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Faculty of Engineering
Department of Mechanical Engineering

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Degree Project:

Recycling System Design

FINAL REPORT

Prepared by:
Ahmed, Mohamed Tariq
ID: 1153392
Perry, Coleman
ID: 1159587
Koidjos, Luis
ID: 1148217
MacNabb, Zachery
ID: 1131531

Project Supervisor: Dr. Sultan Siddiqui
Project Coordinator: Dr. Basel Ismail
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Abstract

This capstone report presents the design and development of an innovative recycling system that improves recycling efficiency at large venues, such as schools, factories, and stadiums. The project aims to provide a better alternative to crushing recyclable materials before outsourcing to recycling plants. The recycling system is designed to reduce the storage space required for cans and bottles by 80%, consequently saving on shipment costs to recycling plants.

The report covers the design criteria, objectives, and iterative design choices made to optimize the recycling system. The final design includes a conveyor system, a sorting mechanism for filtering out trash and glass, a counting mechanism for tracking crushed cans, and a continuous crushing mechanism for improved efficiency. FEM analysis was conducted using Inventor to ensure the effectiveness and functionality of the design.

Additionally, the report explores potential improvements to the current design, such as adding the ability to sort and store plastic bottles, incorporating an internal light for identifying issues, reducing the overall size and cost of the machine, and improving the operator's ability to monitor and maintain the system. By considering these future improvements, the recycling system's effectiveness, efficiency, and cost-effectiveness can be further enhanced, ultimately contributing to increased recycling rates and environmental sustainability.

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1.0 Introduction

This report is an overview of a project constructed by Lakehead University mechanical engineering students. The objective of this project is to design a new system that will improve recycling efficiency. This report will address all the design criteria required to manufacture a recycling system catered to large venues. The intention of this project is to provide a better alternative to crushing recyclable materials before outsourcing to recycling plants. The design criteria and objectives will be elaborated. Down selections made to obtain the final design are illustrated in this report.

1.1 Project Description

Recycling helps to reduce the amount of waste that ends up in our landfills. By recycling we turn waste materials into new products thus reducing the amount of extracted raw materials from the earth. It is important to develop more ways to improve renewability as mass consumers, to reduce the negative impact we have on the environment. Recycling helps to preserve our natural resources for future generations and developing new recycling systems puts us a step in the right direction.

The recycling system designed will reduce the amount of space that cans and bottles take up in storage rooms, thus allowing more room for inventory. This system is set to reduce the void space taken up by these recyclable materials by 80%. Significantly reducing the space these materials occupy will save the company on shipments to recycling plants by increasing the number of recyclable materials that can fit in a shipment truck at a time.

1.2 Design Requirements

Our objective was to make this design as practical as possible. The compact and accessible design will fit in any typical storage room and allow access to anyone without the use of a ladder. Our design can crush all types of bottles and cans. The malleable materials made of aluminium and plastic will pass through the conveyor in the system, and any glass bottles will be crushed into small pieces and collected immediately. Liquids and trash (gum, cigarette buds etc.) have been accounted for and will be disposed of in the system.

1.3 Design Originality

Our recycling system is the best on the market for our targeted clients, it has a sorting mechanism capable of filtering out trash and glass from plastics/aluminium. There is a counting mechanism put in place so the operator can keep track of the number of cans crushed. The crushing mechanism developed allows for continuous crushing, so the operator doesn’t have to continuous feed cans in the system as it is running. The system will run on its own and automatically shut off after the last cans passes through the system. Our targeted clients are large buildings including but not limited to schools, factories, and venues such as bars, stadiums.

1.4 Design Choices

In the development of the can-crushing machine, various design iterations were explored, resulting in both major and minor modifications to improve the device's overall performance. These improvements aimed to enhance the machine's efficiency, reduce costs, and minimize vibrations or impact force, among other goals.

The initial design involved using a pneumatic piston to crush cans and a conveyor system to move the crushed cans into the recycling bin (as shown in *figure 1*). This design had its pros and cons. One of the advantages over the final design is its simplicity, making it easier to build and design. It also has a smaller and more compact form factor, making it more suitable for home use. However, this design also had some limitations, which ultimately led to its rejection as the final design. The most notable issues include a slower crushing speed and the inability to process anything other than aluminum cans, resulting in more work for the operator.

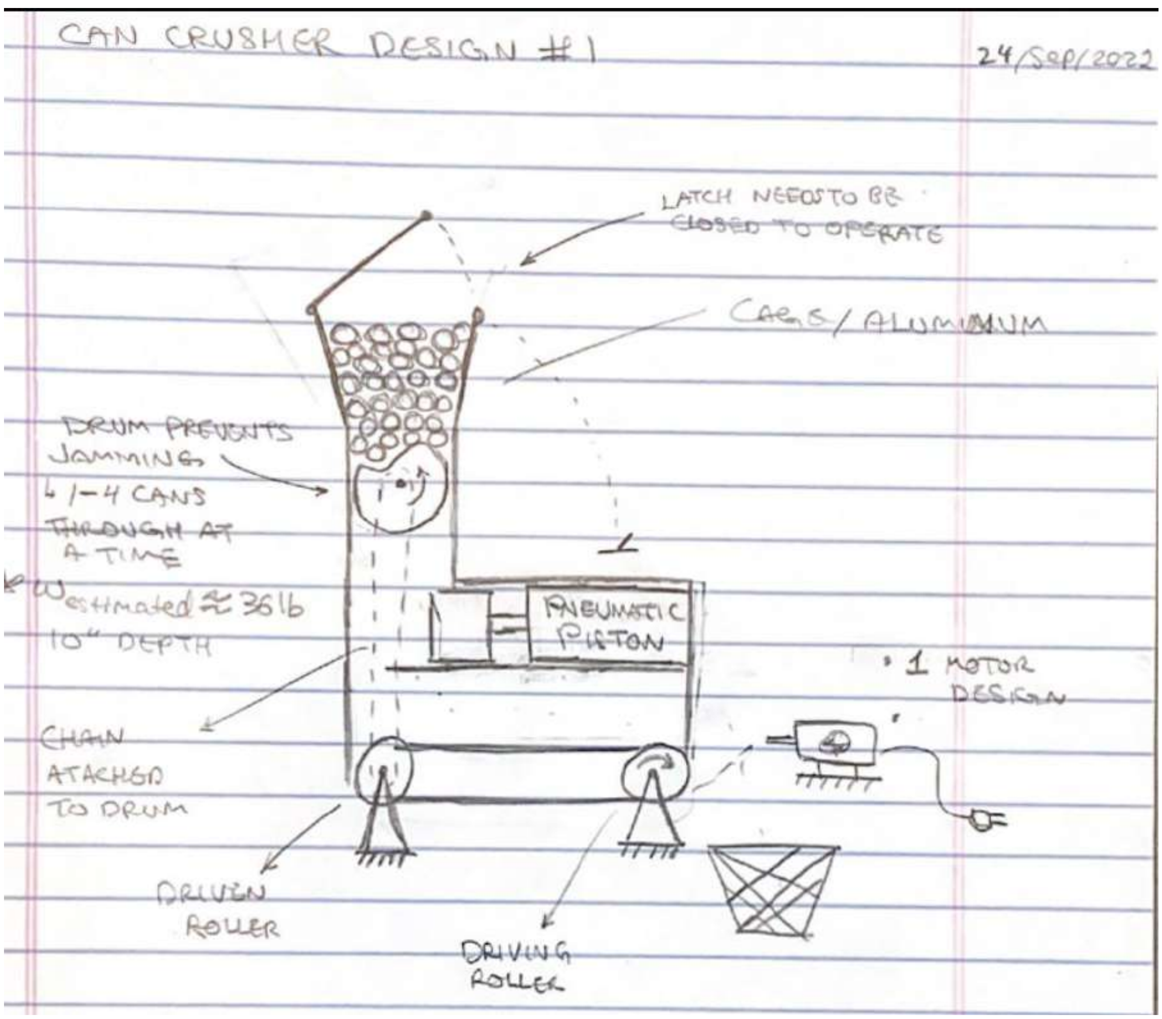

Figure 1 – Initial Design

The final design, which will be discussed in more detail throughout the report, incorporates several changes based on the lessons learned from the initial design. *figure 2* illustrates the exterior of the machine, while *figure 3* provides a view of the interior components. Comparing these figures with *figure 1* reveals the numerous design changes that were made. For example, the most prominent change is the replacement of the piston with drums. Furthermore, the target audience shifted slightly, with the current machine being more suitable for larger-scale events. This new design allows for more versatility and efficiency in the can crushing process, addressing the shortcomings of the initial design, and better meeting the needs of the intended users.

Figure 2 – Interior and Exterior Design

2.0 Crushing Mechanism

The crushing mechanism is the most critical aspect of the can crusher device, as it is responsible for the primary function of crushing cans and other materials. Without an effective and efficient crushing mechanism, the device would not serve its intended purpose. Therefore, it is crucial to design and implement a mechanism that ensures consistent performance and reliability.

2.1 Specifications

The crushing mechanism of the can crusher device consists of two drums designed to apply sufficient force to crush cans and other materials. Several factors were considered when determining the required force, such as the crushing method, the size of the cans, and the amount of liquid remaining in the cans. The worst-case scenario, including a safety factor, requires 200 lbs of force to crush a can. However, other materials may be introduced into the hopper, with glass bottles being the most challenging, requiring approximately 350 lbs of force to break. Therefore, after applying a small safety factor, the drums are designed to produce a crushing force of 500 lbs (*figure 3*).

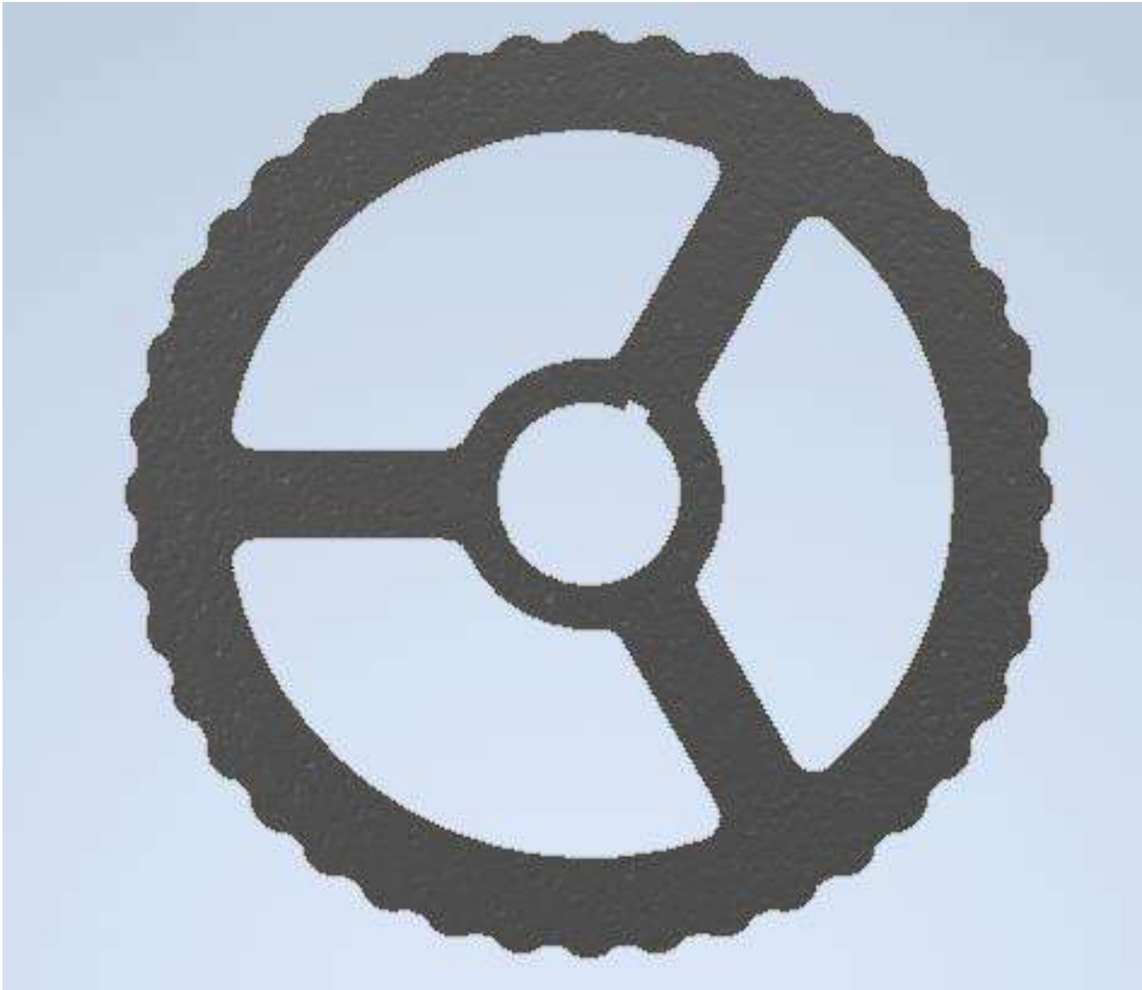

Figure 3 – Drum

Drums were chosen as the crushing mechanism over pistons for several reasons. First, drums can crush more than one can at a time, increasing the efficiency of the process. Second, drums provide a constant crushing force as they spin at a constant rate, resulting in fewer sudden vibrations compared to pistons. Furthermore, a constant crushing force allows the hopper to drop cans at varying rates without affecting the crushing mechanism's performance.

2.2 Procedure

The two drums used in the crushing mechanism rotate at the same speed but in opposite directions, with cans placed between them by the hopper. To improve the crushing efficiency, the drums feature small teeth that help catch and crush the cans and other materials more effectively. The teeth are designed in a way that they do not cut into the cans but rather enable the drums to have an easier time catching and crushing the cans, reducing sharp edges, and allowing the crushed cans to pass through the filtering screen more smoothly, which will be discussed in more detail in a future section (*figure 4*).

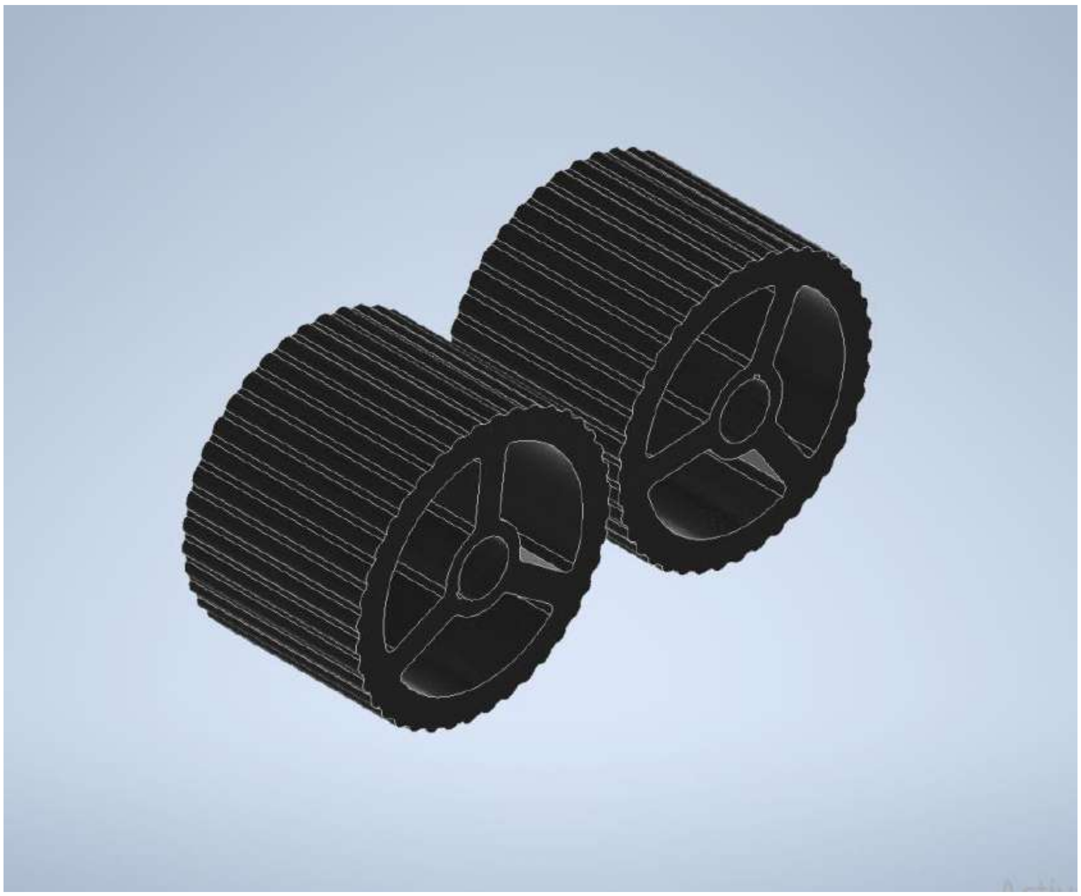

Figure 4 – Isometric view of Drums

Each drum has a diameter of 10 inches and weighs approximately 80 lbs. The drums rotate at a speed of 5 revolutions per minute, resulting in an angular velocity of 6.283 rad per second. To reduce the overall weight of the device, the drums have been designed to be hollow. The power transfer to the drums will be facilitated through a shaft, which will be discussed in more detail in a later section of the report. The crushed cans are expected to have their volume reduced by roughly 80% compared to a non-crushed can, although this number may vary depending on the original size of the can and its orientation when entering the device.

2.3 FEM Analysis

Finite Element Method (FEM) analysis was conducted using Autodesk Inventor software to evaluate the mechanical performance of the drum system. A force of 250 lbs was applied during the analysis, and the drums were designed using stainless steel material. Material properties, such as modulus of elasticity, Poisson's ratio, and yield strength, can be found in Table 1.

Table 1 – Material Information

Name	Stainless Steel	
General	Mass Density	0.289018 lbmass/in^3
	Yield Strength	36259.4 psi
	Ultimate Tensile Strength	78320.4 psi
Stress	Young's Modulus	27992.3 ksi
	Poisson's Ratio	0.3 ul
	Shear Modulus	10766.3 ksi

Figures 5-7 illustrate the displacement of the drums under the applied force, demonstrating that the values are within acceptable limits, ensuring the proper functionality of the drum system. A comprehensive stress analysis for the drums, including the six stress components, six strain components, principal and equivalent strains, and Von Mises stresses, can be found in the Appendix section of this report. This in-depth analysis confirms the reliability and durability of the drum system for its intended purpose.

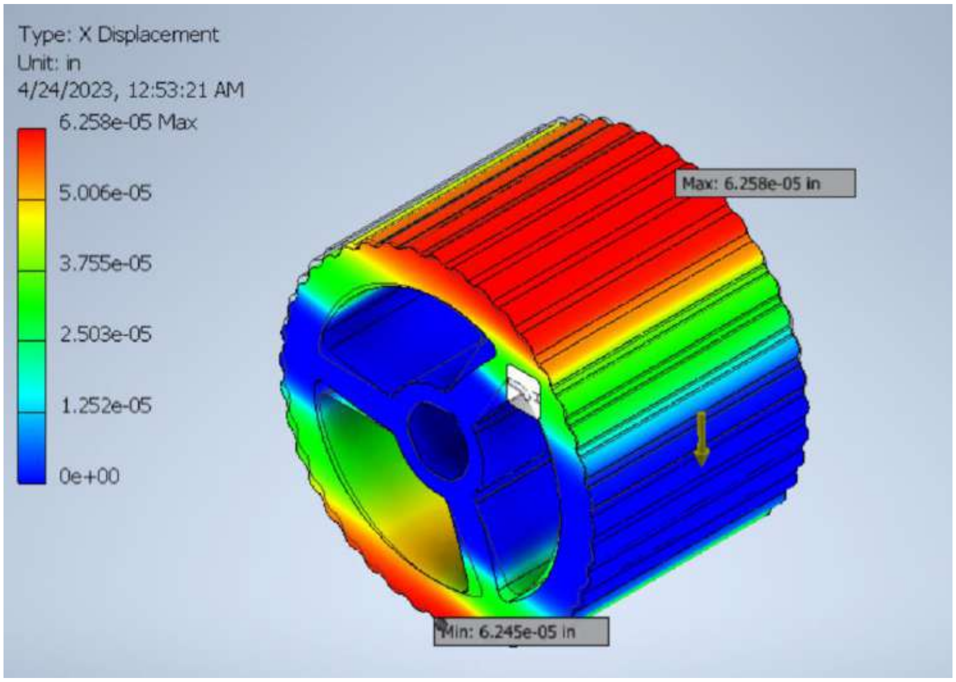

Figure 5 – Drums X displacement

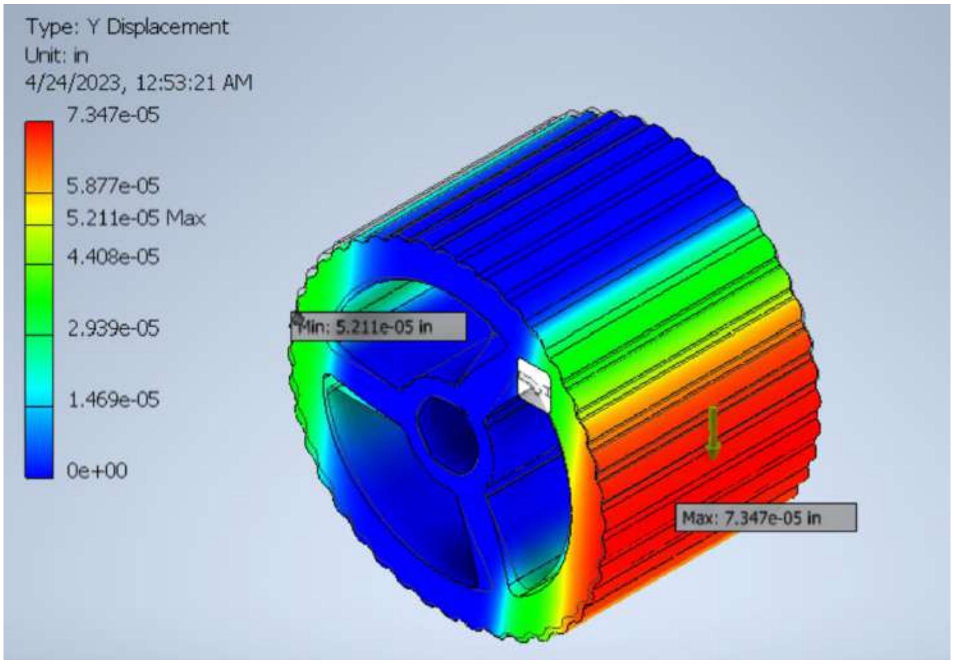

Figure 6 – Drums Y displacement

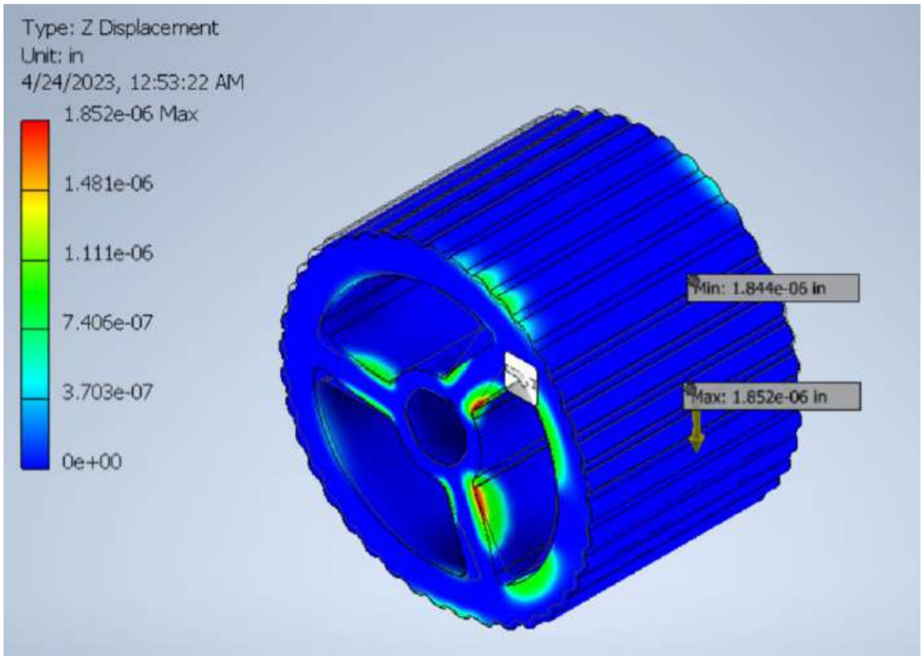

Figure 7 – Drums Z displacement

3.0 Conveyor

The conveyor system is a crucial component of the can crusher device, responsible for transporting the crushed cans from the crushing drums to the recycling bin. One of the main reasons for choosing a conveyor system is the vast customization options available, including length, width, color, flight specifications, material, and tensile strength.

3.1 Specifications

To maintain a consistent and efficient processing rate, there is an interval of 4 seconds between each can entering and exiting the conveyor. This timing ensures that a maximum of 9 cans are present on the conveyor at any given time, preventing overloading and potential jams. The belt is made of 0.5-inch-thick rubber, which provides durability and longevity. The frame of the conveyor is constructed from stainless steel, making it resistant to corrosion and suitable for use in various environments (*figure 8*).

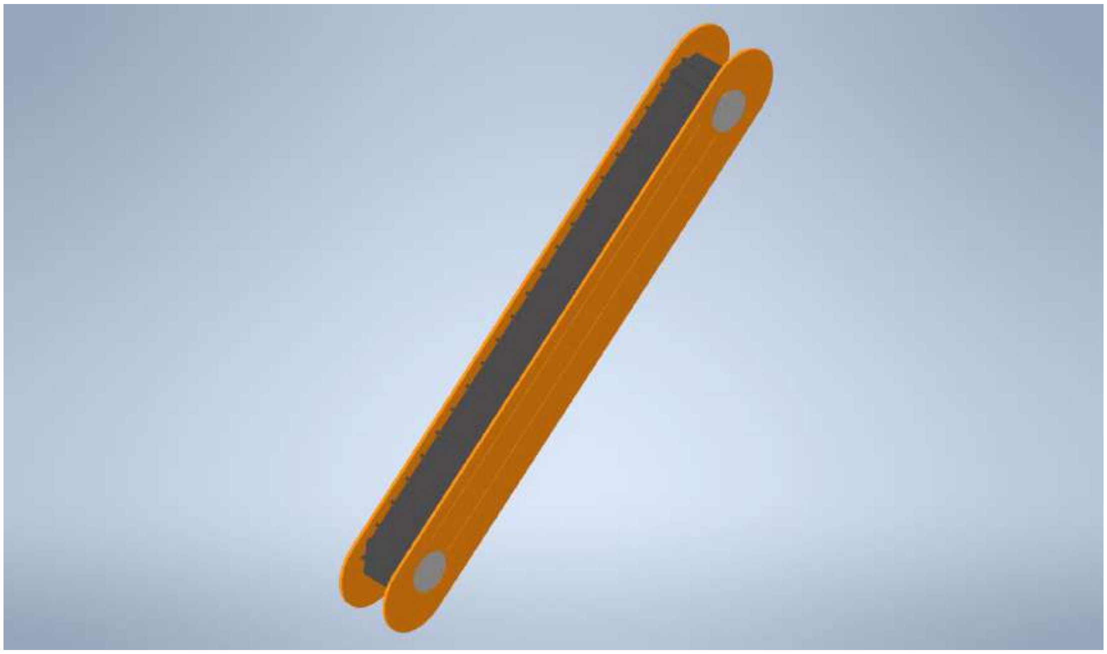

Figure 8 – Conveyor

3.2 Procedure

The conveyor system features flights, which are raised sections on the conveyor belt designed to hold and transport a single crushed can. These flights are angled at 75 degrees from the rest of the conveyor to provide a secure grip on the cans and prevent them from sliding back down the belt. Each flight has a height of 0.5 inches and is spaced 8 inches apart from the next one, ensuring that there is enough room for one crushed can between them. The width of the belt section where the flights are located is also 8 inches. These dimensions were chosen to optimize the capacity of the conveyor while preventing cans from becoming jammed or falling off the belt *figure* 9.

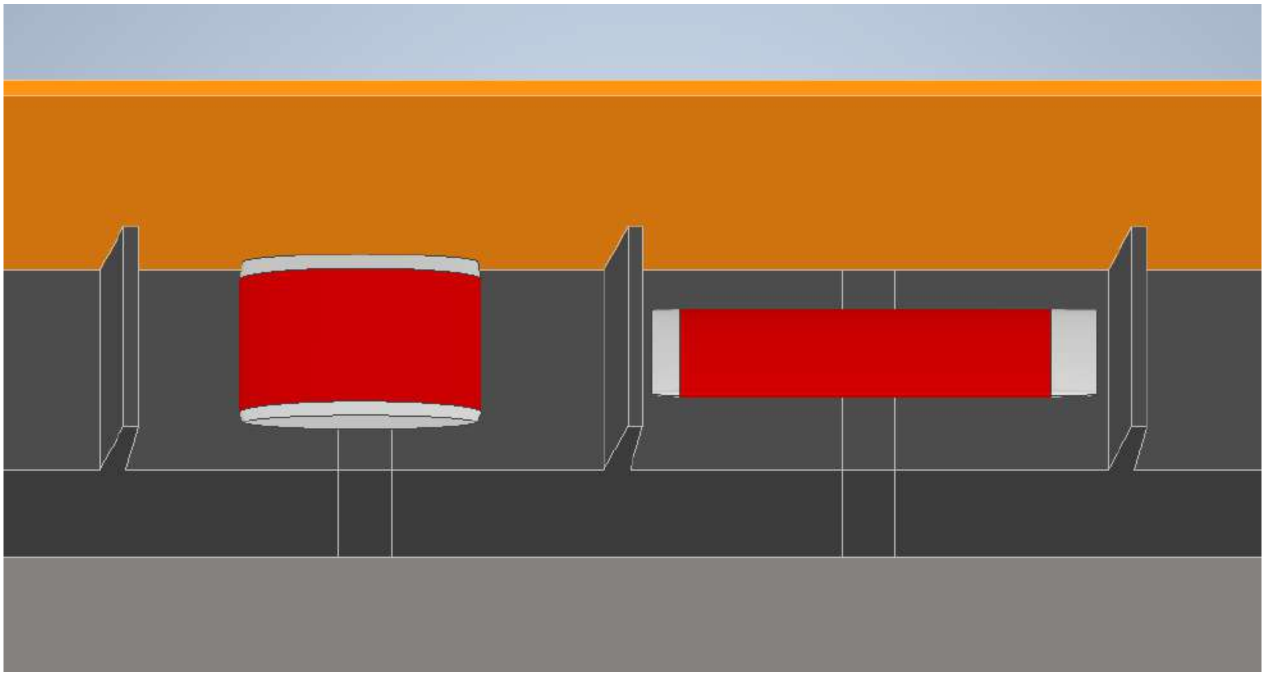

Figure 9 – Crushed Cans on Conveyor

To further clarify the design and dimensions of the flights, a small diagram (*figure 10*) can be included in the report, providing a detailed view of the flight's height and angle, allowing readers to better understand the rationale behind the chosen measurements. As mentioned before the “h” value will be 0.5 inches.

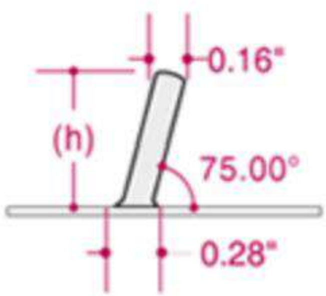

Figure 10 – Flight Design

4.0 Power Transmission

4.1 Specifications

Achieving the desired output speed for the crushing drums was a critical aspect of the system's design. To meet the requirement of 6 rpm for the crushing drums, we needed to develop a chain drive that could effectively transmit power and maintain the desired speed. Fortunately, the selected gearmotor for the system had a loaded output speed of 12 rpm, which allowed us to reduce the number of components required to maintain the slow crushing speed at the drums. This approach not only simplified the system's design but also increased its efficiency and reliability.

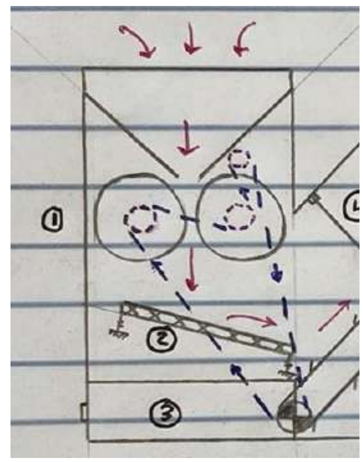

Figure 11 – Crushing mechanism.

As mentioned earlier, the recycling system is to be powered by a single motor, which presented a unique challenge in achieving the required output speed and direction for the crushing drums. To address this challenge, we developed a unique chain path that allowed both crushing drums to rotate in opposite directions. This chain path was carefully designed and optimized to ensure that the system could operate smoothly and efficiently. To better understand the chain path, we created a detailed sketch, which is illustrated in Figure _. This sketch provides a clear visual representation of the chain path and allows us to see how power is transmitted through the system to achieve the desired crushing speed and direction.

4.2 Motor

The chosen motor for the system is the 3/4 horsepower Brother Gearmotor F3 High Torque AC Gear Motor. This motor is an ideal choice for this application because it offers several important advantages over other types of motors. By utilizing a gearmotor, the system is able to significantly reduce the number of required components, which not only simplifies the design but also reduces the risk of mechanical failure. This is due to the fact that the gearmotor combines the motor and gearbox in a single unit, eliminating the need for an external gearbox or additional chain drive. This, in turn, reduces maintenance requirements, which means that the system will be more reliable and require less downtime for maintenance and repairs. Additionally, the high torque output of the Brother Gearmotor F3 means that the system will be able to handle heavy loads with ease, ensuring smooth and efficient operation.

4.3 Shafts

4.3.1 Input Shaft

The drum shaft is a critical component in the can crusher device, responsible for transferring torque from the gears to the drums. To design and size the drum shaft, Shrigley's Mechanical Engineering Design textbook was used as a reference, with relevant tables and equations found in chapters 6 and 7.

The shaft measures 36 inches in length, with a diameter of 2 inches at the sides and an increased diameter of 2.125 inches in the middle right after the shoulder. It is made of stainless steel 304, which provides strength and durability. The shaft is machined to ensure precision and accuracy in its dimensions (*figure 12*). The shaft design includes a shoulder to prevent the drums and gears from slipping. Additionally, a key seat is integrated into the shaft to stop any movement of the drums and gears along the shaft. The key seat serves the essential purpose of providing a secure connection between the shaft and the attached components, preventing any potential misalignment or slippage during operation *figure 13*.

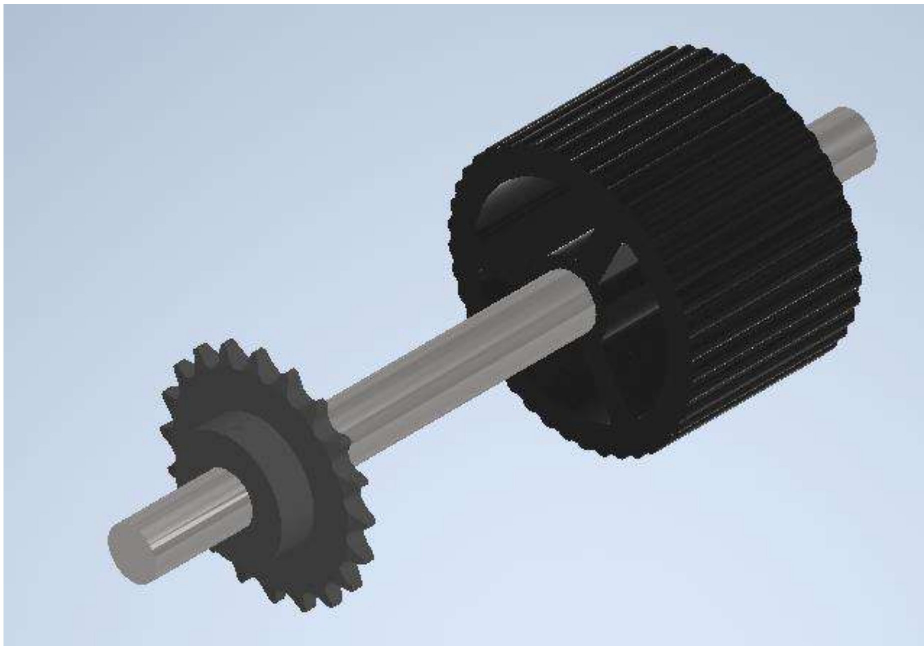

Figure 12 – Drum Shaft

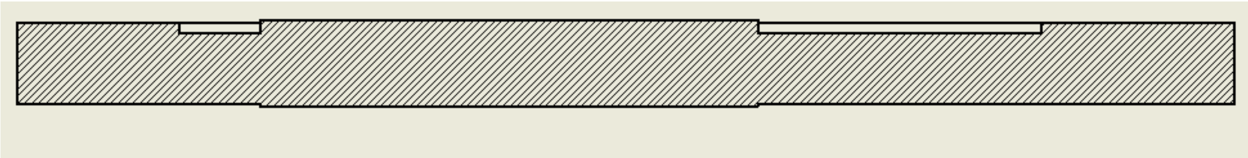

Figure 13 – Section View of Drum Shaft

Several assumptions were made during the design process, which were later verified. The size factor was assumed to be 1 and was confirmed to be correct upon completion of the calculations. The machine's operating temperature was within the normal range, resulting in a temperature factor k_d of 1. A reliability of 99% was chosen to ensure dependable operation, and a safety factor of 3 was applied to account for any uncertainties or potential overloads.

The critical point of the shaft was determined to occur at the shoulder on the same side where the drums are attached. This information helped to optimize the shaft design and ensure it can withstand the forces exerted on it during operation.

4.3.2 Main Shaft

The main shaft is another crucial component in the can crusher device, and its design is closely related to the drum shaft, as discussed in the previous section. Both shafts share similarities in calculations and certain design elements. For example, the main shaft uses the same Se value as the drum shaft in its calculations.

A safety factor of 3 was applied during the design process, resulting in a calculated diameter of 2 inches for the main shaft. However, for convenience and practicality, the main shaft features two different diameters along its length: 2 inches for the smaller diameter and 2.5 inches for the larger diameter. This design choice accommodates various components and provides a secure and accurate alignment. The critical point on the main shaft occurs near the shoulder, where the gear is positioned, making this area particularly important for structural integrity.

The calculations for the main shaft design can be found in the appendix. The report includes a picture of the main shaft with the gear, motor, and conveyor attached, illustrating the overall design and the relationship between the main shaft and the attached components shown on *figure 14*. Additionally, a section view of the shaft is provided (*figure 15*) to display the shoulder more clearly, which plays an important role in the shaft's function and structural integrity.

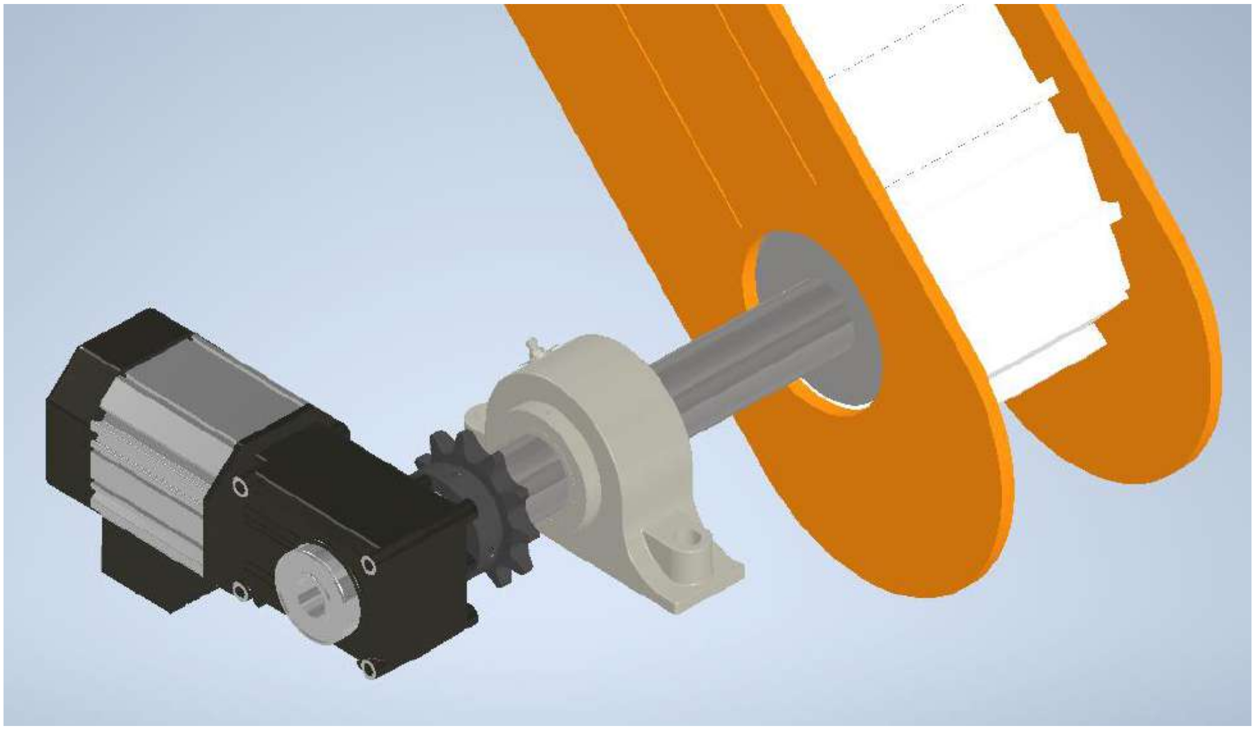

Figure 14 – Main Shaft

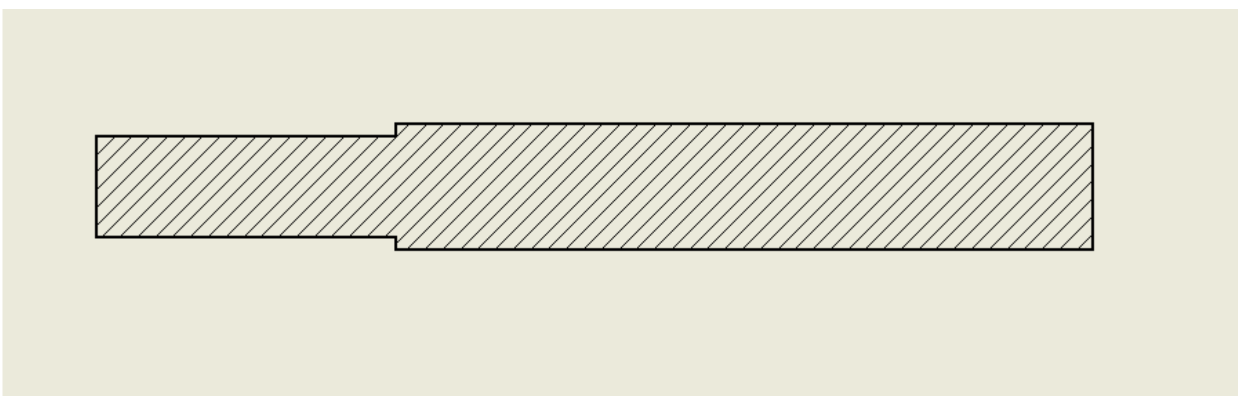

Figure 15 – Section view of Main Shaft

4.4 Gears & Chain

Chain drive components were designed using a step-by-step procedure outlined in Mott's Machine Elements in Mechanical Design. The components were then selected from Dodge Power Transmission catalogue (Dodge 672 – 704).

An excel sheet was created which compared various sizes of chain and sprockets in order to find the most efficient drive components for our design. This Excel sheet, attached in Appendix A, details the steps followed to reach the final design of the chain drive.

5.0 Filtering Screen

5.1 Specifications

The filtering screen was implemented to filter glass and trash form bottles/cans. This screen was modified for our specific applications and constrained to prevent cans from falling out of the system. The screen is angled downslope so all malleable materials will naturally fall and be fed into the conveyor after being crushed. The natural vibration caused by all the moving parts in the system will be used to our advantage. Amplifying this vibration by placing compressive springs in contact with the filtering screen and frame. In case of jamming, this will make the screen vibrate shaking cans down.

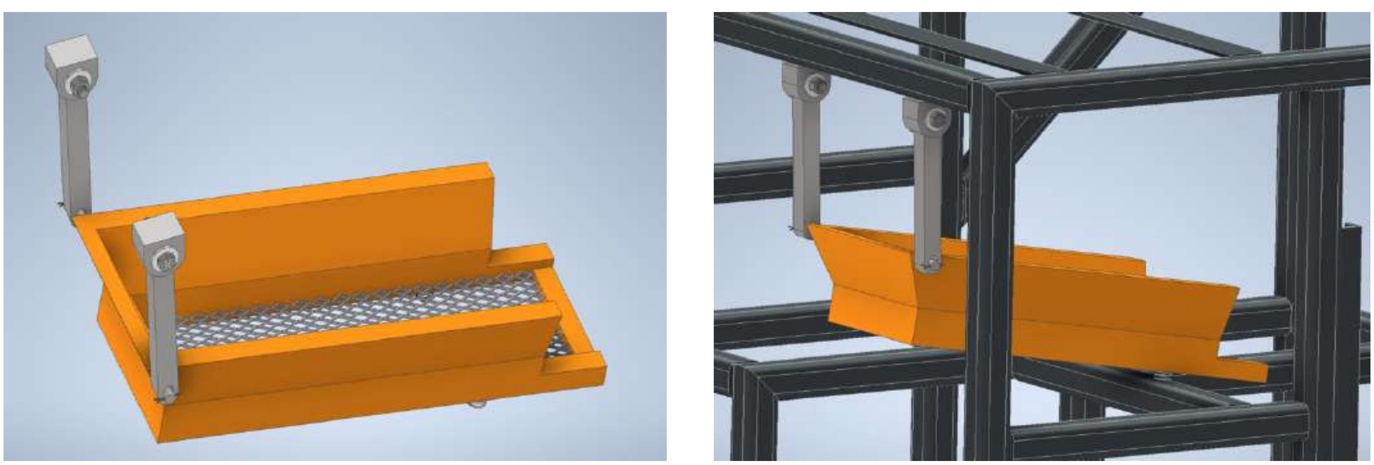

Figure 16 – Filtering screen

6.0 Hopper

6.1 Procedure

The hopper is the first point of contact in this system, where bottles and cans are fed. In our design we ensured that the size of the hopper will be large enough to account for an extra-large bin of cans (70 litres). This size choice is ideal because in a normal cycle the operator will bring at most a heaping bin of recyclable material. The large size of the hopper allows for simultaneous operation as the operator is doing something else. So, the operator does not have to continuously feed the cans in one by one.

6.2 Specifications

Safety in a system with a mechanism capable of crushing 50 lb force is important. To ensure safety we took an extra step adding a latch that will only allow the system to operate when closed. The hopper is made of Aluminum Alloy 2024. This material was chosen because it is light, cheap, and strong enough for our application. The overall hopper dimensions are 18x16x20.

Figure 17 – Hopper

7.0 Bins

In the can crusher device, two bins will be utilized to separate and store the crushed materials. The first bin is the recycling bin, which is responsible for holding the crushed cans and is placed at the end of the machine. The second bin is the waste bin, which is placed directly underneath the mesh and will collect all other crushed materials and the excess liquid from the cans.

7.1 Specifications

The recycling bin is a product purchased from Global Industrial (*figure 18*) and has inside dimensions of 33 inches x 23 inches x 21 inches, resulting in a total volume of 15,939 cubic inches. A non-crushed can typically has a volume of around 25 cubic inches, while a crushed can has a volume of approximately 5 cubic inches. Under ideal conditions, the recycling bin can hold about 3,000 cans.

However, considering that the crushed cans may not be perfectly compacted, and some space may be wasted, the bin can hold at least 2,000 cans. Another limiting factor for the recycling bin is its weight capacity, which is 500 lbs. Given that an empty can weighs a maximum of about 0.1 lbs, the bin can hold up to 5,000 cans considering the weight. As demonstrated, the limiting factor is the dimensional size, so the recycling bin's capacity is estimated to be around 2,000 cans.

Figure 18 – Recycling bin

7.2 Procedure

The waste bin serves the purpose of storing everything else that isn't an aluminum can, such as liquids and other materials that are put into the hopper. This bin has dimensions of 16.5 inches x 14.5 inches x 9 inches, resulting in a total volume of 2,153 cubic inches (*figure 19*). Its volume is approximately seven times smaller than that of the recycling bin, making it more suitable for collecting the smaller amount of waste materials and liquids that are not aluminum cans.

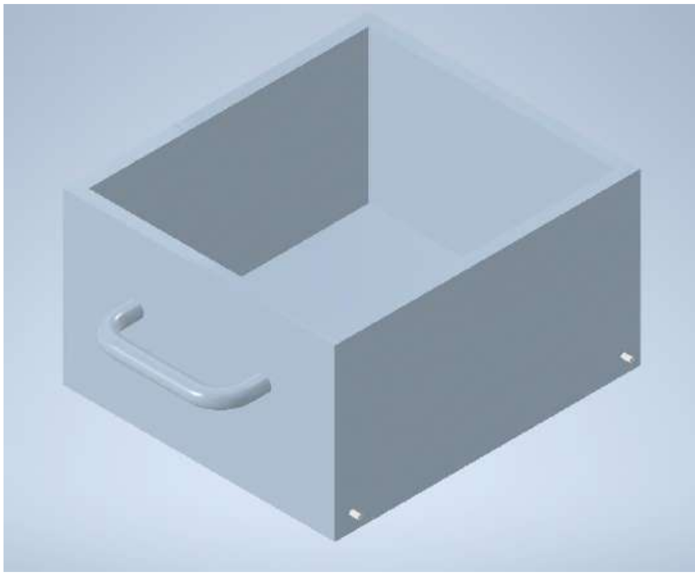

Figure 19 – Waste bin

8.0 Frame

8.1 Procedure

The frame is a major part of the can recycling system. The first step in creating the frame was to build a basic outline of the desired footprint. It was desirable to create a system with a small profile for organization and placement. Clients should be able easily transport the crusher to a desired location and not have it taking up an excessive amount of space. To achieve these goals, we created a frame seven feet long, by seven feet tall, with a width of three feet. The entire frame was to be made from AISC square tubing. The internal members were constructed as mechanical components were designed which helped with member placement. The final design, illustrated in *figure 20,* shows the completed frame.

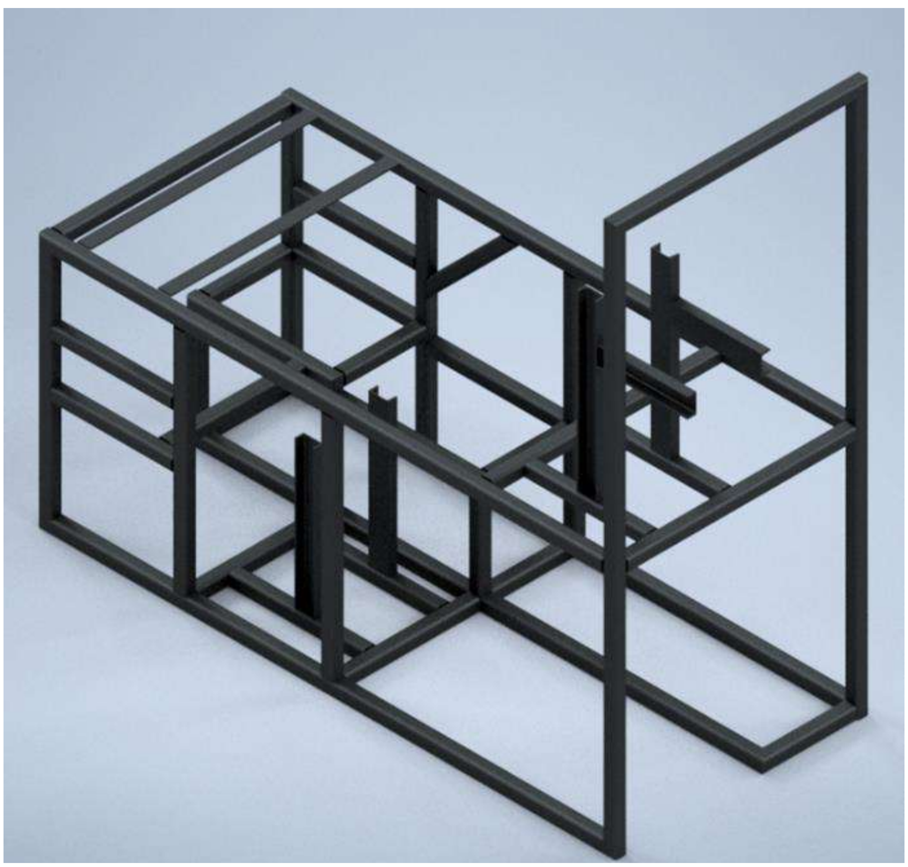

Figure 20 – Overall frame design

8.2 FEM Analysis

Once the frame was completed, a Finite Element Method (FEM) analysis was done in order to confirm safety and reliability of the system. It was determined that the most critical section was the connection points of the conveyor to the frame since the conveyor is the heaviest component. The conveyor, once selected, was found to have an overall weight just under 250 pounds. With this information, it was assumed that the loads posed no threat to failure on the frame, however, an analysis was done to confirm our assumptions.

8.2.1 Constraints

To simulate the system resting on the ground, the bottom surface of the frame was pinned. However, fixed supports could have been utilized if the client preferred the system to be firmly fastened to the ground. It is worth noting that since there was no lateral motion, as would be the case in a piston-crushing system, the analysis was conducted using only pinned supports. Nevertheless, the stability and safety of the system could be enhanced by considering the use of fixed supports, particularly if the system is expected to experience lateral forces.

8.2.2 Loads

To test the system's strength, exaggerated loads of 100 lbf were applied to all four conveyor connection points, while 25 lbf loads were placed on the beams supporting the hopper to simulate a full load of cans prior to crushing. A schematic of these loads can be seen in *figure 21.*

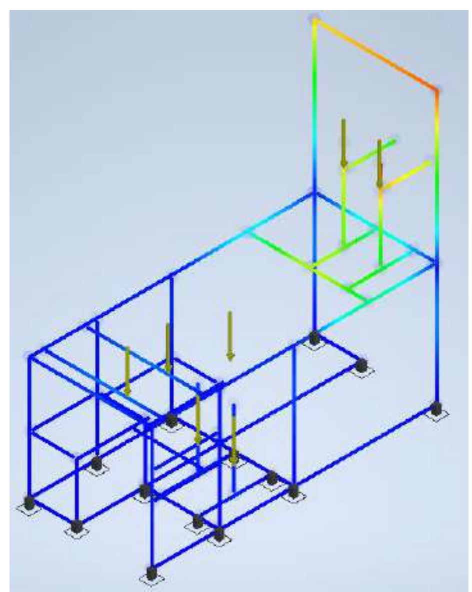

Figure 21 – Frame FEM

8.2.3 Results

The detailed report generated within Inventor provides us with comprehensive results that help us understand the behavior of our system. Our analysis reveals that the maximum displacement recorded is a small but significant 0.0065, indicating that the system experiences some deformation under the applied load. The maximum stress recorded is 0.796 ksi, which gives us insight into the material's response to the applied forces. We can further investigate the system's behavior by analyzing the locations of these maximum values, which are clearly presented in the report illustration. *figure 22* shows the location of the maximum displacement, and *figure 23* shows the location of the maximum stress.

To ensure that our system meets the required safety standards, we calculated the minimum safety factor, which is 32. This value confirms that our assumptions about the system's design and material properties are correct and that the system is operating well within its safe limits. These results are crucial in ensuring the long-term reliability and functionality of our system, and we can use them to inform any necessary design modifications or maintenance.

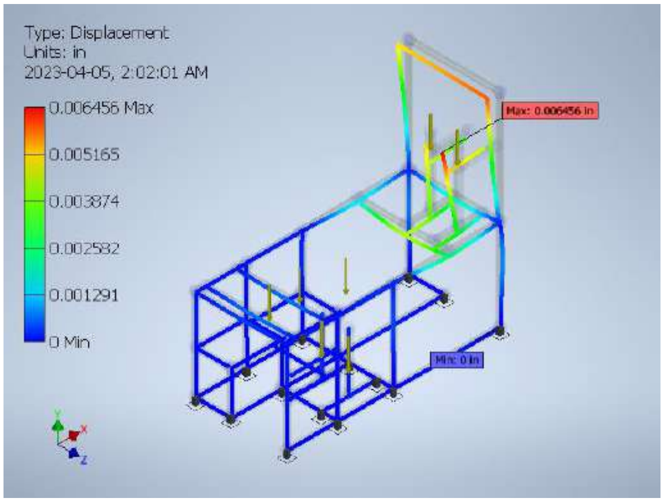

Figure 22 – Frame: location of max. displacement

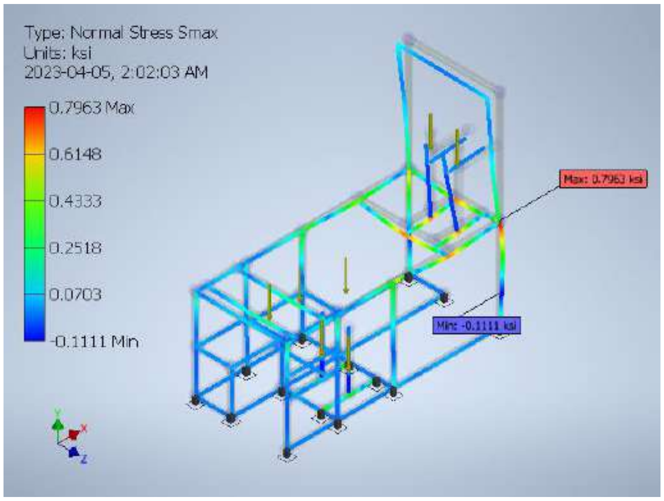

Figure 23 – Frame: location of max. stress

9.0 Housing

9.1 Specifications

Figure 24 – Housing

In addition to its visually appealing design, the housing of the system serves a crucial function of containing any liquids or beverages that may be released during operation. This ensures that the system remains hygienic and easy to maintain, while also preventing any potential damage or malfunction that may occur as a result of fluid exposure.

Despite the importance of this feature, the components used in the housing design do not require any significant resistance to stress or impact, which allowed us to prioritize cost and weight reduction without compromising on the overall functionality and durability of the system. This strategic decision enabled us to optimize the design for both performance and affordability, without sacrificing quality or reliability.

Moreover, the careful selection of materials and manufacturing techniques ensured that the housing components are both lightweight and robust, providing an optimal balance of strength and efficiency. This not only improves the overall user experience, but also helps to reduce the environmental impact of the system by minimizing the number of resources and energy required for production and operation.

9.2 Procedure

The entire housing is comprised of multiple sheets of aluminum. This allows for easy removal during maintenance or inspection. The entire system, pictured in *figure 24,* shows the housing fastened to the frame using bolts or self-tapping screws. DXF's of the panel profiles were created which are to be sent to a fabrication team for laser cutting. Each sheet will be cut from 1/8-inch aluminum in order to reduce weight and cost, while also maintaining corrosion resistance.

10.0 Bearings

For the bearing design, it was required that all bearings contain spherical and cylindrical rollers. No plain surface bearings were permitted.

Figure 25 – Ball bearing with two-bolt flange

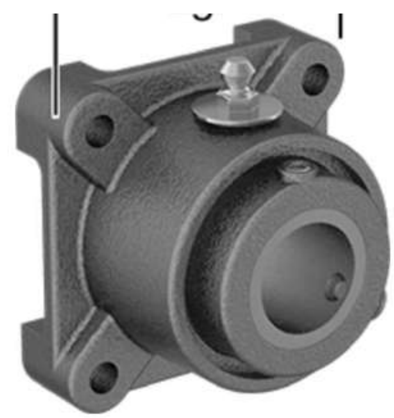

Figure 26 – Roller bearing with four-bolt flange

10.1 Specifications

The fixed bearing on each shaft was to be designed for an axial load equal to 25 % of the maximum radial load on the shaft. The **two bearings** used: Mounted Tapered Roller Bearings with Four-Bolt Flange, and Mounted Sealed Ball Bearings with Two-Bolt Flange, with Cast Iron Housing, and set screws. These bearings were used for the following reasons: Tapered Roller Bearings: rollers in these bearings support large shafts at high static loads. The shafts speeds are approximately 10rpm – 5rpm. (Low speed/high load); Ball Bearings:

rollers in these bearings support smaller shafts at lower static loads. For mounting, the four-bolts are used for better support of higher shaft loads and the two-bolts are used for support of lower shaft loads.

10.2 Bearing End caps

Specifications for the bearing end caps, shown in Figure 33, include that they must be used to locate the bearings axially in the housing, and that the dimensions be modified to suit the design as required [1, p. 10]. The bearing end caps not only locate the bearings, but also compress the housing seals to the proper operational width, allowing them to function as intended.

Figure 27 – Bearing end cap

Protection was taken into consideration and the following measures were taken seals to block out dust and contaminants and Cast-Iron Housing for corrosion resistance and durability.

11.0 Seals

11.1 Specifications

Requirements for the seals included that they must be provided where the input and output shafts protrude through the wall of the housing. The seals are required to act in conjunction with bearing caps to resist leaking of oil out of the gearbox, as well as contaminants from entering.

11.2 Procedure

Selection of seals from SKF Canada was primarily based upon the diameter of the shaft that required the seal. One seal was needed for the input shaft, and one for the output shaft. V-ring type seals, shown in *figure 28*, were used, as they are simple, and

Figure 28 – V-ring Seals

fit directly over a rotating shaft while providing axial sealing against a stationary counter face.

12.0 Bolts and Fasteners

12.1 Specifications

The bolts used for this design were the **Medium-Strength Grade 5 Steel Hex Head Screws** (Zinc-flake-coated steel): made from Grade 5 steel, these screws are suitable for fastening most machinery and equipment. To maintain corrosion resistance the following fasteners were used: **Medium-Strength Grade 5 Steel Hex Nut** (Zinc-flake-coated) **General Purpose Washers** (Zinc yellow-chromate). Fasteners are required to join the housing components together; however, no detailed calculations were required.

12.2 Procedure

Fasteners were added to the housing assembly to join components together that may need to come apart again, whether for replacement of parts or maintenance. All bolts are used with flat and locking washers to ensure adequate function. Locking washers are used to keep components from loosening due to vibration during operation. All fastening components are listed in the Bill of Materials (BOM).

Figure 29 – Bolts, washers, nuts

13.0 Sensors

13.1 Specifications

Incorporating sensors in the machine is essential to enhance its performance and ensure safety. Sensors play a crucial role in modern machinery, providing real-time data, automating processes, and improving overall efficiency. For this machine, two distinct sensors will be implemented, each serving a unique function.

13.2 Procedure

The hinge actuated safety switch is designed to ensure the operator's safety. This sensor will be installed on the hopper and the lid, connecting them. The hinge actuated safety switch operates by shutting down the entire circuit, stopping the drums and all other components, if the lid is opened more than 4 degrees. This safety measure prevents the machine from running when a body part may be close to the drums, protecting the operator from potential harm. This sensor is a commercially available component sold by McMaster (*figure 30*).

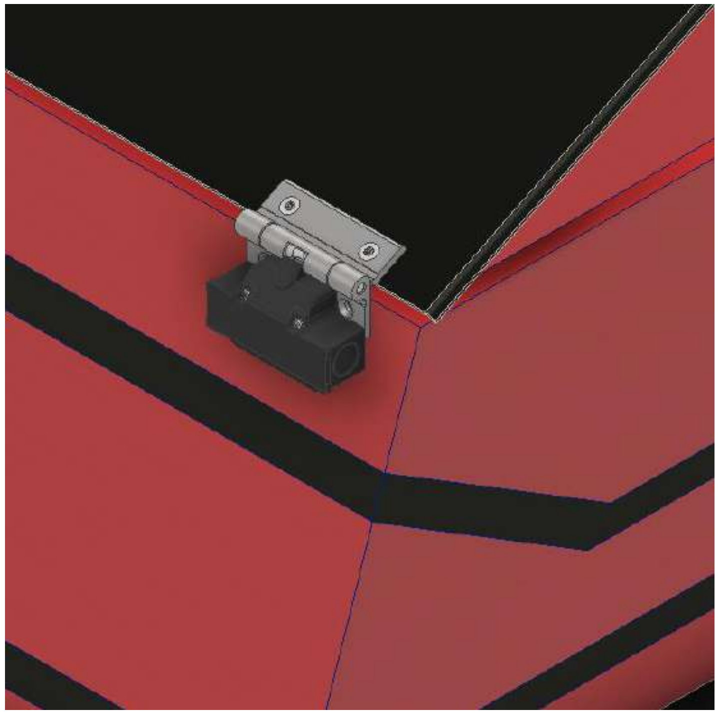

Figure 30 – Safety sensor

Another sensor will be used to count the cans. This sensor will also be a purchased component (*figure 31*) and will utilize motion sensing technology. Two primary types of sensors were considered for this purpose: impact sensors and motion sensors. The motion sensor was chosen because of its improved accuracy in counting lightweight cans, as the impact sensor occasionally provided inaccurate results. Additionally, the motion sensor is a more cost-effective option. This sensor will be positioned at the end of the conveyor, right before the crushed cans enter the recycling bin, to accurately count the processed cans.

Figure 31 – Motion sensor

14.0 Electrical Components

The electrical system of the can crusher device comprises various components such as wires, PLC, electrical wiring diagrams, and logic ladder diagrams. These elements ensure efficient communication and control of the buttons, sensors, and motor.

14.1 PLC Specifications

The main controller for the can crusher is the Siemens LOGO! Expansion module (6ED1055-1FB00-0BA2), which is responsible for connecting and coordinating the buttons, sensor, and motor (*figure 32*). It was chosen for its compact size, the availability of 8 digital inputs (sufficient for all the components), 4 digital outputs capable of handling 240 volts (the motor's required voltage), compatibility with the environment's temperature (maximum of 55°C), and the lack of a display screen, which is not necessary for an internal machine component.

Figure 32 – PLC

14.2 Wiring Procedure

The wiring for the can crusher will utilize 16 AWG single-strand copper wire, which can handle up to 300 volts and operate within the environmental temperature range. This wire ensures proper power delivery to all electrical components while maintaining safety and durability.

The electrical system features two separate wiring diagrams due to the differing voltage requirements of the motor and other components. The first diagram includes the on/off button, kill switch, and both sensors, operating at 120 volts. The second diagram is dedicated solely to the motor, which operates at 240 volts (*figure 33*).

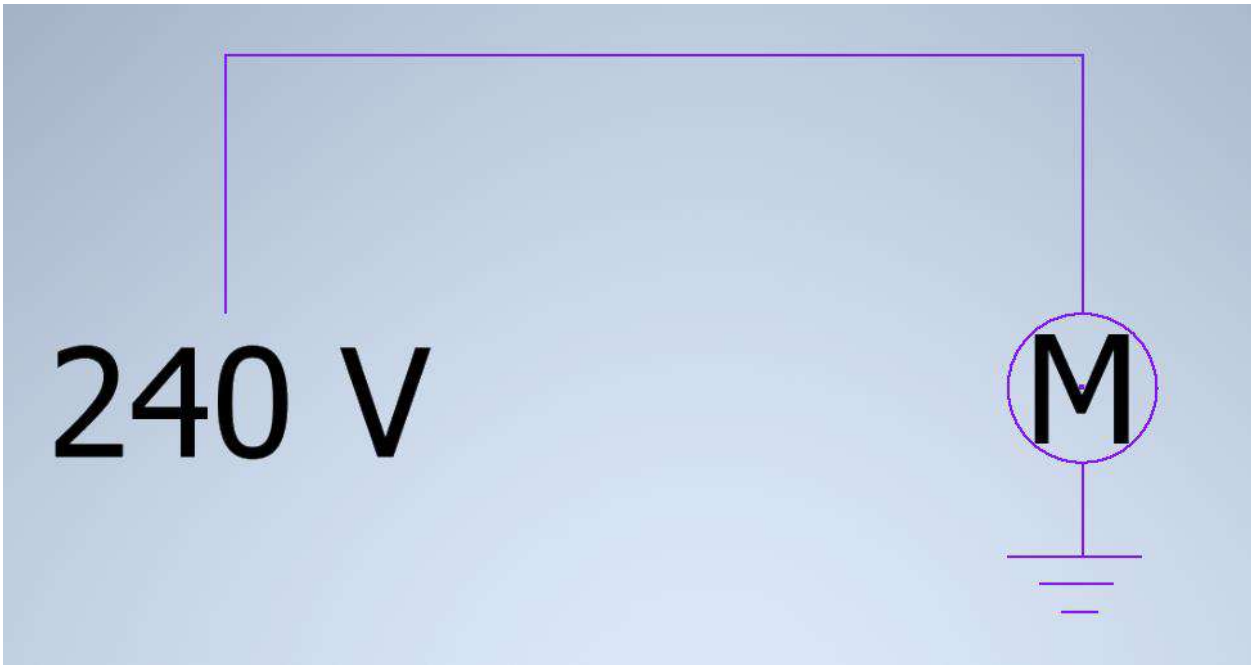

Figure 33 – Motor Electrical Circuit Diagram

14.3 Ladder Logic Diagram

A ladder logic diagram provides a visual representation of the system's control logic. On the second line of the diagram, if the sensor counting the cans does not detect any cans for 2 minutes, the machine will automatically turn off as a safety feature. The third line of the diagram indicates that if the lid is not fully closed, the machine will also turn off to ensure operator safety (*figure 34*).

Figure 34 – Ladder logic Diagram

15.0 Materials

15.1 Specifications

Throughout the design process, careful consideration was taken for each component during material selection. The recycling system must be able to withstand liquids and acidic beverages for its entire lifecycle. With that in mind, there are two materials which held the required corrosion resistance. Aluminum is a great material where high strength is not needed which provides the additional benefits of being lightweight and cost efficient for production. Stainless steel is another option and can be used for components which require high strength. Problems arise when welding is needed for certain components as both aluminum and stainless steel require specialized welding processes, increasing the cost of the system.

15.2 Frame

Despite being the original choice for the frame material, stainless steel tubing is significantly more expensive than carbon steel, prompting a shift in material selection. The final design holds a rigid frame used entirely of mild carbon steel. After the frame is fabricated, a deep penetrating, corrosion resistant paint will be applied.

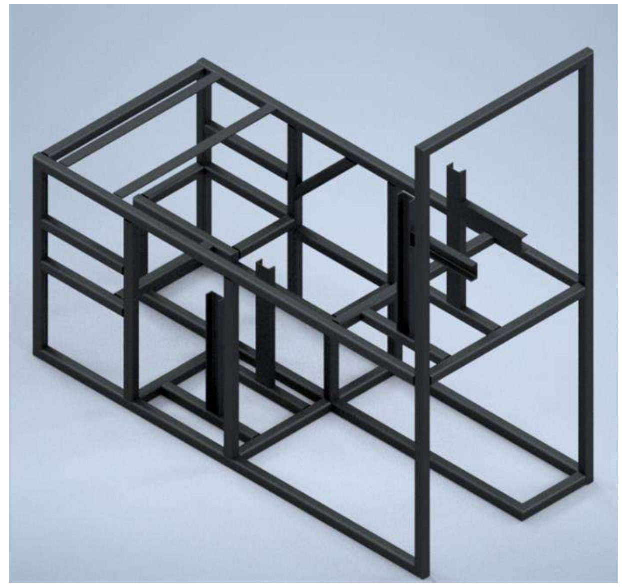

Figure 35 – Overall frame

15.3 Hopper & Panelling

The choice of aluminum as the material for both the hopper and paneling was made after careful consideration of various factors, such as strength-to-weight ratio, corrosion resistance, and cost-effectiveness. While material strength is not the primary concern, aluminum's durability and lightweight properties make it an excellent choice. For the hopper, we will be using 1/2-inch aluminum sheet, which will be laser-cut and then welded together. This will result in a sturdy and reliable hopper. For the paneling, we will be using 1/8-inch aluminum sheet, which will be laser-cut to the desired profiles and fastened securely to the frame using bolts. This manufacturing process ensures that we can reduce the overall weight and cost of the product while maintaining excellent corrosion resistance properties.

Figure 36 – Hopper isometric view

Figure 37 – Side panels

15.4 Crushing Drums

The crushing drums are a critical component of the can crushing system. After careful consideration of various materials, we chose 316 stainless steels for its superior strength and corrosion resistance properties. These drums are precision-machined to meet the specific requirements of the can crushing process and are designed to withstand the constant crushing of not only cans but any other materials that may be accidentally fed through the system. The use of 316 stainless steel ensures that the drums can withstand the harsh operating conditions and continue to operate efficiently for an extended period.

16.0 Cost Analysis

16.1 Specifications

A detailed engineering Bill of Materials (BOM) was created to determine the cost of the entire system. The BOM, shown below in *figure 38,* lists every individual component within the design and the quantity used. The BOM comprises several essential columns, which include the part number (Part No.), Description, Unit of Measure, quantity (Qty.), Unit Cost, Total Cost, and reference (Ref). The Part No. column provides a unique identifier for each component. Description column offers a brief overview of each component's purpose and functionality, helping to ensure that the correct components are used during assembly. The Unit of Measure column specifies the unit of measurement for each component, such as pieces, meters, or pounds. The Qty. column lists the quantity of each component required to build the system, while the Unit Cost column specifies the cost per unit of each component. The Total Cost column calculates the total cost of each component, obtained by multiplying the quantity by the unit cost. Finally, the Ref column provides a reference for each component, including the source from which it was obtained and its corresponding price. This information is essential for budgeting and cost management purposes, as it allows for accurate tracking of the total cost of each component and the overall cost of the system.

16.2 Tables

Engineering Bill of Materials						
Part No.	Description	Unit of Measure	Qty.	Unit Cost	Total Cost	Ref
F3S45S200-WB05TAVEN	Brother Gearmotor F3 High Torque AC Gear Motor	Each	1	$ 1,553.00	$ 1,553.00	Oriental Motor
100621	100BTL11H-1615, Roller Chain Sprocket, Main Shaft	Each	1	$ 169.22	$ 169.22	McMaster Carr, Dodge PT
100632	100BTL22H-2517, Roller Chain Sprocket, Drum Mounted	Each	1	$ 282.27	$ 282.27	McMaster Carr, Dodge PT
6663K207	Wear-Resistant Wide-Hub Idler Sprockets for ANSI Roller Chain	Each	1	$ 258.53	$ 258.53	McMaster Carr
1498N14	Mounted Roller Bearings with Four-Bolt Flange	Each	3	$ 511.00	$ 1,533.00	McMaster Carr
6233K38	Spring Chain Tensioner	Each	1	$ 220.35	$ 220.35	McMaster Carr
1495N19	Base Mounted Roller Bearings	Each	1	$ 662.87	$ 662.87	McMaster Carr
6261K178	ANSI Roller Chain	Feet	8	$ 24.82	$ 198.56	McMaster Carr
6261K181	ANSI Roller Chain Connecting Link	Each	1	$ 5.31	$ 5.31	McMaster Carr
-	Pu Cleated Conveyor Belt, 200 - 1200 N, Belt Thickness: 7 - 20 mm	Each	1	$ 1,100.00	$ 1,100.00	India Mart
6ED1055-1FB00-OBA2	Siemens PLC	Each	1	$ 100.62	$ 100.62	PLC City
71008	Single Phase On/Off Switch	Each	1	$ 14.99	$ 14.99	Powertech
16UL1007	16 AWG Stranded Wire	per 100ft	1	$ 22.42	$ 22.42	Remington Industries
7480T12	Push Button Switch	Each	1	$ 41.73	$ 41.73	McMaster Carr
7777K48	Hinge Safety Switch	Each	1	$ 244.45	$ 244.45	McMaster Carr
T9F800311RD	Recycling Bin	Each	1	$ 310.95	$ 310.95	Global Industrial
91257A723	1/2"-13 Grade 8 Steel Hex Head Screw	per 10	1	$ 17.32	$ 17.32	McMaster Carr
90580A315	1/2"-13 High Stength Steel Hex Nut	per 25	1	$ 12.88	$ 12.88	McMaster Carr
90107A033	1/2" General Purpose Washer	Per 25	1	$ 10.31	$ 10.31	McMaster Carr
92375A550	7/8"-1" Hairpin Cotter Pin	Per 5	1	$ 16.82	$ 16.82	McMaster Carr
1498N14	2" 4 Bolt Flange Mounted Roller Bearing	Each	4	$ 511.00	$ 2,044.00	McMaster Carr
5968K73	3/4" 2 bolt Flange Mounted Roller Bearing	Each	1	$ 62.35	$ 62.35	McMaster Carr
-	2x2x1/4 in Square Tubing	Per ft	110	$ 22.50	$ 2,475.00	Princess Auto
-	1/8" Aluminum Sheet	Per Square ft	100	$ 15.00	$ 1,500.00	Princess Auto
CRS-S23-A1-CRS Assembly	Full Assembly	Each	1	-	$ 12,856.95	

Figure 38 – BOM table

CHAIN DRIVE DESIGN				
Initial Input Data:				REF
Application:	Can Crusher			
Drive/Type:	Electric Motor			
Driven Machine:	Crusher			
Power Input:	0.75			
Service Factor:	1		Class A fairly uniform running load	687
Input Speed:	12		rpm	
Desired Output Speed:	6		rpm	
Computed Data:				
Design Power:	0.75			
Speed Ratio:	2			
Design Decisions - Chain Type and Teeth Numbers				
Number of Strands	1	1		
Strand Factor	1	1		688
Required power per strand	0.75	0.75	hp	
Selected power per strand	0.81	1.10		
Chain Number	100	120		
Chain Pitch	1.25	1.5	in	
Number of teeth - Driver sprocket	11	9		
Lubcrication Type:	A	B		
Computed no. Of teeth - Driven sprocket	22	18		
Enter: Chosen number of teeth	22	18		674
Resulting OD of Driven Sprocket	9.44	9.407		
Computed Data:				
Actual Output Speed	6	6		
Pitch diameter-Driver sprocket	4.438	4.356	in	702
Pitch diameter-Driven sprocket	8.784	8.639	in	702

Figure 39 – Load specifications

17.0 Operator Safety

A primary consideration in the design of the can crusher machine is ensuring the safety of its operators. Various design elements have been implemented with the sole purpose of enhancing operator safety.

One such design choice is the incorporation of a sensor on the hopper. This sensor's primary function is to ensure that the machine is fully turned off if the lid is even slightly open. This automatic shutdown feature is designed to prevent the operator from coming into close contact with the moving drum or other hazardous components when opening the lid to insert more cans.

Additionally, it is essential that access to the machine is limited to authorized individuals, excluding minors or those unable to lift cans to a height of about 4 feet. The operator must be physically strong enough to perform this task, and anyone who cannot meet this requirement will not be permitted to operate the machine.

Training employees to use the machine properly is another critical aspect of operator safety. Basic demonstrations of proper form and strategies for safe device operation will be provided. These may include lifting techniques and guidelines for ensuring that the cans being placed inside the hopper are not too heavy.

To further safeguard the operator, certain rules must be followed. For instance, if someone needs to access the machine's interior for any reason, such as to unjam it, diagnose an issue, or fix a problem, the machine must be unplugged and turned off. This precaution minimizes the risk of injury from moving parts while the individual is inside the machine.

While not required, it is recommended that operators use personal protective equipment to reduce the likelihood of injury. Gloves are advised to prevent cuts from falling cans and to protect hands from the liquids inside the cans, ensuring that grip is not weakened. Additionally, wearing a long-sleeved shirt made of a material that is resistant to cuts is recommended for added protection from the cans and other materials that may be placed inside the machine.

18.0 Maintenance

A crucial part of the machine is the overall maintenance of the mechanism used for a longer life span.

18.1 Lubrication

This process was also researched and according to our findings, we have concluded that the best options in the market for lubrication is grease. Grease is better lasting and will definitely be beneficial for the gears and chains used in our design.

18.2 Procedure

Grease/lubrication application was made easy for the operator as they are able to access the inside of the machine by unhooking the side panels for quicker access. Although this process will not be as often, but it was still taken into consideration in the case of any issues that may arise in the future.

19.0 Improvements

The current design of the device, as analyzed through calculations and FEM analysis, has proven to be functional and effective in sorting and crushing aluminum cans. However, there are always opportunities for improvement to optimize its performance, efficiency, and cost-effectiveness. Potential improvements include adding the capability to sort and store plastic bottles, incorporating an internal light to identify issues, reducing the overall size of the machine, and finding ways to decrease the cost.

One of the ways our design can be improved is by incorporating the ability to sort and store plastic bottles alongside crushed cans. The sorting process can be achieved through various methods, such as installing a scanner in the middle of the conveyor to determine if the object is made from aluminum. If the object is aluminum, the path at the end of the conveyor will switch, leading to two separate recycling bins at the end of the machine, each storing either aluminum or plastic. A unique counter can be used to keep track of the number of items in each bin, ultimately increasing revenue generation and recycling efficiency.

Another potential improvement is the installation of a light within the machine. This light would flash red to indicate an issue, such as a jam, or change colors to signal when the hopper is empty and requires more cans. It could also change colors to show when the recycling bins are full and need to be emptied. This system would enhance the operator's ability to monitor and maintain the machine effectively.

The current design has some drawbacks, mainly regarding the size and cost of the machine. To address these concerns, several solutions can be implemented. One option is to reduce the size of the conveyor, shortening it from six feet to three feet and adjusting the angle accordingly. This change would save costs by reducing the required frame and panel materials. Another approach to reducing costs is to explore more affordable options for specific components and materials, without compromising the overall functionality and durability of the machine. By considering these future improvements, the machine's effectiveness, efficiency, and cost-effectiveness can be further enhanced, ultimately contributing to increased recycling rates and environmental sustainability.

20.0 Conclusion

The recycling system was designed as practical as possible, with a compact design that is easily assessable. The overall dimension of the system is made to be accessible to anyone and everyone with the hazard safety considered. The design is capable of crushing all recyclable beverage materials, and sorting. This was an interesting project to work on, and we are confident enough to say that it is ready for the market.

References

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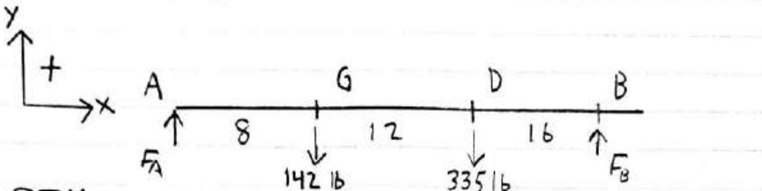
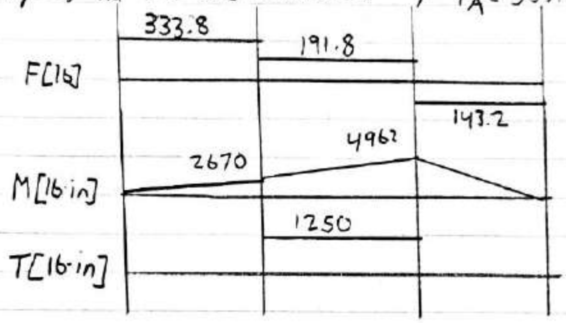
Appendix A: Calculations

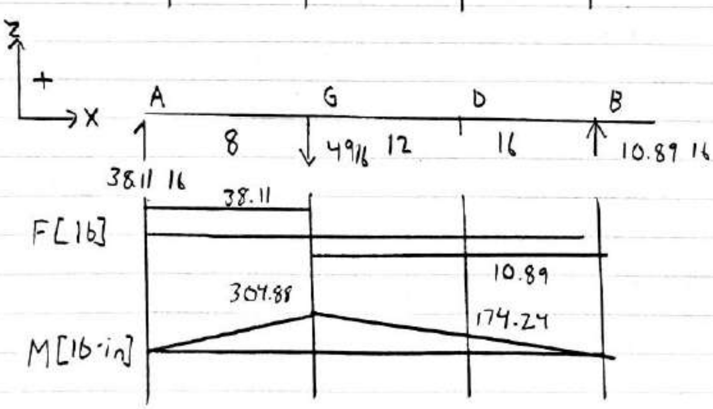
Drum Shaft



$\circlearrowleft + \sum M_A = 0, \ (36)F_B - 142(8) - 12(335) = 0 \quad , \quad F_B = 143.2\text{ lb} \uparrow$

$\uparrow \sum F_y = 0, \ F_A - 142 - 335 + 143.2 = 0 \quad , \quad F_A = 333.8\text{ lb} \uparrow$





Using 304 Stainless Steel

$S_y = 40$ kPsi $\quad S_u = 82.4$ kPsi

$S_e' = 0.5(82.4) = 41.2$ kPsi

$\left.\begin{array}{l} a = 2 \text{ kpsi} \\ b = -0.217 \end{array}\right\}$ Ref Table 6-2

$k_a = 2(82.4)^{-0.217} = 0.7678$

$k_b = 1$
$k_c = 1$
$k_d = 1$
$k_e = 0.753$ at 99.9% reliability

$S_e = k_a k_b k_c k_d k_e S_e'$

$S_e = (0.7678)(1)(1)(1)(0.753)(41.2) = 23.82$ kPsi

At Shoulder
$k_f = 2.7 \quad k_{fs} = 2.2$

At Keyseat
$k_f = 2.14 \quad k_{fs} = 3.0$

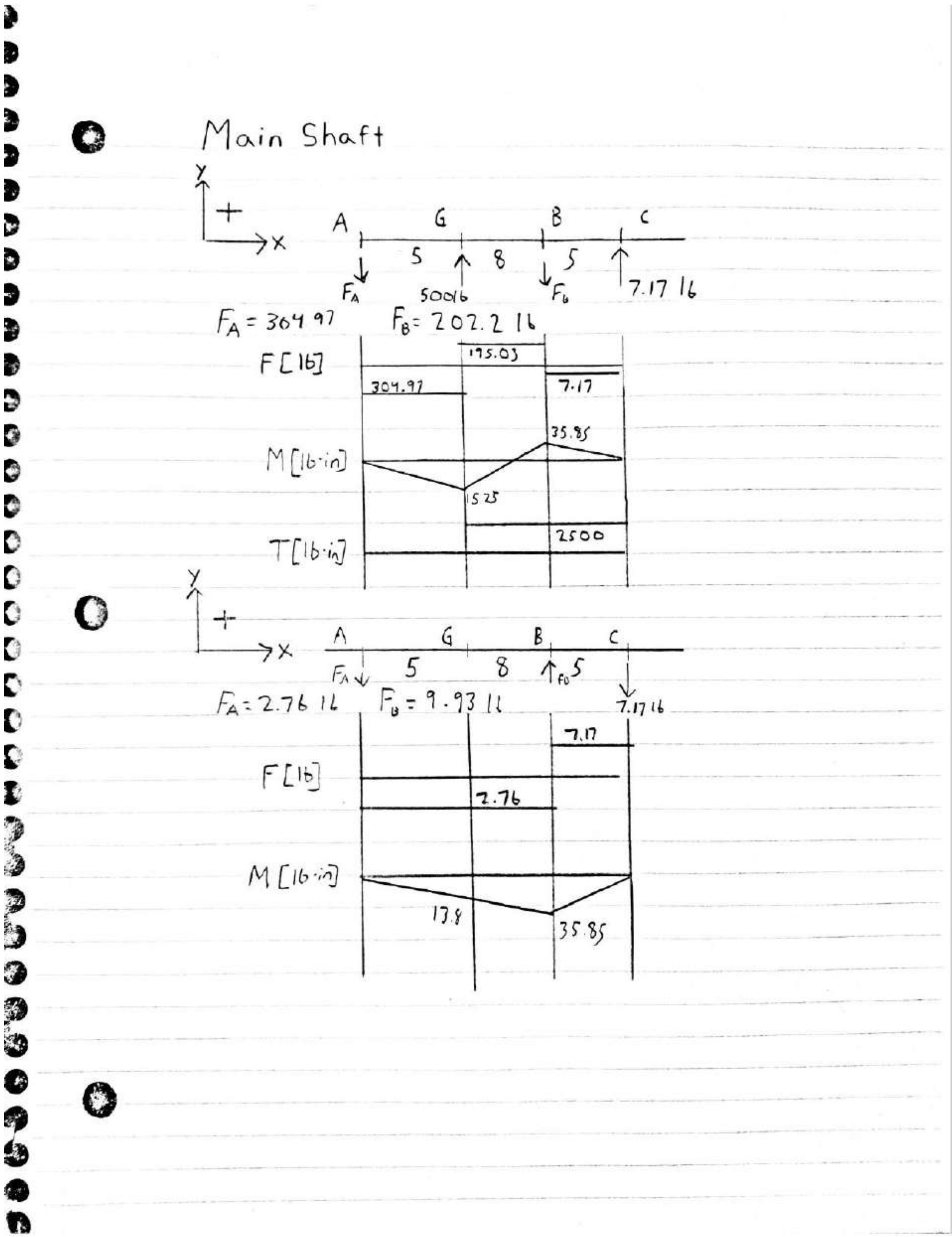
At Shoulder at Point D
$M = 4965$ lb·in $\quad T = 1250$ lb·in

$$A = \sqrt{4(K_f M_a)^2} = \sqrt{4(2.7(4965))^2} = 26811$$
$$B = \sqrt{3(K_{fs} T_m)^2} = \sqrt{3(2.2(1250))^2} = 4763$$

$$d = \left[\frac{16(3)}{\pi}\left(\frac{26811}{23.82\times10^3} + \frac{4763}{82.4\times10^3}\right)\right]^{1/3} = 2.08 \text{ in}$$

At keyseat at Point D
$A = 21250 \quad B = 6495$

$d = 1.81$ in


Main Shaft
y
+
x
A
G
B
C
5
8
5
F_A
500 lb
F_b
7.17 lb
F_A = 304.97
F_B = 202.2 lb
F [lb]
175.03
304.97
7.17
M [lb·in]
35.85
1525
T [lb·in]
2500
y
+
x
A
G
B
C
F_A
5
8
F_b
5
F_A = 2.76 lb
F_B = 9.93 lb
7.17 lb
7.17
F [lb]
2.76
M [lb·in]
13.8
35.85

Se value for the main shaft is going to be the same as the drum shaft

K_f & K_{fs} is the same as the drum

Weakess point occurs at point G

At Shoulder

$A=\sqrt{4(K_f M_a)^2} = \sqrt{4(2.7(1525))^2} = 8235$

$B=\sqrt{3(2.2(2500))^2} = 9526$

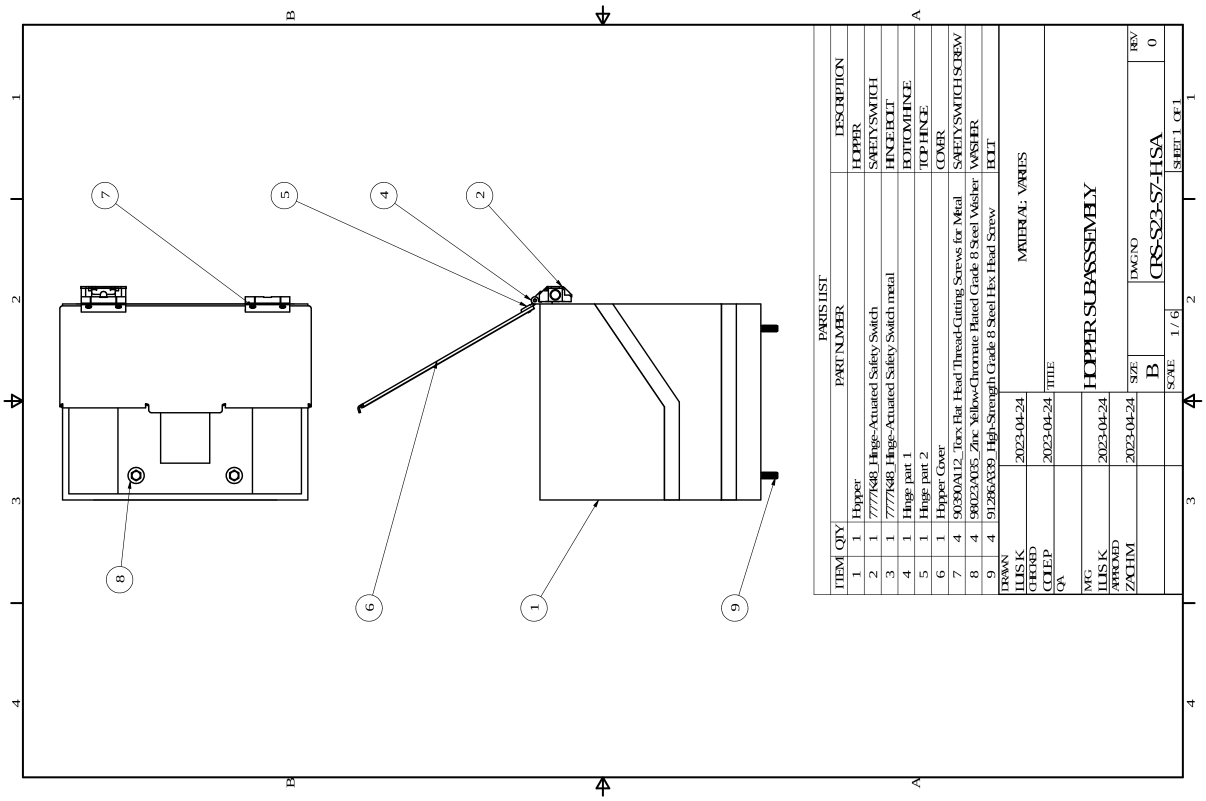
$d = 1.92$ in

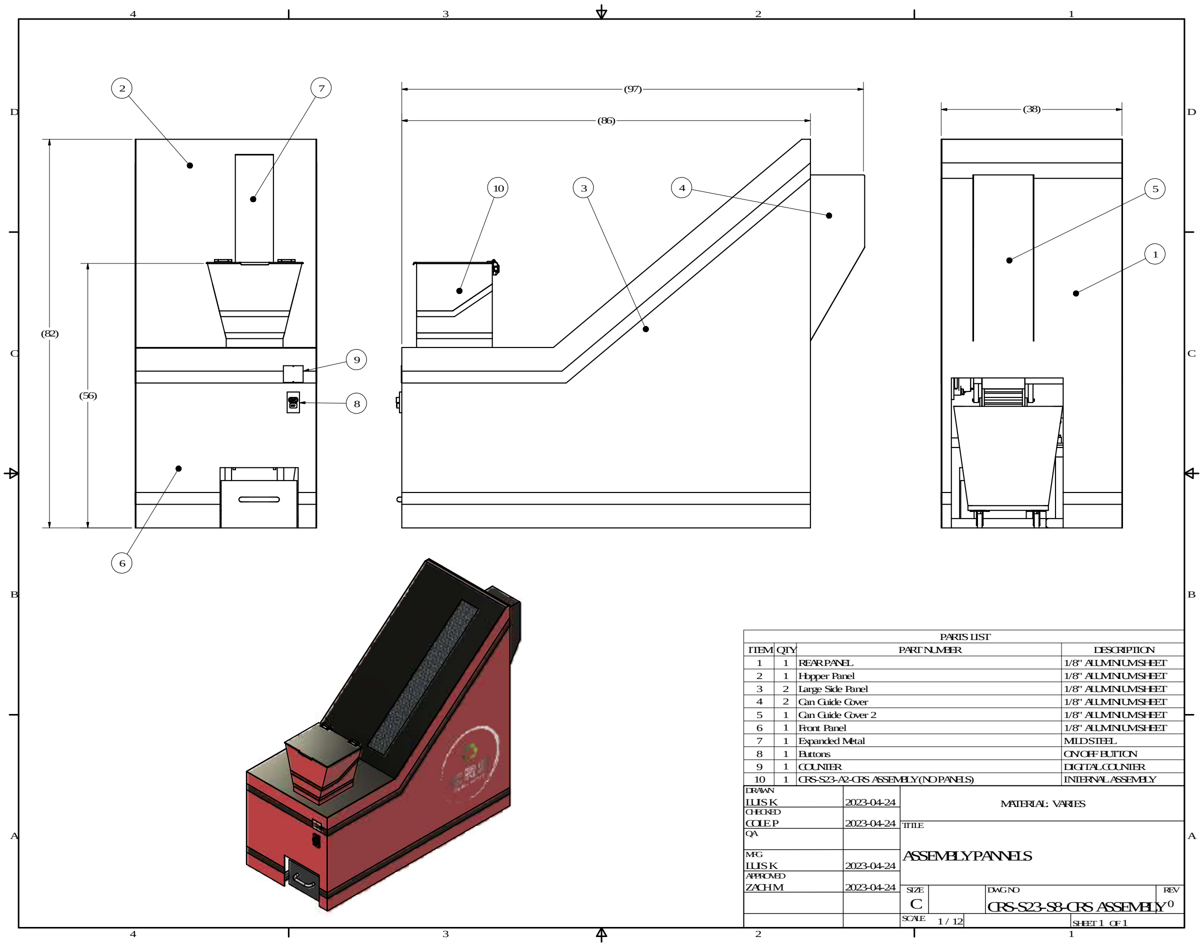
At keyseat

$A = 6527$ $B = 12990$

$d = 1.98$ in

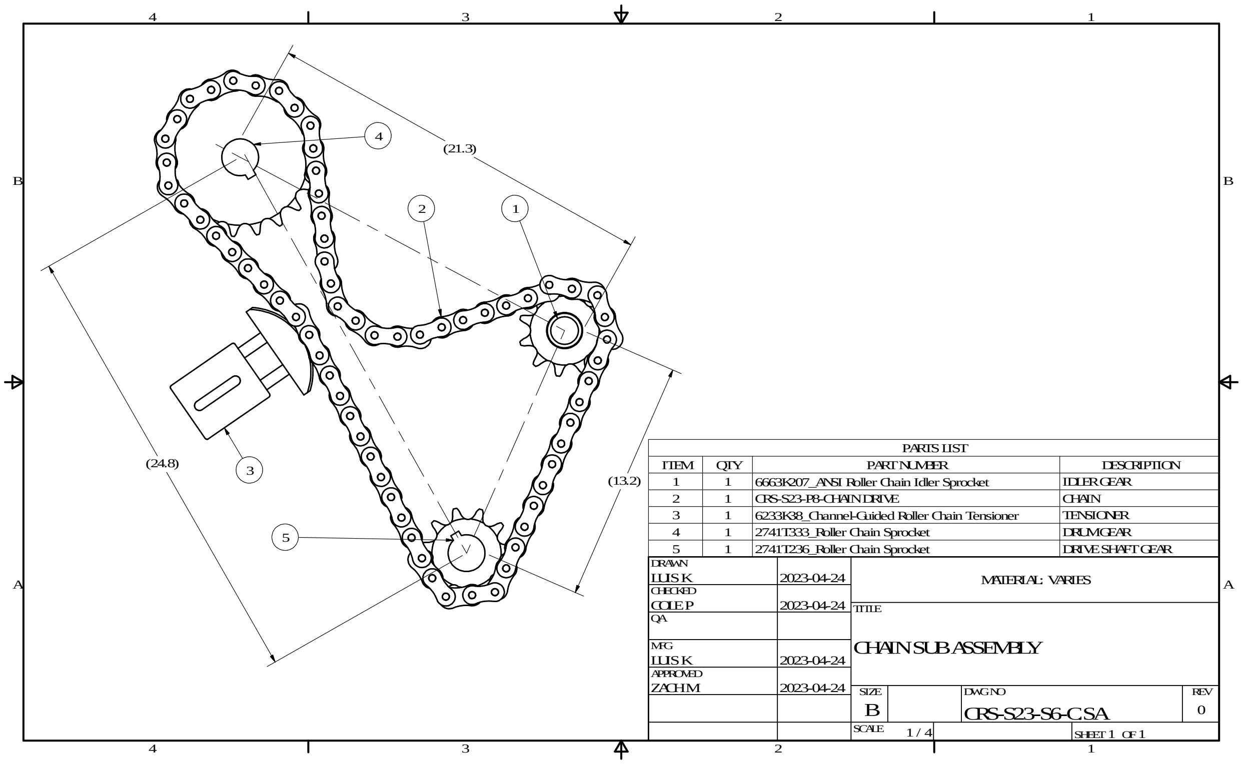
Appendix B: Drawings

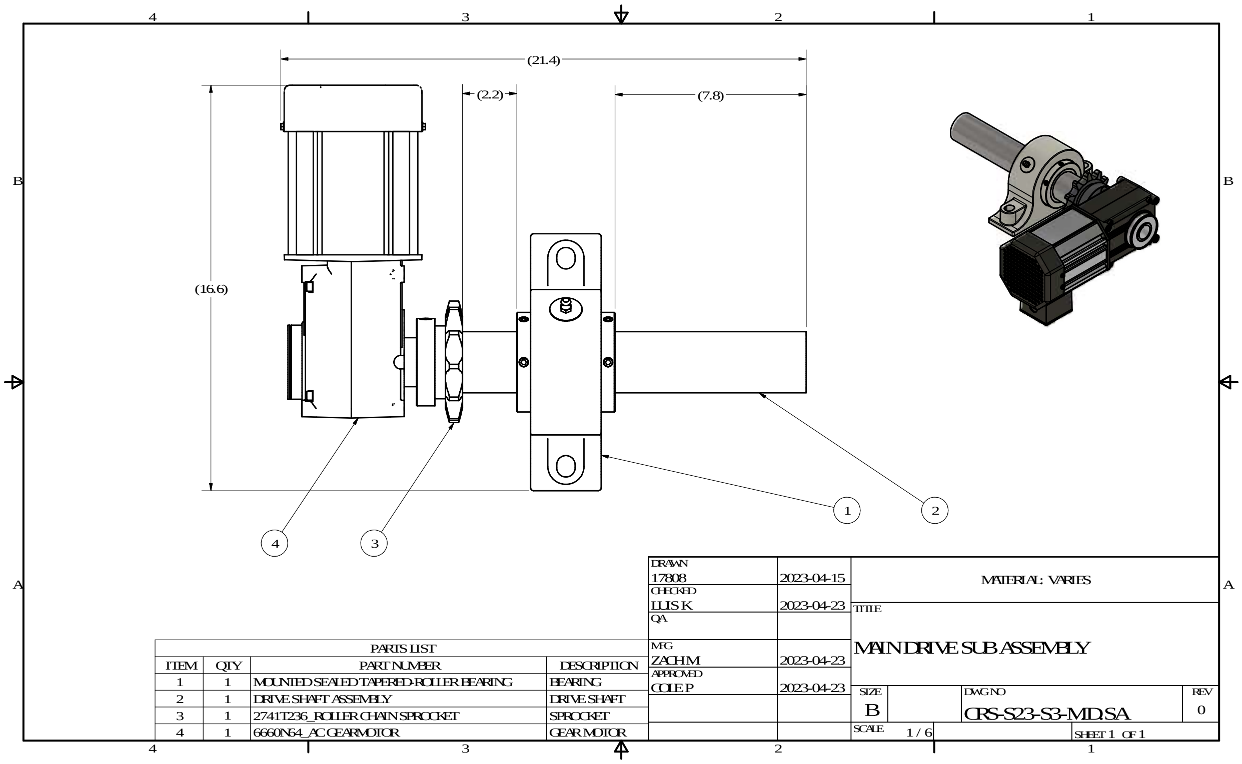




PARTS LIST

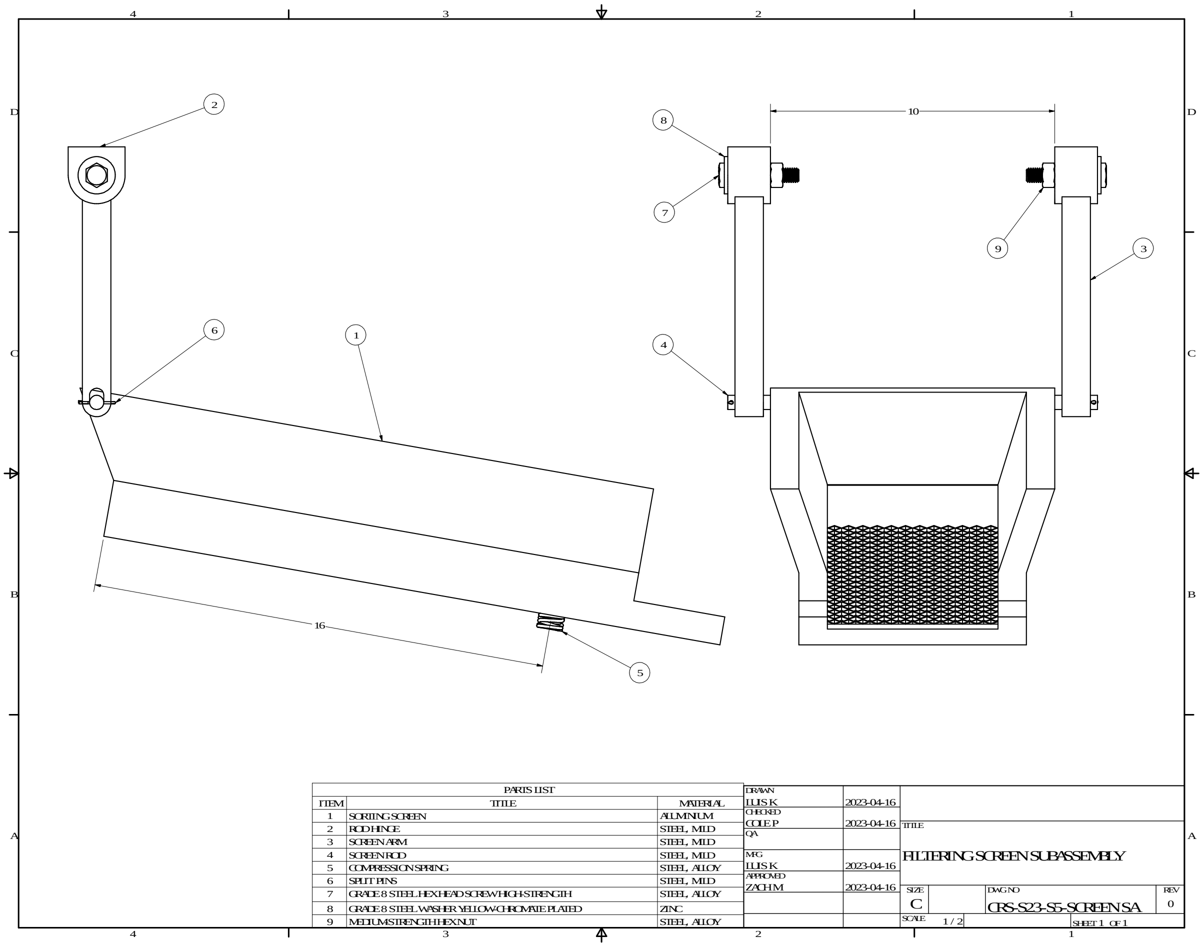
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	REAR PANEL	1/8" ALUMINIUM SHEET
2	1	Hopper Panel	1/8" ALUMINIUM SHEET
3	2	Large Side Panel	1/8" ALUMINIUM SHEET
4	2	Can Guide Cover	1/8" ALUMINIUM SHEET
5	1	Can Guide Cover 2	1/8" ALUMINIUM SHEET
6	1	Front Panel	1/8" ALUMINIUM SHEET
7	1	Expanded Metal	MILD STEEL
8	1	Buttons	ON/OFF BUTTON
9	1	COUNTER	DIGITAL COUNTER
10	1	CRS-S23-A2-CRS ASSEMBLY (NO PANELS)	INTERNAL ASSEMBLY

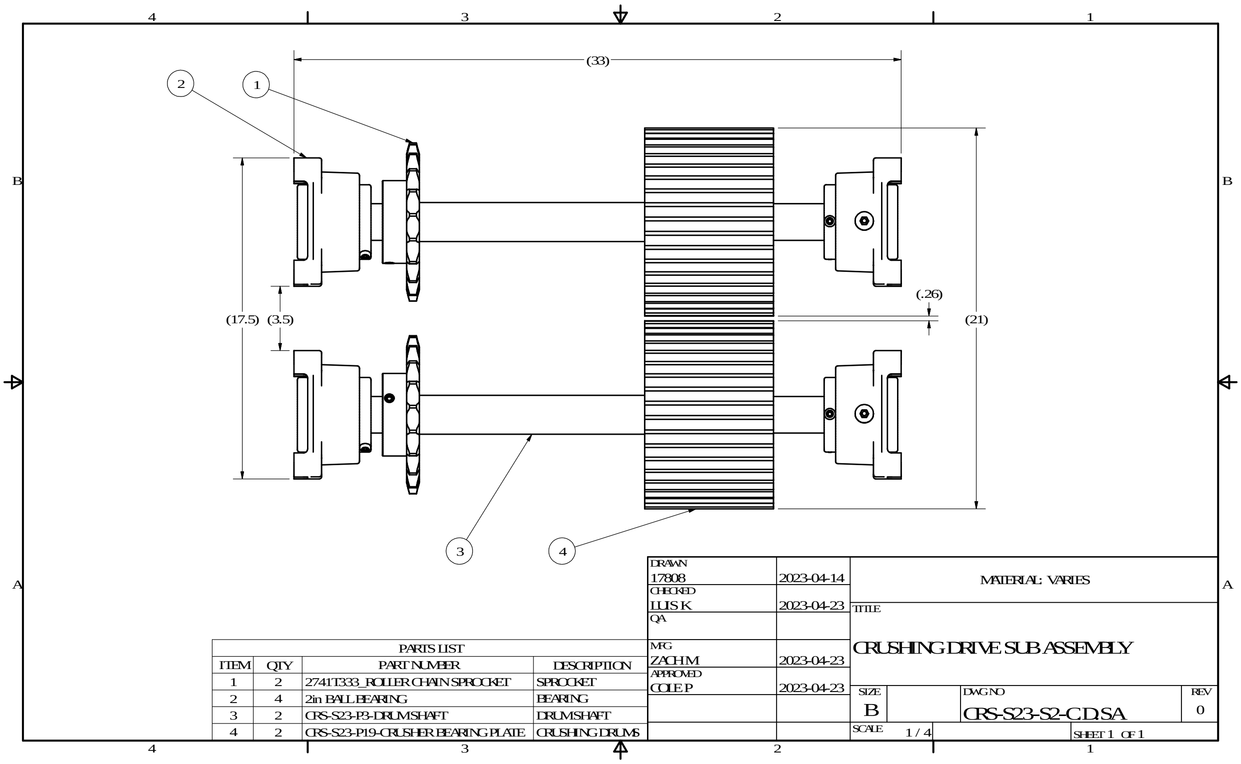

(21.3)
(24.8)
(13.2)
PARTS LIST
ITEM QTY PART NUMBER DESCRIPTION
1 1 6663K207_ANSI Roller Chain Idler Sprocket IDLER GEAR
2 1 CRS-S23-P8-CHAIN DRIVE CHAIN
3 1 6233K38_Channel-Guided Roller Chain Tensioner TENSIONER
4 1 2741T333_Roller Chain Sprocket DRUM GEAR
5 1 2741T236_Roller Chain Sprocket DRIVE SHAFT GEAR
DRAWN
ILLIS K 2023-04-24
CHECKED
COLE P 2023-04-24
QA
MFG
ILLIS K 2023-04-24
APPROVED
ZACH M 2023-04-24
MATERIAL: VARIES
TITLE
CHAIN SUB ASSEMBLY
SIZE
B
DWG NO
CRS-S23-S6-CSA
REV
0
SCALE 1 / 4
SHEET 1 OF 1



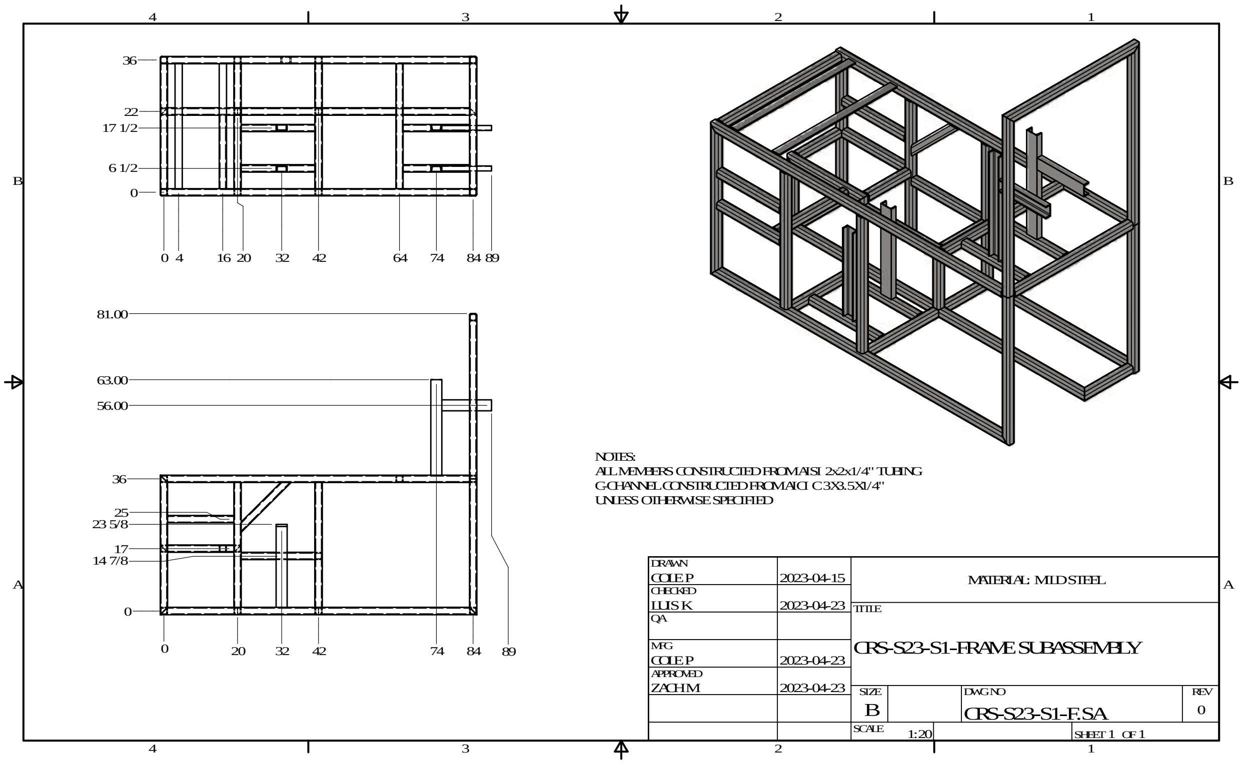
PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	MOUNTED SEALED TAPERED-ROLLER BEARING	BEARING
2	1	DRIVE SHAFT ASSEMBLY	DRIVE SHAFT
3	1	2741T236_ROLLER CHAIN SPROCKET	SPROCKET
4	1	6660N54_AC GEARMOTOR	GEAR MOTOR

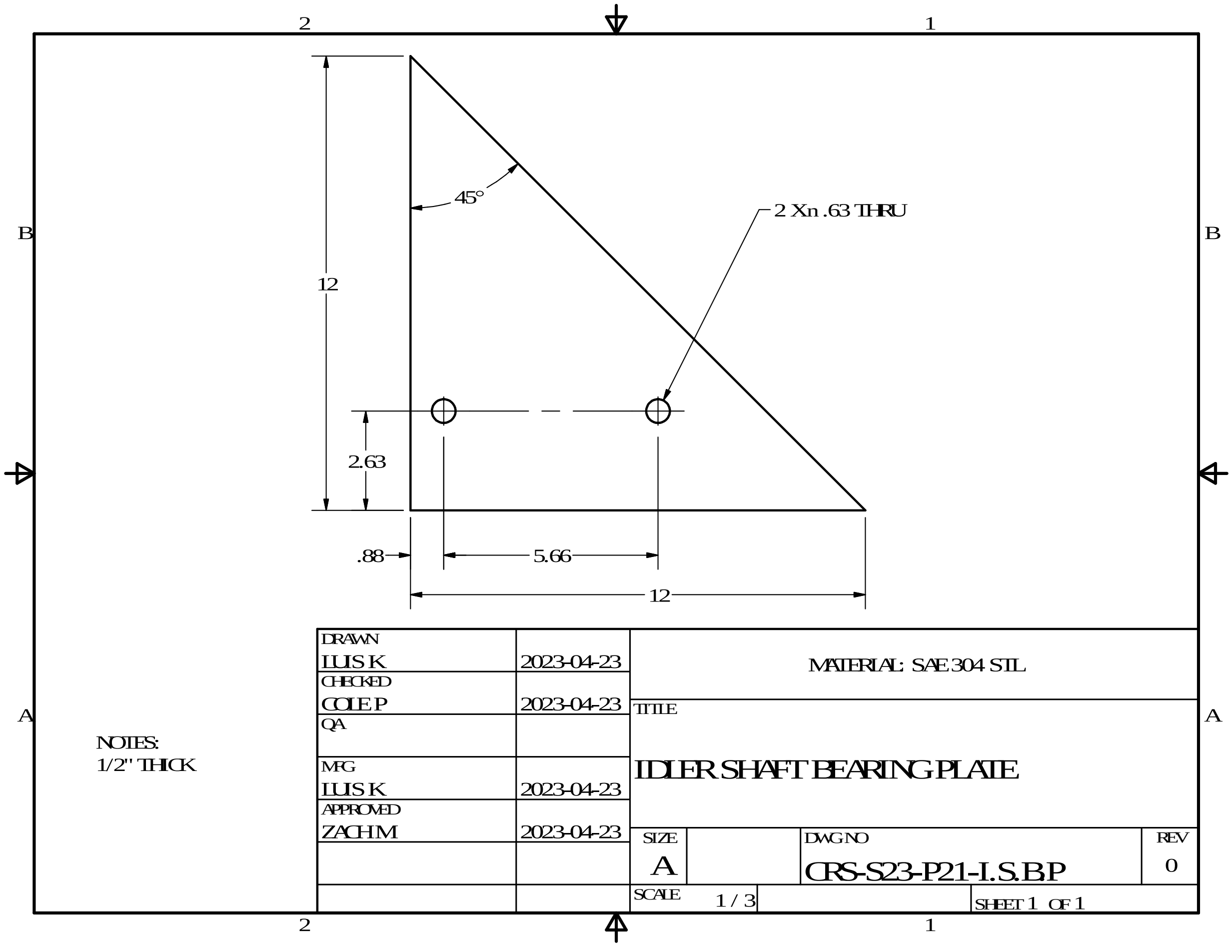
DRAWN 17808	2023-04-15	MATERIAL: VARIES
CHECKED LUIS K	2023-04-23	TITLE
QA		MAIN DRIVE SUB ASSEMBLY
MFG ZACH M	2023-04-23	
APPROVED COLE P	2023-04-23	SIZE B; DWG NO CRS-S23-S3-MD.SA; REV 0
		SCALE 1 / 6; SHEET 1 OF 1

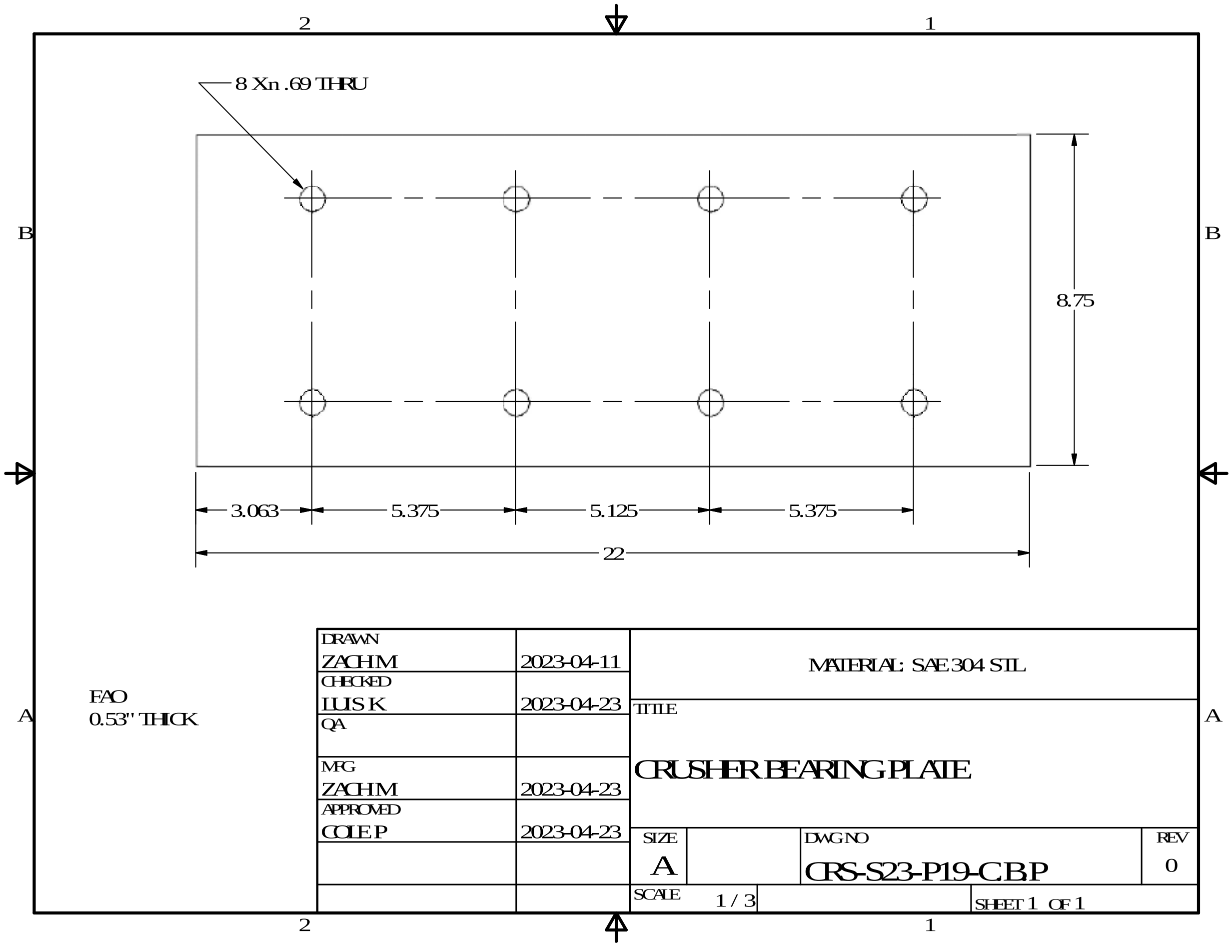

10
16
1
2
3
4
5
6
7
8
9
PARTS LIST
ITEM TITLE MATERIAL
1 SORTING SCREEN ALUMINIUM
2 ROD HINGE STEEL, MILD
3 SCREEN ARM STEEL, MILD
4 SCREEN ROD STEEL, MILD
5 COMPRESSION SPRING STEEL, ALLOY
6 SPLIT PINS STEEL, MILD
7 GRADE 8 STEEL HEX HEAD SCREW HIGH-STRENGTH STEEL, ALLOY
8 GRADE 8 STEEL WASHER YELLOW-CHROMATE PLATED ZINC
9 MEDIUM STRENGTH HEX NUT STEEL, ALLOY
DRAWN
LUIS K 2023-04-16
CHECKED
COLE P 2023-04-16
QA
MFG
LUIS K 2023-04-16
APPROVED
ZACH M 2023-04-16
TITLE
FILTERING SCREEN SUBASSEMBLY
SIZE
C
DWG NO
CRS-S23-S5-SCREEN SA
REV
0
SCALE 1 / 2
SHEET 1 OF 1

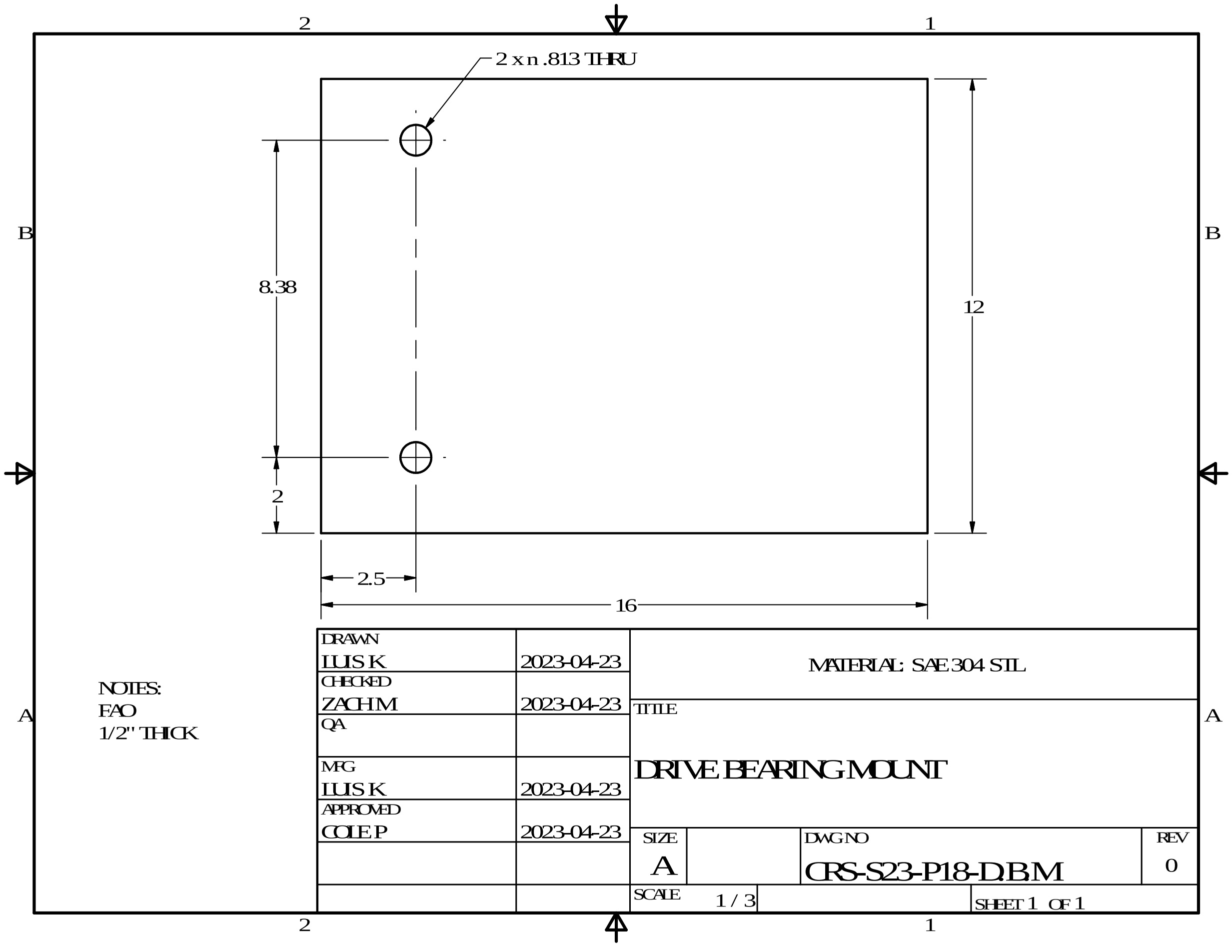


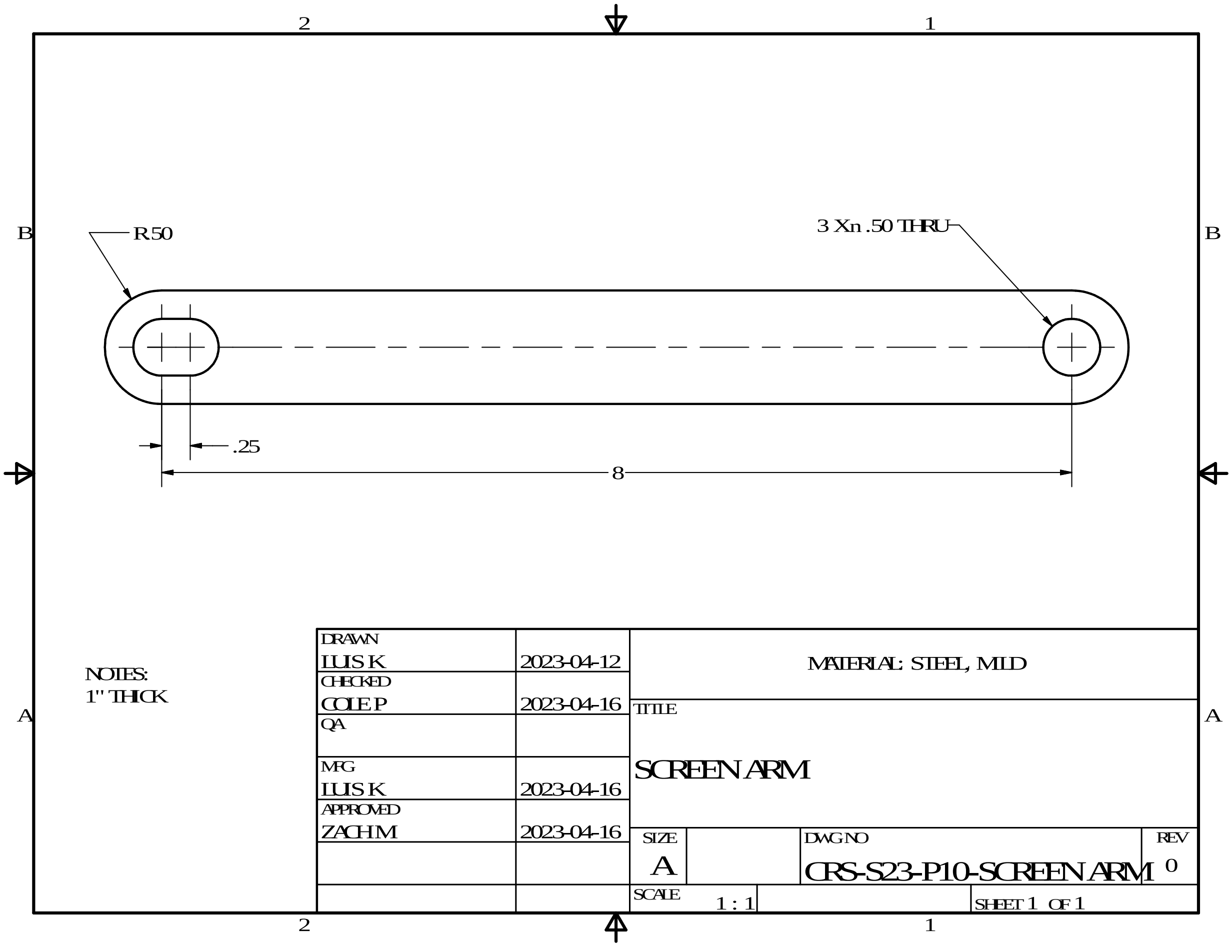
PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	2	2741T333_ROLLER CHAIN SPROCKET	SPROCKET
2	4	2in BALL BEARING	BEARING
3	2	CRS-S23-P3-DRUM SHAFT	DRUM SHAFT
4	2	CRS-S23-P19-CRUSHER BEARING PLATE	CRUSHING DRUMS

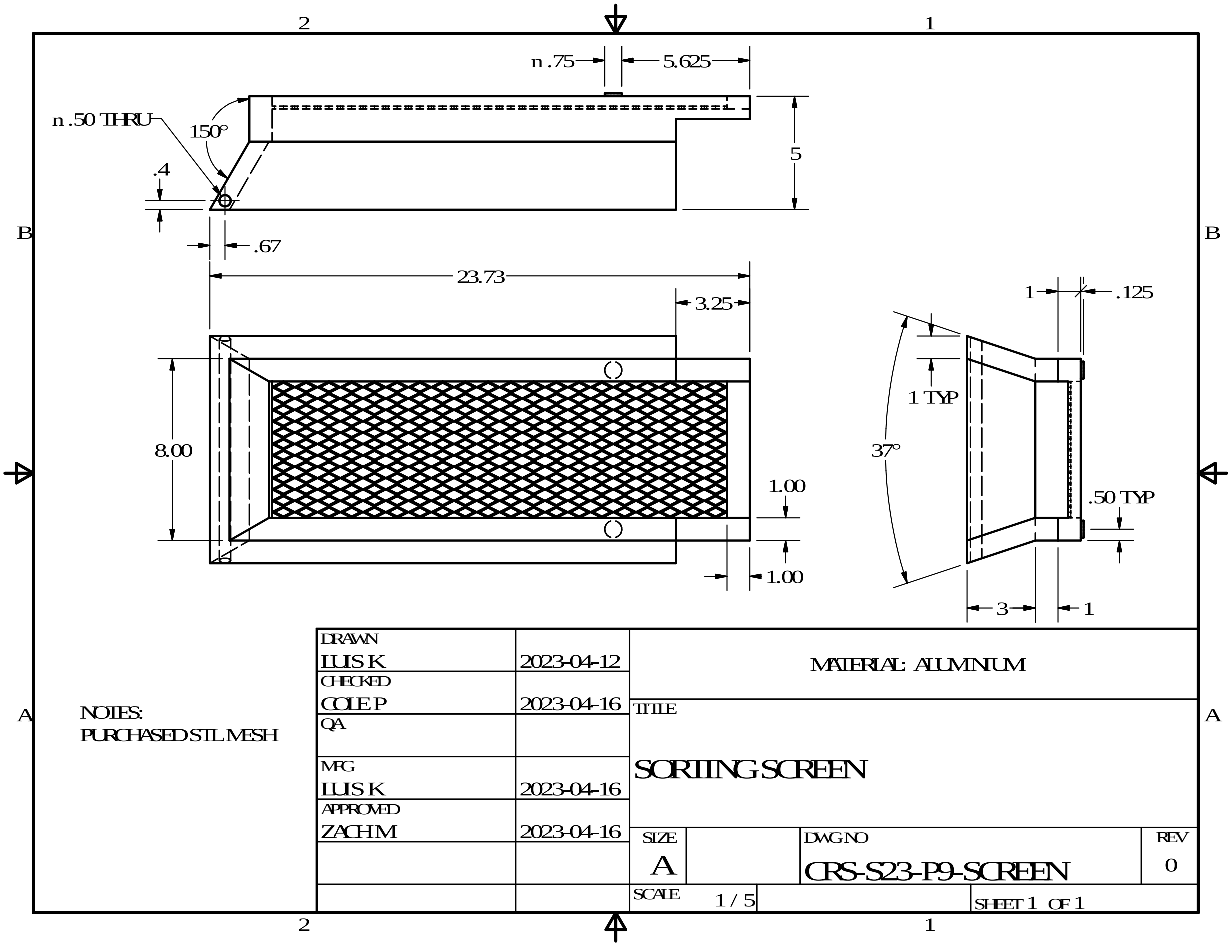

36
22
17 1/2
6 1/2
0
0 4 16 20 32 42 64 74 84 89
81.00
63.00
56.00
36
25
23 5/8
17
14 7/8
0
0 20 32 42 74 84 89
NOTES:
ALL MEMBERS CONSTRUCTED FROM AISI 2x2x1/4" TUBING
G-CHANNEL CONSTRUCTED FROM AICI C3X3.5X1/4"
UNLESS OTHERWISE SPECIFIED
DRAWN
COLE P 2023-04-15
CHECKED
LLIS K 2023-04-23
QA
MFG
COLE P 2023-04-23
APPROVED
ZACH M 2023-04-23
MATERIAL: MILD STEEL
TITLE
CRS-S23-S1-FRAME SUBASSEMBLY
SIZE B
DWG NO CRS-S23-S1-F.SA
REV 0
SCALE 1:20
SHEET 1 OF 1

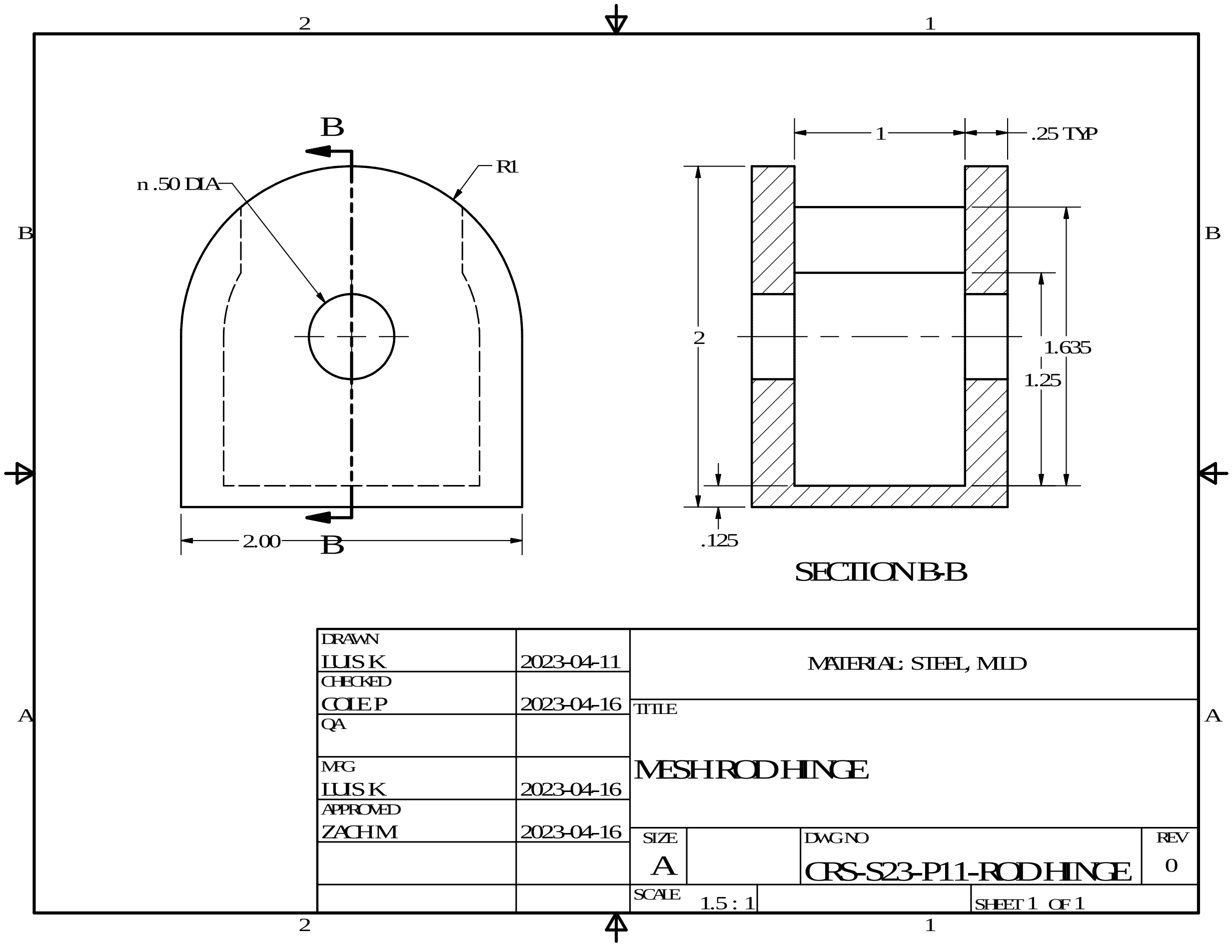

45°
2 X n .63 THRU
12
2.63
.88
5.66
12
NOTES:
1/2" THICK
DRAWN
LUIS K
2023-04-23
CHECKED
COLE P
2023-04-23
QA
MFG
LUIS K
2023-04-23
APPROVED
ZACH M
2023-04-23
MATERIAL: SAE 304 STL
TITLE
IDLER SHAFT BEARING PLATE
SIZE
A
DWG NO
CRS-S23-P21-I.S.B.P
REV
0
SCALE
1 / 3
SHEET 1 OF 1

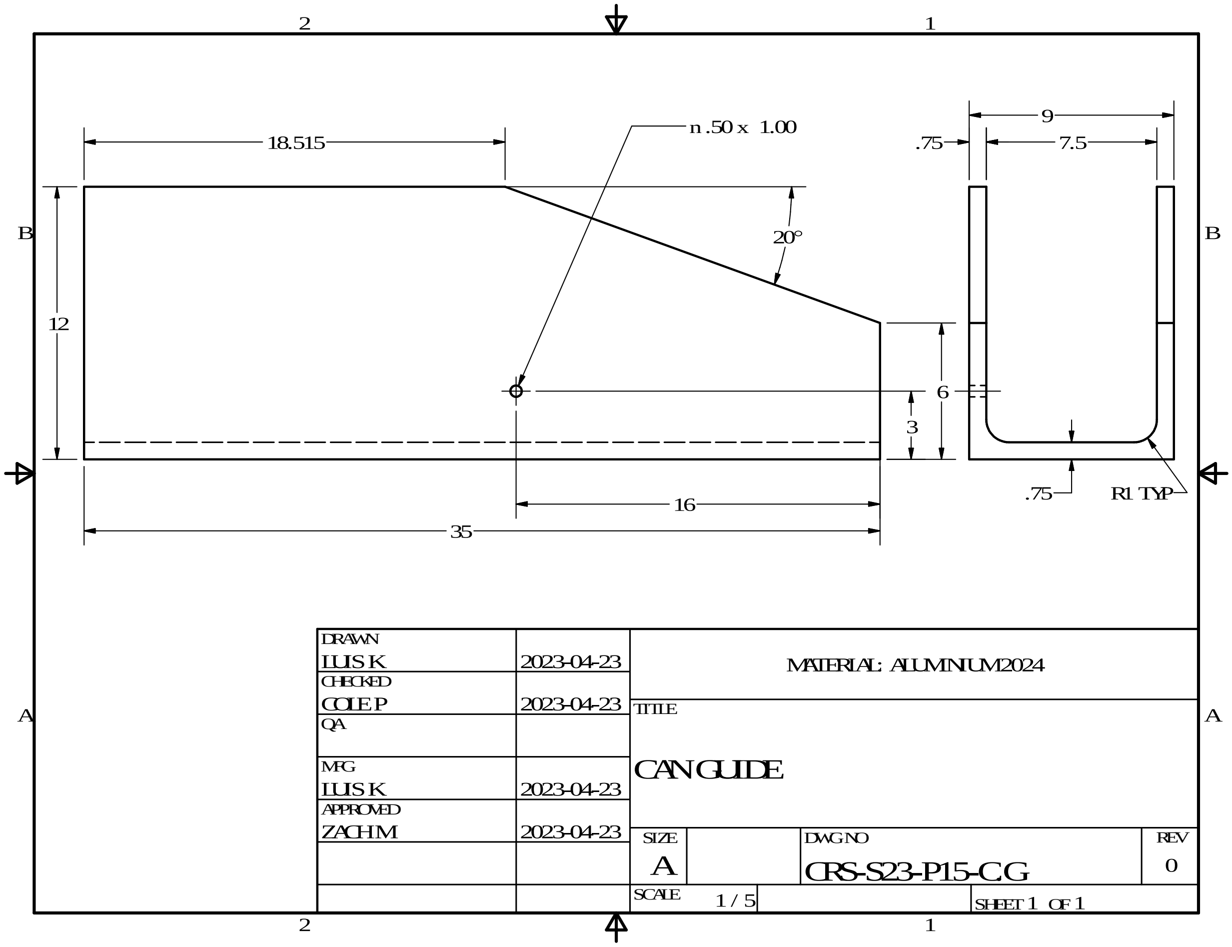

8 X n .69 THRU
8.75
3.063
5.375
5.125
5.375
22
FAO
0.53" THICK
DRAWN
ZACH M
2023-04-11
CHECKED
LUIS K
2023-04-23
QA
MFG
ZACH M
2023-04-23
APPROVED
COLE P
2023-04-23
MATERIAL: SAE 304 STL
TITLE
CRUSHER BEARING PLATE
SIZE
A
DWG NO
CRS-S23-P19-CBP
REV
0
SCALE
1 / 3
SHEET 1 OF 1


2 x n .813 THRU
8.38
12
2
2.5
16
NOTES:
FAO
1/2" THICK
DRAWN
LUIS K
2023-04-23
CHECKED
ZACH M
2023-04-23
QA
MFG
LUIS K
2023-04-23
APPROVED
COLE P
2023-04-23
MATERIAL: SAE 304 STL
TITLE
DRIVE BEARING MOUNT
SIZE
A
DWG NO
CRS-S23-P18-D.B.M
REV
0
SCALE
1 / 3
SHEET 1 OF 1

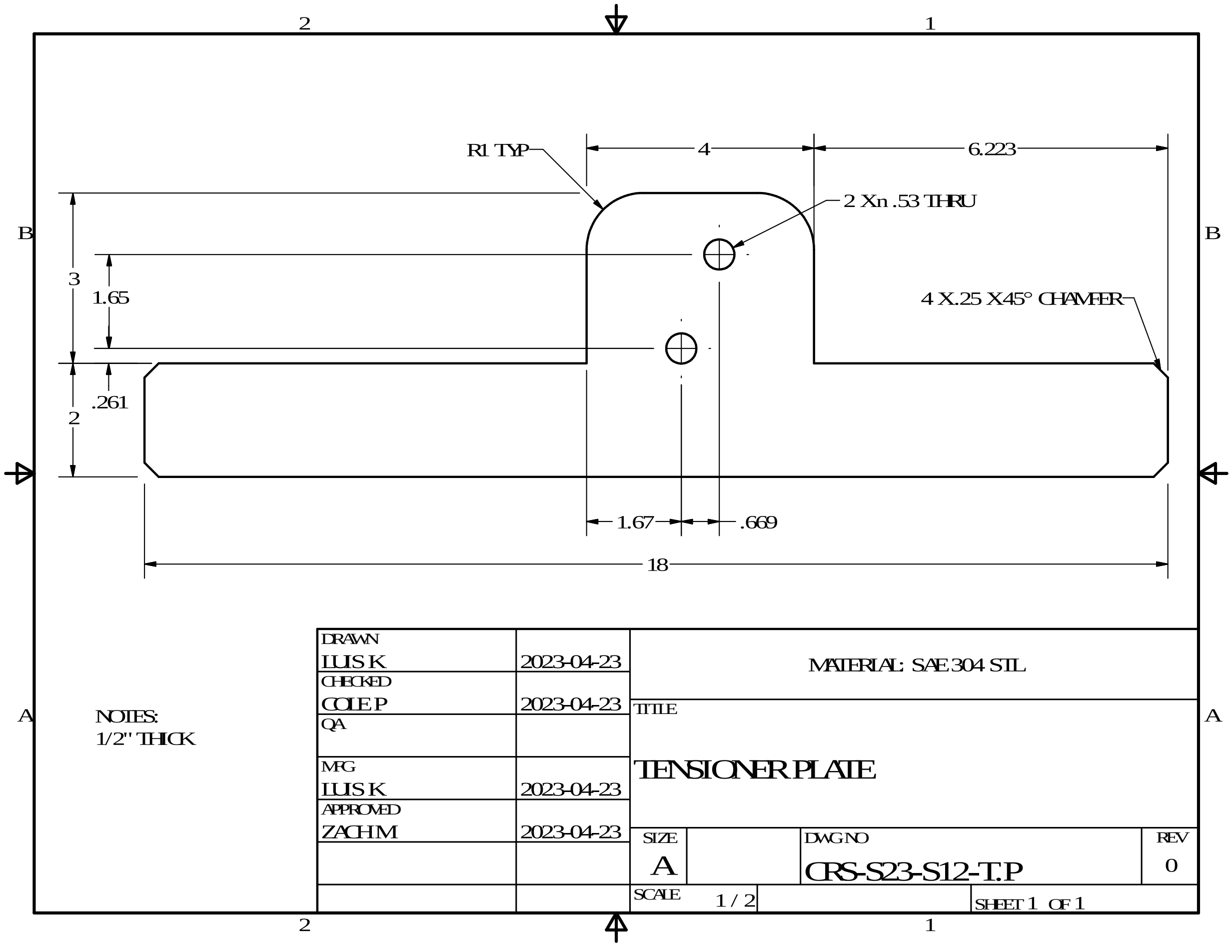

R50
3 X ⌀ .50 THRU
.25
8
NOTES:
1" THICK
DRAWN
LUIS K
2023-04-12
CHECKED
COLE P
2023-04-16
QA
MFG
LUIS K
2023-04-16
APPROVED
ZACH M
2023-04-16
MATERIAL: STEEL, MILD
TITLE
SCREEN ARM
SIZE
A
DWG NO
CRS-S23-P10-SCREEN ARM
REV
0
SCALE
1 : 1
SHEET 1 OF 1

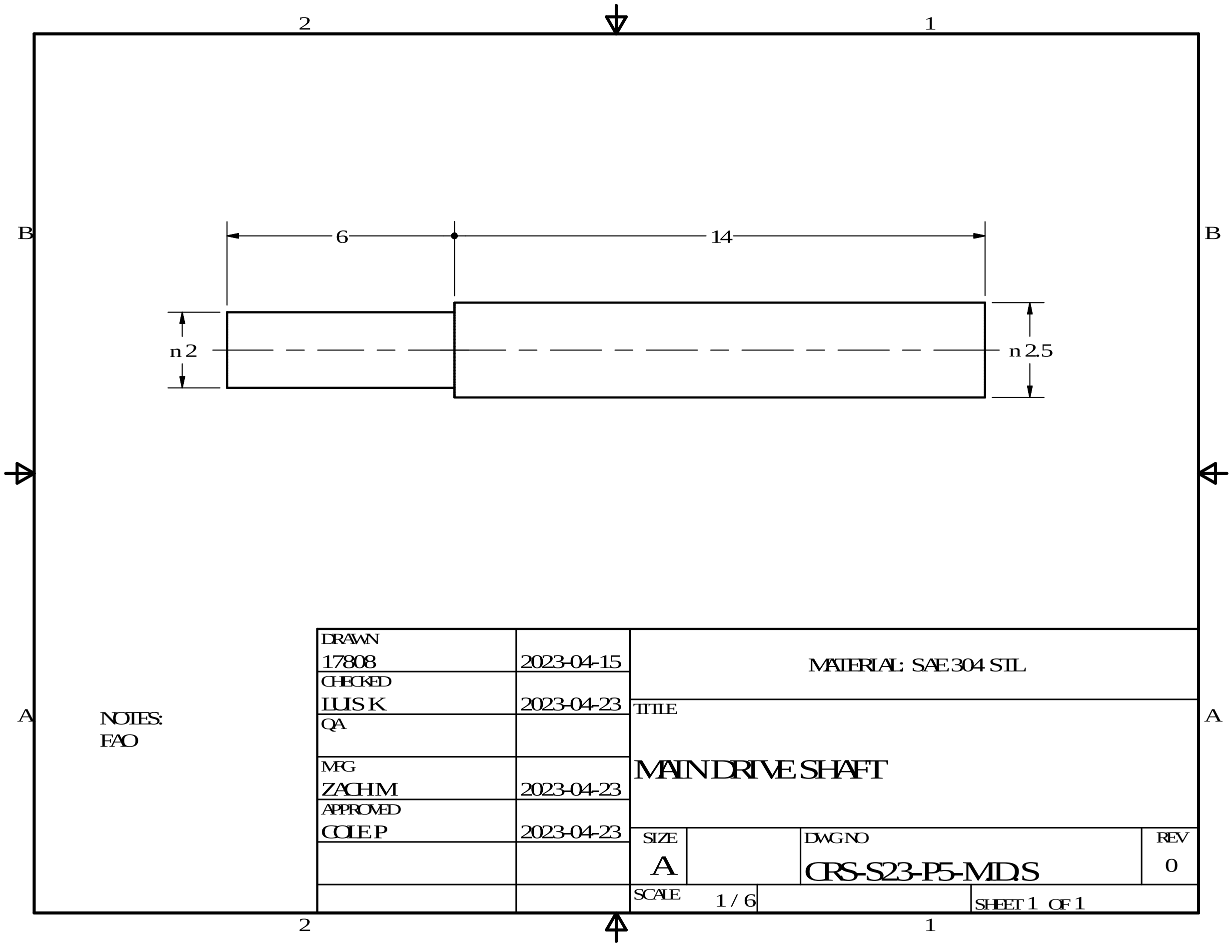

n .75
5.625
n .50 THRU
150°
.4
5
.67
23.73
3.25
1
.125
1 TYP
37°
8.00
1.00
.50 TYP
1.00
3
1
DRAWN
LUIS K
2023-04-12
CHECKED
COLE P
2023-04-16
QA
MFG
LUIS K
2023-04-16
APPROVED
ZACH M
2023-04-16
MATERIAL: ALUMINUM
TITLE
SORTING SCREEN
SIZE
A
DWG NO
CRS-S23-P9-SCREEN
REV
0
SCALE 1 / 5
SHEET 1 OF 1
NOTES:
PURCHASED STL MESH


n .50 DIA
R1
B
B
2.00
1
.25 TYP
2
1.635
1.25
.125
SECTION B-B
DRAWN
LUIS K
2023-04-11
CHECKED
COLE P
2023-04-16
QA
MFG
LUIS K
2023-04-16
APPROVED
ZACH M
2023-04-16
MATERIAL: STEEL, MILD
TITLE
MESH ROD HINGE
SIZE
A
DWG NO
CRS-S23-P11-ROD HINGE
REV
0
SCALE
1.5 : 1
SHEET 1 OF 1

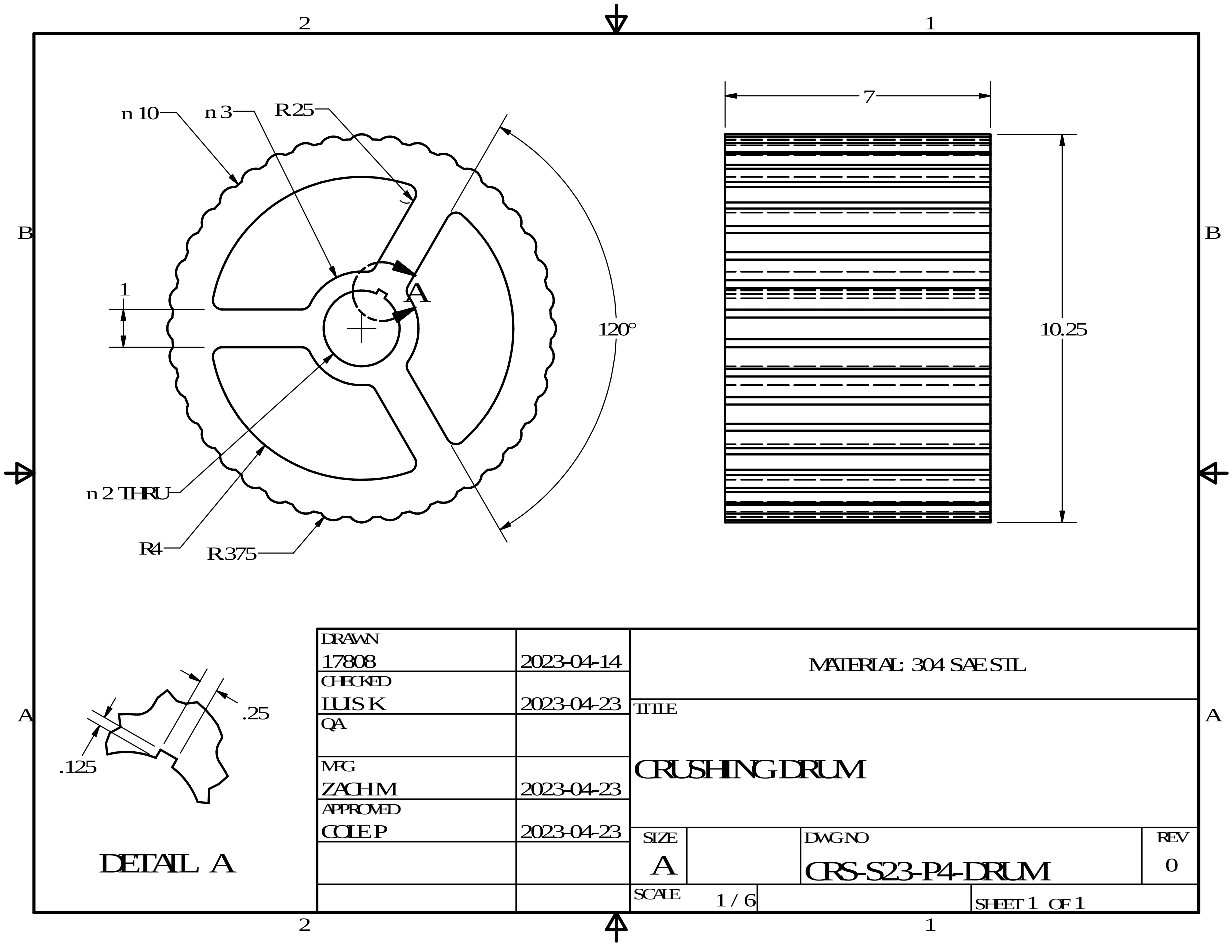


2
1
B
A
18.515
n .50 x 1.00
9
.75
7.5
20°
12
6
3
16
35
.75
R1 TYP
DRAWN
LUIS K
2023-04-23
CHECKED
COLE P
2023-04-23
QA
MFG
LUIS K
2023-04-23
APPROVED
ZACH M
2023-04-23
MATERIAL: ALUMINUM 2024
TITLE
CAN GUIDE
SIZE
A
DWG NO
CRS-S23-P15-CG
REV
0
SCALE
1 / 5
SHEET 1 OF 1

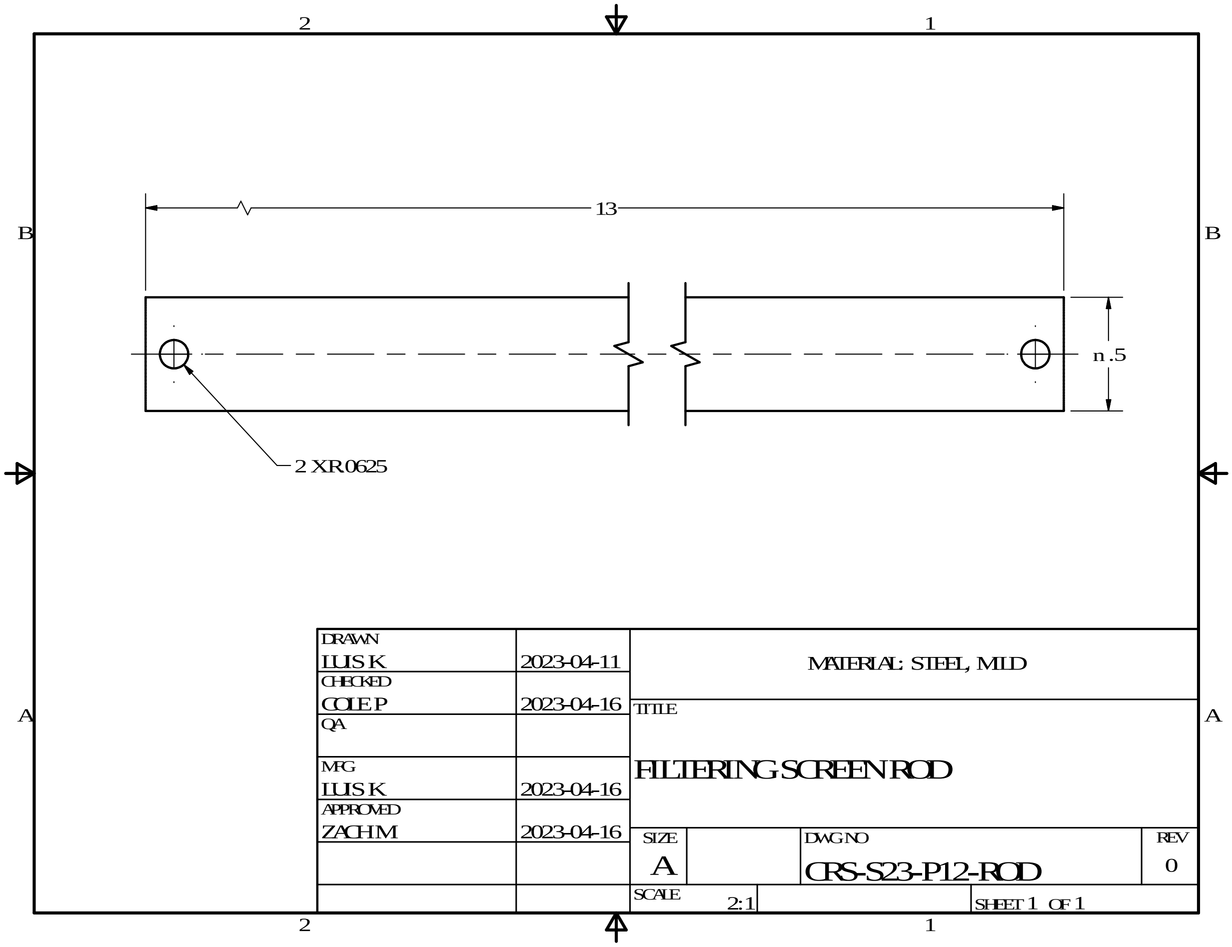

R1 TYP
4
6.223
2 X⌀ .53 THRU
3
1.65
4 X .25 X 45° CHAMFER
.261
2
1.67
.669
18
NOTES:
1/2" THICK
DRAWN
LUIS K
2023-04-23
CHECKED
COLE P
2023-04-23
QA
MFG
LUIS K
2023-04-23
APPROVED
ZACH M
2023-04-23
MATERIAL: SAE 304 STL
TITLE
TENSIONER PLATE
SIZE
A
DWG NO
CRS-S23-S12-T.P
REV
0
SCALE
1 / 2
SHEET 1 OF 1

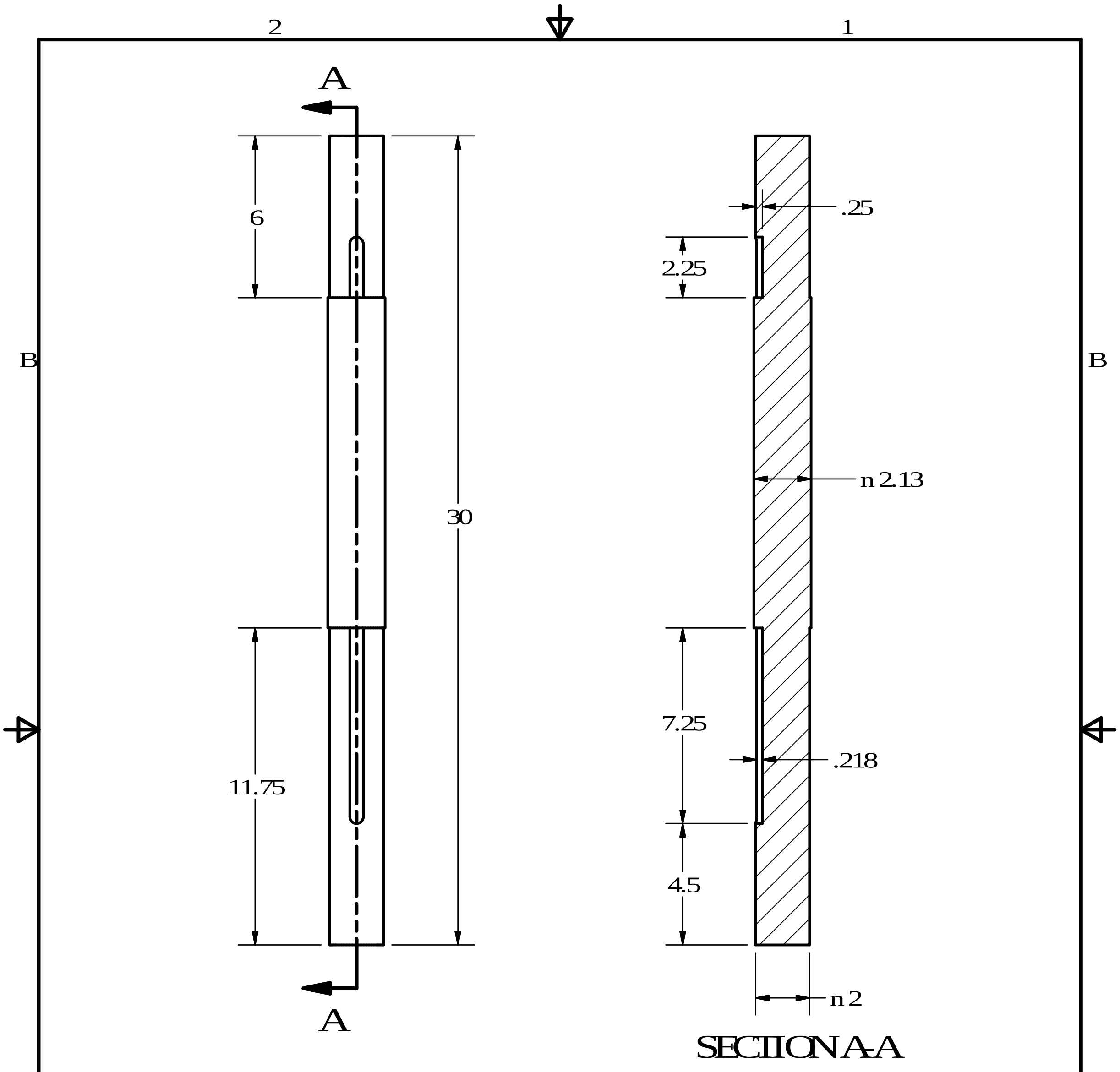


6
14
n 2
n 2.5
NOTES:
FAO
DRAWN
17808
2023-04-15
CHECKED
LUIS K
2023-04-23
QA
MFG
ZACH M
2023-04-23
APPROVED
COLE P
2023-04-23
MATERIAL: SAE 304 STL
TITLE
MAIN DRIVE SHAFT
SIZE
A
DWG NO
CRS-S23-P5-MD.S
REV
0
SCALE
1 / 6
SHEET 1 OF 1



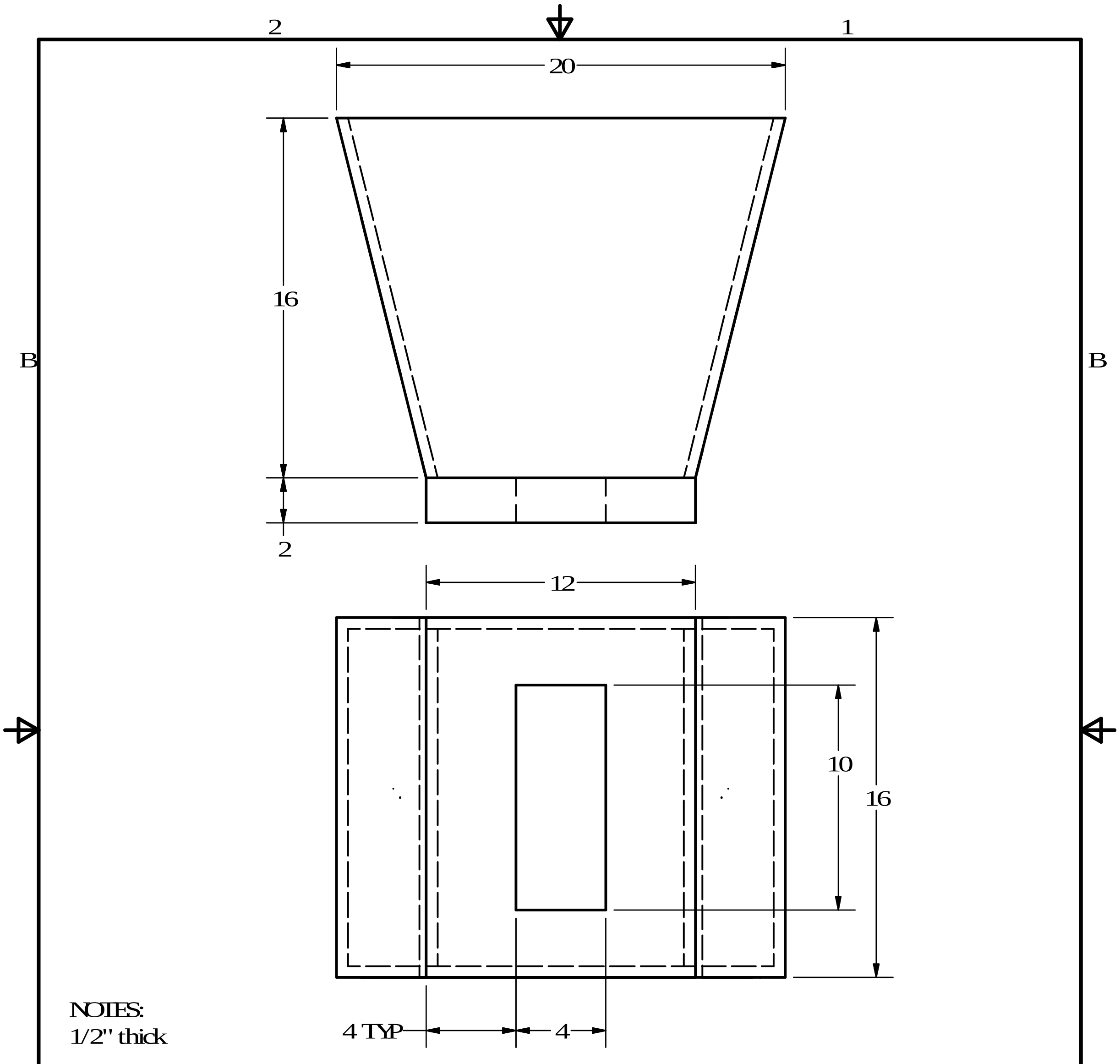
n 10
n 3
R.25
1
A
120°
7
10.25
n 2 THRU
R4
R.375
.25
.125
DETAIL A
DRAWN
17808
2023-04-14
CHECKED
LUIS K
2023-04-23
QA
MFG
ZACH M
2023-04-23
APPROVED
COLE P
2023-04-23
MATERIAL: 304 SAE STL
TITLE
CRUSHING DRUM
SIZE
A
DWG NO
CRS-S23-P4-DRUM
REV
0
SCALE
1 / 6
SHEET 1 OF 1


13
n .5
2 XR.0625
DRAWN
LUIS K
2023-04-11
CHECKED
COLE P
2023-04-16
QA
MFG
LUIS K
2023-04-16
APPROVED
ZACH M
2023-04-16
MATERIAL: STEEL, MILD
TITLE
FILTERING SCREEN ROD
SIZE
A
DWG NO
CRS-S23-P12-ROD
REV
0
SCALE
2:1
SHEET 1 OF 1



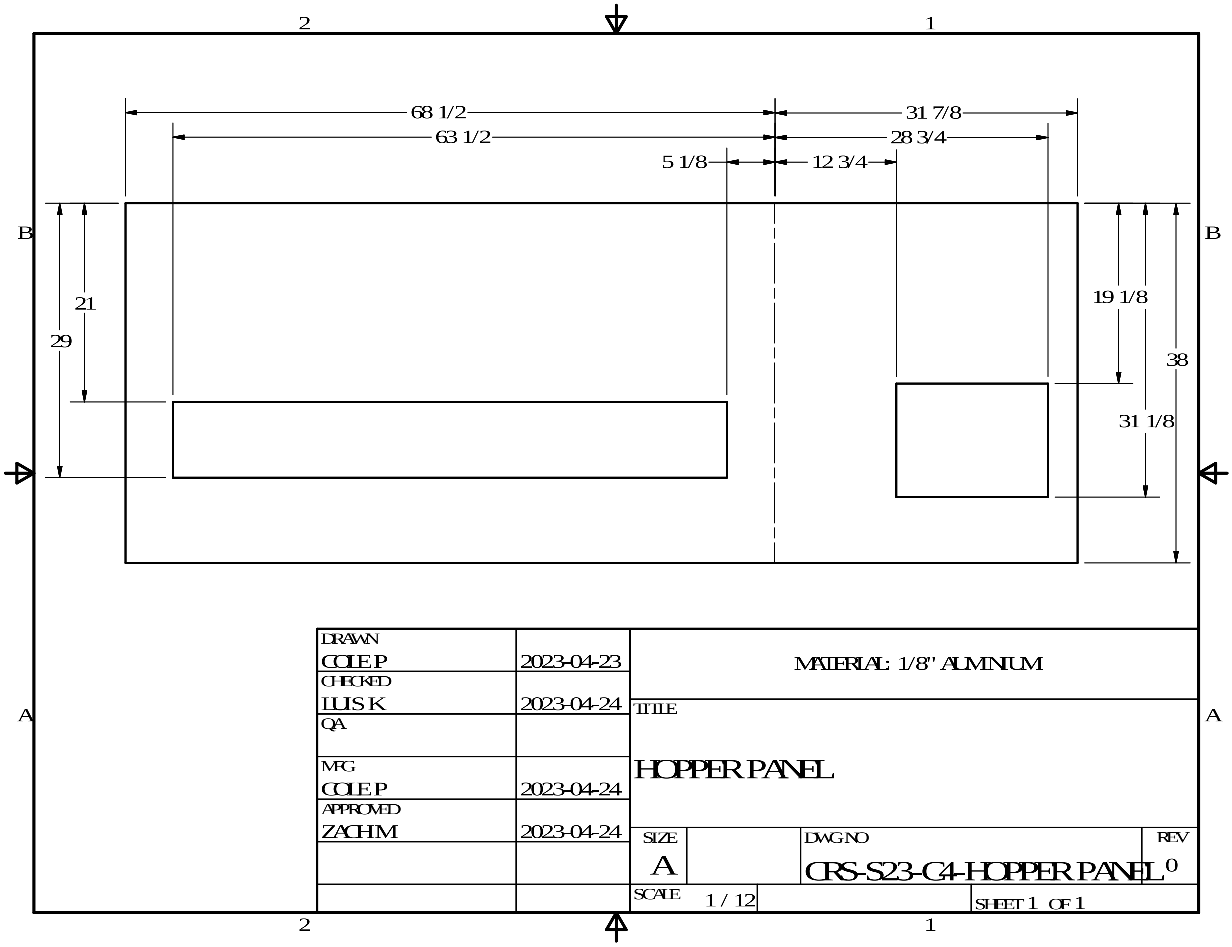
DRAWN 17808	2023-04-14	MATERIAL: SAE 304 STL	
CHECKED LUIS K	2023-04-23	TITLE	
QA		DRUMSHAFT	
MFG ZACH M	2023-04-23		
APPROVED COLE P	2023-04-23	SIZE A	DWG NO CRS-S23-P3-DRUMSHAFT, REV 0
		SCALE 1 / 9	SHEET 1 OF 1

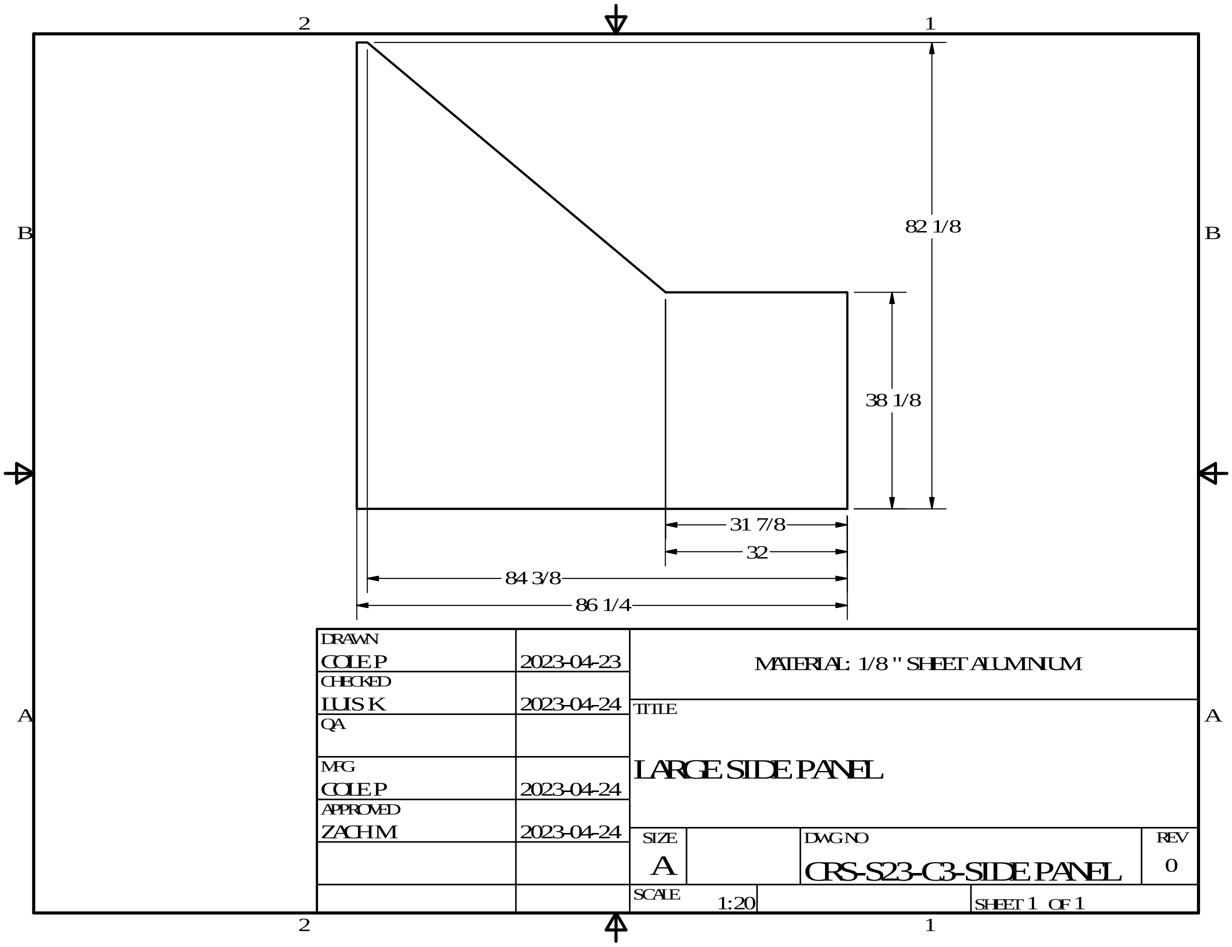
2 1



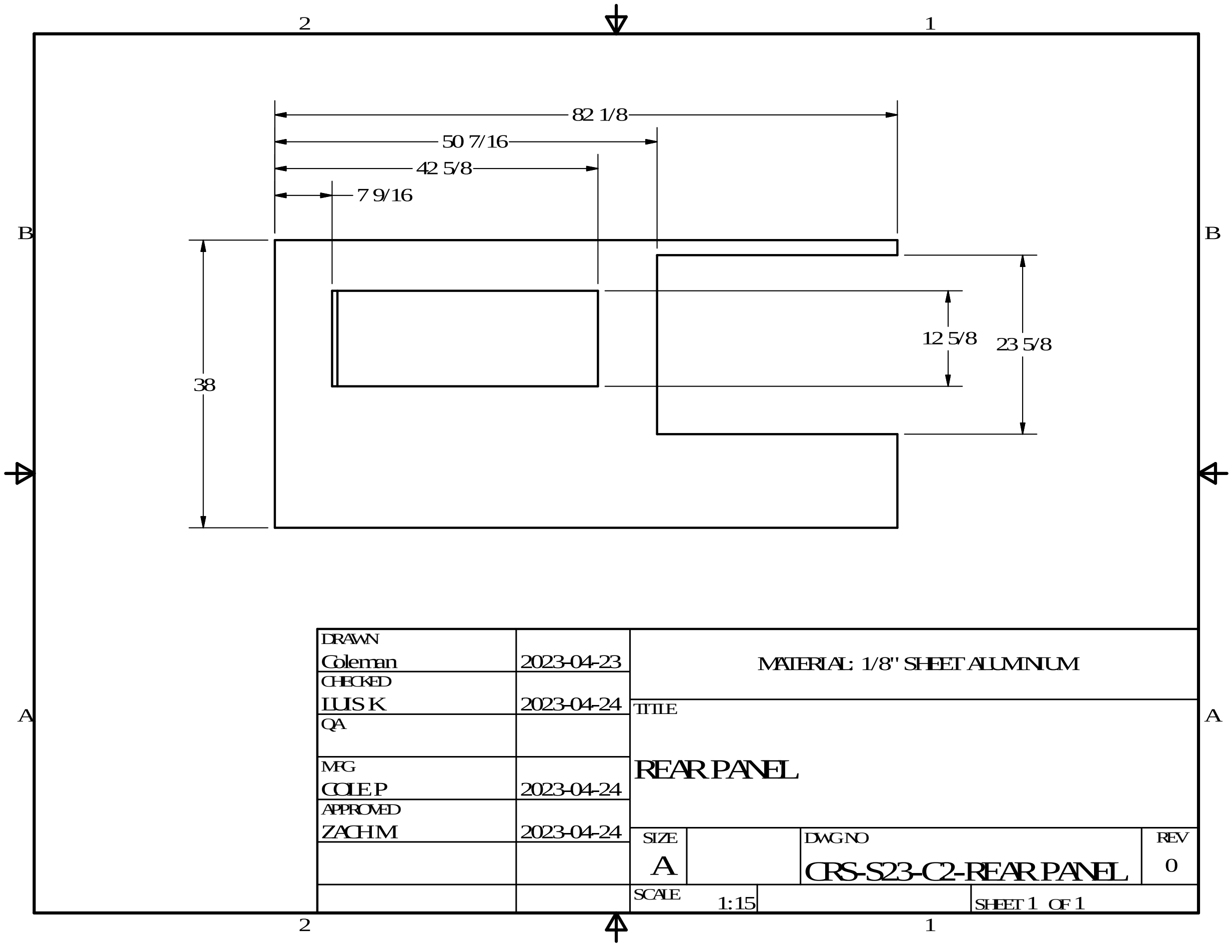
NOTES:
1/2" thick

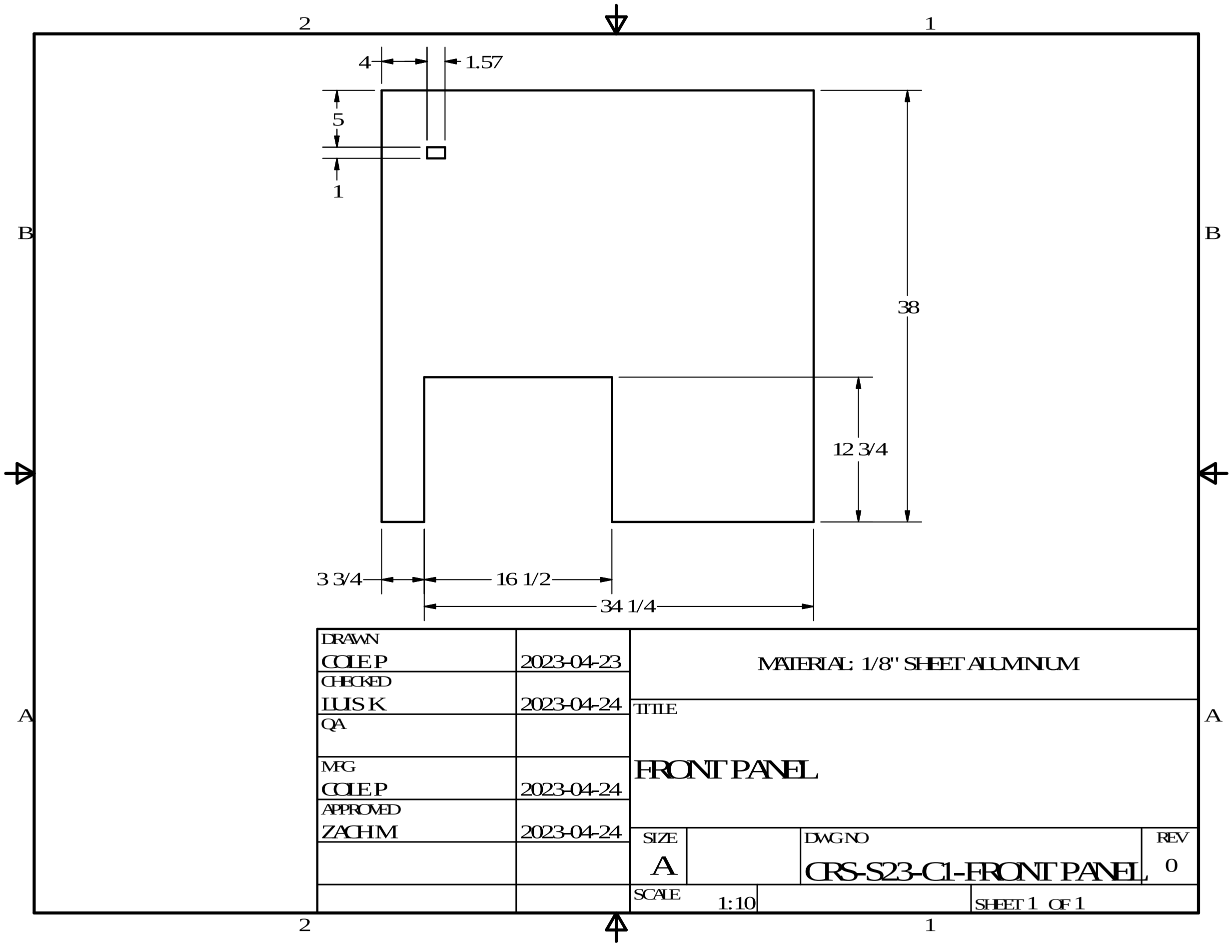
DRAWN LUIS K	2023-04-11	MATERIAL: ALUMINUM		
CHECKED COLE P	2023-04-16	TITLE HOPPER		
QA				
MFG LUIS K	2023-04-16			
APPROVED ZACH M	2023-04-16	SIZE A	DWG NO CRS-S23-P1-HOPPER	REV 0
		SCALE 1 / 6	SHEET 1 OF 1	

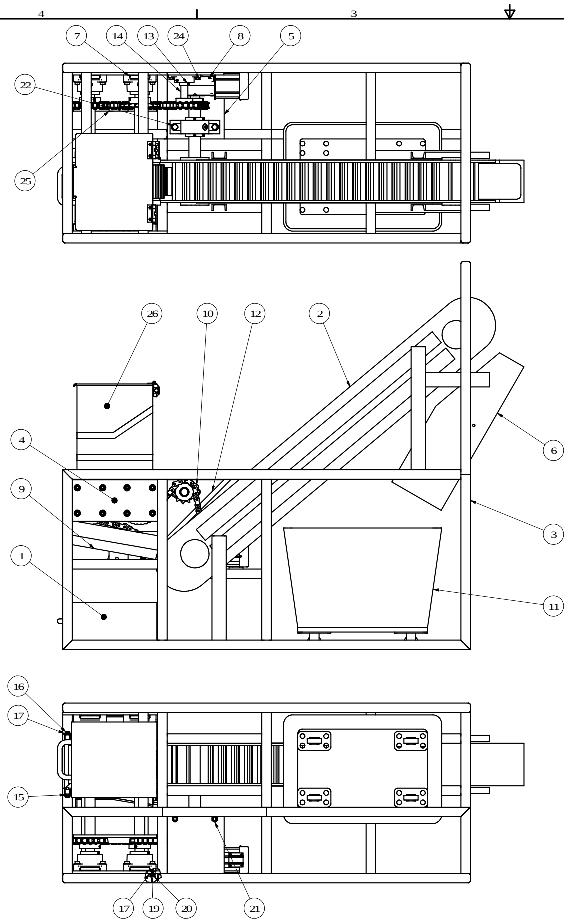

68 1/2
63 1/2
5 1/8
31 7/8
28 3/4
12 3/4
21
29
19 1/8
38
31 1/8
DRAWN
COLE P
2023-04-23
CHECKED
LUIS K
2023-04-24
QA
MFG
COLE P
2023-04-24
APPROVED
ZACH M
2023-04-24
MATERIAL: 1/8" ALUMINUM
TITLE
HOPPER PANEL
SIZE
A
DWG NO
CRS-S23-C4-HOPPER PANEL
REV
0
SCALE
1 / 12
SHEET 1 OF 1

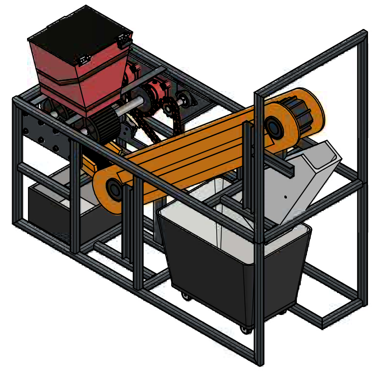


2
1
B
A
82 1/8
38 1/8
31 7/8
32
84 3/8
86 1/4
DRAWN
COLE P
2023-04-23
CHECKED
LUIS K
2023-04-24
QA
MFG
COLE P
2023-04-24
APPROVED
ZACH M
2023-04-24
MATERIAL: 1/8 " SHEET ALUMINUM
TITLE
LARGE SIDE PANEL
SIZE
A
DWG NO
CRS-S23-C3-SIDE PANEL
REV
0
SCALE
1:20
SHEET 1 OF 1


82 1/8
50 7/16
42 5/8
7 9/16
38
12 5/8
23 5/8
DRAWN
Coleman
2023-04-23
CHECKED
LUIS K
2023-04-24
QA
MFG
COLE P
2023-04-24
APPROVED
ZACH M
2023-04-24
MATERIAL: 1/8" SHEET ALUMINUM
TITLE
REAR PANEL
SIZE
A
DWG NO
CRS-S23-C2-REAR PANEL
REV
0
SCALE
1:15
SHEET 1 OF 1


4
1.57
5
1
38
12 3/4
3 3/4
16 1/2
34 1/4
DRAWN
COLE P
2023-04-23
CHECKED
LUIS K
2023-04-24
QA
MFG
COLE P
2023-04-24
APPROVED
ZACH M
2023-04-24
MATERIAL: 1/8" SHEET ALUMINIUM
TITLE
FRONT PANEL
SIZE
A
DWG NO
CRS-S23-C1-FRONT PANEL
REV
0
SCALE
1:10
SHEET 1 OF 1





		PARTS LIST	
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Waste bin assembly	WASTE BIN BUYOUT
2	1	Indianmart conveyor	CONVEYOR BUYOUT
3	1	Frame Assembly	HSS FRAME ASSEMBLY
4	2	Bearing Plate	BEARING PLATE
5	1	Base for mount bearing	BASE MOUNT
6	1	slide	CAN GUIDE
7	1	CRS-S23-S2-CRUSHING DRIVE	CRUSHING DRIVE
8	1	CRS-S23-S3-MAIN DRIVE SUBASSEMBLY	MAIN DRIVE
9	1	CRS-S23-S5-SCREEN SUBASSEMBLY	SCREEN SUB ASSEMBLY
10	1	CRS-S23-S4-CHAIN COMPONENTS	CHAIN SUB ASSEMBLY
11	1	Recycle Bin	BIN
12	1	CRS-S23-P21-IDLER SHAFT PLATE	IDLER TRIANGLE PLATE
13	1	5968K79_Mounted Sealed Ball Bearing with Two-Bolt Flange	IDLER BEARING
14	1	CRS-S23-P22-IDLER SHAFT	IDLER SHAFT
15	2	BS 1574 - 5/64 x 1	SPLIT COTTER PIN
16	2	91286A330_High-Strength Grade 8 Steel Hex Head Screw	HEX HEAD SCREW
17	38	98023A035_Zinc Yellow-Chromate Plated Grade 8 Steel Washer	STEEL WASHER
18	2	95462A033_Medium-Strength Steel Hex Nut	HEX NUT
19	16	91286A407_High-Strength Grade 8 Steel Hex Head Screw	HEX HEAD SCREW
20	16	95462A533_Medium-Strength Steel Hex Nut	HEX NUT
21	2	95462A538_Medium-Strength Steel Hex Nut	HEX NUT
22	2	91286A463_High-Strength Grade 8 Steel Hex Head Screw	HEX HEAD SCREW
23	2	95462A528_Medium-Strength Steel Hex Nut	HEX NUT
24	2	AS 2465 - 9/16 x 1 1/2 UNC	UNC HEX BOLT
25	1	TENSIONER PLATE	
26	1	CRS-S23-S7-HOPPER SUBASSEMBLY	HOPPER AND COVER

DRAWN LUIS K	2023-04-24	MATERIAL: VARIES	
CHECKED COLE P	2023-04-24	TITLE	
QA		INTERNAL ASSEMBLY	
MFG LUIS K	2023-04-24		
APPROVED ZACH M	2023-04-24	SIZE C	DWG NO CRS-S23-S4-CRS I.A — REV 0
		SCALE 1 / 12	SHEET 1 OF 1

Appendix C: FEM Analysis

Stress Analysis Report

Analyzed File:	CRS-S23-P4-DRUM.ipt
Autodesk Inventor Version:	2023 (Build 270158000, 158)
Creation Date:	4/24/2023, 12:52 AM
Study Author:	17808
Summary:	

Modal Analysis:1

General objective and settings:

Design Objective	Single Point
Study Type	Modal Analysis
Last Modification Date	4/24/2023, 12:19 AM
Model State	[Primary]
Number of Modes	8
Frequency Range	Undefined
Compute Preloaded Modes	No
Enhanced Accuracy	No

iProperties

Summary

Title	6325K32_Metal Gear - 14-1-2 Degree Pressure Angle.STEP
Author	Administrator
Company	Managed by Terraform

Project

Part Number	Drum gear
Description	STEP AP203
Revision Number	ANY
Designer	luisk
Cost	$0.00
Date Created	10/20/2022

Status

Design Status	WorkInProgress

Custom

Sending System	SolidWorks 2017
Preprocessor	SwSTEP 2.0

Physical

Material	Stainless Steel

Stress Analysis Report

Analyzed File:	CRS-S23-P4-DRUM.ipt
Autodesk Inventor Version:	2023 (Build 270158000, 158)
Creation Date:	4/24/2023, 12:52 AM
Study Author:	17808
Summary:	

Modal Analysis:1

General objective and settings:

Design Objective	Single Point
Study Type	Modal Analysis
Last Modification Date	4/24/2023, 12:19 AM
Model State	[Primary]
Number of Modes	8
Frequency Range	Undefined
Compute Preloaded Modes	No
Enhanced Accuracy	No

iProperties

Summary

Title	6325K32_Metal Gear - 14-1-2 Degree Pressure Angle.STEP
Author	Administrator
Company	Managed by Terraform

Project

Part Number	Drum gear
Description	STEP AP203
Revision Number	ANY
Designer	luisk
Cost	$0.00
Date Created	10/20/2022

Status

Design Status	WorkInProgress

Custom

Sending System	SolidWorks 2017
Preprocessor	SwSTEP 2.0

Physical

Material	Stainless Steel

Density	0.289018 lbmass/in^3
Mass	84.7072 lbmass
Area	670.021 in^2
Volume	293.086 in^3
Center of Gravity	x=-0.000378032 in y=-0.00065477 in z=3.5 in

Note: Physical values could be different from Physical values used by FEA reported below.

Mesh settings:

Avg. Element Size (fraction of model diameter)	0.08
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	Yes

Material(s)

Name	Stainless Steel	
General	Mass Density	0.289018 lbmass/in^3
	Yield Strength	36259.4 psi
	Ultimate Tensile Strength	78320.4 psi
Stress	Young's Modulus	27992.3 ksi
	Poisson's Ratio	0.3 ul
	Shear Modulus	10766.3 ksi
Part Name(s)	CRS-S23-P4-DRUM.ipt	

Results

Frequency Value(s)

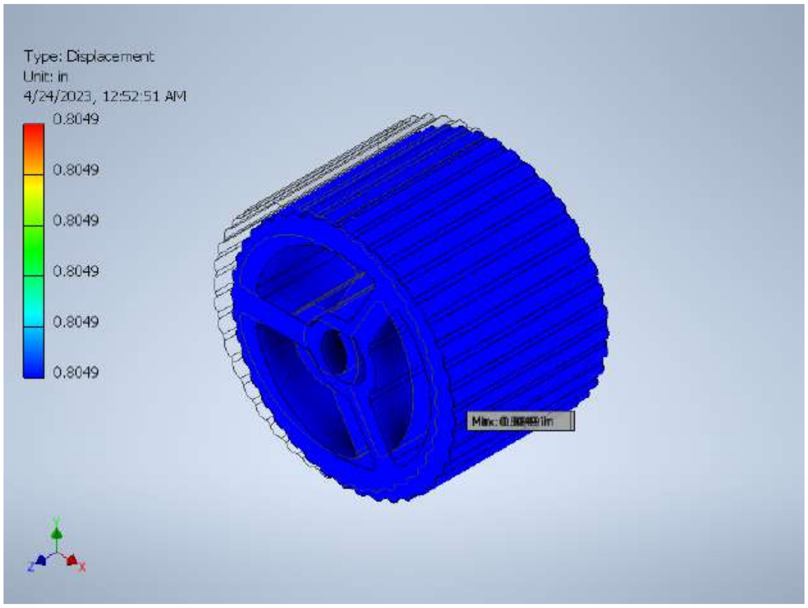
F1	0.00 Hz
F2	0.00 Hz
F3	0.00 Hz
F4	0.00 Hz
F5	0.00 Hz
F6	0.00 Hz
F7	2472.76 Hz
F8	2473.74 Hz

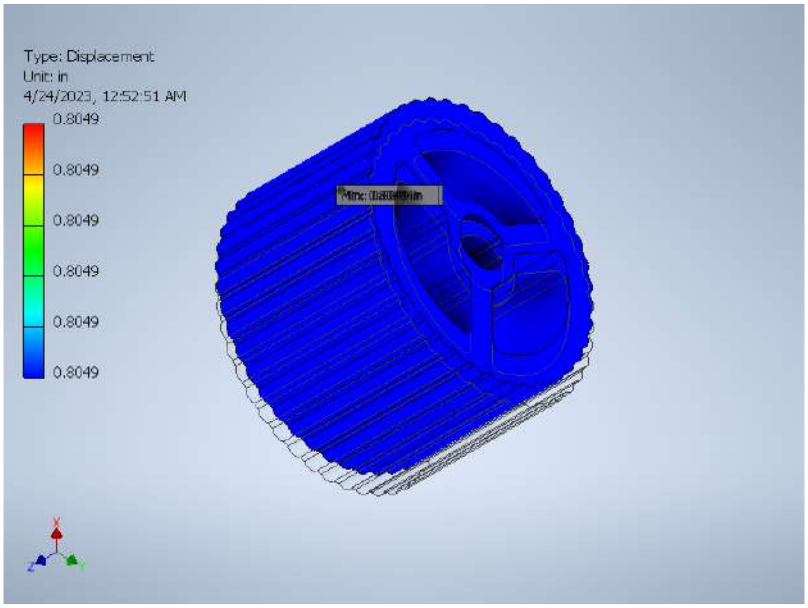
Result Summary

Name	**Result Value**
Volume	293.086 in^3
Mass	84.7072 lbmass

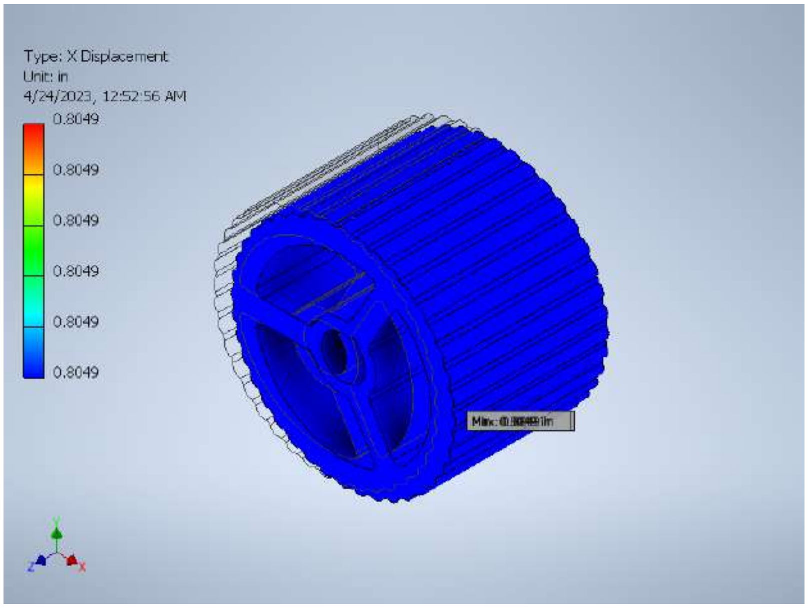
Figures

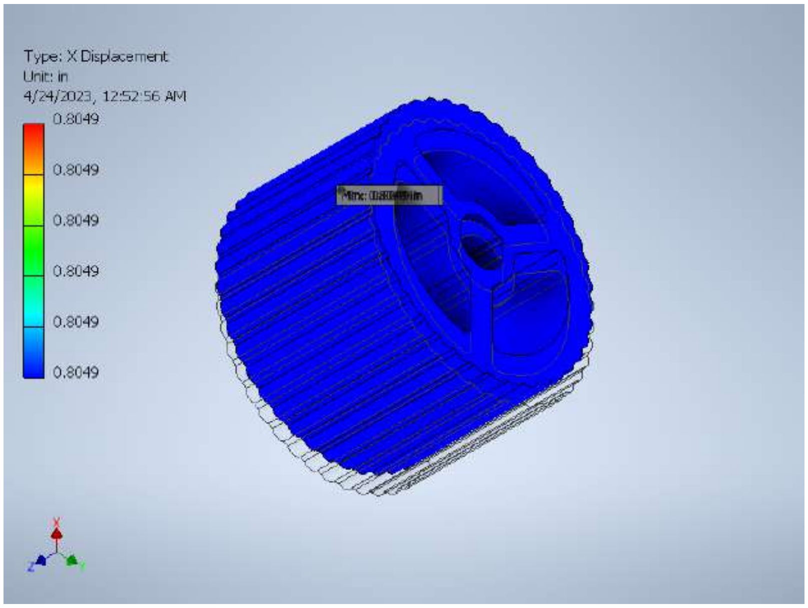
F1 0.00 Hz Displacement



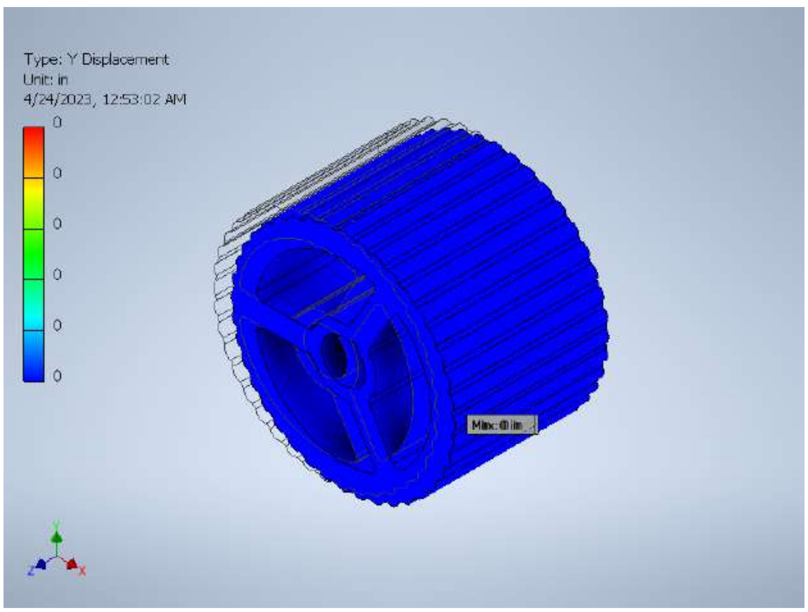


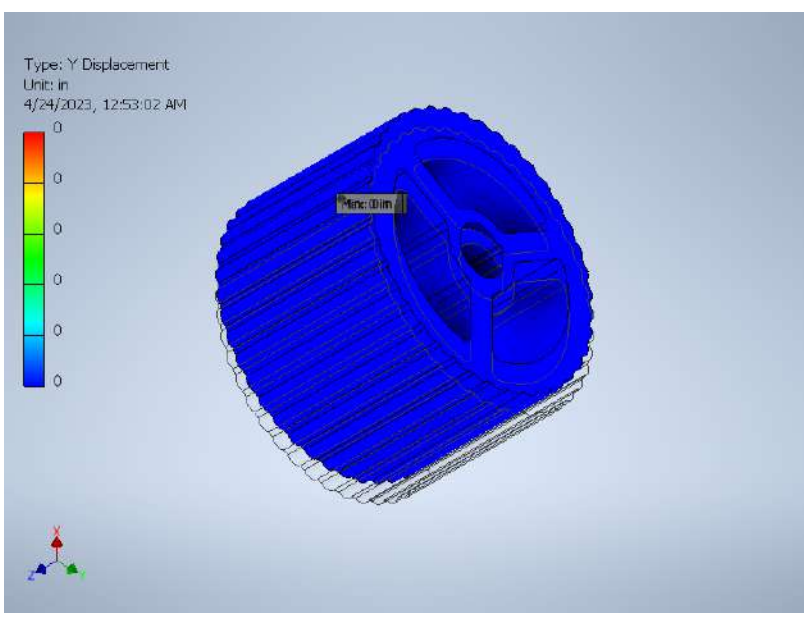
F1 0.00 Hz X Displacement



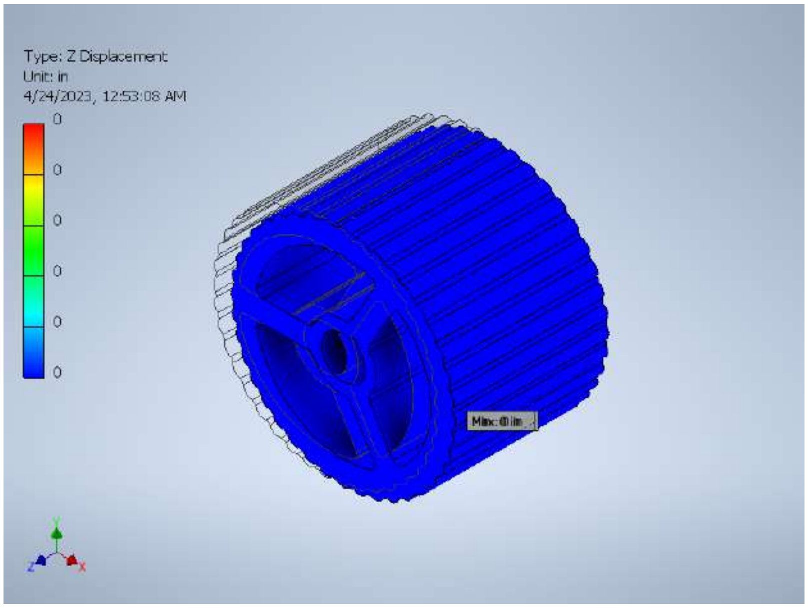


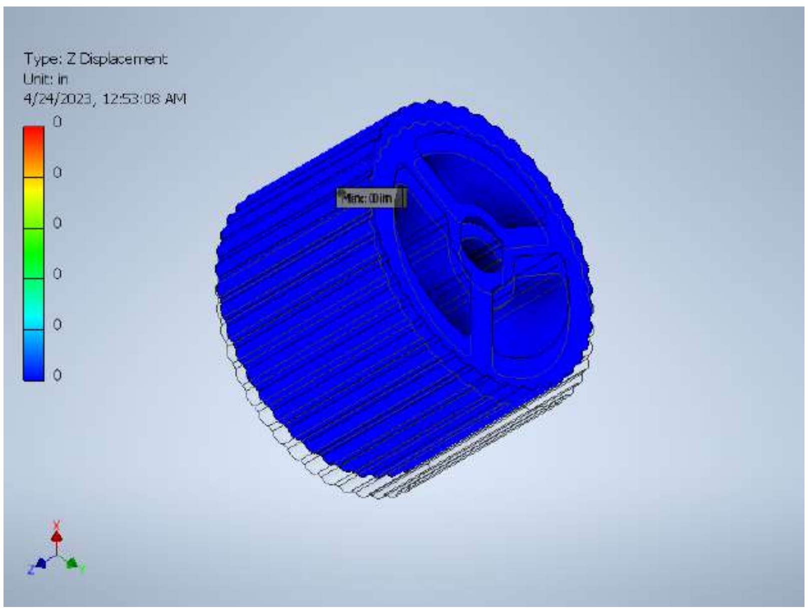
F1 0.00 Hz Y Displacement



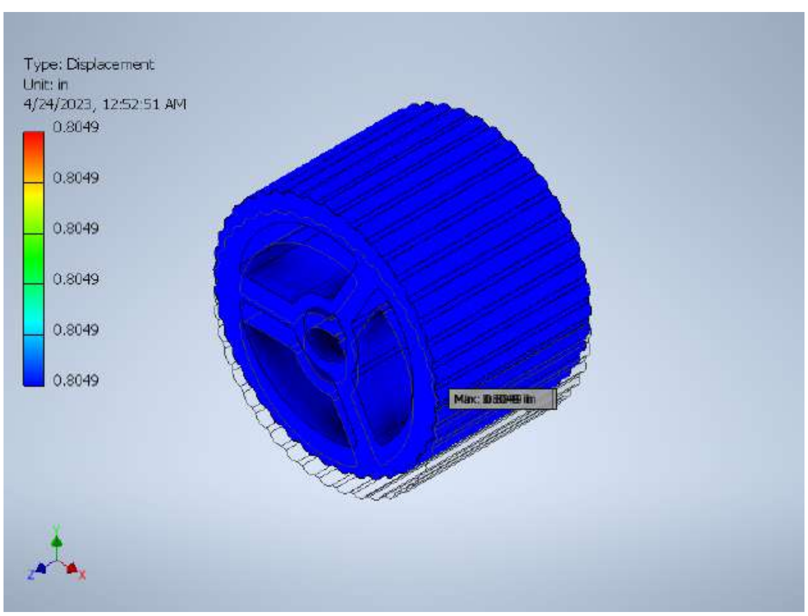


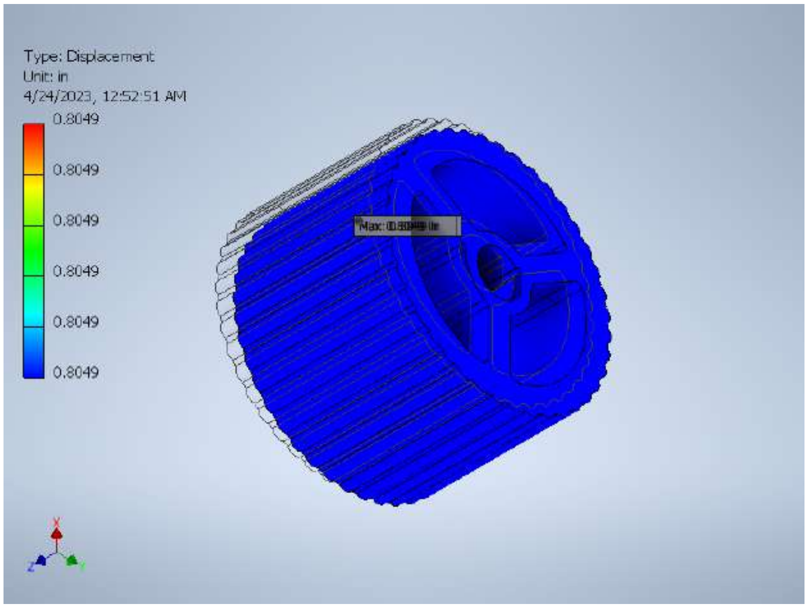
F1 0.00 Hz Z Displacement



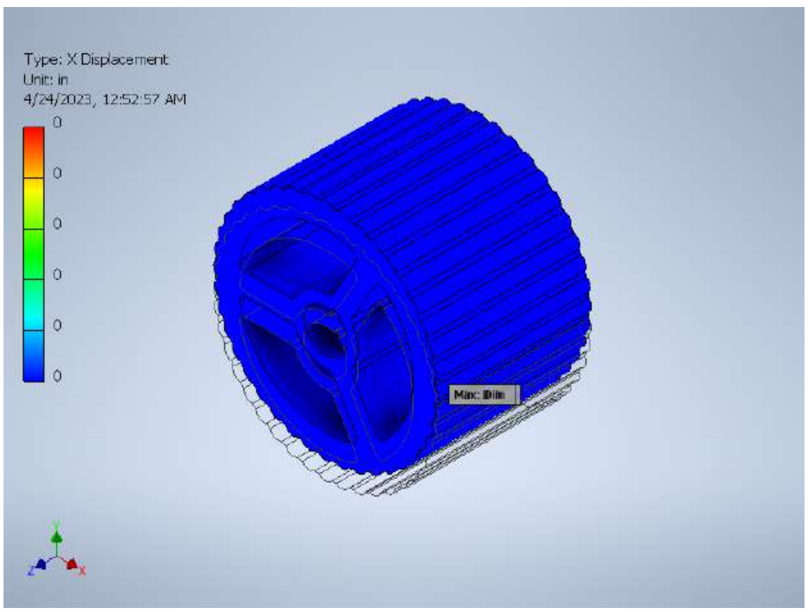


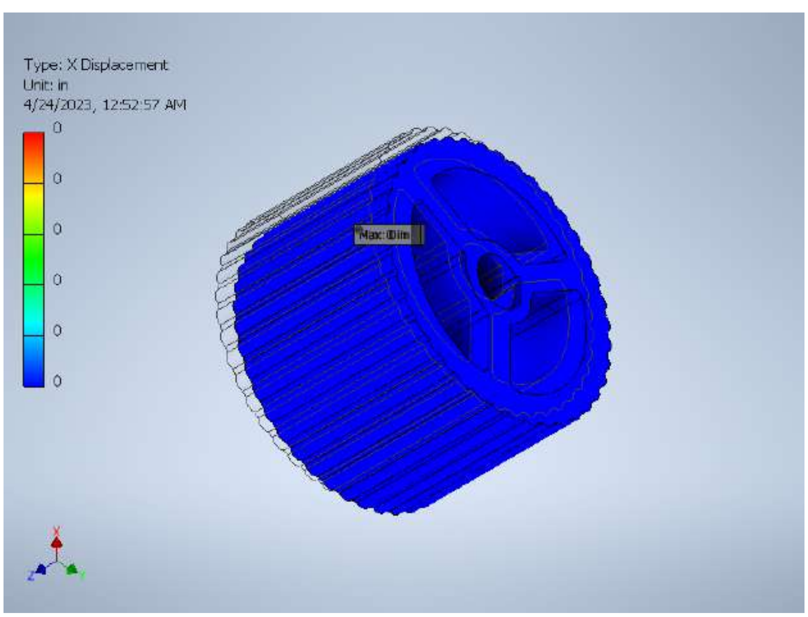
F2 0.00 Hz Displacement



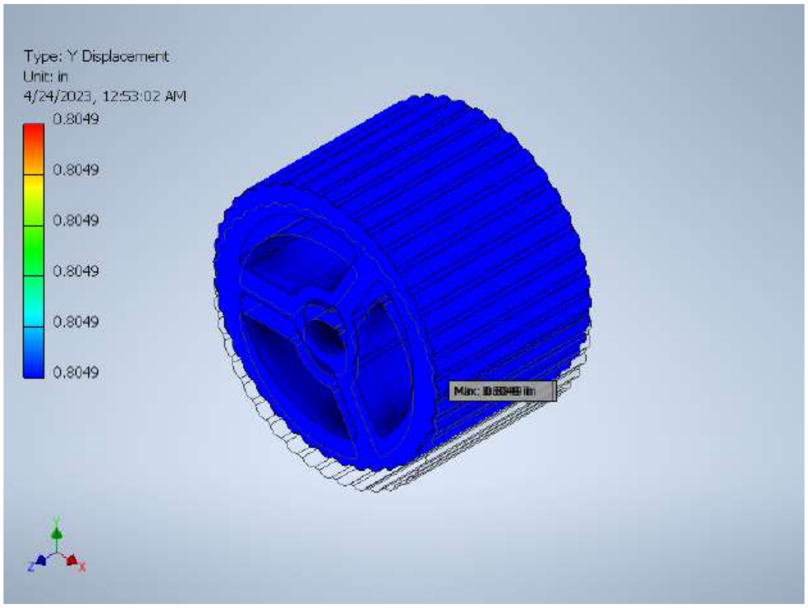


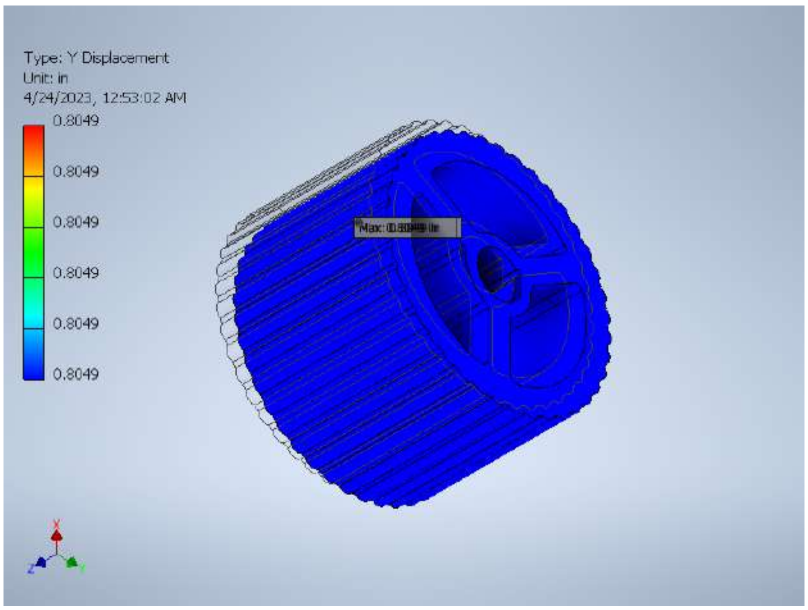
F2 0.00 Hz X Displacement



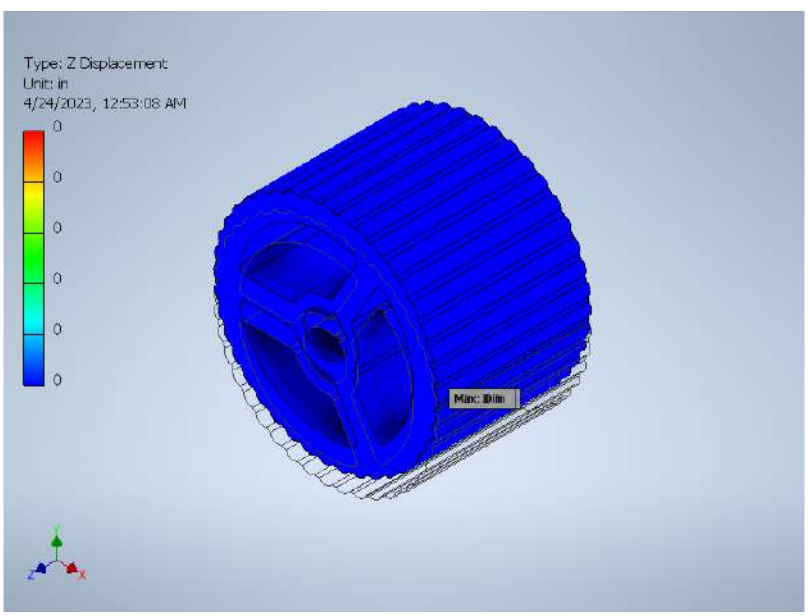


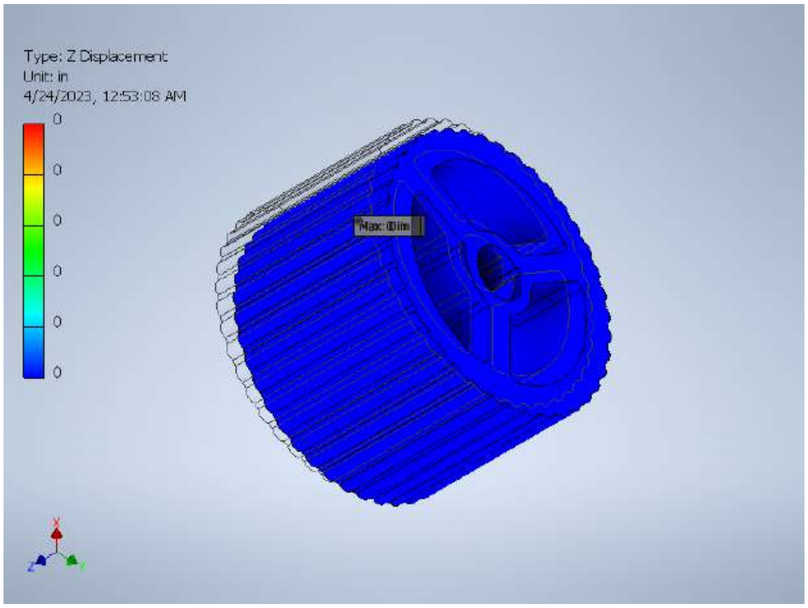
F2 0.00 Hz Y Displacement



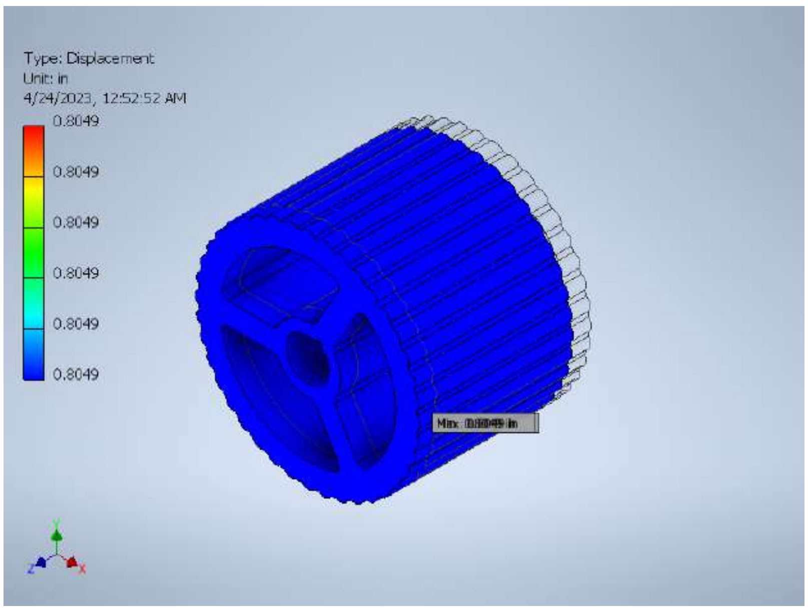


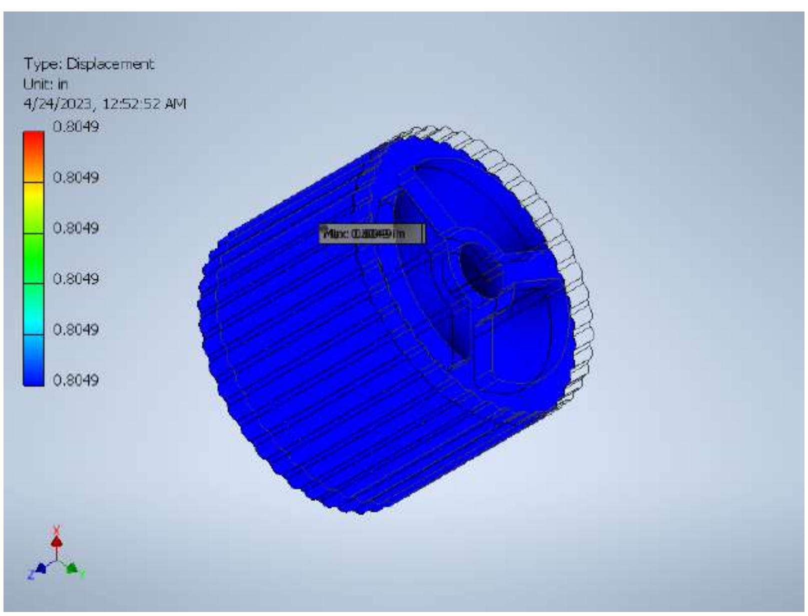
F2 0.00 Hz Z Displacement



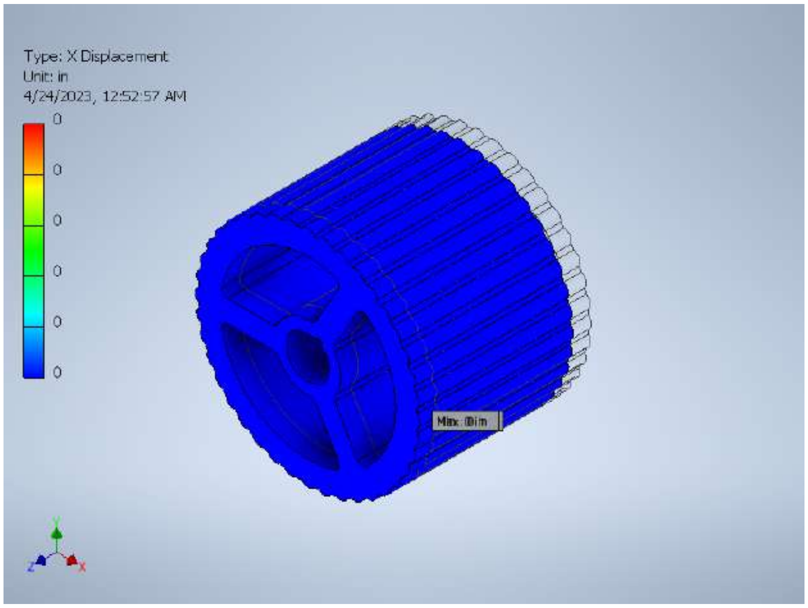


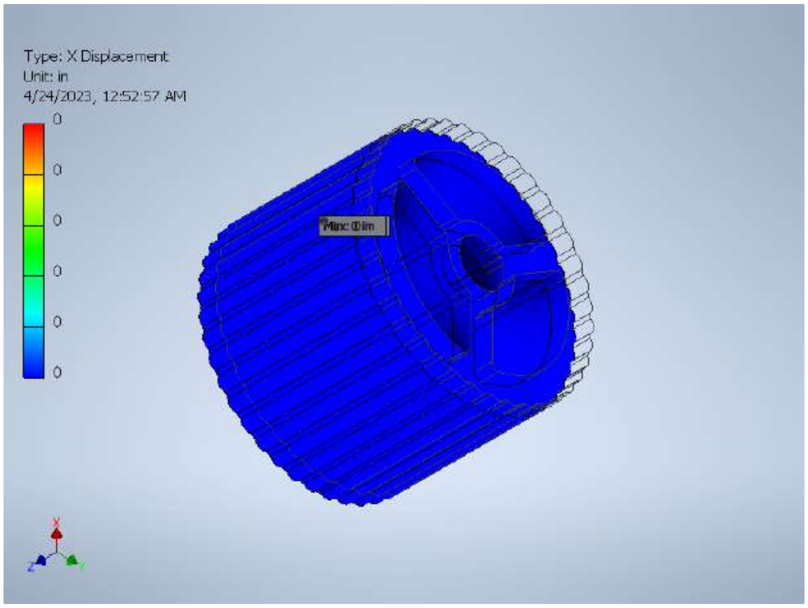
F3 0.00 Hz Displacement



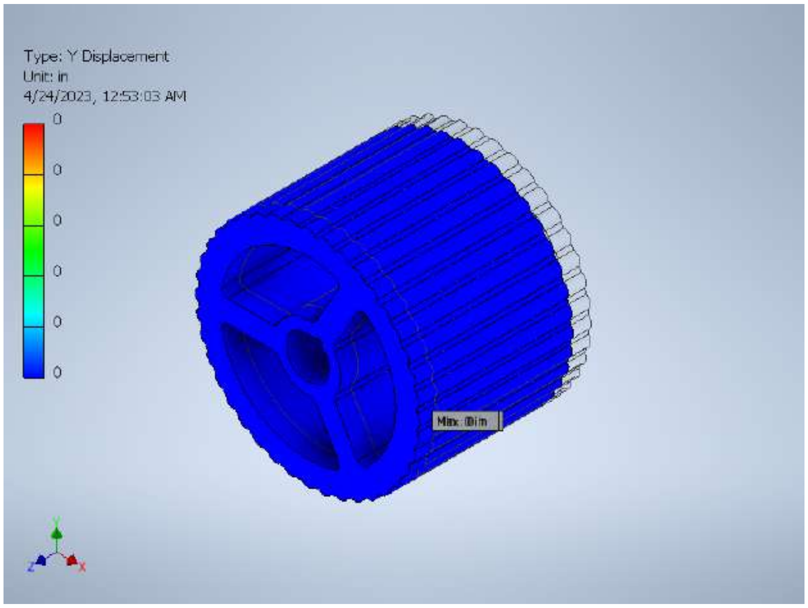


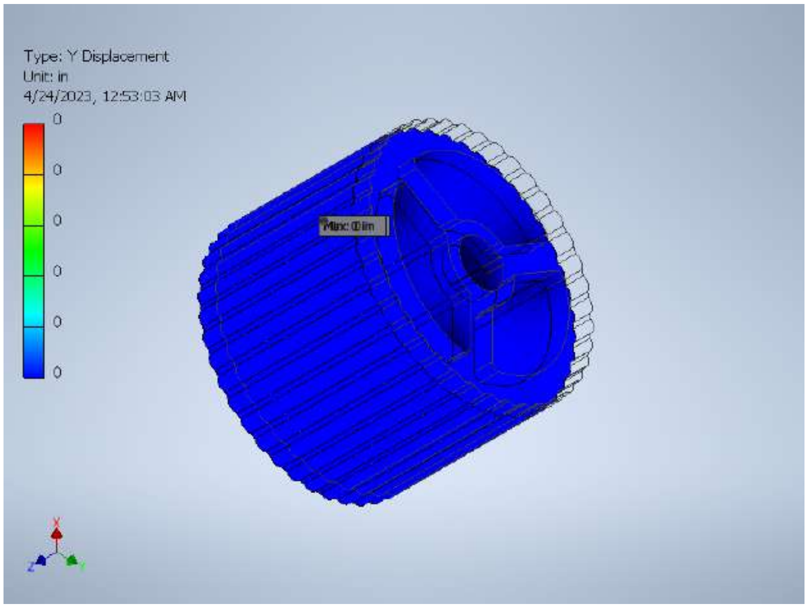
F3 0.00 Hz X Displacement



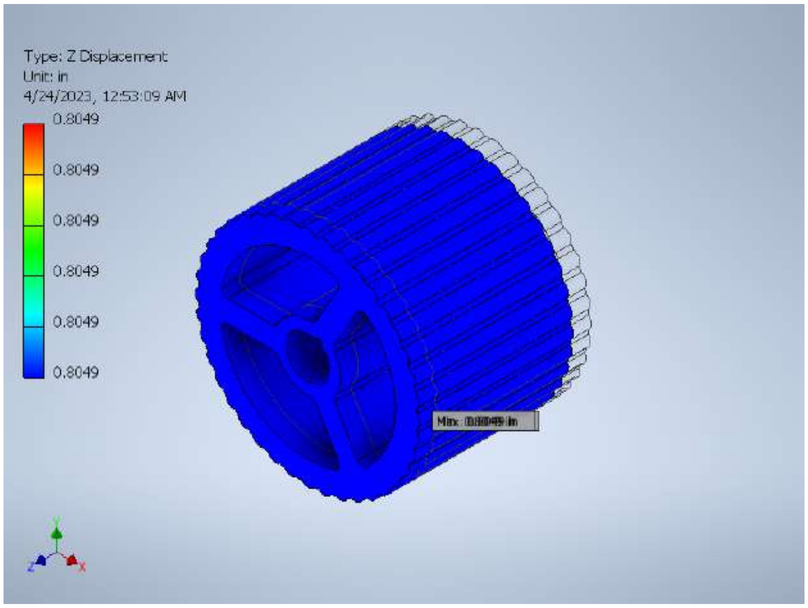


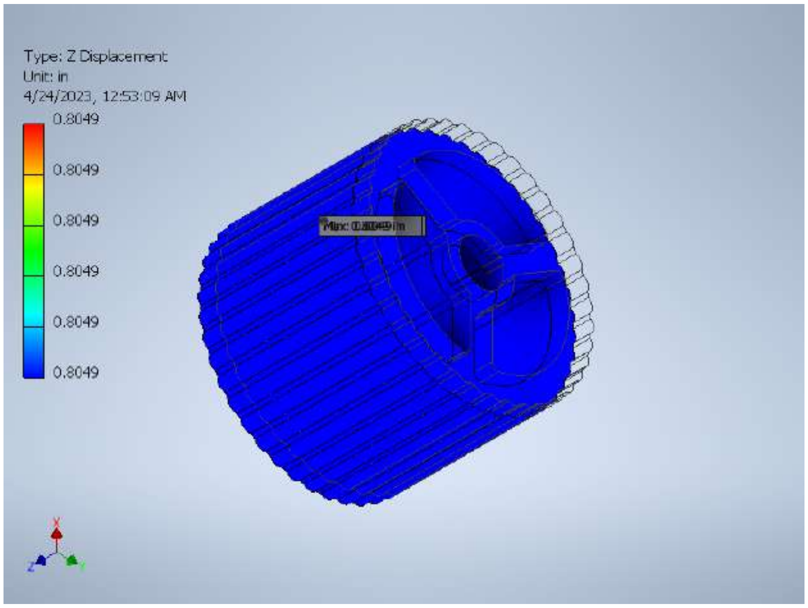
F3 0.00 Hz Y Displacement



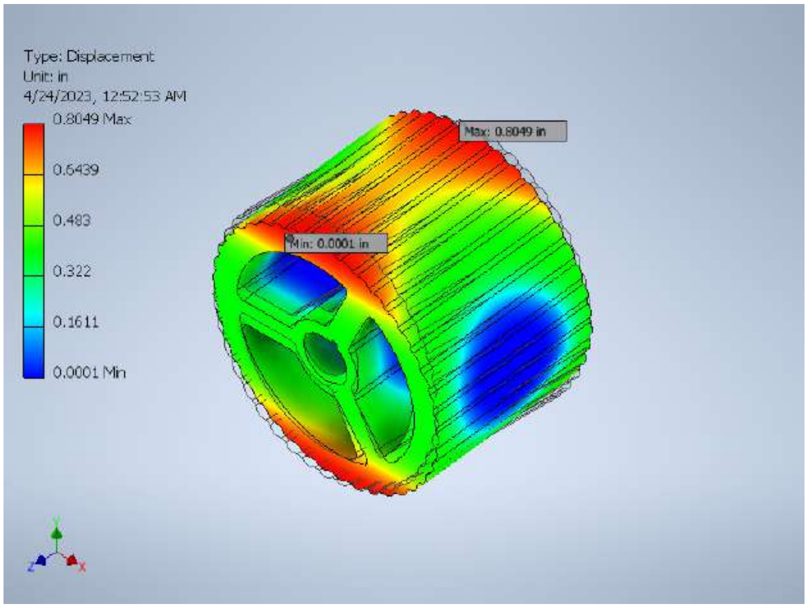


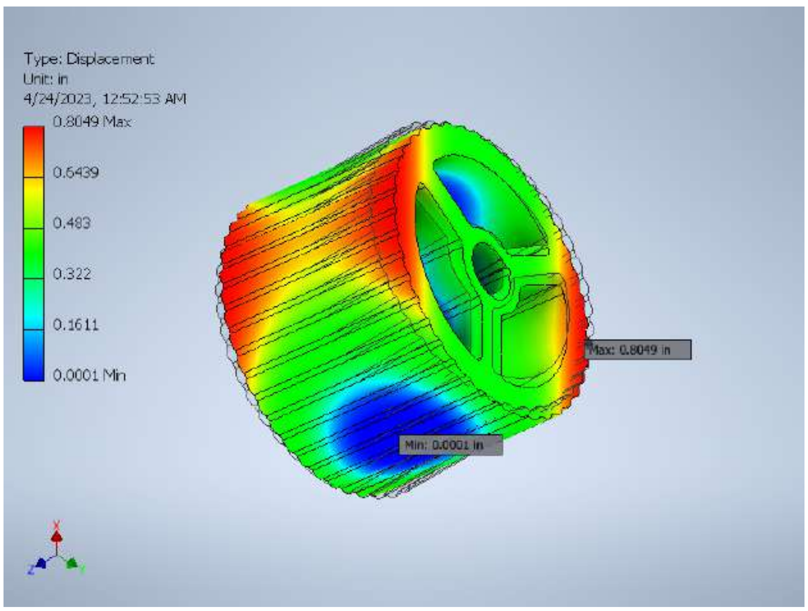
F3 0.00 Hz Z Displacement



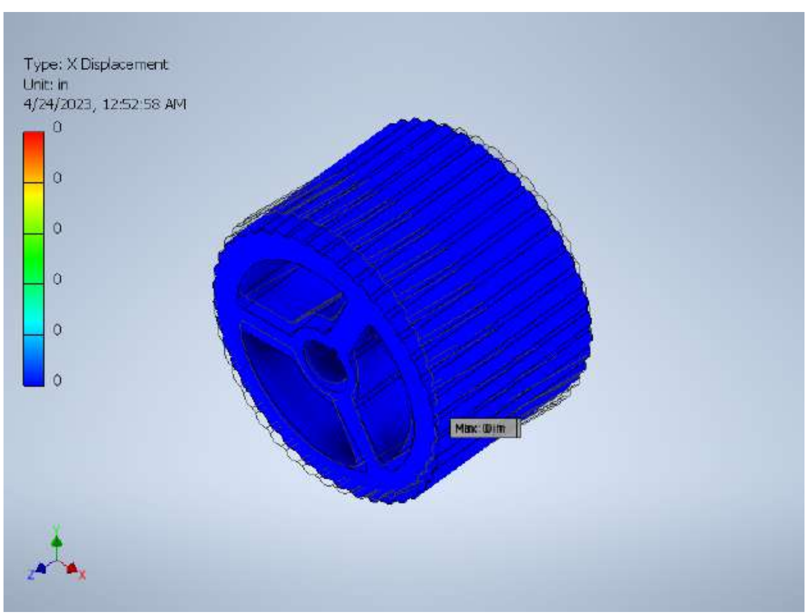


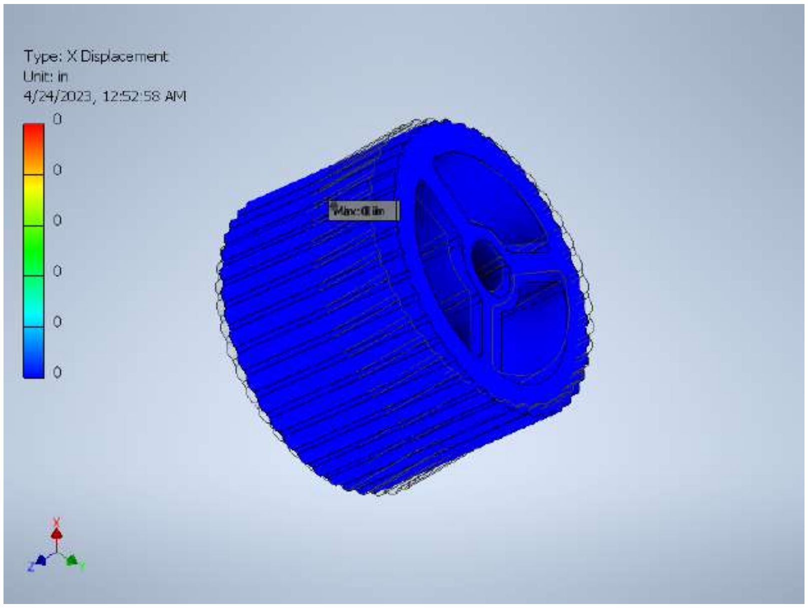
F4 0.00 Hz Displacement



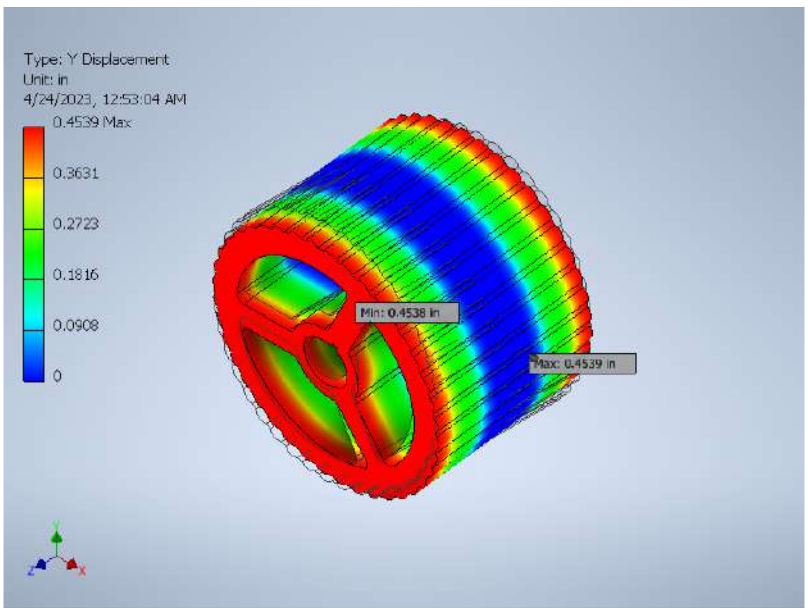


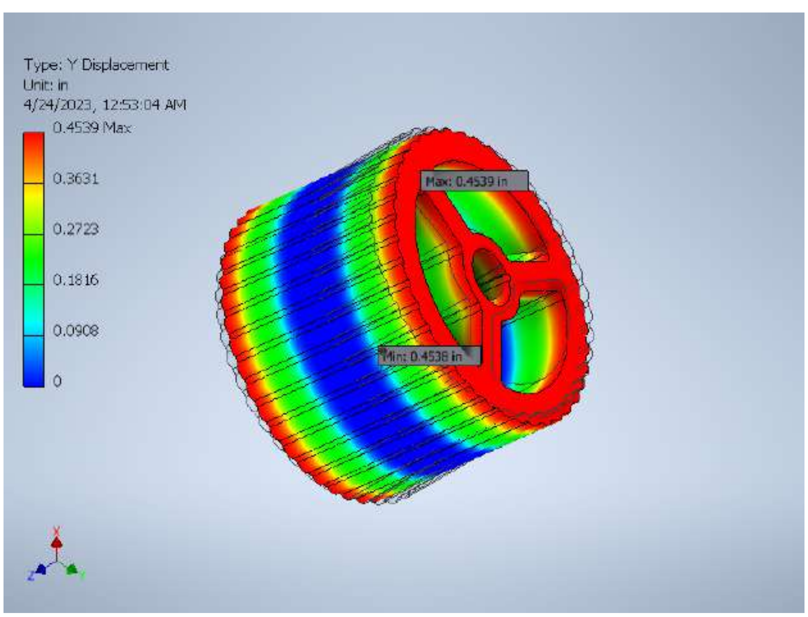
F4 0.00 Hz X Displacement



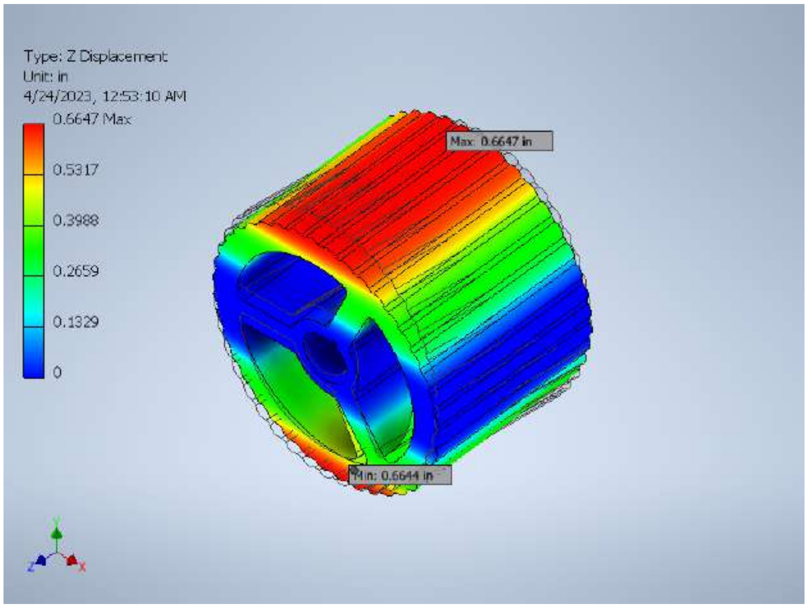


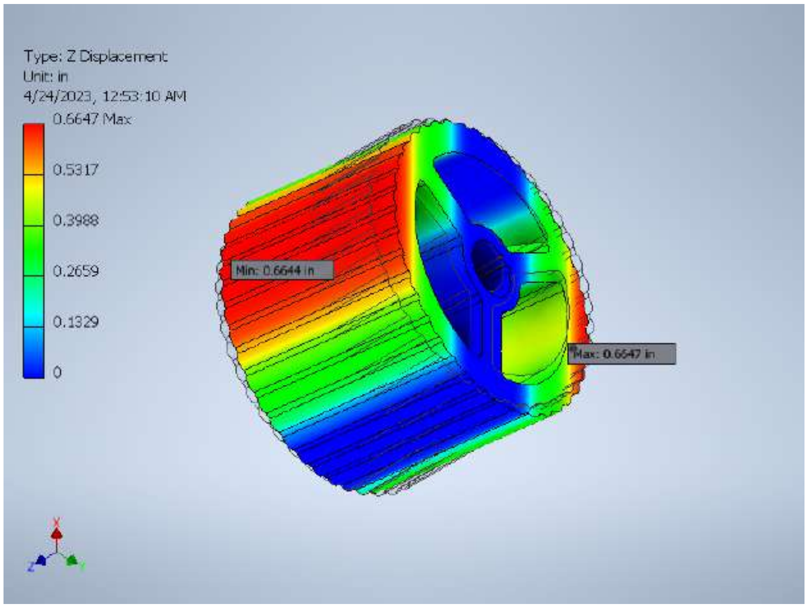
F4 0.00 Hz Y Displacement



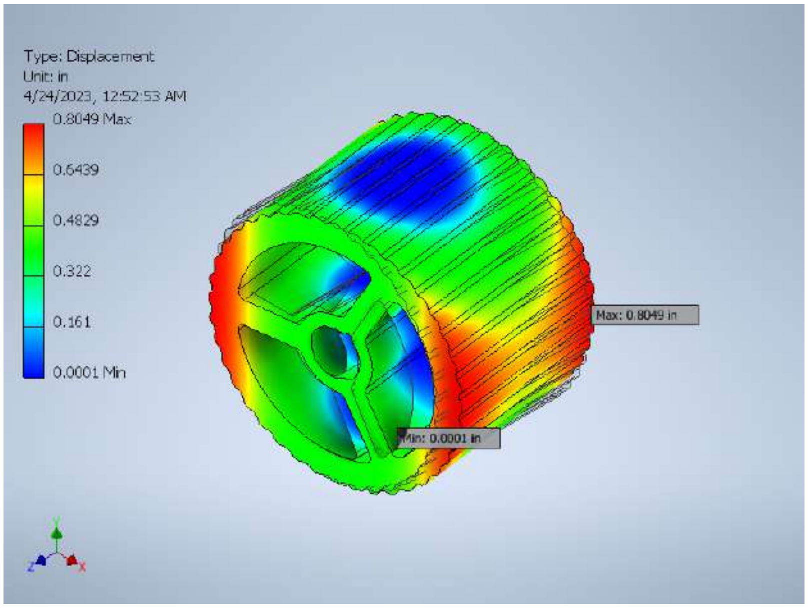


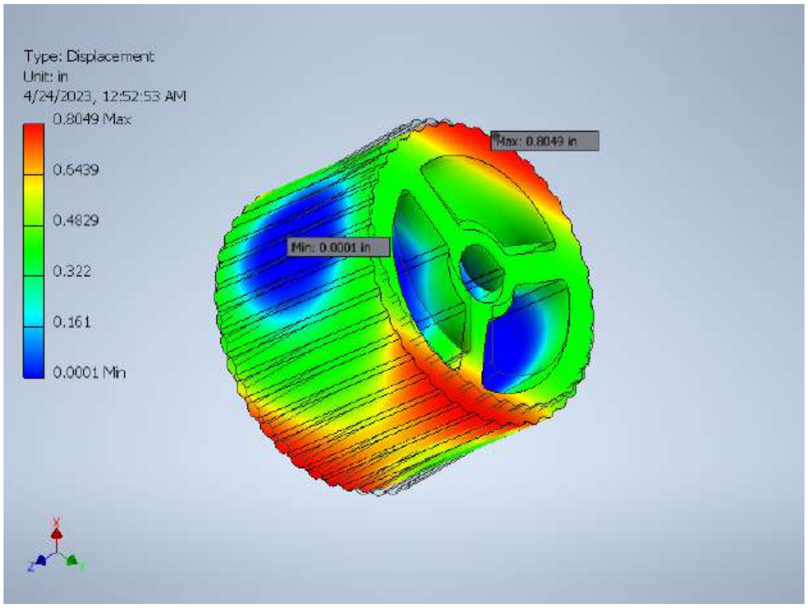
F4 0.00 Hz Z Displacement



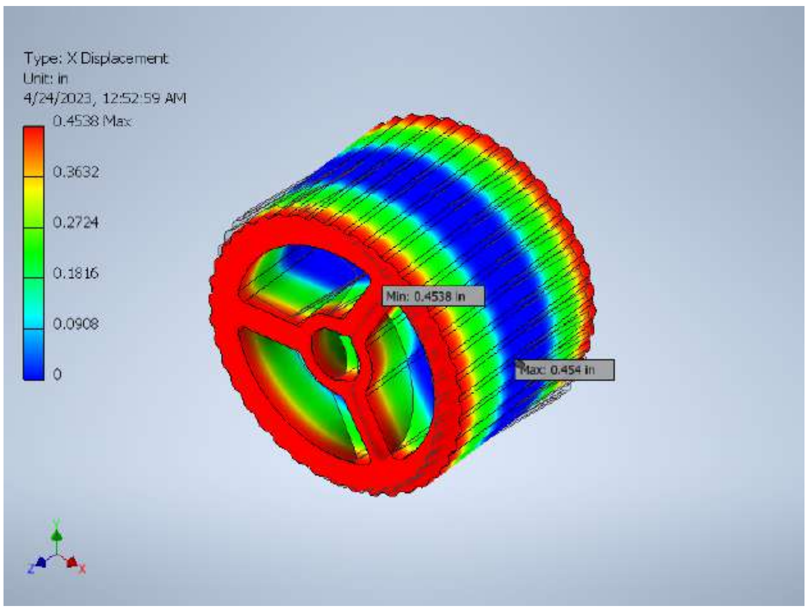


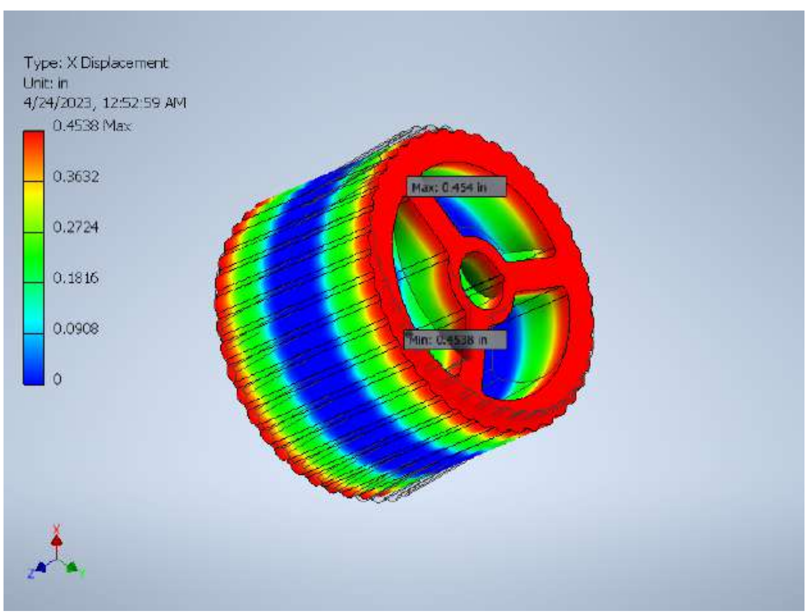
F5 0.00 Hz Displacement



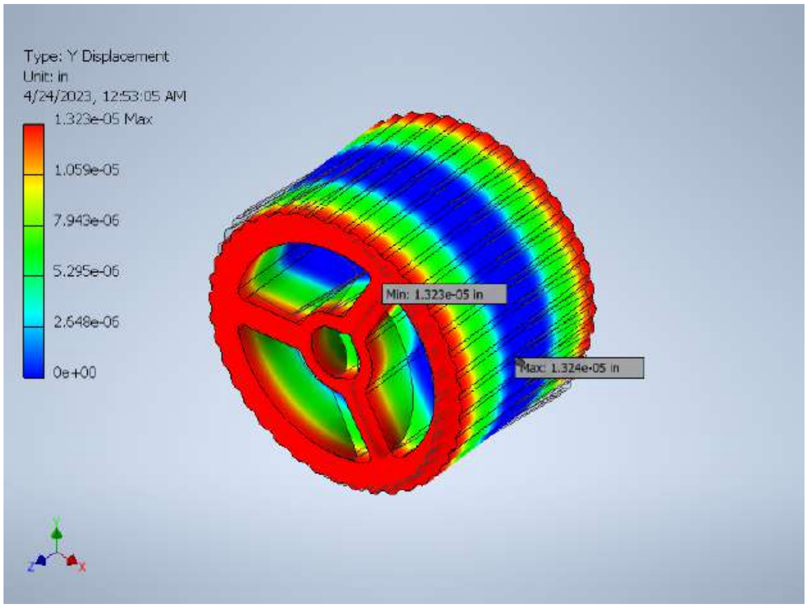


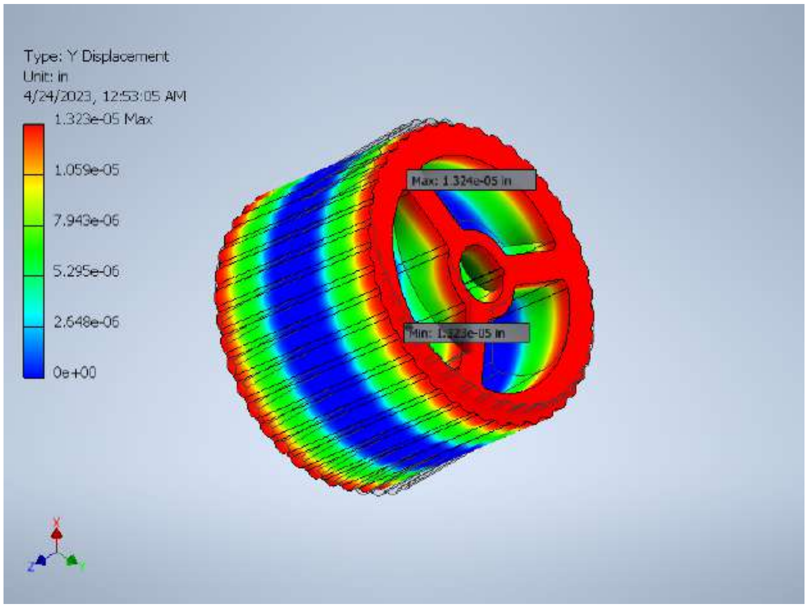
F5 0.00 Hz X Displacement



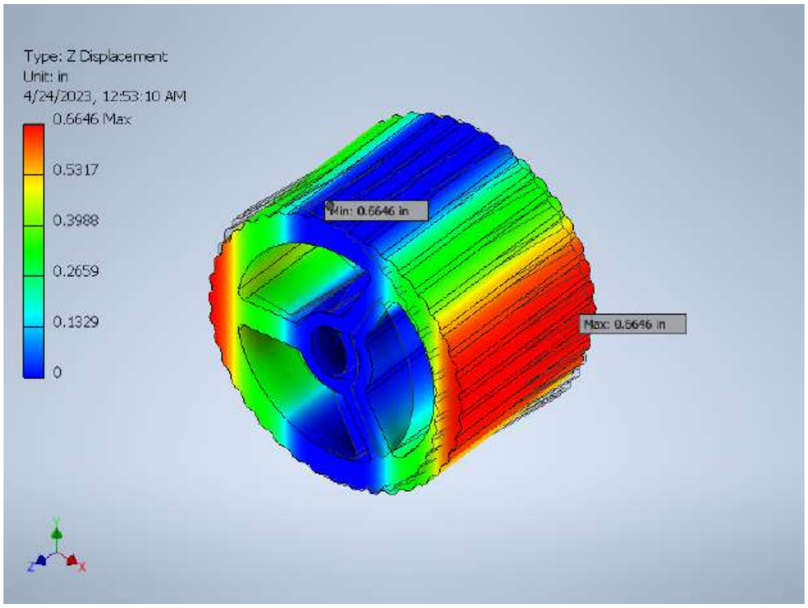


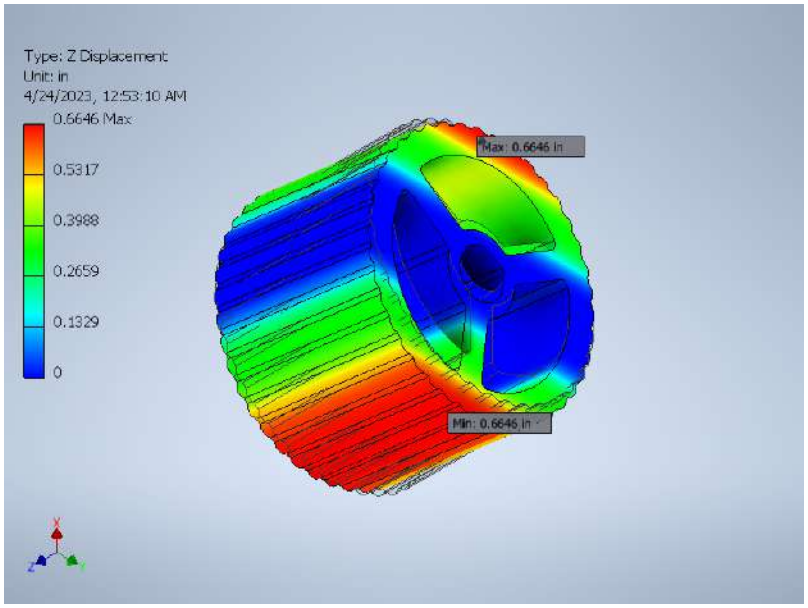
F5 0.00 Hz Y Displacement



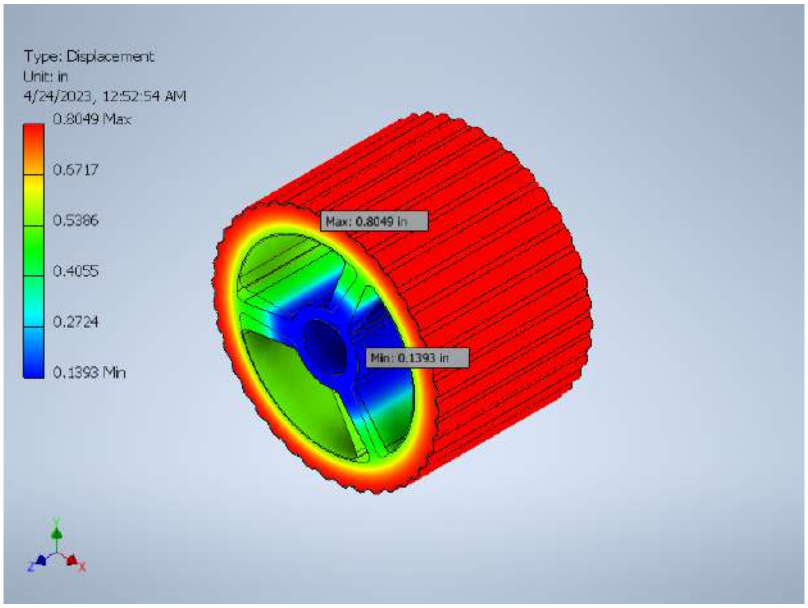


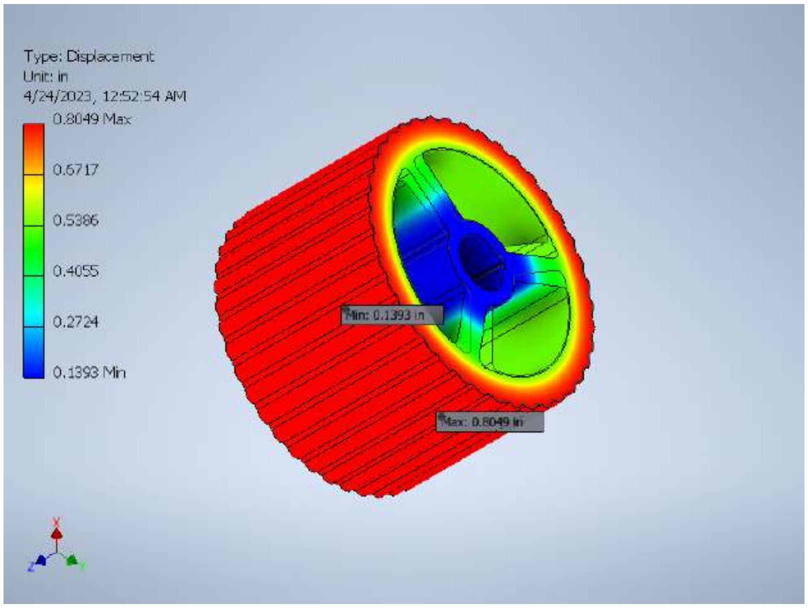
F5 0.00 Hz Z Displacement



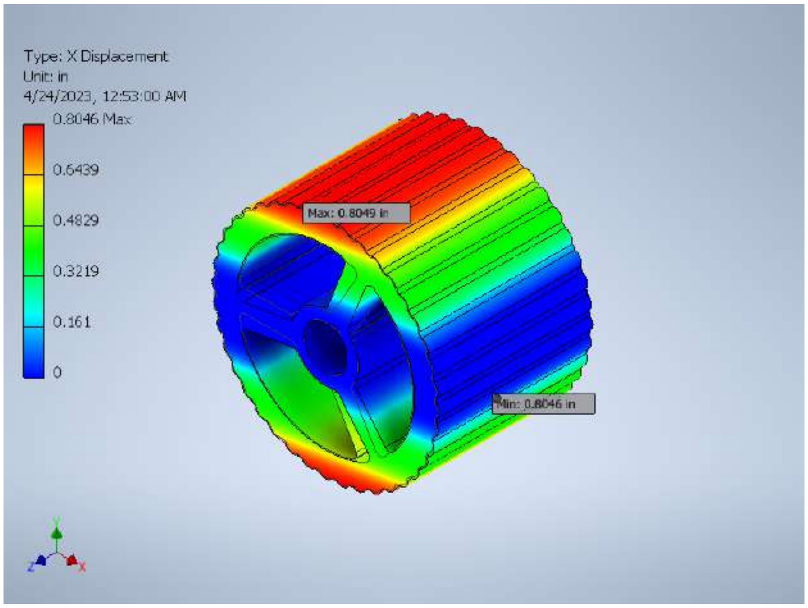


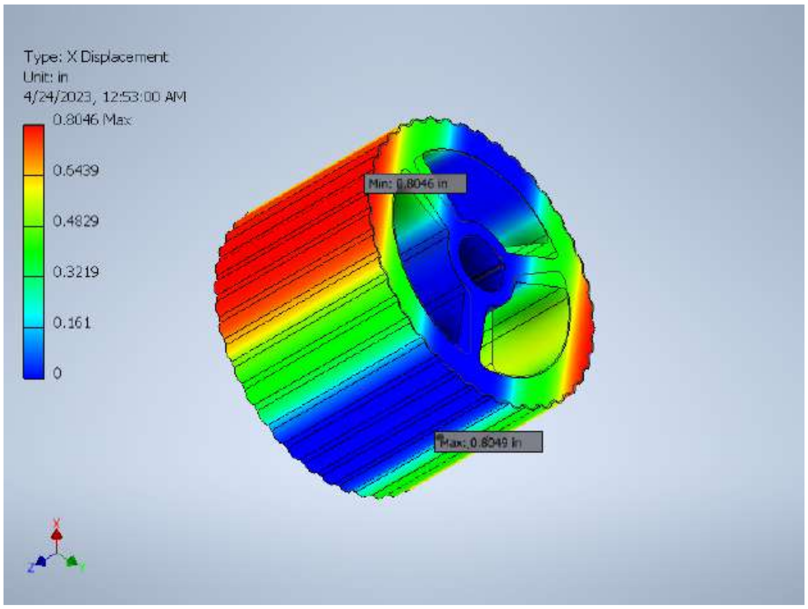
F6 0.00 Hz Displacement



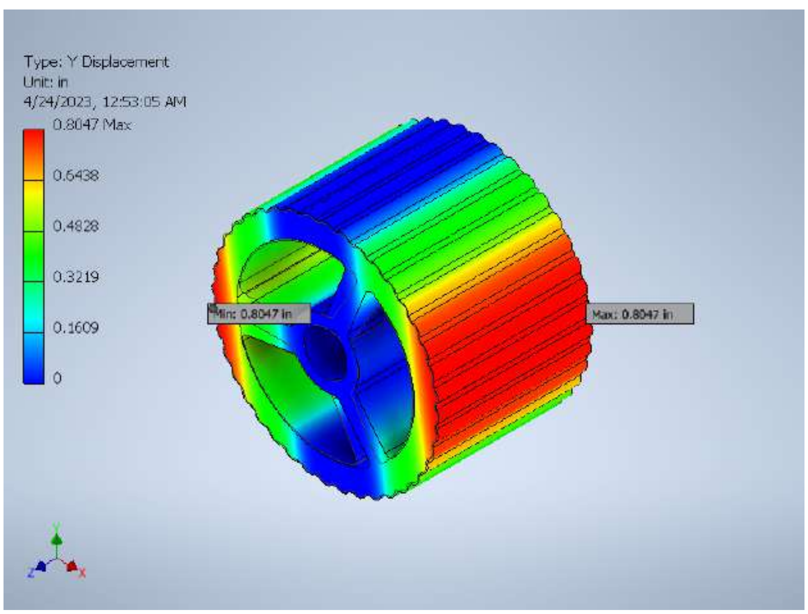


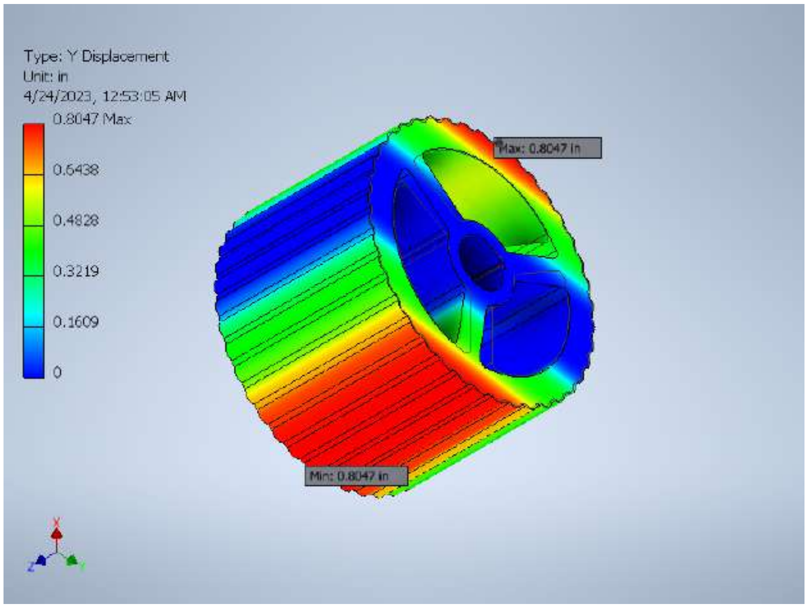
F6 0.00 Hz X Displacement



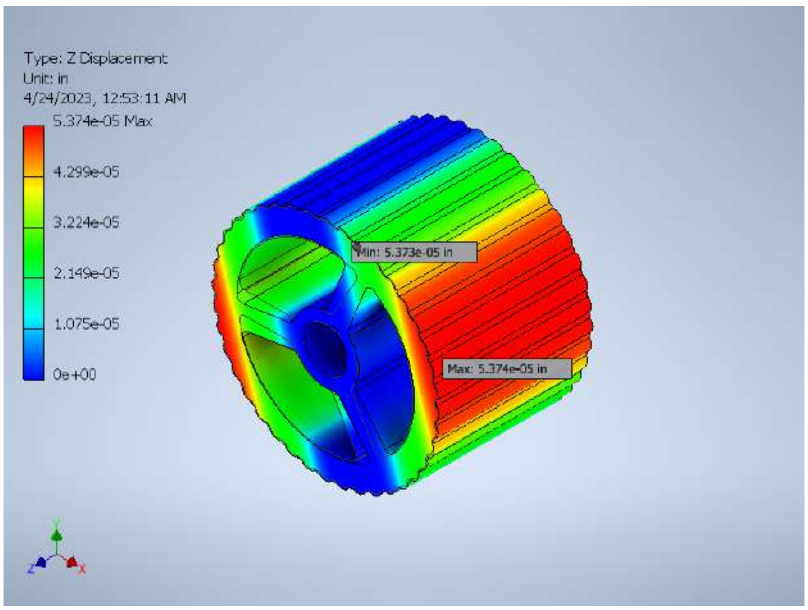


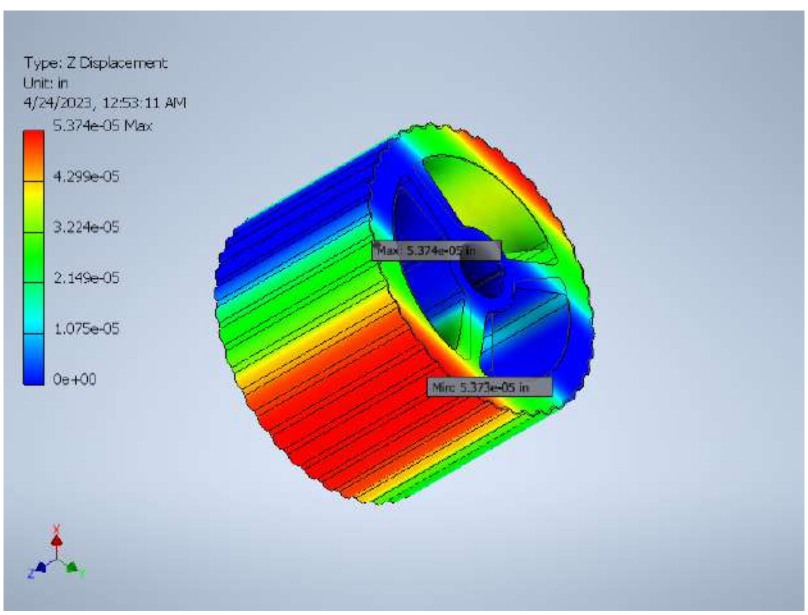
F6 0.00 Hz Y Displacement



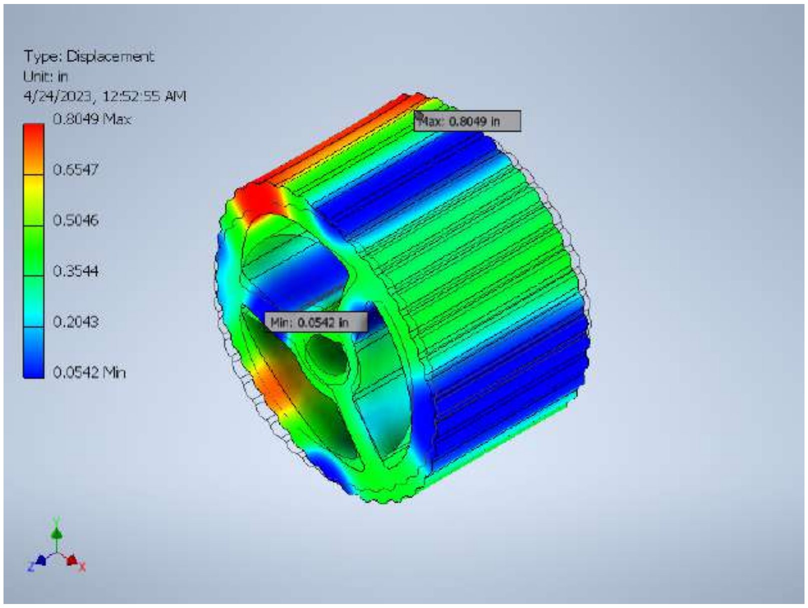


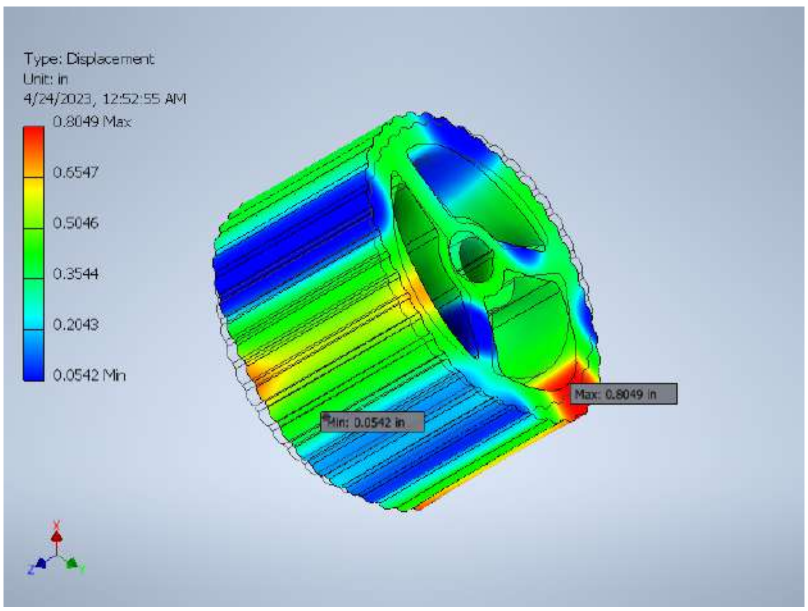
F6 0.00 Hz Z Displacement



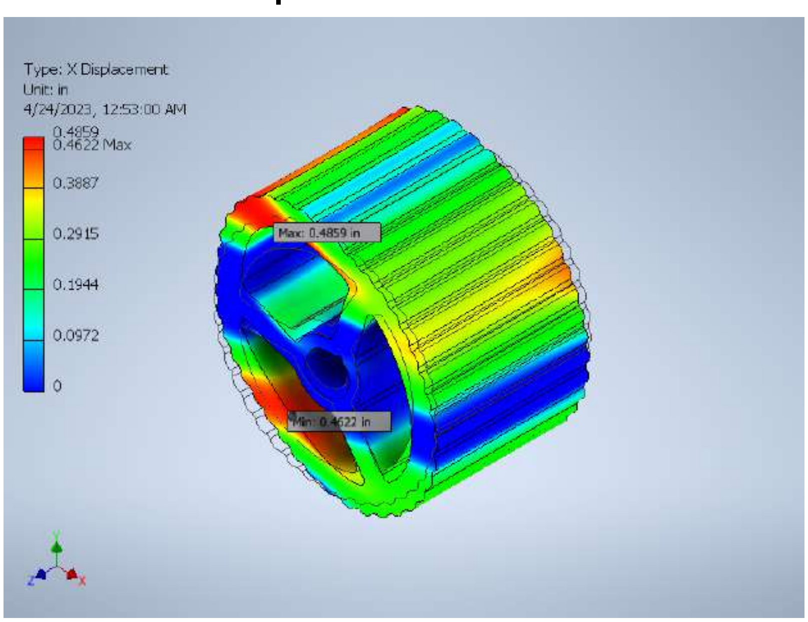


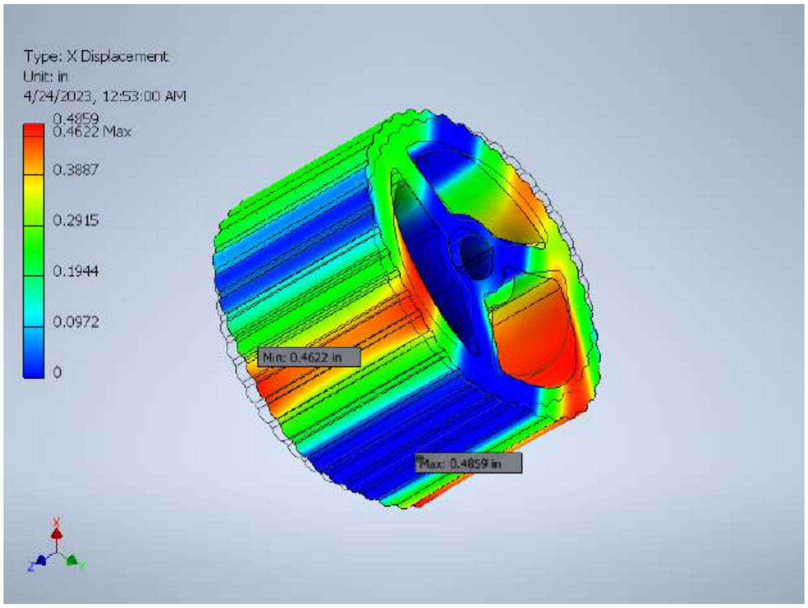
F7 2472.76 Hz Displacement



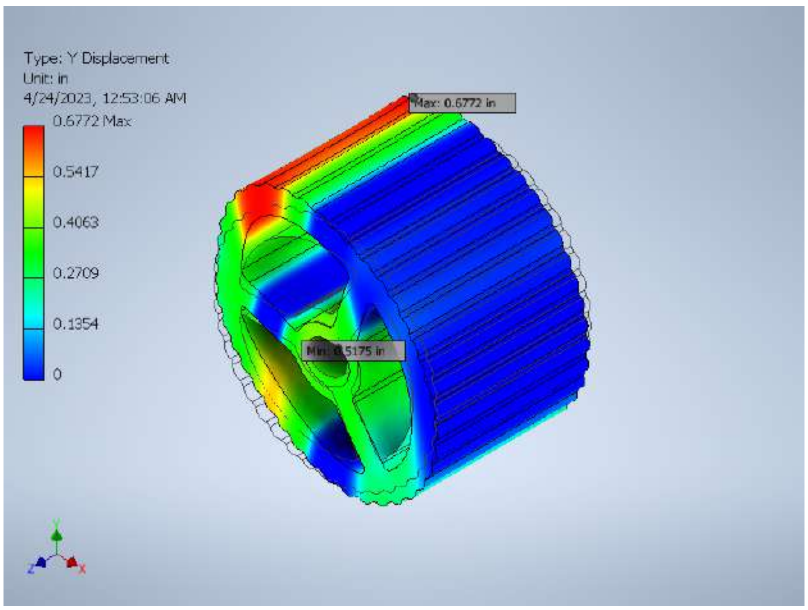


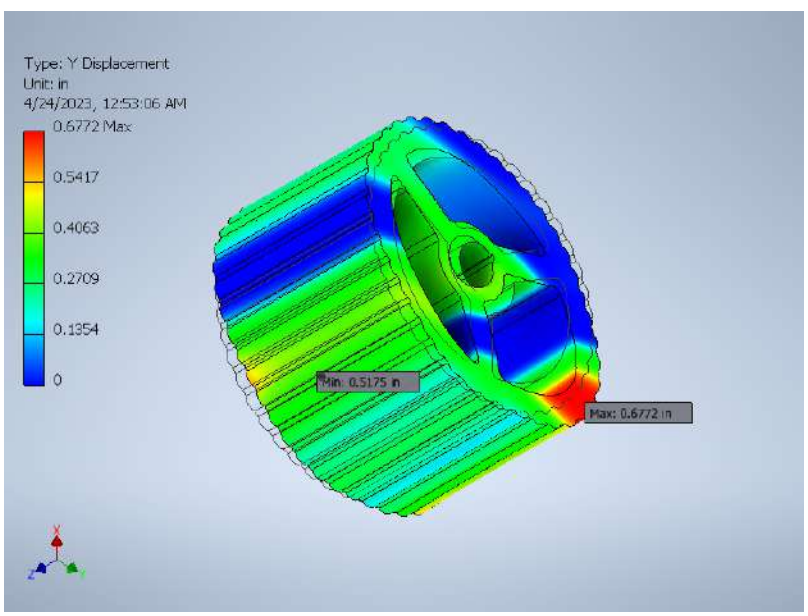
F7 2472.76 Hz X Displacement



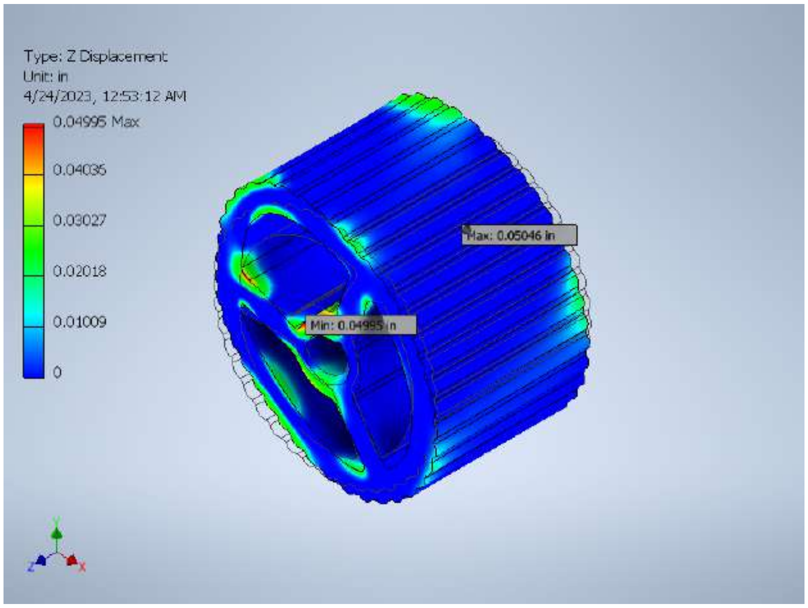


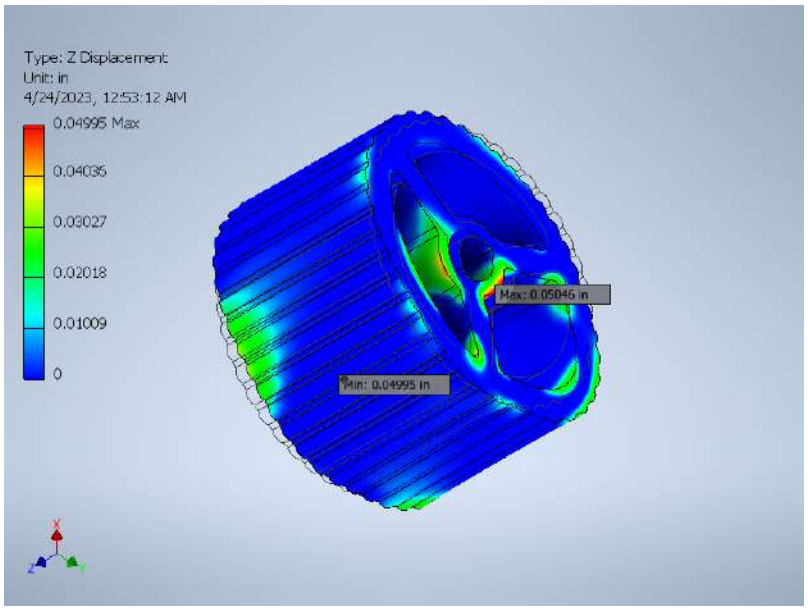
F7 2472.76 Hz Y Displacement



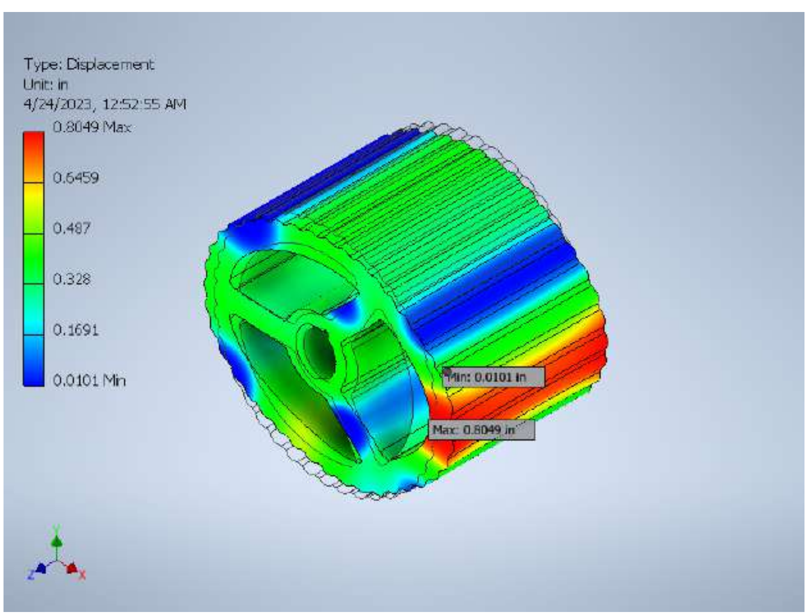


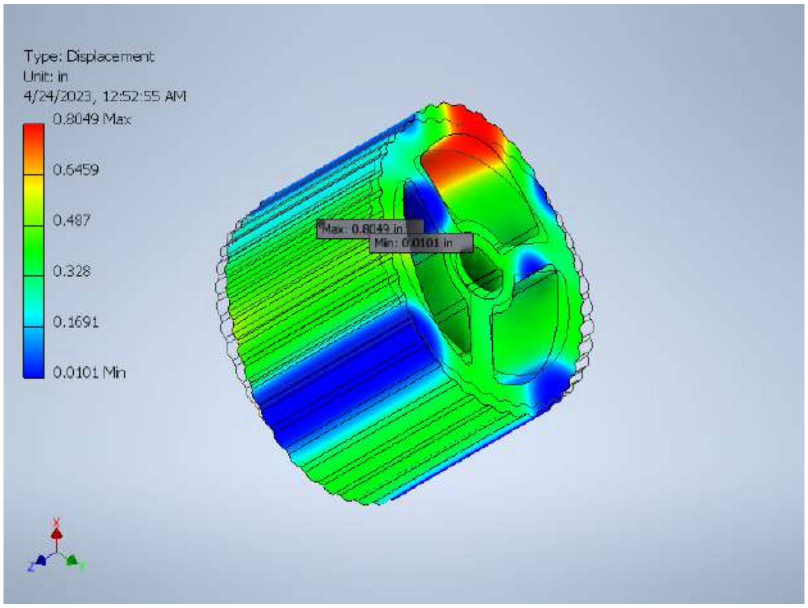
F7 2472.76 Hz Z Displacement



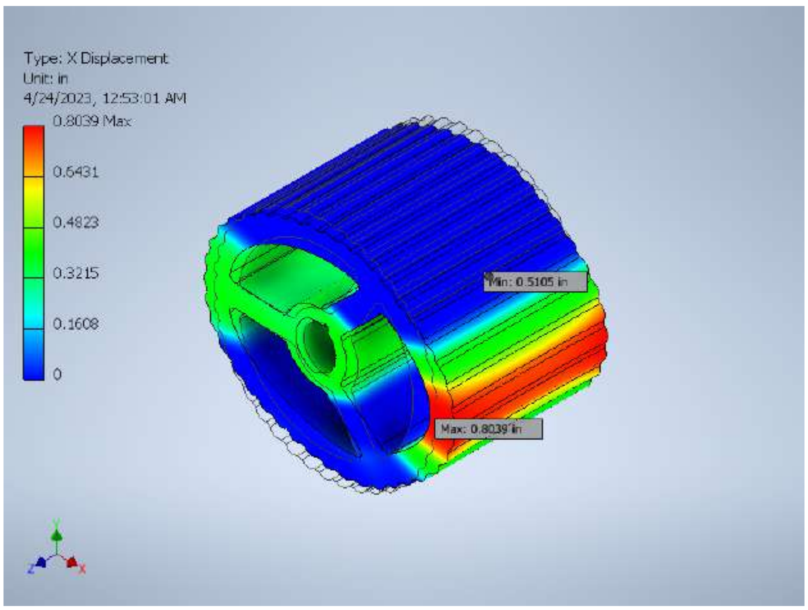


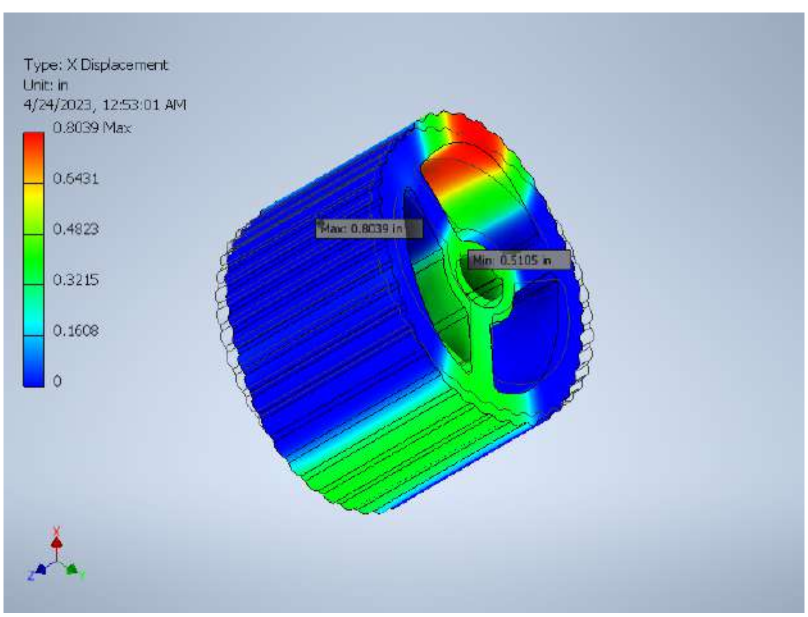
F8 2473.74 Hz Displacement



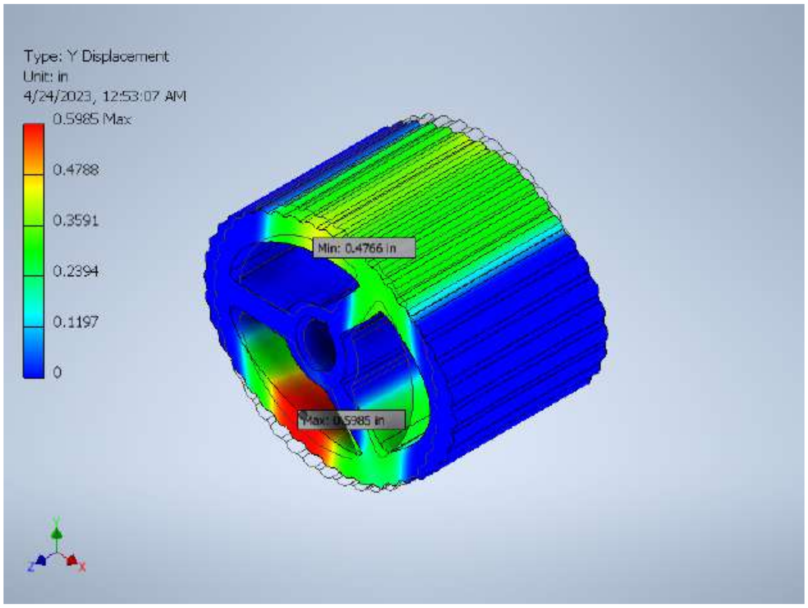


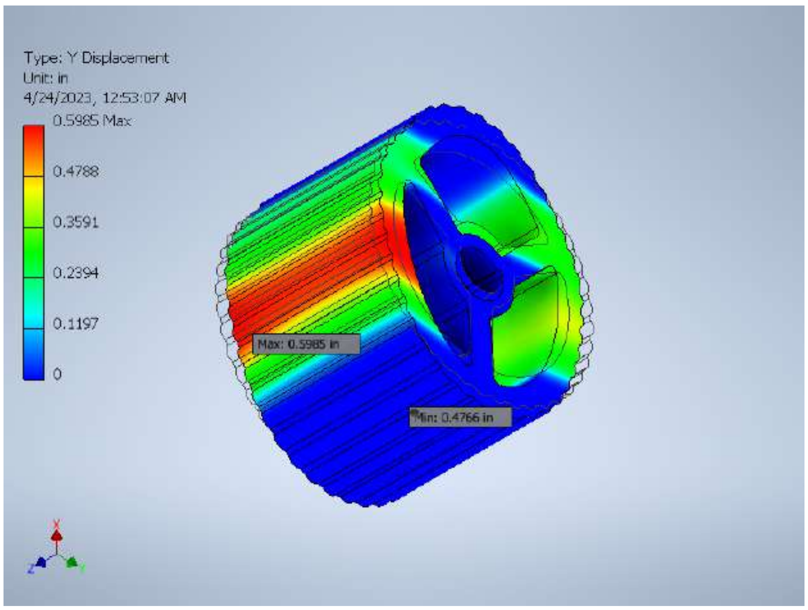
F8 2473.74 Hz X Displacement



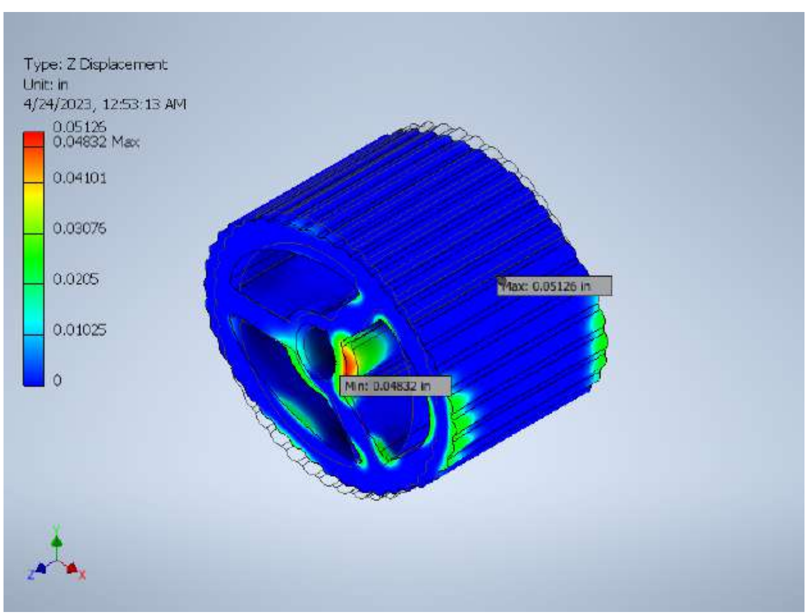


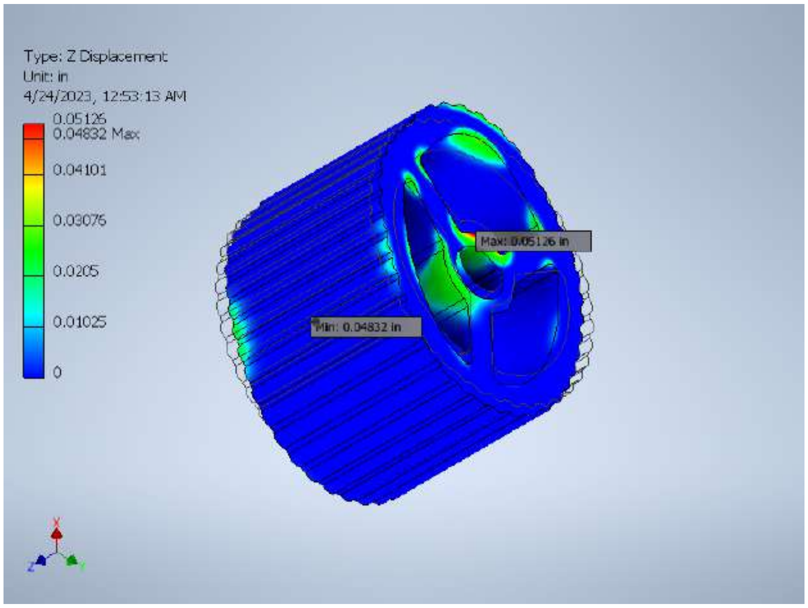
F8 2473.74 Hz Y Displacement





F8 2473.74 Hz Z Displacement





Static Analysis:1

General objective and settings:

Design Objective	Single Point
Study Type	Static Analysis
Last Modification Date	4/24/2023, 12:49 AM
Model State	[Primary]
Detect and Eliminate Rigid Body Modes	No

iProperties

Summary

Title	6325K32_Metal Gear - 14-1-2 Degree Pressure Angle.STEP
Author	Administrator
Company	Managed by Terraform

Project

Part Number	Drum gear
Description	STEP AP203
Revision Number	ANY
Designer	luisk
Cost	$0.00
Date Created	10/20/2022

Status

Design Status	WorkInProgress

Custom

Sending System	SolidWorks 2017
Preprocessor	SwSTEP 2.0

Physical

Material	Stainless Steel

Density	0.289018 lbmass/in^3
Mass	84.7072 lbmass
Area	670.021 in^2
Volume	293.086 in^3
Center of Gravity	x=-0.000378032 in y=-0.00065477 in z=3.5 in

Note: Physical values could be different from Physical values used by FEA reported below.

Mesh settings:

Avg. Element Size (fraction of model diameter)	0.1
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	Yes

Material(s)

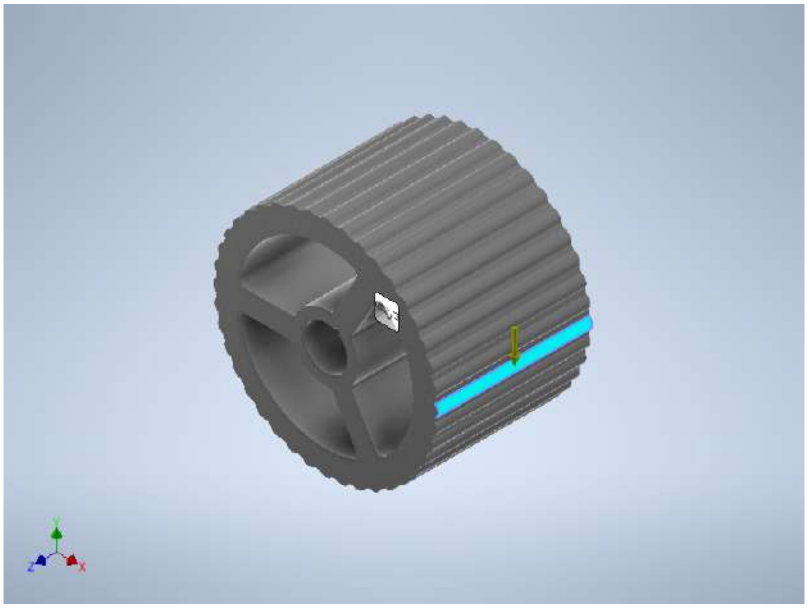
Name	Stainless Steel	
General	Mass Density	0.289018 lbmass/in^3
	Yield Strength	36259.4 psi
	Ultimate Tensile Strength	78320.4 psi
Stress	Young's Modulus	27992.3 ksi
	Poisson's Ratio	0.3 ul
	Shear Modulus	10766.3 ksi
Part Name(s)	CRS-S23-P4-DRUM.ipt	

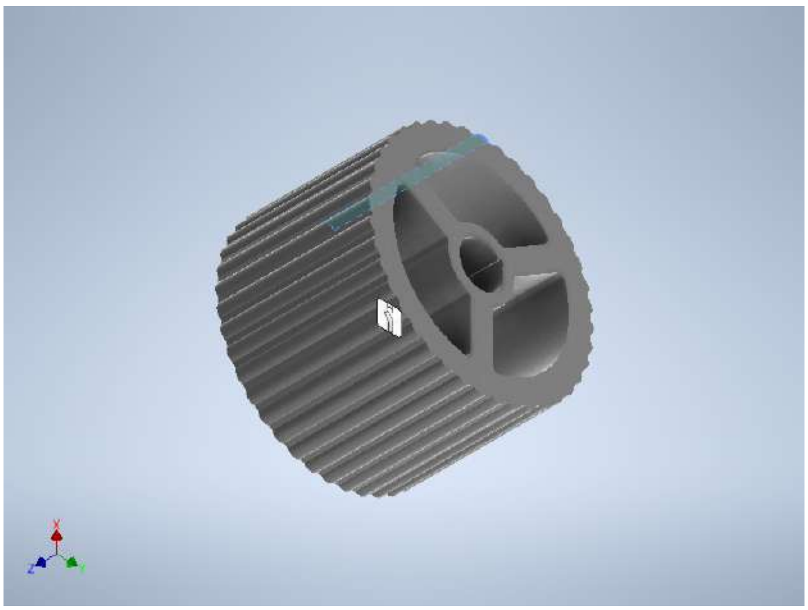
Operating conditions

Force:1

Load Type	Force
Magnitude	250.000 lbforce
Vector X	0.000 lbforce
Vector Y	-250.000 lbforce
Vector Z	0.000 lbforce

Selected Face(s)

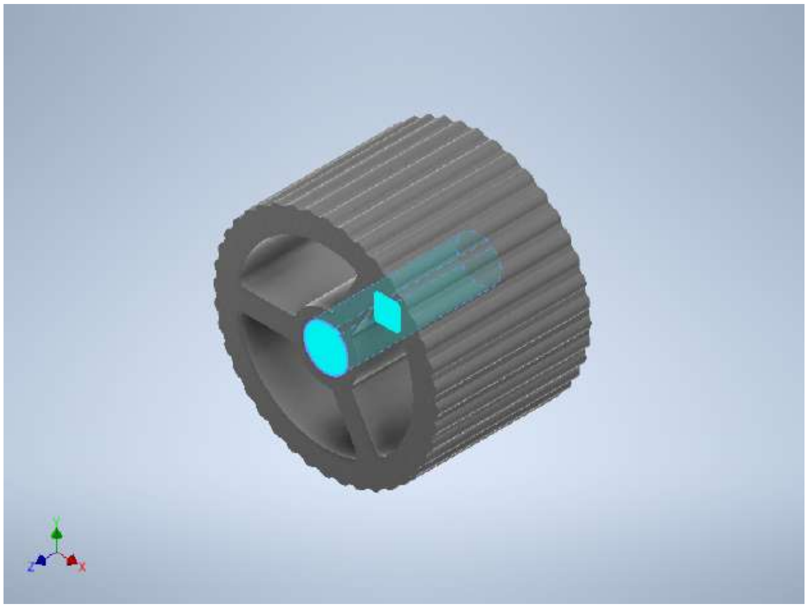


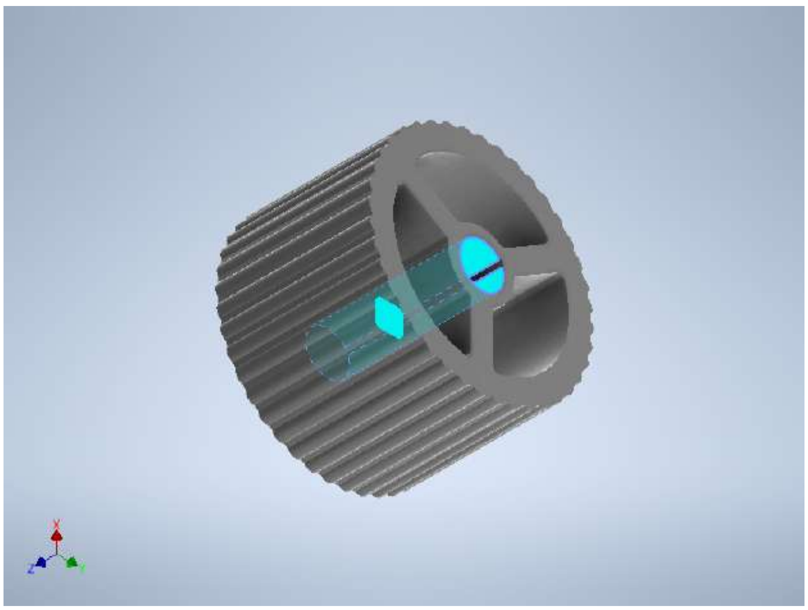


Pin Constraint:1

Constraint Type	Pin Constraint
Fix Radial Direction	Yes
Fix Axial Direction	Yes
Fix Tangential Direction	No

Selected Face(s)

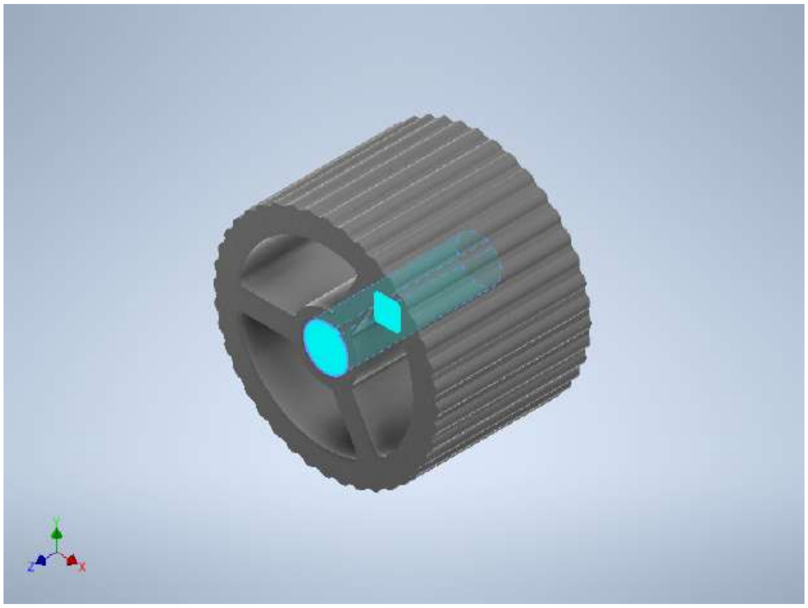


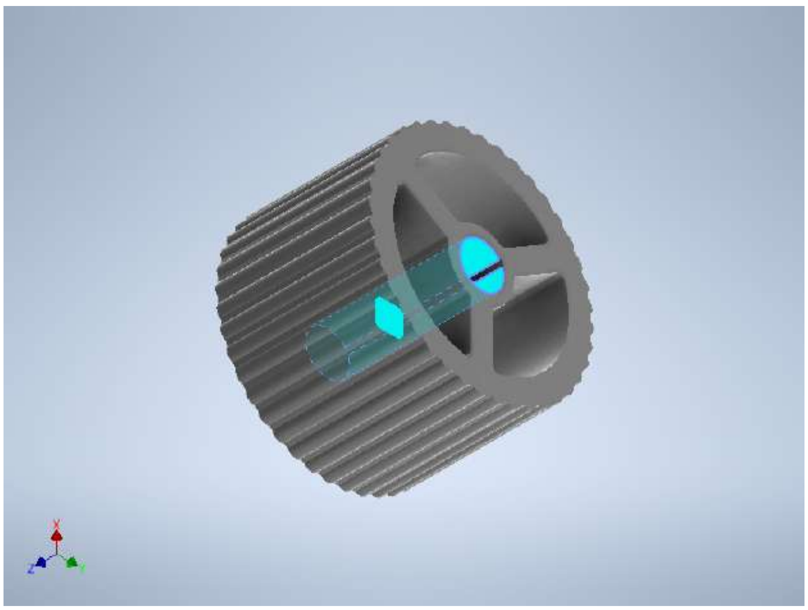


Fixed Constraint:1

Constraint Type	Fixed Constraint

Selected Face(s)





Results

Reaction Force and Moment on Constraints

Constraint Name	Reaction Force		Reaction Moment	
	Magnitude	Component (X,Y,Z)	Magnitude	Component (X,Y,Z)
Pin Constraint:1	125.001 lbforce	0 lbforce	53.0561 lbforce ft	0 lbforce ft
		125.001 lbforce		0 lbforce ft
		0 lbforce		53.0561 lbforce ft
Fixed Constraint:1	125.001 lbforce	0 lbforce	53.0561 lbforce ft	0 lbforce ft
		125.001 lbforce		0 lbforce ft
		0 lbforce		53.0561 lbforce ft

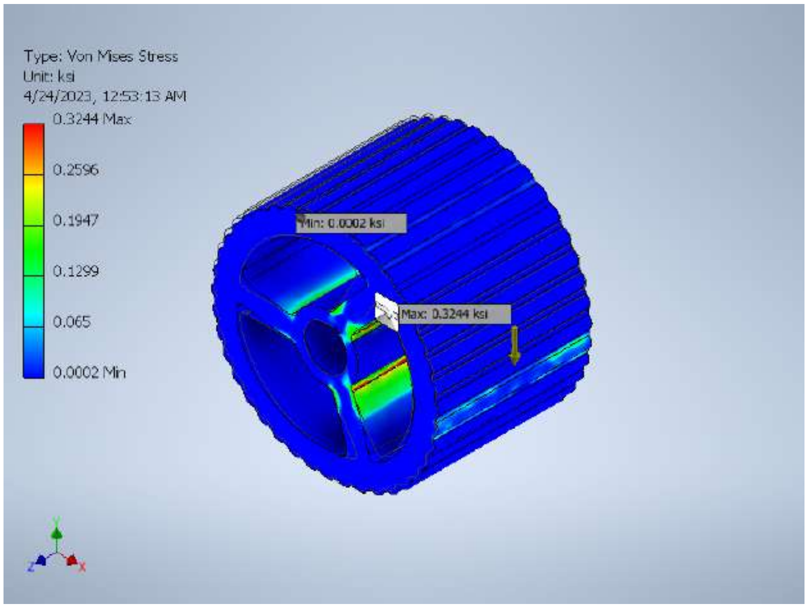
Result Summary

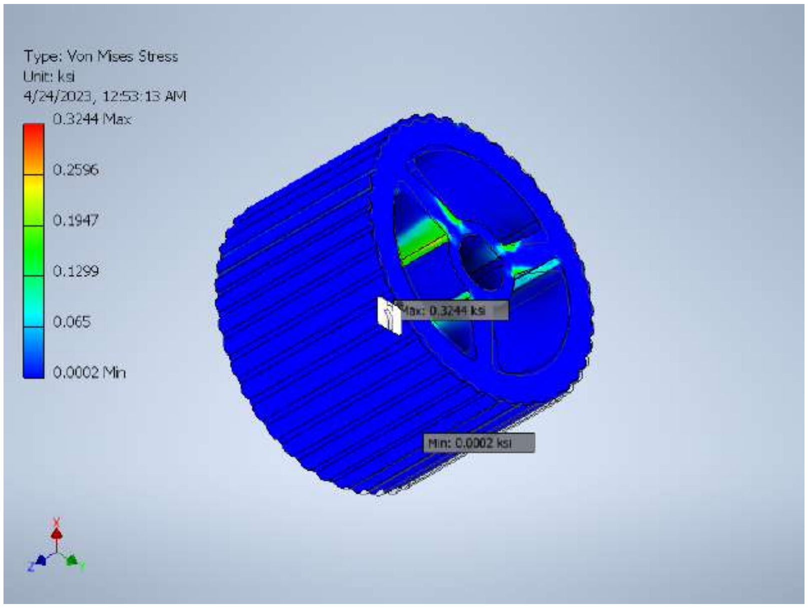
Name	Minimum	Maximum
Volume	293.086 in^3	
Mass	84.7072 lbmass	
Von Mises Stress	0.000156164 ksi	0.324442 ksi
1st Principal Stress	-0.055082 ksi	0.376287 ksi

3rd Principal Stress	-0.374156 ksi	0.0545432 ksi
Displacement	0 in	0.0000734676 in
Safety Factor	15 ul	15 ul
Stress XX	-0.237734 ksi	0.222778 ksi
Stress XY	-0.113576 ksi	0.151292 ksi
Stress XZ	-0.0254008 ksi	0.0267272 ksi
Stress YY	-0.352399 ksi	0.36185 ksi
Stress YZ	-0.0300834 ksi	0.0369684 ksi
Stress ZZ	-0.118225 ksi	0.118375 ksi
X Displacement	-0.0000624483 in	0.0000625761 in
Y Displacement	-0.0000734675 in	0.0000521097 in
Z Displacement	-0.00000184352 in	0.00000185155 in
Equivalent Strain	0.00000000488508 ul	0.0000105905 ul
1st Principal Strain	0.00000000490755 ul	0.0000119051 ul
3rd Principal Strain	-0.0000120385 ul	-0.00000000342227 ul
Strain XX	-0.00000701868 ul	0.00000691188 ul
Strain XY	-0.00000527463 ul	0.00000702622 ul
Strain XZ	-0.00000117965 ul	0.00000124125 ul
Strain YY	-0.0000108657 ul	0.0000113102 ul
Strain YZ	-0.00000139712 ul	0.00000171687 ul
Strain ZZ	-0.00000283434 ul	0.00000289358 ul

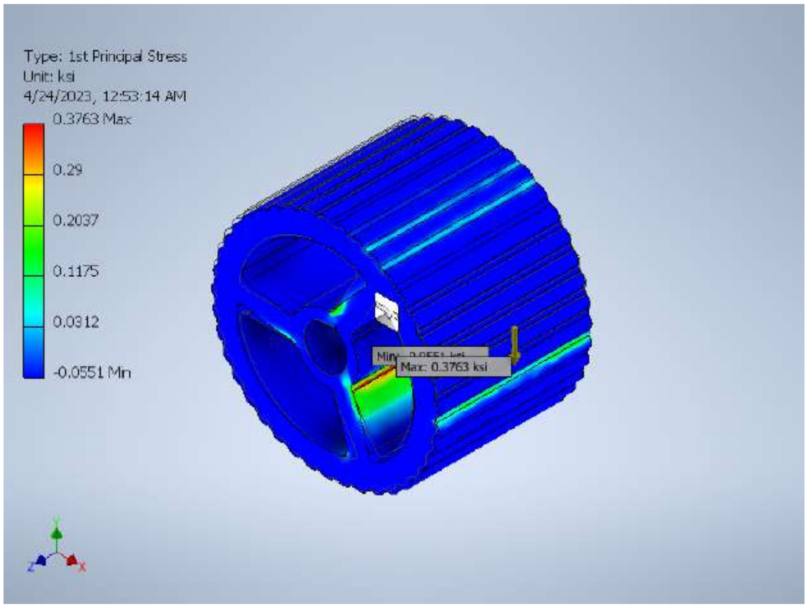
Figures

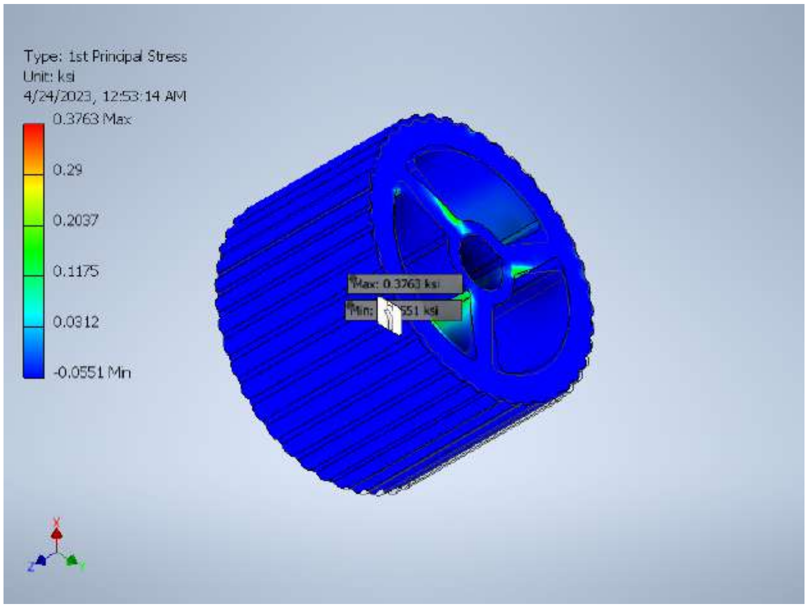
Von Mises Stress



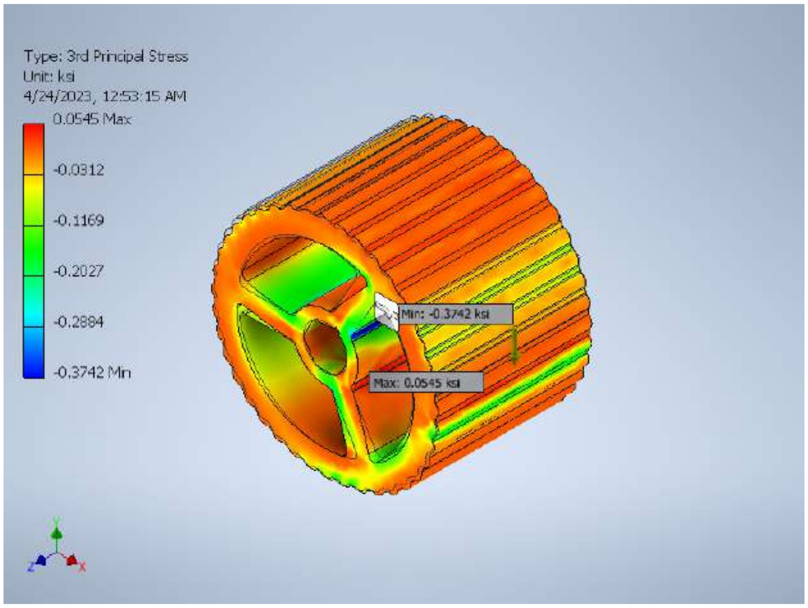


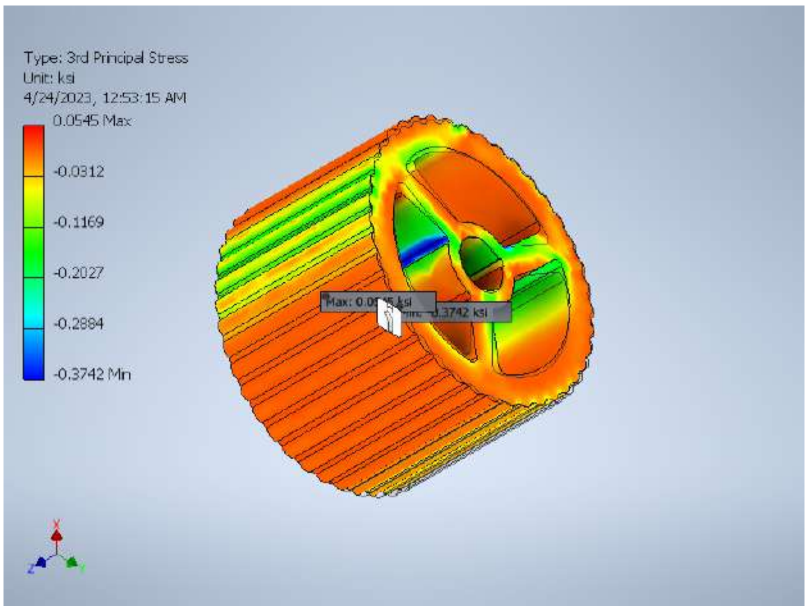
1st Principal Stress



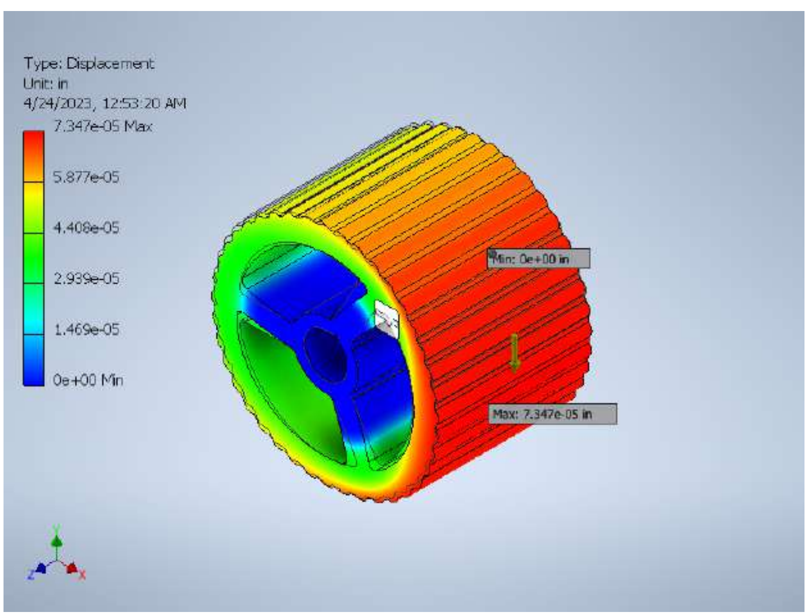


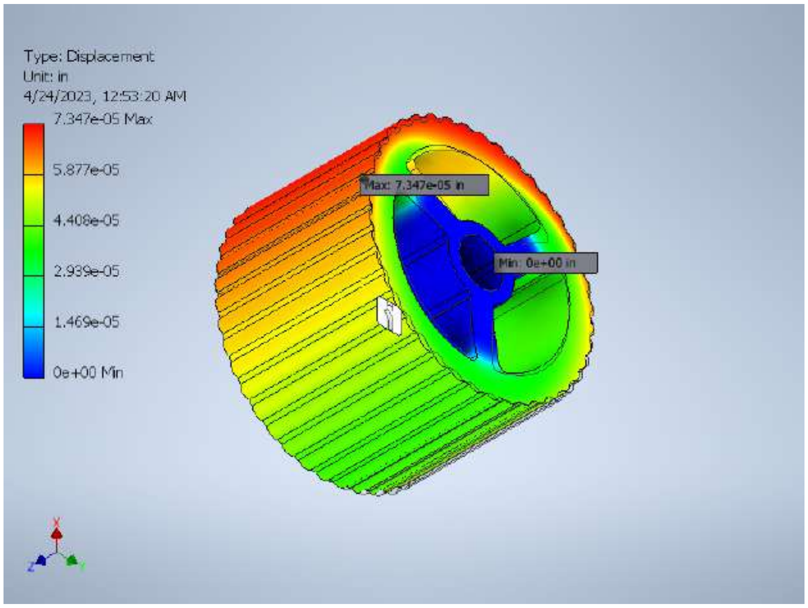
3rd Principal Stress



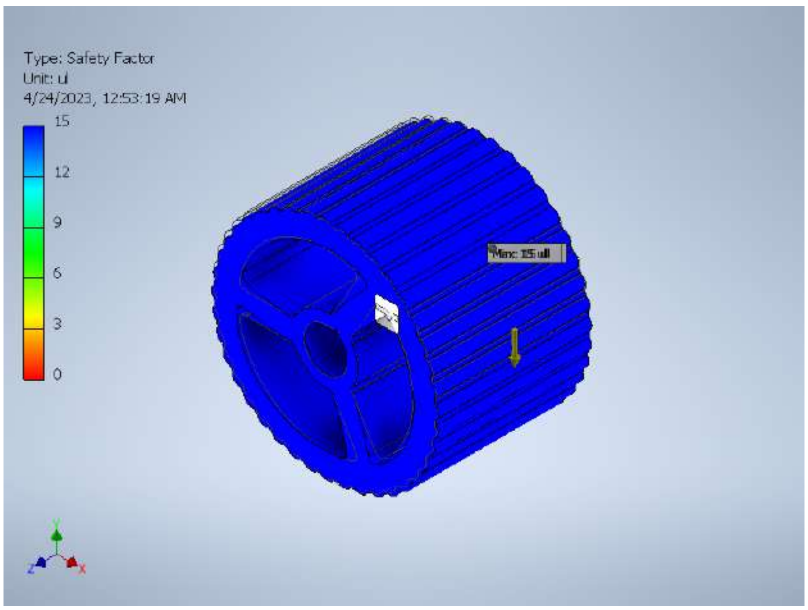


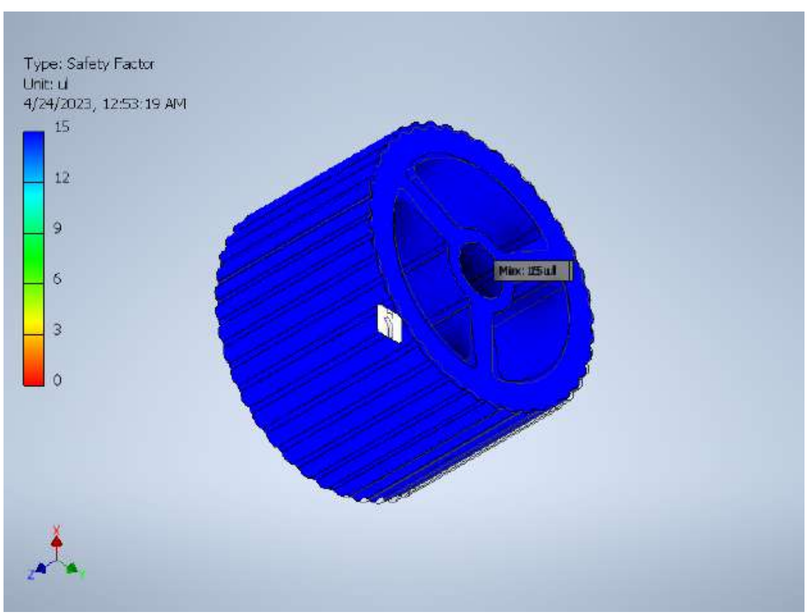
Displacement



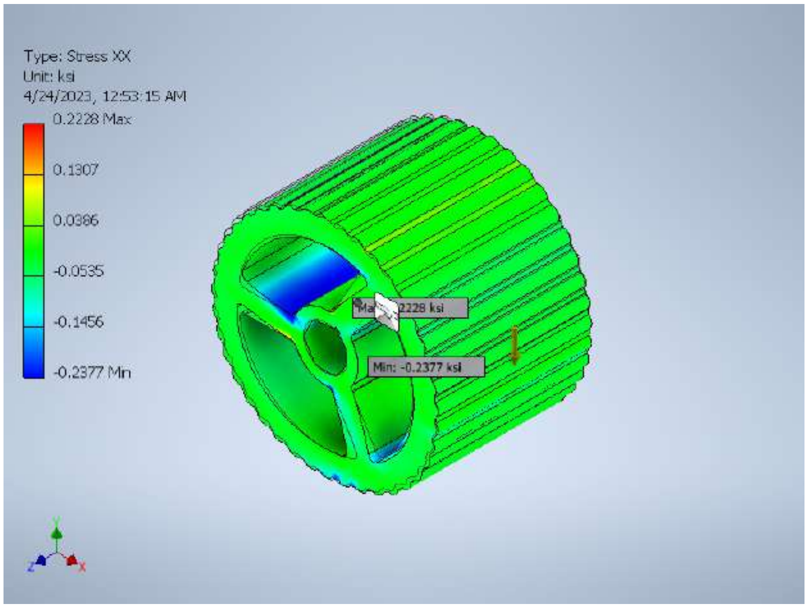


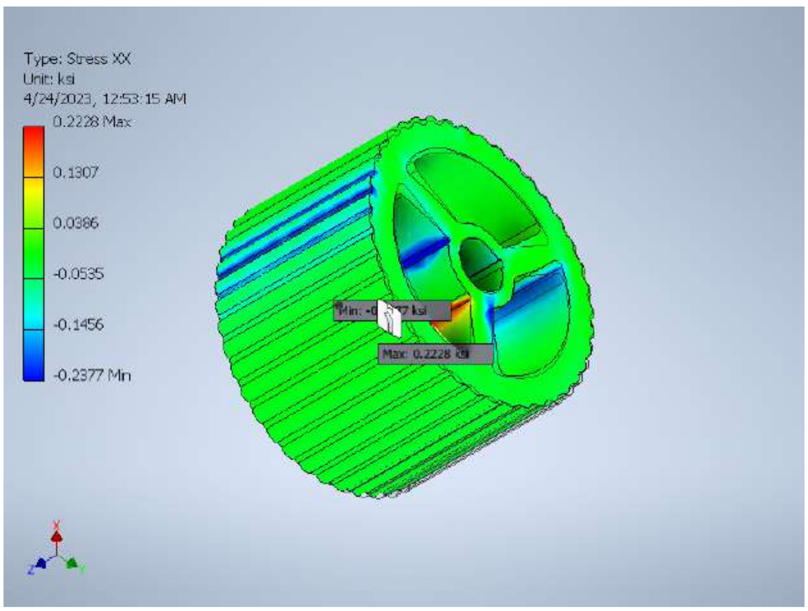
Safety Factor



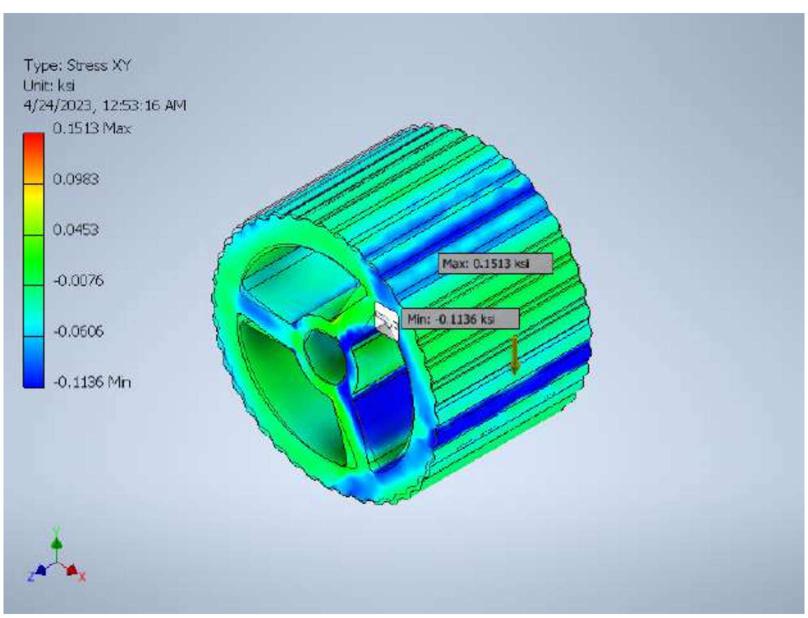


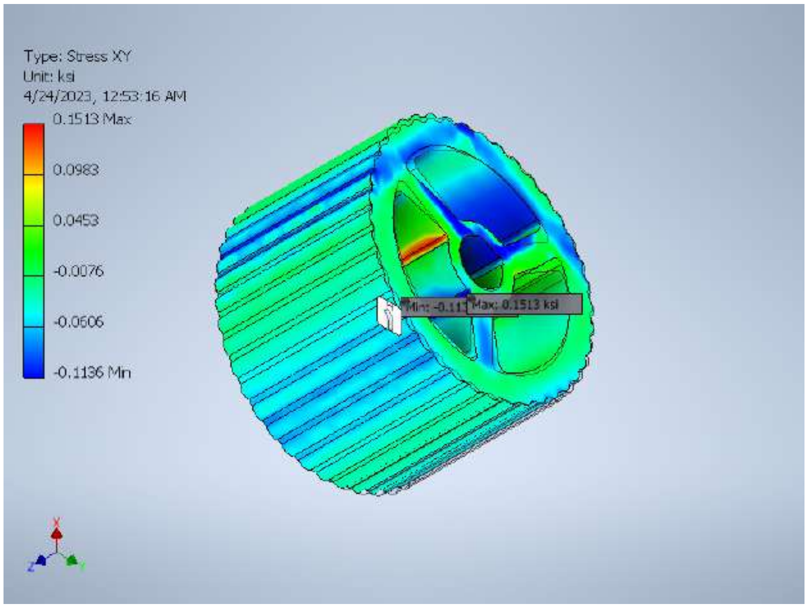
Stress XX



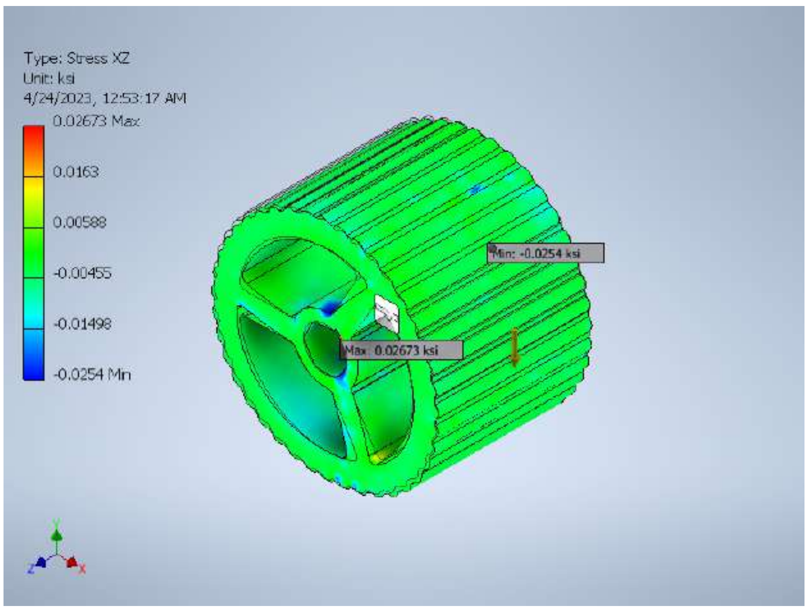


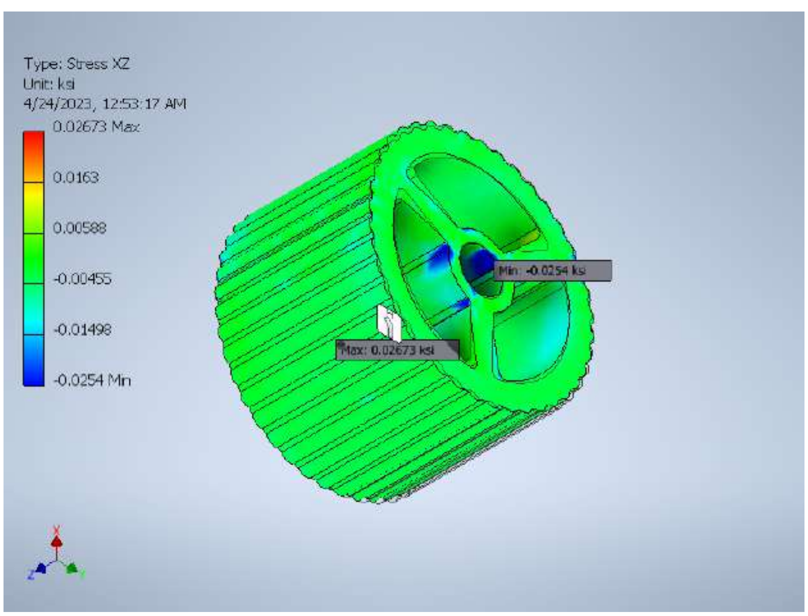
Stress XY



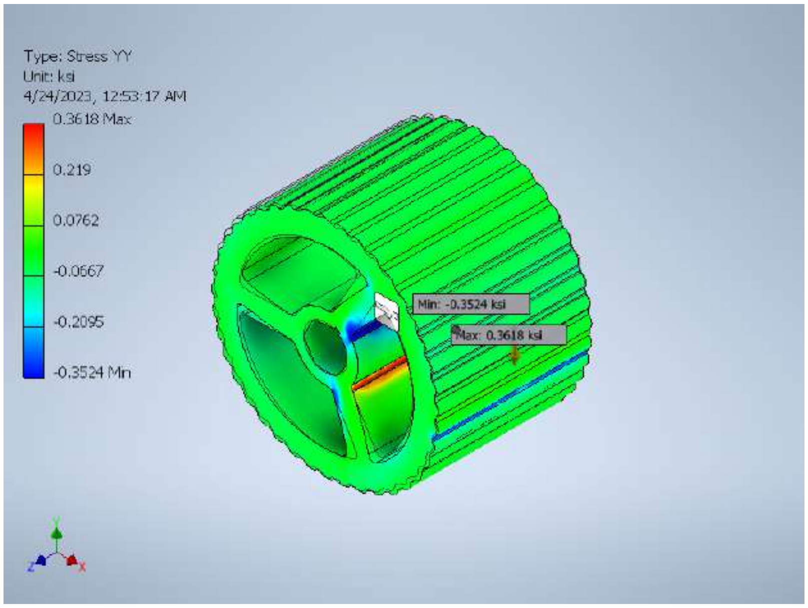

Type: Stress XY
Unit: ksi
4/24/2023, 12:53:16 AM
0.1513 Max
0.0983
0.0453
-0.0076
-0.0606
-0.1136 Min
Max: 0.1513 ksi

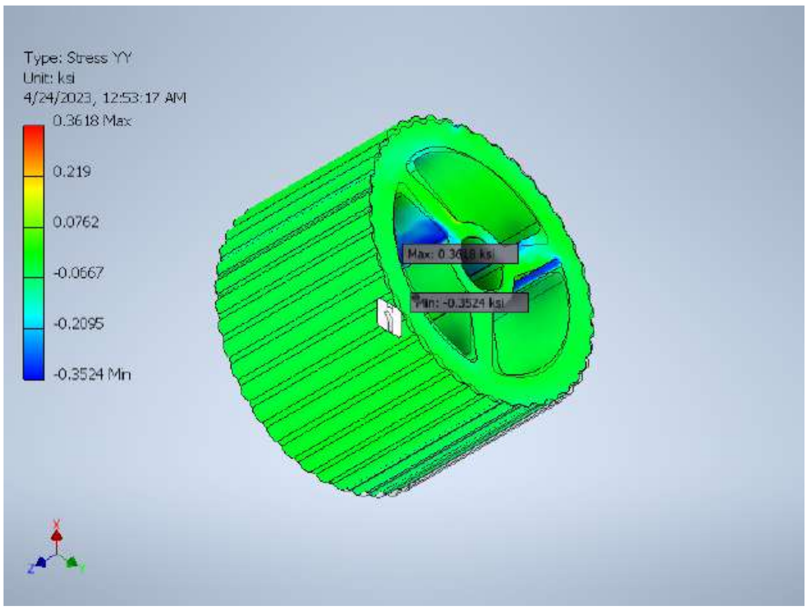
Stress XZ


Type: Stress XZ
Unit: ksi
4/24/2023, 12:53:17 AM
0.02673 Max
0.0163
0.00588
-0.00455
-0.01498
-0.0254 Min
Min: -0.0254 ksi
Max: 0.02673 ksi

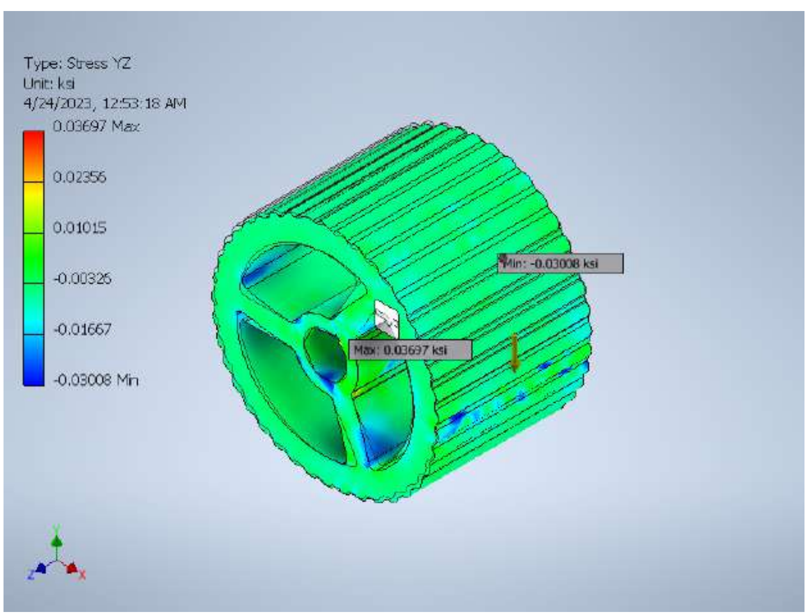

Type: Stress XZ
Unit: ksi
4/24/2023, 12:53:17 AM
0.02673 Max
0.0163
0.00588
-0.00455
-0.01498
-0.0254 Min
Min: -0.0254 ksi
Max: 0.02673 ksi

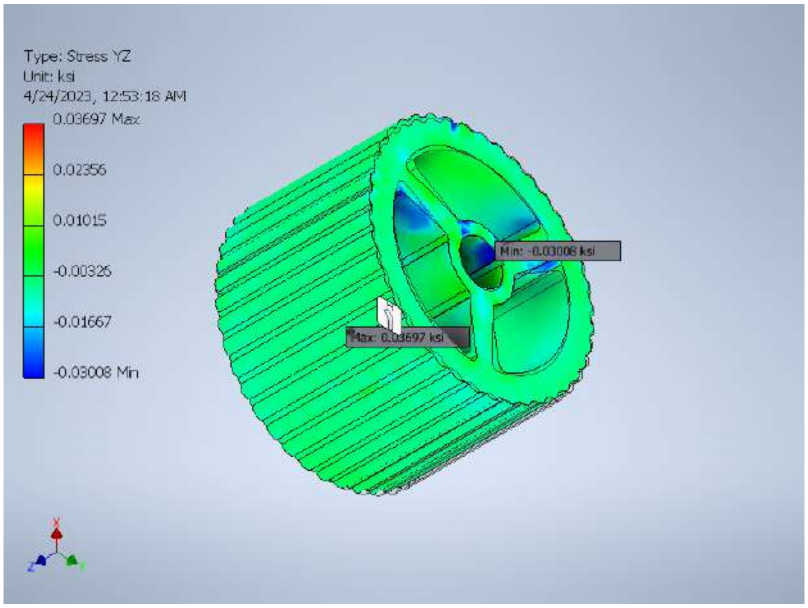
Stress YY



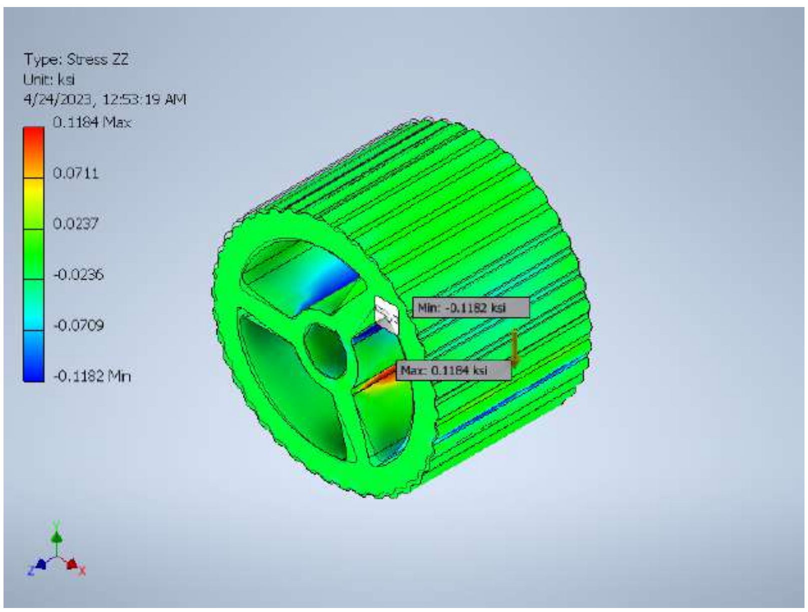


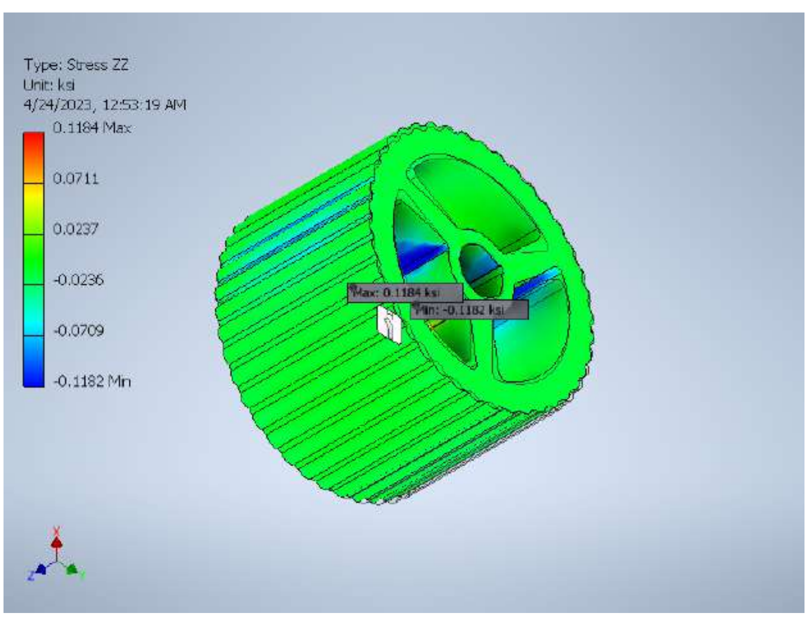
Stress YZ



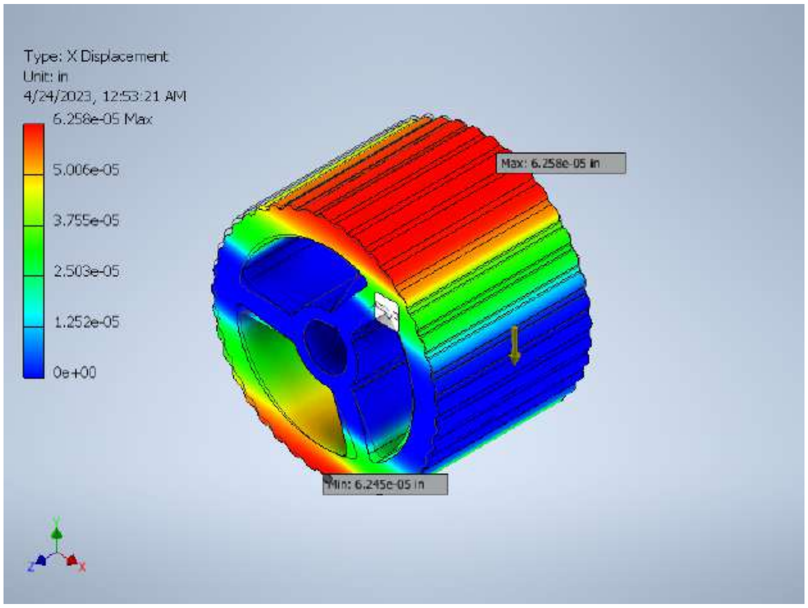

Type: Stress YZ
Unit: ksi
4/24/2023, 12:53:18 AM
0.03697 Max
0.02356
0.01015
-0.00326
-0.01667
-0.03008 Min
Min: -0.03008 ksi
Max: 0.03697 ksi

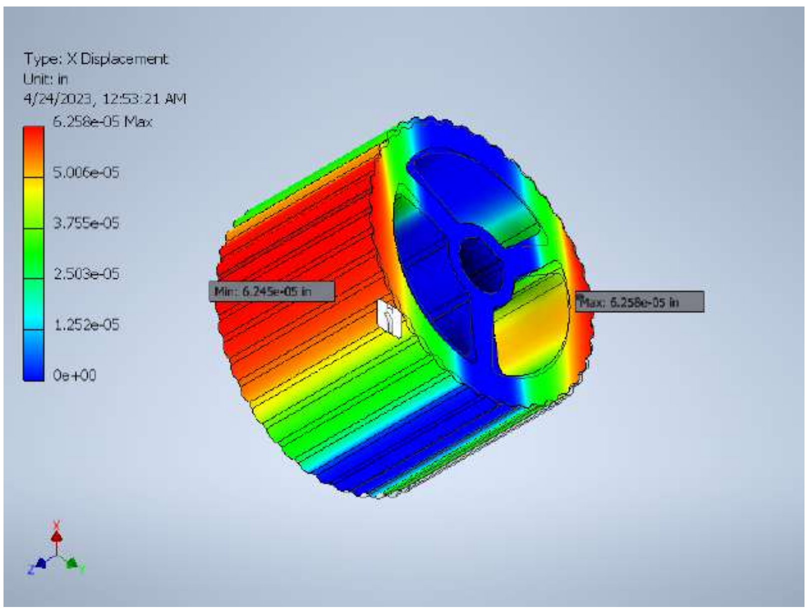
Stress ZZ


Type: Stress ZZ
Unit: ksi
4/24/2023, 12:53:19 AM
0.1184 Max
0.0711
0.0237
-0.0236
-0.0709
-0.1182 Min
Min: -0.1182 ksi
Max: 0.1184 ksi

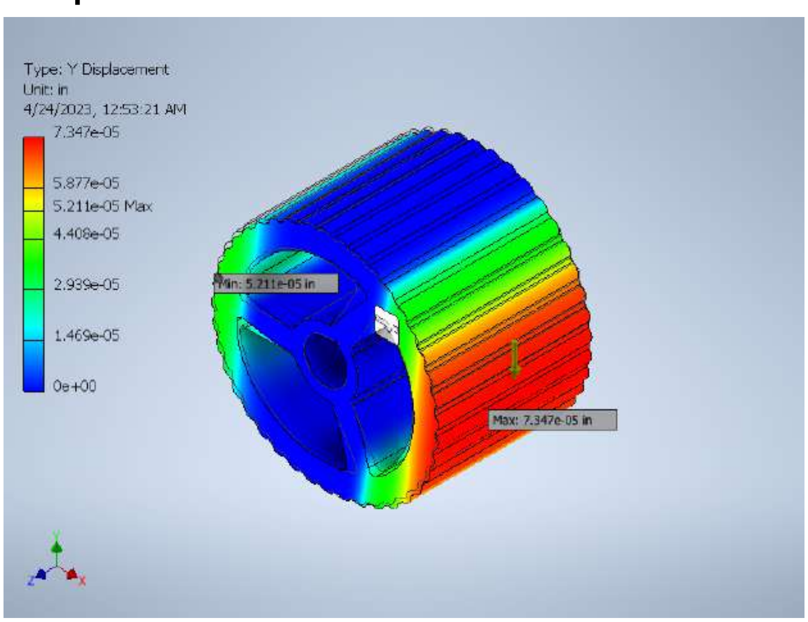

Type: Stress ZZ
Unit: ksi
4/24/2023, 12:53:19 AM
0.1184 Max
0.0711
0.0237
-0.0236
-0.0709
-0.1182 Min
Max: 0.1184 ksi
Min: -0.1182 ksi

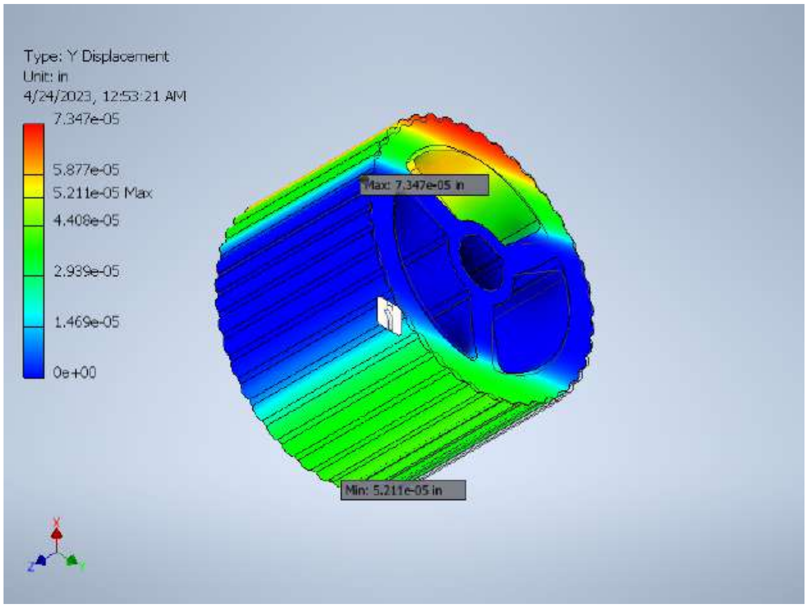
X Displacement



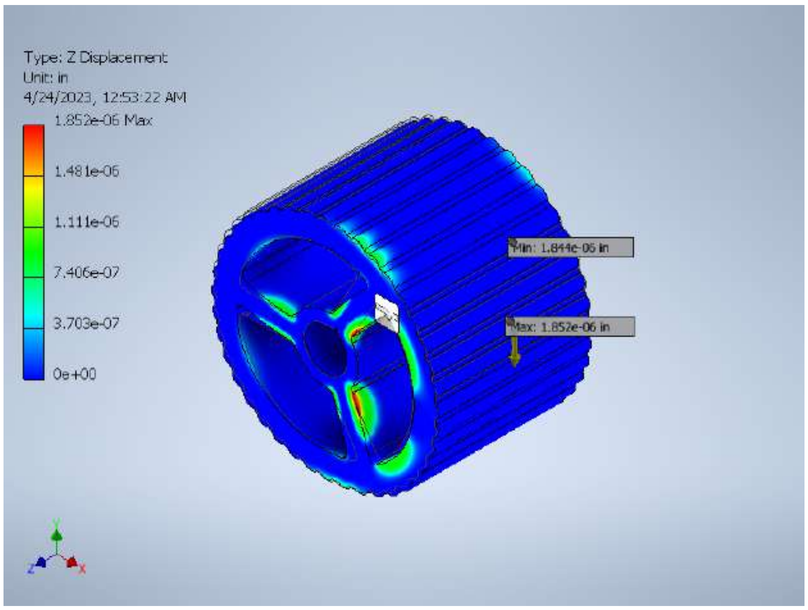


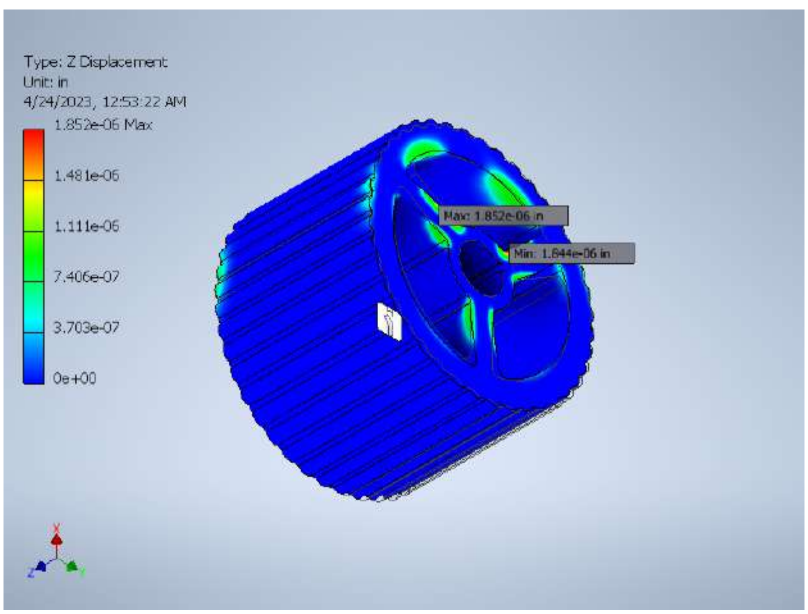
Y Displacement



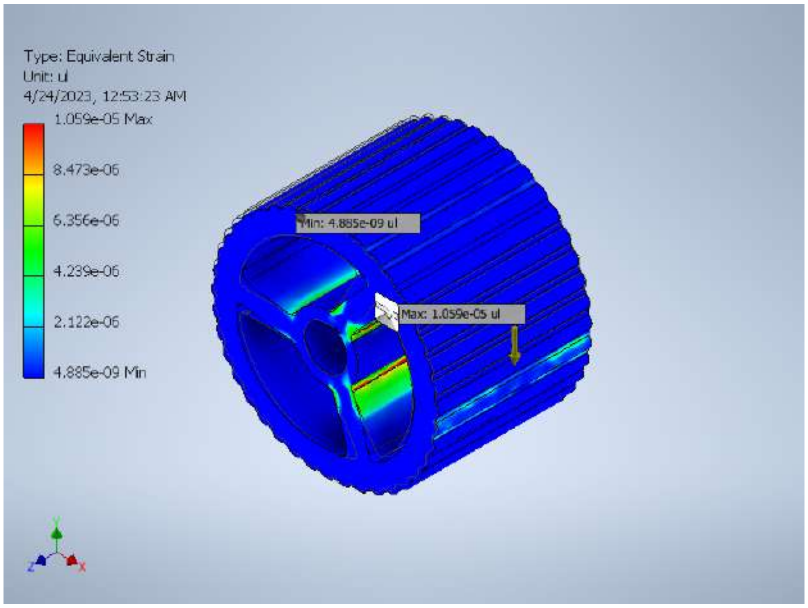


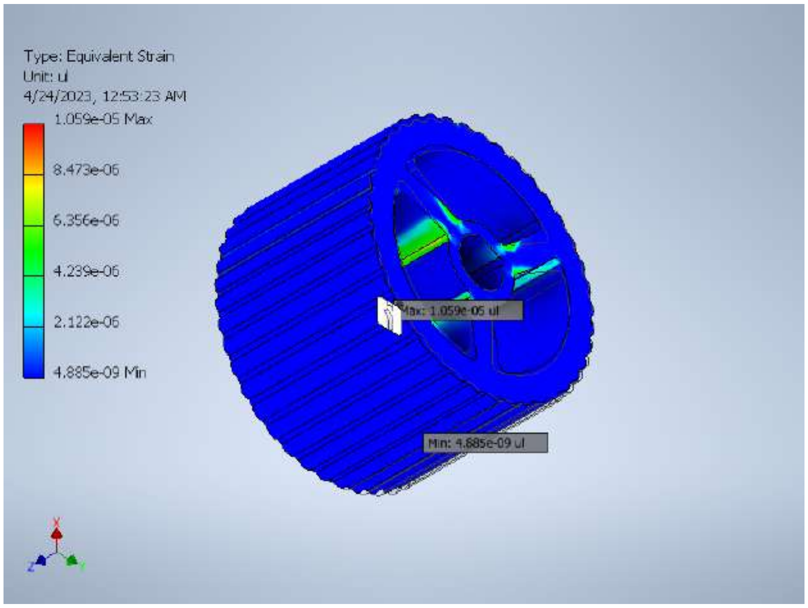
Z Displacement



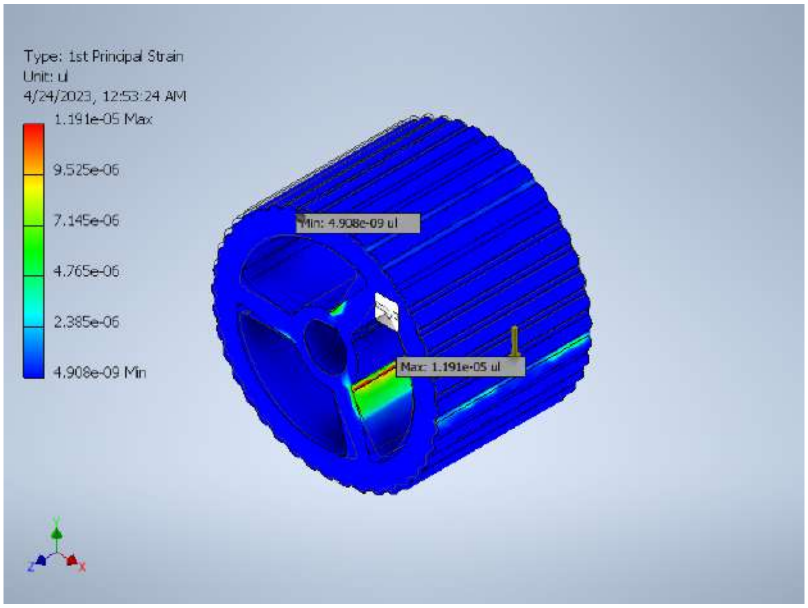


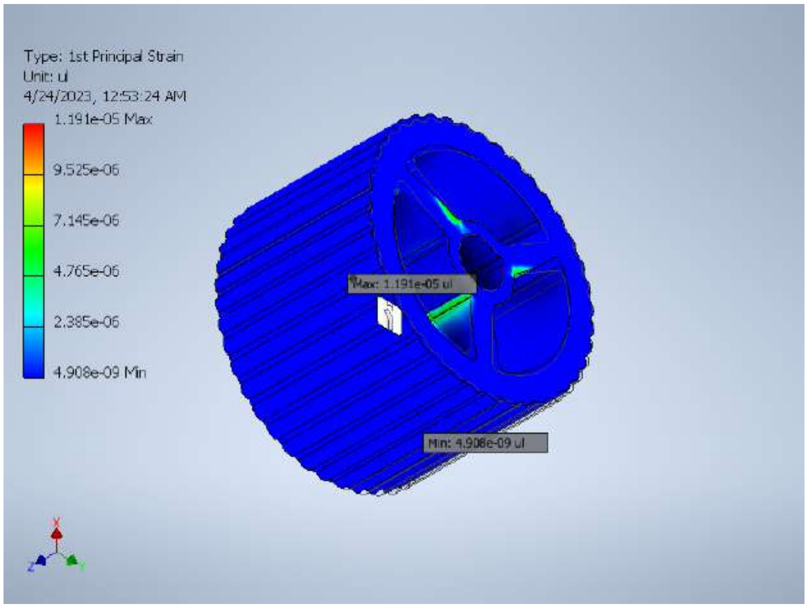
Equivalent Strain



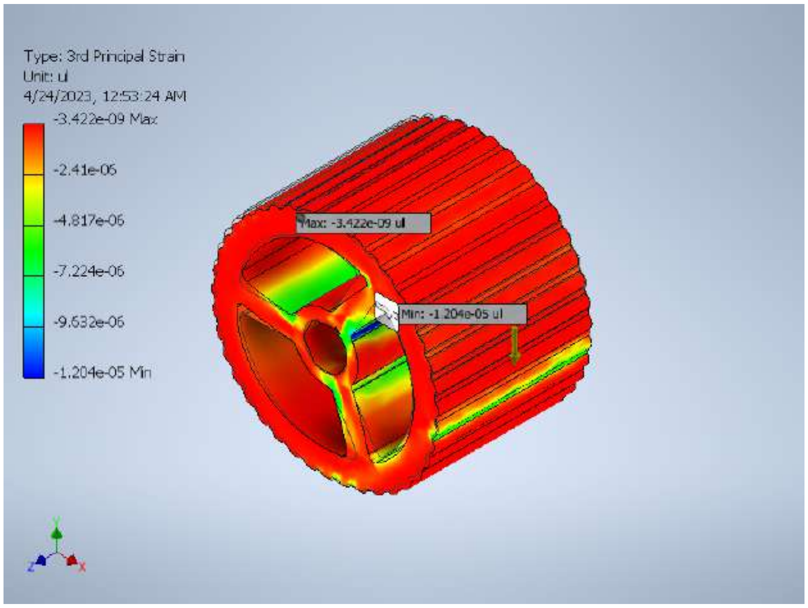


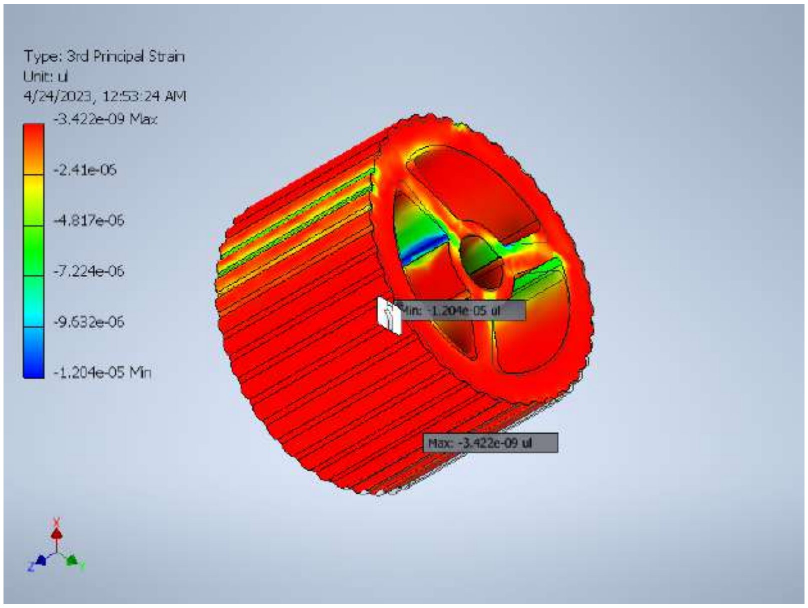
1st Principal Strain



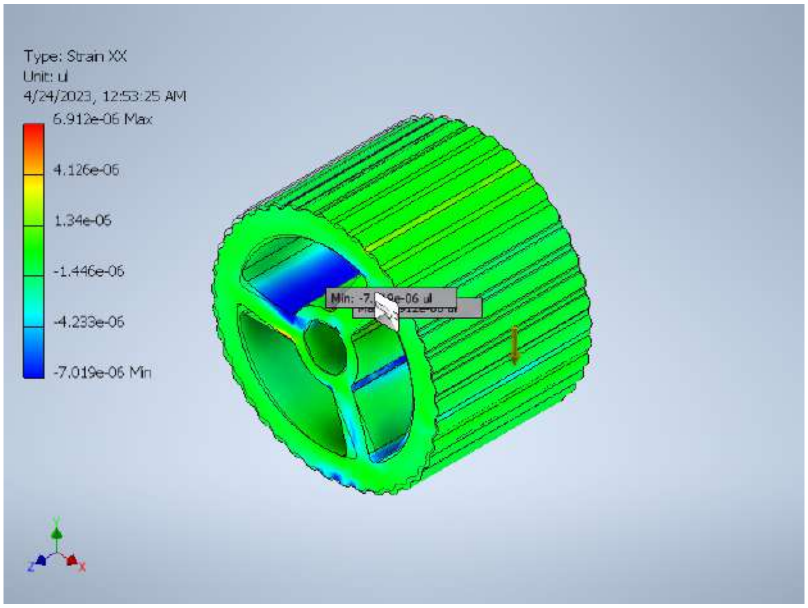


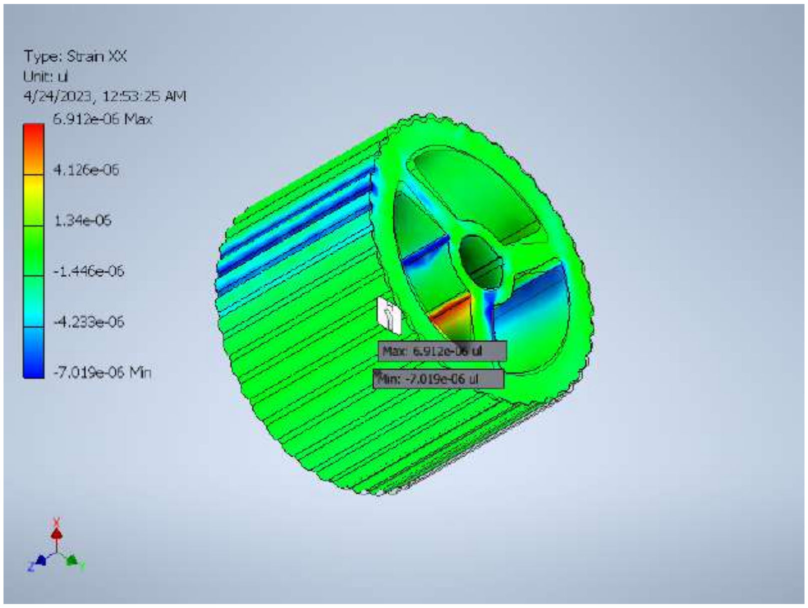
3rd Principal Strain



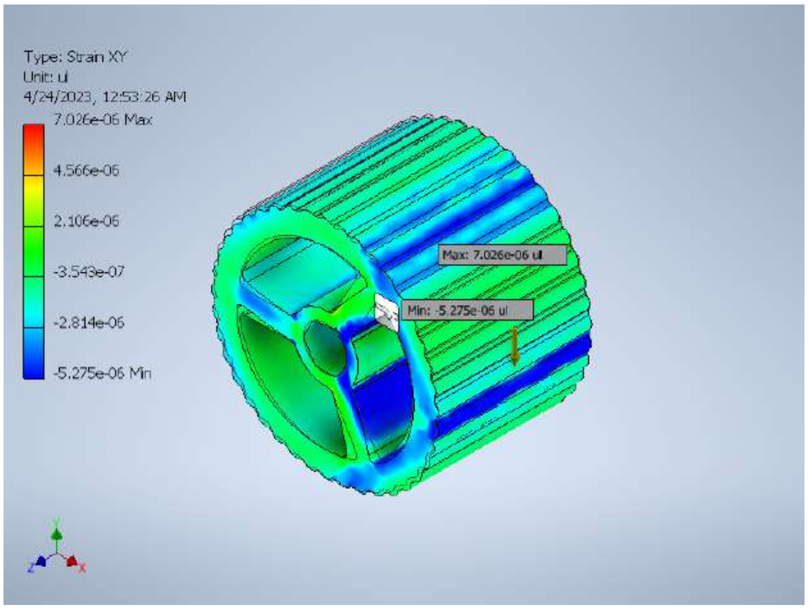


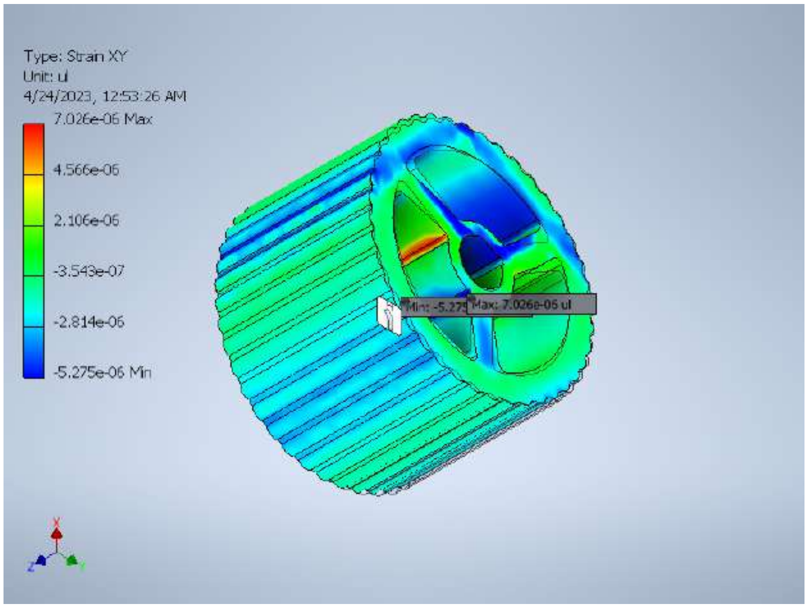
Strain XX



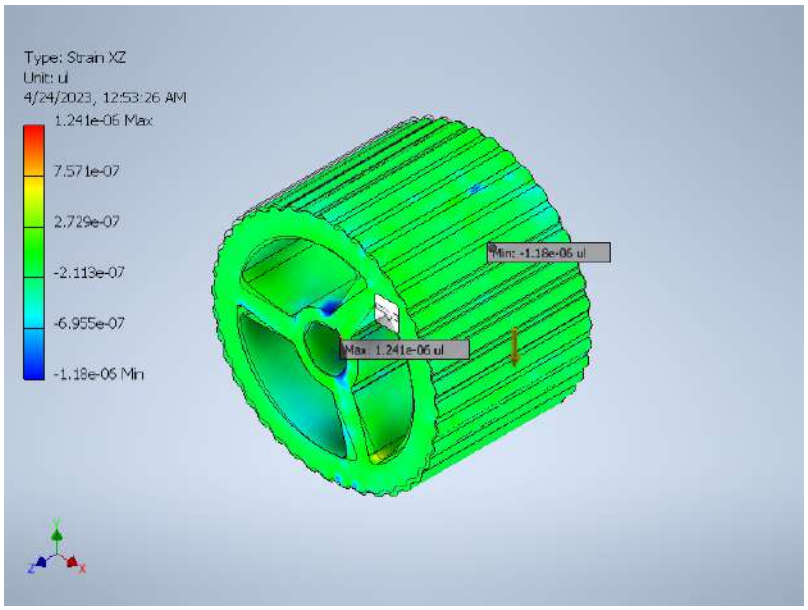


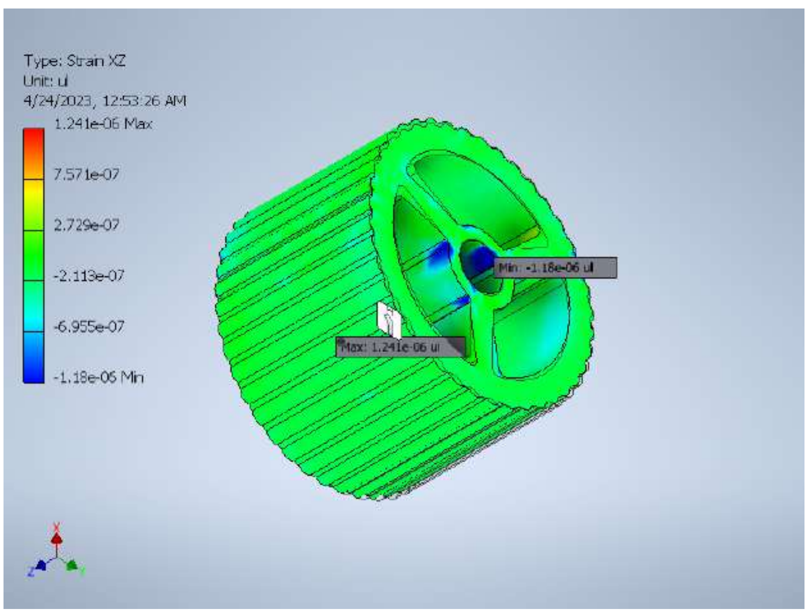
Strain XY




Type: Strain XY
Unit: ul
4/24/2023, 12:53:26 AM
7.026e-06 Max
4.566e-06
2.106e-06
-3.543e-07
-2.814e-06
-5.275e-06 Min
Max: 7.026e-06 ul

Strain XZ


Type: Strain XZ
Unit: ul
4/24/2023, 12:53:26 AM
1.241e-06 Max
7.571e-07
2.729e-07
-2.113e-07
-6.955e-07
-1.18e-06 Min
Min: -1.18e-06 ul
Max: 1.241e-06 ul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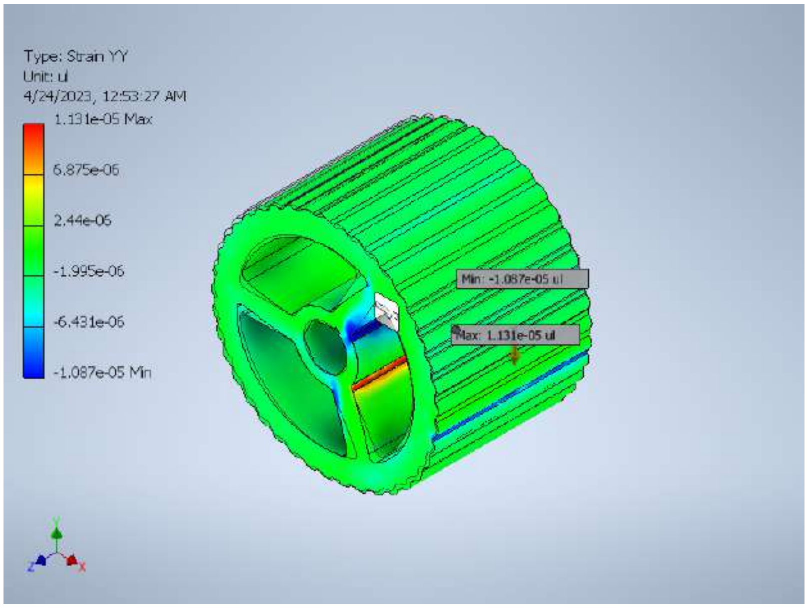
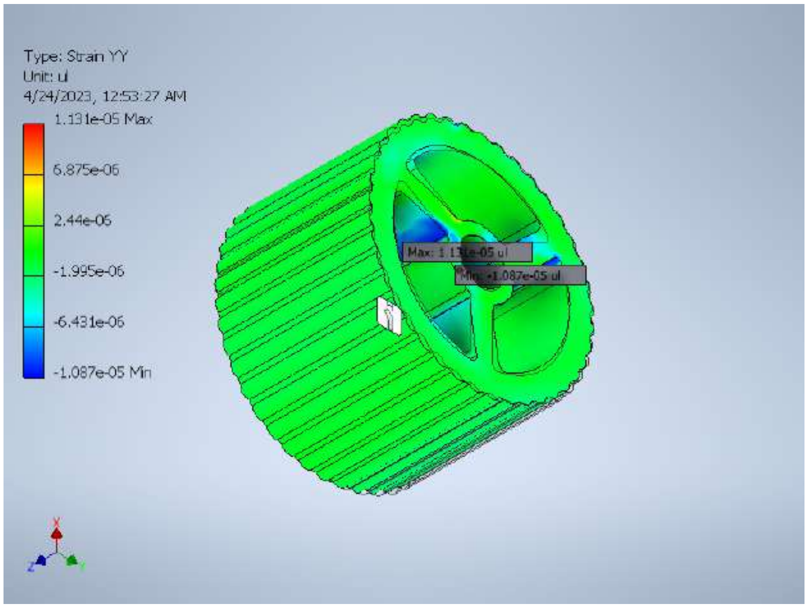
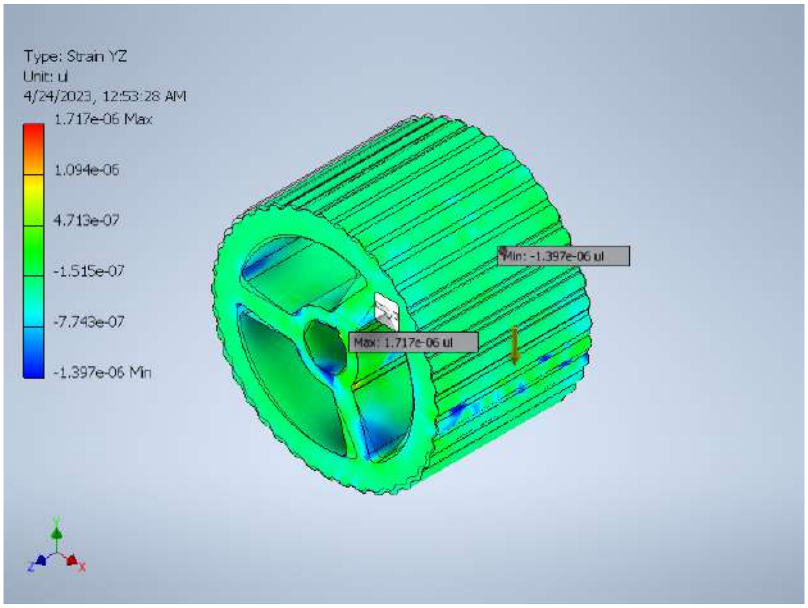
7.571e-07
2.729e-07
-2.113e-07
-6.955e-07
-1.18e-06 Min
Min: -1.18e-06 ul
Max: 1.241e-06 ul

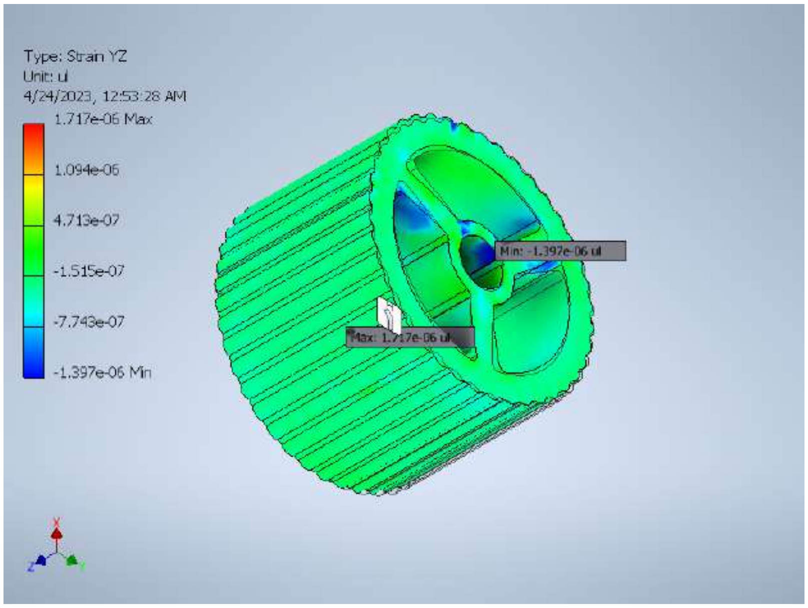
Strain YY



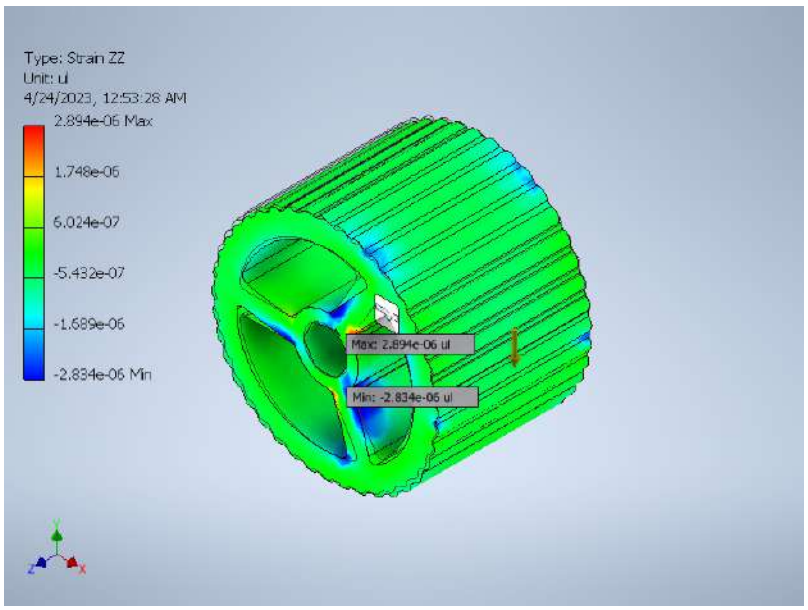


Strain YZ




Type: Strain YZ
Unit: ul
4/24/2023, 12:53:28 AM
1.717e-06 Max
1.094e-06
4.713e-07
-1.515e-07
-7.743e-07
-1.397e-06 Min
Min: -1.397e-06 ul
Max: 1.717e-06 ul

Strain ZZ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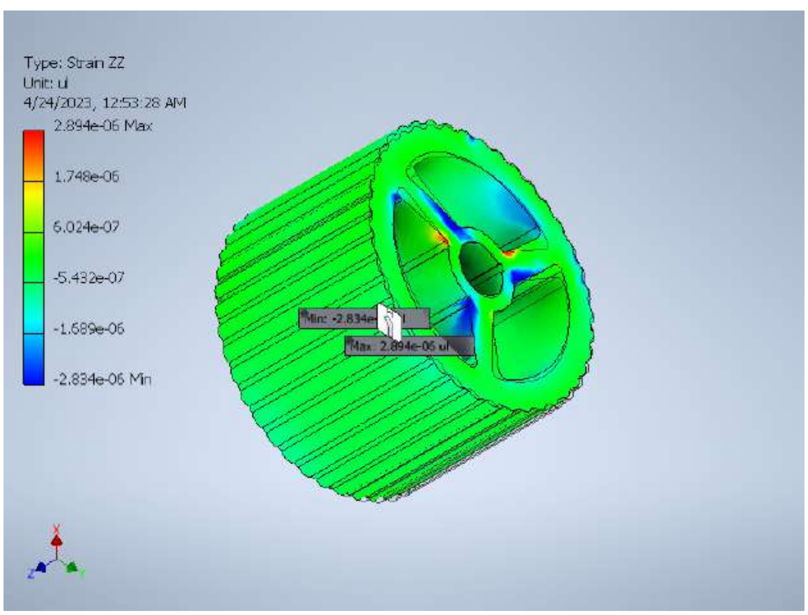
Unit: ul
4/24/2023, 12:53:28 AM
2.894e-06 Max
1.748e-06
6.024e-07
-5.432e-07
-1.689e-06
-2.834e-06 Min
Max: 2.894e-06 ul
Min: -2.834e-06 ul


Type: Strain ZZ
Unit: ul
4/24/2023, 12:53:28 AM
2.894e-06 Max
1.748e-06
6.024e-07
-5.432e-07
-1.689e-06
-2.834e-06 Min
Max: 2.894e-06 ul