MODELLING, SIMULATION AND RAPID PROTOTYPING OF MODULAR HORIZONTAL CAROUSEL STORAGE SYSTEMS

A Project report submitted in partial fulfilment of the requirement
for the award of the degree of

BACHELOR OF ENGINEERING
IN
MECHANICAL ENGINEERING

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(Affiliated to Andhra University, Approved by AICTE, Accredited by NBA, NAAC with “A” grade)
SANGIVALASA, VISAKHAPATNAM (District) – 531162
2018

ANIL NEERUKONDA INSTITUTE OF TECHNOGY & SCIENCES

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CERTIFICATE

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ACKNOWLDGEMENT

We express immensely our deep sense of gratitude to **Sri. J.V BHANU TEJ**, Assistant Professor, Department of Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences, Sangivalasa, Bheemunipatnam Mandal, Visakhapatnam district for his valuable guidance and encouragement at every stage of the work made it a successful fulfillment.

We are very thankful to **Professor T.V.Hanumantha Rao**, Principal and **Professor B.Naga Raju**, Head of the Department, Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences for their valuable suggestions.

We express our sincere thanks to the members of non-teaching staff of Mechanical Engineering for their kind co-operation and support to carry on work.

Last but not the least, we like to convey our thanks to all who have contributed either directly or indirectly for the completion of our work.

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ABSTRACT

Horizontal Carousel Systems are ideal for high speed automated picking, parts delivery and sortation applications. This system consists of storage bins attached to the rotating frame driven by top (or) bottom drive motor. Automation is employed for storage and retrieval of components, an operator enters the storage bin number, then the carousel rotates in optimal path and brings the requested bin to delivery station. The main problem with this system is that the entire bins have to rotate to bring the required bin to delivery station thus increasing the power usage and torque requirement of the motor. Also the other limitation like fixed installation of the system and expansion of carousel as per the need, limits its usage for various storage applications. An attempt is made in this project to design a horizontal carousel system to overcome these limitations.

The library book storage system is selected as application of horizontal carousel storage system. The mechanism is designed initially. Then the part models of the designed system are modeled, assembled and simulated in the Autodesk Inventor Professional 2013 software. Then the produced CAD models are converted into STL files and print parameters are setup. All parts are 3D printed with 20% infill density using flash forge 3D printer. After the post processing, the parts are assembled and tested for mechanism and modularity.

It has been observed from the prototype that the mechanism works similar to the simulation. It was observed that modularity of the horizontal carousel is possible. The power usage and torque requirement of motor can be reduced, as it is observed from the simulation that individual modules can be rotated separately by engaging or disengaging the gear from the gear train using solenoid.

LIST OF CONTENTS

LIST OF FIGURES

LIST OF DRAWINGS

LIST OF TABLES

LIST OF GRAPHS

LIST OF CHARTS

CHAPTER - I

INTRODUCTION

CHAPTER – I

INTRODUCTION

1.1 Carousel storage systems :

A carousel storage system is a dynamic solution that users vertically rotating shelves to bring stored items to the system operator. A carousel storage system functions according to the "goods to man" principle. Employees do not have to walk back and forth through the warehouse looking for stored items, which is a time-consuming process. The carousel storage system is controlled and managed by special software so that stored items are found and retrieved quickly.

Carousel storage systems support automated put and pick operations, making storage and retrieval tasks much safer – workplace accidents in the warehouse are a thing of the past. Requested items are quickly located and transported to the system access point for retrieval – this can all be integrated in the overarching production process. Carousel storage systems optimize operations and production processes by making them more efficient and economical. Furthermore, stored products are transported to the access point at an ergonomic height – this contributes to employee health and safety.

There are two distinct types of carousel storage units. Horizontal storage carousels rotate and store product in a horizontal plane. Vertical storage carousels rotate and store product in a vertical plane. A third type of system, called a Vertical Lift Module (VLM) or “Shuttle”, looks similar to a vertical carousel and stores product in a vertical plane but has distinct differences and productivity advantages not found in carousels.

The primary advantages all of these systems offer are:

1) built-in position sensing controls that present a specific storage bin or shelf to the operator on demand and;
2) elimination of non-value added worker travel time in the item selection and stock put-away process.

Carousels and shuttles can be controlled manually by an operator, but they provide the greatest productivity gains when coupled with :

batching software and hardware that presents order selection cartons, totes or kits to the operator and automatically interfaces with the carousel movement;

Ø software that automatically locates and advances the next product to be picked to the carousel operator workstation;

Ø picking displays that tell the operator how much to pick of each item and;

Ø put displays that tell the operator how many of each item to place into each kit or container.

1.1.1 Horizontal carousels:

Horizontal carousels have storage bins with shelves hanging from trolleys. The carousel bins are hooked together and travel around an oval-shaped horizontal track. Horizontal carousel units usually aren't enclosed.

Picking software is commonly used to automatically advance the next pick location to the operator and pick displays or lights tell the operator how many items to pick from a location on each horizontal carousel shelf.

Fig 1.1 Horizontal carousel

1.1.2 Vertical carousels :

Vertical carousels are essentially horizontal units that rotate in a vertical plane. Vertical carousel units are enclosed in a metal housing and have an opening to store and pick goods through. Vertical carousels provide the same features as horizontal units with the added benefits of better utilization of vertical building space and better security provided by the unit's enclosure.

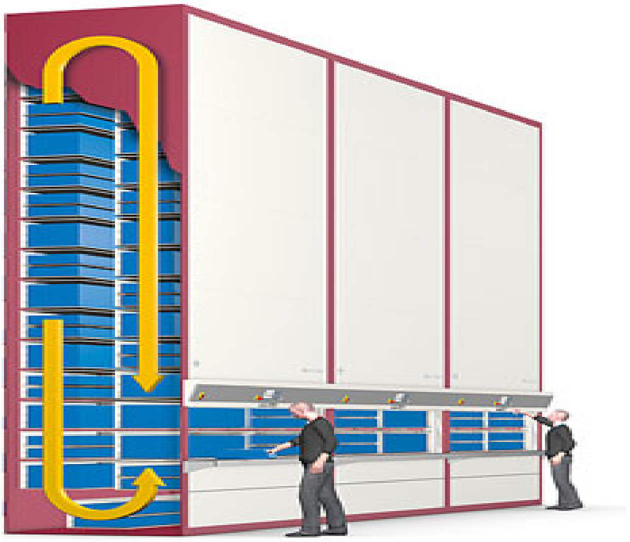


Fig 1.2 Vertical Carousel

1.1.3 Vertical lift modules:

Vertical Lift Modules (VLM) or "Shuttles" are similar to vertical carousels in appearance and basic function, but that's where the similarities end. VLMs don't rotate product to the operator position like carousels. Goods are stored on individual trays in a vertical lift module. The trays are moved between operator workstations and storage locations of the unit by an internal shuttle device.

1.2 GEARS :

A gear or cogwheel is a rotating machine part having cut teeth, or cogs, which mesh with another toothed part to transmit torque. Geared devices can change the speed, torque, and direction of a power source. Gears almost always produce a change in torque, creating a mechanical advantage, through their gear ratio, and thus may be considered a simple machine. The teeth on the two meshing gears all have the same shape. Two or more meshing gears, working in a sequence, are called a gear train or a transmission.

There are different types of gears available in the market , but we are using only spur gears because of its simplicity.

1.2.1 Spur gear :

Spur gears are the most common type of gears. They have straight teeth, and are mounted on parallel shafts. Sometimes, many spur gears are used at once to create very large gear reductions.

Fig 1.3 Spur Gear

1.3 Motor :

A motor is an electrical machine that converts electrical energy into mechanical energy. The reverse of this is the conversion of mechanical energy into electrical energy and is done by an electric generator, which has much in common with a motor.

Most electric motors operate through the interaction between an electric motor's magnetic field and winding currents to generate force. In certain applications, such as in regenerative braking with traction motors in the transportation industry, electric motors can also be used in reverse as generators to convert mechanical energy into electric power.

Electric motors may be classified by electric power source type, internal construction, application, type of motion output, etc.; here we are dealing with step motor because they are good for positioning, speed control and low speed torque.

1.3.1 Step motor :

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.

Fig 1.4 Step Motor

1.3.2 Working principle of stepper motor:

- The principle of working of stepper motor is Electro magnetism.
- It consists of a rotor that is of permanent magnet and rotor that is of electro magnets.
- Now when we give supply to stator’s winding, there will be a magnetic field developed in the stator. Now rotor of motor that is made up of permanent magnet will try to move with the revolving magnetic field of stator.

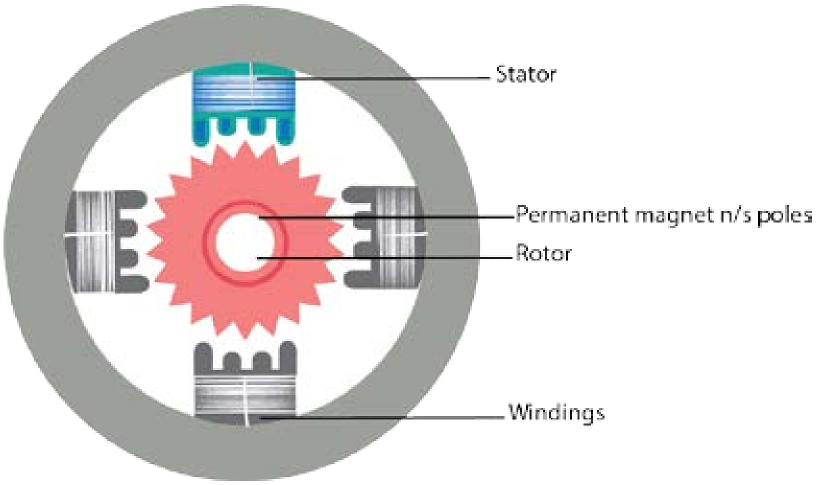


Fig 1.5 Working principle

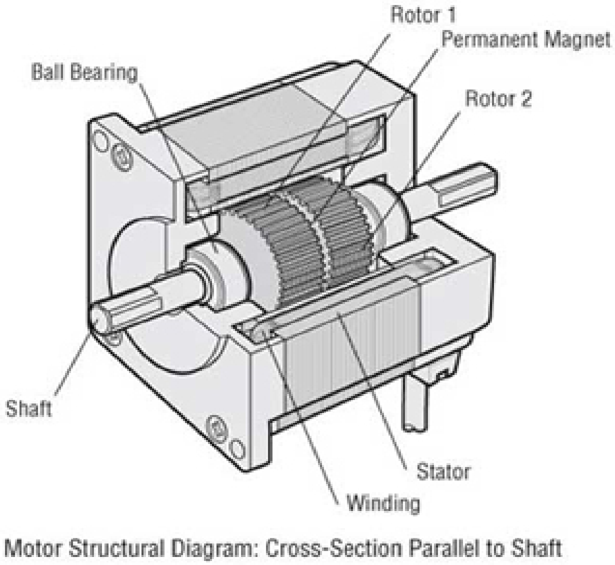


Fig 1.6 Structural diagram of Motor

1.4 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.

1.4.1 Foot step 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 radially 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.

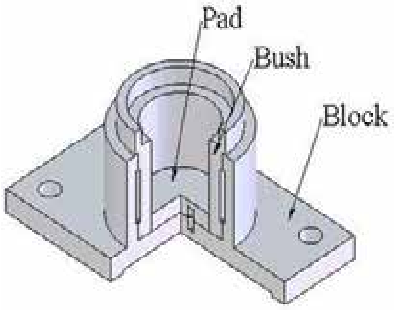


Fig 1.7 Foot Step Bearing

1.5 Solenoid valve :

A solenoid valve is an electromechanically operated valve. The valve is controlled by an electric current through a solenoid: in the case of a two-port valve the flow is switched on or off; in the case of a three-port valve, the outflow is switched between the two outlet ports. Multiple solenoid valves can be placed together on a manifold.

Solenoid valves are the most frequently used control elements in fluidics. Their tasks are to shut off, release, dose, distribute or mix fluids. They are found in many application areas. Solenoids offer fast and safe switching, high reliability, long service life, good medium compatibility of the materials used, low control power and compact design.

The following figures shows operation of solenoid valve :

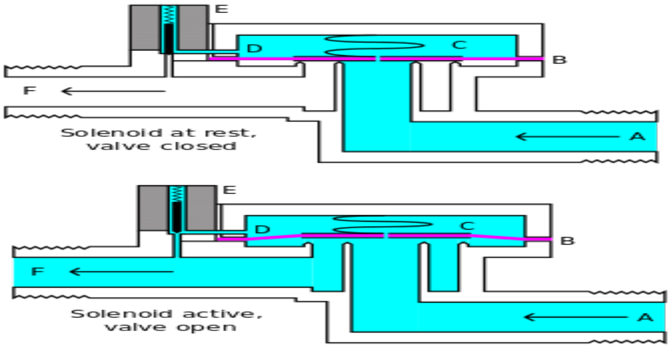


Fig 1.8 Working of Solenoid Valve

Fig 1.9 Solenoid valve

1.6 Shaft :

A shaft is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another, or from a machine which produces power to a machine which absorbs power. The various members such as pulleys and gears are mounted on it.

Shafts are classified into two types :

1) Transmission shafts are used to transmit power between the source and the machine absorbing power. E.g. counter shafts and line shafts.
2) Machine shafts are the integral part of the machine itself. E.g. crankshaft.

Fig 1.10 Solid shaft

Fig 1.11 Hollow shaft

1.7 Chain drives:

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. The gear is turned, and this pulls the chain putting mechanical force into the system. Another type of drive chain is the Morse chain, this has inverted teeth.

Chains are of three types :

1) Link chain or Load lifting chain
2) Hauling chain or block chain
3) Power transmission chain

Here we are using only power transmission chains to transfer torque from to mechanism

Fig 1.12 Chain Drives

1.7.1 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.

Fig 1.13 Sprocket

1.8 Rapid Prototyping (RP):

The term rapid prototyping refers to the class of technologies that can automatically construct physical models from computer aided design (CAD) data. The main advantage of the system is that almost any shape can be produced. Time and money savings vary from 50-90% compared to conventional systems. Rapid prototyping techniques are often referred to solid free-form fabrication; Computer automated manufacturing or layer manufacturing. The computer model is sliced into thin layers and the part is fabricated by adding layers onto of each layer. Rapid prototyping is a group of techniques used to quickly fabricate a scale model of physical part or assembly using three- dimensional computer aided design data. Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology.

The first methods of rapid prototyping became available in the late 1980s and were used to produce models and prototype parts. Today they are used for a wide range of applications and used to manufacture production-quality parts in relatively small numbers if desired without the typical unfavorable short-run economics. This economy has encouraged online service bureaus. Historical surveys of RP technology start with discussions of simulacra production techniques used in 19th century sculptors. The ability to reproduce designs from a dataset has given rise to issues of rights, as it is now possible to interpolate volumetric data from one dimensional image.

1.8.1 Current Techniques and Materials:

A wide range of techniques and materials can be used for rapid prototyping. Commercial techniques are available to produce objects from numerous plastics, metals, and wood-like paper.

Among those some techniques are

- Stereo lithography
- Selective laser sintering
- Fused deposition modelling or fused filament fabrication
- Three dimensional printing
- Laminated object manufacturing
- Multi jet modelling
- Laser engineered net shaping.

1.8.2 Basic Steps Involved in RP:

Basically there are five steps in rapid prototyping technology for development of the prototypes they are given below:

- 3D CAD model creation of the parts
- CAD data in a specific file format (STL) is processed and oriented in an optimal build position.
- The data is then sent to the RP machine where it is numerically sliced into thin layers.
- The RP machine then fabricates each 2D cross-section and bonds it to the previous layer.
- A complete prototype is built by stacking layer upon layer until the prototype is completed.
- Cleaning and finishing the model. The costs can also be reduced because rapid prototyping processes are fully automated and therefore, need the skill of individual craftsmen for no more than finishing the part.

CAD MODEL STL FILE PROTOTYPE

Fig 1.14 Process of RP

1.8.3 Applications:

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.

1.9 Problem Definition:

The main problem with horizontal carousel system is that the entire bins have to rotate to bring the required bin to delivery station thus increasing the power usage and torque requirement of the motor. Also the other limitation like fixed installation of the system and expansion of carousel as per the need, limits its usage for various storage applications. An attempt is made in this project to design a horizontal carousel system to overcome these limitations.

1.10 Scope of the Project:

The main scope of this project is to develop the horizontal carousel system to overcome its limitations. 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 Inventor Professional 2013 software. Then the produced CAD models are converted into STL files and print parameters are setup. All parts are 3D printed with 20% infill density using flash forge 3D printer. After the post processing, the parts are assembled and tested for mechanism and modularity.

CHAPTER - II

LITERATURE

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 [DC]. 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 analyse 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 servedby 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 andd iscuss 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 e€ects 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. # 1999 Elsevier Science Ltd. All rights reserved.

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 takes 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 sytematic 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, 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

MODELLING AND SIMULATION

CHAPTER – III

MODELLING AND SIMULATION

In this chapter, modelling and simulation of various parts in the model can be done. Modelling can be done in various methods such as wireframe modelling, surface modelling, solid modelling etc., The easiest way is chosen for modelling of the experimental setup. Here we have chosen solid modelling method of creating a solid. There are many packages for modelling, out of which Autodesk Inventor has been selected for its ease of availability and as it is user friendly.

3.1 Autodesk Inventor:

The main features of Autodesk inventor software are

- It is 3D mechanical engineering, design, visualization and simulation software.
- Autodesk inventor is a parametric and feature-based solid modelling tool. It allows us to convert basic 2D sketch into a solid model using very simple modelling options.
- It creates digital prototyping as opposed to physical prototyping by integrating 2D AutoCAD drawings and 3D data into a single digital model.
- It can quickly and easily create stunning renderings, animations and presentations that improve communication.
- It can easily generate and share production-ready drawings for manufacturing teams.
- The automatic updating feature allows easy changes in models.
- It has a simulation environment that allows motion simulation, static and model finite element analysis(FEA) of parts, assemblies and load bearing frames.

Autodesk Inventor’s parametric studies and optimization technology lets users modify design parameters within the assembly stress environment and compare various design options, then update the 3D model with the optimized parameters.

3.2 Data interoperability and exchange:

Inventor uses specific file formats for paths(IPT), assemblies(IAM) and drawing views (IDW and DWG).Files can be imported or exported in DWG format. Design Web Format (DWF) is Autodesk’s preferred 2D\3D data interchange and review format. Inventor includes a building information modelling (BIM) Exchange tool, used to create and publish simplifies 3D representations, intelligent connections points and additional information in native file formats for AutoCAD MEP (mechanical, electrical and plumbing) software.

3.3 Part Modelling:

The horizontal carousel storage system parts are modelled first in the Autodesk Inventor software in order to fabricate the setup.

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

- Step 1: creating new part file with extension”.ipt”
- Step 2: creating the base part 2D sketch
- 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.

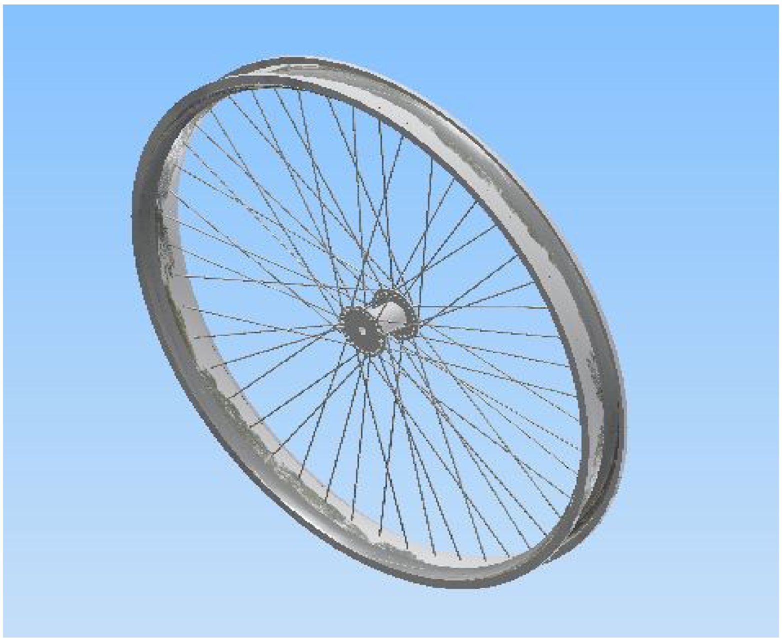


Fig 3.1 Rim

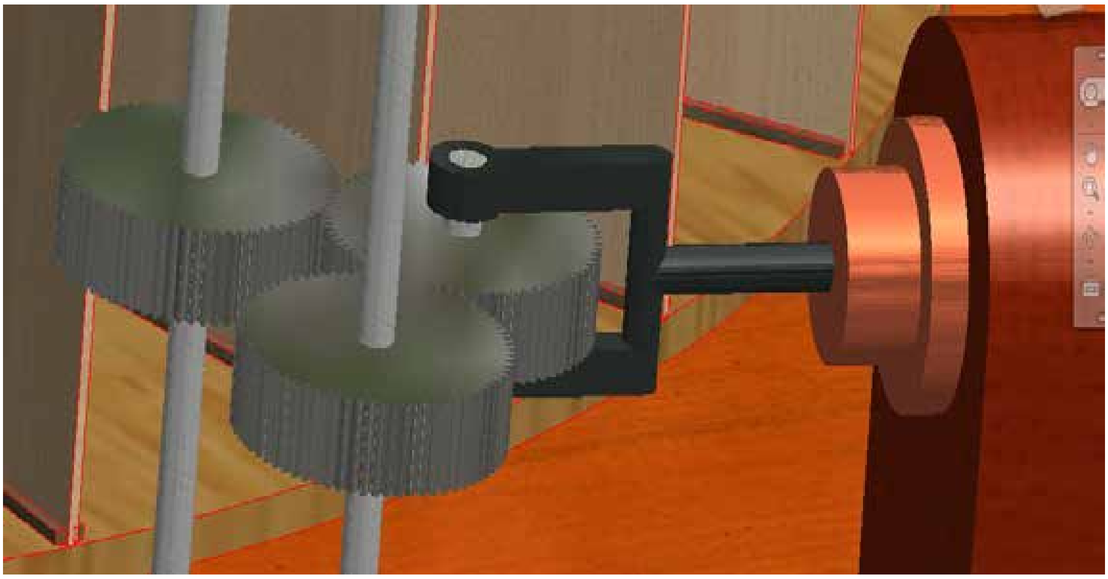


Fig 3.2 Spur gear

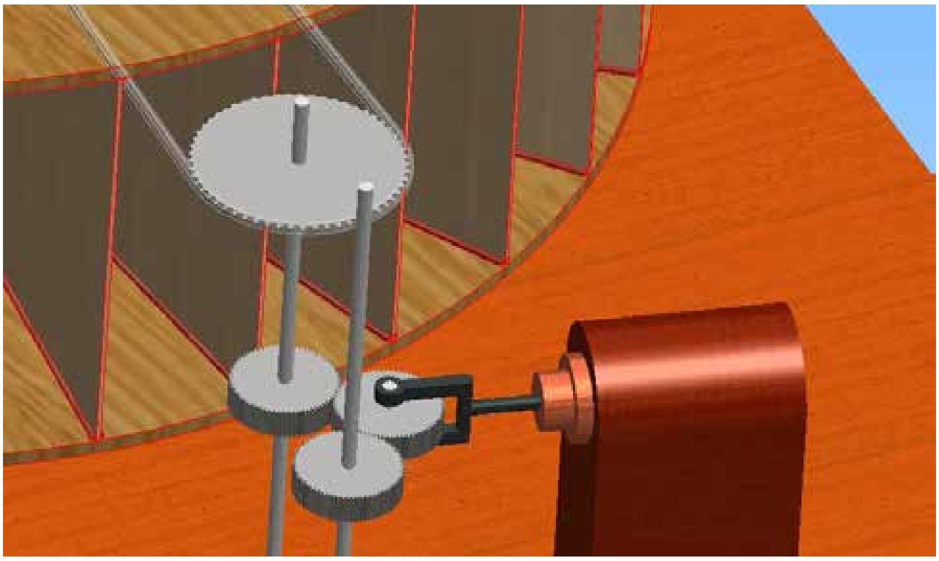


Fig 3.3 Solenoid valve

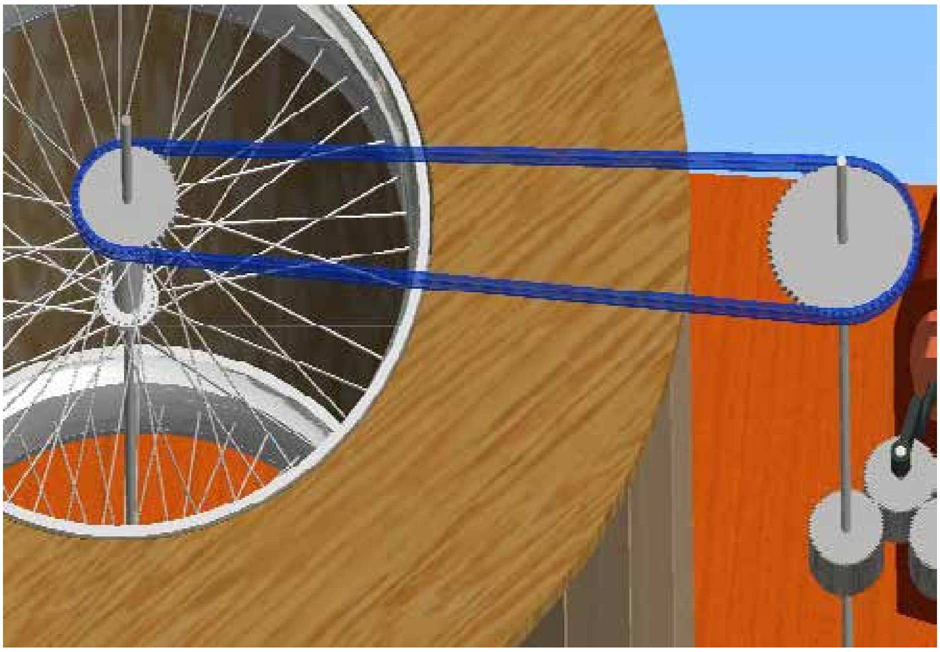


Fig 3.4 Chain drive

3.4 Assembly Modelling:

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

Ø Step 1: Crating new assembly file with extension “.iam”.

Ø Step2: Import the base part first and ground it.

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

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

Ø Step5: Saving the file with desired file name.

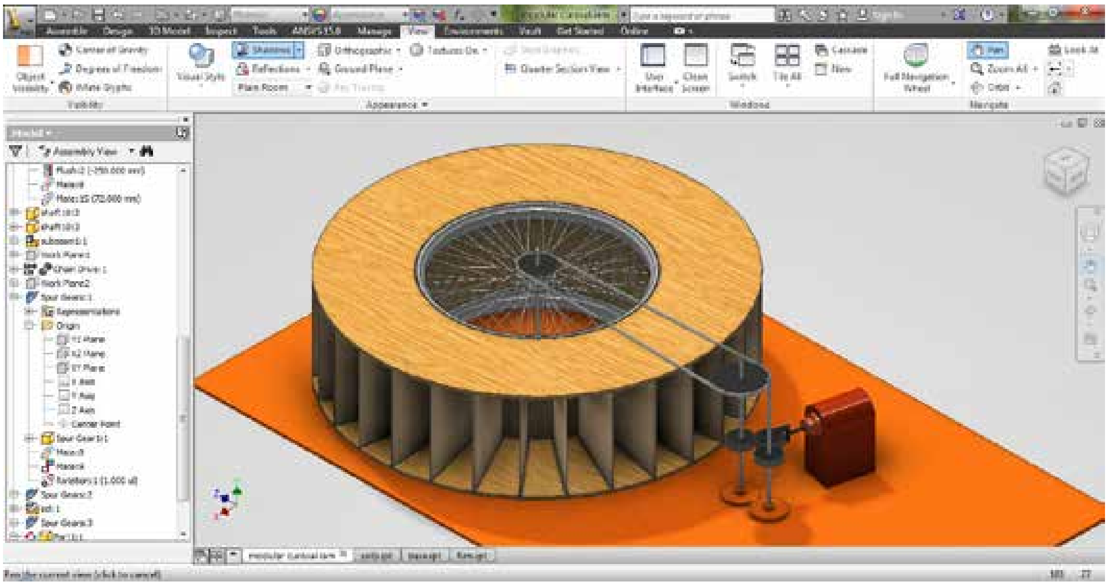


Fig 3.5 Mechanism Assembly

The mechanism assembly is as shown in figure 3.5 and complete assembly of the modular horizontal carousel system is as shown in figure 3.6

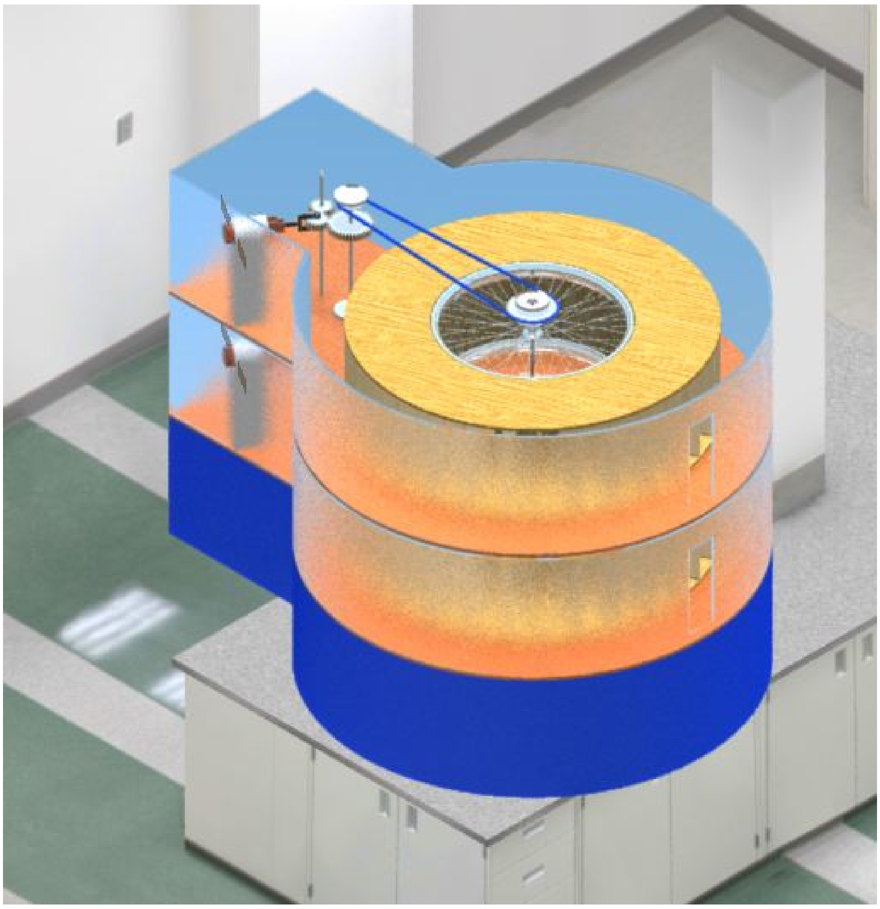


Fig 3.6 Modular Horizontal carousel system

The part and assembly drawings are shown in drawings 3.1 to 3.6. Same part models are further used for 3D printing.

3.5 Motion Simulation:

A more cost-effective alternative is to leverage the digital prototype by using Autodesk Inventor simulation suite software. This software enables designers to automatically convert assembly constraints to mechanical joints to apply external forces including gravity and to measure the effects of contact friction, damping and inertia. From this information the software calculates the reaction forces, velocity, acceleration and much more reaction forces. Build optimized and competitive products.

Use collision detection when we drive constraints to identify incorrectly positioned components. Apply constraints to position the components as intended and then drive constraints to simulate the mechanical motion. If components collide, a message is displayed and the affected components are highlighted in the browser. Use drive constraint on the context menu to simulate the mechanical motion by driving a constraint through a sequence of steps. The drive constraint command is limited to one constraint, but we can drive additional constraints by using equations to create algebraic relationship between constraints.

Motion check is needed to ensure that the designed, assembled mechanism will able to function properly in real time. For motion simulation select the desired revolutionary constraint and drive to check the mechanism. Also identify the intersecting objects in the path by enabling collision detection. The model is successfully simulated and the model can be fabricated as per CAD design.The simulated assembly is as shown in the figure 3.7 below.

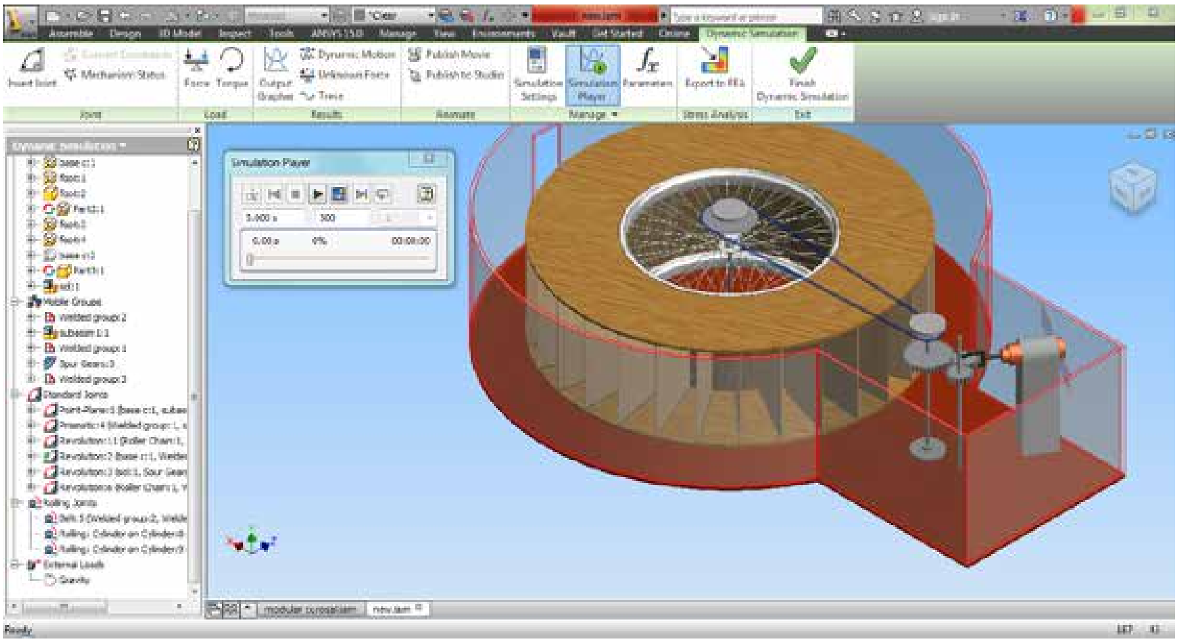
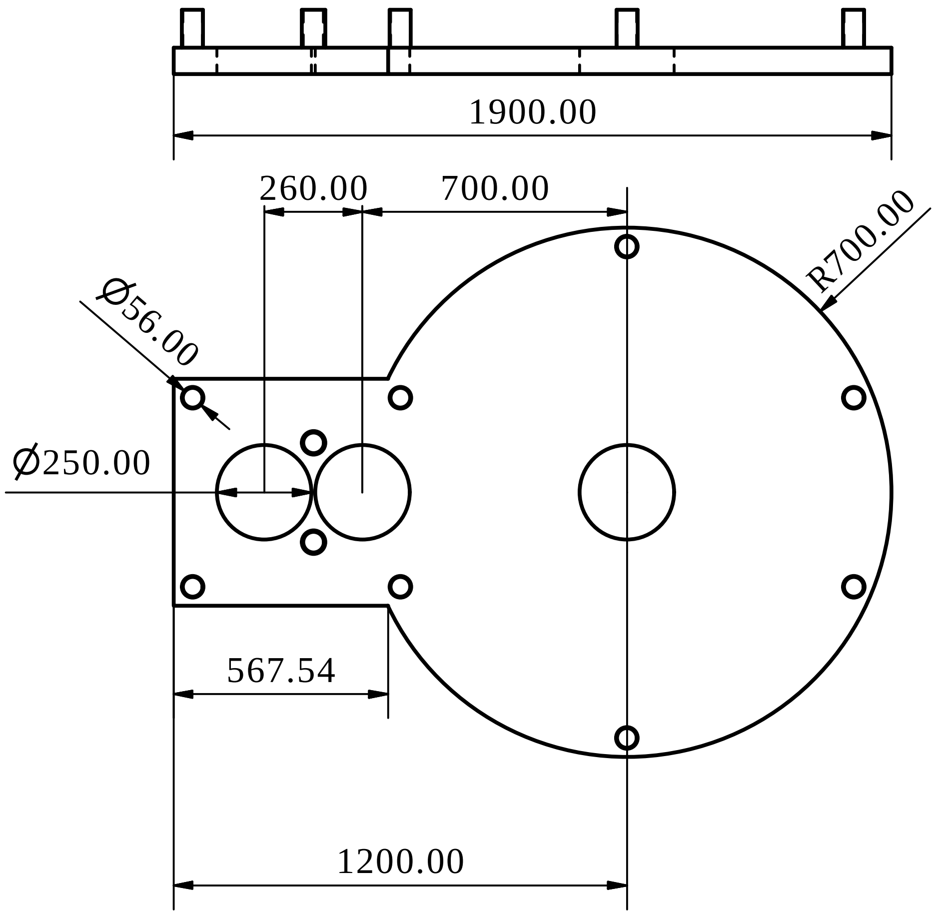


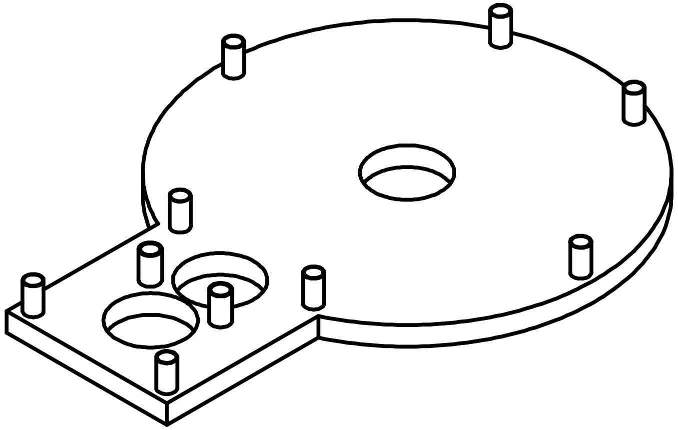
Fig 3.7 Simulation of mechanism

The simulated values are tabulated in table 3.1. the angular displacement of input and output shafts are studied through this analysis and also the mechanism is verified virtually.

Table 3.1 angular displacement input shaft vs output shaft

Time (s)	INPUT SHAFT (deg)	OUTPUT SHAFT (deg)
0.00000	0.00000	0.00000
0.20000	14.40000	3.70475
0.40000	28.80000	7.40950
0.60000	43.20000	11.11420
0.80000	57.60000	14.81890
1.00000	72.00000	18.52370
1.20000	86.40000	22.22840
1.40000	100.80000	25.93310
1.60000	115.20000	29.63830
1.80000	129.60000	33.34256
2.00000	144.00000	37.04730
2.20000	158.40000	40.75230
2.40000	172.80000	44.45630
2.60000	187.20000	48.16130
2.80000	201.60000	51.86630
3.00000	216.00000	55.57130
3.20000	230.40000	59.27565
3.40000	244.80000	62.98030
3.60000	259.20000	66.68530
3.80000	273.60000	70.39030
4.00000	288.00000	74.09430
4.20000	302.40000	77.79930
4.40000	316.80000	81.50430
4.60000	331.20000	85.20830
4.80000	345.60000	88.91330
5.00000	360.00000	92.61818





ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES

PART NAME:BASE AND TOP CAP OF HORIZONTAL CAROUSEL

PROJECT MEMBERS	
P.RAVI TEJA	(314126520129)
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K.SATHIPANDU	(314126520076)
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PROJECT GUIDE

J V BHANUTEJ
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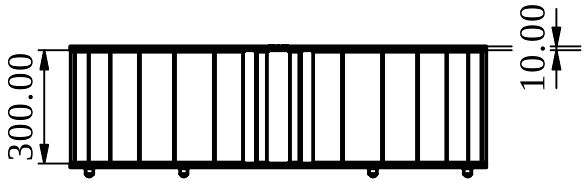
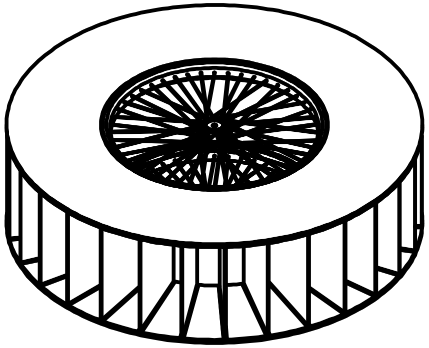
Engineering

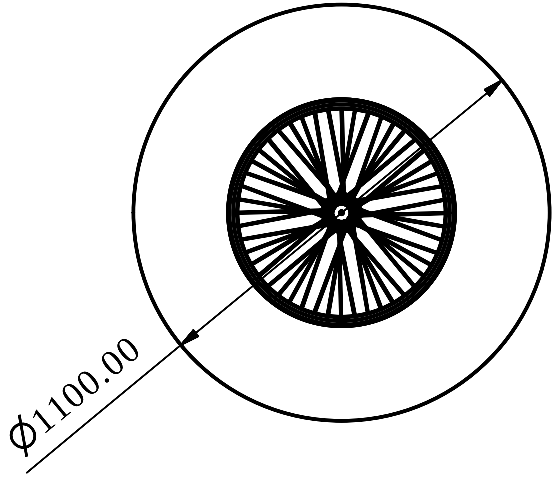
ALL
DIMENSIONS
ARE IN MM

DRAWING NO: 3.1

SCALE: 1:20







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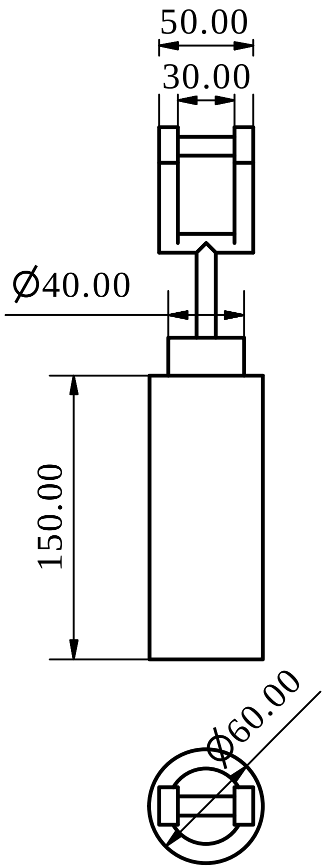
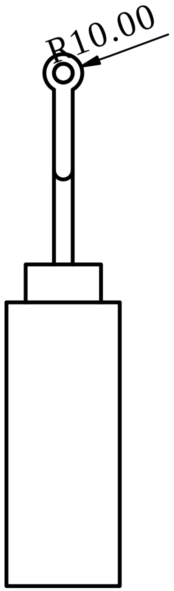
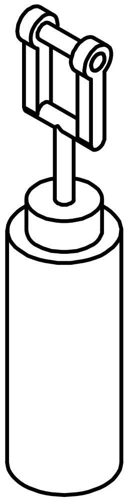
ALL
DIMENSIONS
ARE IN MM

DRAWING NO: 3.2

SCALE: 1:20







ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES

PART NAME:SOLENOID MECHANISM

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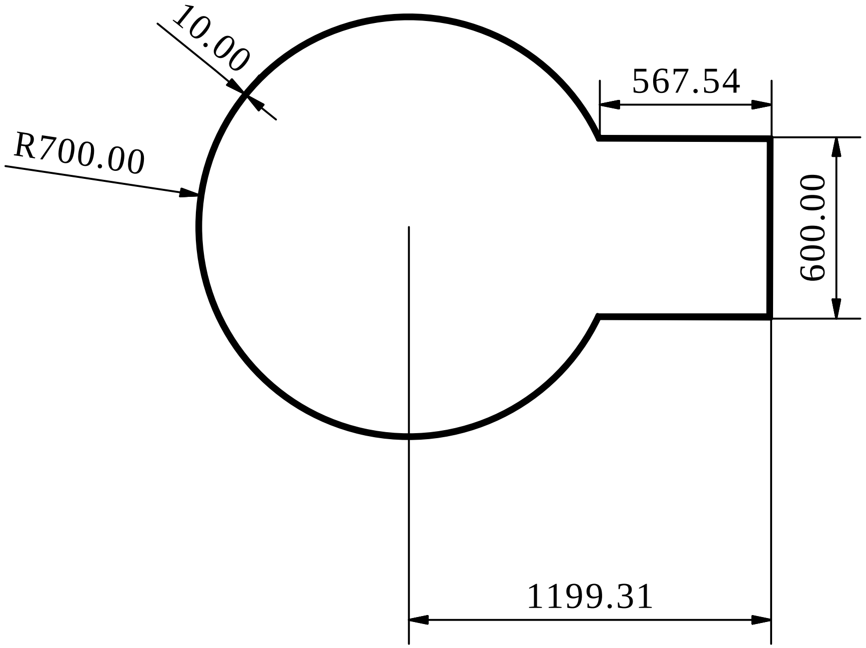
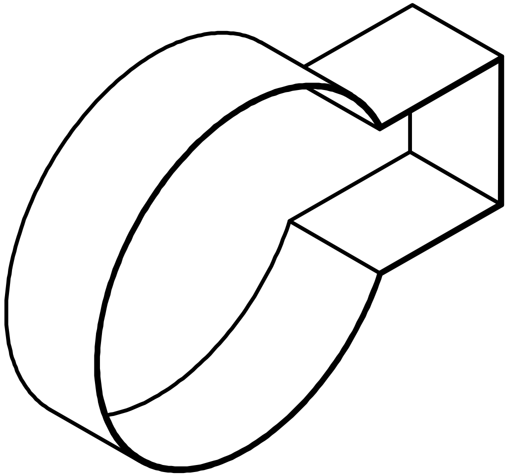
ALL DIMENSIONS ARE IN MM	DRAWING NO: 3.3 SCALE: 1:4





ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES

PART NAME:OUTER CASING OF CAROUSEL MODULE

PROJECT MEMBERS	PROJECT GUIDE
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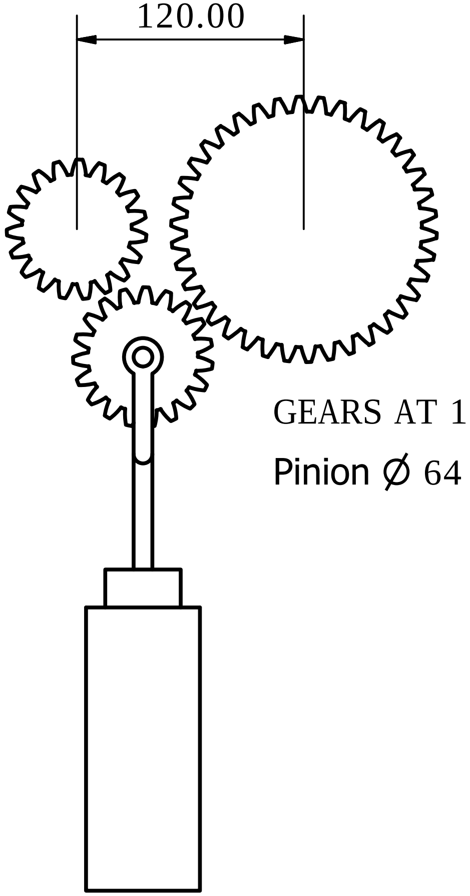
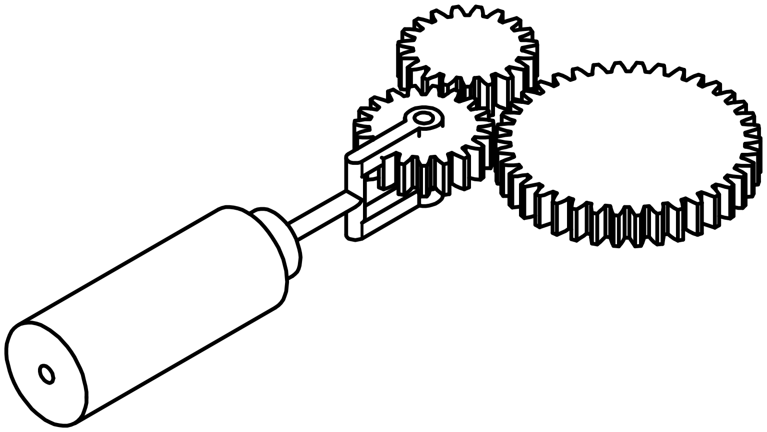
ALL DIMENSIONS ARE IN MM	DRAWING NO:3.4 SCALE: 1:25



GEARS AT 1:2

Pinion Ø 64



ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES

PART NAME: SOLENOID GEAR TRANSMISSION ASSEMBLY

PROJECT MEMBERS	PROJECT GUIDE
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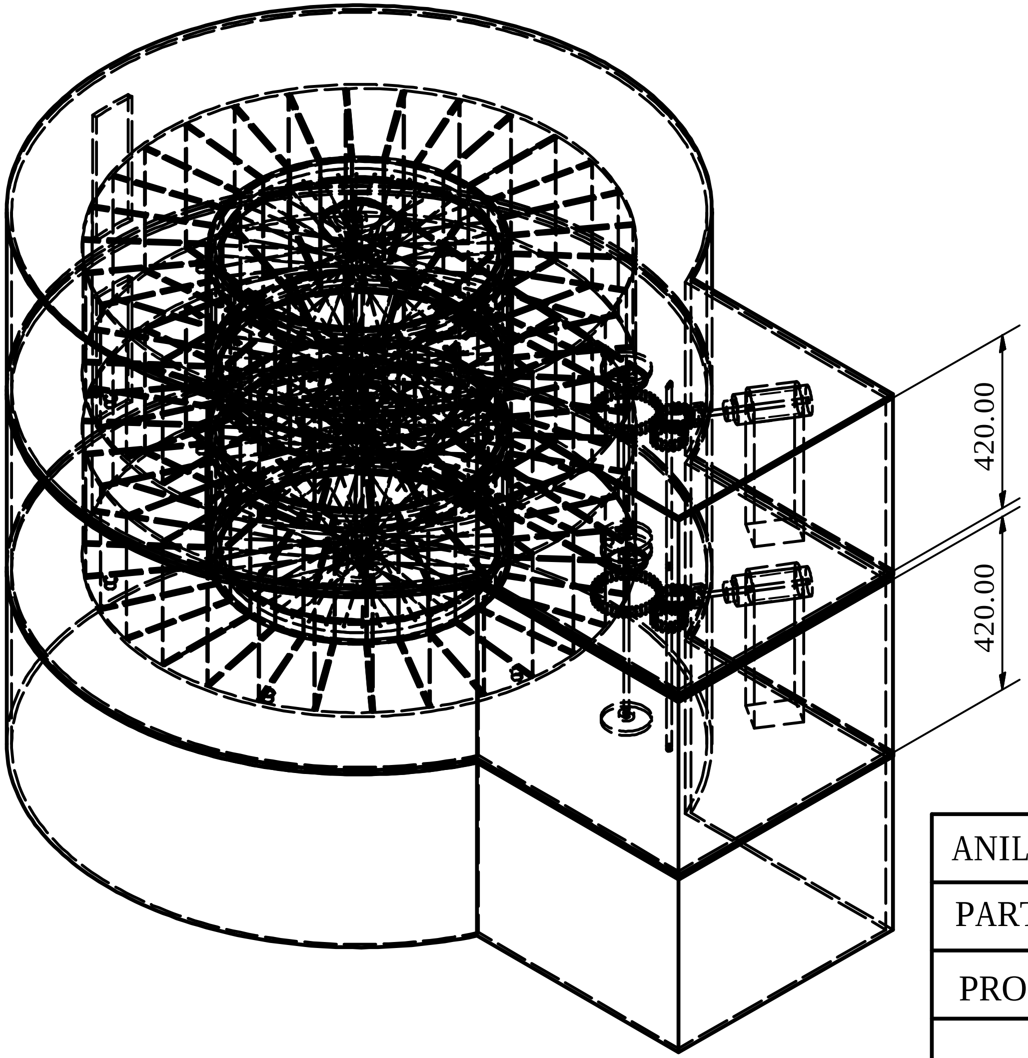
ALL DIMENSIONS ARE IN MM	DRAWING NO:3.5 SCALE: 1:4



ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES

PART NAME: MODULAR HORIZONTAL CAROUSEL ASSEMBLY

PROJECT MEMBERS	PROJECT GUIDE
P.RAVI TEJA (314126520129) P.PRATHYUSHA PANI (314126520114) R.V.H.MAHESWARI (314126520133) K.SATHIPANDU (314126520076) P.V.SARATH CHANDRA (314126520124)	J V BHANUTEJ Assistant Professor Dept of Mechanical Engineering
ALL DIMENSIONS ARE IN MM	DRAWING NO: 3.6 SCALE: 1:15

CHAPTER - IV

FABRICATION OF PROTOTYPE

CHAPTER – IV

FABRICATION OF PROTOTYPE

The carousal parts are converted into STL files for rapid prototyping. There are many rapid prototyping methods available in the market. The cost effective one is the fused filament fabrication (FFF). The machine used for the fabrication is Flash Forge Dreamer Dual Extruder.

4.1 FUSED FILAMENT FABRICATION:

Ø FFF (fused filament fabrication) is an additive manufacturing technology. A fused filament fabrication tool deposits a filament of a material (such as plastic, wax, or metal) on top or alongside the same material, making a joint (by heat or adhesion).

Ø The rapid prototype machine used here is the Flash Forge Dreamer Dual Extruder. Any FFF based RP machine contains these common parts, materials and terms as below.

4.2 FLASH FORGE DREAMER DUAL EXTRUDER DETAILS:

Ø **Extruder:** The extruder on a FDM printer is the part that extrudes the plastic filament in a liquid form and deposits it on a printing platform by adding successive layers. The printing head is made of many distinct parts including a motor to drive the plastic filament and a nozzle (or extruder) to extrude the plastic. To regulate the plastic cooling process, some printers are enclosed. This helps maintain a uniform temperature in the manufacturing chamber, ensuring greater consistency in the print result.

Ø **Nozzle:** The actual hole where melted FFF material is extruded is the nozzle. Typical nozzle sizes are in the 0.5mm to 0.25 mm range, although larger nozzles are sometimes used to fill in (infill) the interior of a model more quickly, and smaller nozzles are sometimes used for more detail. The smaller your nozzle, the more pressure is needed to extrude the material, the slower your print speed will be, and the more likely it is to get plugged.

- **Thermocouple**: A temperature sensor typically used on both the hot end (nozzle) of the printer and a heated print bed so that the electronics can maintain a consistent temperature.

- **Stepper/Step motor:** The Stepper or Step Motor, is a very precise motor that moves the Extruder along its coordinates.

- **Print bed/Printer bed**: The Print Bed is where your Finished Project/Product will end up. Normally the size of a 3D Printer's Print Bed and the maximum range of motion for the length (Y Axis), width (X Axis), and height (Z Axis) of the Printer is a pretty good indication to the size of the largest object you can print with that Printer at one time. The size of the Print Bed is commonly referred to as the Print Volume. The Print Bed moves up and down along the Z Axis to adjust to the height of the object being printed while the Extruder moves along the X and Y Axis's.

- **Guide way/Guide rods:** The Guide way is the track/rod that allows the Extruder of your 3D Printer to move along its axes. The vertical/Z Axis rod is usually indistinguishable from/part of the Frame.

- **LCD Screen:** An LCD Screen is/can be added to many 3D Printers which allows your Printer to provide you information, such as the current Extruder temperature, without the use/need of a computer.

- **Fused Deposition Modelling (FDM):** A trademarked term used by the Stratasyscorporation, equivalent to FFF which describes the process of manufacturing an object by melting a filament of material and laying down molten material which immediately solidifies (fusing to previous layers) under programmatic control. Objects are built up layer by layer.

- **Slicer:** Slicer is the tool you need to convert a 3D model into printing instructions for your 3D printer. It cuts the model into horizontal slices (layers), generates tool paths to fill them and calculates the amount of material to be extruded.

- **Perimeter:** Perimeter defines the minimum number of vertical shells (i.e. walls) a print will have. Unless the model requires single width walls it is generally recommended to have a minimum of two perimeters as this gives some insurance that if a section of the perimeter is not printed correctly then the second perimeter will help cover it.

- **Infill:** Fill density is defined on a scale of between 0 and 1, where 1 is 100% and 0.4 would be 40%. For the majority of cases it makes no sense to 100% fill the model with plastic, this would be a waste of material and take a long time. Instead, most models can be filled with less material which is then sandwiched between layers filled at 100%.

- **Support:** Because printed objects are built one layer at a time, having an overhung is problematic, as plastic would need to be printed unsupported in open air. Support material is material that is not part of the finished object, but it is printed under “overhangs” so that the plastic for the object being printed will have something to rest upon. Dual extruder or sometimes multi extruder printers can use a different (presumable, easier to remove or dissolvable) material in separate extruder.

- **Skirt:** Extra material printed around the base of an object, typically to prime the extruder and test the levelling and distance to the print bed. If the skirt is not adhering to the print bed properly, the print can be aborted and the Z-axis height or print bed heater can be adjusted. In advance operations, skirts can also be made more than one layer thick, which can be useful to shield an object from drafts while it is being printed.

- **Brim:** Extra material printed touching the base of an object on the first layer to increase the surface area of the bottom layer, to promote adhesion to the print bed. Typically used for small objects or tall objects. After the printing is completed the brim is filed.

- **Raft:** A bed of printed material that is several layers thick is printed on the print bed under the object. The raft can act like a brim (increasing the surface area of the object to the print bed) as well as compensating for minor levelling problems of the print bed, but must be removed from the object after printing.

4.3 MATERIALS FOR RP:

PLA– Polylactic acid polymer is biodegradable and bioactive thermoplastic aliphatic polyester which is derived from processing renewable resources i.e any number of plant products including corn, potatoes or sugar-beets etc. PLA is considered a more 'earth friendly' plastic compared to petroleum based ABS. Used primarily in food packaging and containers, PLA can be composted at commercial compost facilities. It won't bio-degrade in your backyard or home compost pile however. It is naturally transparent and can be coloured to various degrees of translucency and opacity. Also strong, and more rigid than ABS, it is occasionally more difficult to work with in complicated interlocking assemblies and pin-joints. Printed objects will generally have a glossier look and feel than ABS. With a little more work, PLA can also be sanded and machined. The lower melting temperature of PLA makes it unsuitable for many applications as even parts spending the day in a hot car can droop and deform.

4.4 FLASH FORGE DREAMER- SLICING AND SETUP FOR 3D PRINT IN FLASH PRINT:

The supported slicer for the flash forge dreamer is the Flash print desktop application. The setup of 3D printer is shown below. In this the required setups for 3D printing is done through the following steps:

Step1: Importing the STL file.

Step2: Keeping the model in the correct orientation on the virtual platform.

Step3: Scaling the model to required size.

Step4: Developing the support structures- manually or automatically.

Step5: Assigning the left extruder to parts and right extruder to support material.

Step6: Setting up print parameters like materials, temperatures, infill, layer heights, initial layer thickness etc.

Step7: The print ready file which has the g-code for 3D printing is given as the input to 3D printer to get the rapid prototype. The sliced view of the object can be seen in the Flash print software application.

The same process is continued for all the 3D modelled individual parts of the centrifugal pump and is printed and the observations of the time estimation, number of layers etc. are observed and tabulated. The Fig 4.1shows the environment of the flash print software in order to give the print preferences such as the infill capacity, model orientation, number of perimeter layers, nozzle temperatures, print speed type of printing (low, medium, hyper) etc..

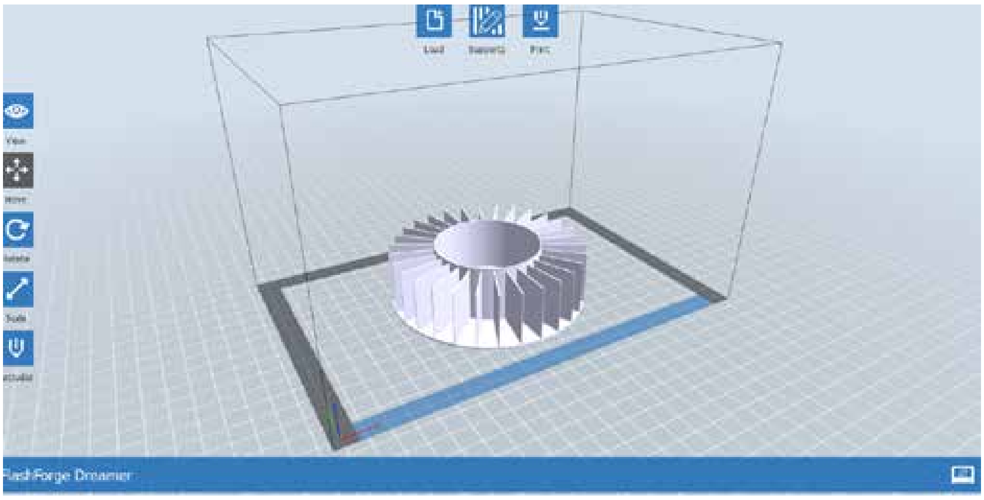


Fig 4.1 Environment of Flash print software application

The position in which the element to be printed can be adjusted in this environment just by altering the rotate option. Similarly, the scale option is used for enlarging of reducing the size of the component. Move option is used to alter translation position of the object to be printed. Extruder option is to select from which extruder the printing process has to be done. Cut option is used in general when large intricate shapes are to be printed. The entire object is cut into pieces and is printed. Supports option is to give the supports when layer of the object is to be printed without any support designed. These temporary supports can be removed easily. When all the options are set, the print option is selected. Then a G-code is saved which is the input to the 3D printer.

The Figures from below shows the individual components of sliced 3D models in the flash print software.

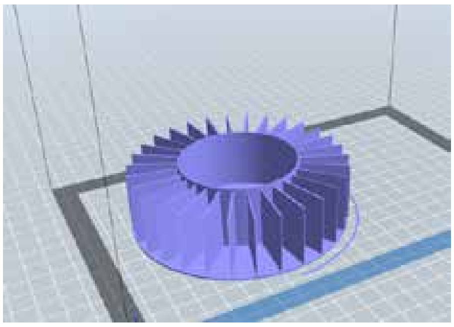


Fig 4.2 Sliced book rack

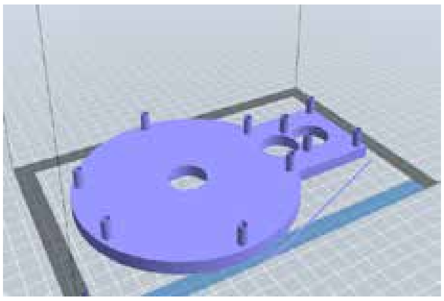
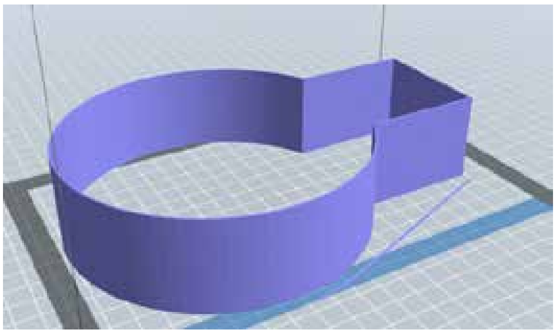


Fig 4.3 Sliced base plate



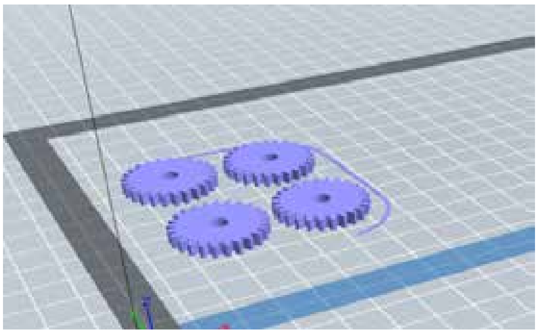
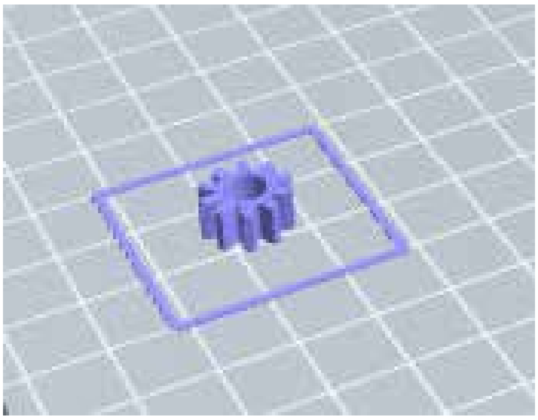


Fig 4.4 Sliced boundary

Fig 4.5 Sliced Gears



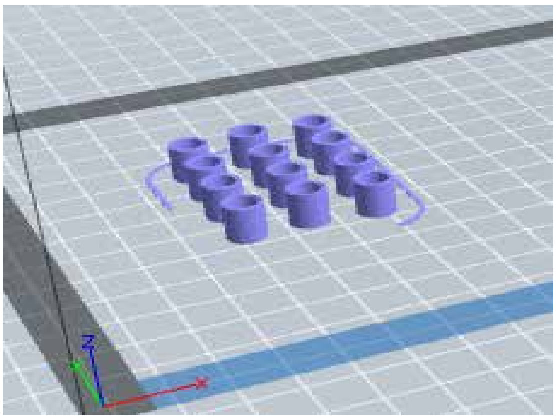
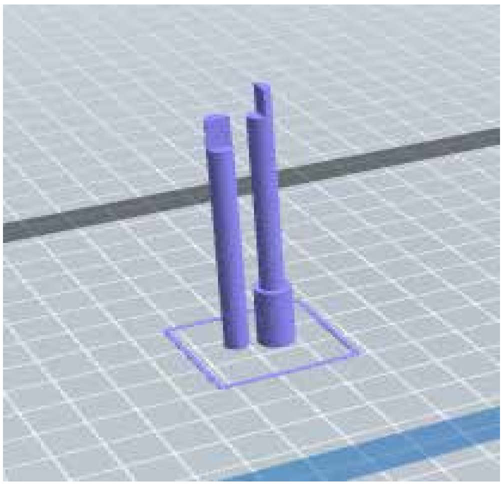


Fig 4.6 **Sliced pinion gear**

Fig 4.7 Sliced holders



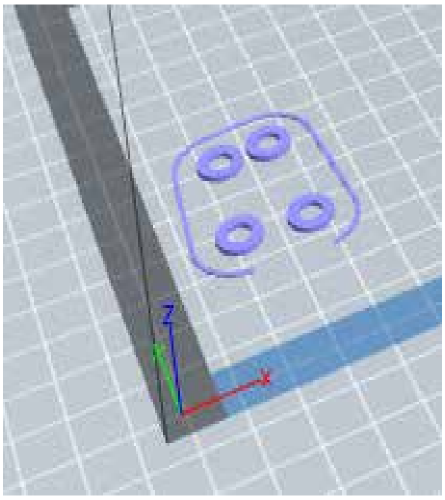


Fig 4.8 Sliced motor shafts

Fig 4.9 Sliced rings

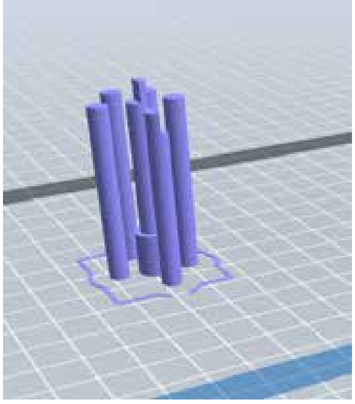


Fig 4.10 Sliced shafts

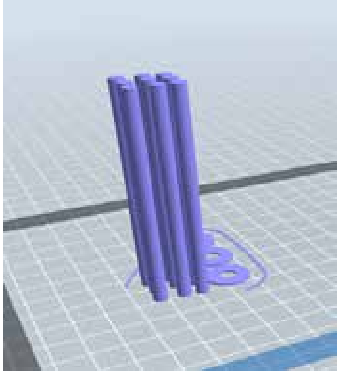


Fig 4.11 Sliced supports

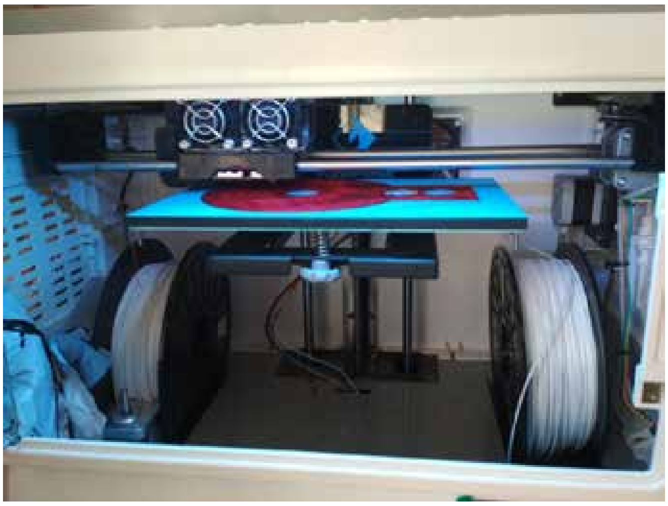


Fig 4.12 3D Printer Setup

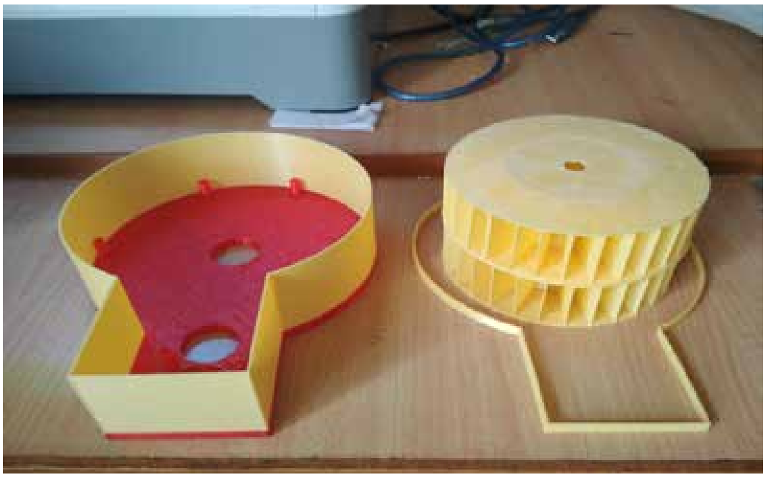


Fig 4.13 3D Printed Parts

Fig 4.14 Sub-assembly of 3D printed parts

Table 4.1 Details of print time and material used for 3D printing

S.No	PART NAME	PRINTING TIME per file in minutes	MATERIAL USED per file in meters	No of times printed	TOTAL PRINTING TIME in minutes	TOTAL MATERIAL USED in meters
1	Book rack	92	9.71	2	184	19.42
2	Base plate	94	14.5	5	470	72.5
3	Boundary	53	8.36	3	159	25.08
4	Gears	27	2.67	1	27	2.67
5	Pinion Gear	2	0.13	1	2	0.13
6	Holders	9	0.97	1	9	0.97
7	Motor shafts	13	0.83	1	13	0.83
8	Rings	1	0.12	12	12	1.44
9	Shafts	34	2.39	2	68	4.78
10	Supports	61	3.97	2	122	7.94
				Total	1066	135.76

The print time and material consumed for various parts 3D printing are tabulated in table 4.1

CHAPTER - V

RESULTS AND DISCUSSION

CHAPTER – V

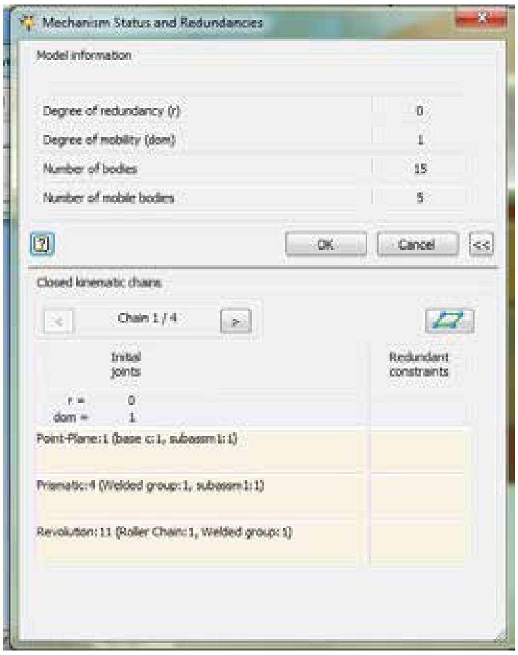
RESULTS AND DISCUSSIONS

5.1 Simulation Results

The horizontal carousel system parts were first modeled in the Autodesk Inventor software. Proper constraints were used while assembling the model, the simulation of the individual module of assembly is carried out to check the mechanism status. The mechanism was successfully simulated and the following results were obtained

Table 5.1 Mechanism status and Redundancies

S.No		
1.	Degree of redundancy	0
2.	Degree of mobility	1
3.	Number of bodes	15
4.	Number of mobile bodies	5



Model information	
Degree of redundancy (r)	0
Degree of mobility (dom)	1
Number of bodies	15
Number of mobile bodies	5

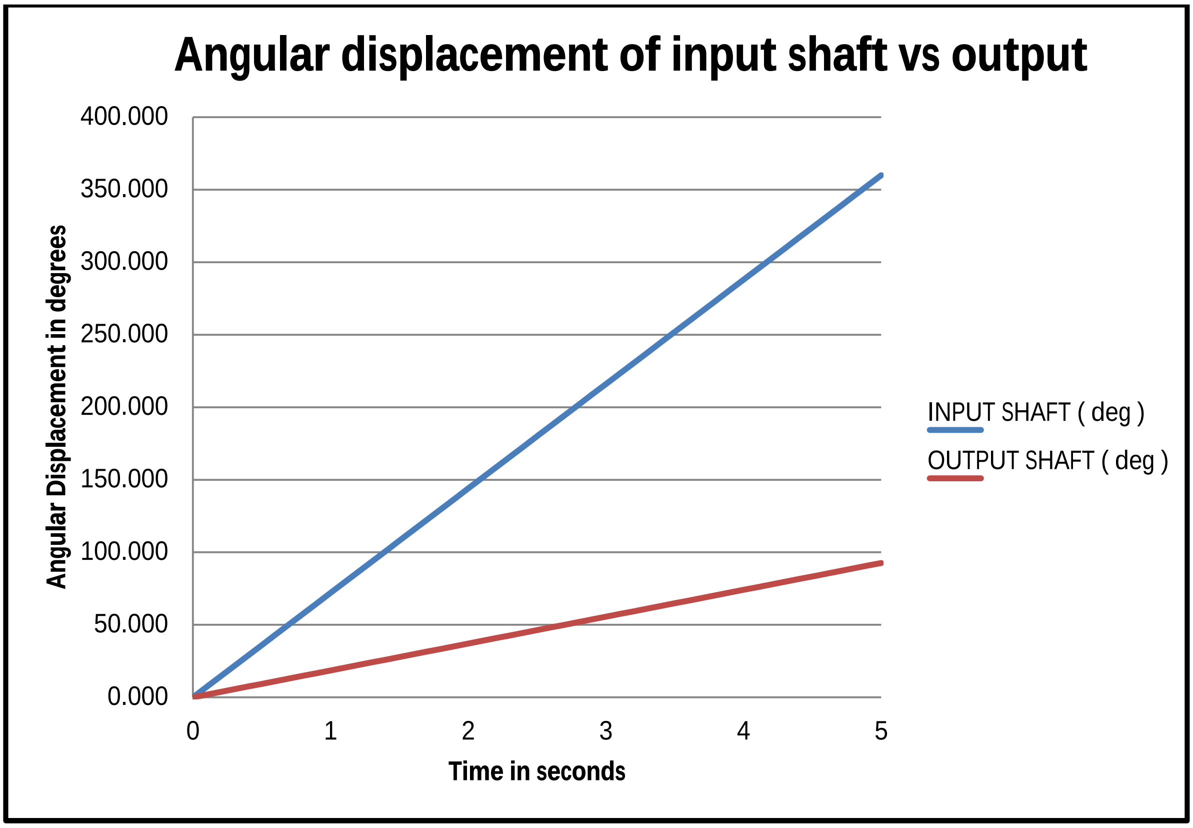
r = 0
dom = 1

Point-Plane: 1 (base c:1, subassm 1:1)

Prismatic: 4 (Welded group: 1, subassm 1:1)

Revolution: 11 (Roller Chain: 1, Welded group: 1)

Fig 5.1 Mechanism status and Redundancies



Graph 5.1 Angular displacements of input shaft vs output shaft with respect to time

The angular displacements of input and output shafts are measured from the simulation. The graph 5.1 shows the relation between the input and output motions. The output shaft speed is reduced 4 times as designed in the mechanism to reduce the torque load on the motor.

5.2 Comparison of build time and material consumption for fabricated parts.

The observations taken from the 3D printing are shown in terms of pie charts individually for both time take for 3D printing and also the material used for fabrication.

The pie chart 5.1 represents the percentage of fabrication time for each part. Total time for the fabrication is 1066 minutes.

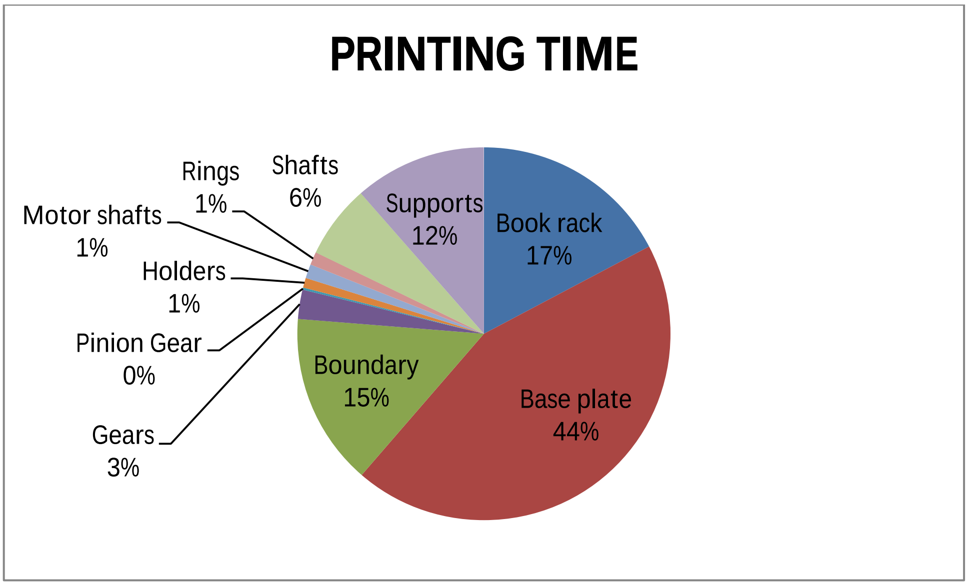


Chart 5.1 Time taken by each part for fabrication

The material used for the fabrication process is also observed and pie chart is plotted for the percentage of material used by each part in the pie chart 5.2. Total material used for the complete fabrication of the centrifugal pump is of length 135.76 meters and diameter of 1.75mm filament.

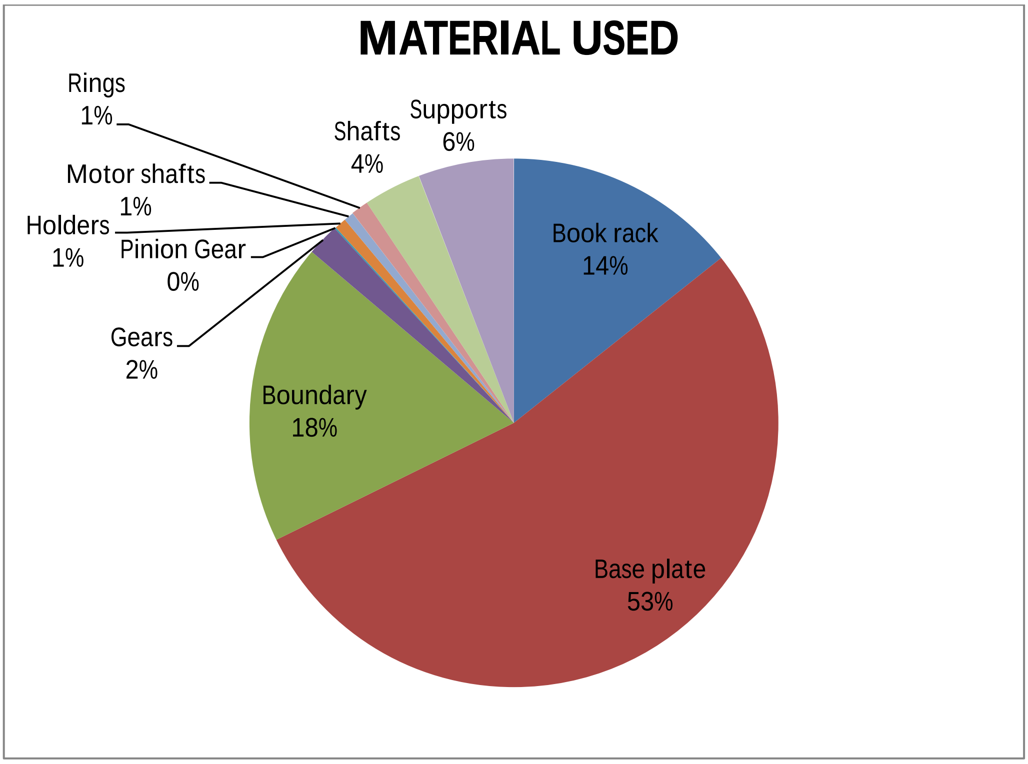


Chart 5.2 Material used for the fabrication of individual parts

5.3 Mechanism testing of the horizontal carousel system prototype

All fabricated parts are post processed and assembled part by part. Slight modifications were done in the gear train and other part for manufacturing feasibility. Solenoid gear was not employed in the gear train which is simulated virtually in simulation. First the mechanism was tested with single module of horizontal carousel and it is observed that the mechanism is functioning quite well, even the slight modifications from the simulated model.

Then the modular design was tested by assembling second module on the top of the first one as shown in figure 5.2. It was observed that modularity of horizontal carousel system is possible.

Fig 5.2 Final assembly of prototype

CHAPTER - VI

CONCLUSION

CHAPTER-VI

CONCLUSION

6.1 Conclusion:

Horizontal Carousel Systems are ideal for high speed automated picking, parts delivery and sortation applications. The main problem with this system is that the entire bins have to rotate to bring the required bin to delivery station thus increasing the power usage and torque requirement of the motor. Also the other limitation like fixed installation of the system and expansion of carousel as per the need, limits its usage for various storage applications. An attempt is made in this project to design a horizontal carousel system to overcome these limitations. The library book storage system is selected as application of horizontal carousel storage system to design. A rapid Prototyping technique is used for Prototyping the model. Further, the scope of this work also includes simulating the designed model virtually and also tests the working of prototype model to check their mechanism and functionality. The following conclusions were made after prototyping and simulations

i. It has been observed from the prototype that the mechanism works similar to the simulation.
ii. It was observed that modularity of the horizontal carousel is possible.
iii. The power usage and torque requirement of motor can be reduced, as it is observed from the simulation that individual modules can be rotated separately by engaging or disengaging the gear from the gear train using solenoid.
iv. Modular racks are used, which can be easily placed and removed depending on the need, thus overcoming the limitation of fixed system.

6.2 Future Scope:

i. Actual model could be built after designing key elements like gear trains and chain drive.
ii. Finite element analysis could be done to analyze various stress acting on the structure and other parts
iii. Stepper motor could be programed to various conditions to automate this mechanism for real time application
iv. The supporting software could be developed for optimal rack movement for books selection.

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CERTIFICATE

This is to certify that the Project Report entitle **“MODELLING, SIMULATION AND RAPID PROTOTYPING OF MODULAR HORIZONTAL CAROUSEL STORAGE SYSTEMS”** has been carried out by *P.V.SARAT CHANDRA(314126520124)* under the esteemed guidance of Sri **J.V.BHANU TEJ**, in partial fulfilment of the requirements for the award of the Degree of Bachelor of Mechanical Engineering by Andhra University, Visakhapatnam.

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