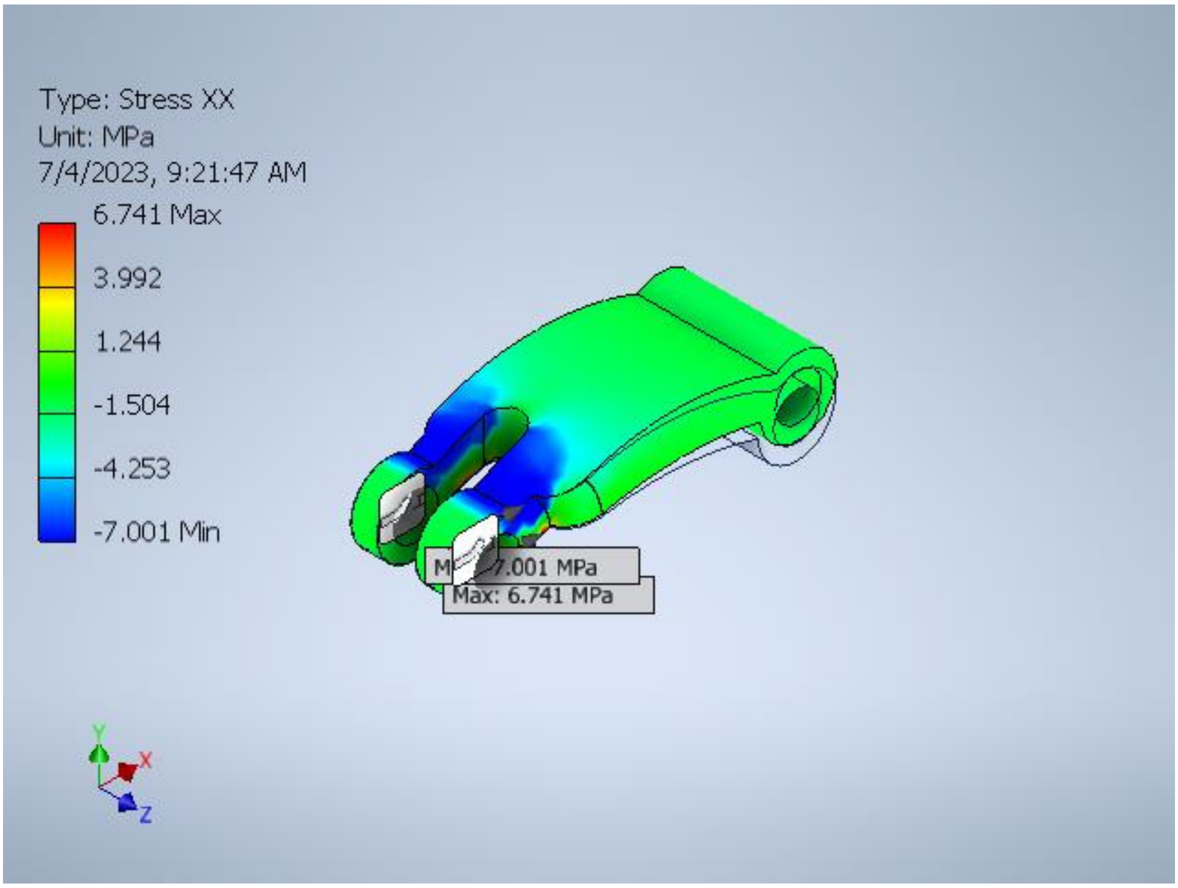

Type: Stress ZZ
Unit: MPa
7/4/2023, 9:21:51 AM
1.859 Max
0.958
0.058
-0.843
-1.743
-2.644 Min
Max: 1.859 MPa
Y
X
Z

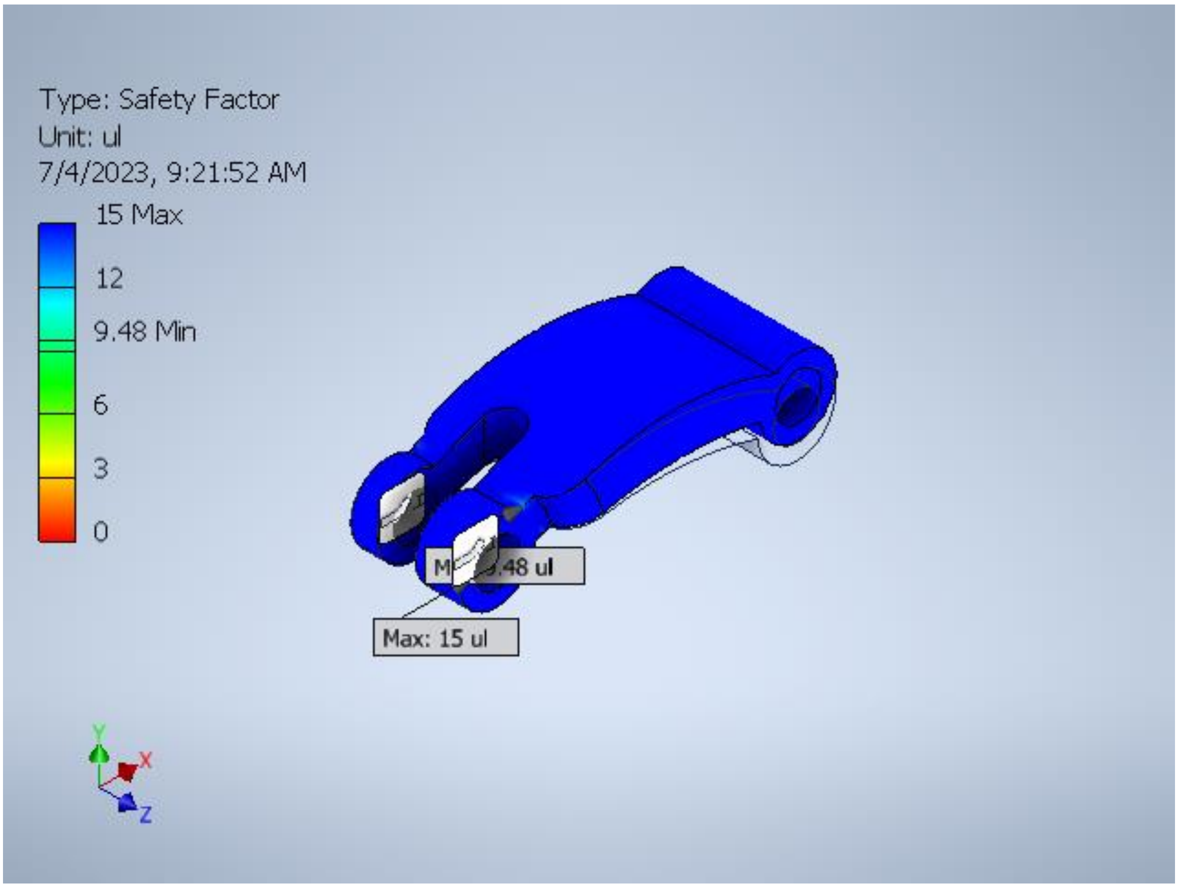

Type: Stress YZ
Unit: MPa
7/4/2023, 9:21:50 AM
0.7914 Max
0.4693
0.1471
-0.1751
-0.4972
-0.8194 Min
Max: 0.7914 MPa
Y
X
Z


Type: Stress YY
Unit: MPa
7/4/2023, 9:21:50 AM
3.438 Max
1.953
0.468
-1.016
-2.501
-3.986 Min
Max: 3.438 MPa
Y
X
Z

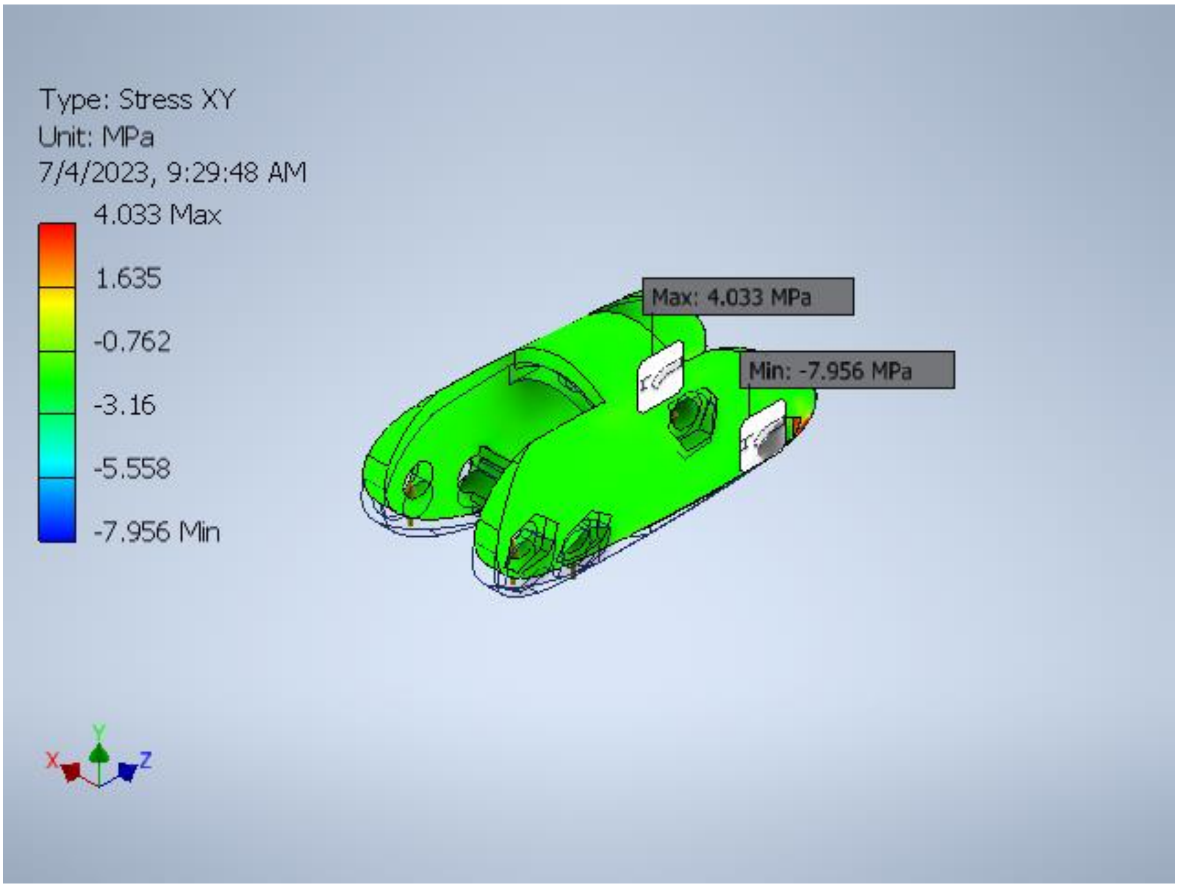

Type: Stress XZ
Unit: MPa
7/4/2023, 9:21:49 AM
1.451 Max
0.834
0.217
-0.4
-1.017
-1.634 Min
-1.634 MPa
Max: 1.451 MPa

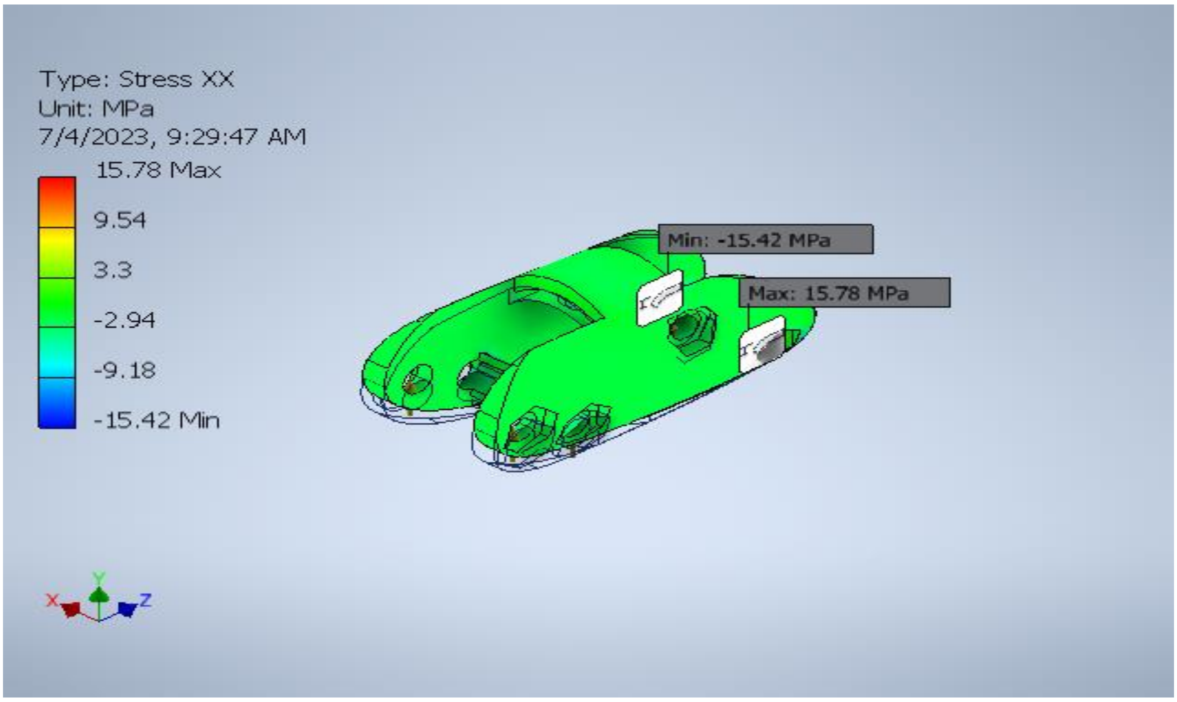

Type: Stress XY
Unit: MPa
7/4/2023, 9:21:48 AM
2.34 Max
1.445
0.55
-0.344
-1.239
-2.134 Min
2.134 MPa

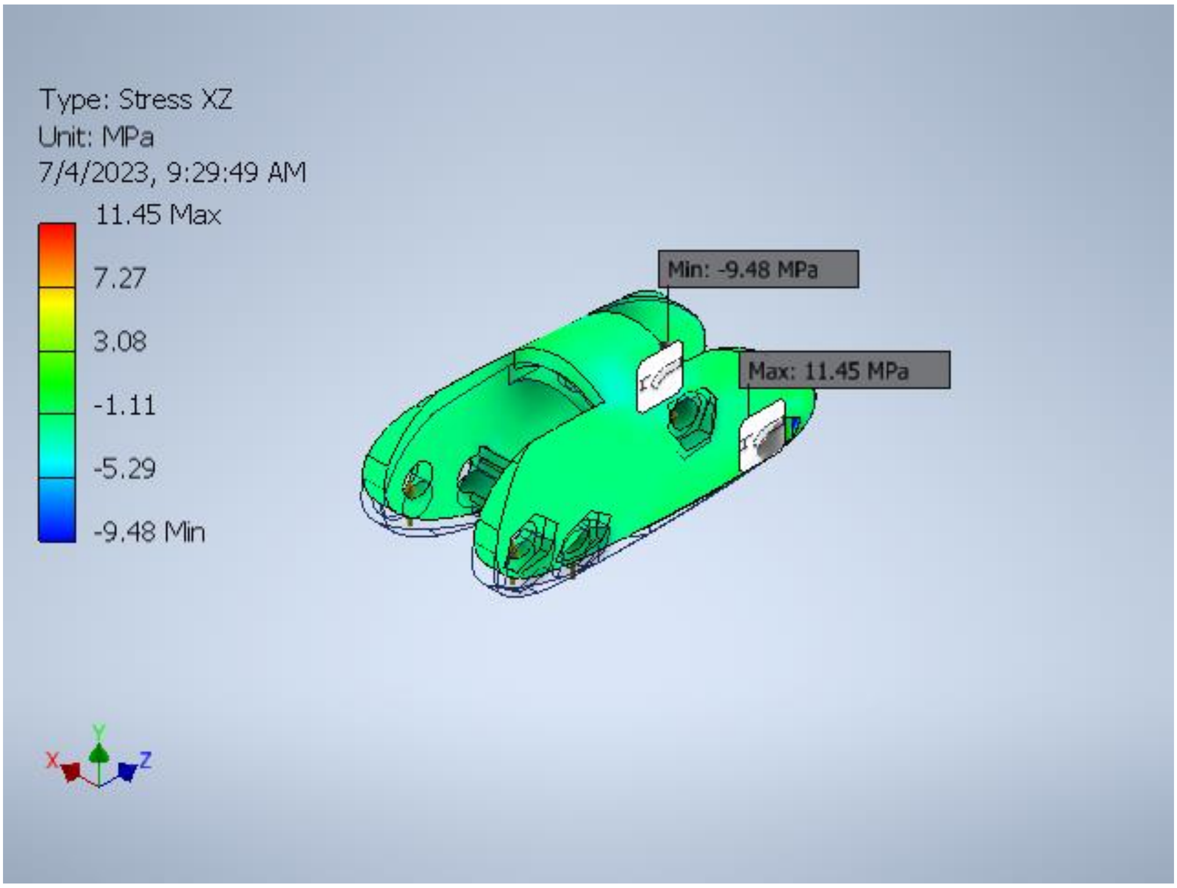

Type: Stress XX
Unit: MPa
7/4/2023, 9:21:47 AM
6.741 Max
3.992
1.244
-1.504
-4.253
-7.001 Min
Max: 6.741 MPa
Y
X
Z

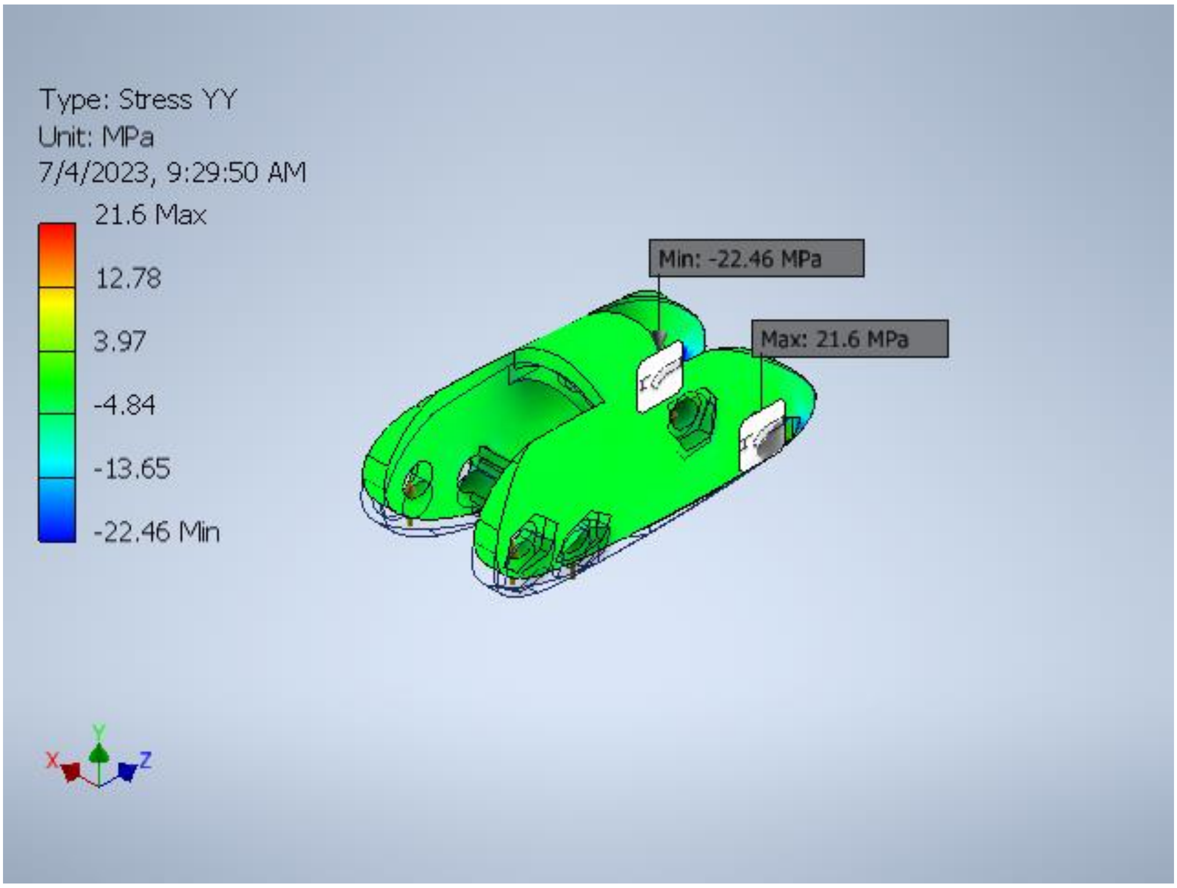

Type: Safety Factor
Unit: ul
7/4/2023, 9:21:52 AM
15 Max
12
9.48 Min
6
3
0
Max: 15 ul
Y
X
Z

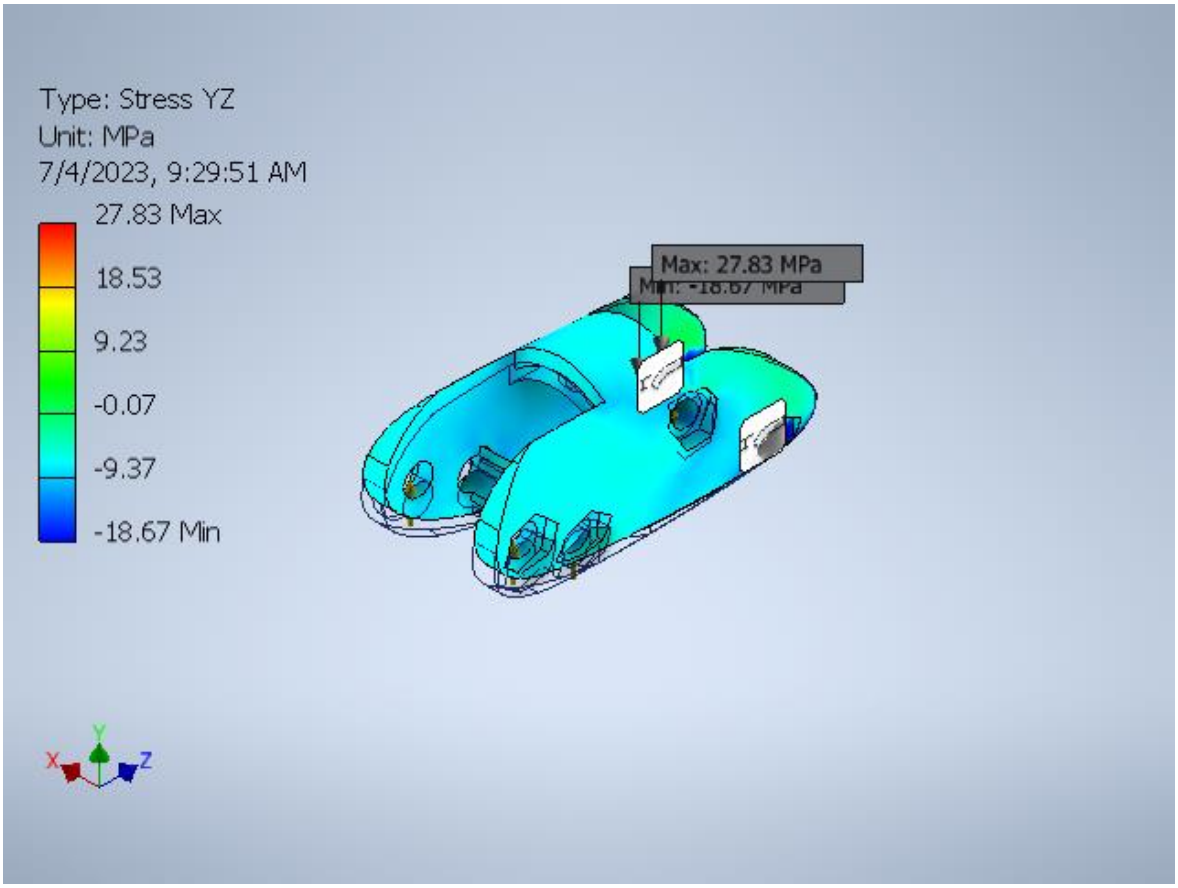
Link 3:

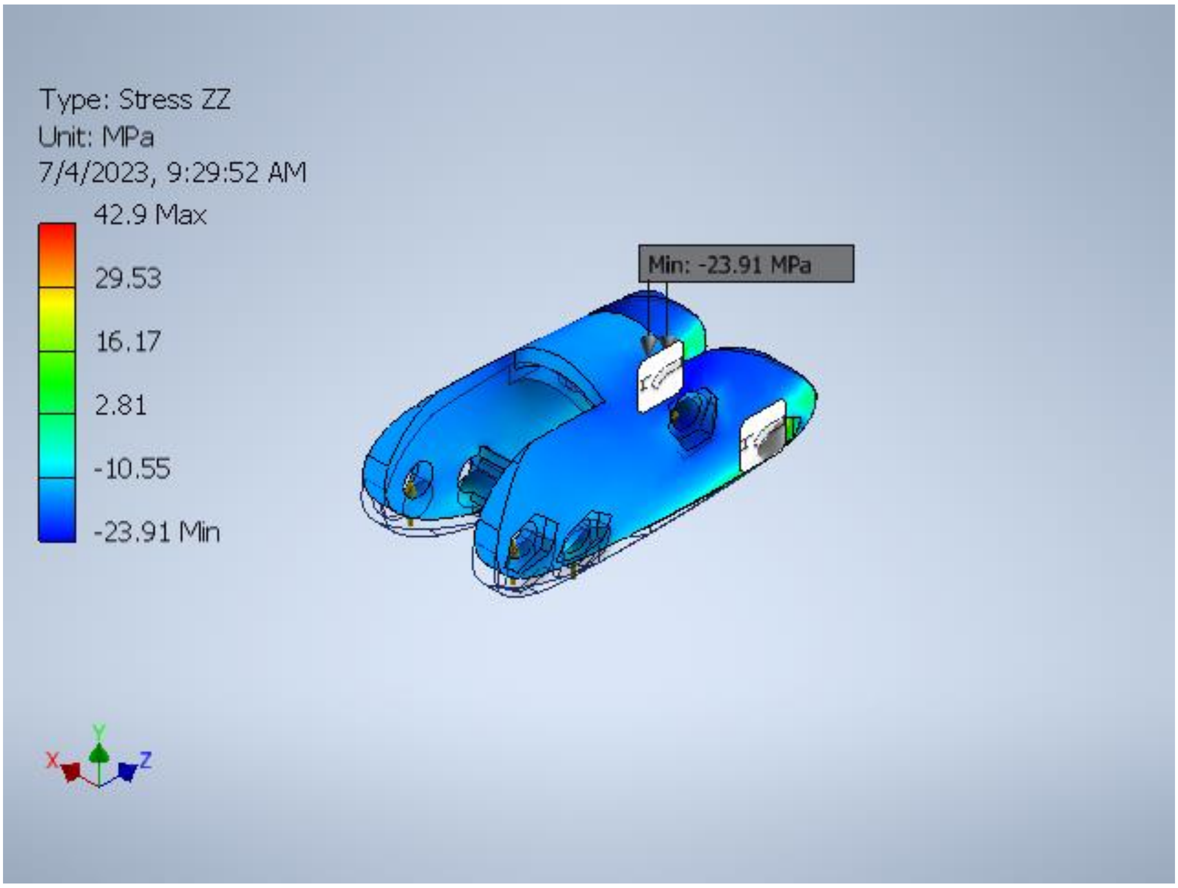

Type: Stress XY
Unit: MPa
7/4/2023, 9:29:48 AM
4.033 Max
1.635
-0.762
-3.16
-5.558
-7.956 Min
Max: 4.033 MPa
Min: -7.956 MPa

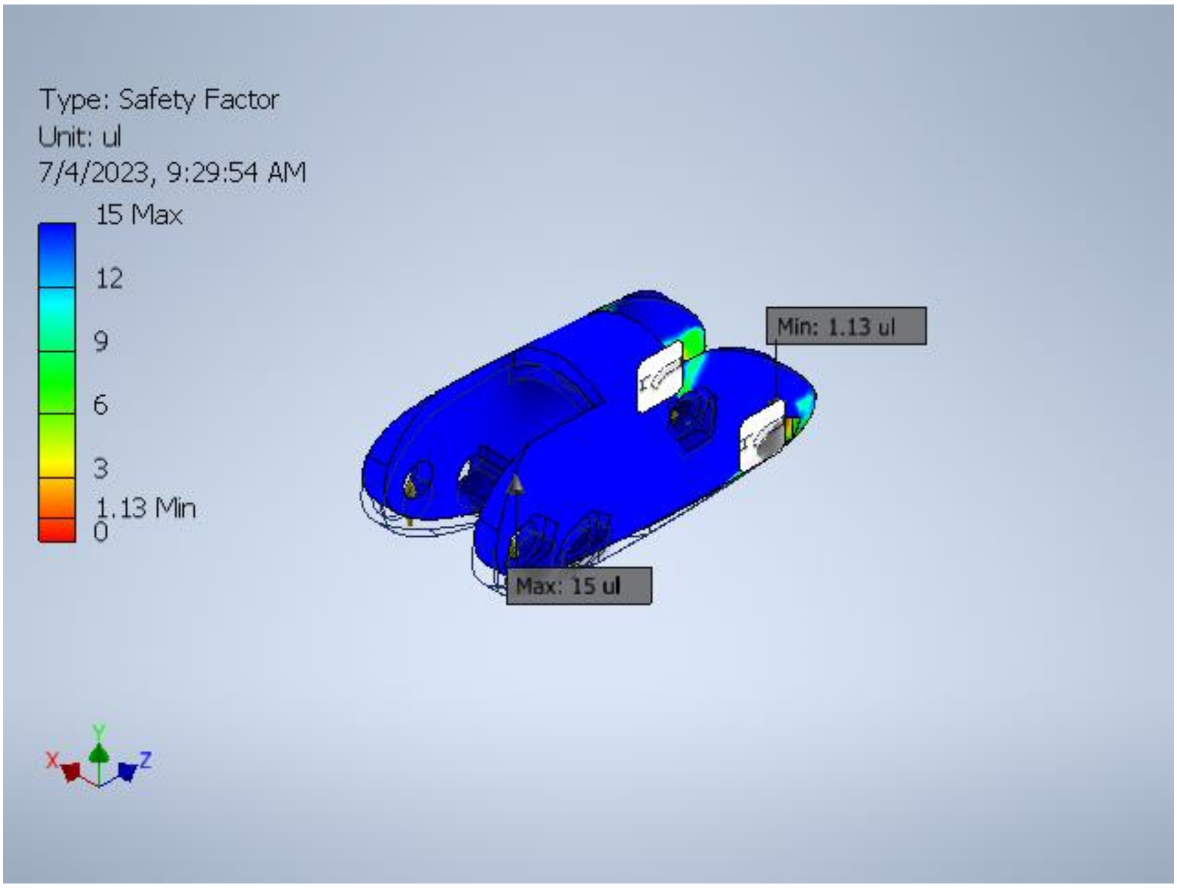

Type: Stress XX
Unit: MPa
7/4/2023, 9:29:47 AM
15.78 Max
9.54
3.3
-2.94
-9.18
-15.42 Min
Min: -15.42 MPa
Max: 15.78 MPa


Type: Stress XZ
Unit: MPa
7/4/2023, 9:29:49 AM
11.45 Max
7.27
3.08
-1.11
-5.29
-9.48 Min
Min: -9.48 MPa
Max: 11.45 MPa
X
Y
Z

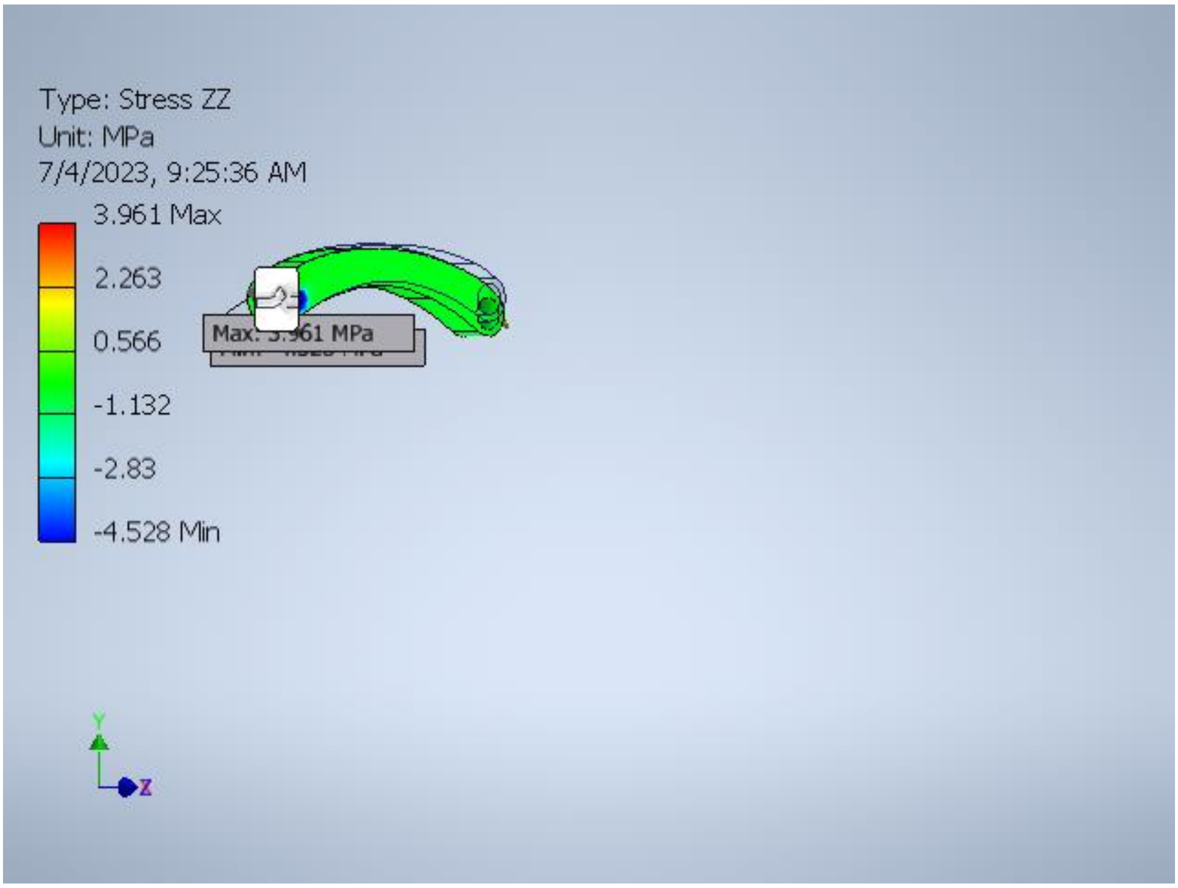

Type: Stress YY
Unit: MPa
7/4/2023, 9:29:50 AM
21.6 Max
12.78
3.97
-4.84
-13.65
-22.46 Min
Min: -22.46 MPa
Max: 21.6 MPa
X
Y
Z

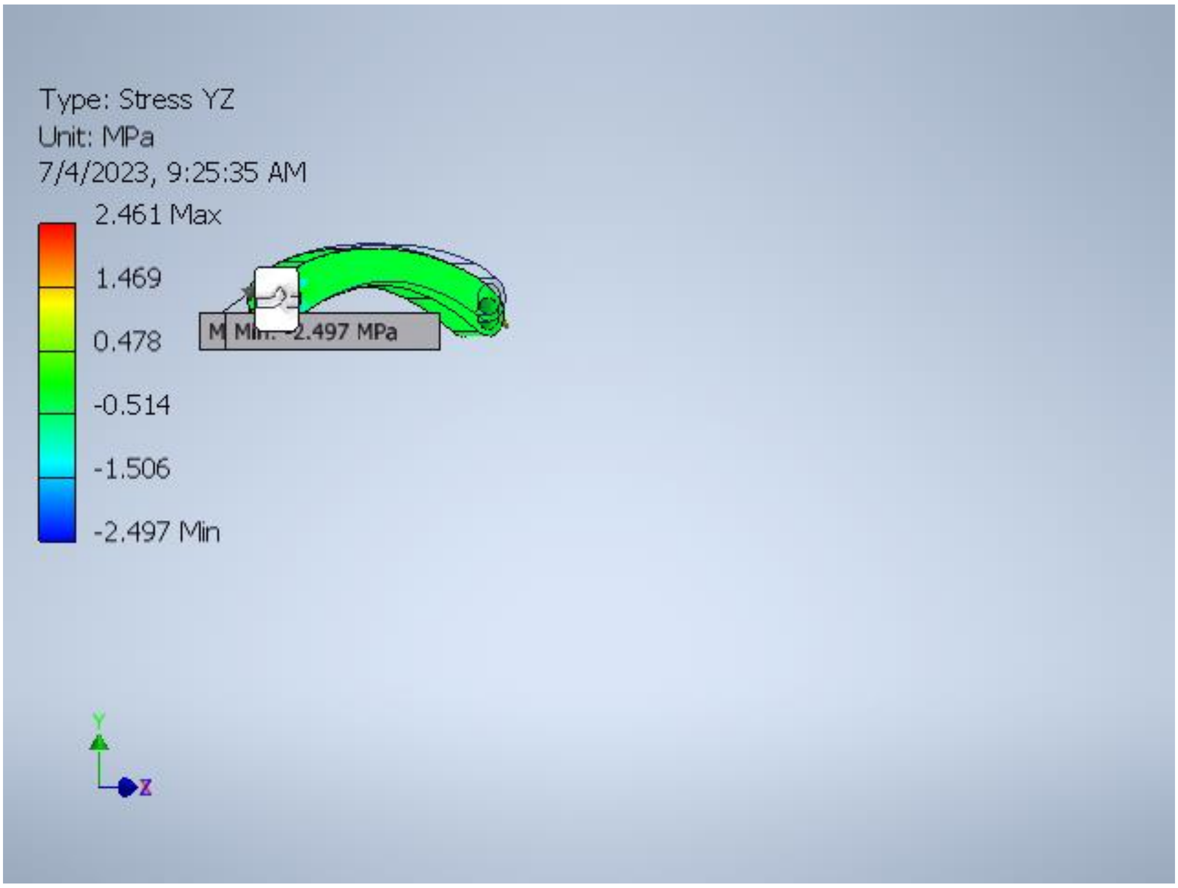

Type: Stress YZ
Unit: MPa
7/4/2023, 9:29:51 AM
27.83 Max
18.53
9.23
-0.07
-9.37
-18.67 Min
Max: 27.83 MPa
Min: -18.67 MPa

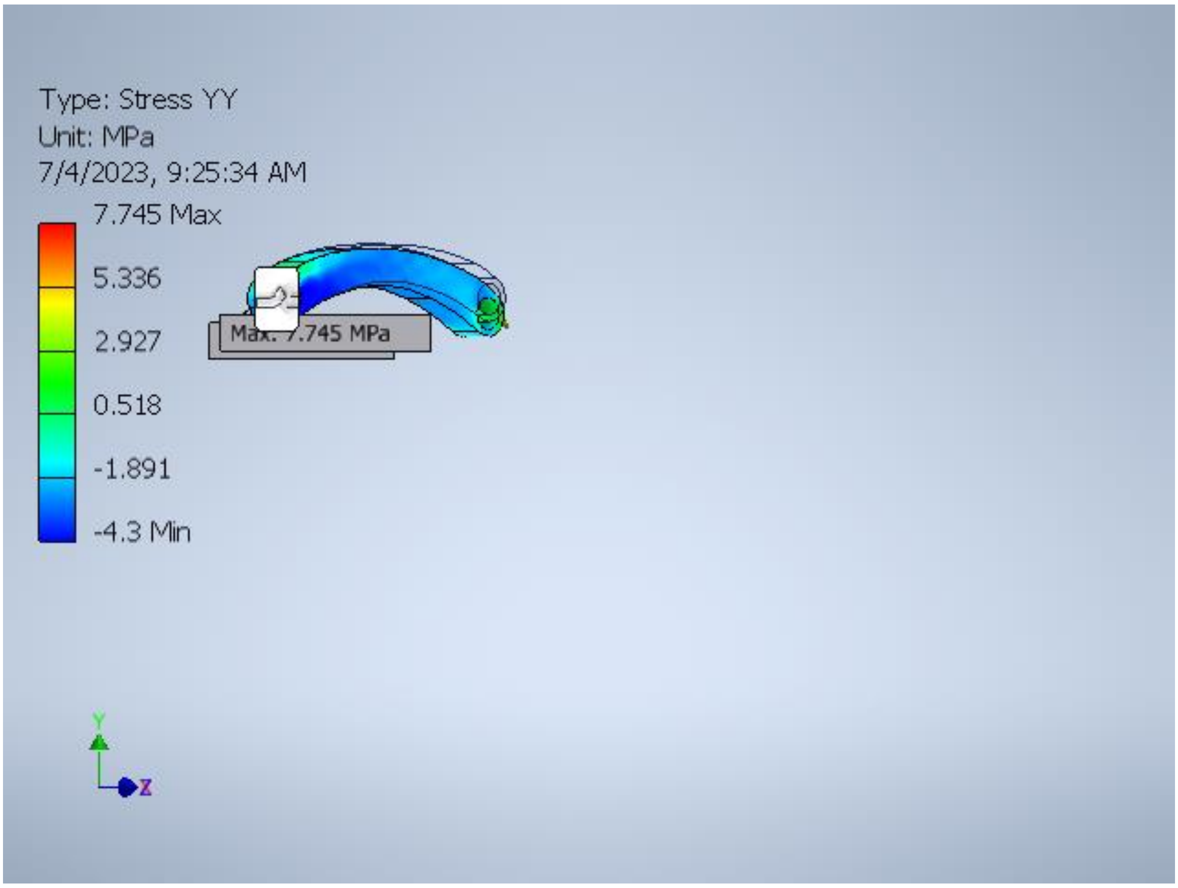

Type: Stress ZZ
Unit: MPa
7/4/2023, 9:29:52 AM
42.9 Max
29.53
16.17
2.81
-10.55
-23.91 Min
Min: -23.91 MPa

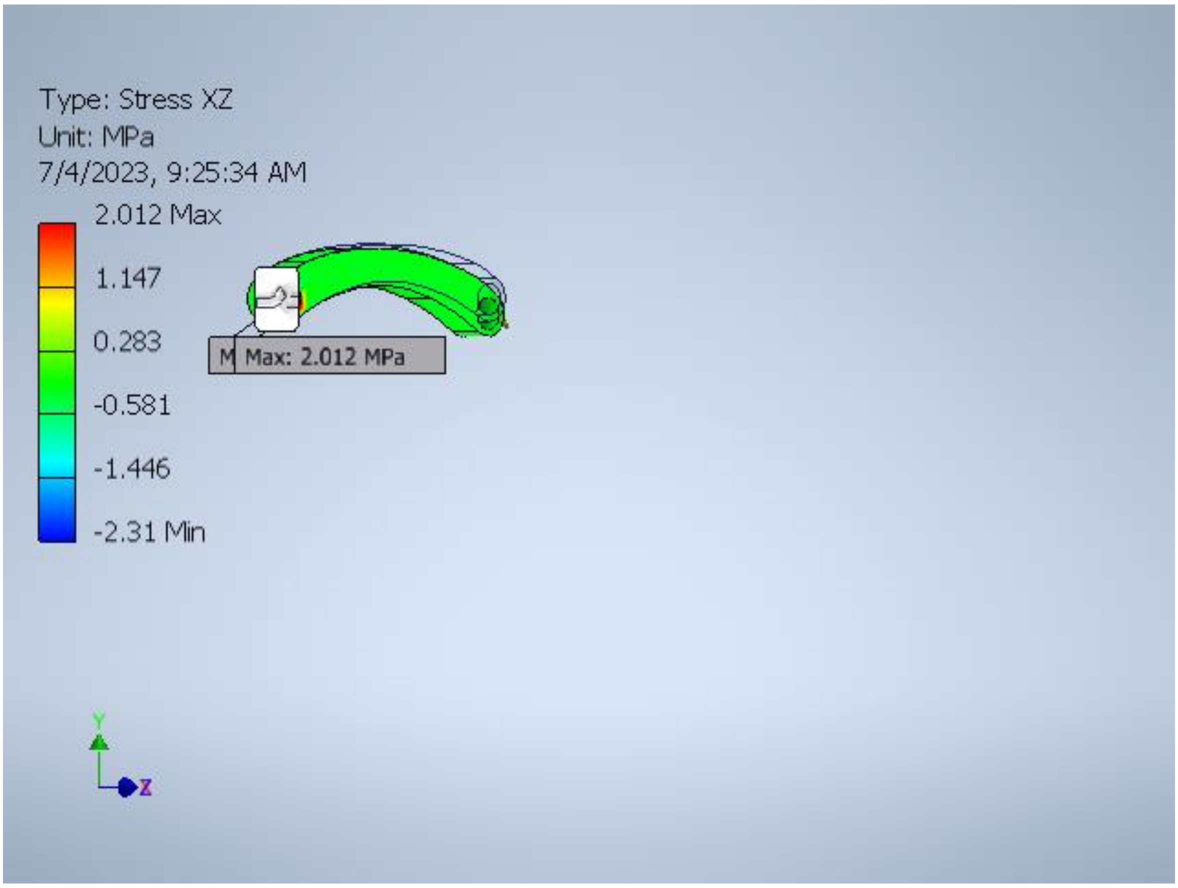

Type: Safety Factor
Unit: ul
7/4/2023, 9:29:54 AM
15 Max
12
9
6
3
1.13 Min
0
Min: 1.13 ul
Max: 15 ul
X
Y
Z

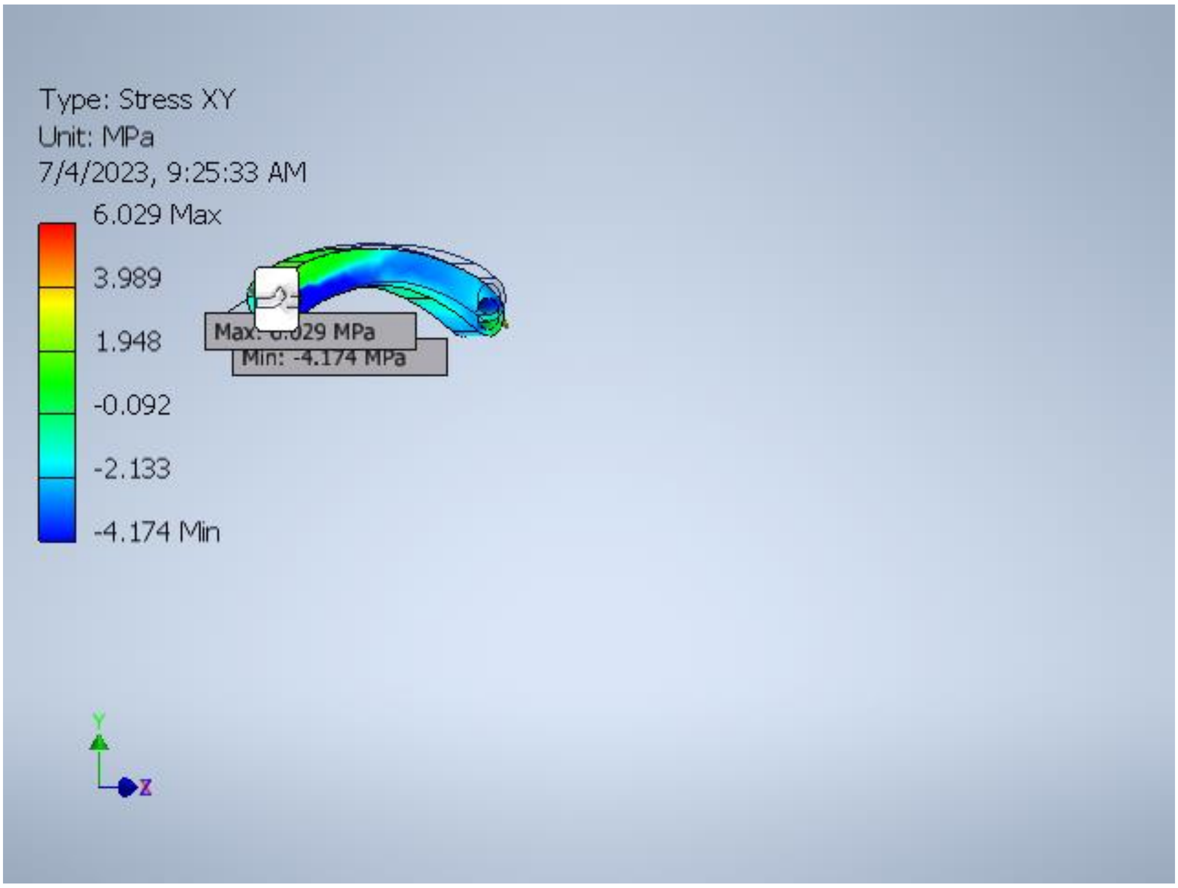
Link 4:

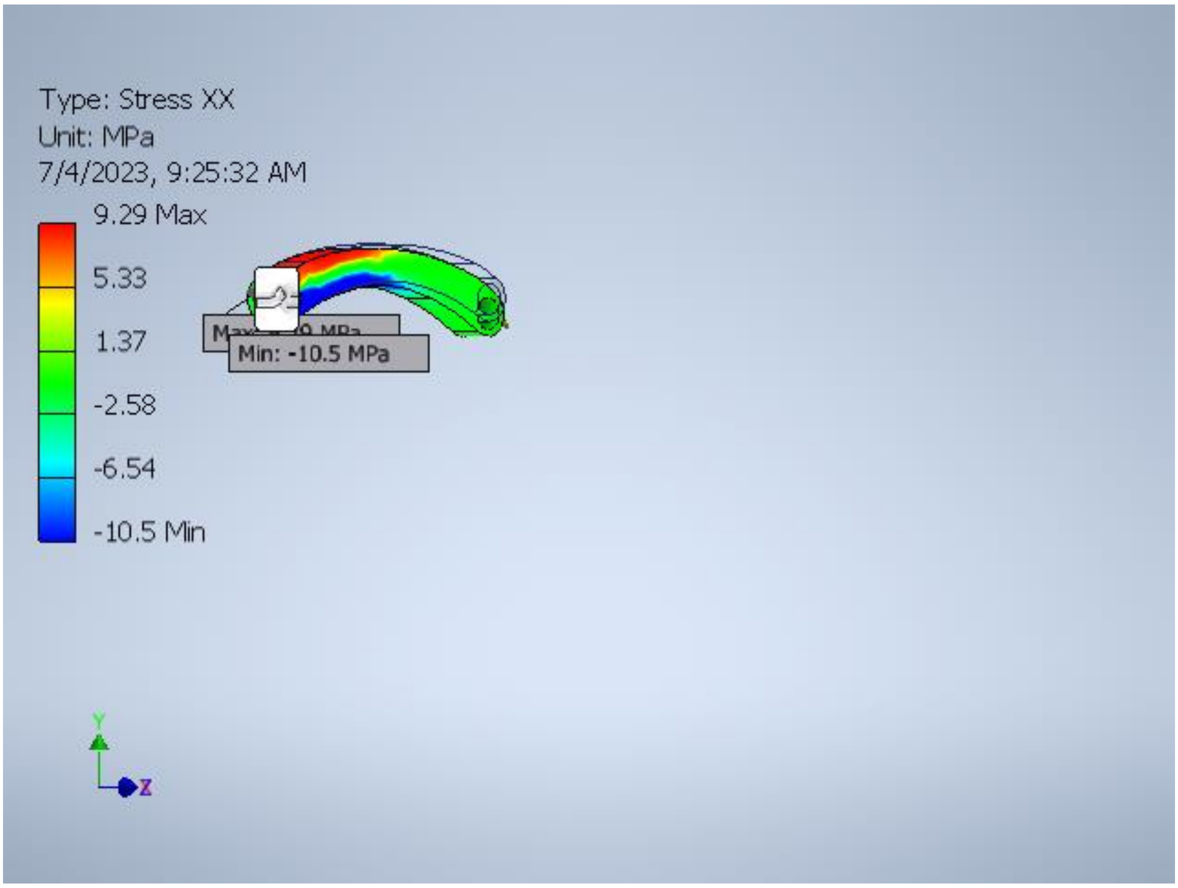

Type: Stress ZZ
Unit: MPa
7/4/2023, 9:25:36 AM
3.961 Max
2.263
0.566
-1.132
-2.83
-4.528 Min
Max: 3.961 MPa
Y
Z

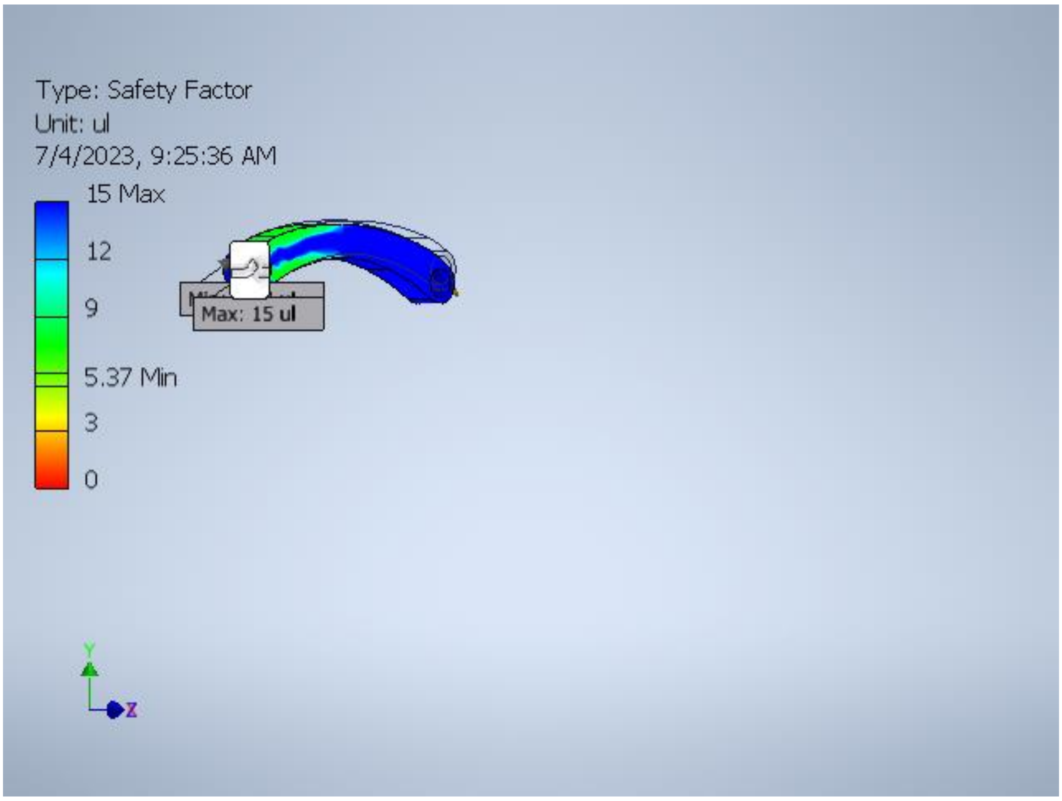

Type: Stress YZ
Unit: MPa
7/4/2023, 9:25:35 AM
2.461 Max
1.469
0.478
-0.514
-1.506
-2.497 Min
Min: -2.497 MPa
Y
Z


Type: Stress YY
Unit: MPa
7/4/2023, 9:25:34 AM
7.745 Max
5.336
2.927
0.518
-1.891
-4.3 Min
Max: 7.745 MPa
Y
Z

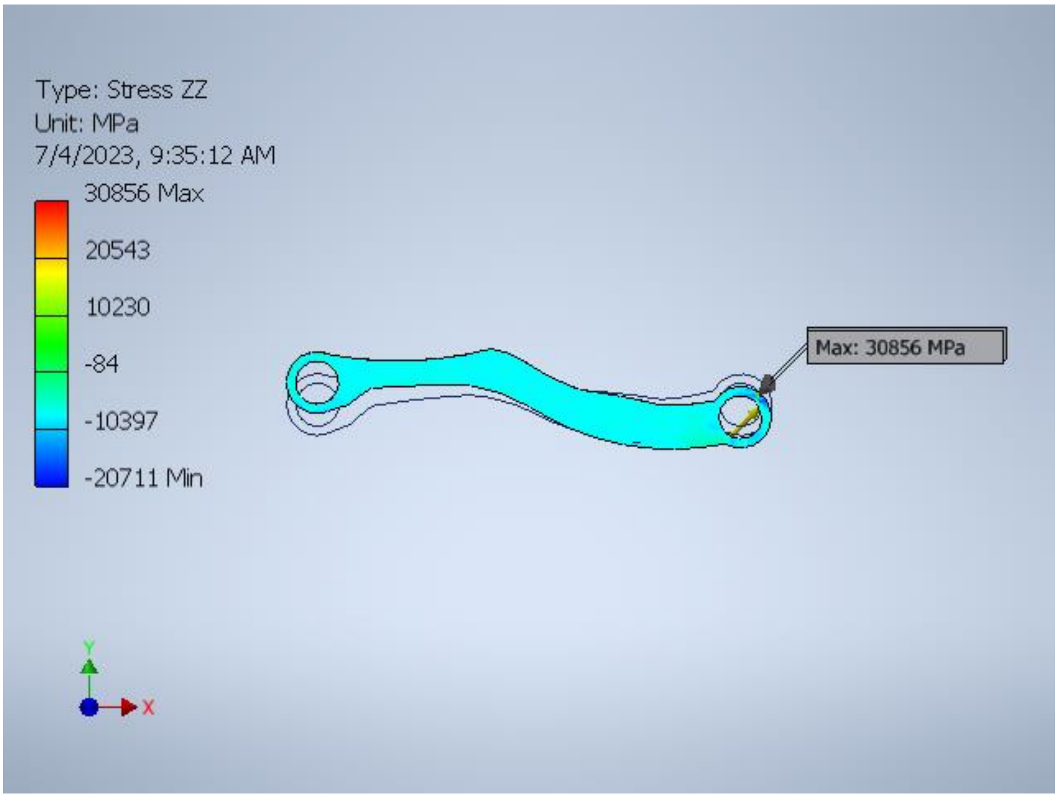

Type: Stress XZ
Unit: MPa
7/4/2023, 9:25:34 AM
2.012 Max
1.147
0.283
-0.581
-1.446
-2.31 Min
Max: 2.012 MPa
Y
Z

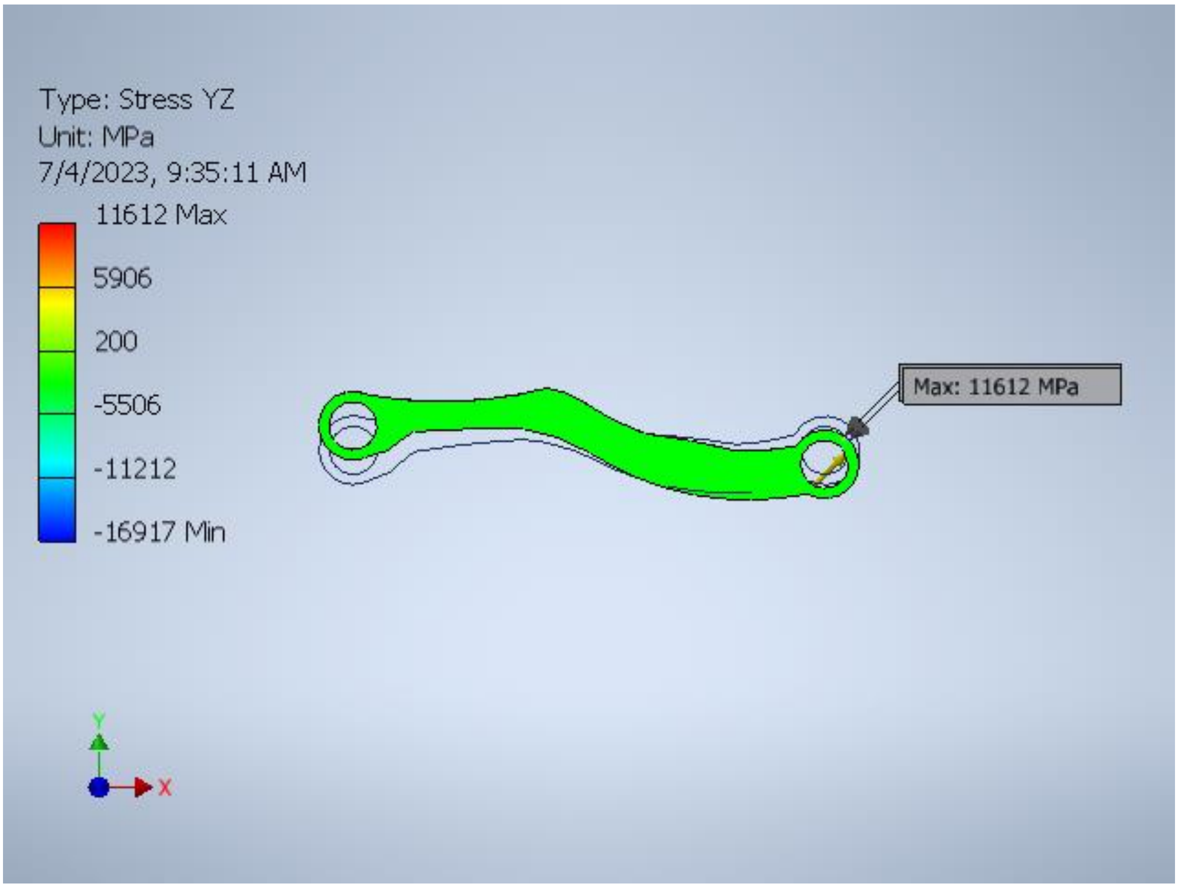

Type: Stress XY
Unit: MPa
7/4/2023, 9:25:33 AM
6.029 Max
3.989
1.948
-0.092
-2.133
-4.174 Min
Min: -4.174 MPa
Y
Z

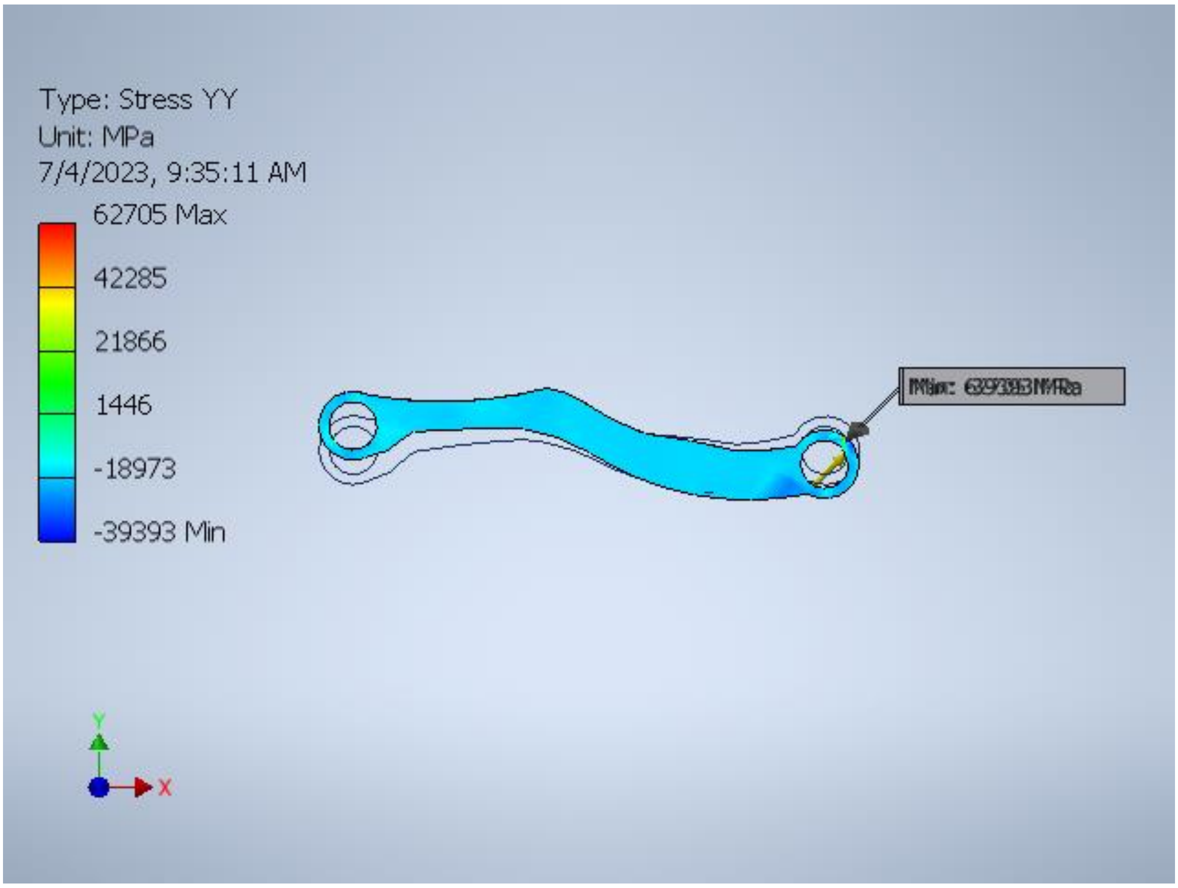

Type: Stress XX
Unit: MPa
7/4/2023, 9:25:32 AM
9.29 Max
5.33
1.37
-2.58
-6.54
-10.5 Min
Min: -10.5 MPa
Y
Z

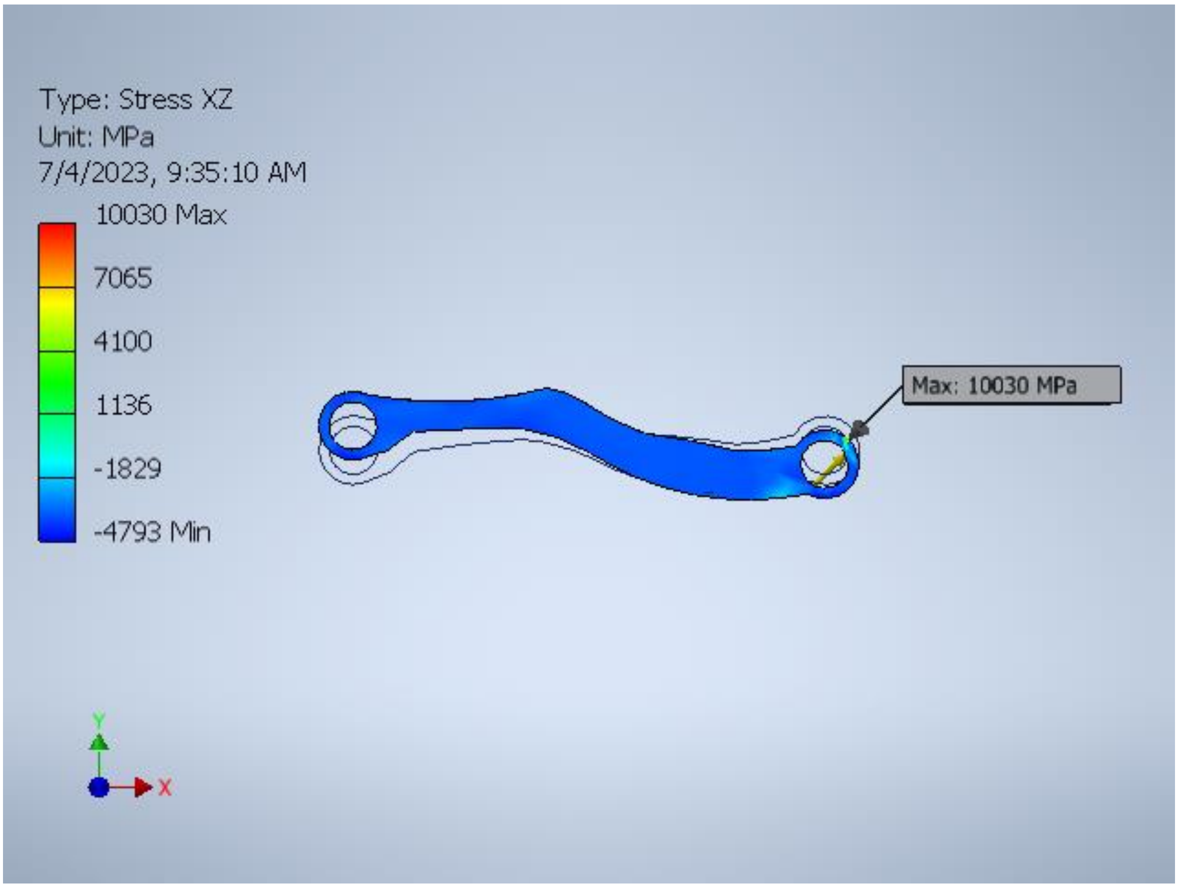

Type: Safety Factor
Unit: ul
7/4/2023, 9:25:36 AM
15 Max
12
9
5.37 Min
3
0
Max: 15 ul
Y
Z

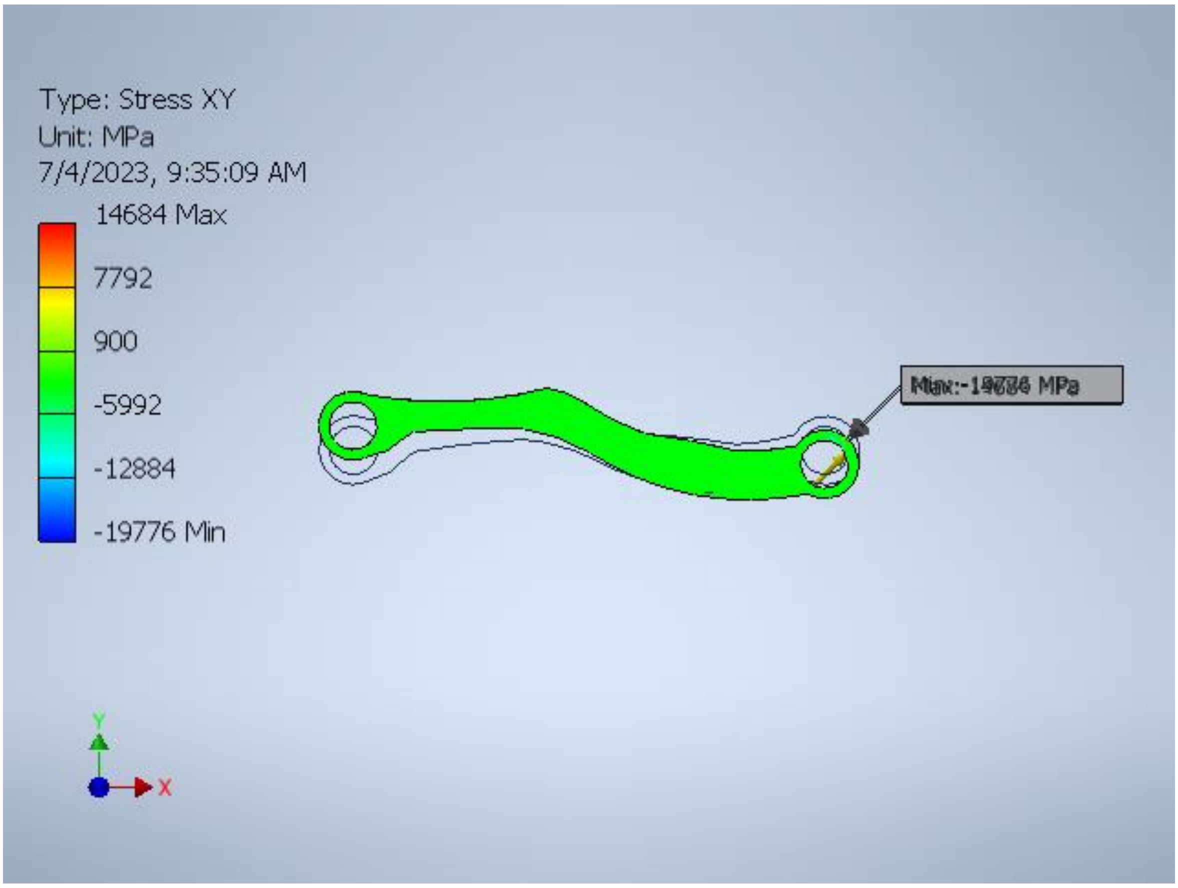
Link 5:

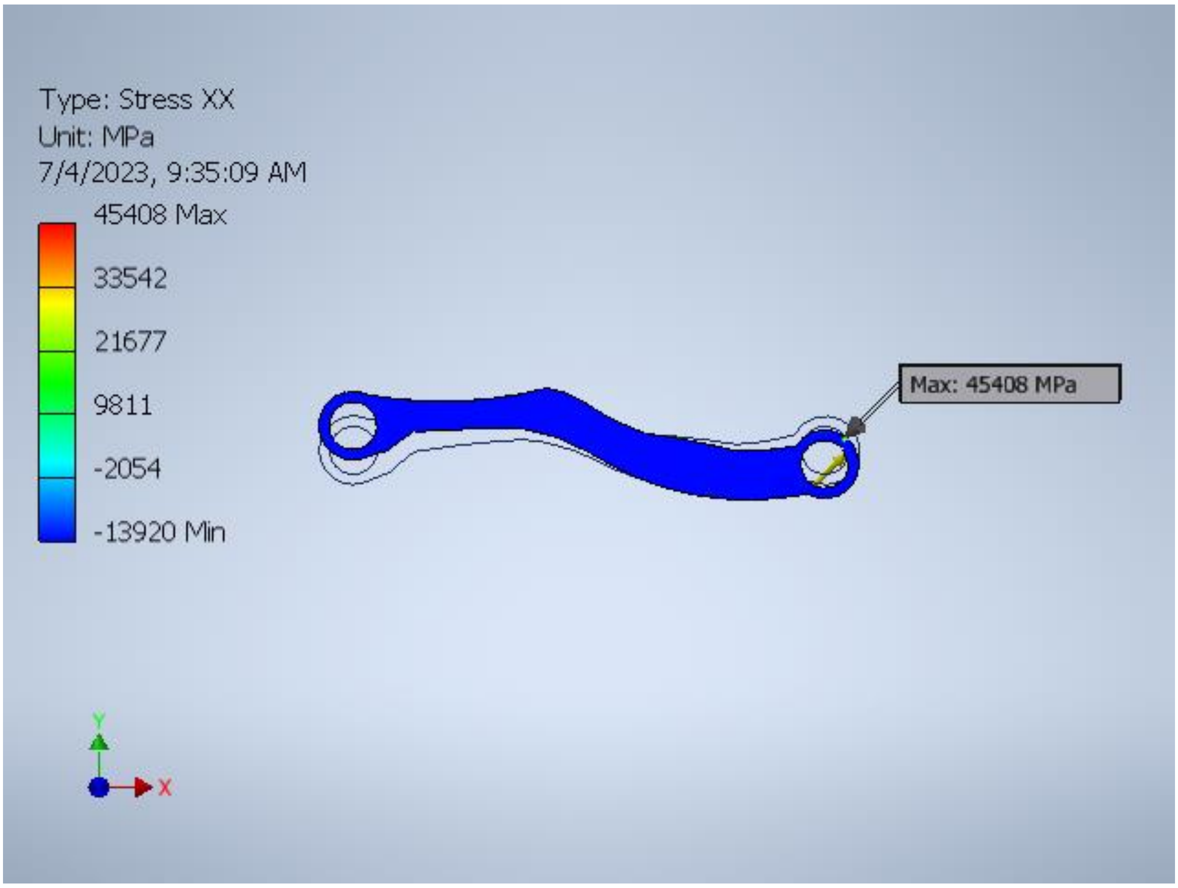

Type: Stress ZZ
Unit: MPa
7/4/2023, 9:35:12 AM
30856 Max
20543
10230
-84
-10397
-20711 Min
Max: 30856 MPa
Y
X

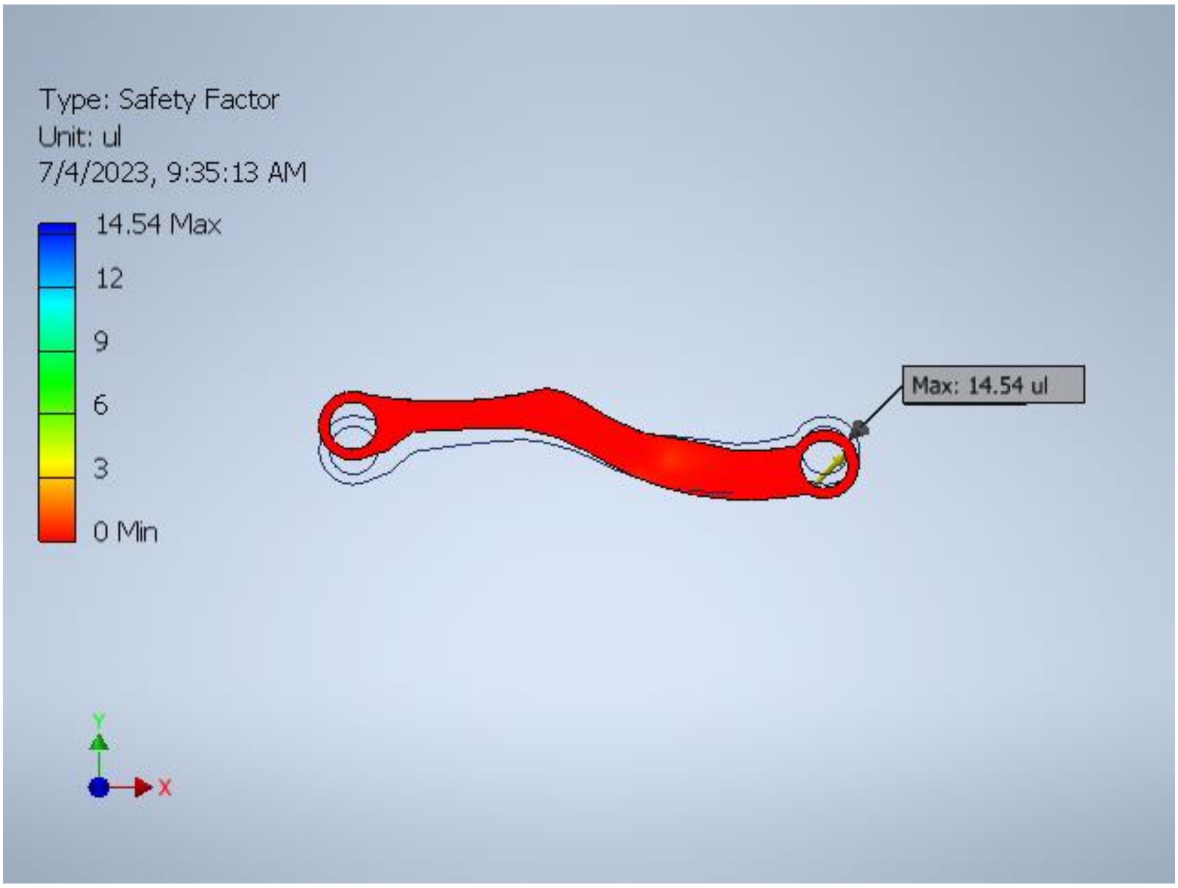

Type: Stress YZ
Unit: MPa
7/4/2023, 9:35:11 AM
11612 Max
5906
200
-5506
-11212
-16917 Min
Max: 11612 MPa
Y
X


Type: Stress YY
Unit: MPa
7/4/2023, 9:35:11 AM
62705 Max
42285
21866
1446
-18973
-39393 Min
Y
X

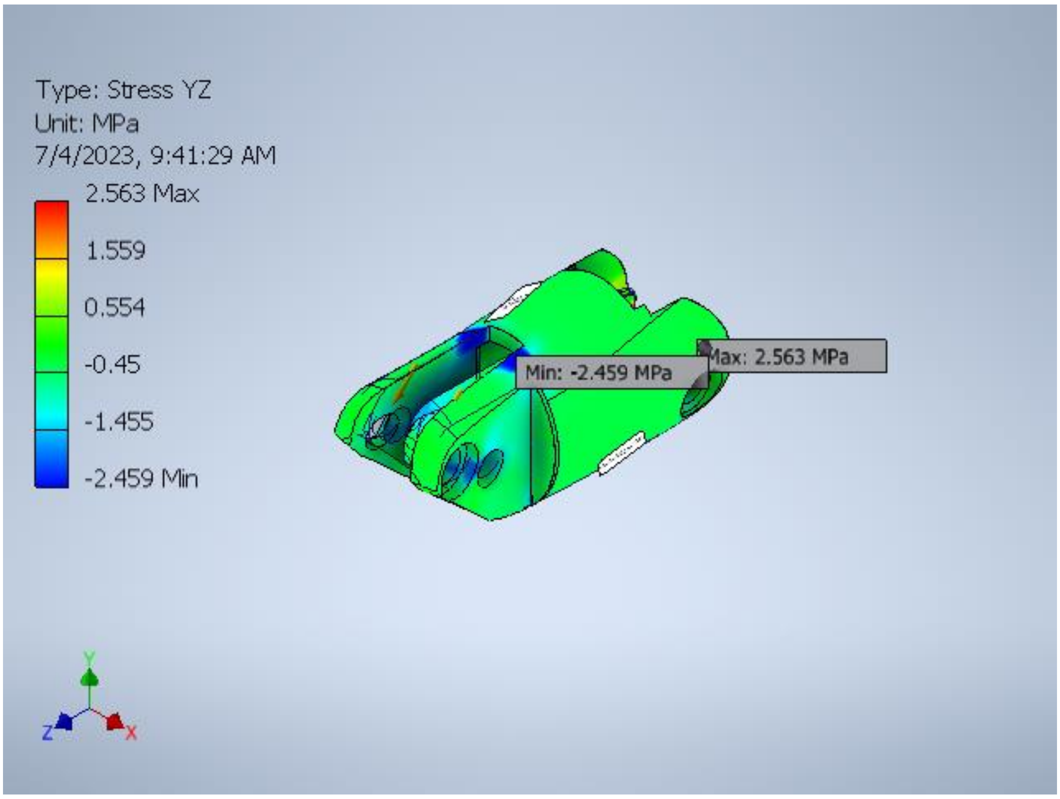

Type: Stress XZ
Unit: MPa
7/4/2023, 9:35:10 AM
10030 Max
7065
4100
1136
-1829
-4793 Min
Max: 10030 MPa
Y
X

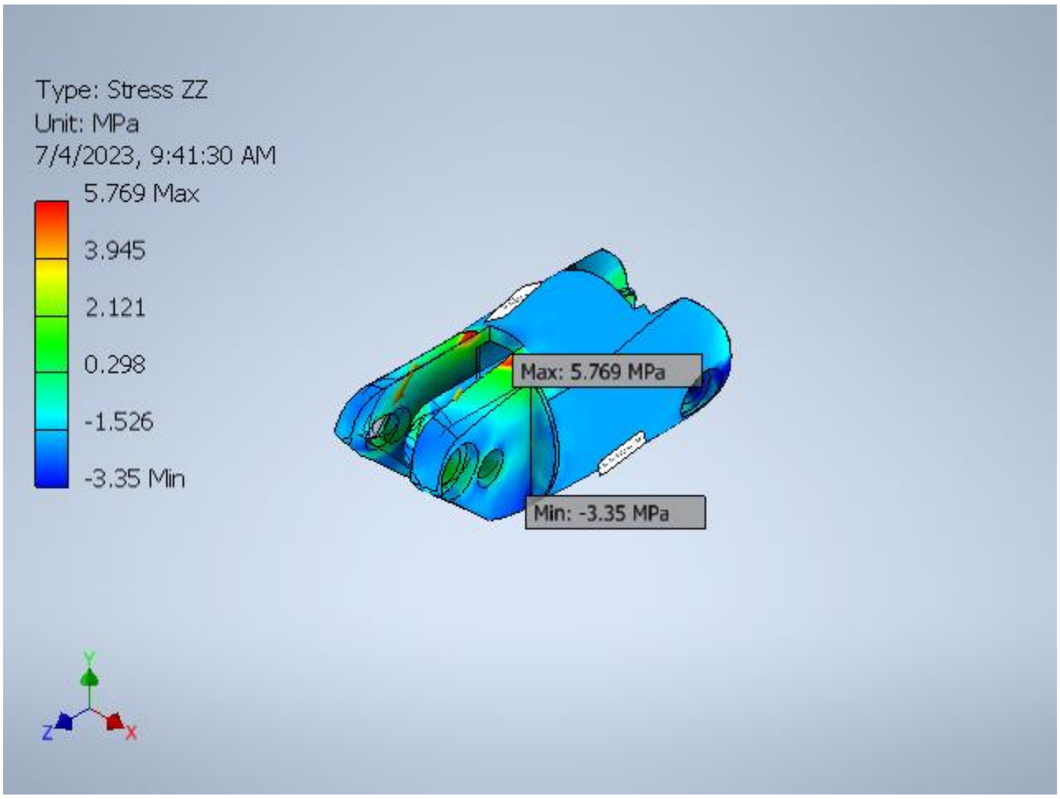

Type: Stress XY
Unit: MPa
7/4/2023, 9:35:09 AM
14684 Max
7792
900
-5992
-12884
-19776 Min
Y
X

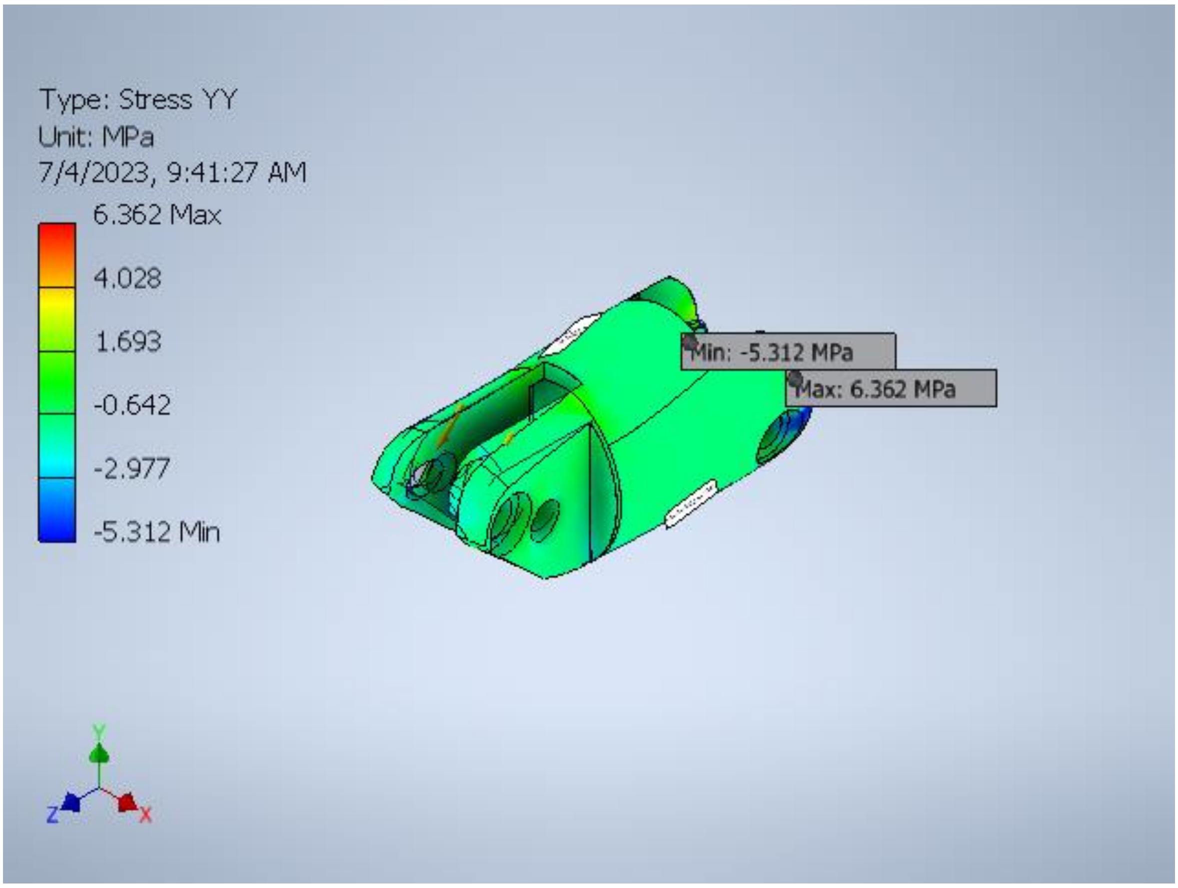

Type: Stress XX
Unit: MPa
7/4/2023, 9:35:09 AM
45408 Max
33542
21677
9811
-2054
-13920 Min
Max: 45408 MPa
Y
X

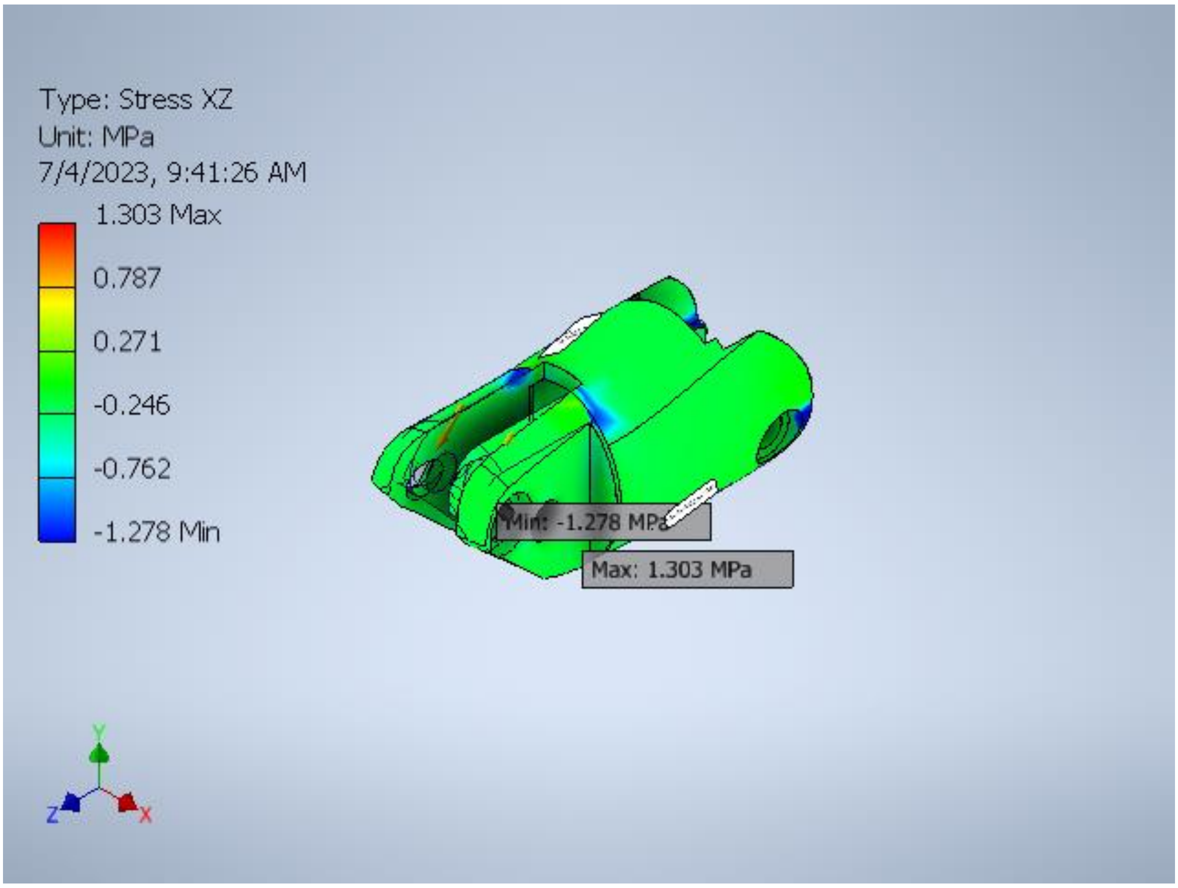

Type: Safety Factor
Unit: ul
7/4/2023, 9:35:13 AM
14.54 Max
12
9
6
3
0 Min
Max: 14.54 ul
Y
X

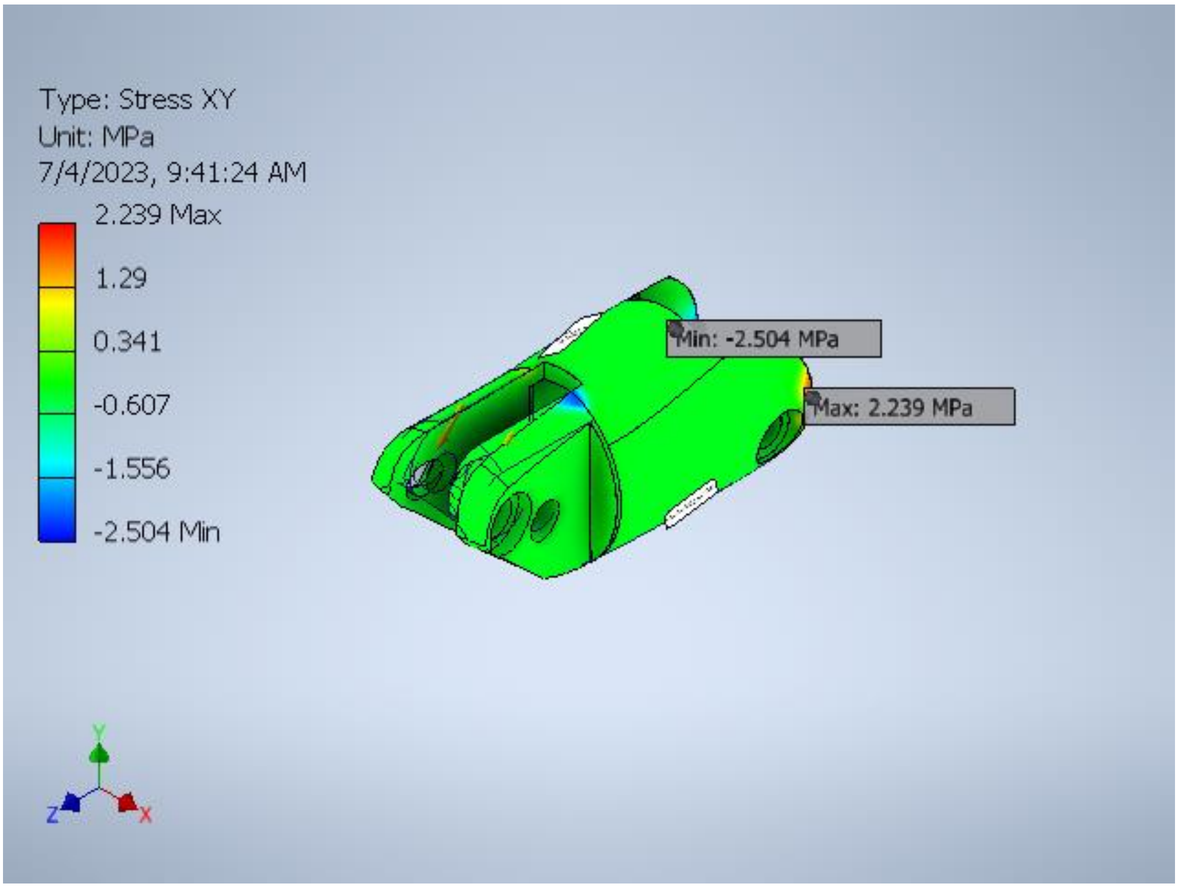
Link 6:

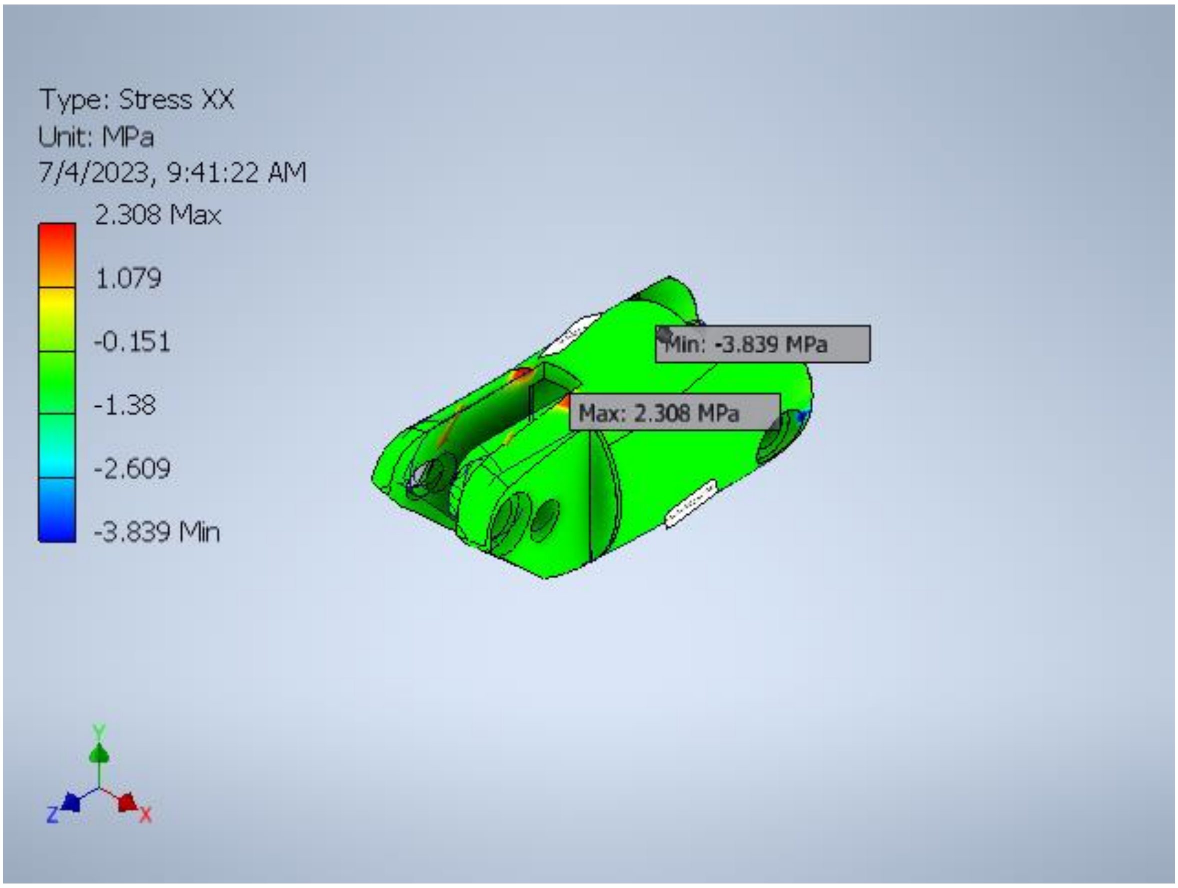

Type: Stress YZ
Unit: MPa
7/4/2023, 9:41:29 AM
2.563 Max
1.559
0.554
-0.45
-1.455
-2.459 Min
Min: -2.459 MPa
Max: 2.563 MPa
Y
Z
X

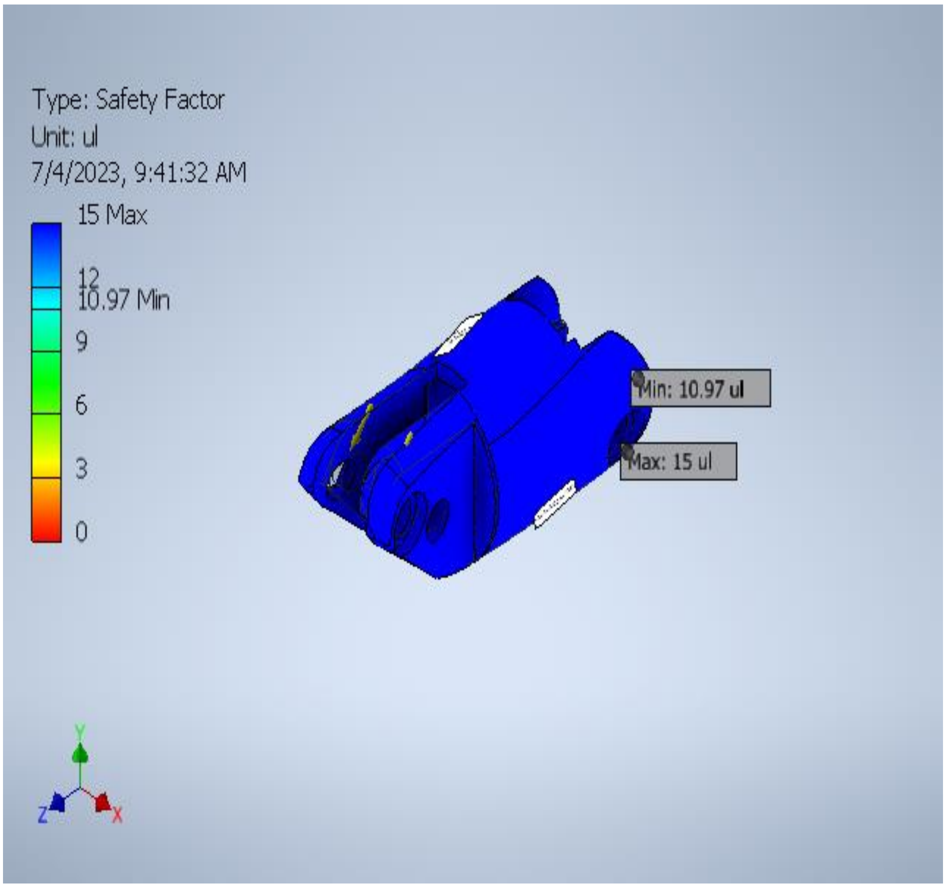

Type: Stress ZZ
Unit: MPa
7/4/2023, 9:41:30 AM
5.769 Max
3.945
2.121
0.298
-1.526
-3.35 Min
Max: 5.769 MPa
Min: -3.35 MPa
Y
Z
X


Type: Stress YY
Unit: MPa
7/4/2023, 9:41:27 AM
6.362 Max
4.028
1.693
-0.642
-2.977
-5.312 Min
Min: -5.312 MPa
Max: 6.362 MPa
Y
Z
X

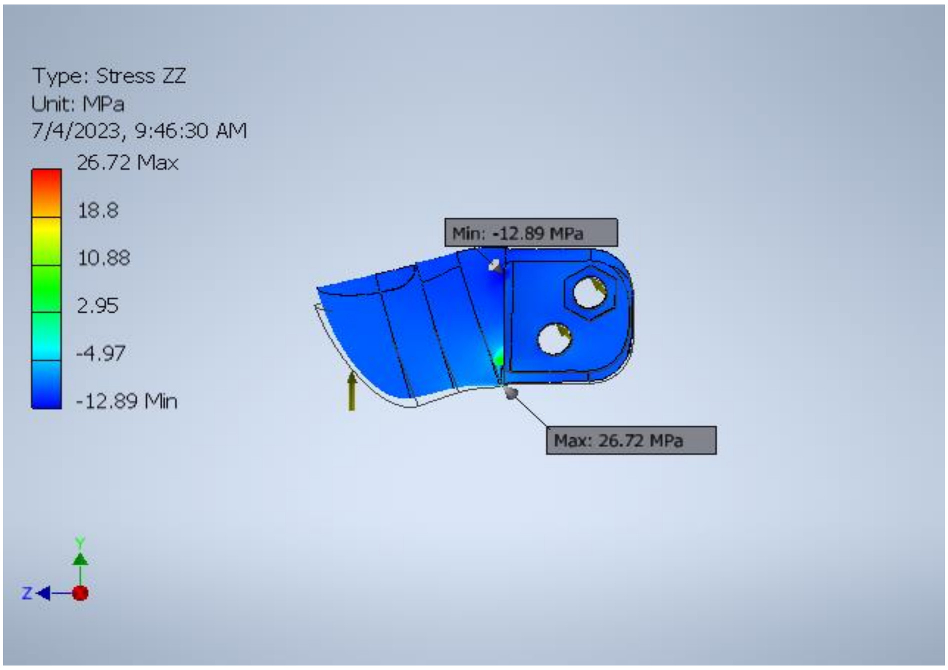

Type: Stress XZ
Unit: MPa
7/4/2023, 9:41:26 AM
1.303 Max
0.787
0.271
-0.246
-0.762
-1.278 Min
Min: -1.278 MPa
Max: 1.303 MPa
Y
Z
X

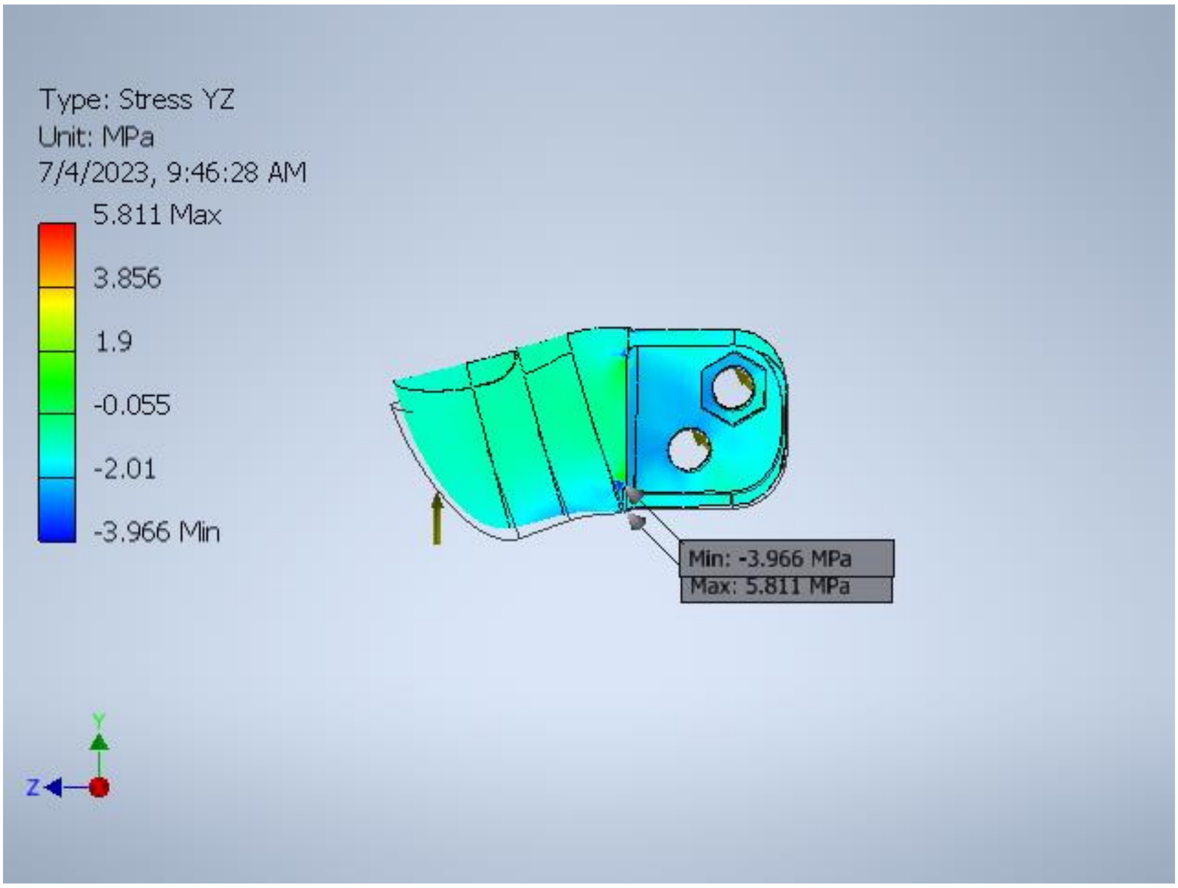

Type: Stress XY
Unit: MPa
7/4/2023, 9:41:24 AM
2.239 Max
1.29
0.341
-0.607
-1.556
-2.504 Min
Min: -2.504 MPa
Max: 2.239 MPa
Y
Z
X

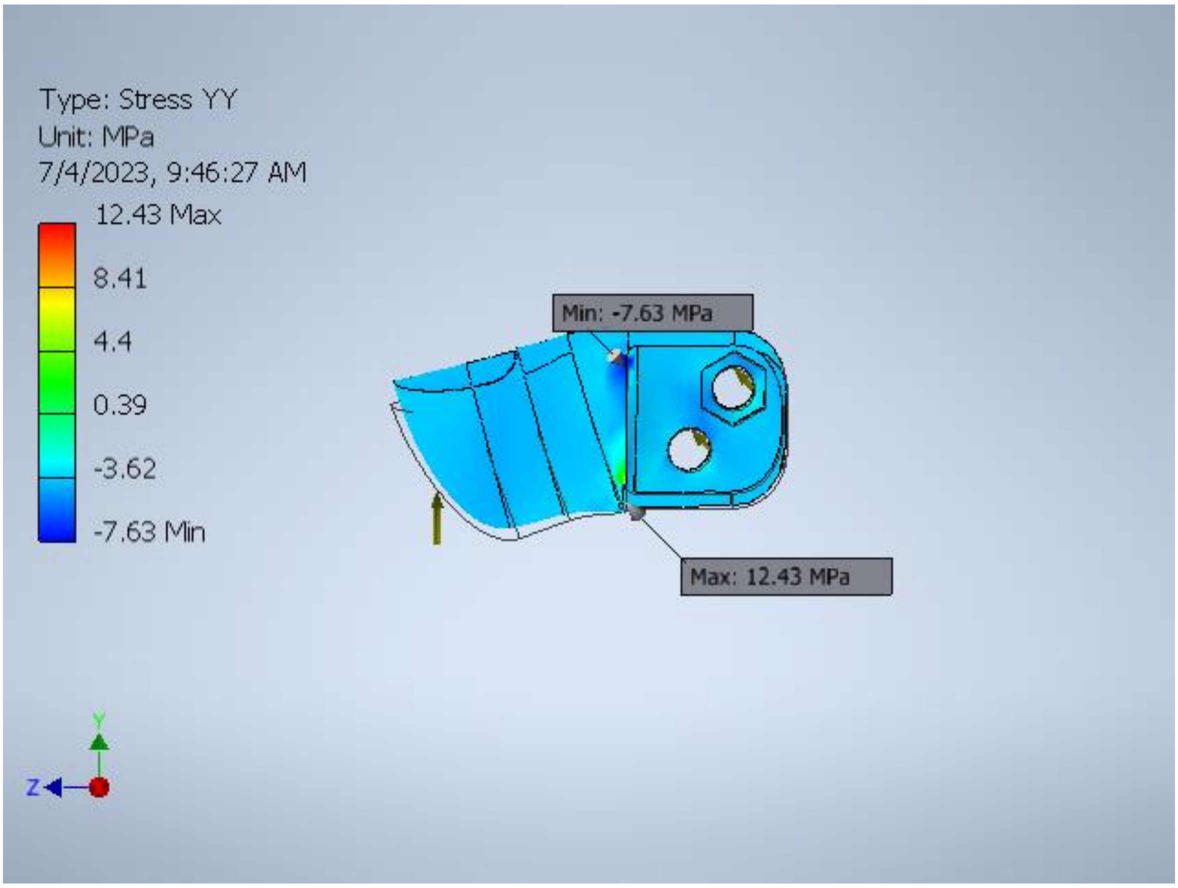

Type: Stress XX
Unit: MPa
7/4/2023, 9:41:22 AM
2.308 Max
1.079
-0.151
-1.38
-2.609
-3.839 Min
Min: -3.839 MPa
Max: 2.308 MPa
Y
Z
X

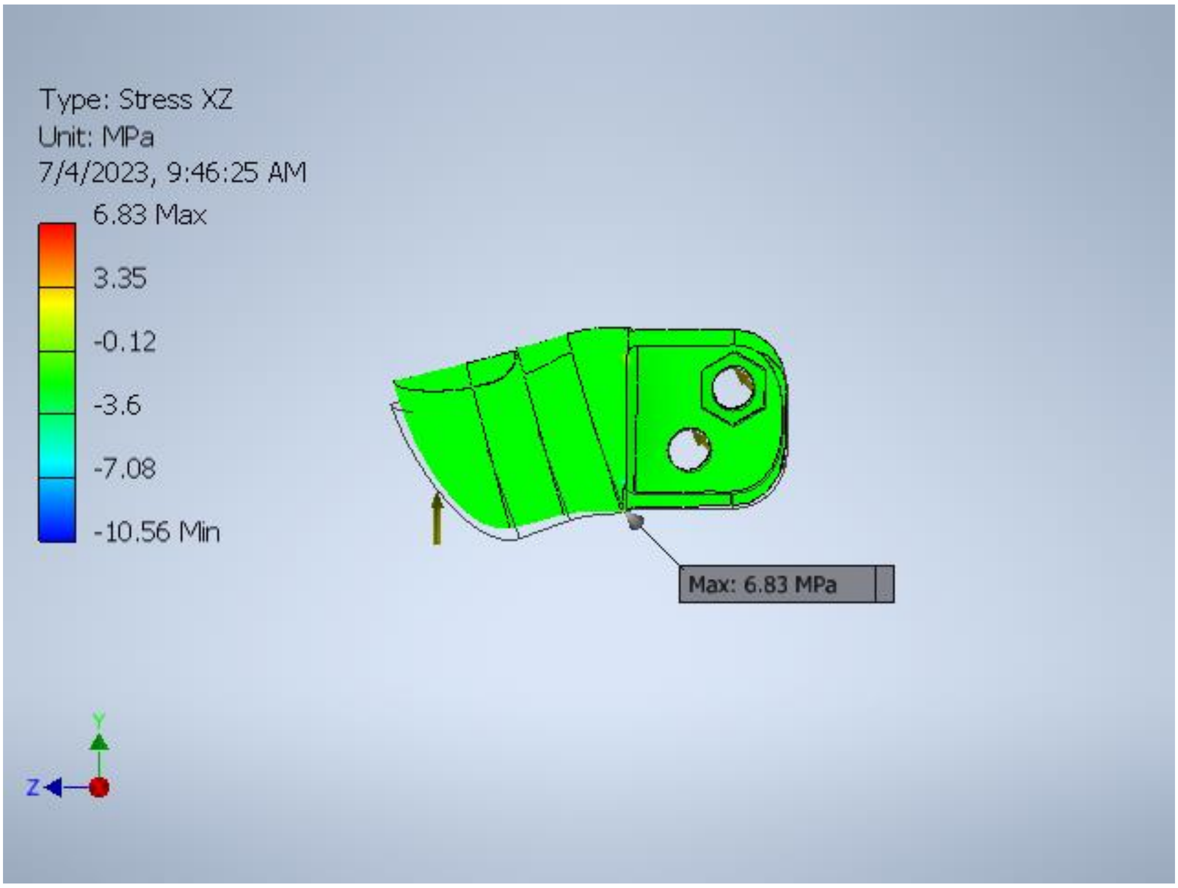

Type: Safety Factor
Unit: ul
7/4/2023, 9:41:32 AM
15 Max
12
10.97 Min
9
6
3
0
Min: 10.97 ul
Max: 15 ul
Y
Z
X

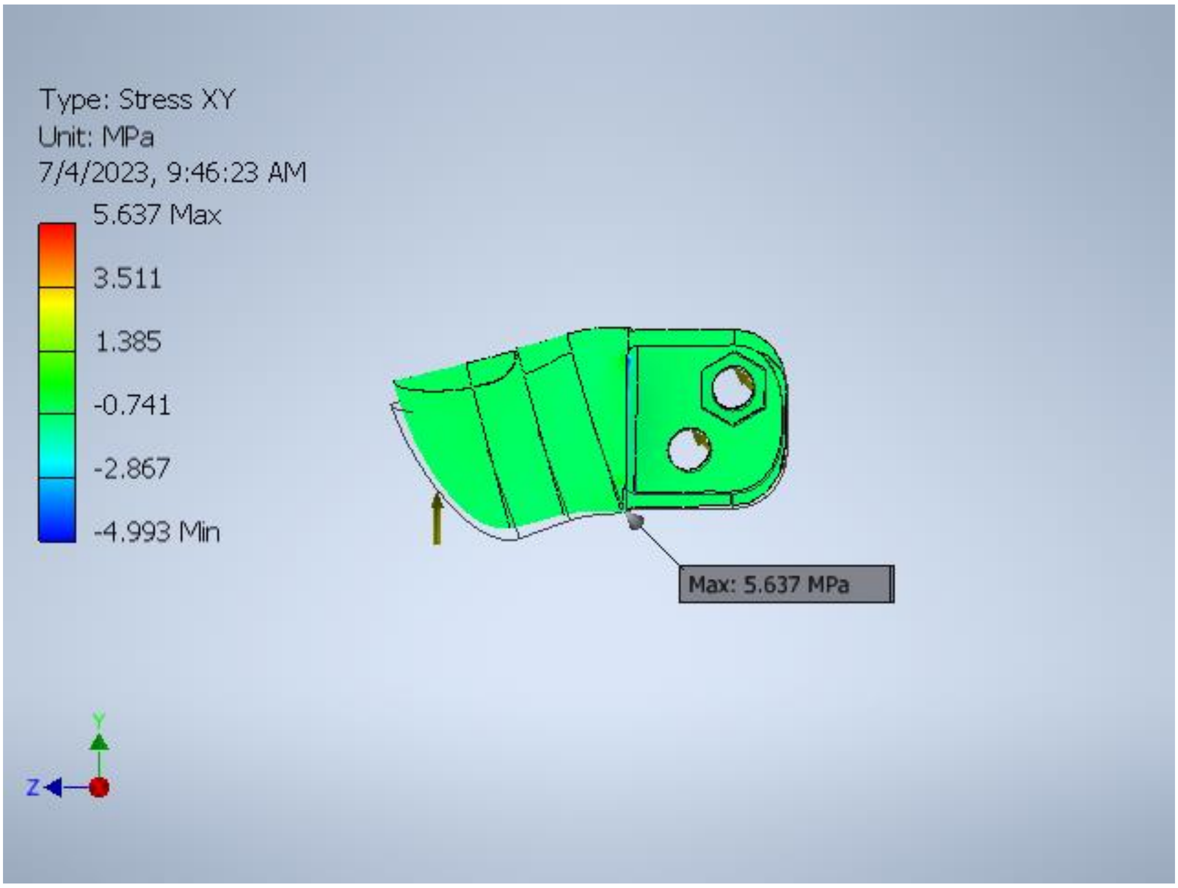
Link 7:

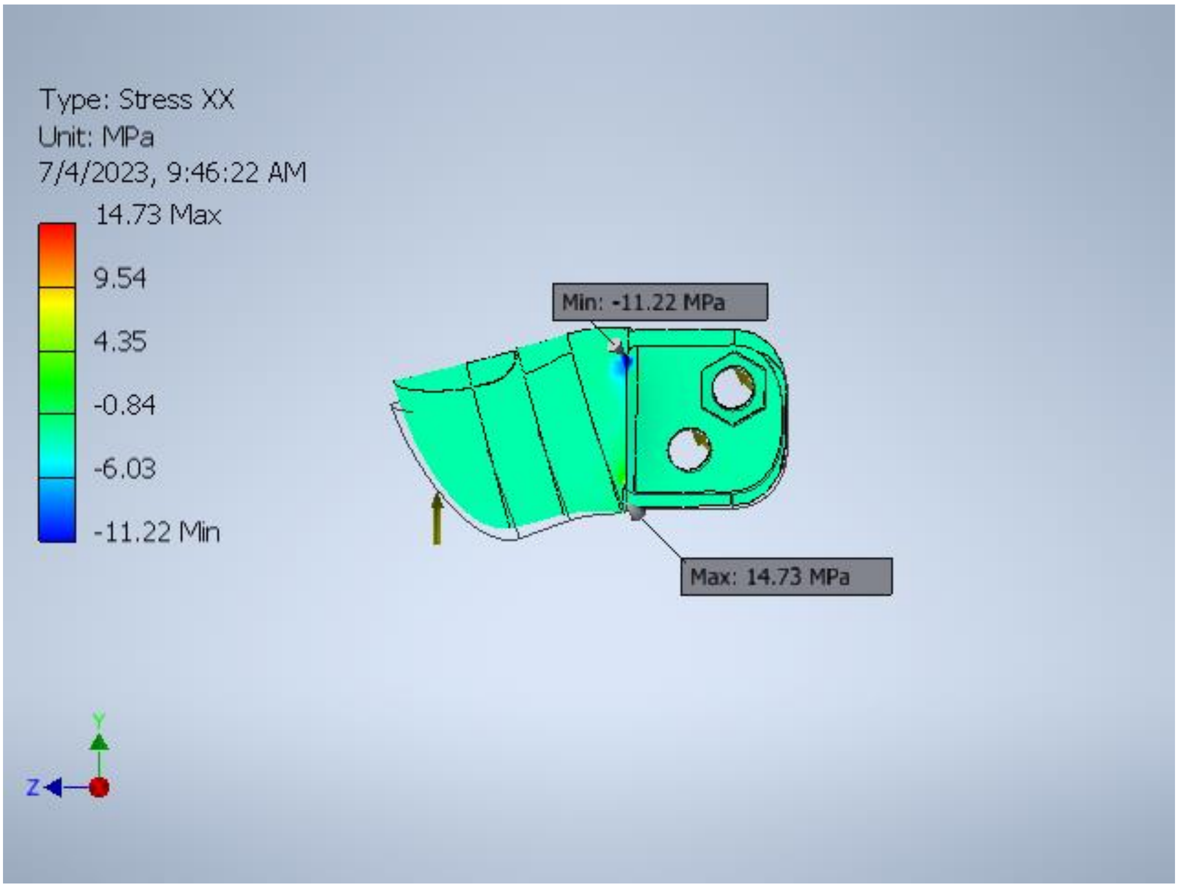

Type: Stress ZZ
Unit: MPa
7/4/2023, 9:46:30 AM
26.72 Max
18.8
10.88
2.95
-4.97
-12.89 Min
Min: -12.89 MPa
Max: 26.72 MPa
Y
Z

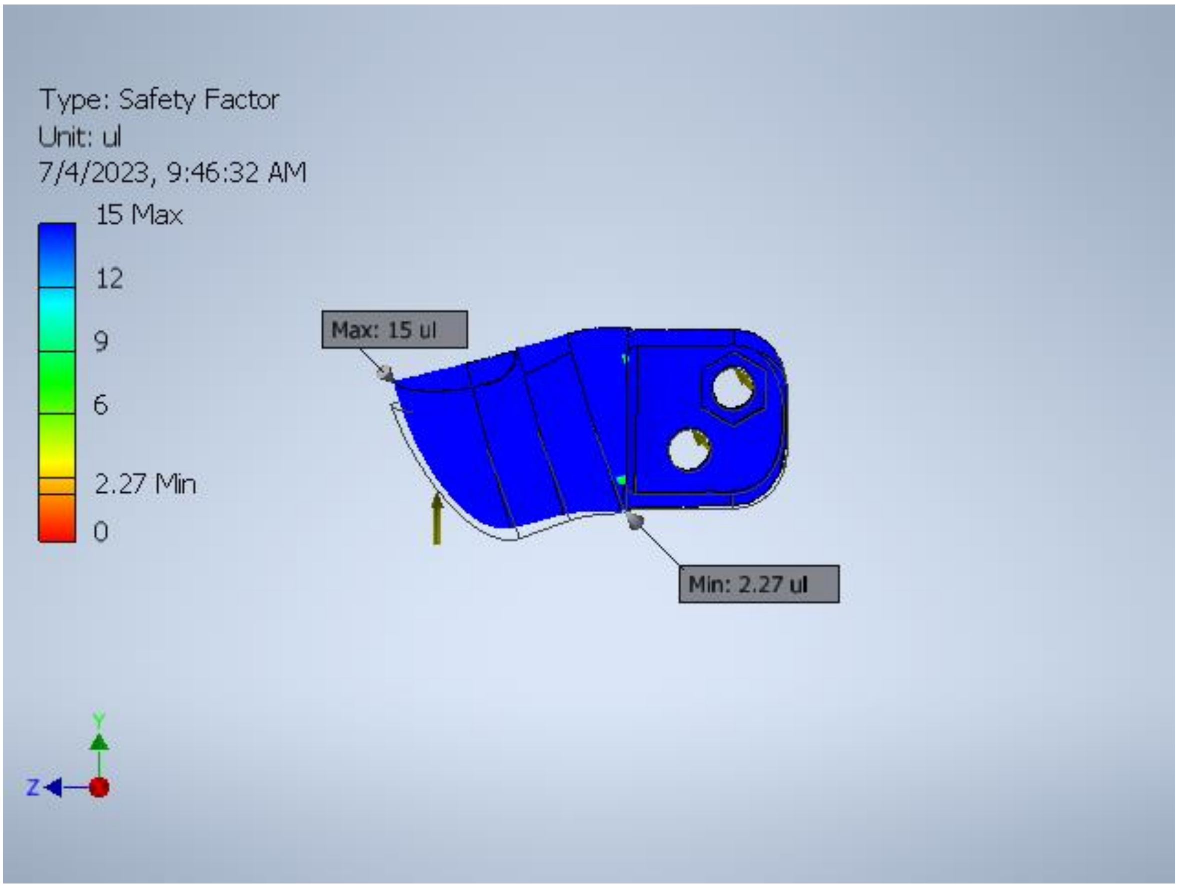

Type: Stress YZ
Unit: MPa
7/4/2023, 9:46:28 AM
5.811 Max
3.856
1.9
-0.055
-2.01
-3.966 Min
Min: -3.966 MPa
Max: 5.811 MPa
Y
Z


Type: Stress YY
Unit: MPa
7/4/2023, 9:46:27 AM
12.43 Max
8.41
4.4
0.39
-3.62
-7.63 Min
Min: -7.63 MPa
Max: 12.43 MPa
Y
Z


Type: Stress XZ
Unit: MPa
7/4/2023, 9:46:25 AM
6.83 Max
3.35
-0.12
-3.6
-7.08
-10.56 Min
Max: 6.83 MPa
Y
Z


Type: Stress XY
Unit: MPa
7/4/2023, 9:46:23 AM
5.637 Max
3.511
1.385
-0.741
-2.867
-4.993 Min
Max: 5.637 MPa
Y
Z


Type: Stress XX
Unit: MPa
7/4/2023, 9:46:22 AM
14.73 Max
9.54
4.35
-0.84
-6.03
-11.22 Min
Min: -11.22 MPa
Max: 14.73 MPa
Y
Z


Type: Safety Factor
Unit: ul
7/4/2023, 9:46:32 AM
15 Max
12
9
6
2.27 Min
0
Max: 15 ul
Min: 2.27 ul
Y
Z

2. **Code**:

Library

<Servo.h>

The library allows to control the servo motor.

Functions

PID function

This is a basic implementation of a PID (Proportional Integral Derivative) control algorithm in a function called `pid`. The function takes in the current error , the previous error , and the tuning constants for the proportional, integral, and derivative terms . It returns the output of the PID controller .

Motor control function

This function assumes that the motor is connected to a driver that is capable of controlling its direction and speed using PWM. The direction pins are used to set the direction of the motor, and the PWM pin is used to set the speed of the motor. The `output` value is a float value between -1 and 1, where 0 represents no motion, -1 represents maximum backward motion, and 1 represents maximum forward motion. The output comes from pid function

ISR_Sensor function

This is an ISR function called `sensor_ISR` that is triggered by an external sensor interrupt from attiny chip . The function sets the target angles for five dc motors and servo based on the mode I have chosen . The function also sets a flag called `sensor_flag` to indicate whether the the motors should make the grip or return to initial position .

Read encoder function

The function increments or decrements encoder position depending on the current state of the encoder input pin.

```
#include<Servo.h>

#include <HardwareSerial.h>


HardwareSerial Serial2(USART2);


// servo pin

#define servopin PC11


// sensor pin

#define sensor PC13


// Motor pins
```

```
#define motor1_pwm PB0

#define motor1_dir1 PB1

#define motor1_dir2 PB2

#define motor2_pwm PB3

#define motor2_dir1 PB4

#define motor2_dir2 PB5



#define motor3_pwm PB6

#define motor3_dir1 PB7

#define motor3_dir2 PB8

#define motor4_pwm PB9

#define motor4_dir1 PB10

#define motor4_dir2 PB12

#define motor5_pwm PB13

#define motor5_dir1 PB14

#define motor5_dir2 PB15



// Encoder pins

#define enc1_pin1 PA0

#define enc1_pin2 PA1

#define enc2_pin1 PA2
```

```
#define enc2_pin2 PA3


#define enc3_pin1 PA4

#define enc3_pin2 PA5

#define enc4_pin1 PA6

#define enc4_pin2 PA7

#define enc5_pin1 PA8

#define enc5_pin2 PA9


bool sensor_flag = true ;// true for go


// PID variables

float Ki1 = 0.0001,Kd1 = 1 , Kp1 = 15;

float Ki2 = 0.0001,Kd2 = 1 , Kp2 = 15;

float Ki3 = 0.0001,Kd3 = 1 , Kp3 = 15;

float Ki4 = 0.0001,Kd4 = 1 , Kp4 = 15;

float Ki5 = 0.0001,Kd5 = 1 , Kp5 = 15;


float error1, prevError1;

float error2, prevError2;

float error3, prevError3;
```

```
float error4, prevError4;

float error5, prevError5;


// Target angles

volatile float target1 = 0;

volatile float target2 = 0;

volatile float target3 = 0;

volatile float target4 = 0;

volatile float target5 = 0;


// Encoder variables

volatile int enc1Pos = 0;

volatile int enc2Pos = 0;

volatile int enc3Pos = 0;

volatile int enc4Pos = 0;

volatile int enc5Pos = 0;


// Modes

char mode= "D";
```

```
Servo servo;


void setup() {
  Serial.begin (9600);
  Serial2.begin(9600);

  // attach servopin
  servo.attach(servopin);

  // Set motor pins as outputs
  pinMode(motor1_pwm, OUTPUT);
  pinMode(motor1_dir1, OUTPUT);
  pinMode(motor1_dir2, OUTPUT);
  pinMode(motor2_pwm, OUTPUT);
  pinMode(motor2_dir1, OUTPUT);
  pinMode(motor2_dir2, OUTPUT);
  pinMode(motor3_pwm, OUTPUT);
  pinMode(motor3_dir1, OUTPUT);

  pinMode(motor3_dir2, OUTPUT);
```

```
pinMode(motor4_pwm, OUTPUT);

pinMode(motor4_dir1, OUTPUT);

pinMode(motor4_dir2, OUTPUT);

pinMode(motor5_pwm, OUTPUT);

pinMode(motor5_dir1, OUTPUT);

pinMode(motor5_dir2, OUTPUT);



// Set encoder pins as inputs


pinMode(enc1_pin1, INPUT);

pinMode(enc1_pin2, INPUT);

pinMode(enc2_pin1, INPUT);

pinMode(enc2_pin2, INPUT);

pinMode(enc3_pin1, INPUT);

pinMode(enc3_pin2, INPUT);

pinMode(enc4_pin1, INPUT);

pinMode(enc4_pin2, INPUT);

pinMode(enc5_pin1, INPUT);

pinMode(enc5_pin2, INPUT);
```

```
  // set sensor pin as input
   pinMode(sensor,INPUT);


  attachInterrupt(digitalPinToInterrupt(enc1_pin1), readEncoder1, RISING);
  attachInterrupt(digitalPinToInterrupt(enc2_pin1), readEncoder2, RISING);
  attachInterrupt(digitalPinToInterrupt(enc3_pin1), readEncoder3, RISING);
  attachInterrupt(digitalPinToInterrupt(enc4_pin1), readEncoder4, RISING);
  attachInterrupt(digitalPinToInterrupt(enc5_pin1), readEncoder5, RISING);
  attachInterrupt(digitalPinToInterrupt(sensor), sensor_ISR , RISING);
}


void loop() {


   if (Serial2.available()) {
    mode = Serial2.read();
    sensor_ISR();
  }


   // Calculate errors
   error1 = target1 - enc1Pos;
   error2 = target2 - enc2Pos;
```

```
error3 = target3 - enc3Pos;
error4 = target4 - enc4Pos;
error5 = target5 - enc5Pos;

// PID logic
float motor1_output = pid(error1, prevError1, Kp1, Ki1, Kd1);
float motor2_output = pid(error2, prevError2, Kp2, Ki2, Kd2);
float motor3_output = pid(error3, prevError3, Kp3, Ki3, Kd3);
float motor4_output = pid(error4, prevError4, Kp4, Ki4, Kd4);
float motor5_output = pid(error5, prevError5, Kp5, Ki5, Kd5);

// Set motor speeds and directions
motorControl(motor1_pwm, motor1_dir1, motor1_dir2, motor1_output);
motorControl(motor2_pwm, motor2_dir1, motor2_dir2, motor2_output);
motorControl(motor3_pwm, motor3_dir1, motor3_dir2, motor3_output);
motorControl(motor4_pwm, motor4_dir1, motor4_dir2, motor4_output);
motorControl(motor5_pwm, motor5_dir1, motor5_dir2, motor5_output);

// Store previous errors
prevError1 = error1;
prevError2 = error2;
```

```
  prevError3 = error3;
  prevError4 = error4;
  prevError5 = error5;

  Serial.println(error1);
  Serial.println(error2);
  Serial.println(error3);
  Serial.println(error4);
  Serial.println(error5);
}
void readEncoder1() {
 if (digitalRead(enc1_pin2) == HIGH) {
    enc1Pos++;
   }
 else {
    enc1Pos--;
 }
}
void readEncoder2() {
 if (digitalRead(enc2_pin2) == HIGH) {
    enc2Pos++;
```

```
    }
  else {
      enc2Pos--;
  }
}
void readEncoder3() {
  if (digitalRead(enc3_pin2) == HIGH) {
      enc3Pos++;
    }
  else {
      enc3Pos--;
  }
}
void readEncoder4() {
  if (digitalRead(enc4_pin2) == HIGH) {
      enc4Pos++;
    }
  else {
      enc4Pos--;
  }
}
```

```
void readEncoder5() {
  if (digitalRead(enc5_pin2) == HIGH) {
      enc5Pos++;
    }
  else {
      enc5Pos--;
  }
}
void sensor_ISR()
{
  if(sensor_flag)
  {
    if (mode == "1"){
    target1 = 180;
    target2 = 180;
    target3 = 180;
    target4 = 180;
    target5 = 180;

    servo.write(90);
```

```
sensor_flag = false ;

}


else if (mode == "2"){

target1 = 50;

target2 = 60;

target3 = 90;

target4 = 90;

target5 = 90;


servo.write(90);


sensor_flag = false ;

}


else if (mode == "3"){

target1 = 90;

target2 = 90;

target3 = 90;

target4 = 50;

target5 = 60;
```

```
sensor_flag = false ;

}


else if (mode == "4"){

target1 = 40;

target2 = 40;

target3 = 40;

target4 = 50;lllllllllllllllllllllllllll;;;;ppppppppppppppppppppppppppppppp[pp[[

target5 = 50;


sensor_flag = false ;

}


else if (mode == "5"){

target1 = 30;

target2 = 30;

target3 = 30;

target4 = 30;

target5 = 30;
```

```
  sensor_flag = false ;
  }
   else if (mode == "D"){
  target1 = 80;
  target2 = 80;
  target3 = 80;
  target4 = 80;
  target5 = 80;

  servo.write(90);

  sensor_flag = false ;
  }

}
else
{
  target1 = 0;
  target2 = 0;
  target3 = 0;
  target4 = 0;
```

```
    target5 = 0;


    servo.write(0);


    sensor_flag = true ;
  }
}
// Motor control function
void motorControl(int pwm,int dir1, int dir2, float output) {
  if (output > 0) {
    digitalWrite(dir1, HIGH);
    digitalWrite(dir2, LOW);
  } else {
    output = -output;
    digitalWrite(dir1, LOW);
    digitalWrite(dir2, HIGH);
  }
  analogWrite(pwm,output);
}


// PID function
```

```
float pid(float error, float prevError, float Kp, float Ki, float Kd) {

  float P = Kp * error;

  float I = Ki * (error + prevError);

  float D = Kd * (error - prevError);

  float pid_output = P + I + D;

  return pid_output;

}
```

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9 SUMMARY IN ARABIC:

تشهد التقدمات في العلوم والتكنولوجيا تقدمً واعدًا في مجال الأطراف الصناعية، ولا سيما في مجال تصميم الأيدي الصناعية. إن هذا المجال متعدد التخصصات يتطلب معرفة في علم الفسيولوجيا وعلم التشريح والأنظمة الكهربائية والإلكترونية والتصميم الميكانيكي والبرمجيات، وغير ذلك، وذلك حسب نوع التحكم المستخدم. ومع ذلك، فإن معظم الأبحاث في هذا المجال لا تزال تقتصر على المختبرات بسبب تحديات طبيعتها متعددة التخصصات والتمويل المحدود.

وتعتمد الاختيارات المتاحة للأطراف الصناعية على متطلبات المستخدم الفردية. في هذا المشروع، يتم التركيز على الأذرع الكهروميكانيكية، وهي الأكثر شيوعًا بين الأجهزة الكهربائية. تحتوي هذه الأذرع على محركات وبطاريات لتشغيل حركتها، وتتحكم فيها إشارات كهربائية تولدها عضلات الجزء المتبقي من الجسم.

يتم توفير التدريب على الأذرع الكهروميكانيكية عادةً من قبل أخصائي العلاج الوظيفي وفنيي العظام. عندما يتقلص عضلة ما، فإنها تنتج إشارة كهربائية يتم التقاطها بواسطة الكابلات المرتبطة بالجلد في الجيب الصناعي. تنتقل هذه الإشارات إلى جهاز تحكم يبدأ الحركات وفقًا لنوايا المستخدم. على سبيل المثال، عندما يرغب المستخدم في إغلاق اليد الصناعية، يقوم بتقلص العضلات المقابلة، وسوف تغلق اليد على النحو المطلوب. توفر التكنولوجيا الحديثة الآن إمكانية التحكم بوظائف متعددة باستخدام يد واحدة، مثل نمط قبضة واحدة، ودوران المعصم، وثني الكوع، وحتى حركة الكتف.

تتمتع الأذرع الكهروميكانيكية بعدة مزايا مقارنةً بالأجهزة المستندة إلى الحركة الجسدية. فهي تقلل من الحاجة إلى استخدام الأشرطة والمشابك، وتوفر قوة بدون مجهود، وتوفر أنماط قبضة متعددة، وتمكن من حركات يد أكثر طبيعية. بالإضافة إلى ذلك، يستمتع الكثيرون بالمظهر الروبوتي الذي يمكن أن تقدمه الأذرع الكهروميكانيكية عندما لا تكون مغطاة بقفاز تجميلي. على الرغم من أن هناك قيودًا تشير إليها كثير من الأبحاث حول الأذرع الكهروميكانيكية، مثل عدم قدرتها على الماء، إلا أن التقدمات الحديثة في تقنيات تصنيع المقابض والمفاصل تعمل على حل هذه المشكلة لبعض الأجهزة الطرفية والمفاصل.

تعتبر التقدمات العلمية والتكنولوجية في مجال الأطراف الصناعية من الجوانب الرئيسية التي تدفع نحو تطبيقها العملي في البحوث. تركز تصميم الأيدي الصناعية على الجوانب المتعددة والأساسية مثل الفيزيولوجيا وعلم التشريح، والأنظمة الكهربائية، والميكانيكية، والبرمجيات. ومع ذلك، يتم إجراء معظم الأبحاث في المختبرات ويواجه العديد من التحديات بسبب طبيعته المتعددة التخصصات ونقص التمويل.

تتوفر أنواع مختلفة من الأيدي الصناعية، بما في ذلك تلك التي تعتمد على واجهات عصبية وقد تم اختبارها. يعتمد اختيار اليد الصناعية على متطلبات المستخدم. في هذا المشروع، يتم التركيز على الأذرع الكهروميكانيكية، والتي هي الأكثر شيوعًا. تعمل هذه الأذرع بواسطة محركات وبطاريات لتحريك الجهاز، ويتم التحكم فيها عن طريق إشارات كهربائية تنشأ من عضلات جذع الجسم.

عبر التاريخ، شهدت الأذرع البيونية تطورًا متسارعًا. في السابق، تم استخدام الأذرع البسيطة التي تعتمد على الحركة الميكانيكية لنقل الحركة، ولكنها كانت غير قابلة للتحكم بشكل كامل. مع التقدم التكنولوجي، تم تطوير الأذرع البيونية المزودة بأنظمة كهروميكانيكية تتحكم بالحركة باستجابة للإشارات الكهربائية المنبعثة من عضلات الجسم.