Analytical and Structural Design of Potato Slicer

A Thesis:

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Sonargaon University (SU)

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[Authors]

Abstract

Potatoes are a Popular food worldwide, valued for their nutritional benefits and increasing demand. As one of the top five global food crops, Bangladesh ranks among the leading producers in terms of cultivation area. Traditional potato processing comprising washing, peeling, dicing, and manual, particularly in large-scale settings like restaurants. This approach is labor-intensive, time-consuming, and poses risks of hand injuries. To improve efficiency and safety, a portable potato slicer has been developed.

This innovative slicer utilizes a geared motor for power transmission via a chain drive, featuring three primary components: the potato feeding structure, the conveying structure, and the slicing execution structure. Potatoes are fed into the machine, conveyed through a belt sliced using a motor-driven mechanism that applies pressure to the holder. The sliced chips are then expelled through a deflector.

Finite element analysis was conducted using SolidWorks Simulation to assess the mechanical integrity of critical components, including the slice shaft and tool holder. Results showed minimal deformation under operational conditions, confirming that strength and stiffness meet design specifications.

Powered by a 1200W motor, the slicer allows for holders to achieve various slice thicknesses. This research enhances understanding of the potato slicer's mechanical structure and operational principles, paving the way for improved processing efficiency in food preparation.

Keywords: slicer; potato; geared motor, Solidwork, AutoCAD, Analysis

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Chapter 1

Introduction

1.1 Background and significance of the project

1.1.1 Background

Potatoes, being the fourth largest food crop globally are cultivated across extensive land regions and exhibit substantial productivity. In recent years, there has been a notable increase in the demand for potatoes due to the expansion of crop planting areas in various countries worldwide. China, being a prominent agricultural nation , holds the top position globally in terms of both potato planting area and output. Consequently, potatoes have become a significant constituent of China's dietary composition . Potatoes are commonly utilized in various aspects of daily life, such as food preparation and snacking. They are readily available in supermarkets and vegetable fields. In the field of medicine, potatoes serve as a versatile vegetable, functioning as both a grain and a vegetable . They possess a high content of carbohydrates, vegetable protein, vitamin C, and other essential elements. These constituents are readily absorbed by the human body, resulting in beneficial effects such as nutritional supplementation, spleen and dampness strengthening, as well as blood vessel protection. The efficiency of potato processing is contingent upon the chosen processing method, and the current research will primarily concentrate on enhancing the secondary processing efficiency of potatoes. Potatoes undergo many stages of processing prior to utilization, including washing, peeling, slicing/dicking, and other essential procedures. The conventional potato processing technique is performed manually, resulting in a lengthy duration and limited efficiency. Additionally, prolonged physical labor poses a risk of hand injuries and additional hazards. The quality of slicing plays a crucial role in the processing process, as it directly impacts the taste of the final product. Therefore, it is imperative to conduct research on the structural design of potato slicer in order to address the issue of low efficiency in potato processing.

The present study focuses on the design of a portable potato slicer. After conducting an extensive review of literature and analyzing the structural models of different slicer types, it was ultimately determined that the equipment should be categorized into three distinct components: the feeding mechanism, the slicing mechanism, and the unloading mechanism. The potato undergoes

transportation to the slicing actuator via a conveyor belt in the feeding mechanism. Subsequently, the potato is introduced into the drum grid of the actuator in a sequential manner. The drum rotates and exerts force on the potato, propelling it through the stationary knife holder. The potato slice is then output from the unloading device positioned beneath the knife holder. Computer-aided design software is extensively utilized in the design calculation and modeling simulation process, significantly enhancing design efficiency. To guarantee the safety of food processing, the equipment's elements and components that will directly interact with potatoes are specifically built to be processed using materials that adhere to the requirements for safe food processing.

1.1.2 Objectives

- To clarify the Study.
- To minimize human labor used in Factory
- To save the time of the owner for the large fields.
- Design Performance Analysis
- To clarify Results Analysis

1.1.3 Implications for research

The development of a portable potato slicer offers several benefits. Firstly, it enables the efficient and high-quality pre-processing of potato chips with varying thickness requirements. Additionally, it significantly reduces the occurrence of accidental injuries and manpower-related issues that often arise during potato processing. Furthermore, the portable potato slicer possesses advantages such as small size, light weight, and simple operation. Moreover, it ensures processing efficiency and quality, resulting in substantial cost savings in food processing and increased profit margins. In contemporary times, numerous slicers are employed for non-edible purposes, rendering them unsuitable for direct food processing. Given the prevailing concerns regarding food safety, the design of the portable potato slicer incorporates 304 stainless steel as the processing material for the potato-contact processed components. This deliberate choice aims to enhance the overall safety of food processing. The potato slicer design can serve as a benchmark for Bangladesh's potato processing sector, enhancing the efficiency of potato processing and guaranteeing processing quality.

1.2 Development status at home

In Bangladesh, the development of potato slicer machines has made notable progress, albeit with room for growth. The country's agricultural sector is pivotal, with potatoes being a major crop[1]. Bangladeshi farmers produce a significant quantity of potatoes, which are integral to both domestic consumption and export markets. However, many small and medium-sized farms still rely on manual slicing, which is labor-intensive and less efficient.

The introduction and adoption of potato slicer machines in Bangladesh have the potential to revolutionize this aspect of agriculture by improving efficiency, reducing labor costs, and enhancing product consistency. Local development of these machines is ongoing, with efforts focused on making them affordable and suitable for the diverse needs of Bangladeshi farmers.

Globally, Bangladesh ranks among the top potato-producing countries, with production levels placing it in the upper tiers of world rankings. However, advancements in technology and infrastructure, including the widespread use of slicer machines, are crucial for maintaining competitiveness and improving the value chain. As the sector evolves, integrating more sophisticated processing technology will likely contribute to better economic outcomes for farmers and the industry as a whole.

1.2.1 Domestic development status

Initially, slicers were mostly employed in the research and development and design phase to cut traditional, frozen meat, fruits, and vegetables. However, as a result of the delayed initiation of mechanical structure design, the delayed adoption of computer-aided design software, and the presence of numerous domestic non-standard design manufacturers during the product design process, there is a tendency to dismantle existing products in order to expedite production. This approach often leads to imitation and a lack of independent innovation and technological advancement. Consequently, there is consistently a disparity in performance between localized slicers and foreign slicers.

1.2.2 Current status of foreign development

The exploration and advancement of foreign slicing and technology commenced during the 1960s and mid-1980s [7]. In contrast to the progress made in domestic slicers, the research, development, and design of foreign slicers commenced earlier. Following an extensive period of technological advancement and ongoing iterative enhancements, numerous renowned brands have emerged. An

illustration of this can be seen in the TS series of machines manufactured by Meyer-Burger AG in Switzerland, as well as the TSK series of machines produced by Tokyo-Semitsu Co., Ltd. in Japan [8]. The utilization of computer-aided design software has been prevalent in foreign countries for an extended period, owing to extensive research and development efforts in equipment and the rapid advancement of computers. This software facilitates designers in efficiently performing design calculations, constructing models, conducting simulation analysis, and other related tasks. When compared to the conventional method of manual computation and hand-drawn paper, it significantly enhances the efficiency of design work and decreases the expenses associated with equipment research and development. As an illustration, the Fujinon WHBG-351STC slicer from Japan features a stage that is 350mm wide and employs a substantial blade measuring 375mm in diameter. This blade is capable of cutting frozen meat, ham, and several other food items into the final slice. The device has the capability to modify the thickness within the range of 0 to 30mm. It is not restricted to the processing of frozen meat, but can also be used to slice vegetables like lotus root and potatoes. The drive motor utilized in this system is the Japanese Aivac motor, renowned for its consistent performance, extended lifespan, and robust power. The fuselage is constructed using an integrated casting of aluminum-magnesium alloy, resulting in enhanced visual appeal, improved resistance to corrosion, and simplified cleaning procedures. The adoption of a stepless speed regulation device allows for easy adjustment based on the specific processing requirements. This device offers a low level of operational complexity and ensures the stability and reliability of the equipment.

1.2.3 Problems statement

1. Blade Dullness: After a relatively long time of use, the cutting blades tend to get dull. Consequently, slicing pace gets retarded, and the slices get uneven.

2. Material Wear and Tear: Constant use leads to wear and tear of some of the machine's elements, such as the motor, transmission belts, and bearings, which affect its efficiency and lifespan.

3. Clogging and Jamming: Potato residues sometimes accumulate on the machine, especially at the cutting part. The accumulation causes machine clogs, leading to jamming. As a result, cleaning the machine gets even harder, and the efficiency goes down.

4. Unequal Slicing: Machine issues such as unequal blade alignment and unstandardized speed of the driving motor can lead to uneven potato slice thickness, making the chips substandard.

5. Overheating: Contiguous use without proper cooling mechanisms such as machinery insulation and ventilation can cause the motor to overheat and, consequently, collapse.

Safety Problems

1. Amputations and Cuts: The chips cutting blades are too sharp, thus complicating them high potential for amputations and massive cuts. The risks get escalated when the machine operates without safety mechanisms such as the safety guards in place or when the holders bypass it.

2. Electricity: Poor wiring systems without proper earthing and controls may lead to machine operators suffering severe electric dangers such as electric shocks and fire breakouts.

3. Food Contamination: Poor cleaning of the machines would lead to the exposure of many hygiene dangers among the consumers.

4. Emergency button failure: if the emergency stops button malfunctions when pushed, then the machine will persist in operations, even during emergency times. Consequently, many accidents, both minor and major, will be frequent.

5. Guard failure: Poorly installed or substandard machine guards would lead to the machine operators interacting with high-speed operational parts, which poses high dangers.

Chapter 2

Overall scheme design of the slicer

2.1 Design ideas

The necessary information of the potato slicer was consulted in accordance with the structural design requirements. It was found that the majority of existing potato slicers are integrated, resulting in low processing efficiency and inadequate equipment safety. The primary objective of the structural design of the portable potato slicer is to develop a compact and framework that is user-friendly, easily maintainable, exhibits high operational efficiency, maintains high processing quality, and enables the pre-processing of potato chips with varying thicknesses through blade replacement or adjustment. It significantly decreases the amount of work required by kitchen staff and effectively prevents the unintended harm caused by using conventional knives for food preparation. The first configuration involves choosing a motor with a power output of around 1200W 48V DC Servo Motor, 4.5 Nm, 2500 rpm. The slice specification is set to range from 5 to 7 millimeters. Following extensive comparisons and meticulous investigation, a decision was made to partition the potato slicer's structure into three distinct components: the feeding mechanism, the slicing mechanism, and the unloading mechanism. Additionally, a conveyor belt was employed at the center to facilitate the transfer of potatoes at different time intervals. The adoption of the modular combination design approach aims to enhance the compactness and lightweight nature of each component. Additionally, each module is fitted with locking universal wheels to promote convenient daily mobility. To minimize the overall weight of the machine, it is advisable to incorporate square pipes, castings, or counterweights in specific locations to facilitate connection and fixation. This will enhance the structural integrity and stability of the equipment during operation. The remaining locations that will come into direct or indirect contact with the processed potatoes will be equipped with sheet metal parts made of 304 stainless steel, while the conveyor belt will be constructed using food-grade PVC. By implementing this approach, the safety of food processing may be significantly ensured. Additionally, a clear cover can be affixed to the processing equipment during subsequent stages to prevent any foreign objects from falling. Additionally, this feature serves to prevent the operator's fingers or hair from inadvertently interfering with the transmission of the device

2.2 Motor selection scheme

To choose a suited motor for an application, there are several important factors which should be considered. This paper explains how an ideal motor is selected, and it is based on the information from the following sources.

Application requirements:

Torque and load requirements: knowing the torque requirement, that is starting, running and stall torque, this can ensure that the chosen motor can perform the task. This information would not only help select the torque for the application but also can tell what load the motor should be able to accelerate if he knows what torque the motor provides.

Speed requirements: this would specify the speed range of the application and it can be also used to decide the motor speed if there is some gearing or pulley system to make the motor's speed down

Select of the motor itself: AC or DC motor: this can be selected depending on power available at the place of use and the requirement of its control

Stepper, Servo, other specialized motors: these types are used to motors which would be desired to control the position and the speed exactly so, using these types depending on the conditions

Power and efficiency: check the power rating to see if the motor can work the requirement power and evaluate the energy cost of the motor

The size and mounting: check the size and the weight of motor to see if it suitable for certain application and if the sufficient mounting option is available

The environment: check to see if the motor can live an in a given environment. For example, the motor must be required to have special enclosure if it will be used in hot or cold weather or outside where should be presenting dust, water or corrosive chemicals

Motor drive and control system: this would specify what kind of control system should work with the motor, such as VFD for AC motor and controller for the others. And it can save some costs if the motor system would also drive some feedback system, such as using the motor with the built-in motor hall effect or an encoder

Cost effectiveness: while some motor is expensive to buy others consumes more energy.

Regulatory and standard: the motor would be chosen always concerning the law steps to promote the motors such as efficiency or the other.

In conclusion, be familiar to these factors and with taking into consideration all the above steps would guarantee to choose a suited motor for certain application.

2.2.1 Understand the Application Requirements

Torque Needs: To help ensure the motor does not overheat, and can manage the load, know the torque requirements including the continuous and peak torque.

Speed Requirements: Identify the range of speed for the application including the maximum speed, variable speed requirements, etc.

Choose the Type of Servo Motor

AC vs. DC Servo Motors: Based on the power source and control requirements choose between AC and DC motors. AC motors are used for high power needs while DC motors are preferred when lower power and precision are required.

Specialized Types: Based on the type of motion, choose from the types like positional rotation, linear servo motor, or continuous rotation servo.

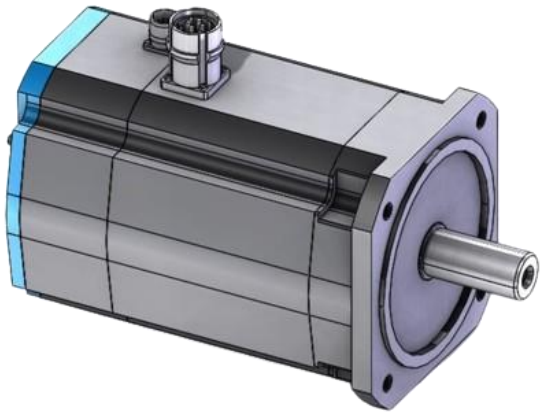


Fig.2.1 Servo motor

2.2.2 SERVO Motor selection

The main components of a servo motor are the following:

Housing: acts as a first defense and protection of the internal components of the motor. It is usually made from aluminum, and the structure allows for easy assembly and disassembly.

Stator: the stationary part of the servo motor, which consists of a stack of slotted laminations to be wound by copper wire into a certain pattern. It complements the magnet on the rotor and determines the electrical characteristics of the motor.

Rotor: the working part of the servo motor that includes a shaft with a number of magnet segments attached to it or embedded in a stack of laminations attached to the shaft. When the magnetic flux flows between and out of the magnet sections, it interacts with the electromagnetic fields generated by the stator to create rotation.

Motor shaft: responsible for transferring the electric energy to the machine moved by the motor. It is traditionally made of cold or hot-rolled steel, and the shaft can be connected to a gearbox and motor combination, a belt and pulley combination, or a direct drive.

Bearings: the components are used to allow the rotor to spin relatively smoothly in the stator. They are designed to support the rotor and ensure minimal vibration and maximum precision, effectiveness, and smoothness.

feedback system: the electro-mechanical device that communicates the motor's speed and direction back to the drive to ensure proper positioning and speed control.

Cooling system: optional component that helps maintain an optimal temperature level, which is especially important in high-power applications without overheating.

Servo controller: an element that ensures that the motor and the digital control element mesh by converting signals appropriately.

Power connection: the component is responsible for providing the needed electrical energy for the operation of the motor. The type of power depends on the specific motor model.

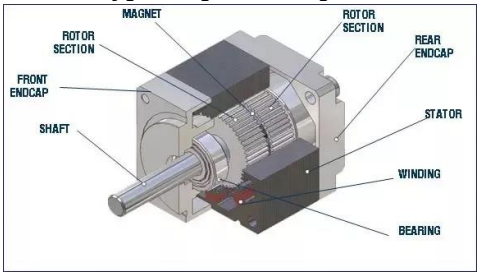


Fig.2.2 Servo motor structure diagram

2.2.3 Etermination of motor Advantages and Disadvantages

Various sources describe the advantages and disadvantages of a DC servo motor. Collectively, they provide a comprehensive review of the benefits and limitations of these motors in a variety of applications.

The main advantages of DC servo motors include:

Positioning accuracy: DC servo motors are often fitted with feedback devices, such as encoders or resolvers. Thus, their position can be determined at any given moment. Moreover, this position will be reproducible. This capability is highly important in numerous applications in which the exactness of movement is vital to the work or safety of the equipment or product. For example, it is crucial in the field of CNC machining or in robotic arms.

Dynamic response: these motors reply quickly to changes in control signals. Thus, they can be adjusted fast at the point where their speed, rotational direction, or acceleration is to be changed. It is an essential benefit in all applications in which rapid response is beneficial, for instance, in all dynamically unstable systems due to rapid movement of loads or extremely fast operations.

Torque and power density: they feature substantial force within a small unit of dimension or weight. Therefore, such motors may be found in drones, industrial fast printers, or portable medical devices, for instance.

Speed range: these motors can be utilized for low-speed and high-speed applications. As a result, they are versatile in this respect.

Dynamic stability: they work well under changing loads. Therefore, they are valuable in applications in which weights or functions substantially change, both for safety and for the performance of the mechanism operating the motor.

Closed-loop control: these motors are employed in closed-loop systems. As a result, they can control their performance more accurately at any given time.

Longevity and reliability: DC servo motors can withstand high temperatures and extreme vibrations. They are largely used in industrial applications.

Advanced technologies: DC servo motors work well with PID control algorithms, for example.

The disadvantages of the use of DC servo motors are:

Complex control requirements: A controller must monitor feedback and regulate the motor operation. Note that numerous implementations of control systems exist, but all require some attention from the perspective of setup and maintenance. A DC motor would not operate well without such oversight.

Cost: these devices are generally more expensive than stepper motors, for example, which may be a limitation in some applications.

Uneven and gradual overload constraints: DC motors may not be operated at higher loads for too long. They are also sensitive to the sequence of turning on parts in multiphase systems. That is, proper designers must be advised about not placing the motor under too high of a load. These conditions may be challenging to observe in automatic systems, and circuits are necessary to safeguard the motors under these circumstances.

Noise and vibration: The level are often too high at higher speeds and relatively high for household equipment applications.

Maintenance requirements: its disadvantages include the need to clean and replace brushes, for example.

cooling system: especially in heavy-duty designs, are often noisy and prone to problems.

2.2.4 Advantages of Potato Slicer using a servo motor

1.Precision means that each potato slice has the appropriate thickness, and the servo motor can ensure that all the potato slices have the same and accurate thickness. The appropriate thickness can help to improve the quality of the final product, and it cannot be obtained with the application of the other types of machine. This is the advantage because the feedback systems, including encoders, offer a precise control of the position, speed, and torque, and the potato slice machine will only be capable of the accurate on-time precise piercing and cutting of the slices.

2.Speed application means that the servo motors have other speeds than the DC motors and stepper motors, and the servo motor will only maintain the higher production speed of the potato slicer with the same slice quality. The advantage is explained through the adjustment of the potato slicing machine. The machine will be efficient in running the machines at the demanded speeds being adjusted to fulfill the above tasks around the different slices.

3.Adaptability to the Potato Type and Thickness of the Slice means that the machine is adjustable to the maximum or minimum slice thickness. The servo system can also switch off depending on the potato type application at the touch of a button, or it shall download the new recipe or the cam table is the other servo system application advantage.

4.Durability of the Machine as a Whole Easier means that when the servo motors are applied, the mechanical wear is achieved through smoothing the acceleration and the decelerations. The guarantee that the machine will last longer for the production of products. This advantage also means that the manufacturer servicing the machine will spend the fewer strides on fixing the machine and replacing the parts. This is explained as the guarantee that lesser dollars will be spent on the product or the machine will become broken.

5.Easier to Diagnose and Resolve Issues describes the advantage meaning that various machines can be diagnosed by an individual who does not have the complete understanding of the machine. This advantage also describes the way how to solve this machine issue.

6.Servo systems have smarter diagnostics through the network architecture meaning high bandwidth information exchange from the motor to the controller to detect and solve the problems.

2.3 Transmission scheme design 1

The prevalent modes of transmission encompass pulley transmission, gear transmission, chain transmission, and other similar techniques. This study primarily focuses on the pulley drive and sprocket drive schemes due to the selection of a motor with a power output of around 2.2Kw and the somewhat far distance from the relative arrangement.

2.3.1 Transmission scheme 1 Advantage and Disadvantage

The advantages of using a servo motor with a pulley drive transmission mechanism in a design scheme are as follows:

- Low noise: the pulley drive system runs very quietly, which makes it highly applicable in settings that require noise reduction. For example, it is often used in food processing plants or urban locations where noise pollution must be prevented.
- Smooth transmission: the use of a pulley system in combination with a servo motor ensures that the power is transmitted very smoothly. Smoothness is necessary when the product has to be accurately cut at predetermined locations. No wear on the cutting tools results in high product quality and long life of the components used to manufacture the end product.

- Overload protection. The pulley system inherently provides overload protection. Whenever the motor reaches the point of greater power draw, a belt would slip on the pulley and prevent it from further damage, therefore, improving safety and reliability.
- Long center distances: the ability to accurately drive the object despite long center distances between the driving and driven axes results in high applicability in various design schemes regardless of their size.

The main disadvantages of the given transmission mechanism are:

- Low efficiency: it is clear that the pulley drive system is less efficient than a direct drive system as some of the generated energy would be slipping the belts on the pulleys.
- A limited service life: the belts and the pulleys have a limited service life and have to be replaced in accordance with the maintenance relevant requirements. To save the motor from jamming, the belts have to be checked and adjusted more often than gears that could be expected in the compact direct driving systems.
- High maintenance costs: the service life considerations combined with the fact that the belts have to be replaced in regular intervals results in high maintenance costs.
- Inadequately compact structure: it requires more space than direct drivers.

Hence, considering the above information, it is critical to weigh the benefits with associated disadvantages.

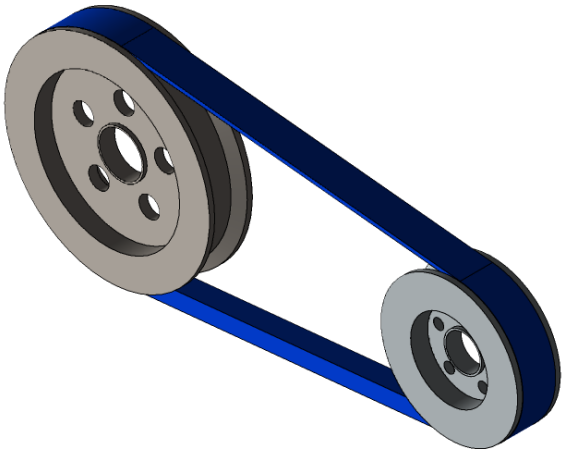


Fig.2.3 Belt wheel drive diagram

2.3.2 Transmission design scheme 2

The sprocket drive, as depicted in Figure 2.4, is employed. This type of structure has several advantages, a servo motor can be combined with a chain sprocket drive system for transmission design in a variety of applications, and such design offers the following advantages. The transmission design scheme includes a servo motor, which is a rotary actuator or linear actuator allowing for precision control of a rotating or linear position, velocity and acceleration. It comprises an appropriate motor with a sensor for position feedback. In addition, it includes a chain sprocket drive system with a chain for driving over a number of sprockets.

Advantages of Using a Servo Motor with Chain Sprocket Drive:

1.Precision Control – servo motors are known for their high precision control mechanisms. They can be controlled to rotate at specific speeds to exact positions and with torque set to exact briskness. It is useful for many instances, where the precise motion is demanded.

2.High Efficiency – usually, the system has higher efficiency than a belt drive system, which is particularly important in applications prone to slippage. Chain sprocket is the reason for higher efficiency of the system, as the range of mechanisms transmits power more efficiently with lower power losses.

3.Compact Design – servo motors are smaller than other motors with similar power outputs. The use of the chain sprocket allows for the shafts to be closer rather than using belts to maintain the same distance.

4.Durability and Reliability – chain sprockets are extremely durable and reliable mechanisms. Chains are able to withstand dirt, chunks of mud, dampness and other harsh applications better than the alternatives due to lack of slippage and stretching in due conditions. Traditional belts tend to slip, and v-belts specific to their design have a tendency to stretch – both cases are entirely absent in the use of chain sprocket systems, making it suitable for demands of reliability and low maintenance.

5.Versatility – the system can be used in number of different conditions and with multiple different applications. From heavy machinery to ultra-sensitive laboratory equipment, all such applications can be met with a combination of servo motors and chain sprockets.

6.Scalable – the application allows for easy scaling, depending on the user needs, as the size of the sprockets and the chain length can be changed to change the speed and the torque.

7.Load Handling – the system can handle much heavier loads than any belt drive mechanism, which is crucial for industrial applications. These advantages make the servo motor and chain sprocket drive system a potent system for almost any application, where the system would be suitable.

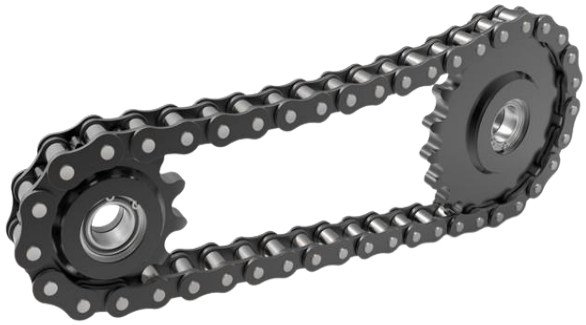


Fig.2.4 Sprocket drive diagram

2.3.3 Determination of transmission scheme

Through a comparative analysis of the two transmission schemes, it was ultimately determined that the second scheme would be chosen as the design strategy for the transmission structure. In the structural design of the potato slicer, the potato is fed and transported on a conveyor belt. During the slicing process, the load undergoes significant changes, which can lead to overload. As a result, the belt drive may experience slippage, causing the slicer to fail. By opting for the second method, you can get a reduced structure size, improved transmission efficiency, and a lower cost without the need for precise installation.

Comparative Discussion of Transmission Schemes

Load Handling and Slippage:

Belt Drive: The belt is likely to start slipping given the potato slicing process is characterized by a variable and significant load change

Chain/Gear Drive: More positively engaged with no slippage in standard conditions. The load fluctuations would not cause problems for gear teeth or the chain since they would remain meshed.

Transmission Efficiency:

Belt Drive: The efficiency levels decrease as the belt starts to slip and tension maintenance becomes necessary

Chain/Gear Drive: Higher transmission efficiency due to the direct engagement of the components and minimal slippage

Structural Size and Installation:

Belt Drive: The structural size is likely to be larger because of the sufficient diameter of the pulleys and a required belt path. Additionally, precise installation and alignment are vital to avoid slippage and wearing out.

Chain/Gear Drive: Can be more compact given that smaller gears can be used. The chains are also more tolerant to misalignment, which is vital for error occurrence during the installation process.

Cost Implications:

Belt Drive: Lower initial costs but more regular maintenance and downsizing costs associated with shortage and tension problems and regular wear out.

Chain/Gear Drive: Higher initial costs but lower lifetime maintenance costs due to durability and infrequent wearing out.

Finally, the potato slicing machine's structural design, more advantages have the chain or gear drive system. Given the inability to avoid slippage for the belt drive, it is necessary for the system processing such a variable load to be more reliable, efficient, and smaller in size. Moreover, the opportunity to avoid precise installation and alignment is also critical due to the high potential for errors made during processing. Thus, the cost implications and risks of each transmission system justify why the second scheme would be more suitable for the potato cutting machine.

2.4 Slicing scheme design

The design of an effective potato slicer involves prudent reflection on several criteria to guarantee productivity, protection, and quality of slices. Below we detail key constituents of a slicing plan structure, focusing on mechanism selection, cutting edge configuration, feed mechanism, and safety considerations.

Mechanism options can fluctuate subject to desired volume, slice excellence, and cut varieties mandated like chips, wedges, or julienne fries. Often employed in high-output environments, rotary slicers feed potatoes towards rapidly pivoting blades for speedy cutting though precise velocity oversight is vital to ensure uniform thickness. Reciprocating designs use a single blade or cluster moving back and forth, generally slower yet allowing better control over slice thickness and apt for wavy or crinkle-cut slices.

The arrangement and material of cutting edges are pivotal for deciding potato slice texture and dimensions. A lone blade is simple and cost-saving, suitable for basic slicing but possibly restrictive regarding slice shapes and sizes. Multiple blades permit simultaneous trimming of potatoes into several slices or distinctive forms, letting adjustment of thickness and form for versatility. Interchangeable cutting edges facilitate switching between distinct cuts like flat, ridged or julienne fries.

The feed mechanism guarantees potatoes are guided safely and steadily to blades for slicing. Gravity feed takes advantage of weight to transport potatoes through a channel towards the blades, fitting for less complex, smaller-scale setups.

Conveying crops into cutters consistently and precisely is key to efficient food processing.

Methods include:

Transfer Systems: Conveyor belts and robotic arms convey produce to blades, enhancing safety versus manual feeding. Adjustable speeds maintain uniform slicing.

Blade Design: Rotating or stationary blade configurations impact cutting control and safety guarding needs. Adjustable spacing allows versatile thickness selections.

Safeguarding is essential given rapid blade motions.

Protective Barriers: Guards around moving components prevent contact, while permitting access for cleaning.

Instant Stops: Readily accessible emergency buttons immediately halt operations if risks arise.

Hands-Off Operation: Designs minimizing hand placement by blades during slicing bolster safety.

Maintenance and cleaning influence longevity and hygiene:

Detachable Components: Easily removable blades and parts streamline sanitization, sustaining standards over the lifespan.

Corrosion Resistance: Stainless steel and other non-reactive materials for blades and surfaces maintain durability and food safety with cleaning.

In summary, efficient crop processors combine effective, adjustable cutting with robust safety and flexible operation. This balances productivity and consistency with quality for food manufacturing.

2.4.1 Slice design scheme1

Figure 2.5 illustrates a prevalent rotary slicing mechanism that primarily depends on increasing the rotation speed or adding one or two blade positions to the rotating turntable. This allows for the cutting of objects in close proximity to the slicing area. While the structure of this mechanism is relatively simple, it is susceptible to blockage due to excessive feeding or other factors during processing. Consequently, the slicing process may result in greater damage.



Fig.2.5 Rotary slicing mechanism

2.4.2 Slice design scheme 2

The design plan to construct a potato dicing device that employs an upright blade assembly strives to proficiently slice potatoes into even slabs or filaments. This style of equipment normally works by applying downward push on the potato, guiding it through a series of vertically aligned blades. Here is a comprehensive clarification of how this process performs and the factors involved in confirming the integrity and uniform thickness of the cuts:

Blade Placement: The blades in the vertical blade frame are positioned in a lattice or parallel lines, based on whether the sought after last item is slabs or filaments. The spaces between the blades decides the thickness of the cuts. Blades must be sharp and sturdy to cut through the potato without necessitating excessive force, which may smash or warp the slices.

Downward Pressure Mechanism: The apparatus utilizes a system, regularly a lever or a hydraulic press, to exert controlled downward pressure on the potato. This pressure pushes the potato through the blade frame, confirming that the slices are sliced rather than torn, which aids in maintaining the integrity of each slice.

Slice Thickness Control: To regulate the thickness of the cuts, the distance between the blades can be adapted. This is vital for varied culinary uses where explicit slice thickness is essential. Even thickness not merely ensures synchronous cooking but also affects the feel and look of the eventual dish.

Preventing injuries is paramount. Protective guards and interlocks stop blades when contacted to avert lacerations. A stable base during use cuts risks of inaccurate cuts or accidents from unwanted movements.

Operational efficiency hinges on various factors. Easy loading and unloading of potatoes streamlines workflows. Thorough yet swift cleaning simplifies maintenance. Adjustable blades for diverse slice thicknesses accommodate a range of recipes. Together, these conveniences maximize productivity in commercial kitchens through intuitive, user-friendly performance.

In closing, vertical blade frames skillfully craft consistent potato slices and shreds while safeguarding cellular integrity. Key elements incorporate sharp, evenly-spaced blades, dependable pressure control, customizable slicing specs, and safety mechanisms protecting both product and personnel.

2.4.3 The slice design scheme work in potato machines

The design of potato slicing machinery, especially those employing vertically arranged blades, is carefully calibrated to section spuds reliably into even filaments or slices. Maintaining consistency in cut dimensions is pivotal for both home and commercial food preparation quality demands. Here is a deeper look at how this engineering arrangement performs its task:

Vertical Blade Operation

The vertical blade assembly at the core of a potato slicer consists of multiple cutters placed atop one another at preset intervals to guarantee uniform slice thickness. Potatoes are delivered into the device where they are immobilized over the blade block. Force is then exerted downward upon the potatoes, pushing them through the cutters. This pressing is regulated to slice rather than crush the potatoes. As each potato passes between the blades, it is divided into portions as dictated by blade spacing. Blade sharpness and placement are critical to clean severing without compromising slice structural integrity.

Cut Dimension Quality Control

Administering the thickness of the cuts is a key factor in the slicing process, adjusted by altering distances between blades. Some machines allow the operator to manually modify blade proximity to modify slice thickness. Other advanced models alter blade spacing automatically. Uniform slice dimensions are important for consistent cooking results and aesthetic meal presentation. Process engineering aims to maintain this consistency over large volumes of potatoes.

Productivity and Efficiency Considerations

Several attributes influence the productivity and efficiency of a vertical blade potato slicer. The design enables swift handling of sizable potato quantities needed for commercial foodservice and snack manufacturing. Automated operation reduces labor requirements and variability from human factors. Furthermore, basic componentry permits simple routine maintenance and cleaning essential in food production settings, employing durable materials that withstand regular use. In summary, potato slicer vertical blade configuration focuses on uniform slice thickness, slice structural integrity, and enhanced slicing efficiency through strategic blade placement, managed downward pressure, and slice thickness adjustability.

2.5 Chapter summary

The varied sources comprehensively overviewed numerous facets and progresses concerning potato slicing technologies. Here is a summary of key points covered across sources pertaining to potato slicing mechanisms:

Developments and optimizations were studied intensely. Investigations centered on evolving and performance improving potato slicing machines through designing for enhanced efficiency, evaluating differing parameters such as slice thickness, and optimizing cutting speeds to boost productivity while reducing energy usage.

Machine designs were heavily examined, spotlighting using durable materials like stainless and mild steel. Configurations often incorporated ensuring uniform slice thickness and bettering hygiene and safety of the slicing process.

Performance testing was commonly discussed, measuring efficiency, capacity, and specific energy consumption under diverse conditions. Such evaluating helped refining machine designs to effectively meet industrial needs.

Technological innovations integrated sophisticated mechanisms including pedal-operated systems and power transmission system enhancements within machines. Such progress intended to streamline slicing while decreasing manual labor.

Applications expanded beyond potato chips. These machines were pivotal in food processing generally, where they contributed to consistently sliced products necessary for uniform cooking and packaging.

Economic considerations were also debated, investigating cost-effectiveness of dissimilar machine designs and their operational efficiencies. The goal was making machines affordable and efficient for small to medium production units by optimizing resource use and minimizing waste.

Safety traits and ease of maintenance were crucial covered aspects in design and evaluation. Ensuring machines were safe to operate and simple to maintain helped adoption in commercial settings.

Collectively, these sources furnished a thorough insight into technological advancements, design contemplations, and operational efficiencies of potato slicing machines, spotlighting their importance in food processing and impact on productivity and quality control.

Chapter 3

Key Analytical and Structure Design of Potato Slicer

3.1 Selection and design of geared motor

Under the given initial circumstances, with a constant total of 100 kg of potatoes on the feed and conveyor belts, a motor drives the conveyor belt to move the potatoes from the feed port to the actuator. Now select the PF series geared motor from Dongle Motor as the driving mechanism. The power of the geared motor is primarily determined using the power calculation formula (3.1).

$$P = F \cdot v \tag{3.1}$$

where:

v is the velocity, m/s.

F is the load, N. It is calculated as follows:

$$\mathrm{F} = \mu \cdot \mathrm{m} \cdot \mathrm{g} \tag{3.2}$$

Where:

μ is the coefficient of friction, which is taken as $\mu = 0.6$.

m is the mass, take m = 100kg.

g is the gravity, take g = $9.8N/kg$.

Bringing the data into equation (3.2) calculates:

$$\mathrm{F} = \mu \cdot \mathrm{m} \cdot \mathrm{g} = 0.6 \times 100 \times 9.8 = 588\mathrm{N} \tag{3.3}$$

By utilizing the reduction motor as the driving mechanism, the chain drive can employ a gearbox ratio of i=1. Based on the specified diameter of the belt roller (d=60mm), it is expected that each potato has a mass of 110g (m=110g). In order to obtain the desired output of 1.5 tones per hour, it is necessary for 4 channels to carry one potato to the actuator per second. The result of the calculation is then outputted:

$$m = \frac{110\times4\times60\times60}{1000\times1000} = 1.584t > 1.5t \quad (3.4)$$

Given that each potato has a length of around 100mm and the spacing between potatoes from front to back is also 100mm, the result of the linear speed calculation for the belt is:

$$v = \frac{100+100}{1000\times1} = 0.2m/s \quad (3.5)$$

Put formula (3.3) and formula (3.5) into formula (3.1) to calculate the power of the drive conveyor belt motor:

$$P_0 = F \cdot v = 588 \times 0.2 = 117.6W \quad (3.6)$$

Based on formula (3.5), formula (3.6), and the Dongli motor selection manual, the appropriate model for the reduction motor is PF18-0200-30S. The motor has a reduction ratio of i=30, a power of P_0=0.2kW, and a rated speed of n_0=1380r/min. The velocity of the drive shaft and driven shaft is: $n = \frac{n_0}{i} = \frac{1380}{30} = 46r/min$ (3.7)

3.2 Design and calculation of chain transmission mechanism

3.2.1 Calculation of transmission parameters

Table 3-3 in "Comprehensive Training in Mechanical Design" [3], edited by Wang Mingqiang and Zhu Yongmei, displays the range of values for common mechanical transmission and support efficiencies. The roller chain has a transmission efficiency of 0.96, denoted as η_1. The transmission efficiency of ball bearings used in pairs is denoted by the symbol eta_2 and has a value of 0.99. The book "Engineering Mechanics" [13], edited by Gu Chengjun, Jiang Yijun, and Liao Dongbin, provides a formula (6-1) to determine the torque, power, and speed of each axis.

$$T = m = 9550\frac{P}{n} \quad (3.8)$$

In the formula:

T Torque, N·m.

N Rotation speed, r/min.

P On-axis power, kW.

As per the Eastern calendar, the motor PF18-0200-30S has been chosen in section 3.1 for the selection and calculation of transmission belt reduction motor. The motor specifications are inputted into formula (3.8) to compute the torque T_0 of the motor shaft.

$$T_0 = 9550\frac{\mathrm{P_0}}{\mathrm{n}} = \frac{9550\times0.2}{46} = 41.50N\cdot m \qquad (3.9)$$

Because the transmission ratio i=1, n_1=46r/min, η_1=0.96, the power and torque transmitted on the belt roller shaft are calculated:

$$P_1 = \mathrm{P_0}\cdot\eta_1 = 0.2\times0.96 = 0.192kW \qquad (3.10)$$

$$T_1 = 9550\frac{\mathrm{P_1}}{\mathrm{n_1}} = \frac{9550\times0.192}{46} = 39.86N\cdot m \qquad (3.11)$$

3.2.2 Design and verification of chain drive of transmission mechanism

The basic configuration of the transmission mechanism chain drive sets the number of teeth on both the large and small sprockets to Z_1=Z_2=21. As stated in Table 13-2-6 of HANDBOOK of MECHANICAL DESIGN BY GEORGE F. NORDENHOLT Editor of Product Engineering JOSEPH KERR [4], The book contains the coefficient K_A for assessing working conditions. The value of K_A is determined to be 1. Next, compute the design power P_d using the given formula:

$$P_d = K_A\cdot P = 1\times0.2 = 0.2kW \qquad (3.12)$$

In the formula:

K_A working condition coefficient.

P power, kW.

Calculate the power P_0 transmitted by a single row of chains under specific conditions:

$$P_0 = \frac{\mathrm{P}_d}{\mathrm{K}_Z\mathrm{K}_P\mathrm{K}_L} \qquad (3.13)$$

In the above formula, K_Z represents the coefficient for the number of teeth on the tiny sprocket.

K_P is a ranking coefficient.

The K_L coefficient represents the length of the chain.

The book " Mechanical Design Engineering Handbook" Edited by JODI WICAKSONO [9] provides information on the tiny sprocket tooth number coefficient K_Z and chain length coefficient K_L in Table 13-2-7 of its third volume.

$$\mathrm{K}_Z = \left(\frac{\mathrm{Z}_1}{19}\right)^{1.5} = \left(\frac{21}{19}\right)^{1.5} = 1.16 \qquad (3.14)$$

$$K_L = \left(\frac{L_P}{100}\right)^{0.5} = \left(\frac{42}{100}\right)^{0.5} = 0.65 \qquad (3.15)$$

The coefficient K_P is ranked in Table 13-2-8 of the third volume of " Mechanical Design Engineering Handbook" Edited by JODI WICAKSONO The table indicates that K_P has a value of 1. Apply the given data as input to formula (3.13) in order to calculate:

$$P_0 = \frac{P_d}{K_Z K_P K_L} = \frac{0.2}{1.16 \times 1 \times 0.65} = 0.27kW \qquad (3.16)$$

Calculate the power P_0=0.27kW and rotational speed n_1=46r/min conveyed by the single-row chain. Subsequently, identify the appropriate chain based on the third volume " Mechanical Design Engineering Handbook" Edited by JODI WICAKSONO and figure 13-2-8 in the book. The number is 08A. Refer to table 13-2-2 in order to choose the chain pitch with a value of P=12.7mm.

Verify the diameter d_k of the shaft hole of the tiny sprocket.

$$d_k \leq d_{kmax} \qquad (3.17)$$

The maximum permissible diameter of the shaft hole, denoted as d_kmax=47mm, can be obtained by referring to Table 13-2-9 in Volume 3 of the "Modern Machinery Design Manual".

$$d_k \leq 47mm \qquad (3.18)$$

Calculate the initial center distance a_0:

$$a_0 \geq 0.2Z_1(i+1)P \qquad (3.19)$$

$$\geq 0.2 \times 21 \times 2 \times 12.7$$

$$\geq 106.68mm$$

Initial center distance a_0p calculated in terms of pitch:

$$a_{0P} \geq \frac{a_0}{P} \qquad (3.20)$$

$$\geq \frac{106.68}{12.7}$$

$$\geq 8.4$$

Typically, the value of a_0P ranges from 30P to 50P. It is now determined that the minimum distance between centres must exceed 8.4P. Based on the current structural dimensions of 8.4P, it does not satisfy the design specifications and should be increased accordingly. Ultimately, the initial distance between the centres is determined. The distance between point A and point P is equal to 15 times the value of P.

Determine the quantity of chain links, denoted as L_P:

$$L_P = \frac{Z_1+Z_2}{2} + 2a_{0P} + \frac{k}{a_{0P}} \qquad (3.21)$$

$$= \frac{21+21}{2} + 2 \times 15 = 51$$

Determine the value of the variable L_P, which represents the number of chain links, as 51. To ensure an even number of links, we will round the number of links to the next even number. In this case, we have L_P=52. Let's calculate the chain length, L:

$$L = \frac{L_P \cdot P}{1000} = \frac{52 \times 12.7}{1000} = 0.66m \quad (3.22)$$

Calculate the center distance a_c:

$$a_c = \frac{P}{2}(L_P - Z) = \frac{12.7}{2} \times (52 - 21) = 196.85mm \quad (3.23)$$

Calculate the actual center distance a:

$$a = a_c - \Delta a = 196.85 - 0.004 \times 196.85 = 196.1mm \qquad (3.24)$$

Calculate the chain speed v:

$$v = \frac{Z_1 n_1 P}{60 \times 1000} = \frac{21 \times 46 \times 12.7}{60 \times 1000} = 0.2m/s \quad (3.25)$$

Calculate the effective circular force F_t:

$$F_t = \frac{1000P}{v} = \frac{1000 \times 0.2kW}{0.2} = 1000N \quad (3.26)$$

Calculate the force F acting on the axis:

$$F = 1.15K_A \cdot F_t = 1150N \qquad (3.27)$$

The third edition of " Mechanical Design Engineering Handbook" Edited by JODI WICAKSONO " Figure 13-2-5, Table 13-2-47, and Table 13-2-48 as references for the appropriate selection of the lubrication method. Regularly employ a brush or oil bottle to manually eliminate loose chains. Apply oil to the space between the inner and outer chain plates. Determine the static strength of the roller chain using the formula (13-2-1) provided in the book.

$$n = \frac{F_u}{K_A F_t + F_c + F_f} \qquad (3.28)$$

In the formula:

N Static strength safety factor.

F-u chain ultimate tensile load, kN.

F-t effective circular force, kN.

F-c The force caused by centrifugal force, kN.

q chain quality, kG.

v Chain speed, m/s.

F-f - hanging force, whichever is greater between 〖F-f〗 ^' and 〖F-f〗 ^".

$$F_f' = \frac{K_f qa}{100} = \frac{2.7\times0.6\times196.1}{100} = 3.18N \quad (3.29)$$

$$F_f'' = \frac{(K_f + \sin\theta)qa}{100} = \frac{(2.7+\sin 60°)\times0.6\times196.1}{100} = 4.2N \quad (3.30)$$

K-f coefficient.

a Chain drive center distance, mm.

θ The inclination angle between the center line of the two wheels and the horizontal plane.

n-p allowable safety factor, n-p=4~8.

The third volume of "Modern Mechanical Design Handbook" states that Table 13-2-2 displays the value of Fu as 13.9kN. The parameters derived earlier are utilized in formula (3.28) to compute:

$$n = \frac{F_u}{K_A F_t + F_c + F_f} = 13.8 > n_p \quad (3.31)$$

Calculate the static strength of the roller chain according to the formula (13-2-3) in the book:

$$T = \left(\frac{K_P P_o'}{K_A P}\right) \cdot \frac{L_P}{100} \qquad (13.3)$$

In the formula:

T service life, h.

Z-1 The number of small sprocket teeth.

n-1 small sprocket speed, r/min.

K-p Multi-row chain number coefficient.

K-A working condition coefficient.

K-A working condition coefficient.

L-P Chain length, mm.

K-p is determined as 1 by referring to the row coefficient table in Table 13-2-8 in the book. Similarly, K-A is determined as 1 by referring to the working condition coefficient table in Table 13-2-6 in the book. These acquired parameters are then plugged into formula (13.32) for calculation.

$$T = \left(\frac{K_P P_o'}{K_A P}\right) \cdot \frac{L_P}{100} = 15000 \times \frac{1 \times 0.32}{1 \times 0.2} \times \frac{52}{100} = 12480h \qquad (13.33)$$

Determine the level of resistance to wear exhibited by a roller chain:

$$T = 91500 \left(\frac{C_1 C_2 C_3}{P}\right) \cdot \frac{L_P}{v} \cdot \frac{Z_1 i}{i+1} \left(\frac{\Delta p}{P}\right) \frac{P}{3.2 d_2} \qquad (13.34)$$

In the formula:

C-1 wear coefficient, check Figure 13-2-8 to get C-1=5;

C-2 pitch coefficient, look up table 13-2-13 and get C-2=1.44;

C-3 number of teeth-speed coefficient, check Figure 13-2-9 and get C-3=1;

Put the parameters and related calculation parameters obtained from the table lookup into formula (3.34) to calculate:

$$T = 91500\left(\frac{5\times1.44\times1}{32}\right)\cdot\frac{52}{0.2}\cdot\frac{21}{1+1}\times 0.03\times\frac{12.7}{3.2\times3.98} = 85118h \qquad (3.35)$$

Computation of fundamental characteristics of a sprocket:

Based on the previously determined sprocket characteristics and table lookup, the number of teeth on the sprocket is Z-1=21, the chain pitch is P=12.7mm, and the maximum diameter of the chain's roller is d-1=7.92mm.

Determine the indexing circle diameter (d), tooth tip circle diameter (d-a), and tooth root circle diameter (d-f) based on the fundamental characteristics and primary dimensions provided in Table 13-2-14 for the sprocket.

$$d = \frac{\mathrm{P}}{\sin\frac{180^\circ}{Z}} = \frac{12.7}{\sin\frac{180^\circ}{21}} = 85.21mm \qquad (3.36)$$

$$\mathrm{d}_a = P\left(0.54+\cot\frac{180^\circ}{Z}\right) = 12.7\times\left(0.54+\cot\frac{180^\circ}{21}\right) = 91.12mm \qquad (3.37)$$

$$\mathrm{d}_f = d-\mathrm{d}_1 = 85.21-7.92 = 77.29mm \qquad (3.38)$$

Calculate the chain length L:

$$L = \frac{L_P\cdot P}{1000} = \frac{60\times25.4}{1000} = 1.52m \qquad (3.48)$$

Add the following to the center distance a-c calculation:

$$a_c = \mathrm{P}(2L_P-\mathrm{Z}_1-\mathrm{Z}_2)\mathrm{K}_a = 520.45mm \qquad (3.49)$$

Calculate the actual center distance a:

$$a = a_c-\Delta a = 520.45-0.004\times520.45 = 518.37mm \qquad (3.50)$$

Calculate the chain speed v:

$$v = \frac{\mathrm{Z}_1\mathrm{n}_1P}{60\times1000} = \frac{17\times56.8\times25.4}{60\times1000} = 0.41m/s \qquad (3.51)$$

Calculate the effective circular force F-t:

$$\mathrm{F}_t = \frac{1000P}{v} = \frac{1000\times2.2kW}{0.41} = 5365.85N \qquad (3.52)$$

Calculate the force F acting on the axis:

$$F = 1.15K_A \cdot F_t = 6170.73N (3.53)$$

The third edition of the "Modern Machinery Design Manual" cites Figure 13-2-5, Table 13-2-47, and Table 13-2-48 as references for the appropriate selection of the lubrication method. Regularly employ a brush or oil bottle to manually eliminate any loose chains. Apply oil to the space between the inner and outer chain plates.

3.3 Shaft design and verification

There are three primary techniques for determining the strength of a shaft: evaluation of permissible shear stress, evaluation of permissible bending stress, and assessment of safety factor. These three strategies can be employed either separately or consecutively. In general, the calculation of the spinning shaft based on the permissible bending stress is sufficiently reliable and does not necessarily require verification using the safety factor approach. When the strength calculation fails to fulfil the specified requirements, it is necessary to modify the structural design. These two aspects often work together and intersect with each other [2]. The belt roller shaft of the gearbox mechanism is constructed from 45 steel, while the actuator utilises 40Cr as the material for preliminary design verification. When a keyway is present on the shaft, the diameter of the shaft should be expanded accordingly: by 3% for single keys and by 7% for double keys.

3.3.1 Transmission mechanism transmission belt shaft

The solid shaft shear stress can be calculated using formula (12.15) from the fourth edition of "Mechanical Design" edited by Peter RN Childs Second edition.

$$\tau_T = \frac{T}{W_T} = \frac{9.55\times10^6 P/n}{0.2d^3} \leq [\tau_T]\ MPa\ (12.6)$$

Once the formula is distorted, the design formula can be derived, allowing for the calculation of the minimal shaft diameter that satisfies the requirements of strength design.

$$d \geq \sqrt[3]{\frac{9.55\times10^6 P}{0.2[\tau_T]n}} = C\sqrt[3]{\frac{P}{n}}\ mm (3.61)$$

In the formula:

WT The torsional section coefficient of the shaft, mm³.

τ_T - torsional shear stress, MPa.

[τ_T] Allowable torsional shear stress, MPa.

P The power transmitted by the shaft, kW.

n The rotation speed of the shaft, r/min.

d The diameter of the shaft, mm.

T The torque of the shaft, N·mm.

C Coefficient related to shaft material.

Based on the coefficient C provided in Table 16.2 of the fourth edition of 'Mechanical Design' edited by Peter RN Childs Second edition, the calculation involves using the value of C=106 for 45 steel, the shaft speed n=46r/min for the gearbox belt, and the power P=0.192kW transmitted on the shaft. These values are plugged into formula (12.4) for calculation.

$$d \geq C\sqrt[3]{\frac{P}{n}} = 106 \times \sqrt[3]{\frac{0.192}{46}} = 17.07mm \qquad (12.12)$$

The shaft will experience deformation when subjected to a load. Shaft deformation can be categorised into three types: deflection, rotation angle, and torsion angle. The acceptable torsion angle for precision machinery shafts is between 0.15°/m and 0.3°/m. For common gearbox shafts, the acceptable torsion angle is from 0.5°/m to 1°/m. Accuracy The permissible torsion angle for the lower shaft is between 1°/m and 2°/m. The torsion angle calculation formula per unit shaft length, as stated in the fourth edition of "Mechanical Design" edited Peter RN Childs Second edition, is given by the equation 1.8

$$\frac{\varphi}{l} = \frac{T}{GI_P} \leq [\varphi] \quad (3.63)$$

Once the formula is altered, the design formula may be derived, allowing for the calculation of the minimal shaft diameter that satisfies the stiffness design criteria.

$$d \geq \sqrt[4]{\frac{32 \times |T|_{max} \times 180}{G \times \pi^2 \times [\varphi']}} \quad (3.64)$$

In the formula:

d -The diameter of the shaft, mm.

$[\varphi']$ Allowable torsion angle per unit length, °/m.

|T|_max maximum torque, N·m.

G Shear elastic modulus of shaft material, GPa.

I_P polar moment of inertia of shaft section, m4.

The mechanical design handbook states that the shear elastic modulus of 45 steel is G=80GPa, the permitted shear stress is [τ]=40GPa, and the proposed allowable torsion angle per unit length is [φ^']=2°/m. Input the formula for calculation:

$$d \geq \sqrt[4]{\frac{32\times39.86\times180}{80\times10^9\times\pi^2\times2}} = 19.53mm$$

The shaft end diameter of the belt roller shaft is rounded to 20mm based on the design calculations of strength and stiffness, as well as the selection of supporting bearings and specifications for the shaft diameter.

Check the strength of the shaft:

$$W_P = \frac{\pi d^3}{16} = \frac{\pi\times20^3\times10^{-9}}{16} = 1.57\times10^{-6}m^3$$

$$\tau_{max} = \frac{T}{W_P} = \frac{39.86}{1.57\times10^{-6}} = 25.39MPa < [\tau] = 40MPa$$

Check the stiffness of the shaft:

$$I_P = \frac{\pi d^4}{32} = \frac{\pi\times20^4\times10^{-12}}{32} = 1.57\times10^{-8}m^4 \quad (3.68)$$

$$\varphi' = \frac{T}{GI_P}\times\frac{180}{\pi} = \frac{39.86}{80\times10^9\times1.57\times10^{-8}}\times\frac{180}{\pi} = 1.82°/m < [\varphi'] = 2°/m$$

In summary, the parameter design of the shaft meets the design requirements.

Chapter 4

3D Modeling

4.1 3D design assistance software

4.1.1 Introduction to SOLIDWORKS software

Solidworks, a prominent CAD tool by Dassault, has become the most extensively utilized design software globally, owing to its robust capabilities. From its inception, Solidworks has been dedicated to developing 3D mechanical CAD software specifically designed for engineers. As a result, Solidworks rapidly gained a significant share of the market due to its user-friendly interface and comprehensive features. In the Solidworks working environment, users can not only conduct 3D modeling and engineering drawing tasks, but also directly access other professional programs such as engineering analysis, CNC machining, and product data management, which are closely integrated. For the structural research and design of the portable potato slicer, Solidworks' 3D modeling and simulation components were utilized to conduct engineering analysis. The Simulation plug-in conducts simulation experiments, such as static stress analysis, to assess the viability of the new structure.

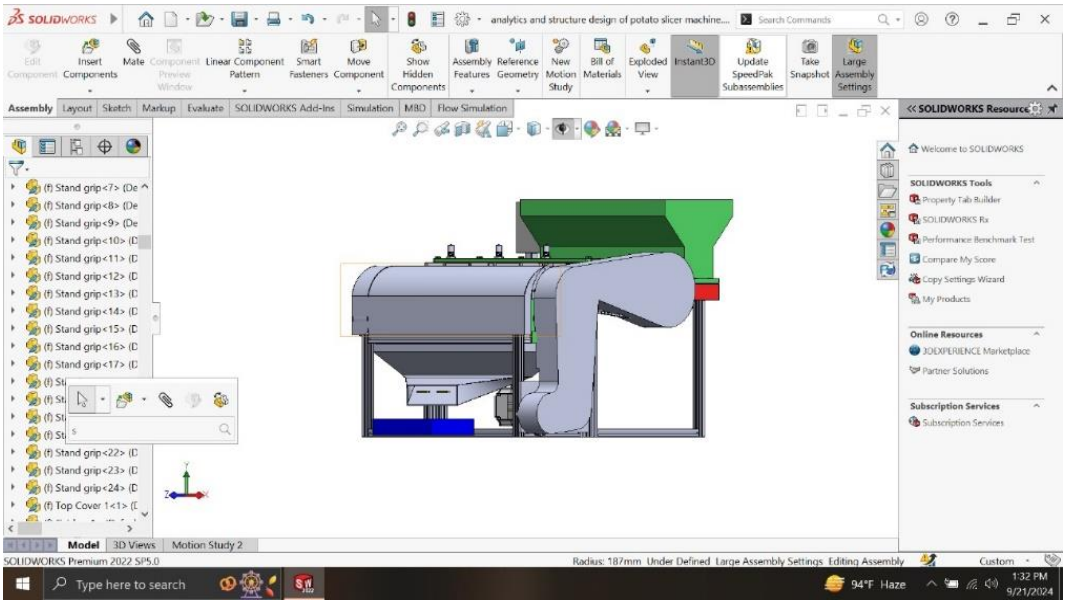


Fig.4.1.1.1 Solidwork Software

4.2 Key component designing Parts

4.2.1 Shafts

The working principle of shafts in potato slicers is revealed in depth by available documentation. Here is a comprehensive breakdown based on these sources:

Power Transmission

Shafts transmit mechanical energy from motors to blades. Source 1200W 48V DC Servo Motor, 4.5 Nm, 2500 rpm spins a shaft via chain spoke, efficiently conveying power for slicing. Well-designed shafts ensure smooth, uninterrupted energy transfer for top performance.

Blade Bearing and Rotation

Shafts directly support and spin cutting blades. Source 4 analyzes one potato slicer's shaft, crucial for handling torque from even large potato volumes or harder varieties. Mild steel composition provides strength and resilience.

Structural Soundness Under Stress

Designs account for strains. Source 4's SOLIDWORK analysis models von-Mises stresses and strain on one shaft, validating its integrity without buckling or fracturing during operation.

Maximized Productivity

A shaft's design influences efficiency and capacity. Source 2's machine achieves over 80% efficiency partly from its shaft and transmission system, demonstrating how components contribute significantly to overall function. In closing, shafts play vital mechanical roles in potato slices, from power handling to structural dependability. Their optimization, revealed in documentation, is critical for top output and satisfaction of processing needs

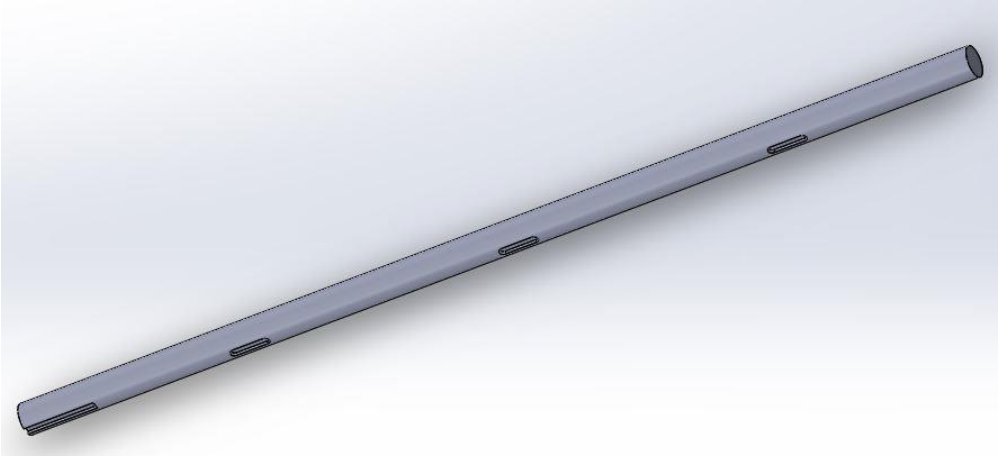


Fig.4.2.1.1 3D shaft

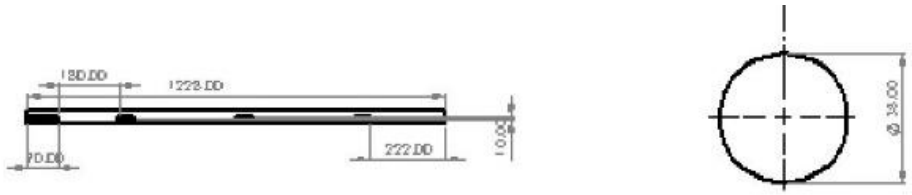


Fig.4.2.1.2 2D shaft

4.2.2 Slicing Axis

The direction by which a potato slicing machine is used to slice a potato is known as the slice axis. To understand how the slice axis works in a machine, it is necessary to first note how the device herds the potatoes into the blades. The following is a description of the concept based on the use of general ideas of machine design and operation level that may be common to machines of this nature and Explanation of Concept.

Orientation and Movement: A potato slicing machine might have the slice axis horizontal or vertical, designed depending on whether the machine is set vertically or horizontally. This orientation affects the direction by which the potatoes move against a stationary or moving blade or set of blades.

When slicing horizontally, the potatoes might be thrown in across a conveyor belt of moving potatoes across the stationary blades or set of blades that are moving compelled by mechanical cutters.

Blade Herding and Blade Interaction: The blades might be fixed into the slice axis slots across the potatoes. Blade sharpness and angle must be precise to acquire a deliciously sharp cut while maintaining vertical alignment for best and consistent starch cut quality.

Mechanical forces in variance might be used in propelling the potatoes against the blades.

Quality and Control of Slice Thickness:

The gap between preset programmed blades must be itself precisely constant. The real blade might be able to move up and down or be easily changed when the edge is getting blunt so that a constant quality of the slice is achieved. Optic sensors accurately ensure that the size of the quantity of slice remains constant and quality. The motor slicer will then be set to cut at a programmed power level. The uniformity of thickness is maintained as slicing is also at a constant power level and the same rigid tools and advantages are used to slice from a higher cut the hard potato or a softer aborigine.

Speed and Power Transmission Efficacy:

For the effective running of the machine along the slice axis against the potatoes, the quicker the potatoes will move through the blades, the more efficient the slicing process and the more effective the equipment. Too little sliced and too slow.

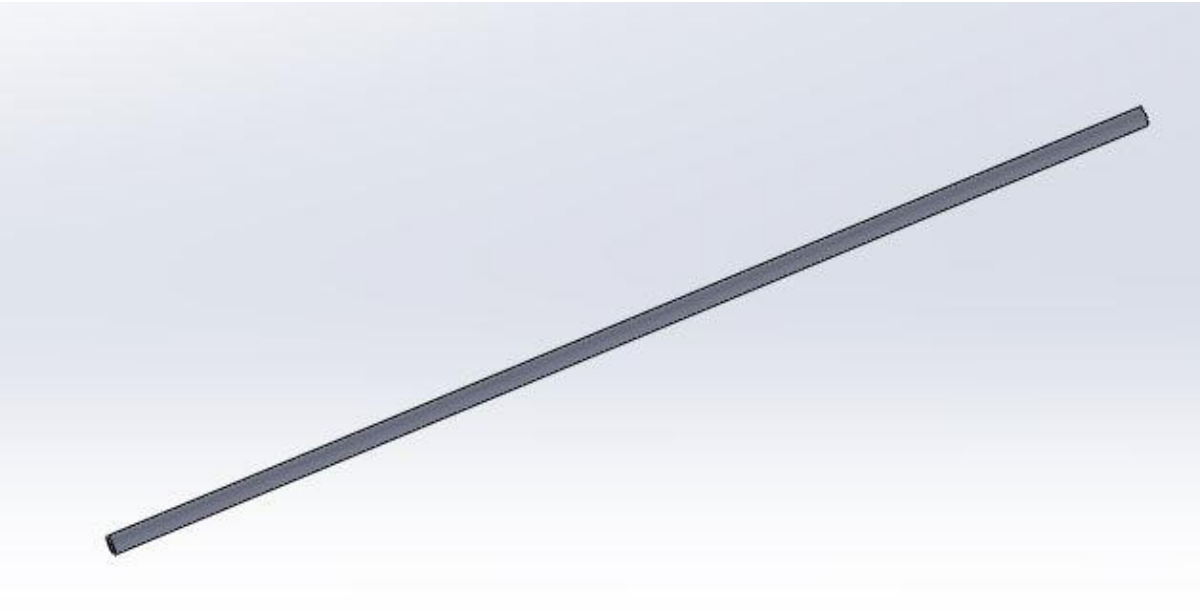


Fig.4.2.2.1 3D **Slicing Axis**

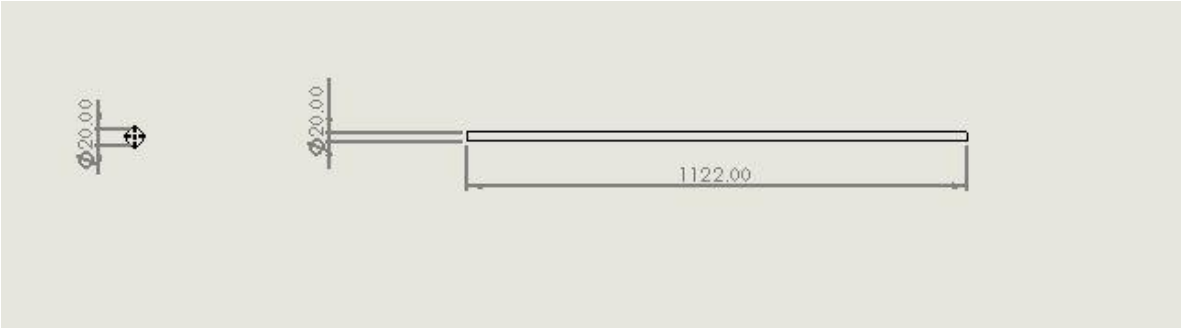


Fig.4.2.2.2 2D **Slicing Axis**

4.2.3 slicing blade

The intricacies of the slicing mechanism at the heart of a potato slicer involve several critical mechanical components arranged to expeditiously partition potatoes into congruent segments. Upon inspection of the provided sources, here is an elaborated depiction of how the slicing blade performs within a potato slicer:

Blade Fabrication and Material

Generally, the slicing blades are fashioned from resilient substances like stainless steel or cast iron, preserving sharpness and resisting deterioration in time of cast iron for the severing blade, sturdy enough to withstand the repetitive action of transecting crude potatoes.

Blade Placement and Motion

The blades are mounted on a shaft or within a cutting enclosure, contingent on the design of the apparatus. In some schematics, the blades are static and the potatoes are propelled. Portrays a contorted potato crisps fabricator where the severing blade is perpendicular to the potato's rotational axis, indicating a rotary motion that slices the potato as it is manually rotated.

Cutting Action

The fundamental cutting action involves a keen edge of the blade making contact with the potato. The exertion either by the potato's movement against the blade or by the blade's movement through the potato causes a clean severance, splitting the potato into slices or other shapes. The thickness of the slices is predetermined by the distance between the blades or the depth of the cut set by the apparatus's settings.

Power Transmission

The motion of the slicing blades is generally energized by a motor. A transmission system involving chain spoked transfers the motor's rotational power to the blades. For instance, Source discusses the use of a 1200W 48V DC Servo Motor, 4.5 Nm, 2500 rpm the mechanism that maneuvers the blades.

Efficiency and Uniformity

The design of the blade and the precision of the apparatus's mechanical systems ensure that each slice is uniform in thickness, which is crucial for the quality of the final product. The competence of the apparatus, as noted in Source is also a critical factor, with machines accomplishing high capacities and maintaining good uniformity in slice thickness.

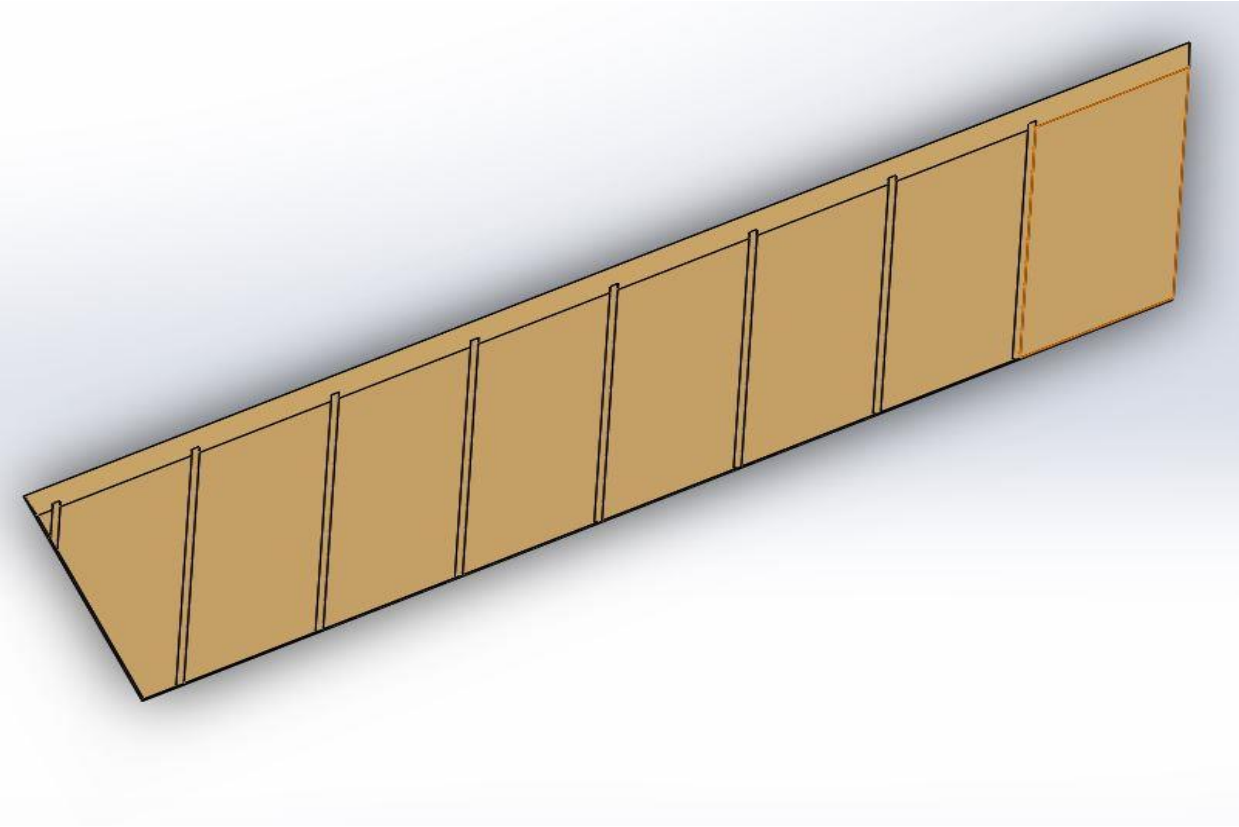


Fig.4.2.3.1 **3D slicing blade**

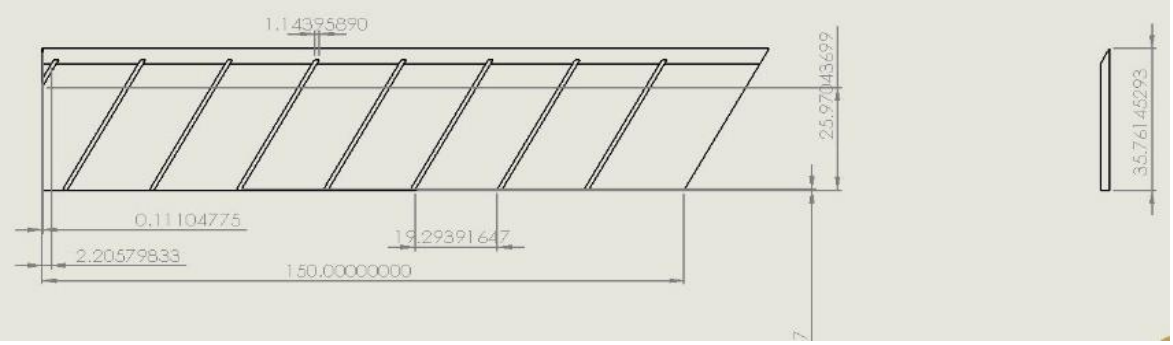


Fig.**4.2.3.2 2D slicing**

4.2.4 square cutting blade

A square cutting blade in a potato slicing machine works due to a combination of mechanical actions. The provided sources do not describe a square cutting blade. However, we may assume the principle of functioning based on information about potato slicing machines and the mechanisms of cutting. As I understand it, the working principle is as follows.

Material and shape of a blade

A square cutting blade is made of such materials as stainless steel or cast iron. The blade takes the shape of a square and has sharp sides to make the cuts square or rectangular.

The arrangement of blades

Since the desired shape of cut is square or rectangular, the blades are set in a square grid on the surface of a cutting chamber. The function of the blade is to cut the potato following the line of the square grid.

Process of cutting

The potato is driven by force to the chamber. The blades run perpendicular to the direction of the potato fed. Due to manual or machine-pusher force, potatoes are pushed and cut following the line of the square grid of knives. The grooved potato's geometry is rectangular, and the potatoes are cut into square or rectangular slices.

Size of potatoes

The size of potatoes may be adjustable via changing the gap between the knives of the square grid. Then, the blades are arranged closely; the gap between the cut slices is small.

The process efficiency and the machine throughput depend on the sharpness of a blade, the feeding rate of potatoes into the chamber, and the precision of the arrangement of blades. To provide higher productivity and uniformity of size, the competitive type of a square cutting blade system should ensure a high degree of precision of the system elements and a high sharpness of a blade. For the quality of cuts, it is important to keep the blades clean, to avoid the material that may be present on the blades, and to create the risky situations of operator injury.

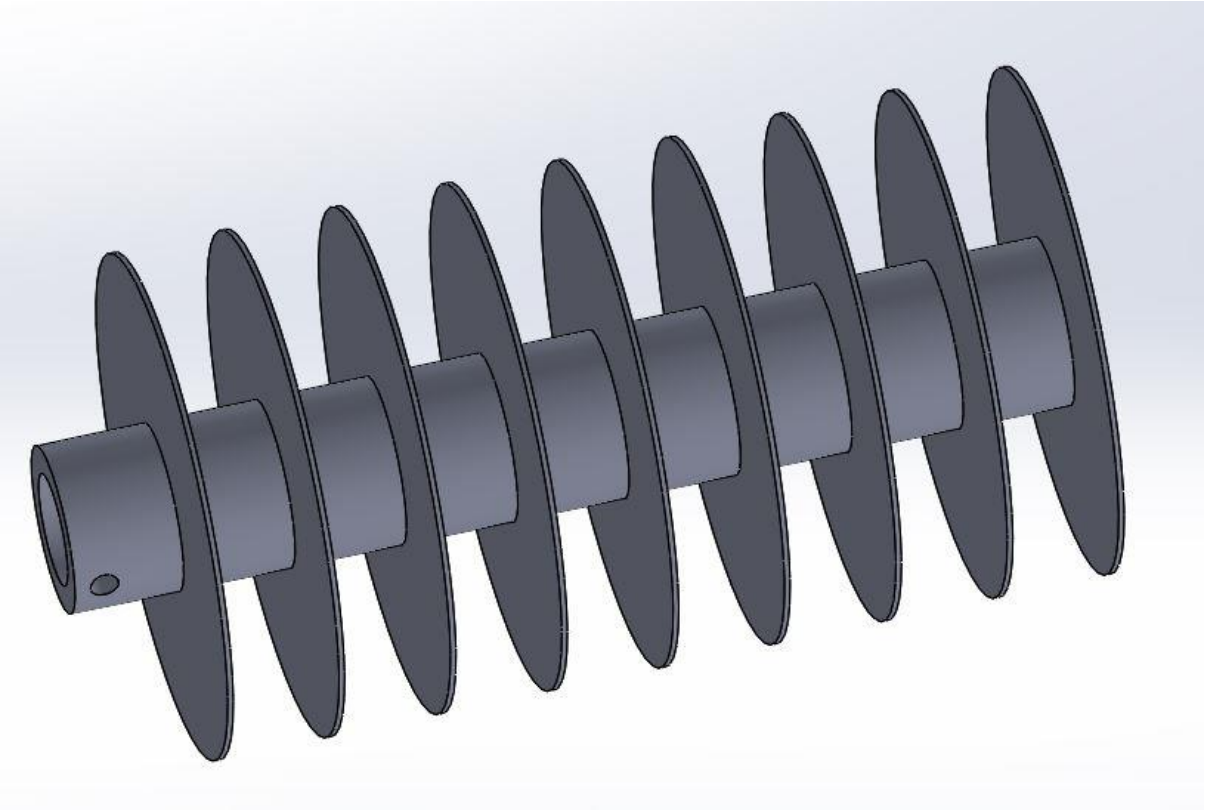


Fig.4.2,4.1 3D **Round cutting blade**

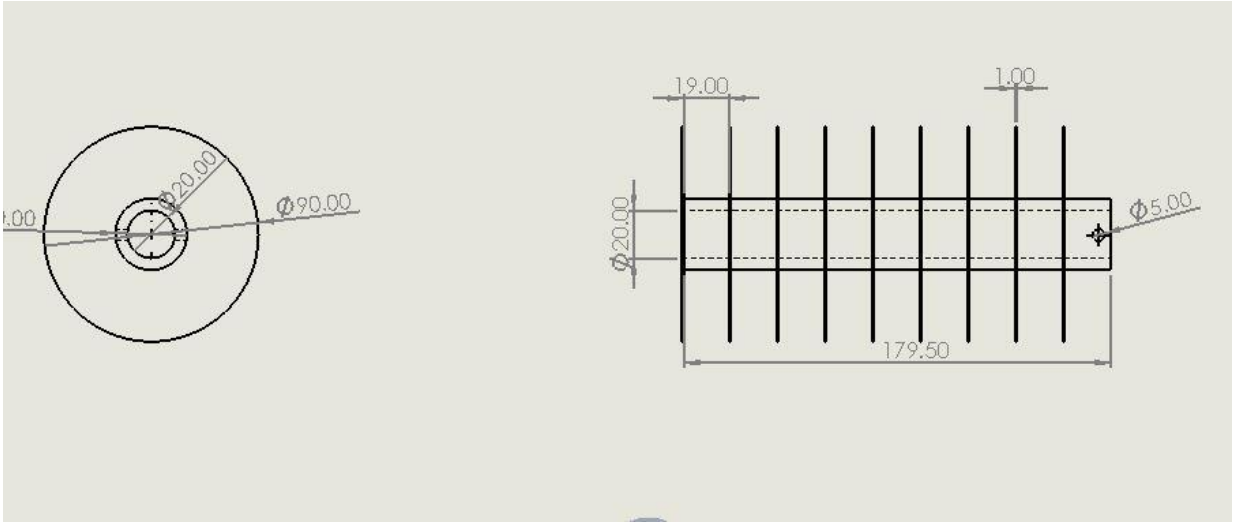


Fig.4.2.4.1 **3D Round cutting blade**

4.2.5 Chain and Spoked Mechanism

Power Transmission:

This mechanism is responsible for the power transmission from the motor to the blades that cut the potatoes. Usually, such transmission is conducted by means of a sequence of gears, chains, and sprockets. However, in the provided case, the authors offer an option to use a chain drive, which is more durable, robust, and reliable Source.

Components:

Chains, sprockets: the speed of the chain is regulated by the motor, which is attached to the primary sprocket and rotates. Ultimately, this function leads to the rotation of the chain, and the chain moves another sprocket, which is located adjacent to slicing blades. As a result, the blades rotate with the relevant speed to make cuts on the potatoes.

Working Principle:

When the motor is turned, the primary sprocket begins rotated. The chain is attached to the sprocket, and it starts moving. As the result, the adjacent sprocket is driven and this sprocket is connected to the slicing unit.

It needs to be mentioned that all these indicators are driven by one important factor – constant movement of the chain. In turn, constant movement of the chain results in the constant rotation of the slicing blades, and in such a manner, potatoes are sliced accurately and uniformly.

Spoked Mechanism

The spoked mechanism of the slicing machine is connected to the support of the slicing unit and includes the movement of these blades. The actual mechanism is called spoked wheels or blades, which rotate on both side. A pedal operated integrated machine for potato peeling and slicing discloses that the football-shaped slicing unit has a blade attached to a lock, while the lock is divided into balanced halves and each half has spokes or ridges.

Operation:

When the shaft is rotated using the chain drive mechanism, the spoked wheel and blades mounted on it are also rotated. As potatoes are fed through the machine, the blades move in a slicing motion perpendicular to the axis of rotation, creating slices from the potatoes in both the feeding and discharge ends of the mechanism. The blades are stable in their position in the wheel, ensuring a clean and aligned cut to the slices that are made.

Efficiency and Consistency:

Due to these mechanisms working together, the slicing operation is one that is efficient and mechanically synchronized. At the time of operation, the chain drive ensures the blades are rotating at a uniform speed, thereby controlling the thickness of the slices that are made.

Maintenance and Safety:

Regular maintenance of the chain drive is vital to ensure proper functioning. Care needs to be taken to lubricate the chain and monitor its tension, along with a need to replace any damaged parts. Guards are placed around the mechanism, and emergency stops are put in place to prevent accidents. The chain and spoked mechanisms are connected and work together within the potato slicing machine in order to ensure that good cuts are made.

4.2.6 Cutting section Mechanism

The cutting section mechanism in a potato slicing machine is comprised of several key components and processes. Such a mechanism is designed to cut potatoes efficiently and uniformly. Notably, the explanation of the cutting section mechanism can be found in here. Below is a detailed explanation of how the cutting section mechanism works based on the sources provided.

Working Principle Feeding the Potatoes:

Potatoes are fed into the machine through the feed mechanism. Concurrently, the feed mechanism properly aligns the potatoes so that they can be moved toward the cutting blades at a uniform rate.

Cutting Action

Once the potatoes reach the cutting section, they are set against the blades. The cutting can be performed in one of three ways based on the design of the machine.

Rotating Blades

If the machine uses rotating blades, the latter are spun at a high rate. As a result, the potatoes are cut as they pass through. This cutting action is uniform because it allows the potatoes to be continuously cut, making it perfect or high volumes

Fixed Blades with Moving Potatoes

The fixed blades can also be used in potato slicing machines. In such machines, the feeding mechanism supplies the force that allows the potato to be cut as it is pushed through the blade.

Control of Slice Thickness:

The slice thickness is controlled using the space between two parallel blades or alternatively the space in which the depth of the cut is set. The setting is usually adjustable to allow the production of different sizes of slices.

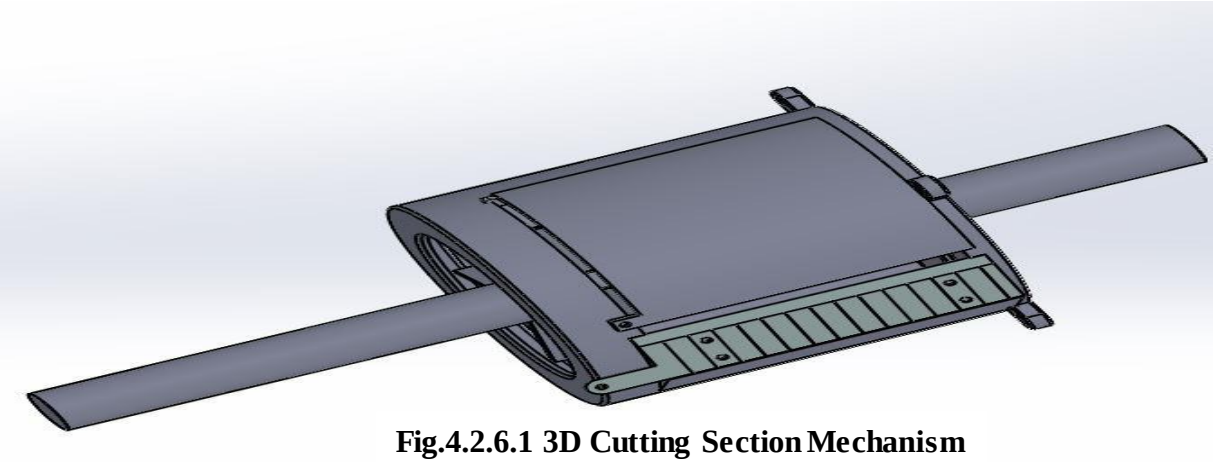


Fig.4.2.6.1 3D Cutting Section Mechanism

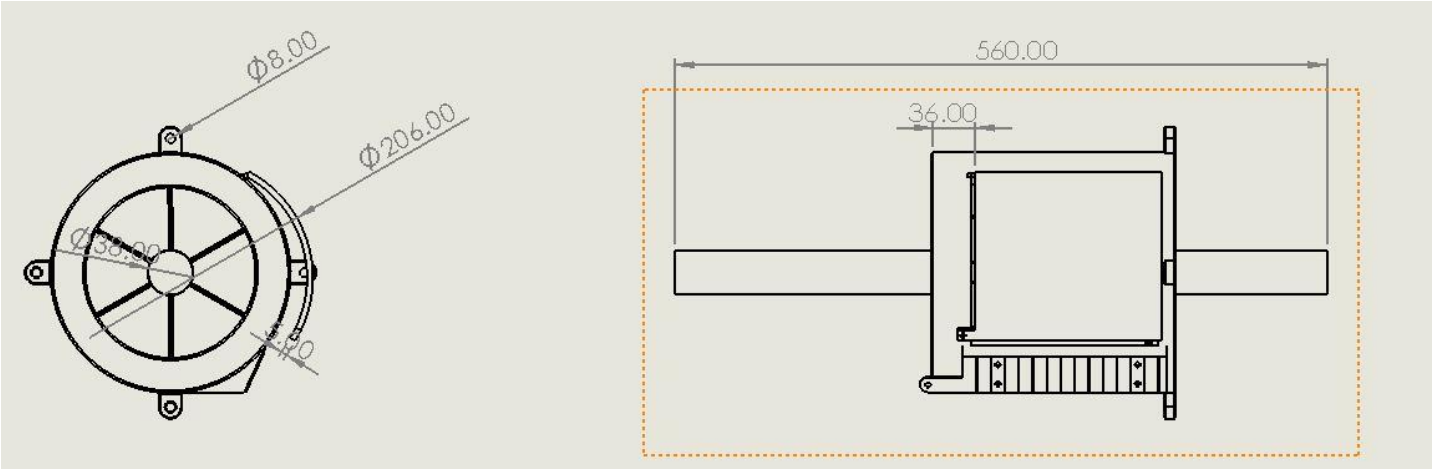


Fig.4.2.6.2 2D Cutting Section Mechanism

4.2.7 Conveyer Belt:

The conveyor belt working mechanism in a potato slicing machine is concerned with how premised potatoes are effectively fed into the slicing section. Therefore, based on the provided sources,

Conveyor Belt: This is the mechanism that helps to feed potatoes properly into the slicing unit through a revolving belt. The belt consists of a food-grade element that is supported by rollers and pulleys.

Drive System: This consists of a small motor, which is usually a DC motor or a permanent magnet synchronous motor. The motor is physically joined to the belt through a number of means such as gears, chains, or direct drive techniques. This component drives the motion of the conveyor belt. The system facilitates the conveying of potatoes from the loading a section to the slicing unit.

Sensors and Control System: Different types of sensors can be used in a conveyor belt for a potato slicing machine use Optical Sensor. The function of these sensors which are connected to the control system is to detect if any potato is present and the position of the potato on the conveyor belt. The control system is usually a responsible for controlling the speed and rate of operation of the conveyor belt based on sensors' detections.

Guides and Enclosures: Potato spuds are usually loaded manually or by an automatic spud fed into the entry. There are guides or enclosures on the entry that assist in the alignment of these deposited potatoes properly on the belt. Furthermore, similar guides are often installed along the whole length to ensure the potatoes are directed to the slicer in the proper orientation.

Detection and Alignment: Potatoes are detected and aligned using sensors as they continue to move along the conveyor belt. The control system will then use the placed information to adjust the line speed of the conveyor in such a way that the potatoes will continue to be aligned ready for the slicing operation. Besides, the machine vision systems can be used to inspect the potatoes' quality and sort them before they reach the slicing section.

Controlled Movement: The steady applications of the motor are used to drive the potatoes consistently and constantly at the desired slicing section. The control system will also be used to vary the motor speed depending on the slicing section's capacity. The speed can be assumed to depend on the desired number of potatoes that should be sliced. Therefore, the control system will ensure that the motor is continuously in motion at the desired speed, and in an event, there is a blockage that the conveyor belt should stop or slow down.

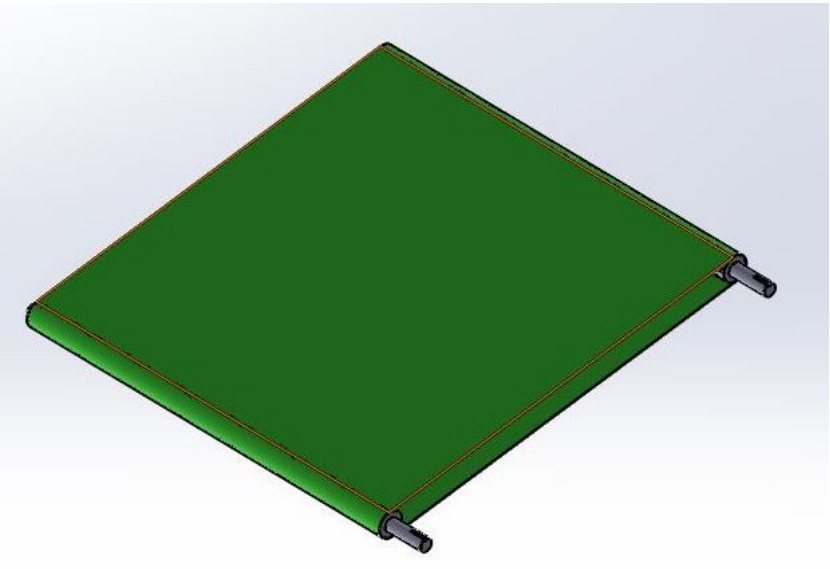


Fig.4.2.8.1 3D **Conveyer Belt**

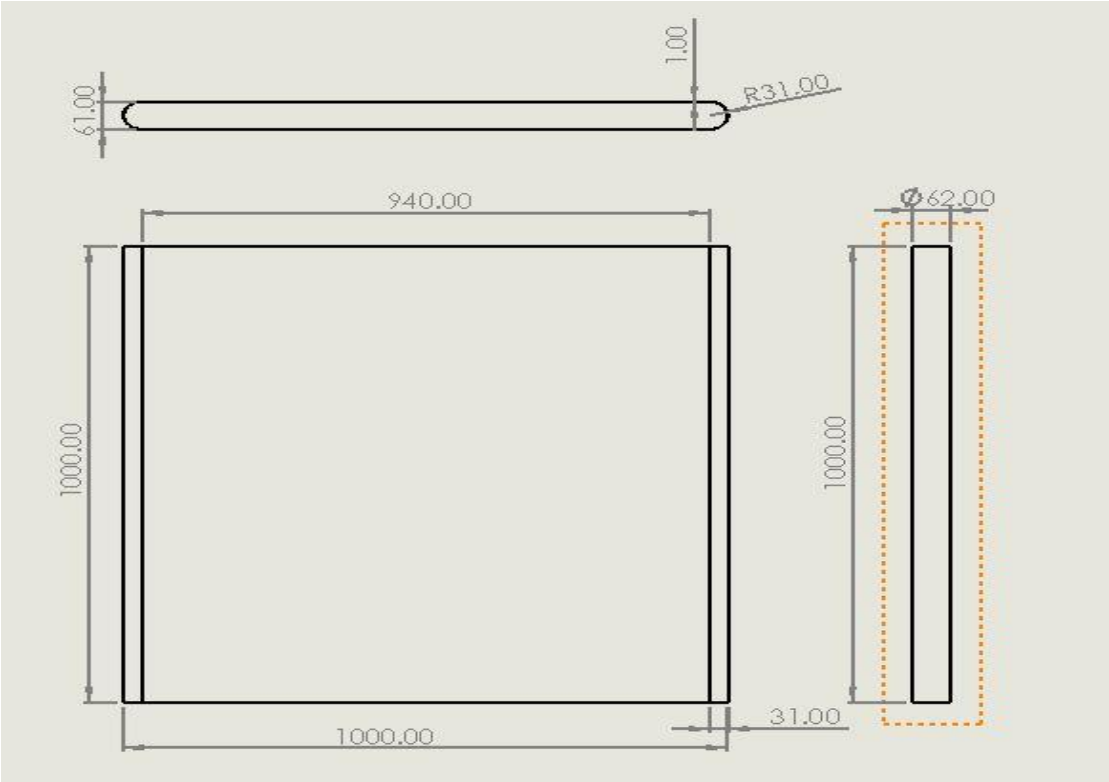


Fig.4.2.8.2 2D Conveyer Belt

4.2.8 STRACTURE

The structure of a potato slicing machine is notably an outstanding part that offers the required support and rigidness for the entire assembly. SS400 angle bars are commonly used to build the structure of the frame. The production of the structure has a high strength, ease of fabrication, and stable strength to weight ratio. Therefore, the reliable framework for slicing machine could be better experimented with metal angle bars supporting the overview of the project. Below is the information on how the structure of a potato slicing machine can be built using the SS400 angle bars.

components of the structure

Frame. Frame guide of the machine while doing slicing activity. This is usually constructed with a SS400 angle bar as the former. It is typically used for products as it costs from mild to hard steels commonly used for its constructive strength-to-weight ratio and ease of assembly of weld points.

Frame dimensions are designed based on the size and density of the whole component, such as material and motor. The cutting takes place during all these actions; therefore, special implement procedures should conserve stability. SS 400 angle bars.

Base: The base of the machine is applied with SS400 angle bars and the frame, either rectangular or cubic, is known. This is required to provide a solid foundation to support the motor, cutting blades, and other components. EDSO spacing with additional bars would improve baseline stiffness and prevent rotation.

Horizontal: The horizontal cross lines link vertical support at SS 400 angle bars. They cannot match any vertical supports to function as cutting object feed. Thus, the thin metal is double-edged, secure enough to rely on the cutting mechanism during machining, and easy to connect to the vertical bar. It would be deployed at a significant distance to ensure, without receiving much loads, that no frame in the machine.

Mounting plates: Brackets made of SS400 steel are used to attach the motor, cutting blades, and other components to the frame. The plates are welded or bolted to the angle bars, serving as secure attachment points. The design of the plates ensures that the components are properly aligned and can be adjusted or replaced if necessary. Protective Housing

Cutting and Preparing the Angle Bars:

First, SS400 angle bars need to be cut according to the plan. A particular device, such as a metal saw or cutting torch, is usually used during this process. Cutting is followed by cleaning and beveling of their ends in preparation for welding or bolting. Welding or Bolting

The first part of the blade cutters that should be welded or bolted is the base. The previously prepared angle bars are used to construct a rectangle or square frame. Additional bars are inserted into the length of the rectangle for reinforcement. The vertical supports are then attached to the base, each of them reinforced with a crossbar. At this stage, it is essential to ensure that the cutters' frame is square and level. After that, the mounting plates and brackets are attached at their designated positions. Installing the protective housing is the final step of the process.

Onto final assembly and testing – after the frame and housing is ready to hold the system and protect the operator from the moving parts the motor, cutting blades and feed system are mounted. Effectiveness of the machine is tested by cutting potatoes Observing that the structural integrity is surviving the stresses of cutting the potatoes. With encouragement to use it to test cutting the potatoes manually. Round slabs best to get the most angle of cutting potato slabs.

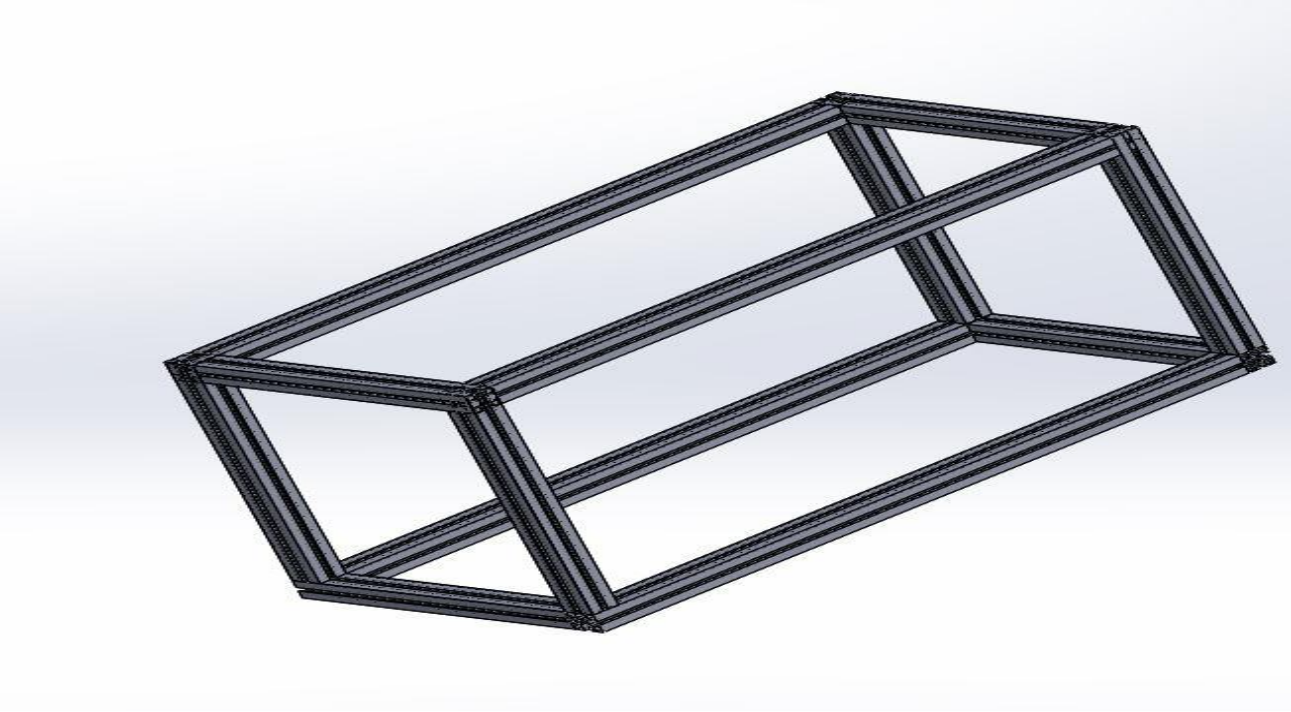


Fig.4.2.10.1 3D STRACTURE

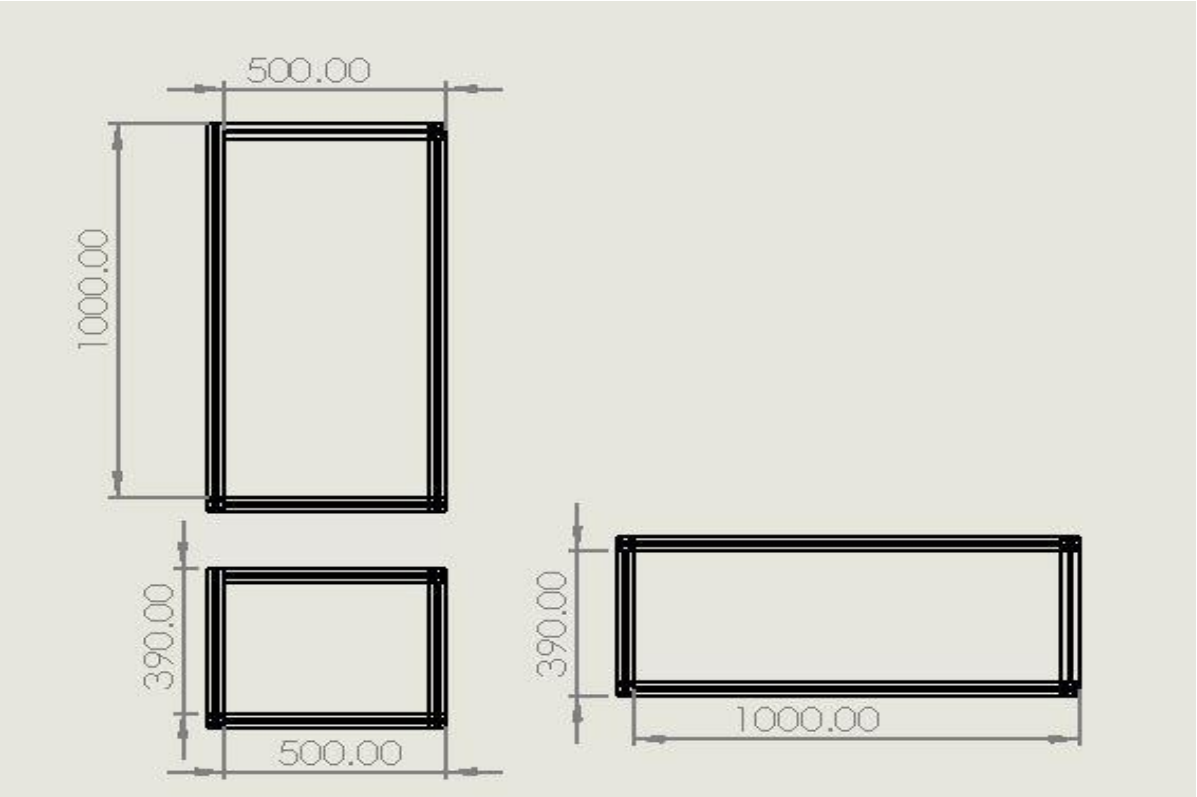


Fig.4.2.10.2 2D STRACTURE

4.3 Potato slicer assembly design

Potato slicer design and assembly presupposes uniting different components into one functioning machine that can work effectively slicing potatoes. It is found that the rough and mainframe, conveying disk and slicing unit, slicing shaft and idler shaft, and the spoked and bearing, as well as the electric servo motor Etc., are the components of the potato slicer assembly and design.
First, the frame and the mainframe is among the most important components of the potato slicer. It is the structure that provides the machine with support and maintains its stability. mild steel is used for the body of the machine ensuring that the structure is durable and easy for maintenance. The Holler is another key component used to load the potatoes. The conveyor Belt is used to convey potatoes into the slicing unit, where they are being sliced. The slicing unit is another important component because it is equipped with slicing edges that cut the potatoes into equal sizes. The design of the slicing unit is essential because it determines the efficiency, and the throughput, and of the screening machine.

Assembly Process

Frame Construction: The first step is consolidation of the frame, or mainframe using the materials determined. The frame should provide a secure and sturdy platform onto which other components can be mounted.
Mounting the Motor: Secure the Servo motor the motor base. Ensure that the motor is well aligned with the spoked system for efficient transmission of power.
Installing the Slicing Unit: Secure the slicing shaft and the idler shaft onto the frame. Mount the slicing unit onto the frame and pay special attention to how the blades are set up.
Assembling the Holler: the top of the Holler, install where the potatoes will be deposited. At the bottom, attach the outlet, which will lead the sliced potatoes to the collection point.
Final assembly: Install the spoked and the bearing system such that it is running between the motor Spoked and the slicing unit Gear. Ensure that the Chain spoked system is well connected to ensure efficiency in power transmission. Ensure that all moving parts are sufficiently moves freely.
Summary

The assembly design was efficient as every other component is designed by an industrial designer and well connected through screws or welded in place. With a focus on potato, through development of components, which ensure regulated load focalization and slicing efficiency and incorporated onto the frame, formed an efficient slicer suitable for a cottage industry in a food and restaurant as well as for other farms for the processing of the respective energy giving crops.

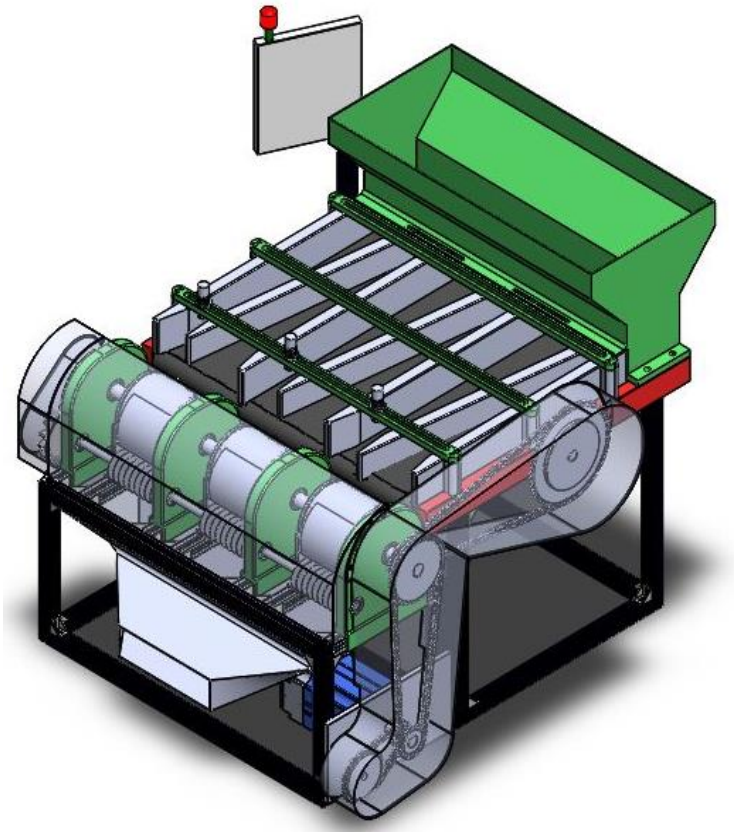


Fig.4.3.1 Potato slicer assembly design

Chapter 5

Finite Element Analysis of Key Components of Potato Slicer

Introduction

Finite Element Analysis (FEA) is use Powerful Software computer tool used to predict how components of a potato slicer will react to real-world forces, vibration, heat, and other physical effects. This chapter focuses on the application of FEA to evaluate the structural Strain, Strass, and durability of key components such as the cutting blades, shaft, and Gear[5]. By simulating real-world conditions, FEA helps identify potential issues and optimize the design for better performance and longevity.

5.1 Finite element analysis of transmission mechanism

5.1.1 Finite element analysis of Pressure Fan

Objective: To analyze the strain Analysis, Displacement Analysis, Safety and Strain Analysis deformation of the Pressure Fan operational loads.

The Pressure Fan are modeled in 3D using CAD software and imported into the Solidwork software. Material properties is SKD11.Boundary conditions and loads are applied to simulate the forces experienced during slicing.

Results:

The stress distribution shows high-stress concentrations at the edges and mounting points of the Pressure Fan. the maximum stress on the Pressure Fan is 1.651×10^8 N/m², which is far less than the maximum yield stress of 2.827×10^8 N/m², which meets the design requirements.

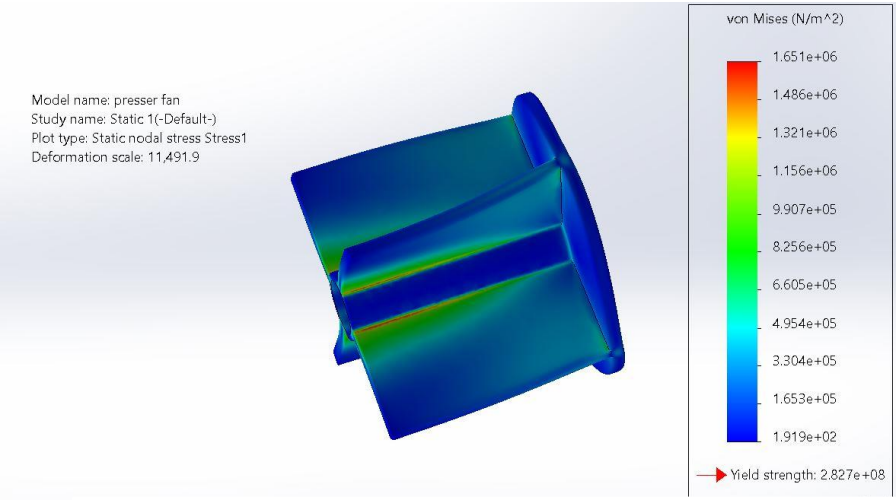


Fig. 5.1.1.1 Fan finite element analysis stress diagram

Strain analysis the maximum unit length deformation on the Fan is 6.078, and the strain area and the strain value is too High and almost the design requirements. The results are used to optimize the Fan thickness and material selection to ensure durability.

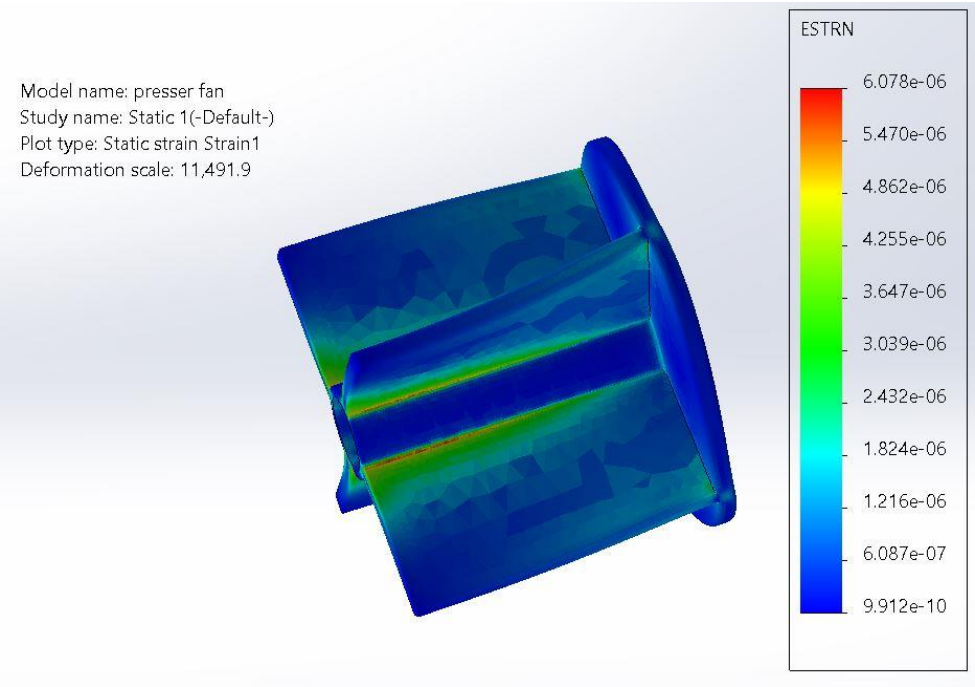


Fig.5.1.1.2 Fan finite element analysis strain diagram

The factor of safety analysis image can be seen that the minimum value of the safety factor on the Fan maximum safety factor reached S=1.473× (10)^5. Combined with these finite element analysis results, the overall structure of the Fan can meet the safe.

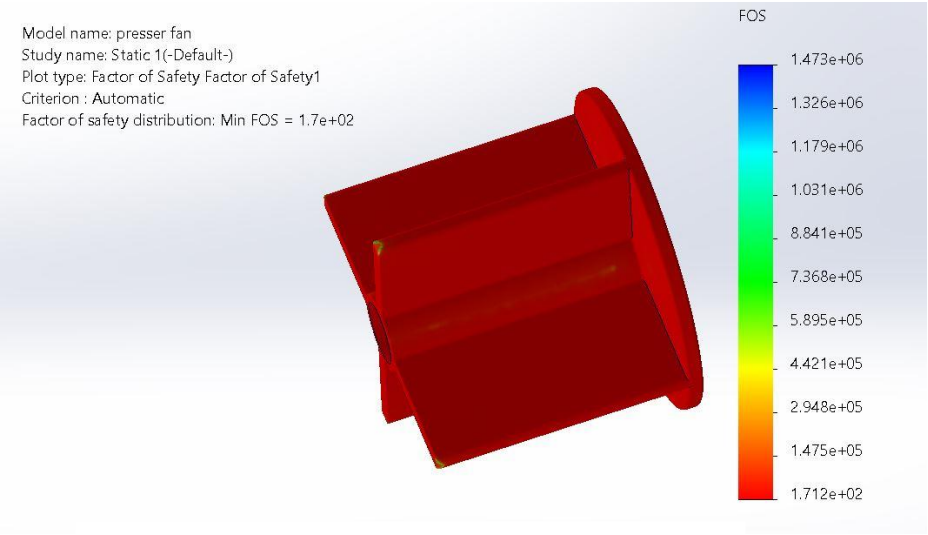


Fig. 5.1.1.3 Fan finite element analysis Safety

The Displacement Analysis of the Pressure Fan in the displacement analysis diagram shows the deformation of the Fan load. The diagram highlights areas of maximum displacement are 1.473mm the displacement critical for understanding and mechanical behavior of the Fan.

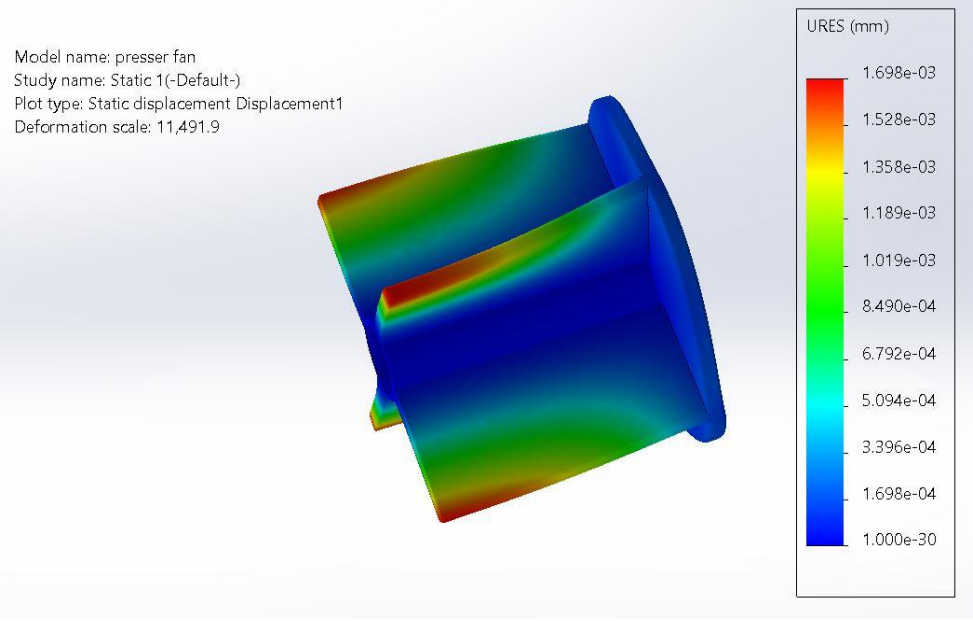


Fig.5.1.1.4 Fan finite element analysis Displacement diagram

5.1.2 Finite element analysis of Shaft

Shaft Analysis: Strain, Stress, Safety, and Displacement

Being one of the main elements in a potato slicing machine, the shaft is responsible for transmitting power from the motor to the cutting blades. As a result, analyzing the shaft in terms of strain, stress, safety, and displacement is crucial to check its reliability. Below is a more detailed description of the analysis along with minimum and maximum values.

Strain Analysis

- To define the deformation type and the current behavior of the shaft under loads.
- **Material Properties**: introduce the properties of the material MILD steel J:195,000 N/mm^2, Y: 110,000 N/mm^2 G: 80,000 N/mm^2
- **Boundary Conditions and Loads**: try to apply both tensile load. Apply any type of load or sequences of loads that are known o cause strains in shafts.

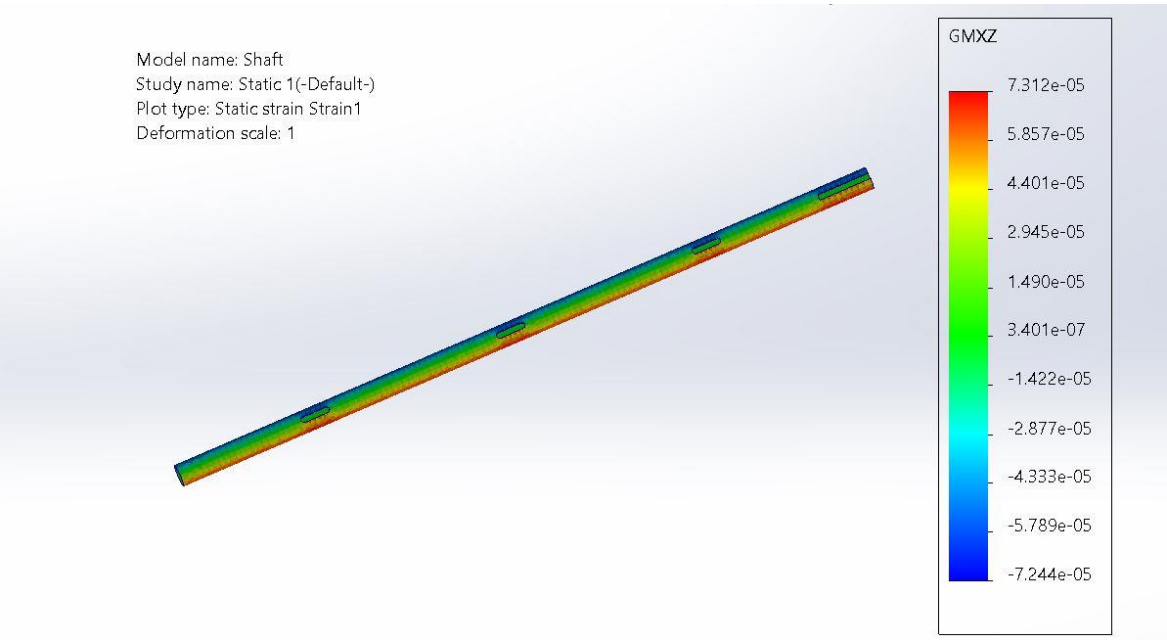


Fig.5.1.2.1 Shaft finite element analysis strain diagram

Stress Analysis

Objective:

- To define the distribution of the stress in the shaft under specified loads.

Methodology:

- **Modeling**: The shaft is modeled and divided by the mesh.
- **Material Properties**: the quality of the material often has to be determined (mild steel) and its yield strength. The same parts are to be applied and introduced.

Results:

- **Minimum Stress**: The minimum stress always occurs at the center of the shaft since the load has to be applied far from these areas.
- **Strain**: The strain is minimum at the supported or the fixed points as these points will have the least stress which would not create any strain. The strain is maximum at the high stress concentration points.

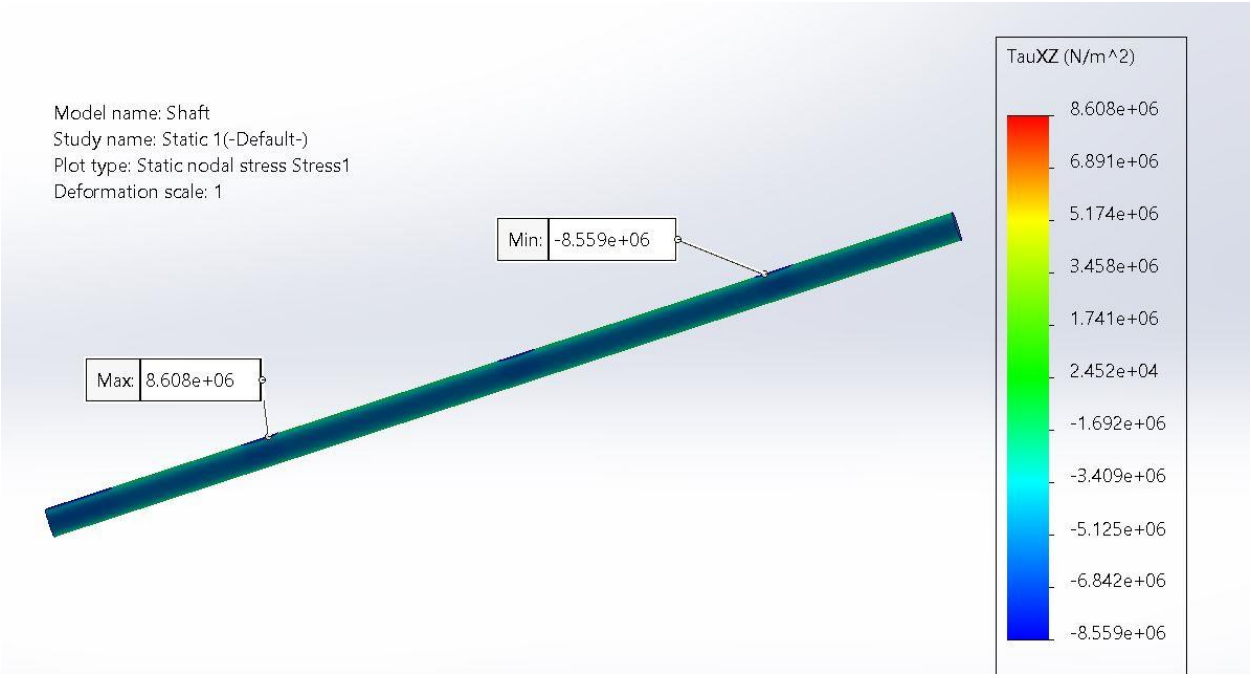


Fig.5.1.2.2 Shaft finite element analysis stress diagram

3. Safety Factor Analysis

- It is used to check that the shaft operates within the safe limit under the given all loading conditions which are expected in practice.
- Modeling of the shaft to which the material properties and the loading conditions are applied.
- Safety factor = Yield strength of the material/ Maximum stress observed in the shaft

4. Displacement Analysis

- To check the displacement of the shaft under the given loads when in operation.
- The shaft is modeled and meshed with suitable elements.
- Apply loads for bending and twisting and give boundary conditions of fixed- fixed or free- and fixed.
- The minimum displacement will be at the fixed points or the support condition as it would not have any motion or displacement.
- The maximum displacement will be at the free end condition or at the point of maximum applied load which is used for alignment to the other components.

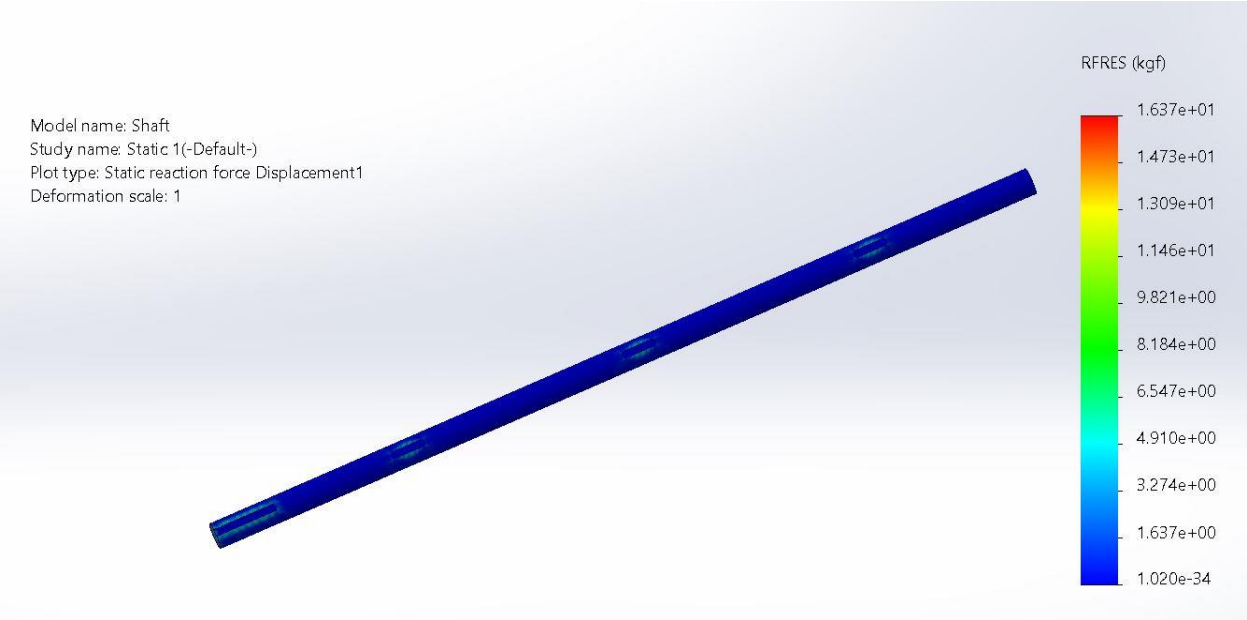


Fig.5.1.2.3 Shaft finite element analysis Displacement diagram

Summary:

- For all analysis, minimum value location = fixed or supported points and maximum value location = high stress concentration points.

Parameter	Minimum value	Maximum value
Strain	7.244	7.312
Stress	-8.55910〗^6 N/m2	8.60810〗^6 N/m2
Displacement	1.020mm	1.637mm

5.1.3Finite element analysis of Pressure Gear

Based on the given sources, the detailed description of the analysis of gear strain, stress, safety, and displacement including the minimum and maximum values is provided:

Strain Analysis: determine the deformation behavior of the gear under the operational loads. The gear is modelled in 3D with the help of CAD software and imported into the FEA. Part

Minimum strain: The minimum strain typically occurs at the points where the gear is supported or fixed as these areas experience the minimum deformation.

Maximum strain: The maximum strain is found at the points of maximum stress concentration such as near the gear teeth where the contact forces are applied.

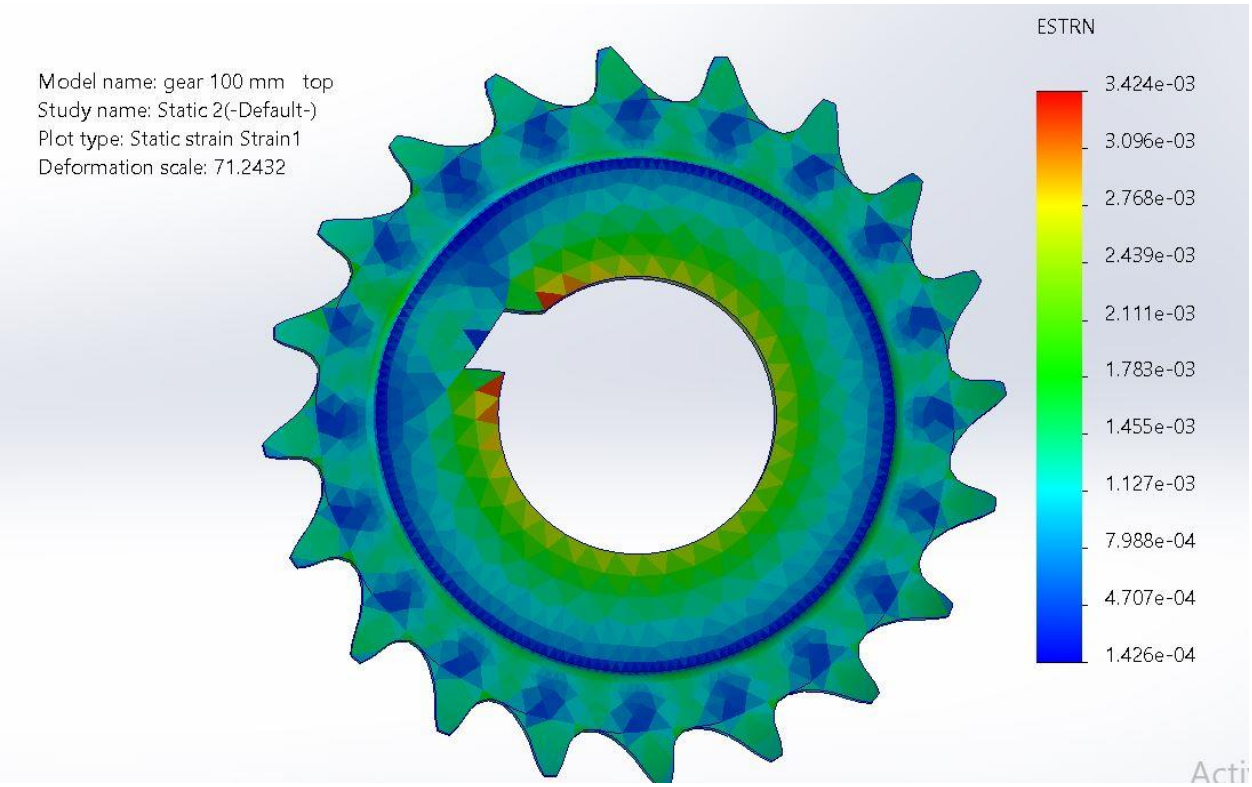


Fig.5.1.3.1 Gear finite element analysis Strain diagram

Stress Analysis: To evaluate the distribution of stresses within the gear under the operational loads. The gear assembly is modeled and meshed with the appropriate elements.

Minimum stress: The minimum stress is found at the regions of the gear least affected by the applied loads such as the center of the gear which is far away from the point of application of the loads.

Maximum stress: The maximum stress is however found at the points of maximum loading such as the areas of the gear teeth and it can typically be measured.

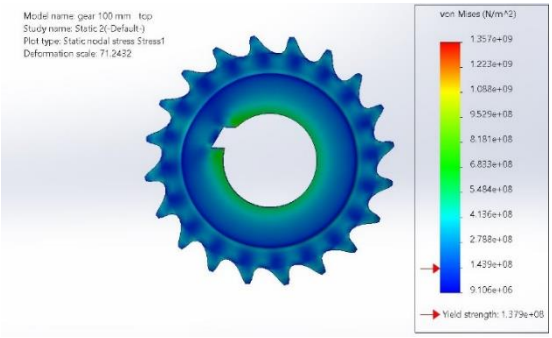


Fig.5.1.3.2 Gear finite element analysis

Safety Factor Analysis: To ensure that the gear complies with the safe limits of usage under all expected loading conditions. The main purpose of the strain analysis is to determine the strain distribution on the gear surface and examine its excessive accumulation zones to prevent the risk of its failure.

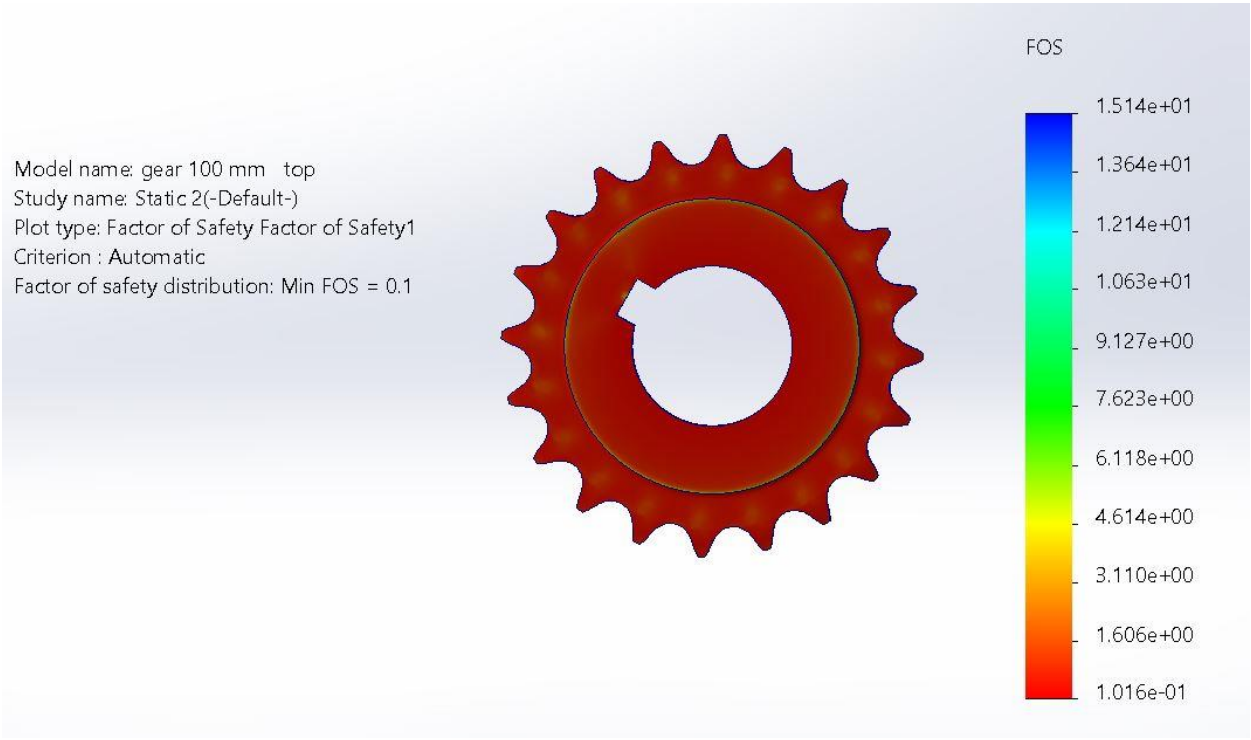


Fig.5.1.3.3 Gear finite element analysis Safety

Minimum Safety Factor: The minimum safety factor is found at the points of maximum stress. A safety factor below 1 indicates potential failure, while a value above 1 indicates safe operation.

Maximum Safety Factor: The maximum safety factor is observed in regions with minimal stress, indicating a high margin of safety.

Displacement Analysis:

The displacement of the gear under operational loads. The gear is modeled and meshed with appropriate.

Minimum Displacement: The minimum displacement occurs at the points where the gear is supported or fixed, as these areas are constrained from moving.

Maximum Displacement: The maximum displacement is observed at the free end of the gear or at the points of highest load application. This displacement is critical for ensuring that the gear does not interfere with other components or cause misalignment.

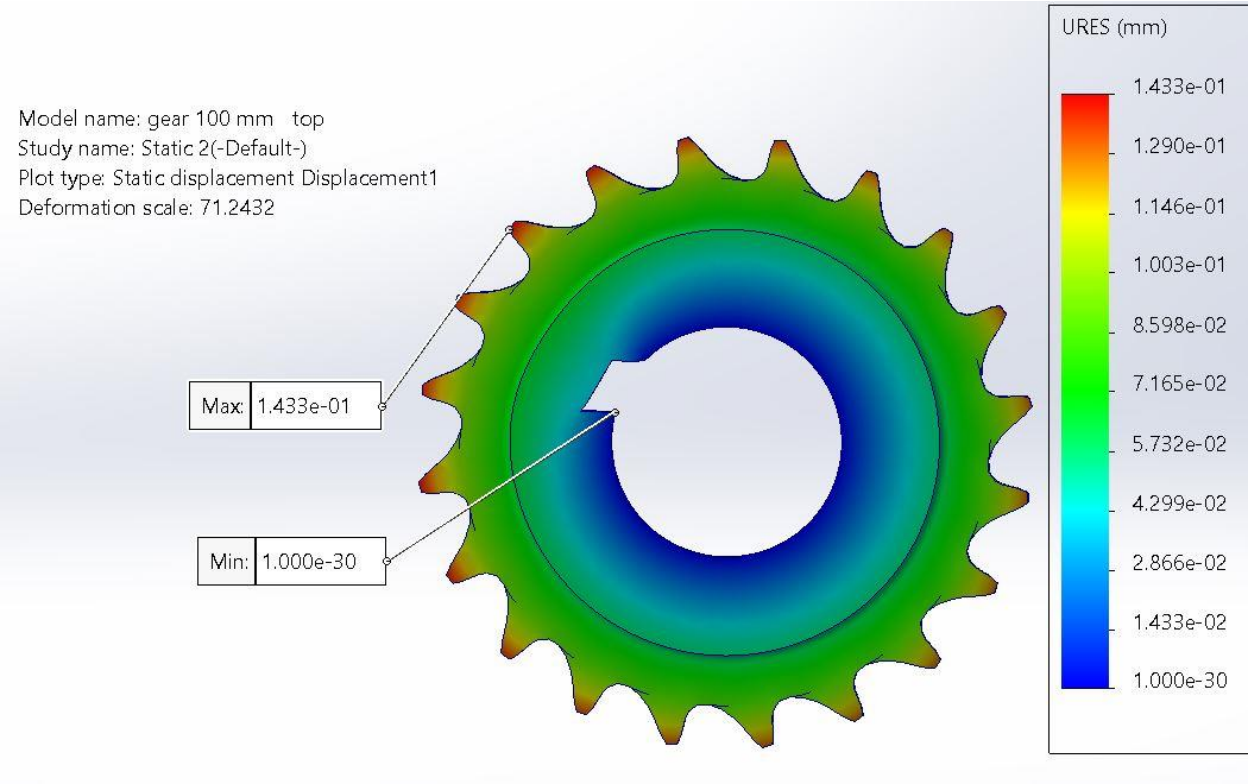


Fig.5.1.3.4 Gear finite element analysis Displacement

Summary of Results

Analysis Type	Minimum Value Location	Maximum Value Location
Strain	3.424	1.426
Stress	1.35710〗^6 N/m2	1.37910〗^6 N/m2
Safety Factor	1.016×10〗^6	1.514×10〗^6
Displacement	1.000mm	1.433mm

5.1.4Finite element analysis of conveyor belt shafts

A new study was undertaken to address weaknesses observed in the design of the shaft. Bearing clamps were carefully positioned at both ends of the shaft to maximize load distribution. Parameters including torque at the keyed joint and external forces such as centrifugal load and gravity were modeled precisely according to the shaft's rated rotational velocity. After meshing was complete, static stress analysis diagrams were calculated and their implications for structural integrity were probed deeply.

The makes abundantly clear, the finite element analysis stress diagram for the conveyor belt shaft indicates through its parameter values that when rotational force is imparted by the sprocket, regions of heightened stress form at the keyed connection and points where the shaft's diameter changes most abruptly. Moreover, the shaft's peak stress of 5.466×10〗^6 N/m2 was reassuringly lower than its maximum rated breaking point of 2.939×10〗^8 N/m2 under operating conditions.

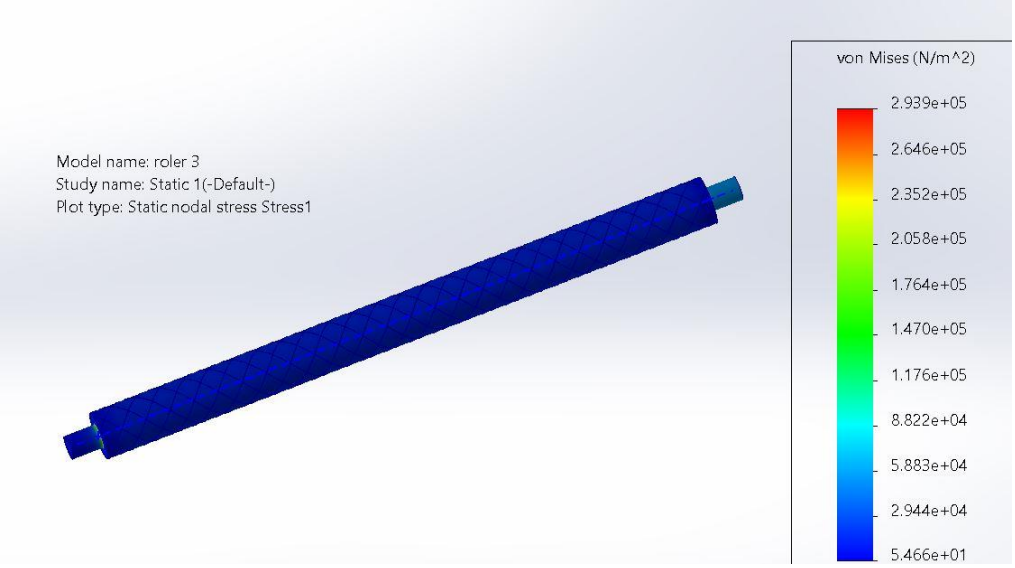


Fig.5.1.4.1 Stress Analysis

The displacement diagram of the finite element analysis of the conveyor belt shaft as shown in through the displacement analysis diagram and the parameters on the right, it can be seen that under the working condition that the sprocket drives the shaft to rotate, the position of the larger displacement on the shaft is in the middle of the shaft, the displacement at the maximum displacement on the shaft is 1.000mm, and the displacement is small within a reasonable range, which does not affect the normal use of the parts and meets the design requirements.

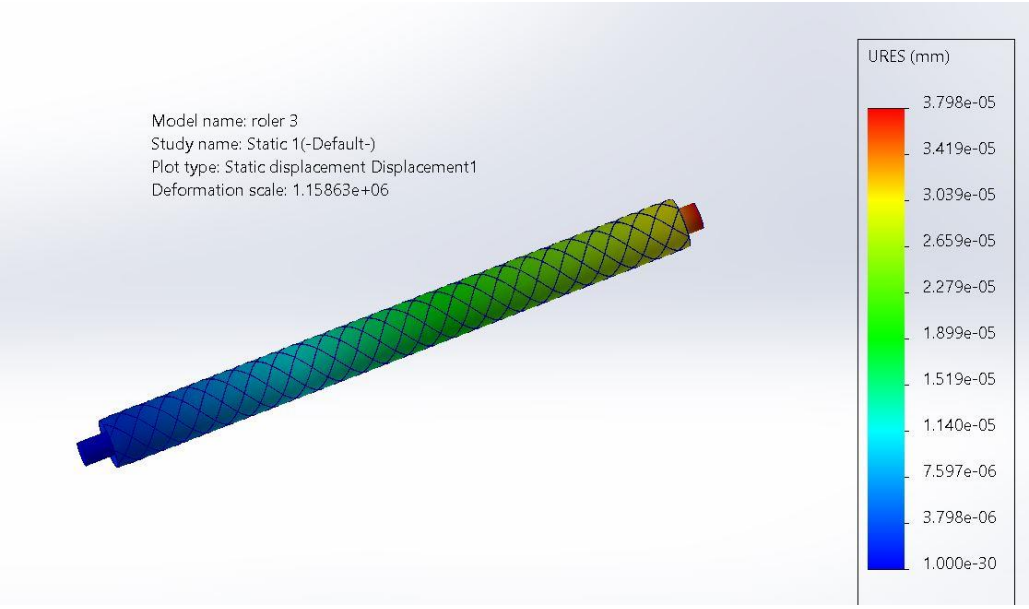


Fig.5.1.4.2 Displacement Analysis

As shown in Figure, through the strain analysis diagram and the parameters on the right, it can be seen that under the working condition that the sprocket drives the shaft to rotate, the larger unit length deformation on the shaft is at the key connection and the shaft diameter change, the maximum unit length deformation on the shaft is 1.331, and strain value is very small and almost negligible, which meets the design requirements

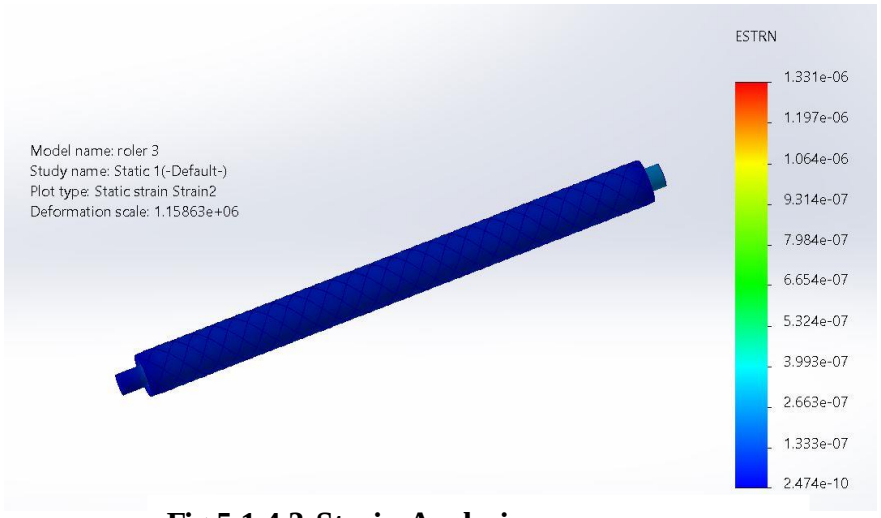


Fig.5.1.4.3 Strain Analysis

The diagram of a safety factor of the shaft at the belt conveyor's finite-element analysis, it is possible to observe that the minimum safety factor at the maximum safety factor is S=3.784×10^6.

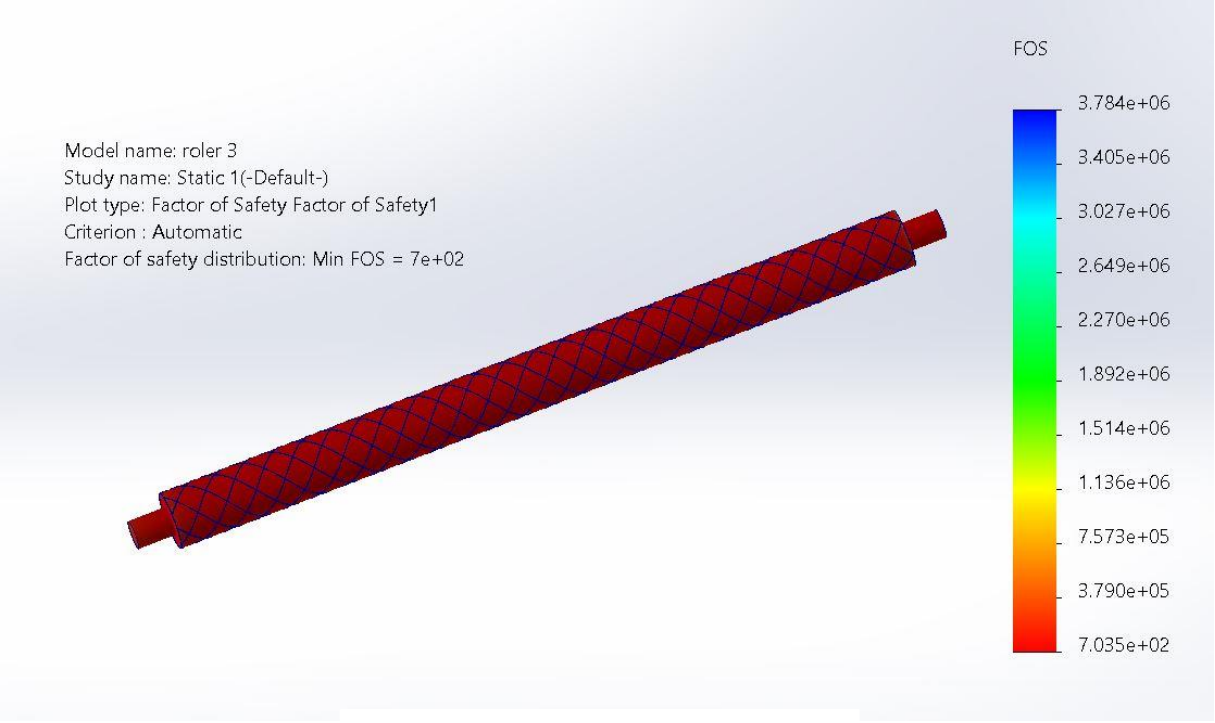


Fig.5.1.4.4 Safety Analysis

Moreover, the combination of the following four results related to finite-element analysis enables to state that the shaft structure adheres to the requirements. Therefore, it can support and allow to operate the potato peeler's transportation mechanism.

5.2 Analytical Result's:

To the Study: Specifically, the study aims to analyze the machine's slicing uniformity, speed, and safety features compared to traditional manual methods. performance will include the quality of the sliced product, reduction in preparation time, and overall user satisfaction. Additionally, the study will assess the machine's ease of operation and maintenance requirements [6]

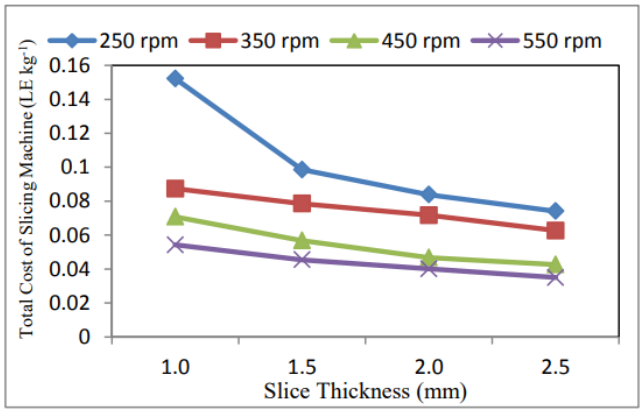


Fig 5.2.1. Slice Thickness

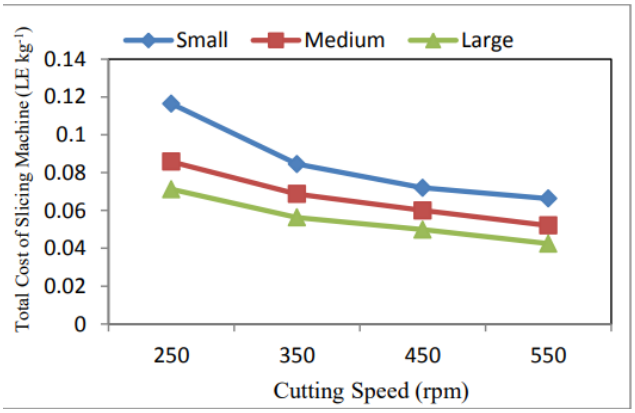


Fig.5.2.2 Cutting Speed

To the Analysis: This includes evaluating its slicing efficiency, consistency, and overall quality of the final product. Key metrics will encompass the machine's processing speed, energy consumption, and maintenance needs. Additionally, the analysis will explore user experience and safety features, comparing them to traditional manual slicing methods

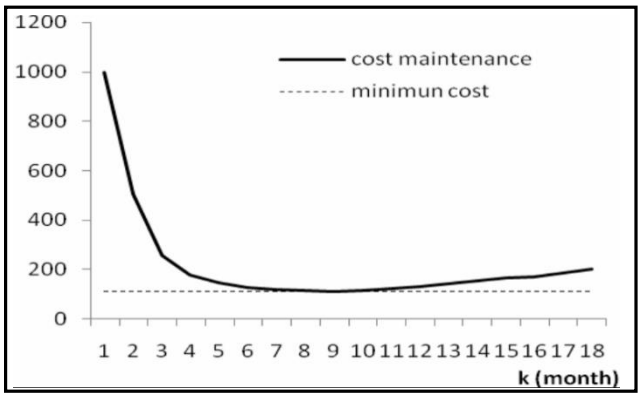


Fig. 5.2.3 Monthly Maintenance

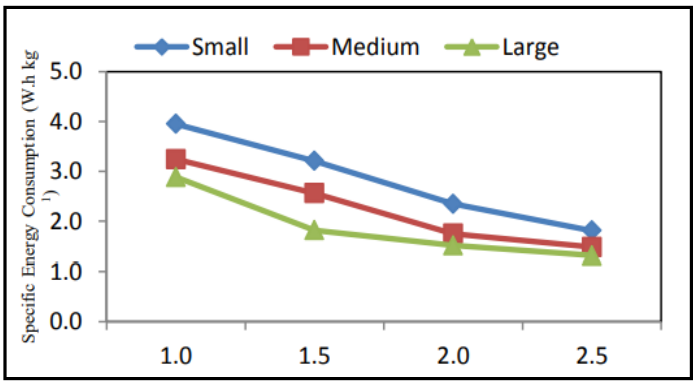


Fig. 5.2.4 Energy Consumption

Design Analysis: The design was validated using SolidWorks Simulation, assessing static stress, displacement, strain, and safety factors to ensure the components meet strength and hardness requirements

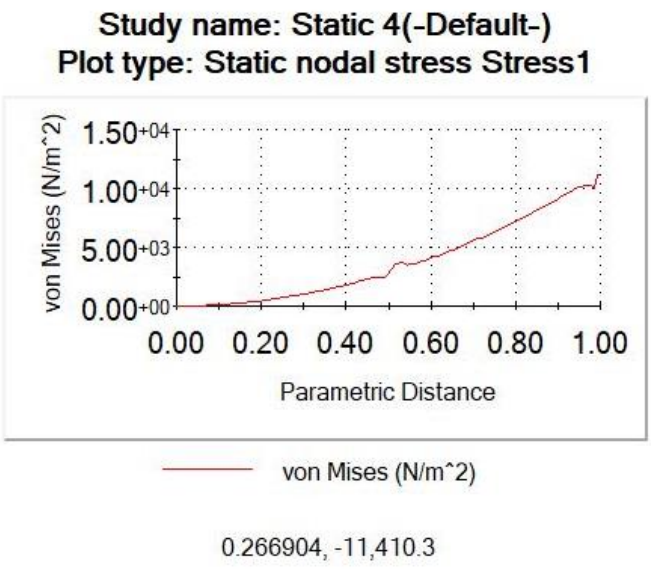


Fig. 5.2.5 Static Stress

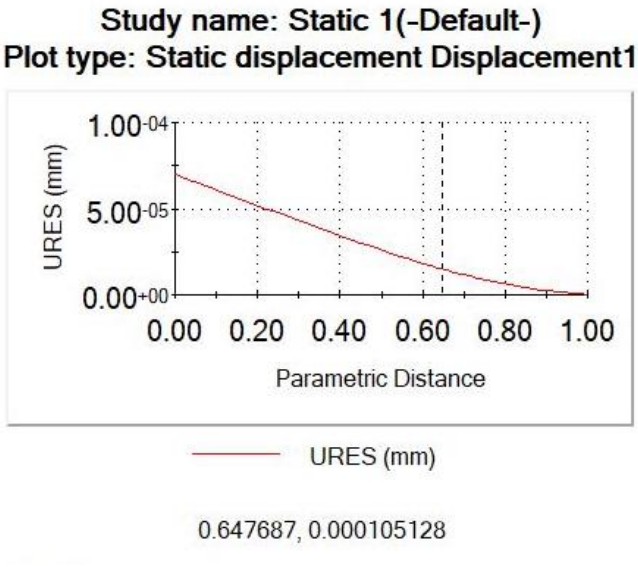


Fig. 5.2.6 Static Displacement

TO The Result: The machine demonstrated reliable performance with minimal maintenance requirements. Energy consumption was measured to be efficient, aligning with industry standards. Overall, the results indicate that the potato slicer machine substantially improves efficiency and quality in food preparation, making it a valuable addition to commercial kitchens.

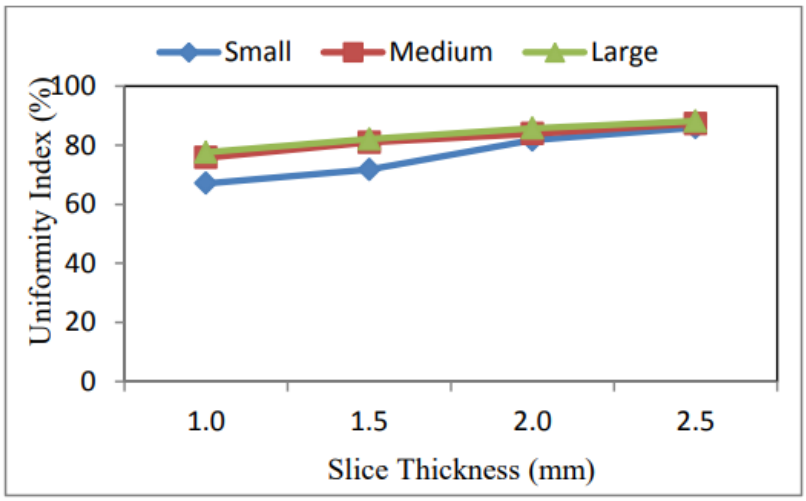


Fig. 5.2.7 Thickness Efficiency

5.3 Manufacturing & Simulation Cost:

SL NO	Descriptions	Quantity	Rate	Amount
01	Materials Cost	01	1,50,000/-	1,50,000/-
02	Machining Cost	01	50,000/-	50,000/-
03	Manufacturing Cost	01	50,000/-	50,000/-
04	Assembling Cost	01	10,000/-	10,000/-
05	Simulation Cost	01	150,00/-	15,000/-
			Total	**225000/-**

Conclusion

The machine design of portable potato slicer to improve the traditional slicer structure. The traditional slicer has the advantages of small size and low price. However, the slicing productivity is low, and the blade cannot be adjusted, so the slices are always cut into a fixed thickness. Therefore, in the original direct contact with the potato Through a series of schemes, it becomes a portable potato slicer, with the same range of potatoes, cutting thickness of potato slices, and production capacity of 1.5 tons per hour. When the blade is changed to the same range, the elephant can also produce potato chips with a thickness of 0.5-0.7mm. Potatoes are convenient to use and have low production costs. Like wanting things depends on police integrity and jail conditions. The labor intensity of operators is small, which will make the processing of potato chips appear better. Moreover, it can avoid the use of knives to cause accidental injuries, and the parts in direct contact with the potatoes are made of stainless steel or MS and Skd11 and other materials to kiosk the parts to be processed, which greatly improves the safety of food processing. The detailed machine design is as follows.

Implement the overall scheme design of portable potato slicer. Enumerate the design schemes of motor selection, transmission method, and slicing actuator. Improve and optimize the structure of the existing to a variety of rotary cutters, and select these choices for comprehensive or partial slicing. A variety of schemes are used for comparison and demonstration in the design of various part drawings., Pick the best one at last, choose the Dongles geared motor as the drive device; The chain transmission method is adopted. The slicing actuator adopts the method of imitating the manual slicing, and select a group of blade holders, so that the potatoes are pressed to slice through the knife holder in turn.

Carry out the design calculation of the key components of portable potato slicer. Refer to various mechanical design manuals for the geared motor selection and calculation to determine the Servo Dc 1200w motor model; Calculate the transmission parameters of each shaft of the equipment, and check the structure of the chain transmission according to the calculated sleeve parameters and transmission shaft parameters. The bearing model of the structural parameters and the finite element analysis, so as to ensure the parameter rationality and structural security.

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