AUTOMATION OF BOOK VENDING MACHINE

A Project report submitted in partial fulfillment of the requirement

For the award of the degree of

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IN

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CERTIFICATE

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ABSTRACT

Technology keeps advancing to make our daily lives easier. We live in a world of advancement, **so can we use technology to *automate* our personal tasks? Automation** is the technology by which a process or procedure is performed with minimal human assistance. It is the use of various control systems for operating equipment such as machinery, processes in factories, boilers and heat treating ovens, switching on telephone networks, steering and stabilization of ships, aircraft and other applications and vehicles with minimal or reduced human intervention.

Here, we have designed an 'Automated Book Vending Machine' which reduces the human effort of maintaining the complicated databases for the books included, the books borrowed and the book returned. And it also is much helpful for the user where, the book is brought right to him through an automated mechanism using a horizontal carousal system, arduino for automation and even helps us to reduce the space occupied by regular sized shelves.

Initially, the concept was taken and the solution for integrating the automation was analyzed. Multiple designs were considered. Horizontal carousal systems were chosen as they had much more efficient structure. The design was made in 2D and 3D, using Autodesk Fusion 360. This design is optimized according to our requirement. The strength and force analysis was done and the structure was modified based on the errors using ANSYS. Gears, shafts and other mechanical devices are selected as per the required dimensions and then, fabricated. All the hardware and the software are combined and calibrated for the use.

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INTRODUCTION

CHAPTER – I

INTRODUCTION

1.1 AUTOMATION

Automation is the technology by which a process or procedure is performed with minimal human assistance. Automation or automatic control is the use of various control systems for operating equipment such as machinery, processes in factories, boilers and heat treating ovens, switching on telephone networks, steering and stabilization of ships, aircraft and other applications and vehicles with minimal or reduced human intervention.

Automation, the application of machines to tasks once performed by human beings or, increasingly, to tasks that would otherwise be impossible. Although the term mechanization is often used to refer to the simple replacement of human labor by machines, automation generally implies the integration of machines into a self-governing system. Automation has revolutionized those areas in which it has been introduced, and there is scarcely an aspect of modern life that has been unaffected by it.

1.2 Carousal Systems

Carousel storage is an automated system where stock or material in bins or on shelves or mandrels revolves on a track. Use of carousels allows for the storage of large quantities of stock in a small floor area. The storage can be located on an assembly floor area, or in a separate room. Carousels are also used in some processes where hot or warm stock is cooled as it travels through the unit. There are two basic kinds of carousel storage systems, horizontal and vertical. As its name implies, the horizontal carousel travels horizontally along the floor or mezzanine, similar to those found in most dry cleaning establishments. The vertical carousel travels in a vertical direction, like a Ferris wheel.

Carousel Systems, also known as Goods to Person, are highly effective systems, which allow an assortment of products to be located and presented to operators in a stationary location. This Goods to Person or G2P allows for highly productive pick rates by retrieving goods and bringing them to the operator with little to no error. There are also different configurations that are based vertically or horizontally. Carousels save space and the time it takes to pick by the racks moving instead of the person searching and picking items from the racks. There have been many advancements in Carousel systems over the past few years which have made this warehouse automation tool easier to install, to scale, and more affordable than in the recent past.

1.2.1 Horizontal Carousal Systems

Horizontal carousels store stock or material in open top or open front bins, wire baskets or on shelves that are attached to a backboard connected to the travel chains. Horizontal carousels could be as high as 20 ft (6 m) and as long as the area permits. These units are usually installed in groups with a narrow aisle between them, sometimes less than 1 ft (0.3 m).

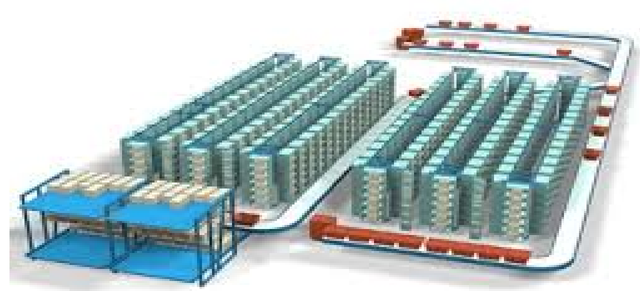


Fig 1.1- A Horizontal Carousel

1.2.2 Vertical Carousal Systems

Vertical carousels store stock or material in shallow trays, baskets or on shelves connected to the travel chains. The units are usually enclosed in housing and have openings where the stock is loaded and unloaded. Vertical units are typically used to store office files, parts along an assembly line, and large quantities of small parts, such as electronic components or nuts and bolts in a small controlled area.

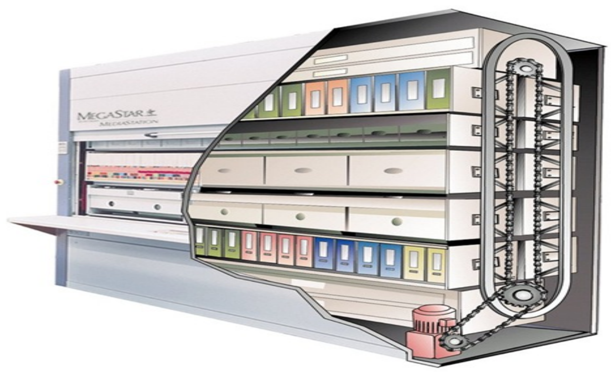


Fig 1.2- A Vertical Carousel

1.3 Thrust Bearing

A **thrust bearing** is a particular type of rotary bearing. Like other bearings they permit rotation between parts, but they are designed to support a predominantly axial load.

Thrust bearings come in several varieties.

- **Thrust ball bearings**, composed of Bearing balls supported in a ring, can be used in low thrust applications where there is little axial load.

- **Cylindrical thrust roller bearings** consist of small cylindrical rollers arranged flat with their axes pointing to the axis of the bearing. They give very good carrying capacity and are cheap, but tend to wear due to the differences in radial speed and friction which is higher than with ball bearings.

- **Tapered Roller Thrust Bearings** consist of small tapered rollers arranged so that their axes all converge at a point on the axis of the bearing. The length of the roller and the diameter of the wide and the narrow ends and the angle of rollers need to be carefully calculated to provide the correct taper so that each end of the roller rolls smoothly on the bearing face without skidding.

Thrust bearings are used in cars because the forward gears in modern car gearboxes use helical gears which, while aiding in smoothness and noise reduction, cause axial forces that need to be dealt with. Thrust bearings are also used with radio antenna masts to reduce the load on an antenna rotator. One specific thrust bearing in an automobile is the clutch 'throws out' bearing, sometimes called the clutch release bearing.

Fig 1.3-Thrust Bearing

1.4 Stepper Motor

A **stepper motor**, also known as **step motor** or **stepping motor** is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any position sensor for feedback (an open loop controller), as long as the motor is carefully sized to the application in respect to torque and speed.

Pulses move the rotor in discrete steps, CW or CCW. If left powered at a final step a strong detent remains at that shaft location. This detent has a predictable spring rate and specified torque limit; slippage occurs it the limit is exceeded. If current is removed a lesser detent still remains, therefore holding shaft position against spring or other torque influences. Stepping can then be resumed while reliably being synchronized with control electronics.

Variable Reluctance (VR) motors have a plain iron rotor and operate based on the principle that minimum reluctance occurs with minimum gap, hence the rotor points are attracted toward the stator magnet poles. Whereas hybrid synchronous is a combination of the permanent magnet and variable reluctance types, to maximize power in a small size. VR motors do not have power off detents.

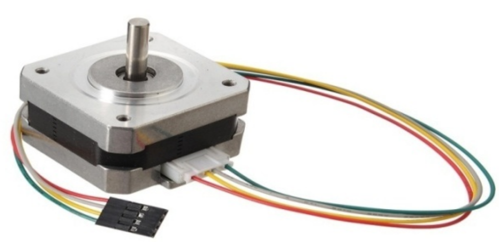


Fig 1.4- A Stepper Motor

1.5 Chain Drive

Chain drive is a way of transmitting mechanical power from one place to another. It is often used to convey power to the wheels of a vehicle, particularly bicycles and motorcycles. It is also used in a wide variety of machines besides vehicles.

Most often, the power is conveyed by a roller chain, known as the **drive chain** or **transmission chain**, passing over a sprocket gear, with the teeth of the gear meshing with the holes in the links of the chain. Another type of drive chain is the Morse chain, invented by the Morse Chain Company of Ithaca, New York, United States. This has inverted teeth.

Sometimes the power is output by simply rotating the chain, which can be used to lift or drag objects. In other situations, a second gear is placed and the power is recovered by attaching shafts or hubs to this gear. By varying the diameter of the input and output gears with respect to each other, the gear ratio can be altered. For example, when the bicycle pedals gear rotate once, it causes the gear that drives the wheels to rotate more than one revolution.

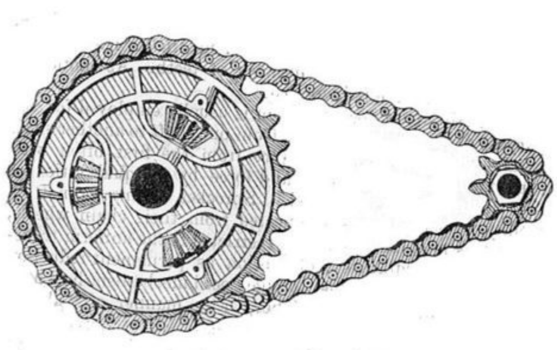


Fig 1.5- A Chain Drive

1.6 Sprocket

A **sprocket** or **sprocket-wheel** is a profiled wheel with teeth, or cogs, that mesh with a chain, track or other perforated or indented material. The name 'sprocket' applies generally to any wheel upon which radial projections engage a chain passing over it. It is distinguished from a gear in that sprockets are never meshed together directly, and differs from a pulley in that sprockets have teeth and pulleys are smooth.

Sprockets are used in bicycles, motorcycles, cars, tracked vehicles, and other machinery to transmit rotary motion between two shafts where gears are unsuitable or to impart linear motion to a track, tape etc. They can be run at high speed and some forms of chain are so constructed as to be noiseless even at high speed.

Fig 1.6-A Sprocket

1.7 Arduino

Arduino is an open-source prototyping platform used for building electronics projects. It consists of both a physical programmable circuit board and a software, or IDE (Integrated Development Environment) that runs on your computer, where you can write and upload the computer code to the physical board. The Arduino board started adapting to the new needs and challenges, differentiating it from simple 8-bit boards to products for IoT applications, wearable, 3D printing, and embedded environments. Arduino can interact with buttons, LEDs, motors, speakers, GPS units, cameras, the internet, and even your smart-phone or your TV.

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

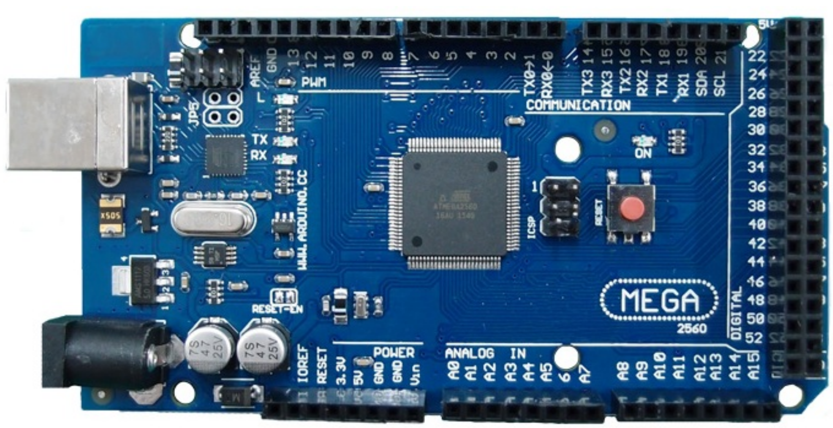


Fig 1.7-Arduino Mega 2560

1.8 LCD Screens

LCD (Liquid Crystal Display) is a type of flat panel display which uses liquid crystals in its primary form of operation. LEDs have a large and varying set of use cases for consumers and businesses, as they can be commonly found in smart phones, televisions, computer monitors and instrument panels.

LCDs were a big leap in terms of the technology they replaced, which include light-emitting diode and gas-plasma displays. LCDs allowed displays to be much thinner than cathode ray tube technology. LCDs consume much less power than LED and gas-display displays because they work on the principle of blocking light rather than emitting it. Where an LED emits light, the liquid crystals in a LCD produce an image using a backlight. As LCDs have replaced older display technologies, LCDs have begun being replaced by new display technologies such as OLED.

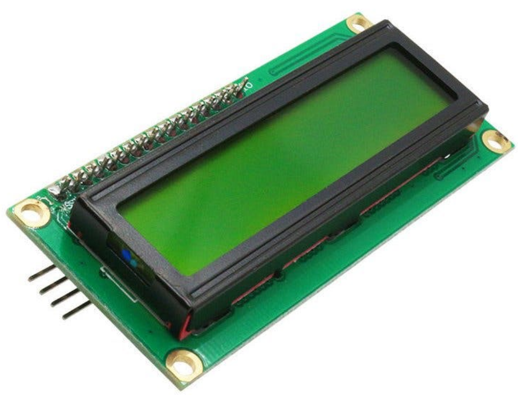


Fig 1.8-A LCD Screen

1.9 Hall Effect Sensor

The Hall Effect is the production of a voltage difference (the Hall voltage) across an electrical conductor, transverse to an electric current in the conductor and to an applied magnetic field perpendicular to the current. It was discovered by Edwin Hall in 1879. The original effect is sometimes called the ordinary Hall Effect to distinguish it from other "Hall effects" which have different physical mechanisms.

The Hall coefficient is defined as the ratio of the induced electric field to the product of the current density and the applied magnetic field. It is a characteristic of the material from which the conductor is made, since its value depends on the type, number, and properties of the charge carriers that constitute the current.

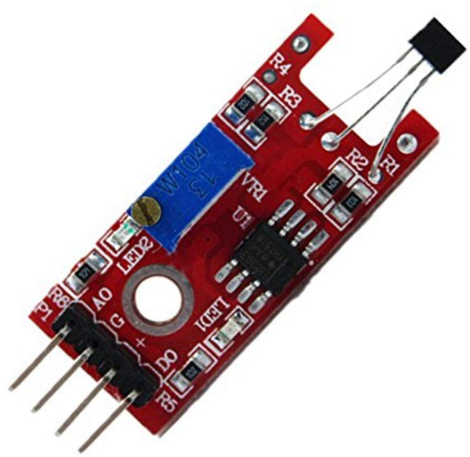


Fig 1.9-Hall Effect sensor

1.10 APPLICATION

The automotive industry is the early adopter of robotics, using these automated machines for material handling, processing operations, and assembly and inspection.

RP technology has potential to reduce time required from conception to market up to 10-50 percent. It has abilities of enhancing and improving product development while at the same time reducing costs due to major breakthrough in manufacturing. Although poor surface finish, limited strength and accuracy are the limitations of RP models, it can deposit a part of any degree of complexity theoretically therefore, RP technologies are successfully used by various industries like aerospace, automotive, jewelry, coin making, tableware, saddletrees, biomedical etc. It is used to fabricate concept models, functional models, patterns for investment and vacuum casting, medical models, models for engineering analysis.

1.11 PROBLEM DEFINATION

Any book reader issuing book from a library has to spend certain amount of time i.e., to search book from the rack, issue book from the librarian after filling the details in the log book and even the librarian or the staff has to verify the details and sign it. This project is made in attempt to reduce the effort taken by the librarian and the book reader trough automation.

1.12 SCOPE OF THE PROJECT

The main scope of this project is to automate the horizontal carousel system to reduce the human interaction in the process of issuing book and reduce time taken for searching book. The library book storage system is selected as application of horizontal carousel storage system. The design of the key elements and mechanism are done initially. Then the part models of the designed system are modeled, assembled and simulated in the Autodesk Fusion 360 software. All parts are made using plywood and wood.

After the post processing, the parts are assembled and tested for mechanism and modularity.

CHAPTER- II

LITERATURE REVIEW

CHAPTER - II

LITERATURE

Horizontal carousel systems have vast applications in the storage systems, but the requirements of this system like fixed installation, space consumption and energy consumptions limiting its applications in some fields. A prototype is necessary to make new design of horizontal carousel system. Rapid prototyping is the advanced prototype fabrication technique. In order to have an easy fabricated model of modular horizontal carousel system Rapid prototyping can be selected.

The following papers were referred to study the rapid prototyping method and carousel system.

2.1 Literature Review:

Jennifer A.Pazour, RussellD.Meller [1]: A carousel system is an example of an automated storage and retrieval system that is used in distribution centers and manufacturing facilities. We analyze the impact batch retrieval processing has on throughput performance for horizontal carousel systems that use automated storage and retrieval machines as robotic pickers. By developing an analytical cycle-time model we provide the theoretical base necessary to support the management decision of whether to batch or not. We conduct a computational experiment to test the accuracy of our analytical model, to demonstrate how our approach can guide management decisions, and to illustrate the throughput improvements that can be realized through the use of a batch policy. Testing indicates that batch processing increases carousel throughput performance over sequential processing. For the instances tested, batch processing resulted in an average decrease in cycle time over sequential sequencing of 20%. Our results indicate that with batch retrievals, adding to the carousel’s length increases storage capacity with a negligible impact on the carousel’s throughput performance.

Khalid Hachemi, Zaki Sari, Noureddine Ghouali [2]: The sequencing of requests in an automated storage and retrieval system was the subject of many studies in literature. However, these studies assumed that the locations of items to be stored and retrieved are known and the sequencing problem consisted in determining a route of minimal travel time between these locations. In reality for a retrieval request an item can be in multiple locations of the rack and so there is a set of locations associated with this item and not only one predetermined location in the rack. In this paper, we deal with the sequencing problem where a required product can be in several rack locations and there is a set of empty locations. Consequently, the retrieval and storage locations are not known a priori. We sequence by the minimum travel time of a double cycle (DXC) An optimization method working step-by-step is developed to determine for each DC and according to storage and retrieval requests, the location of the item to be stored and the location of the item to be retrieved allowing the minimum DC time.
The storage requests are processed in FCFS and retrieval requests retrievals requests are gathered by block according to wave sequencing.

Kees Jan Roodbergen, Iris F.A. Vis [3]: Automated Storage and Retrieval Systems (AS/RSs) are warehousing systems that are used for the storage and retrieval of products in both distribution and production environments. This paper provides an overview of literature from the past 30 years. A comprehensive explanation of the current state of the art in AS/RS design is provided for a range of issues such as system configuration, travel time estimation, storage assignment, dwell-point location, and request sequencing. The majority of the reviewed models and solution methods are applicable to static scheduling and design problems only.

Requirements for AS/RSs are, however, increasingly of a more dynamic nature for which new models will need to be developed to overcome large computation times and finite planning horizons, and to improve system performance.

Several other avenues for future research in the design and control of AS/RSs are also specified**.**

Tian Liu, Yeming Gong, Ren_e B.M. De Koster [4]: In traditional automated storage and retrieval [AS/R] systems, the storage and retrieval machine travels simultaneously in the horizontal and vertical directions. The so-called split platform AS/R [or SP-AS/R] system consists of platforms [or shuttles and lifts] that can move independently in horizontal [shuttles] and vertical [lifts] directions.

This paper studies two dual command travel time models for such systems. We formulate a continuous travel time model for an SP-AS/R system with a dedicated lift per rack and another travel time model for an SPAS/ R system with a dedicated lift per job type. Then we analyze the performance of these two models.

The two models are validated by computer simulation and give quite accurate results. We show that the optimal cycle time gap with the upper bound derived by an existing literature can be as large as 26%. We find interesting management insights for system implementation: when the shape factor of the rack is approximately less than 1, the policy using a dedicated lift per rack is better; when the shape factor of the rack is approximately more than 1, the policy using a dedicated lift per job type outperforms.

Elka' Hassini, RaymondG. Vickson [5]: We describe a problem of storing products in carousels that are grouped in pods of two. Each pod is served by one operator. The aim is to minimize the long-run average rotational time per retrieval operation. We formulate the problem as a new type of nonlinear partitioning problem and discuss several heuristic solution procedures.

Hark Hwang, Young-keun Song, Kap-hwan Kim [6]: Carousel systems become increasingly popular in industries on account of their efficiency and relatively low cost. All the research papers dealing with travel time models of carousel system assumed average uniform velocity for the carousel body movement, disregarding the acceleration/deceleration rate. Consequently, the optimal design and operating policies proposed in the literature are far from optimum, from the practical point of view. With a continuous approximation to the discrete rack face, we develop travel time models by considering the speed profiles of the carousel body movement. Under the randomized assignment policy, the expected travel times are found for a single and dual command cycle. The accuracy of the proposed models is verified by comparison with the results obtained directly from discrete racks.

Hark Hwang, Chae-soo Kim, Kyung-hee Ko [7]: This paper deals with automated carousel systems which have been widely used in various industrial applications. We attempt to measure analytically the effects of double shuttle of the storage/retrieval machine on the throughput of standard and double carousel systems. For the double carousel system, a retrieval sequencing rule is proposed which utilizes the characteristics of two independently rotating sub-carousels.

And then the expected four command cycle time models are developed under the proposed rule. Through sensitivity studies, we compare the performance of the two carousel systems working on the four command cycles with those on the dual command cycles.

Nils Boysen, Dirk Briskorn, Simon Emde [8]: A growing population and increasing real estate costs in many urbanized areas have made space for roomy warehouses with single-deep storage and wide aisles scarce and expensive.

Mobile rack ware- houses increase the space utilization by providing only a few open aisles at a time for accessing the racks. Whenever a stock keeping unit [SKU] is to be retrieved, neighboring racks mounted on rail tracks have to be moved aside by a strong engine, so that the adjacent aisle opens and the SKU can be accessed. As moving the heavy racks take considerable time, the resulting waiting time determines large parts of the picking effort. It is, thus, advantageous to sequence picking orders, such that the last aisle visited for the preceding order is also the first aisle to enter when retrieving a subsequent picking order. We formalize the resulting picking order sequencing problem and present suited exact and heuristic solution procedures. These algorithms are tested in a comprehensive computational study and then applied to explore managerial aspects, such as the influence of the number of open aisles on the picking effort.

David T. Buley and Kenneth Knott [9]: The use of vertical carousels is becoming more widespread as a means of storage in industry. With this wider use one can expect there to be an increase in the level of technology used to control them and an associated increase in the capital investment required. The number of columns in the carousel, the servicing time in the stores and the operator utilization become of economic interest with this development. This paper demonstrates a systematic method, which can be used to maximize the operator utilization while minimizing the number of independent columns in the carousel.

Thierry Rayna, Ludmila Striukova [10]: There is a growing consensus that 3D printing technologies will be one of the next major technological revolutions.

While a lot of work has already been carried out has to what these technologies will bring in terms of product and process innovation, little has been done on their impact on business models and business model innovation. Yet, history has shown that technological revolution without adequate business model evolution is a pitfall for many businesses. In the case of 3D printing the matter is further complicated by the fact that adoption of these technologies has occurred in four successive phases (rapid prototyping, rapid tooling, digital manufacturing, and home fabrication) that correspond to a different level of involvement of 3D printing in the production process. This article investigates the effect of each phase on the key business model components. With the impact of rapid prototyping and rapid tooling is found to be limited in extent, direct manufacturing and, even more so, home fabrication has the potential to be highly disruptive. While much more value can be created, capturing value can become extremely challenging. Hence, finding a suitable business model is critical. To this respect, this article shows that 3D printing technologies have the potential to change the way business model innovation is carried out, by enabling adaptive business models and by bringing the ‘rapid prototyping’ paradigm to business model innovation itself.

2.2 Summary:

Extensive research work has already happened in the field of carousel system. Authors researched in the various carousel systems, some authors [1, 2, 3, 4] highlighted the advantages and improving storage techniques of automated storage and retrieved system. Some authors [5, 6, 7, 8,9] worked on the cycle time and improving storage techniques in horizontal carousel systems. But the problems with horizontal carousel systems as mentioned earlier were not addressed by any. In the present work, we will design, model, simulate and fabricate a prototype of horizontal carousel systems to overcome those limitations. Rapid prototyping is the technology widely used in the prototype fabrication [10], fused filament fabrication is most affordable rapid prototyping method, and the same method has been employed for prototyping horizontal carousel systems.

CHAPTER – III

2D & 3D MODELLING

CHAPTER – III

MODELLING OF THE VENDING MACHINE

In this chapter, we will discuss how we have made the 3-D model for the book vending machine, step by step, the procedure, the tools involved, the software , and how it is constructed using the calculated dimensions from the previous chapter.

3.1 Autodesk Fusion 360

3.1.1 The main features of Fusion 360 are:

- It is mechanical engineering software for design, visualization and simulation of 3D and 2D models.
- Fusion 360 is a parametric and a feature based solid modeling software.
- Sketching, freeform, surface and parametric modeling, mesh modeling, direct modeling and PCB design Integration are some of the few interesting design features offered by Fusion 360.
- Fusion 360 has a unique feature of converting our design file into our desired format, which increases the compatibility of the model being used in various other environments for various purposes.
- Files from Fusion 30 can be accessed anywhere as it uses a cloud technology to store all the design data created by the user.
- Rapid Prototyping is offered in Fusion 360, where we can use it for CAM, Rendering and 3-D printing.

- It has a simulation environment that allows motion simulation, static stress, thermal stress, non-linear stress, modal frequency and various other user friendly options for simulations.

3.1.2 Design of the Vending Machine

Parts of the model:

- ❖ Base plate
- ❖ Lid plate
- ❖ Separators
- ❖ Supporters

Design of each Part:

- Base plate: Draw a circle with 1000mm diameter and then using the extrude feature, extrude the circle with a extrude dimension of 25mm to make it a solid circular plate. This plate will is the base of the Vending machine.

  Now, enter the sketch mode again and now draw a circle at the center of the circle with a radius of 100m. Convert it back to the 3D model an then use the cut extrude feature to cut through the solid circular plate. This hole is made to fix the shaft.

  Grooves in the base: To make the grooves in a desired place, go to the sketch option and then divide the circle into 'n' number of parts. Now draw a tangent to every single line, one by one. Using this tangent is drawn; draw two parallel lines on the either side to the tangent. Now, take away the tangent and the other supporting lines. Cut extrude the parallel line to a depth of 10mm.

This concludes the modeling of the base plate.

- Lid plate: Draw a circle with 1000mm diameter and then using the extrude feature, extrude the circle with a extrude dimension of 25mm to make it a solid circular plate. This plate will is the lid of the Vending machine.
- Separators: Draw a rectangle of 400mm x 75mm and then extrude it to a width of 10mm. This makes us the separators. Duplicate this file to create as many separators as required for the assembly of the model.
- Supporters: Draw a circle of 50mm diameter and then extrude it to a height of 75mm. Duplicate this file to make 4 supporters.

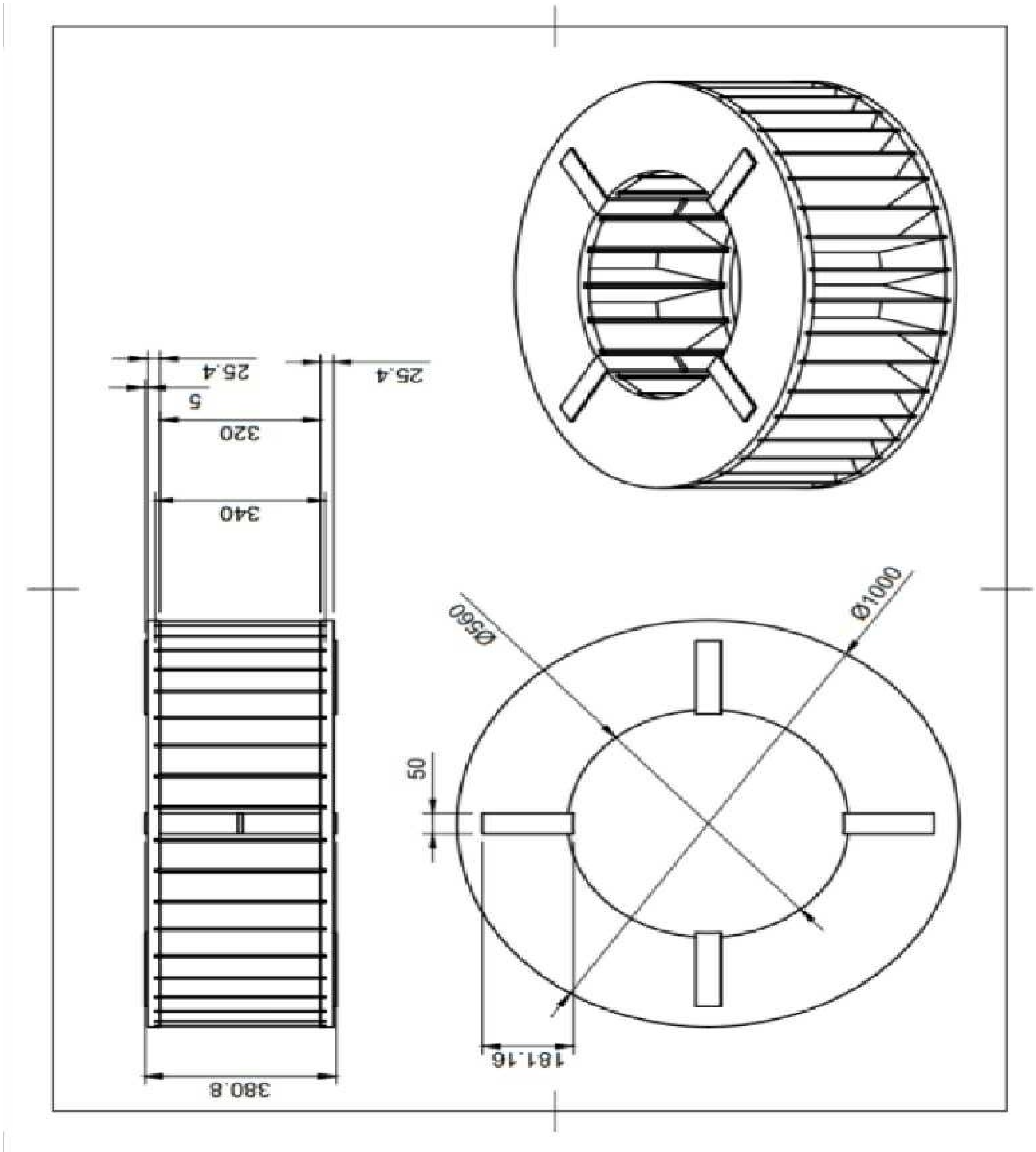
3.1.3 Assembly

- Import all the parts into one file.
- Initially consider the base and then duplicate the separators as many as needed.
- To fix the separators into the grooves, select the inner area of the groove, and the base area of the separator and then they get attached to the base plate. Repeat this process to all the duplicated separators.

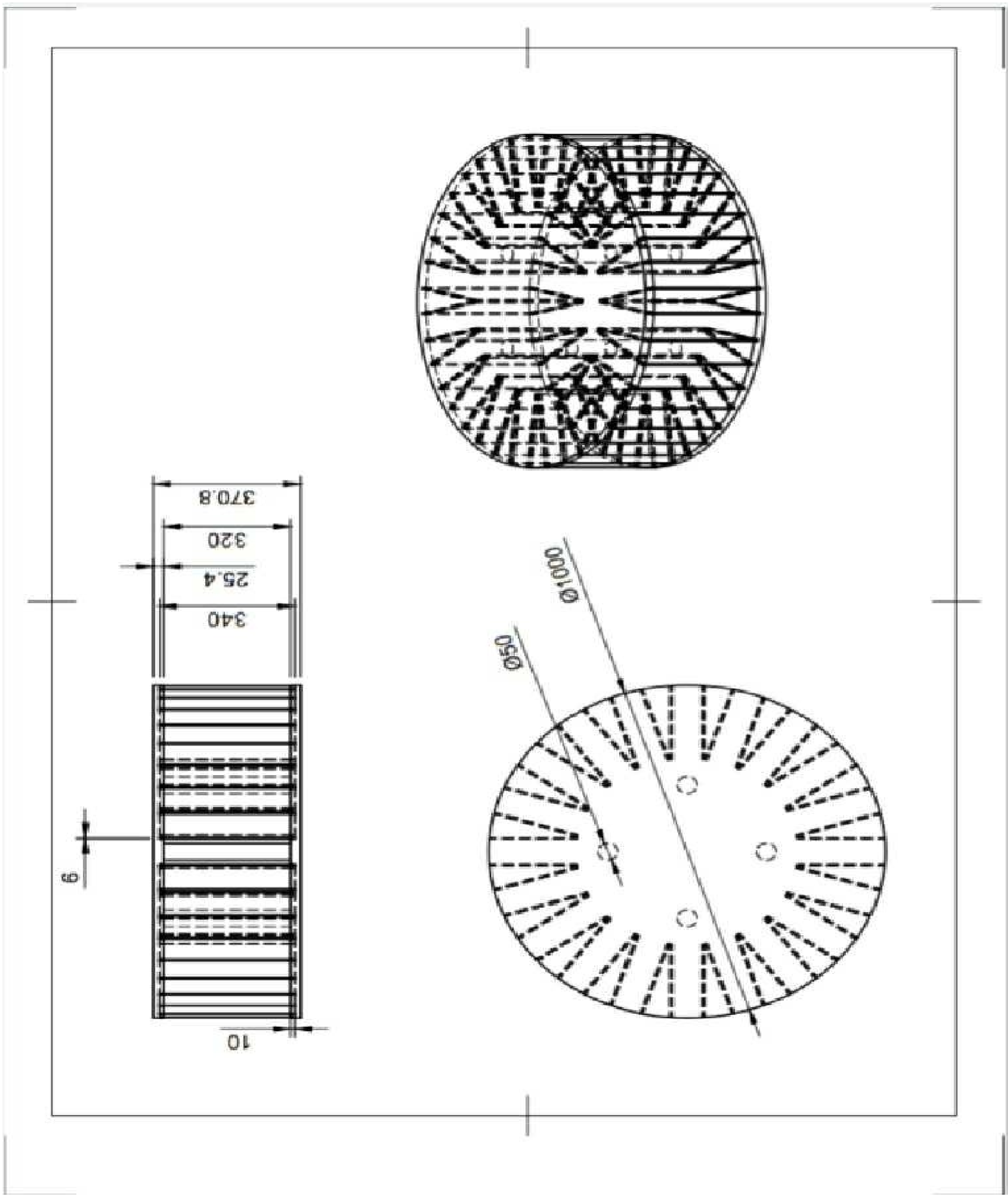
  *make sure that the alternative separators are inclined at an angle with their immediate neighbors. This enables us to have more storage for the books while placing them.

- Now to fix the Supporters, repeat the process followed while attaching the separators. But, we fix them at a four points of a circle of diameter 500mm.
- To Fix the Lid plate of the model, select the assemble button and then choose any one plane of the separators and then the inner area of the groove of the lid plate.

With having followed this procedure, we have modeled the Book Vending machine, and it can be now used for stress analysis and simulation.



Drawing 3.1- Initial drawing



Drawing 3.2- Finalized drawing

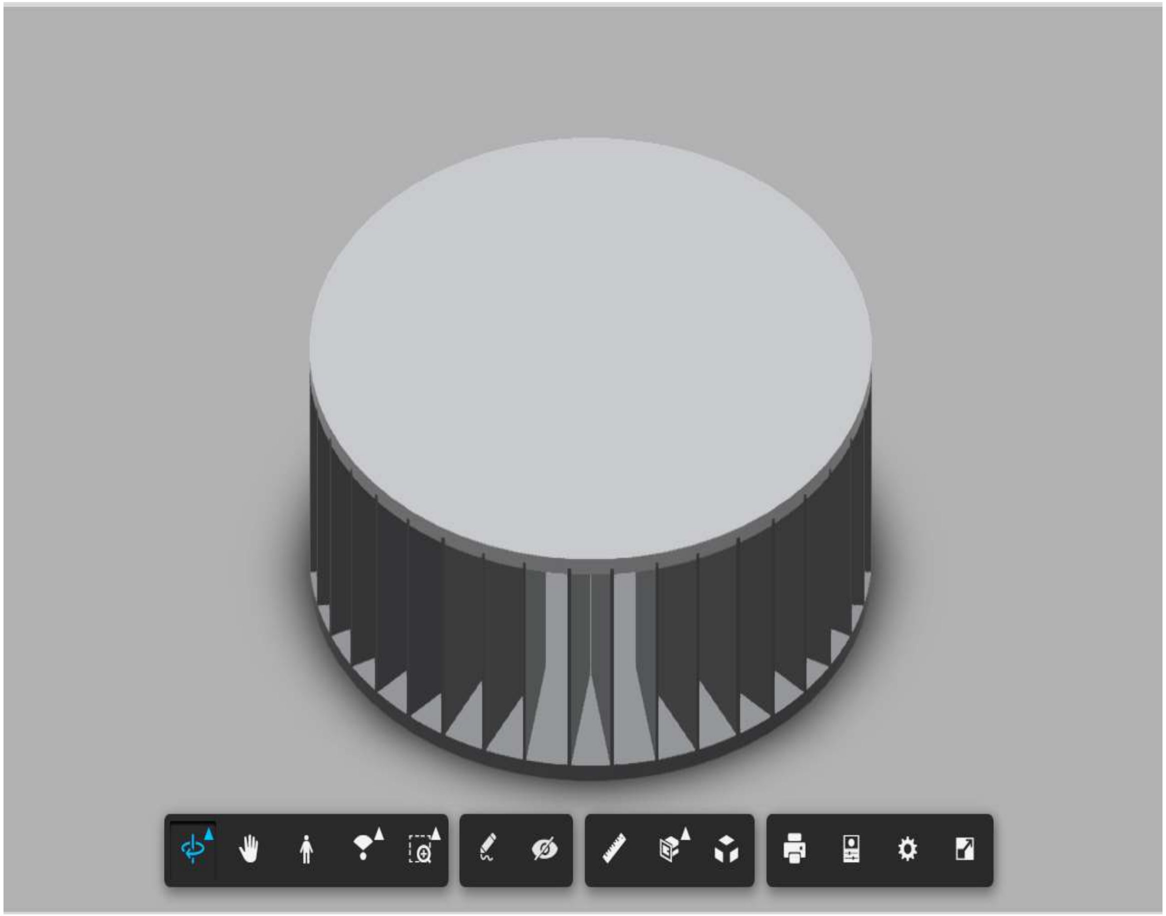


Fig 3.1 Assembled view of the device

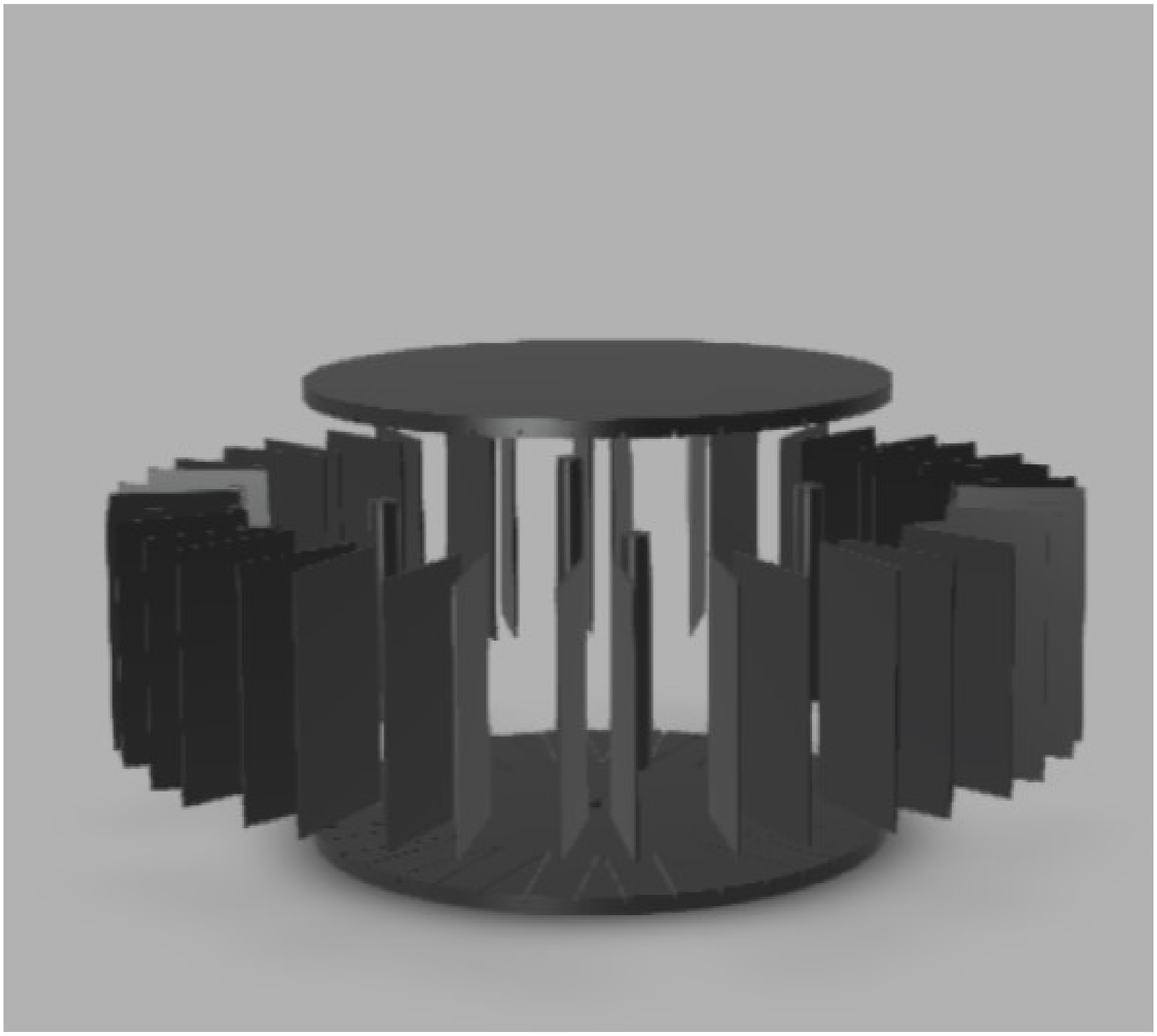


Fig 3.2-Exploded view of the assembly

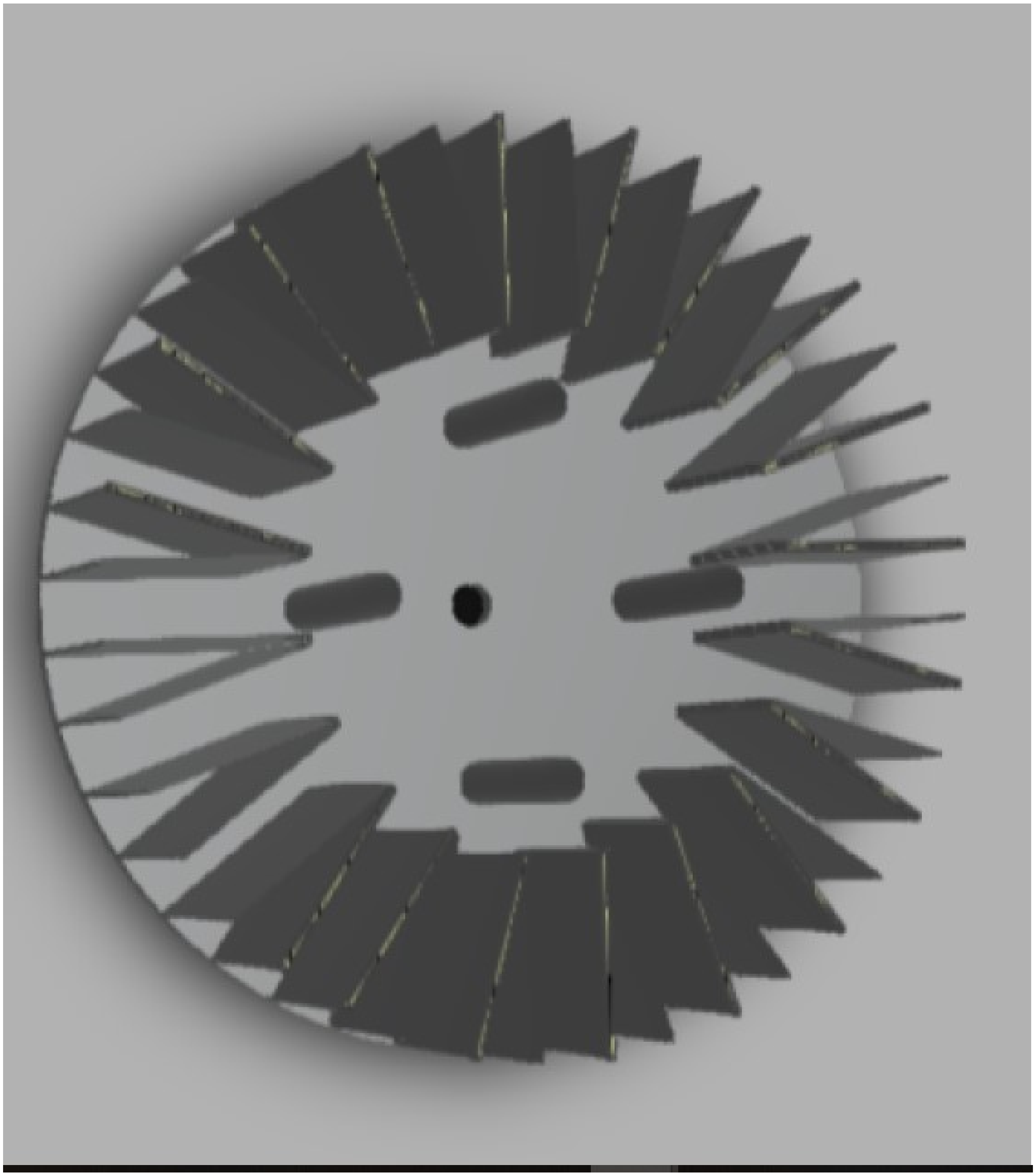


Fig 3.3 Top inner view of the assembly

3.2 Solid works:

- ❖ Solid Works is a solid modeling computer-aided design (CAD) and computer- aided engineering (CAE) computer program that runs primarily on Microsoft Windows.
- ❖ It is a very productive 3D CAD software tool, with its integrated analytical tools and design automation to help stimulate physical behavior such as kinematics, dynamics, stress, deflection, vibration, temperatures or fluid flow to suit all types of design.

3.2.1 Part Modeling:

The horizontal carousel storage system parts are modeled first in the solid works software in order to fabricate the setup.

The part modeling is done by the following steps by top down approach.

- ❖ Step 1: creating new part file.
- ❖ Step 2: creating the base part 2Dsketch.
- ❖ Step 3: converting 2D sketch to required 3D model by using features like extrude, extrude cut, revolve, sweep, chamfers, fillets, holes, spiral etc.
- ❖ Step 4: Saving the file with desired part name.

3.2.2 Assembly Modeling:

The assembly of the parts is done with proper constraints in the following manner to allow the assembled model to simulate.

- ❖ Step 1: Creating new assembly file.
- ❖ Step2: Import the base part first and ground it.

- Step3: Now import all the other parts and assemble them with various constraints to planes and features like mate, align insert etc.

- Step 4: Give the revolutionary joint at which the motor shaft revolving fixture assembled.

- Step5: Saving the file with desired filename.

CHAPTER-IV

FINITE ELEMENT ANALYSIS

CHAPTER-IV

FINITE ELEMENT ANALYSIS

Finite-element method (FEM) is a good choice for the analysis of sheet metal processes since it helps in eliminating the need for time-consuming experiments to optimize the process parameters such as sheet metal thickness, the material of the sheet, punch fillet and percentage clearance. The FEM simulations are increasingly used for investigating and optimizing the punching process. Computer simulations reduce the number of experiments and can obtain accurate results. The results depend on the element type and type of mesh considered for analysis. The main objective of the present work is to create a finite element model to predict the shape of the cut side of a blanked product and to investigate the effect of process parameters' influence on the punching process. Shockwaves produced because of crash and drop test, which can be analyzed using ANSYS explicit dynamics. In high-speed dynamic problems, the time required is compared with reference to the standard specimens and analyzed. Using explicit dynamics, we can reduce the number of steps in the analysis, thereby reducing the time for computing. Finite-element method (FEM) is a good choice for the analysis of sheet metal processes since it helps in eliminating the need for time- consuming experiments to optimize the process parameters such as sheet metal thickness, the material of the sheet, punch fillet and percentage clearance. The FEM simulations are increasingly used for investigating and optimizing the punching process. Computer simulations reduce the number of experiments and can obtain accurate results. The results depend on the element type and type of mesh considered for analysis. The main objective of the present work is to create a finite element model to predict the shape of the cut side of a blanked product and to investigate the effect of process parameters' influence on the punching process. Shock waves produced because of crash and drop test, which can be analyzed using ANSYS explicit dynamics. In high-speed dynamic problems, the time required is compared with reference to the standard specimen and analyzed. Using explicit dynamics, we can reduce the number of steps in the analysis, thereby reducing the time for computing.

4.1 Experimental Procedure:

Static analysis module is selected in the ANSYS Workbench 19.0 to perform analysis on the 3d model that was created in SOLID WORKS software:

- Initially the material is selected in materials library.
- The model is imported into geometrical model.
- Material is assigned to the solid bodies in Mechanical module.
- Punch and die are considered as rigid and sheet as flexible.
- Mesh is auto generated.
- Fixed supports are assigned and the required forces are applied.

In the solution the total deformation, shear stress and von-Misses are studied.

CHAPTER-V
FABRICATION

CHAPTER-V

FABRICATION

5.1 BASE PLATE AND LID PLATE:

Fig.5.1. Base and lid plate

The base and lid plate are the key components in the construction of this automated library storage system. Firstly, a circle of 1000mm diameter is drawn on the wooden board. Then, using a cutting machine the drawn circle is cut smoothly and carefully. And thus, we have the base plate. Similarly, for lid plate another circle of 1000mm diameter is drawn on another wooden board, and using a cutting machine, we cut away the unnecessary part of wood. Hence, we also made the lid plate.

5.2 GROOVES IN THE BASE:

Fig.5.2 Grooves at base and lid plate

For placing the books in between the base plate and lid plate, slots must be made for each book. And to make provision for slots, grooves must be made for support. To make the grooves, firstly the base and lid plates are divided into n equal parts. And at distance x from the centre, a circle is drawn for inner grooves and similarly at a distance of y from centre, a circle is drawn for placing outer grooves. At a distance of z from the dividing line on each side, a plastic support is placed and fixed using nails and a hammer. In this way grooves are made.

5.3 SEPARATORS:

Fig.5.3 Separators

After the grooves are made, the slots must be kept, for that we require separators for differentiating each slot. For that we drew n rectangles of m mm x n mm wooden boards and cut them precisely with the help of cutting machines. And so, the separators were made.

5.4 SUPPORTERS:

Fig.5.4 Supporters

For the purpose of supporting the gap between the base and lid plates, the supporters were made out of wood. They were made with a cross section of s mm x s mm, and of length l. A total of six supporters were used in this construction.

5.5 BEARING:

A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it may prevent a motion by controlling the vectors of normal forces that bear on the moving parts. Most bearings facilitate the desired motion by minimizing friction. Bearings are classified broadly according to the type of operation, the motions allowed, or to the directions of the loads (forces) applied to the parts.

Here we are using foot step bearing because it is the bearing which supports vertical shaft.

5.5.1 FOOTSTEP BEARING:

Fig.5.5 Bearing

A footstep bearing is usually in the form of a block that has a cavity in which the lower part of a shaft can be fitted. It is designed to provide support to a vertical shaft or spindle. A footstep bearing has two parts. One of them is a tubular bushing which radialy guides the spindle shaft. The second part is a bearing step which is located in the frontal end of the bushing. Both the sections are joined together in a compressive interlocking arrangement. In this way a unitary assembly is provided.

This assembled 2 piece footstep bearing can be combined with the structural elements of the spindle bearings, for instance, with a centering tube to give more support.

5.6 STEPPER MOTOR AND SPROCKET:

Fig.5.6 Stepper motor with sprocket

A stepper motor or step motor or stepping motor is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any position sensor for feedback (an open-loop controller), as long as the motor is carefully sized to the application in respect to torque and speed.

5.7 ASSEMBLY:

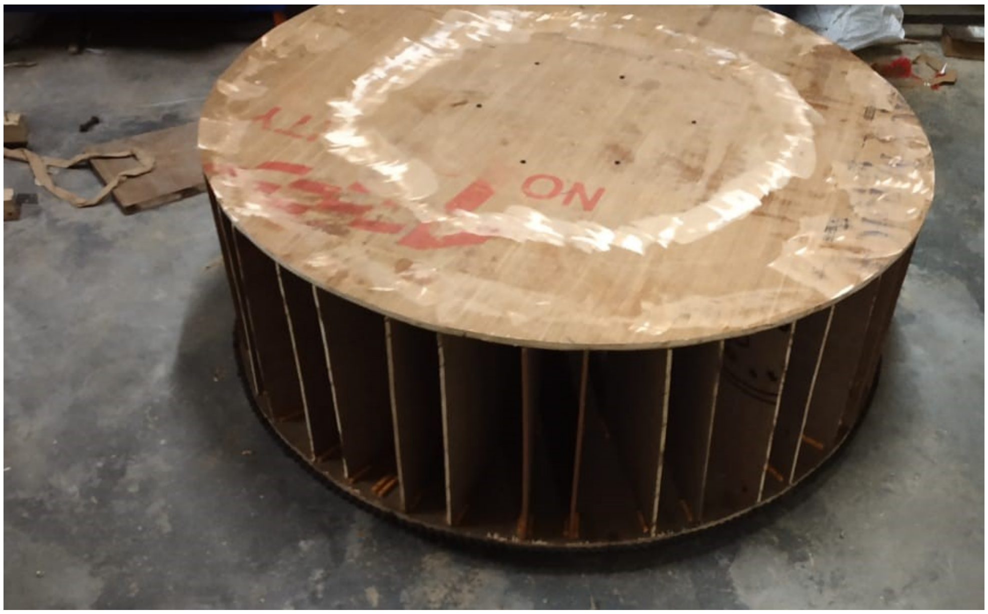


Fig.5.7 Final Assembly

1. The bearing is fixed on the base lid, using nails and hammer.
2. The supporters are fixed to the base plate and are then fixed to the lid plate as well. This forms the main construction.
3. The separators are placed in the grooves provided, thus forming slots for each book to be placed.
4. The chain is glued on the circumference of the base lid.
5. This whole construction is mounted on another rigid frame upon which provision is made for free rotation of this main construction.
6. The stepper motor and the sprocket are mounted in the slot made for that purpose.

CHAPTER-VI

AUTOMATION

CHAPTER-VI

AUTOMATION

6.1 Detection of the 'home position' coordinates.

The very first thing that the device needs to know is how far it is from the home position and how it analyzes its present position. For this, we are using the Hall Effect sensor, for the device to understand and detect where the home position is.

The Hall Effect sensor works based on the principle of Hall Effect and it helps detect a magnetic field around it. Now we are placing a magnet (or a series of magnets) on the rotating disc and this disc, irrelative of its position from the home position, keep rotating till the magnets reach the home position. Now at the home position, we place our Hall Effect sensor, and once the sensor detects the magnetic field, the program in Arduino board ensures that the board stops rotating. Now the vending machine takes note of the present position as the Origin. This is how the device detects the home position using the Hall Effect sensor.

6.2 Getting the User the requested book to the home position

After the vending machine places itself at the home position, it waits for a request to be made by the user for a desired book. To get the desired book at the home position, the device makes a few calculations, based on the rack code allocated to the books and the individual storage.

Initially, the book vending machine carries a total of 40 books, which makes it 9 degrees per book, as all the books occupy 360 degrees of the circular disc. Now, we need to carry out a simple experiment to know how much angular velocity the circular disc possesses, with all the books loaded into it. So, before programming the device, this experiment has to be carried out.

6.3 EXPERIMENTATION

Experimental setup: the book vending machine, a simple stopwatch. In this experiment, our main Aim is to calculate the time taken by the fully loaded book vending machine, to complete one single rotation.

After receiving the values of time from the experiment, we will use them to calculate the angular velocity. This calculated value is constant and can be calibrated time to time, if the load and the friction acting on the book vending machine changes.

And now that we have the angular velocity, which can be used to calculate the time required for a book to travel from its location to the home position. As discussed, the rack codes allocated to the books are actually its location, situated from the home position. We will now subtract the rack code with the initial rack code and then multiply with 9(since every book occupies 9 degrees of angular space). This is our angular displacement. Dividing the angular displacement with the angular velocity gives us the time taken required for getting the book to the home position. We shall use the Millis () function to call a timed function and stop the motor from rotating just as the book reaches the home position.

6.4 Optimization of the code for Book Storage

Now, as we are dealing with even the user placing the book back, the book vending machine should take in the books which make sure that the disc on which the books are placed, are evenly balanced and that there is no uneven forces and weight acting on it.

For this, we have divided the circular disc into four quadrants and each quadrant has 10 books. Every time a book is to be placed in the book vending machine, then the software of the device internally checks the opposite quadrant and compares the number of books in the selected quadrant and the opposite quadrant. If the selected quadrant has more books than compared to the opposite quadrant, then the rack code from the opposite quadrant gets generated. If the books on both the sides are the same, then the device shifts the analysis to the quadrant beside the selected quadrant, and the same process is followed. Based on the results obtained, the vending machine shall generate the rack code. But this procedure can be made more accurate using the results obtained from a 'Finite Element Analysis' method.

CHAPTER-VII

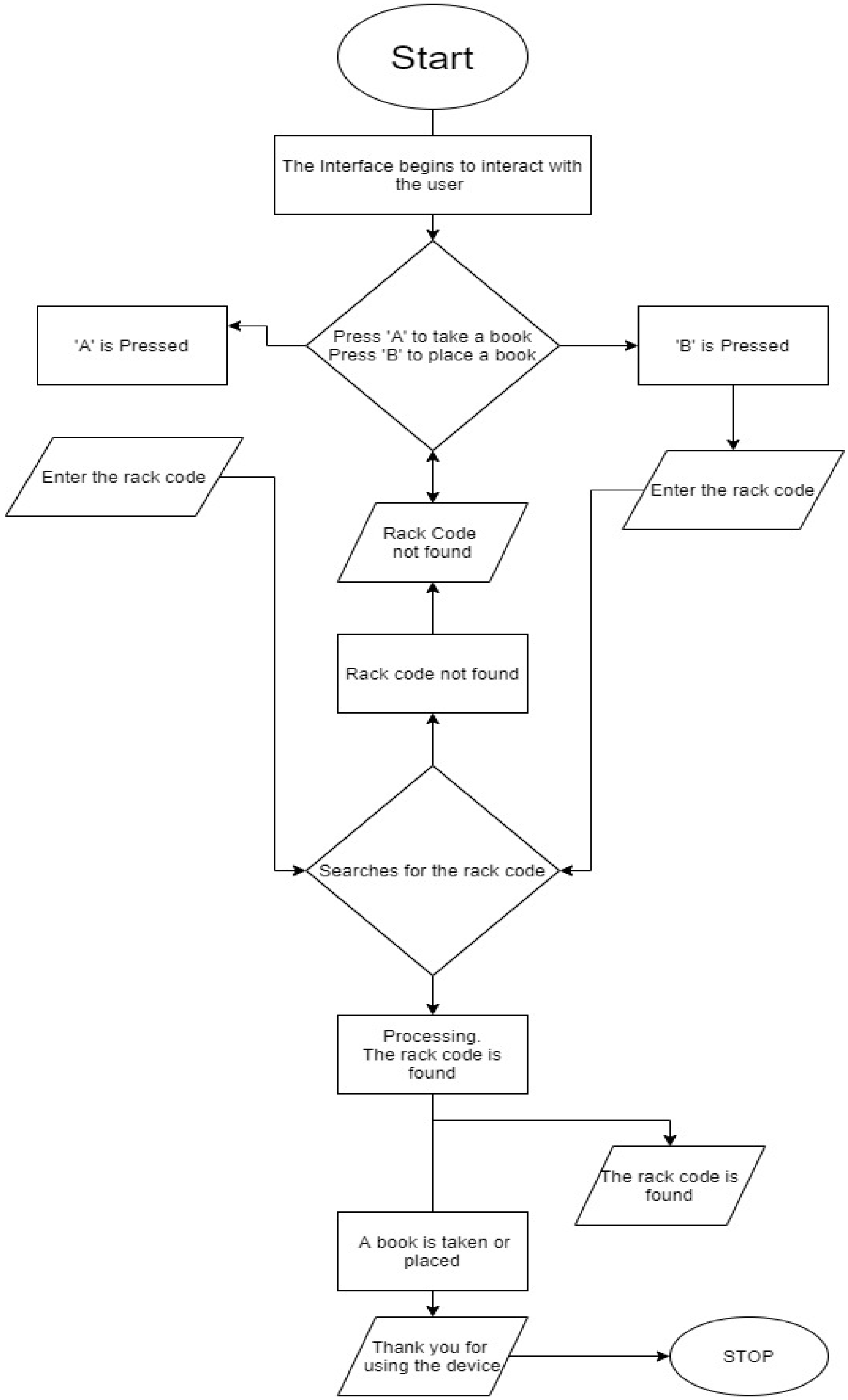
RESULTS AND DISCUSSIONS

CHAPTER VII

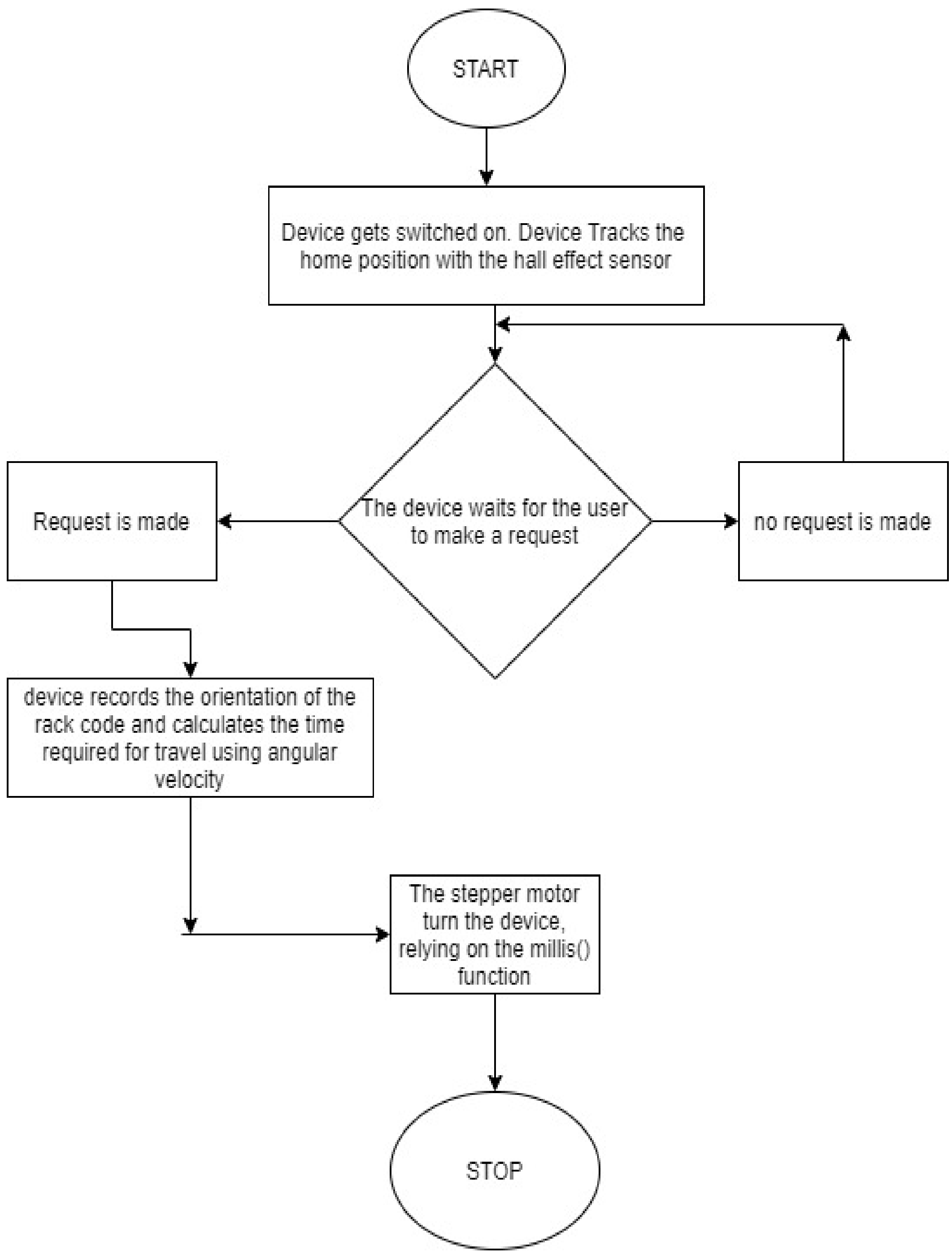
RESULT AND DISCUSSION

7.1 Mechanism and Working of the Automated book vending Machine:

The automation part of the book vending machine has two sides, the backend and the frontend, where the backend consists all the data of the books and the users that have access to the books in the device and the code(s) that run the device. And when it comes to the front end, it consists the user interface with the Input and Output devices, which can directly interact with the user. Now here is a flow chart which showcases the frontend UI experience of the Automated Device. The backend part consists of all the hardware and the software working hand and glove with each and another. Here is a flow chart to demonstrate the working mechanisms of the hardware and the software parts.



Flow chart 7.1: Functioning of UI(software)



Flow chart 7.2: Functioning of hardware part

7.2 RESULT OF ANSYS:

TABLE-1: STRESS

CATEGORY	EQUIVALENT STRESSES (Pa)	
	Max	min
Analysis on free model	0.0020782	0
Analysis on model with 3 rollers	0.00081588	0
Analysis on model with 4 rollers	0.00021592	0
Analysis on model with 5 rollers	0.00015982	0
Half load analysis	0.000269	0
Quarter load analysis	0.00044068	0
Quarter load on opposite sides	0.00037781	0

TABLE 2: DEFORMATION

CATEGORY	TOTAL DEFORMATION (m)	
	Max	min
Analysis on free model	1.9867e6	335.68
Analysis on model with 3 rollers	2.6444e6	148.65
Analysis on model with 4 rollers	1.523e6	181.17
Analysis on model with 5 rollers	1.0307e6	136.82
Half load analysis	1.64e6	135.82
Quarter load analysis	1.2604e6	14.624
Quarter load on opposite sides	9.7243e5	14.197

7.3 Mechanism testing of the real fabricated model of horizontal carousel system

All fabricated parts are post processed and assembled part by part. Slight modifications were done for manufacturing feasibility. First the mechanism was tested with no load condition of horizontal carousel and it is observed that the mechanism is functioning quite well, even the slight modifications from the simulated model.

Then the design was tested by applying load gradually until full load condition. It was observed that it works perfectly and the idea of using horizontal carousel system as an automated book vending system is effective

7.4 REQUIRED SPACE HAS BEEN OPTIMISED

The main problem which being faced by the current library systems is "SPACE" There requires several square meters of space to display or store books in libraries which includes walking space between racks of books.

Generally it is estimated that for the currently running library systems for a square meter we can only put 15 to 21 books but using the system we suggested (horizontal carousel system)we can put 42 books per square meter area(it works by eliminating walking space) which greatly reduces the area of the library required.

7.5 REQUIRED TIME HAS BEEN OPTIMISED

It was observed that the average time required for a person to get a book what he wants and getting his details registered in records is to be 15 to 25 mins and the system we suggested reduces to a great extent nearly to 20 to 30 seconds, there is a drastic fall in the required time because of automation .The book which the person needs has a particular data base in the systems memory, and by entering the books name, the system gets him the book.

The entire system is programmed to set the average service time per a person (time in which the person gets the book) is around 10 seconds.

TABLE 3: COST ANALYSIS

Material	Cost	Alternate materials	Cost
Plywood	8500/-	Alloy sheet	7500/-
		Form sheet	13000/-
		Plastic	6000/-
		Hardwood	7000/-
Bearings (50 ton stainless steel)	2300/-	Foot step bearing	3000/-
		Collar bearing	2500/-
Stepper motor(NEMA23)	2300/-	NEMA17	1700/-
		NEMA11	3000/-
		NEMA34	10000/-
Micro controller (Ardunio Uno)	550/-	ATMEga80	800/-
		Arduino mega	1500/-
		Raspberry pi	4000/-
Drivers for motor	900/-	ULN 2003	960/-
		GjKfun easy drive	600/-
		L298N	300/-
		DRV8825	600/-
		Adafruit TB6612	560/-
Chain &sprocket	500/-	3d printed gear & pinion	5000/-
		Belt drive	2000/-
Rollers (simple Castor rollers)	150/-	Ball rollers	1500/-

7.6 Comparison between time taken for completion of one revolution at no load and full load conditions.

The observations were made conducting a series of test in regards to find the friction acting on the device while rotating in no load and full load conditions.

TABLE 4: TIME TAKEN AT NO LOAD CONDITION

S.NO	NO. OF REVOLUTIONS	TIME TAKEN
1	1	10.34
2	1	10.37
3	1	10.35
4	1	10.50

AVERAGE TIME TAKEN AT NO LOAD CONDTION IS =**10.34 seconds**

TABLE 5: TIME TAKEN AT FULL LOAD CONDITION

S.NO	NO. OF REVOLUTION	TIME TAKEN
1	1	10.41
2	1	10.39
3	1	10.41
4	1	10.42

AVERAGE TIME TAKEN AT FULL LOAD CONDITION = **10.40 seconds**

CHAPTER – VIII

CONCLUSION

CHAPTER – 8

CONCLUSION

8.1 Conclusion

Automation is one of the diverse technologies which are readily adopted by large industries and common people. Automating the day to day machinery in our offices and homes, make lives very easy and fascinating for us. And one of our idea was to make and automate, a book vending machine.

Book vending machines, in the near future, are a replacement the bulk shelves and the vertical and horizontal carousel systems. They occupy a lot of space. As we know, when all the geometrical defined bodies have the same dimensions, then it is the circle which occupies the least area. Based on this geometrical identity, we have constructed a circular vending machine.

This Device reduces the unnecessary time required for searching the required book in the whole lot of the lengthy, bulky book shelves placed in our old fashioned libraries. These improve the expenditure of the quality time of a person, and also get the masses to know more and rely upon the future, the automated devices.

8.2Future Scope

Since this is just the very first version of the book Vending machine which functions based on user and device interaction, the later versions of the device could use much better techniques of Automation and could possibly introduce Internet of Things(IoT) and Artificial intelligence to it.

The mechanical material and design, which is wood and one single layer in our case, can be upgraded with better materials and better mechanisms with multilayer shelves embedded with robust driving mechanisms.

The code for automation which has quite a many sensors for recognizing the orientation of the device can be reduced by programming it with better and efficient sensor with great precision and accuracy.

The User Interface(UI) which is simply restricted to the 16x2 array characters in our case, can be interfaced with better LCD screens with much more interactive GUI. (*In the case of our automated book vending machine, the UI is simple and restricted to the 32 characters of data display which can be increased by upgrading the microcontroller and the interfaced LCD screen).

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APPENDIX

APPENDIX A

Interfacing the 16x2 LCD screen to the Arduino and creating the User Interface.

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <Keypad.h>
const byte ROWS = 4; //four rows
const byte COLS = 4; //three columns

char keys[ROWS][COLS] = {
  {'1','2','3','A'},

  {'4','5','6','B' },

  {'7','8','9','C'},

  {'*','0','#','D'}
};
byte rowPins[ROWS] = {9, 8, 7, 6}; //connect to the row pinouts of the keypad
byte colPins[COLS] = {5, 4, 3, 2}; //connect to the column pinouts of the keypad
Keypad keypad = Keypad( makeKeymap(keys), rowPins, colPins, ROWS, COLS);
LiquidCrystal_I2C lcd(0x27,20,4);  // set the LCD address to 0x27 for a 16 chars and 2 line display

char choice;
int i=7; char key,key1;
String bookcode;
void instructions(){ // sends the instructions to the user
  lcd.setCursor(0,0);
  lcd.print("A. Take a Book");
```

```
 lcd.setCursor(0,1);
 lcd.print("B. Place a Book");
 // this code is repeating but cant be taken as an individual function!
 while(true){
 choice = keypad.getKey();
 if(choice != NO_KEY){
   lcd.clear();
   lcd.setCursor(7,0);
   lcd.print(choice);
   break;} }
   delay(1500);
   lcd.clear();}

void processing()
{ // this helps us to find out the orientation of the book
  lcd.setCursor(3,0);
  lcd.print("Processing");
  lcd.setCursor(7,1);
  lcd.print(bookcode);
  delay(4000);
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print("Thanks for using");
  lcd.setCursor(3,1);
  lcd.print("our device");
  delay(4000);
  lcd.clear();
  bookcode="";
 }
void setup()
{
```

```
  Serial.begin(9600);
  lcd.init();                     // hakuna matata baby
  // Print a message to the LCD.
  lcd.backlight();
  lcd.setCursor(2,0);
  lcd.print("Book Vending");
  lcd.setCursor(5,1);
  lcd.print("Machine");
  delay(3500);
  lcd.clear();
  lcd.setCursor(1,0);
  lcd.print("Software UI by");
  lcd.setCursor(6,1);
  lcd.print("Kasa");
  delay(3500);
  lcd.clear();
}
void loop() {
  // Print a message to the LCD.
  lcd.backlight();

  // this is an important code and can be placed between as an individual function. But let's just see!
  lcd.setCursor(2,0);
  lcd.print("Enter * for");
  lcd.setCursor(1,1);
  lcd.print("Instructions");
  while(true)
  {
  key = keypad.getKey();
  if (key != NO_KEY){
    lcd.setCursor(0,1);
```

```
 lcd.print(key);
 break;
   }
}
lcd.clear();

if(key=='*'){
lcd.setCursor(0,0);
lcd.print("Choose an option");
delay(2500);
lcd.clear();

instructions(); // I'm calling the function here!
if(choice=='A'){
 lcd.setCursor(0,0);
 lcd.print("Enter Rack Code");

 while(true){
   char code = keypad.getKey();
   if(code != NO_KEY){
     lcd.setCursor(i,1);
     if(code=='D'){i=7;break;}
     lcd.print(code); bookcode=bookcode+code; i=i+1;
     } }
 lcd.clear();
 processing();
}

else if(choice=='B'){
 lcd.setCursor(0,0);
 lcd.print("Enter Book Code");
```

```
    while(true){
      char code = keypad.getKey();
      if(code != NO_KEY){
        lcd.setCursor(i,1);
        if(code=='D'){i=7;break;}
        lcd.print(code); bookcode=bookcode+code; i=i+1;
        } }lcd.clear();
     processing();
     }
   else{
   lcd.setCursor(1,0);
   lcd.print("Invalid Option");
   delay(1500);
   lcd.clear();
  }
  }
  else{
   lcd.setCursor(1,0);
   lcd.print("Invalid Option");
   delay(1500);
   lcd.clear();
  }
}
```

APPENDIX B

Interfacing the Hall Effect sensor for determining the home position

```
#include<Stepper.h>
int hallSensorPin = 2;
int ledPin =  13;
int state = 0;
void setup() {
  pinMode(ledPin, OUTPUT);
  pinMode(hallSensorPin, INPUT);
  // the below are the pins for the
  pinMode(6, OUTPUT);
  pinMode(7, OUTPUT);
  pinMode(8, OUTPUT);
  pinMode(9, OUTPUT);
}
void loop(){

  state = digitalRead(hallSensorPin);
  if (state == LOW) {
    digitalWrite(6,HIGH);
    digitalWrite(7,LOW);
    digitalWrite(8,LOW);
    digitalWrite(9,HIGH);
  }
  else {  // this happens when a magnetic field is detected.
    digitalWrite(6,LOW);
    digitalWrite(7,LOW);
    digitalWrite(8,LOW);
    digitalWrite(9,LOW);  }}
```

APPENDIX C

CODE FOR FUNCTIONING OF STEPPPER MOTOR

```
#include<Stepper.h>

void setup() {
  // the below
  pinMode(6, OUTPUT);
  pinMode(7, OUTPUT);
  pinMode(8, OUTPUT);
  pinMode(9, OUTPUT);
}
void loop(){

  int angular_velocity=10;
  int rack_code;
  float cal;

  cal= ((rack_code*9)/angular_velocity);
  int time1=millis();
  while (!(time1>cal)) {
    digitalWrite(6,HIGH);
    digitalWrite(7,LOW);
    digitalWrite(8,LOW);
    digitalWrite(9,HIGH);}
    // this happens when a magnetic field is detected.
    digitalWrite(6,LOW);
    digitalWrite(7,LOW);
    digitalWrite(8,LOW);
    digitalWrite(9,LOW);
}
```