UNIVERSITY OF GAZİANTEP
GRADUATE SCHOOL OF
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DESIGN AND ANALYSIS OF A PLACING (INSERTING) MECHANISM FOR POLYPROPYLENE (PP) AND POLYETHLENE (PE) SACKS

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IN
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Gökhan BAKIR
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Design and Analysis of a Placing (Inserting) Mechanism for Polypropylene (PP) and Polyethylene (PE) Sacks

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Supervisor
Prof. Dr. Lale Canan DÜLGER

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T. C.
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ABSTRACT

DESIGN AND ANALYSIS OF
A PLACING (INSERTING) MECHANISM
FOR POLYPROPYLENE (PP) AND POLYETHYLENE (PE) SACKS

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M. Sc. in Mechanical Eng.
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PE and PP sacks are used to store various items in industry. PE and PP sacks are separately produced and inserted together to form a strong sack for storing artificial fertilizers. The manual procedure for inserting PE and PP sacks is studied. There is no automatic system for the sack inserting procedure at the moment. Many operators can perform the inserting procedure one by one independently on different storing platforms.

Two inserting mechanism alternatives are proposed in this study. Initially the requirements during the insertion are revealed. Two alternative systems are designed and one of them is chosen to be used. Control of inserting mechanism, actuation and synchronization characteristics are studied by looking at trajectories available. Kinematics' analyses of intermittent motion mechanisms are performed. The proposed mechanism is presented with its construction details and the mathematics are available. Automization on the inserting mechanism is performed in the proposed design with necessary synchronization. When the studies on the design of the inserting mechanism are completed, this system will be faster and the number of sacks inserted will be increased together with making the system more intelligent.

Key Words: Polypropylene (PP) sack, Polyethylene (PE) sack, control of placing (inserting) mechanism, conceptual design, kinematics of inserting mechanisms.

ÖZET

POLİPROPİLEN (PP) VE POLİETİLEN (PE) TORBALARIN GEÇİRİLMESİNDE KULLANILABİLECEK BİR MEKANİZMA TASARIMI VE ANALİZİ

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PE ve PP torbalar endüstride birçok malzemenin saklanmasında kullanılmaktadır. Çalışmada anlatılan PE ve PP torbalar birbirinden farklı olarak ayrı hatlarda üretilmekte, daha sonra iç içe geçirilerek yapay gübre saklanmasında kullanılmaktadır. Torbaların iç içe geçirilmesi işçiler tarafından, manüel olarak yapılmaktadır. Aynı anda farklı iş platformlarında çalışan işçiler torbaları iç içe geçirmektedir. Bu işlem için halen mevcut otomatik bir sistem yoktur.

Sunulan çalışmada torbaların otomatik olarak geçirilmesi irdelenmiş, iki geçirme mekanizması alternatifi önerilmiştir. Öncelikle dolum öncesi torbaların iç içe geçirilme prosedürü incelenmiş, manüel sistemden gerçek ölçümler alınarak tasarım ölçütleri belirlenmiş, buna uygun bir tasarım yapılmıştır. Önerilen tasarımda bir seri ölçüt göz önüne alınmış, önerilen modellerden birisi detaylandırılmıştır. Tasarlanan geçirme mekanizmasının denetimi, sürüm ve eş zamanlı karakteristikleri ve geçirme işleminde gereken yörünge biçimleri çalışılmıştır. Burada oluşan kesikli hareket kinematiği çıkarılmış, imalat detaylarıyla sonuçta düşünülen mekanizma ve içerilen matematik sunulmuştur. Böylece sistem üzerinde devam eden çalışmalar tamamlandığında; geçirme mekanizması otomatik hale getirilebilecek, birim zamanda geçirilen torba sayısı artacak ve sistem daha hızlı çalışacaktır.

Anahtar Kelimeler: Polipropilen (PP) torba, Polietilen (PE) torba, Geçirme mekanizmasının denetimi, kavram tasarım, Geçirme mekanizmasının kinematiği.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Today's plastics are one of the most used materials on a volume basis not only in the World but also in Turkey's industrial and commercial life. Plastics are broadly integrated into today's lifestyle and make a major, irreplaceable contribution to virtually all product areas. The roots of modern development go back not only to the research of cellulose nitrate by John Wesley Hyatt in the 1860's, but also to the plastic-like compositions used by man through the centuries.

One can go as far back as the Old Testament to find references about natural materials used as fillers, adhesives, coatings, and the like. These materials were the precursors of modern plastic materials. Historians continue to differ as to the exact year or decade that the plastics industry began because the definition of "plastic" is a matter of interpretation [1].

Plastic is the general common term for a wide range of synthetic or semisynthetic organic amorphous solid materials used in the manufacture of industrial products [2]. Plastics are typically polymers of high molecular mass, and may contain other substances to improve performance and/or reduce costs.

The word is derived from the Greek words, "plastikos", which means fit for molding, and "plastos", meaning molded [3, 4]. It refers to their malleability, or plasticity during manufacture, that allows them to be cast, pressed, or extruded into a variety of shapes such as films, fibers, plates, tubes, bottles, boxes, and much more.

The common word plastic should not be confused with the technical adjective plastic, which is applied to any material which undergoes a permanent change of shape (plastic deformation) when strained beyond a certain point. Aluminium, for instance, is plastic in this sense, but not a plastic in the common sense; in contrast, in their finished forms, some plastics will break before deforming and therefore are not plastic in the technical sense. There are two types of plastics: *thermoplastics* and *thermosetting polymers* [5].

A *thermoplastic*, also known as thermosoftening plastic, is a *polymer* that turns to a liquid when heated and freezes to a very glassy state when cooled sufficiently [6]. Most thermoplastics are high-molecular-weight polymers whose chains associate through weak Van der Waals forces (polyethylene); stronger dipole-dipole interactions and hydrogen bonding (nylon); or even stacking of aromatic rings (polystyrene). Thermoplastic polymers differ from thermosetting polymers (Bakelite) as they can, unlike thermosetting polymers, be remelted and remoulded. Many thermoplastic materials are addition polymers; e.g., vinyl chain-growth polymers such as polyethylene and polypropylene [7].

Thermoplastics soften when heated. This is because their molecules are separate from each other and can move about easily at higher temperatures. Their structure can be linear or branched, and the polymer molecules can be of different sizes. But in all cases, they can be melted and reshaped an indefinite number of times. Some examples of thermoplastics are: Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), Polyvinyl chloride (PVC), Acrylonitrile-butadiene-styrene (ABS), Polycarbonate(PC), Polyethylene terephthalate (PET), Poly(methyl methacrylate) (PMMA) and Expanded Polystyrene (EPS)

A thermosetting plastic, also known as a thermoset, is polymer material that irreversibly cures. The cure may be done through heat (generally above 200 °C (392 °F), through a chemical reaction (two-part epoxy, for example), or irradiation such as electron beam processing. Thermoset materials are usually liquid or malleable prior to curing and designed to be molded into their final form, or used as adhesives. Others are solids like that of the molding compound used in semiconductors and integrated circuits (IC's).

According to IUPAC recommendations: a thermosetting polymer is a prepolymer in a soft solid or viscous state that changes irreversibly into an infusible, insoluble polymer network by curing. Curing can be induced by the action of heat or suitable radiation, or both. A cured thermosetting polymer is called a thermoset. Thermoset materials are generally stronger than thermoplastic materials due to this 3-D network of bonds, and are also better suited to high-temperature applications up to the decomposition temperature [8].

When thermosetting polymers are first moulded, additional chemical bonds are created between the molecules to produce a three dimensional, tightly woven network. Because of these additional chemical bonds, thermosets cannot be re-melted and changed in shape. Some examples of thermosets are Bakelite, Duroplast, Melamine resin, Polyimides, Epoxide (EP), Phenol-formaldehyde (PF), Polyurethane (PUR), Polytetrafluoroethylene (PTFE), Unsaturated polyester resins (UP)

1.2. Definitions of Resins

(i) Polypropylene (PP)

Polypropylene is one of the high-volume “commodity” thermoplastics. Polypropylene was developed out of the Nobel award-winning work of Karl Ziegler and Professor Natta in Europe, and came to the United States in 1957. It belongs to the “olefins” family, which also includes the polyethylenes, but it is quite different in its properties. It has a low density (0,91 $kg/dm^{3)}$, is fairly rigid, has a heat distortion temperature of 150 to 200 ˚F (suitable for “hot-fill” packaging applications), and excellent chemical resistance and electrical properties. Major applications of commercial PP are packaging, automotive, appliances and carpeting. PP is made by polymerizing propylene [CH_3CHCH_2] and in the case of copolymers with monomers, with suitable catalysts, generally aluminum alkyl and titanium tetrachloride mixed with solvents [1].

(ii) Polyethylene (PE):

This plastic came in use during World War II. From that point on, its rise in popularity for both consumer and industrial uses was so spectacular that polyethylene became the first plastic in the U.S. to sell more than 1 billion pounds a year. Today, it is still the largest volume plastic in the United States. Applications for PEs are many and varied, including: packaging films; trash, garment, grocery and shopping bags; molded housewares; toys; containers; pipe; drums; gasoline tanks; coatings and many others. PEs are thermoplastic resins obtained by polymerizing the gas ethylene [C_2H_4]. Low molecular weight polymers of ethylene are fluids used as lubricants; medium weight polymers are waxes miscible with paraffin; and the high molecular weight polymers (i.e., over 6000) are the materials used in the plastics industry. Polymers with densities ranging from about 0,910 to 0,925 kg/dm^3 are called *low density*; those of densities from 0,926 to 0,940 kg/dm^3 are called *medium density*; and those from 0,941 to 0,965 kg/dm^3 and over are called *high density*. PE is manufactured through a variety of processes: gas phase, solution, slurry, or high pressure conversion [1].

Up to here, the plastic terminology and its properties is explained. There are some samples from the nature, as Jute, Raffia Palms etc.

(iii) Jute:

Jute is a long, soft, shiny vegetable fiber that can be spun into coarse, strong threads. It is produced from plants in the genus Corchorus, family Tiliaceae [9]. Jute is a natural fibre with golden and silky shine and hence called *The Golden Fibre*. It is the cheapest vegetable fibre produced from the bast or skin of the plant’s stem. The second most important vegetable fiber after cotton, global consumption, production, and availability. It has high tensile strength, low extensibility, and ensures better breath ability of fabrics. Jute fiber is 100% bio-degradable and recyclable and thus environmentally friendly. It is one of the most versatile natural fibers that have been used in raw materials for packaging, textiles, non-textile, construction, and agricultural sectors. It helps to make best quality industrial yarn, fabric, net, and sacks. Advantages of jute include good insulating and antistatic properties, as well as having low thermal conductivity and a moderate moisture regaining with acoustic insulating properties and manufacture with no skin irritations. Jute has the ability to be blended with other fibers, both synthetic and natural, and accepts cellulosic dye classes such as natural, basic, vat, sulfur, reactive, and pigment dyes [10].

Golden Jute

Jute Twine

Jute Cloths

Figure 1.1. Jute examples

Jute has been used since ancient times in Africa and Asia to provide a cordage and weaving fiber from the stem and food from the leaves. Nearly 75% of Jute goods are used as packaging materials, burlap (Hessian), and sacks. The remaining products are carpet yarn, cordage, felts, padding, twine, ropes, decorative fabrics, and miscellaneous items for industrial-use. Jute has been included in the non-woven industry as it is one of the most cost effective high tensile vegetable fiber. Therefore, the demand for Jute has made its way into the automotive industry. Jute is now being used to manufacture more eco-friendly interiors for cars and automobiles [10].

(iv) Raffia Palm:

The Raffia palms (Raphia) are a genus of twenty species of palms native to tropical regions of Africa, especially Madagascar, with one species (R. taedigera) also occurring in Central and South America [11]. They grow up to 16 m tall and are remarkable for their compound pinnate leaves, the longest in the plant kingdom; leaves of R. regalis up to 25.11 m long and 3 m wide are known. The plants are either monocarpic, flowering once and then dying after the seeds are mature, or hapaxanthic, with individual stems dying after fruiting but the root system remaining alive and sending up new stems [12]. Raffia fibers have many uses, especially in the area of textiles and in construction. In their local environments, they are used for ropes, sticks and supporting beams, and various roof coverings are made out of its fibrous branches and leaves.

1.3. Definitions of Bag (Sack)

A bag (also known as a sack) is a non-rigid mostly semi-rigid container, made of paper, cloth, plastic, leather, or some other flexible material [13]. A sack is a large bag with no handles, made of strong rough material or strong paper or plastic, used for storing and carrying, for example flour, coal, etc [14]. A bag is used for packaging and/or carrying items, and may have one or two handles. A ruck sack has straps to carry it on the back. A bag may be closable by a zipper, snap fastener, etc., or simply by folding (e.g. in the case of a paper bag). A bag may or may not be disposable; however, even a disposable bag can often be used many times, for economic and environmental reasons. There may be logistic or hygienic reasons to use a bag only once [13].

(a) End Consumer Bag

(b) Shopping Bag

(c) Woven Sack

(d) Flexible Intermediate Bulk Containers (FIBC)

Figure 1.2. Different bags in use

1.3.1. Packaging

Packaging is the science, art and technology of enclosing or protecting products for distribution, storage, sale, and use. Packaging also refers to the process of design, evaluation, and production of packages [15]. It contains, protects, preserves, transports, informs, and sells [16]. In many countries it is fully integrated into government, business, institutional, industrial, and personal use. Package labeling (BrE) or labeling (AmE) is any written, electronic, or graphic communications on the packaging or on a separate but associated label.

Packaging and package labeling have several objectives [17] a Physical protection, Barrier protection [18, 19], Containment or agglomeration - Information transmission, Marketing, Security, Packages, RFID tags, or electronic article surveillance [20, 21], Convenience, and Portion control [17].

Thermoplastics can be remelted and reused, and thermoset plastics can be ground up and used as filler, though the purity of the material tends to degrade with each reuse cycle. There are methods by which plastics can be broken back down to a feedstock state. To assist recycling of disposable items, the Plastic Bottle Institute of the Society of the Plastics Industry devised a now-familiar scheme to mark plastic bottles by plastic type. A plastic container using this scheme is marked with a triangle of three cyclic arrows, which encloses a number giving the plastic type [22];

Figure 1.3. Plastics type marks- The resin identification code

Plastics type Marks- The resin identification code

1. PET (PETE), polyethylene terephthalate
2. HDPE, high-density polyethylene
3. PVC, polyvinyl chloride
4. LDPE, low-density polyethylene

5. PP, polypropylene
6. PS, polystyrene
7. OTHER, other: This plastic category, as its name of "other" implies, is any plastic other than the named #1–#6

1.4. Sack Production

There are differences in PP and PE Sack production. Both of them are explained in the following section with related flow charts.

1.4.1. PP Sack Production

Figure 1.4 shows the flowchart for PP production. The tape stretching line serves the production of stretched tapes of PP, HDPE or mixtures of these materials. The granulated material is fed to the extruder via a mixing and dosing unit. In the extruder the material is melt, compressed and homogenized. The pressurized material flows through an adapter and the filter to the flat die. The film leaving the flat die is taken through a water quench where the temperature of the film is reduced for solidification of the melt and to allow the further processing. The subsequent cutting bar cuts the film into tapes of equal width. The edge trim recycling unit sucks the edge trims in from the holding unit and feeds them to the grinder. Afterwards the cut edge trims are taken back to the extruder hopper.

In the extruder, the waste material is also melted for further processing. The hot air oven is arranged between the water quench with the integrated holding unit and the stretching section. The temperature is controlled by means of sensors and controllers providing the correct heating of the air. The first godet unit running at a higher speed than the film haul-off ensures the right film tension necessary for the cutting operation. Between the holding unit and stretching section the tapes are heated and stretched in the hot air oven. The stretching force is obtained by means of the higher speed of the stretching section. The precision take-up cross-winder is especially designed for winding up flat polyolefin tapes on cylindrical cores which are used as weft and warp on the looms. The winding machine is designed for horizontal tape feeding.

PP SACK PRODUCTION

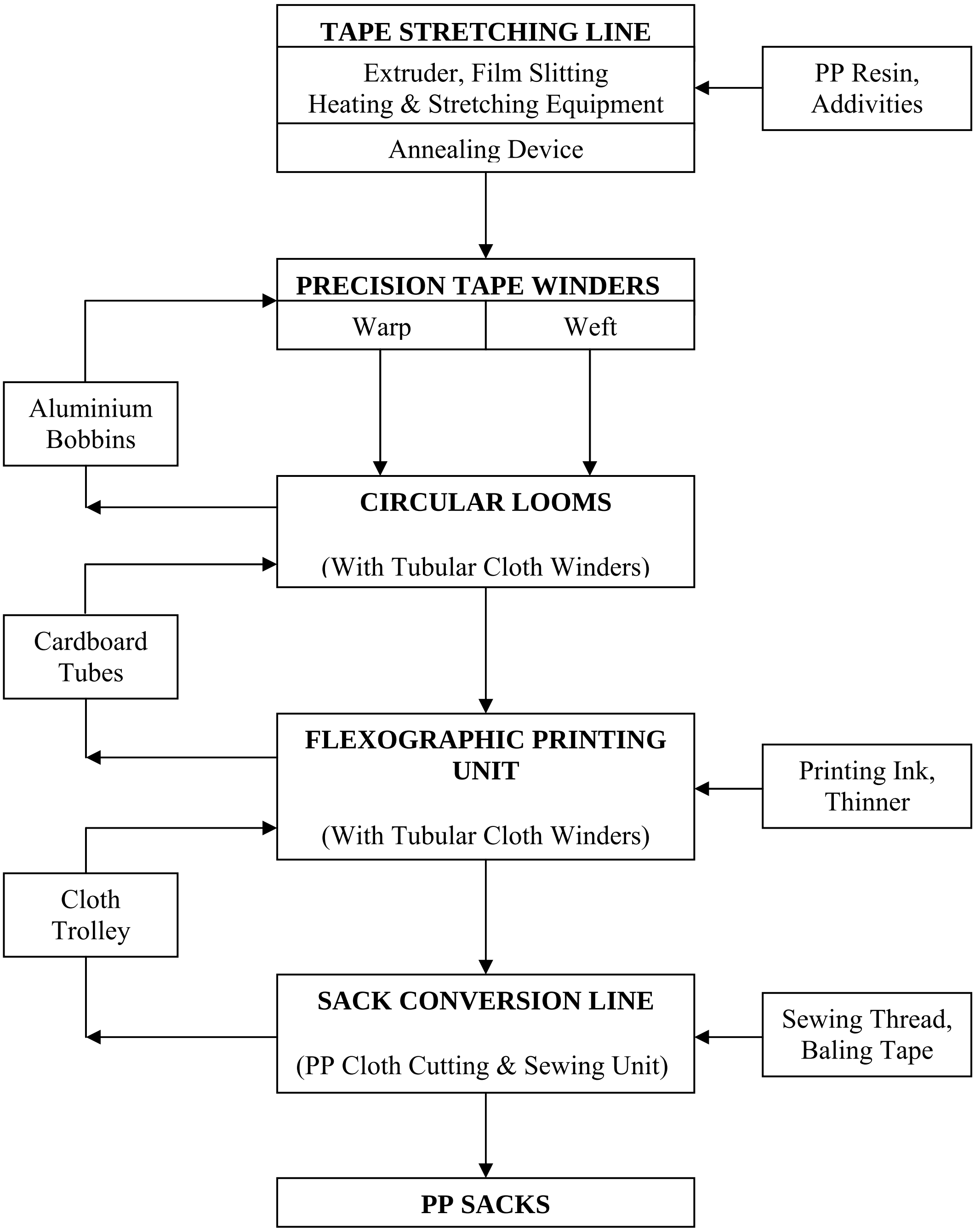


Figure 1.4. PP sack production flow chart

The circular loom is designed to weave endless tubular or flat cloth out of PP, HDPE, LLDPE tapes or other blends of polyolefines. The warp tapes are taken from two creels via rollers to the loom, which ensures uniform warp tension, excellent cloth quality and trouble-free handling. During production the warp bobbins can be changed easily and quickly without shutdown of the loom: tape ends are simply tied in. The weft is inserted by six shuttles running in a reed constructed for this purpose.

The cloth width can be modified by simply changing the weaving ring. The tubular cloth is taken past a calibrating and spreading system to two continuously driven draw-off rollers and subsequently batched onto a cloth winder.

The flexo printing machine is designed for one and/or two sides printing in four or six colours of cloth, woven out of PP or HDPE tapes. The printing machine operating on the flexographic process consists of an ink tub with ink roller and Anilox roller, a stereo cylinder, an impression roller and an ink pump with ink storage receiver. The rubber-coated dipping roller can be adjusted for proper carrying of the ink to the Anilox roller. It wipes the excess ink from the ink roller and transfers the right amount to the rubber stereo. Stereo cylinder marked off in squares to help positioning of the rubber stereo. The cylinder is adjustable in axial and radial direction for final setting for the printing process. The cloth' roll is placed on unwinding unit. The cloth is manually put to a stop on the intake side and passed through transport rolls up to winding unit. It is subsequently run automatically through the printing sections applying the ink. The printed cloth is winded at the winding unit.

The conversion line is designed for cutting, sewing and final stacking of sacks made of endless tubular cloth. In a fully automatic continuous production process the fabric woven out of PP or HDPE tapes is converted to finished sacks. The tubular cloth is drawn off from an unrolling device and cut to the length desired. The gripper feed mechanism takes the cut-off to the sewing unit where the sack bottom is folded by a special device and stitched. Subsequently the finished sacks reach the automatic counting and stacking device. The requested number of sacks is stacked and can be manually removed.

1.4.2. PE Sack Production

Figure 1.5 shows the flowchart for PE Sack Production. The blown film line serves for the production of stretched film of PE, HDPE or mixtures of these materials. The granulated material is fed to the rotaruder via a hopper. In the rotatruder the material is melt, compressed and homogenized. The pressurized material flows through an adapter and the filter to the circular die. The film leaving the circular die is taken through a air quench where the temperature of the film is reduced for solidification of the melt and to allow the further processing. The air cooling nuzzle is arranged between the circular die and the haul-off unit. The roller at winding unit running at a higher speed than the film haul-off ensures the film tension necessary for the right thickness. The circular film width is adjusted by means of pressurized air and is used only at start-up the line. The stretching force is obtained by means of the higher speed of the haul-off section. The winding unit is served for winding up flat polyolefin film on cylindrical cores. The winding machine is designed for horizontal film feeding.

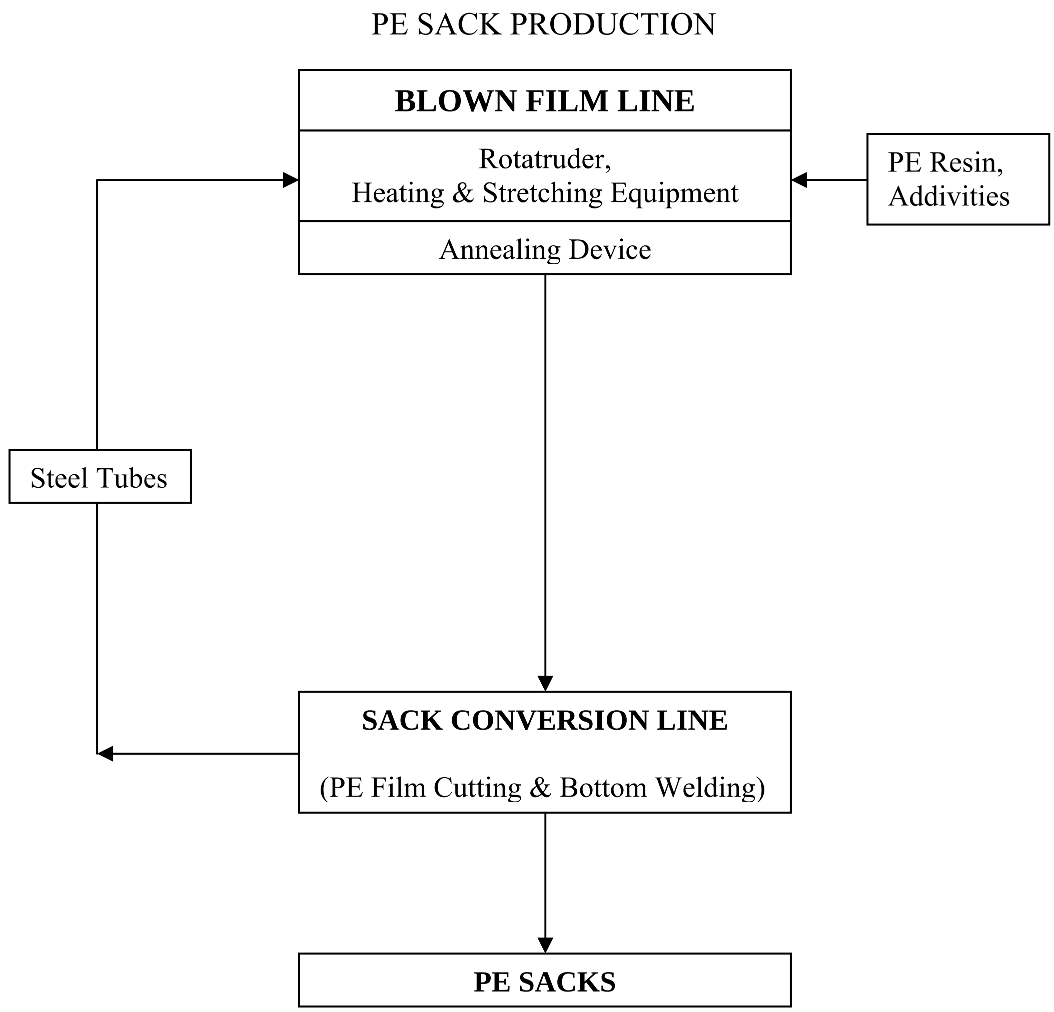


Figure 1.5. PE sack production

The PE sack conversion line is used to cut and seal LDPE and HDPE film tubes, to form bottom weld sacks. In a fully automatic continuous production process the film made of LDPE and HDPE is converted to finished sacks. The infeed film, passing through the machine, is guided through the dancing bar controlling device and the operating mechanism. The tubular film is drawn off from an unrolling device and the cutting and bottom welding is performed simultaneously by cam-actuator head which is contains rotational knife, lower welding bar and upper welding cross beam. The cutting length of sack is adjustable via control panel parameters. The length conveyor belt stacking system serves to gather the sacks into pre-determined number of piles, and to convey them further to the reception station.

1.5. Previous Studies (Literature Survey)

No studies are found on automatic PP and PE sack placing mechanism in literature. An Inside Laminating Bag Machine is designed by Changzhou Hengli Machinery Co., Ltd., China. In this machine, the PE film is produced at Blown Film Line as a circular film and winded on a roller [23]. Afterwards the PE film roll is placed on an unwinding unit as in Figure 1.6 and carried through a loom center via a conveyor roller. The PE film’s open end is passed into a hollow shaft like in Figure 1.7 that is located on the loom cam mechanism up to haul-off unit. So, the PE film is drawn via air-vacuum nozzle from PE film roller while the PP fabric produced by loom. The PE film inserted PP woven fabric is winded together on surface winder unit. Then it is send to Conversion Line to get the final sack which is PE inserted PP sack.

Figure 1.6. Laminating bag machine

Figure 1.7. Processing of PE film

Because of its production process and definition of sack, this machine is not related with our project. It can be only defined as laminating. Because it is inserted as a PE film, not PE sack, into woven fabric made of PP. Then it is cut and sewn together for getting the final sack.

There is a different machine (Figure.1.8) which is designed by Hao Yu Precision Machinery Industry Co., Ltd., Taiwan [24].

Figure 1.8. PP woven tubular fabric inside lamination machine

The PE film and woven fabric made of PP are produced separately and wound on a roller. In this case, PP woven fabric is filled into the fabric delivery unit. Then PE film is inserted through the woven fabric holding pipe of the fabric delivery unit. When the filling process is completed, the woven fabric roll is removed. PP woven fabric and PE film is pulled out together to the direction of lamination device for further operations (oven, hot roll, cooling and rewinding, etc., Figure 1.9). The PE film is guided into hollow pipe by air and sent to the beginning as the same place of woven fabric. When the woven fabric is guided to the end, the PE film is pulled together to the oven. In the oven, the PP woven fabric which is already placed PE film is heated and made inside lamination. Finally, laminated fabric is send to the Conversion Line to obtain the sack.

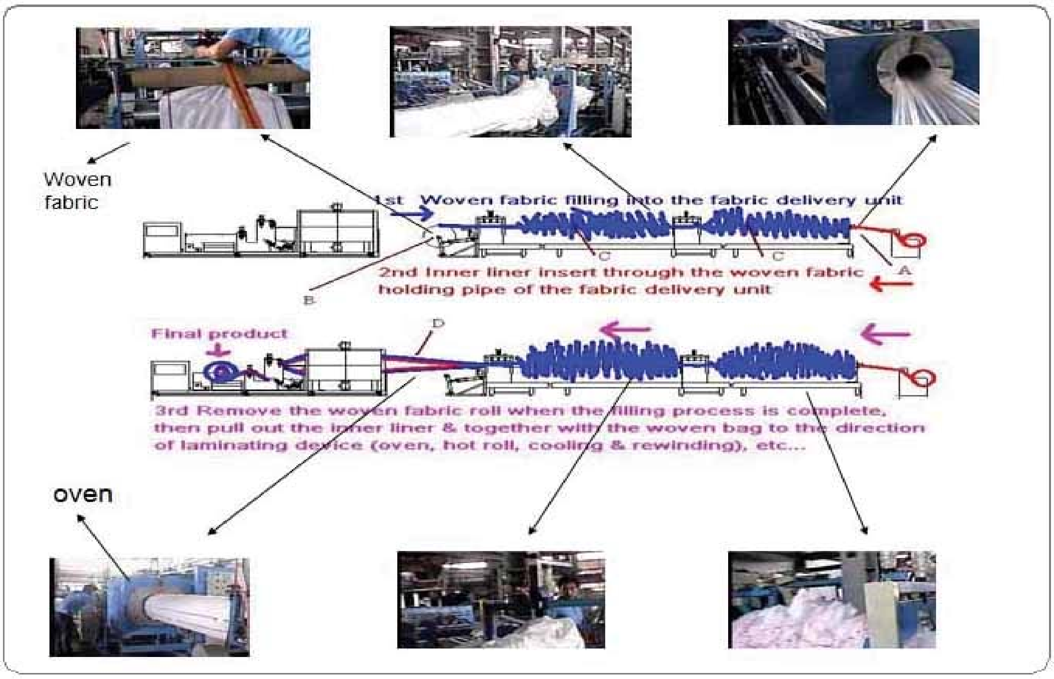


Figure 1.9. Inside lamination process

This machine is also Taiwan made; it is not related with our Project. It can be defined as a different type of laminating. It permits for direct processing of PP woven tubular fabric. The machine's dimensions are 55 meters length, 5 meters width and 5,5 meters height. Thus this is not an inserting mechanism for sacks. In journals, many studies are seen similar to the machines given above. No inserting mechanism is seen.

1.6. Statement of Problem

The installed production capacity of Turkey is about 912 million sacks per year [25]. The sack using areas are defined at Section 1. The scope of this project is related with fertilizer packaging. The PP sacks as well as that of PE are used for protecting the fertilizer from moisture. The PE sack is placed into the PP manually. This labour-intensive process is not only difficult but also causes many problems in practice. Thus, the necessity of an improvement in inserting procedure can clearly be seen.

The aim of this thesis is to design and perform analysis of a placing mechanism for PP and PE sacks. This study involves 3 important parts: design of an inserting mechanism with its auxiliary parts, synchronization with other units during the inserting procedure and the control of sensors and actuators properly in real time. Thus, the sack placing rate will definitely be increased and faults caused by human operators will be overcome. Additionally, the plastic packaging plant will be able to deliver more sacks while consuming less labor and time by using this mechanism. So a design procedure and its feasibility for further application will be presented with real figures taken from a Fertilizer Company. Referred sack dimensions are 550 millimeters width and 950 millimeters length. This proposed design when used in future development will certainly provide a considerable contribution to reducing plant expenses.

1.7 Thesis Structure

Chapter 1 gives an introduction on plastic materials and their use together with problem definition in this study. Chapter 2 includes details on the inserting procedure for PP and PE Sacks. The inserting steps of a sack are also explained by figures and/or photographs. Concept Design, Design Criteria, Alternative Solutions and Evaluation for Final Design are explained respectively.

Chapter 3 contains two sections. In the first section, the general information about Control Structure and Issues the placing of the PP and PE sacks mechanism are presented. Some design requirements on the placing mechanism are determined. Two alternative placing mechanism models are developed and evaluated. In the second section, alternative models are generated for the placing operation of the sacks. Firstly, the placing operations of the sacks are explained. Design requirements of the placing mechanism used in the handmade workbench are determined. Finally, the actuators and synchronization with other systems and automation of the system are explained.

Analysis of the inserting mechanism is presented in Chapter 4. Firstly, kinematics of mechanism and trajectory available are explained and compared to the manual one. A mathematical model is built for a brushless DC motor driven horizontal sack turret with a belt drive. Finally, the conclusions on the thesis and recommendation for further studies are included in Chapter 5.

CHAPTER 2

DESIGN OF INSERTING MECHANISMS

There are different descriptions of inserting mechanisms which can be functional, behavioral, schematic or structural during a design procedure. A functional description gives its purpose for use. A behavioral description explains the input-output characteristics. A schematic description provides the conceptual components with the related interconnections. A structural description gives the materials and its three dimensional geometry to make it clear. Finally, conceptual design refers to the initial stage in the above transformations [26]. The following section includes a manual inserting procedure for PP and PE sacks.

2.1. Manual Inserting Procedure for PP and PE Sacks

The PP and PE sacks are inserted manually in the sub-suppliers' workshop. The sack inserting speed is 6 sacks / min and the production output is 3.200 sacks/10hr per operator. The final sack means PE sack inserted into that of PP. The sack inserting workbench consists of four parts as PE sack storing table, PP sack storing table, the final sack storing table and the sack inserting platform. The PE and PP sacks are separately stored on storing tables. They are put on the left and right side of the inserting platform. That of the final sack is put on the front of the inserting platform as shown in Figure 2.1. The PE sack storing table is 700 x 700 x 1000 mm, and the PP sack 600 x 700 x 1000 mm, and the sack inserting platform 460 x 1050 mm in dimensions for placing the sack (see App. A.2 Figure A.2.1.).

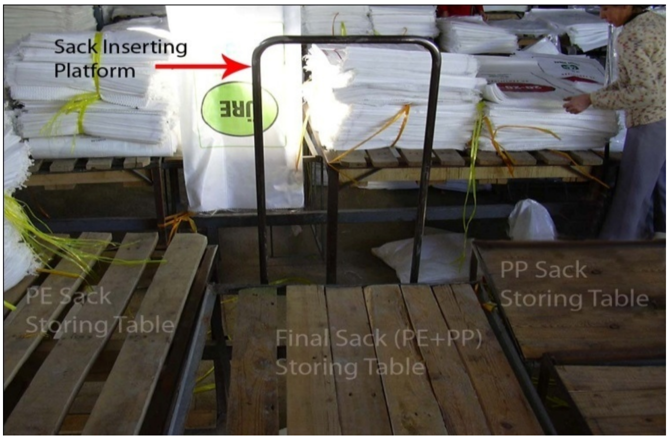


Figure 2.1. Manual inserting platform

The manually sack placing procedure is given as the following.

(i) The PE sack is firstly taken from the storing table (Figure 2.2).

Figure 2.2. The PE sack storing table

(ii) The PE sack is placed on the sack inserting platform (Figure 2.3).

Figure 2.3. Placing the PE sack on the sack inserting platform

(iii) PE sack is pull down up to sealed side of its reach the sack inserting platform (Picture 2.4).

Figure 2.4. Pulling down the PE sack

(iv) The PP sack is taken from the storing table (Figure 2.5).

Figure 2.5. Taking the PP sack

(v) The PP sack slides down on that of PE which is already placed on the sack inserting platform (Figure 2.6).

Figure 2.6. Inserting the PP sack onto that of PE

(vi) The PP sack is pulled down up to its stitched side to reach the sack inserting platform. PE sack which has a length 7 cm. longer than that of PP is then folded outside to form the cuff. The cuff form is made in order to not inadvertently fill fertilizer between both sacks at the fertilizer filling unit. But it is seen that cuff form is not necessary (Figure 2.7).

Figure 2.7. Pulling down procedure for PP sack

(vii) The PE sack inserted PP sack is moved to outside of the sack inserting platform together (Figure 2.8).

Figure 2.8. Taking off the PE inserted PP sack

(viii) Finally the PE sack inserted into that of PP, the final sack, is stored on the finish table (Figure 2.9).

Figure 2.9. Storing of inserted sack for final use

2.2 Concept Design

The manual sack inserting procedure is given in Section 2.1. Because of several movements of the operator, it is seen that sack inserting looks simple but the procedure involves many problems in practice. A cycle should be completed in as short of time as possible. Many independent measurements are taken, and a final sack is completed in 10 seconds.

The PE sack inserting system consists of (i) PE sack storing tables (2) and PP sack storing tables (2), (ii) the horizontal sack-turret, (iii) the horizontal sack-turret stand, (iv) Horizontal and vertical pneumatic cylinders and a vacuum System, (v) Final sack storing tables (2). They are given in the following section with real dimensions.

(i) PE and PP Sack Storing Table

The PE and PP sacks are separately stored on storing tables. These tables are necessary for starting the inserting procedure. They are made of steel profile with dimensions of 560 mm width, 800 mm height and 1000 mm length (see App. A.2 Figure A.2.2.).

(ii) The Horizontal Sack-Turret

The horizontal sack-turret consists of 6 sack inserting platforms and a chassis (Figure 2.10). Every three inserting platforms are used for a sack inserting cycle, shortly in a cycle. On the front of every third inserting platform, there is a final sack storing table. On top of every inserting platform, there is a Horizontal-Vertical Pneumatic Cylinder, and a Vacuum System. Its proposed design with dimensions is given in Appendix A.2 Figure A.2.3.

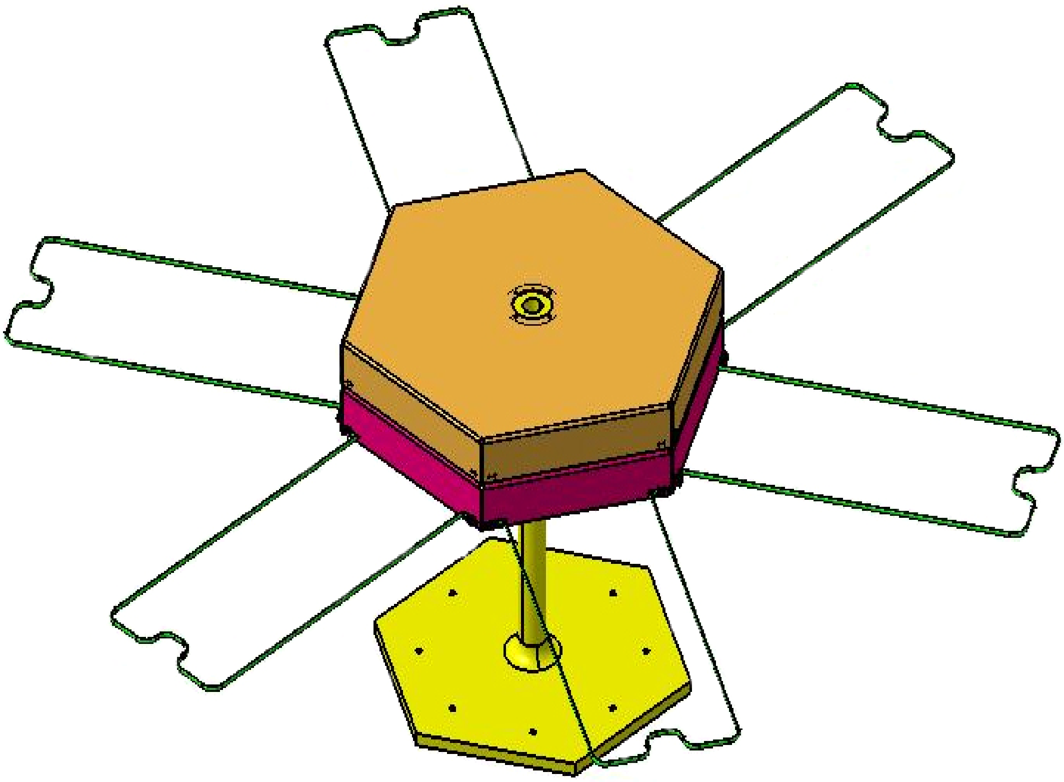


Figure 2.10. The horizontal sack-turret design

(iii) The Horizontal Sack-Turret Stand

In the proposed design, the horizontal sack-turret is actuated by a BLDC motor via belt. Its stand has an overall height of 1300 mm. (see App. A.2 Figure A.2.4). It can carry the motor and transmission system of interest. Here a belt driven system is considered. The sack-turret is fixed to the floor via a hollow shaft and a hexagon support which are made of steel for stability.

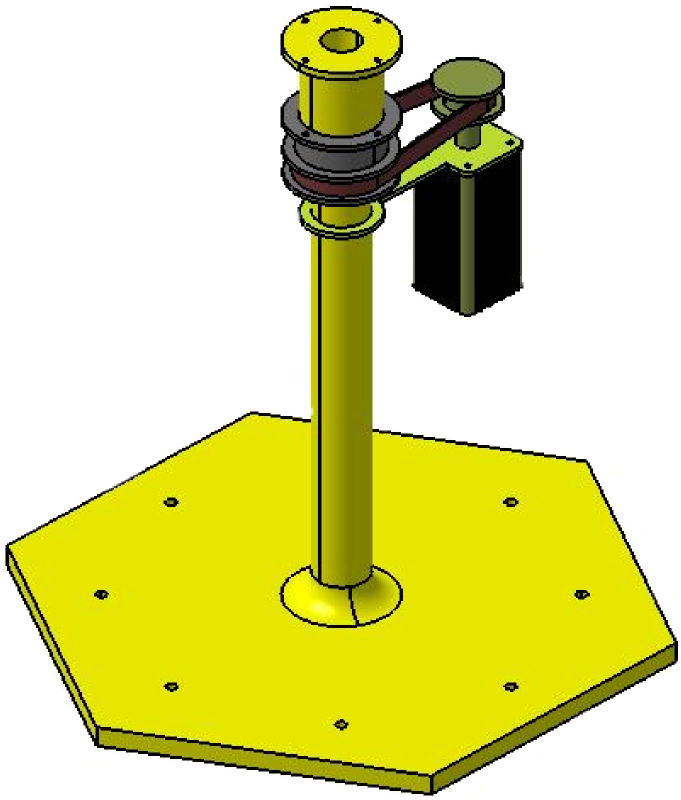


Figure 2.11. Horizontal Sack-Turret stand

(iv) Horizontal and Vertical Pneumatic Cylinders and Vacuum System

The PE and PP sacks will be held and placed via Horizontal and Vertical Pneumatic Cylinders, and a Vacuum System. It is designed by a rodless pneumatic cylinder, two horizontal mechanical supports, a profile pneumatic cylinder, two vertical mechanical supports, twelve bellow suction pads. Its dimensions are given in App. A.2 Figure A.2.5.

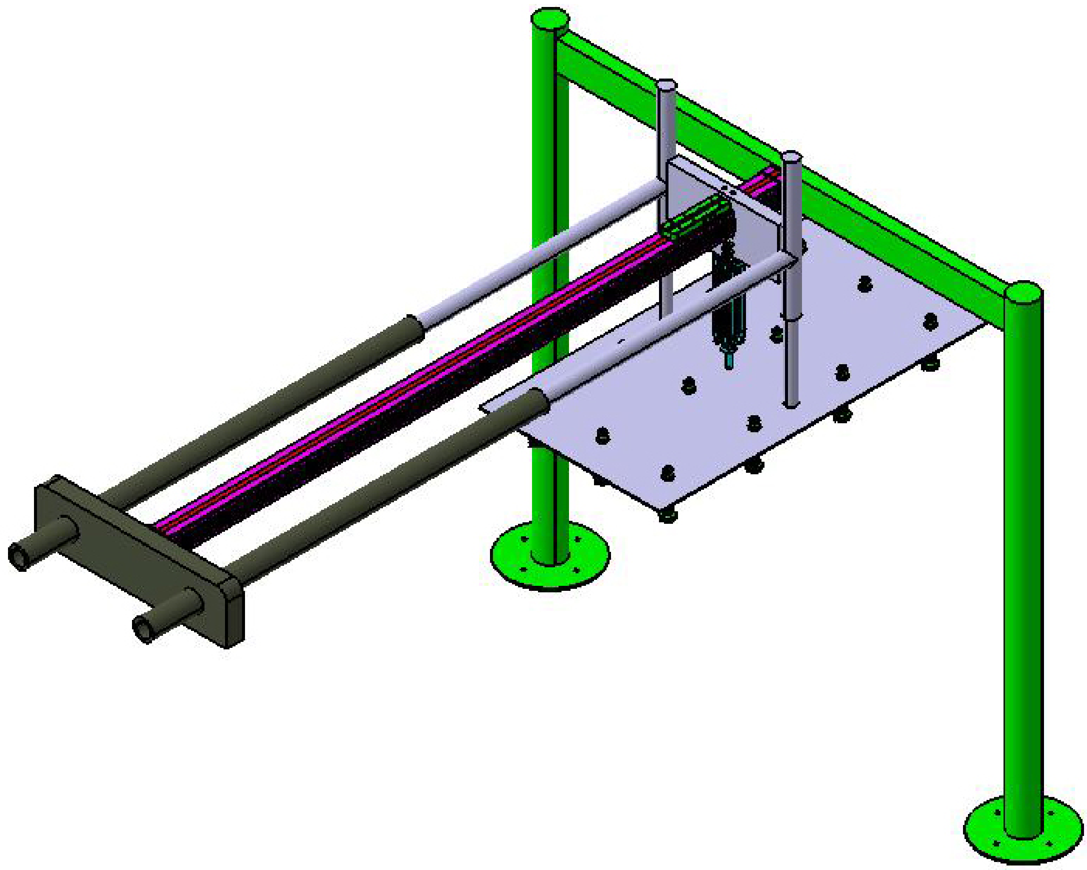


Figure 2.12. Horizontal-vertical pneumatic cylinders and vacuum system

(v) Final Sack Storing Tables

Final sack storing tables are necessary for completing the inserting procedure. They are made of steel profiles with dimensions of 1160 mm width; 800 mm height and 1990 mm length (see App. A.2 Figure A.2.6).

Parts of the proposed design are assembled together using Figures 2.10, 2.11, and 2.12.

Figure 2.13 shows the assembled view for the 1st sack placing mechanism. Figures 2.14 and 2.15 show different views; top and bottom of the 1st sack placing mechanism. Figures 2.16.-2.19 show consecutive views; the vacuum system with suction pads, suction pads and sensors, the horizontal pneumatic cylinder and that of vertical and Support. Dimensions of the 1st sack placing mechanism are given in App. A.2 Figure A.2.7.

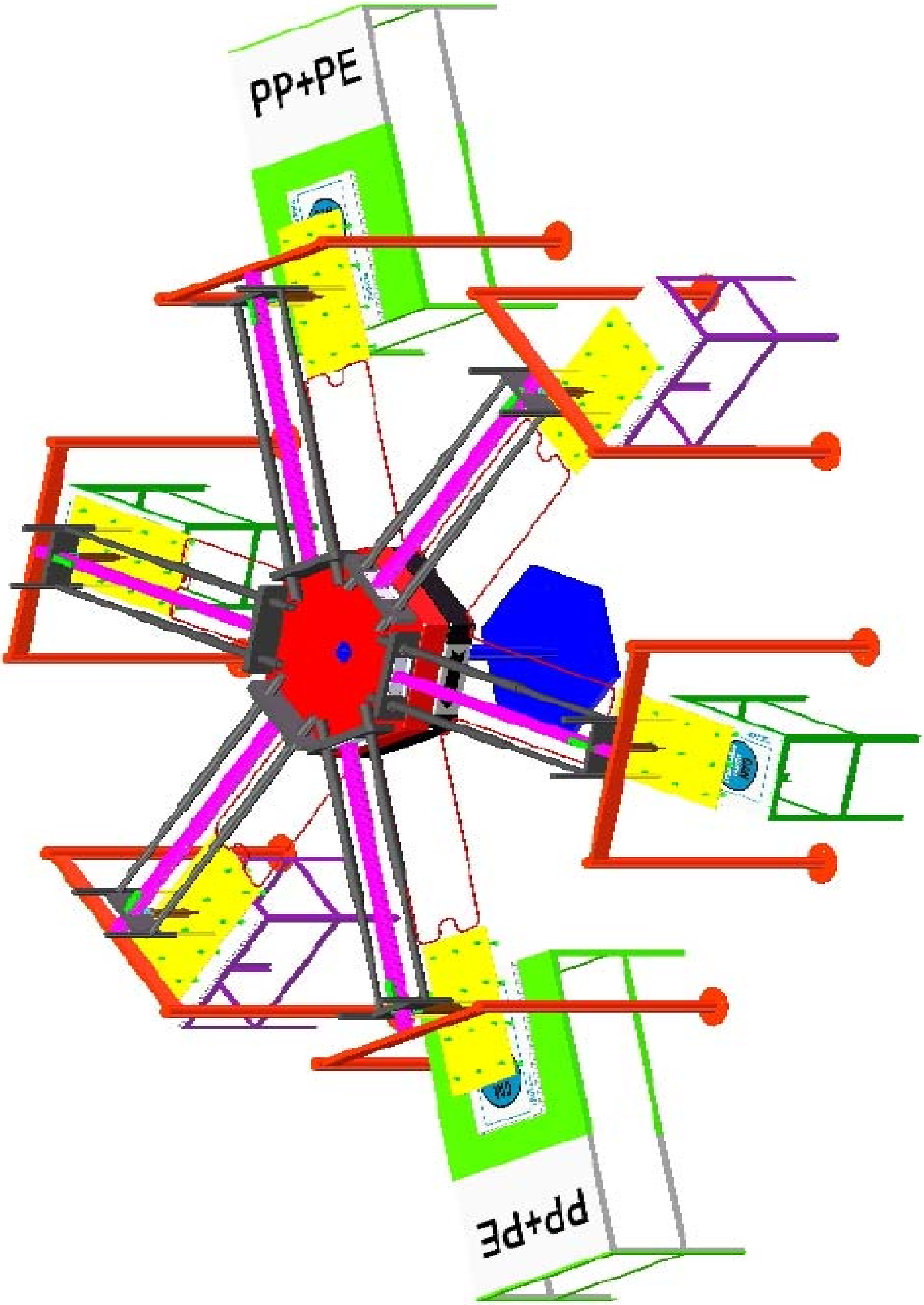


Figure 2.13. An isometric view of horizontal sack placing mechanism (1st Model)

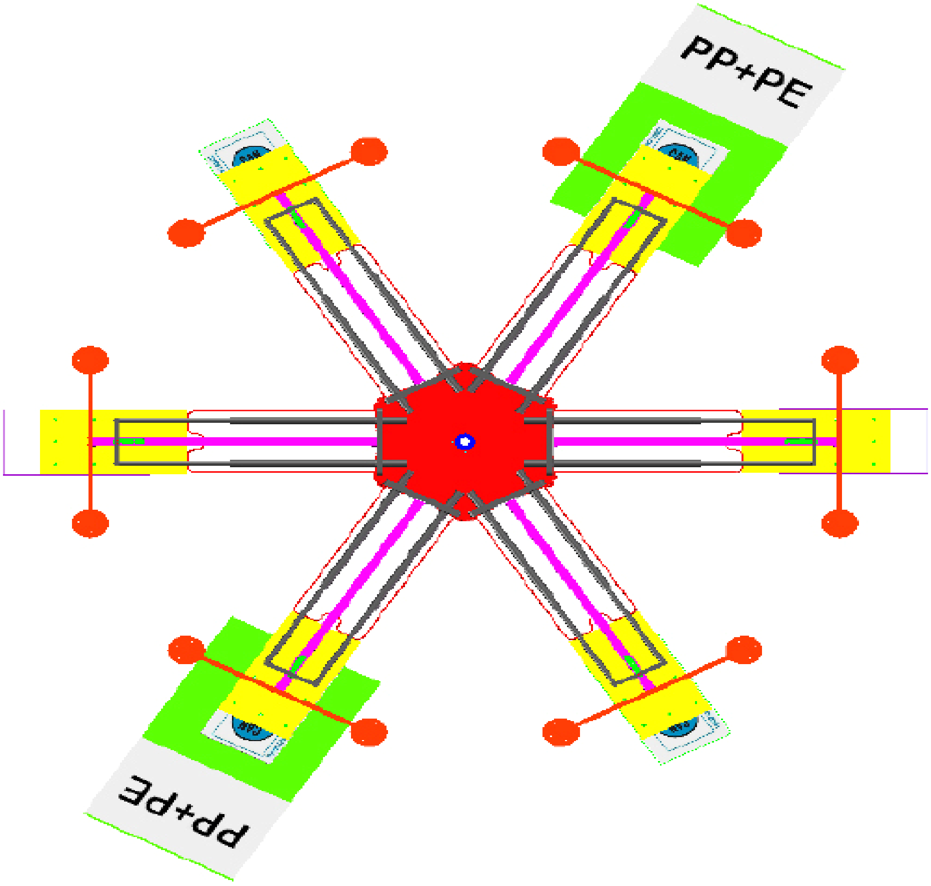


Figure 2.14. A top view of horizontal sack placing mechanism (1st Model)

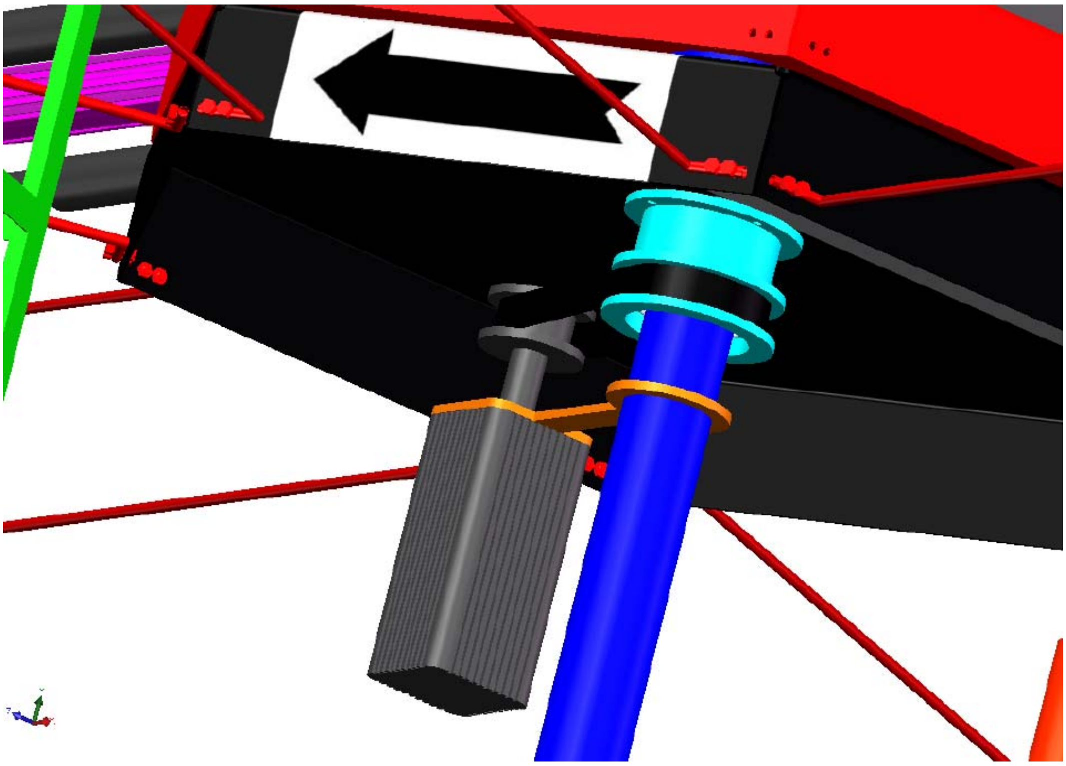


Figure 2.15. Bottom view of horizontal sack placing mechanism (1st Model)

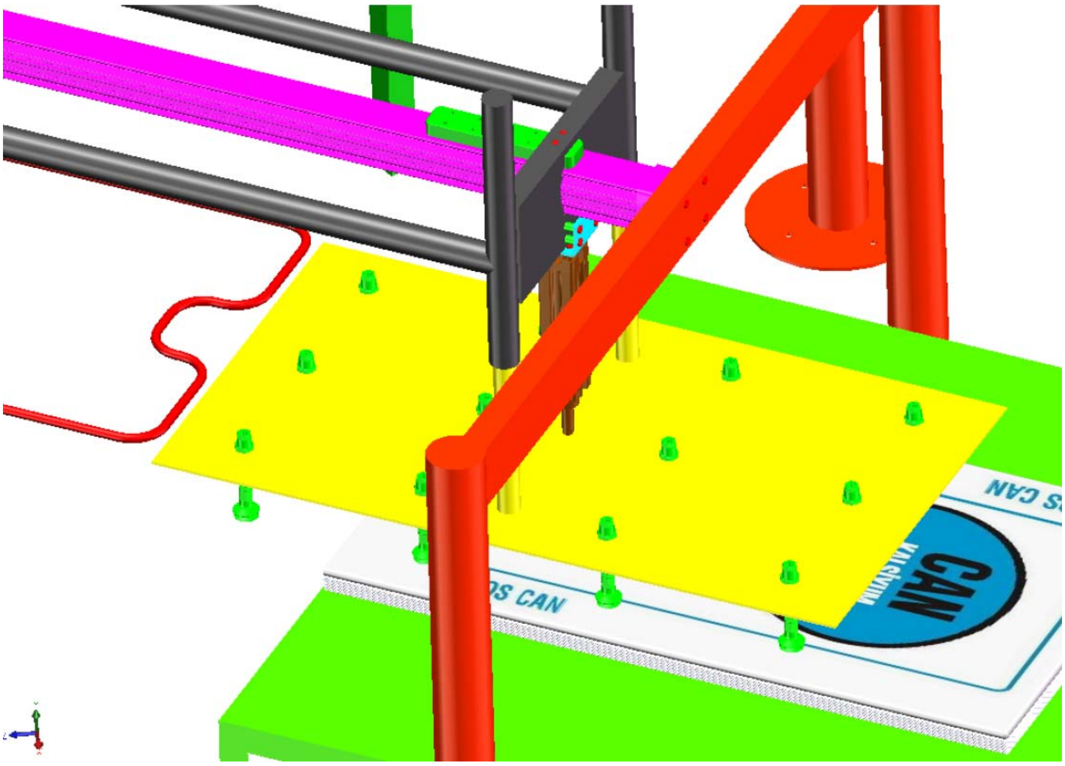


Figure 2.16. A view of vacuum system with suction pads (1st Model)

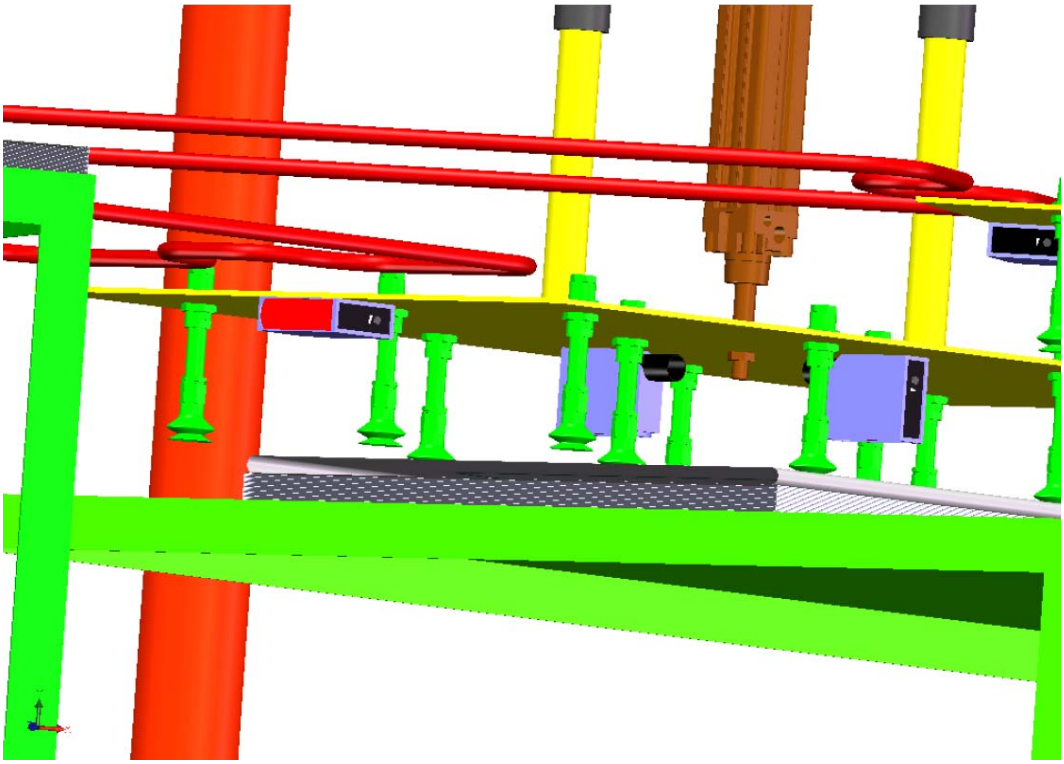


Figure 2.17. A view of vacuum system with suction pads and sensors (1st Model)

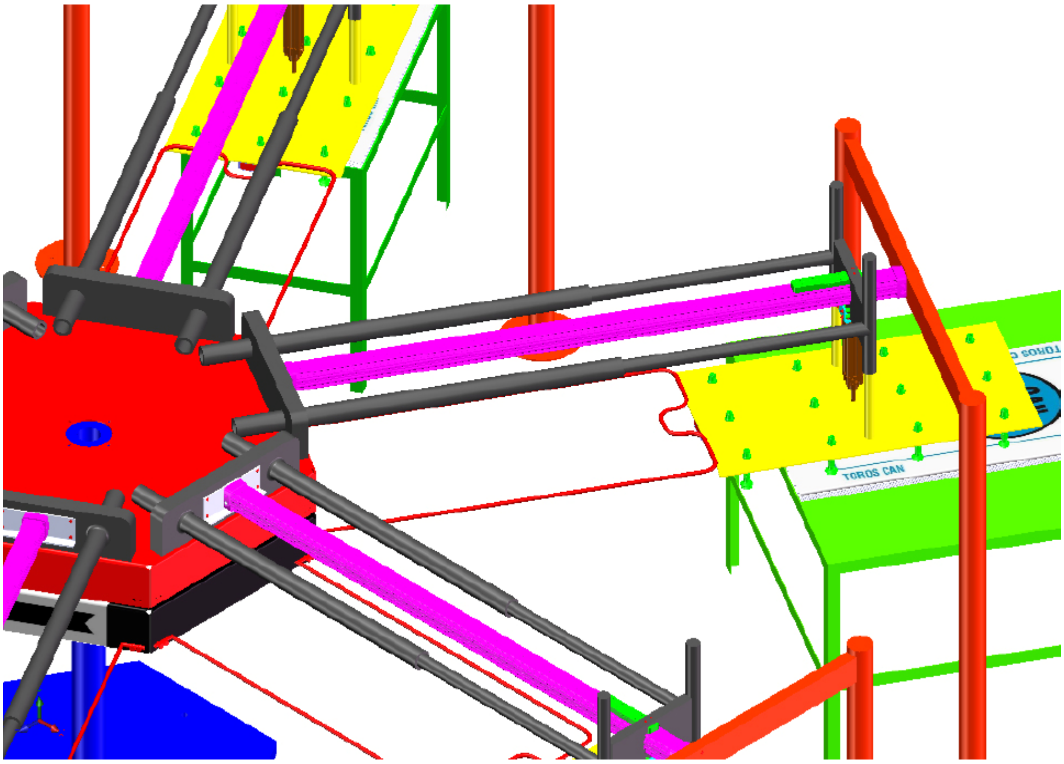


Figure 2.18. A view of horizontal pneumatic cylinder (1^{st} Model)

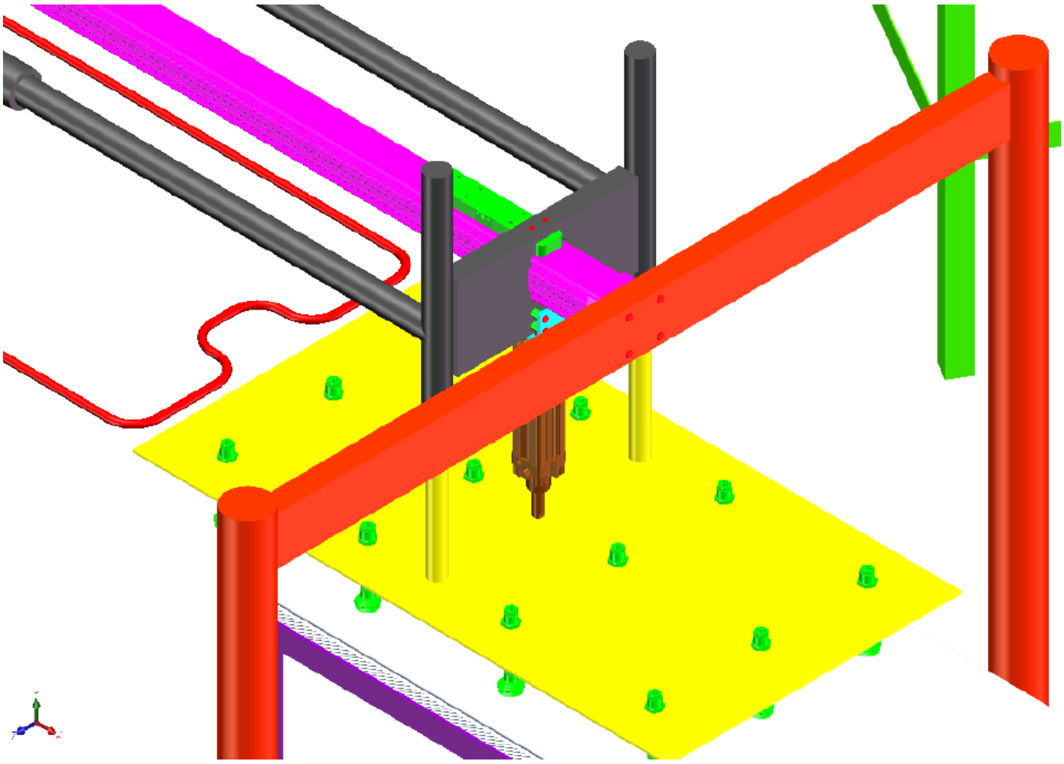


Figure 2.19. A view of vertical pneumatic cylinder and support (1^{st} Model)

2.3. Design Criteria

The mechanism for the inserting operation of PE and PP sacks must satisfy the following design requirements:

i. Every Horizontal and Vertical Pneumatic Cylinders, and Vacuum System must transport PE and PP sack horizontally.

ii. The sack inserting turret mechanism must work in sequence. When the Horizontal and Vertical Pneumatic Cylinders, and Vacuum System that works on the PE sack inserting platform has completed its task, which of PP sack has also completed its task too. In the same time interval, PE inserted PP sack is withdrawn by that of the final sack.

iii. The mechanism must be in optimum geometry to allow sack placing and pulling and must not cause high tension on the sacks.

iv. The sack inserting turret mechanism must be simple and with a compact structure. The mechanism must not use a large space for operation.

v. The mechanism must be simple to control and must be easily manufactured.

2.4. Alternative Solution

One different alternative solution is also generated here for the sack inserting mechanism. Its operating principles are explained, and this mechanism is discussed and compared in terms of design requirements.

As shown in Figure 2.20, there are six sack inserting platforms, three sack storing tables which are for PE sack, PP sack and Final sack, and three Horizontal and Vertical Pneumatic Cylinders-Vacuum Systems, and a Sack-Turret. In the alternative design, the Sack-Turret is designed to operate in the vertical position and its inserting platforms are placed with the vertical turret configuration horizontally on its surface. Figure 2.20 shows an alternative placing mechanism. The Horizontal and Vertical Pneumatic Cylinders- Vacuum Systems work on Z axis (horizontal rodless pneumatic cylinder, linear movement) and on Y axis (vertical pneumatic cylinder, linear movement). Initially the mechanism starts up to place PE sack on to the 1^{st} inserting platform via the 1^{st} horizontal and vertical pneumatic cylinders-vacuum system. After the PE sack is placed, then Vertical Sack-Turret is turned to a step (60^o CCW) via a servo motor. The 1^{st} inserting platform that has already placed the PE sack is moved to the front of the PP sack storing table. After the PP sack is placed via the 2^{nd} horizontal and vertical pneumatic cylinders-vacuum system on the 1^{st} inserting platform, the Vertical Sack-Turret is turned again a step (60^o CCW) via a servo motor to reach the front of the final sack storing table. At this stage, the 3^{rd} horizontal and vertical pneumatic cylinders-vacuum system is used for removing and placing the PE sack inserted PP sack onto the final sack storing table. After placing the finished final sack onto the final sack storing table, the Horizontal and Vertical Pneumatic Cylinders-Vacuum Systems are moved to their initial positions which are onto sack storing tables and holding station until the Vertical Sack-Turret turns 180^o CCW. Then it is ready to run the next inserting operation of another sack.

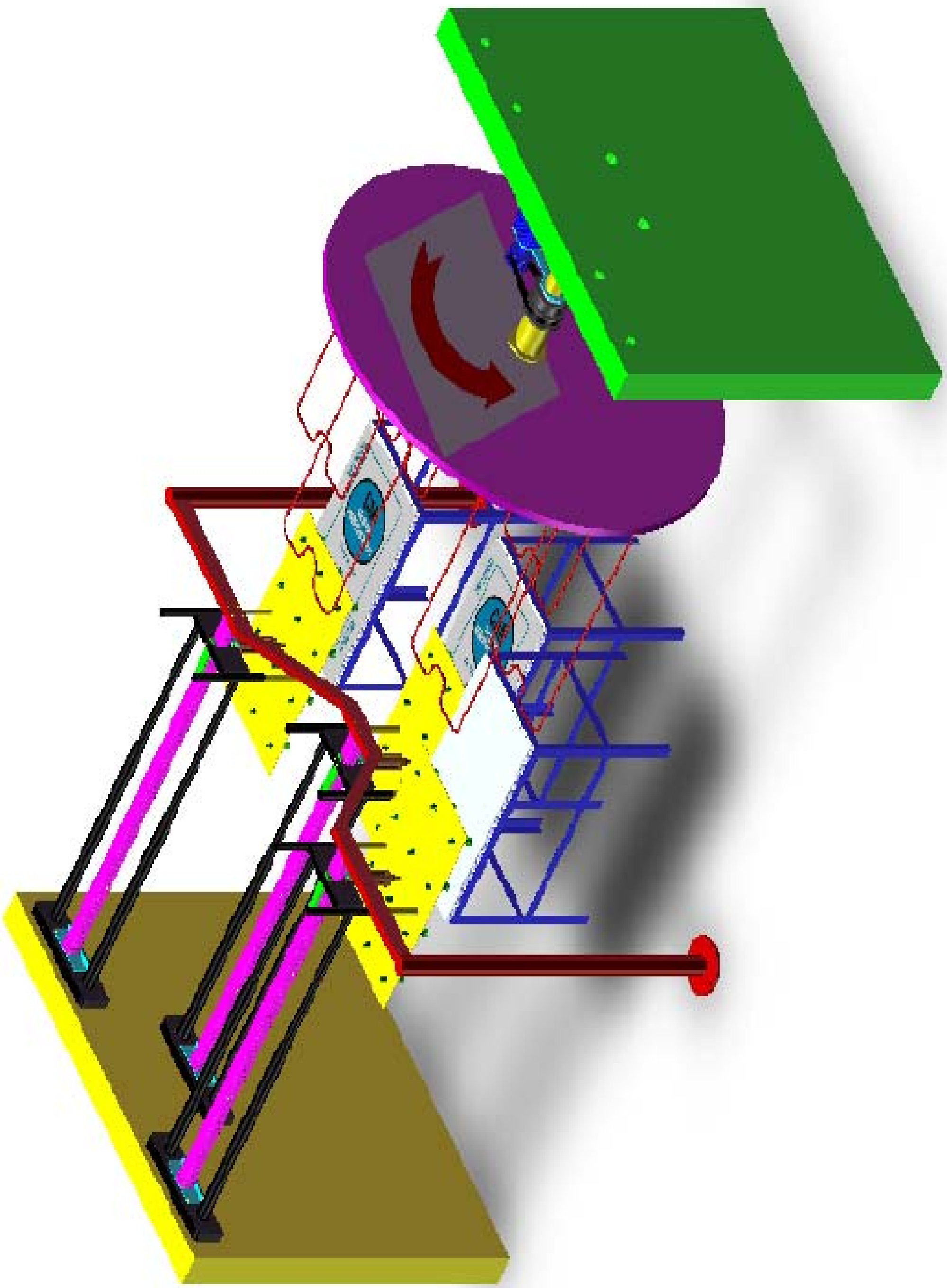
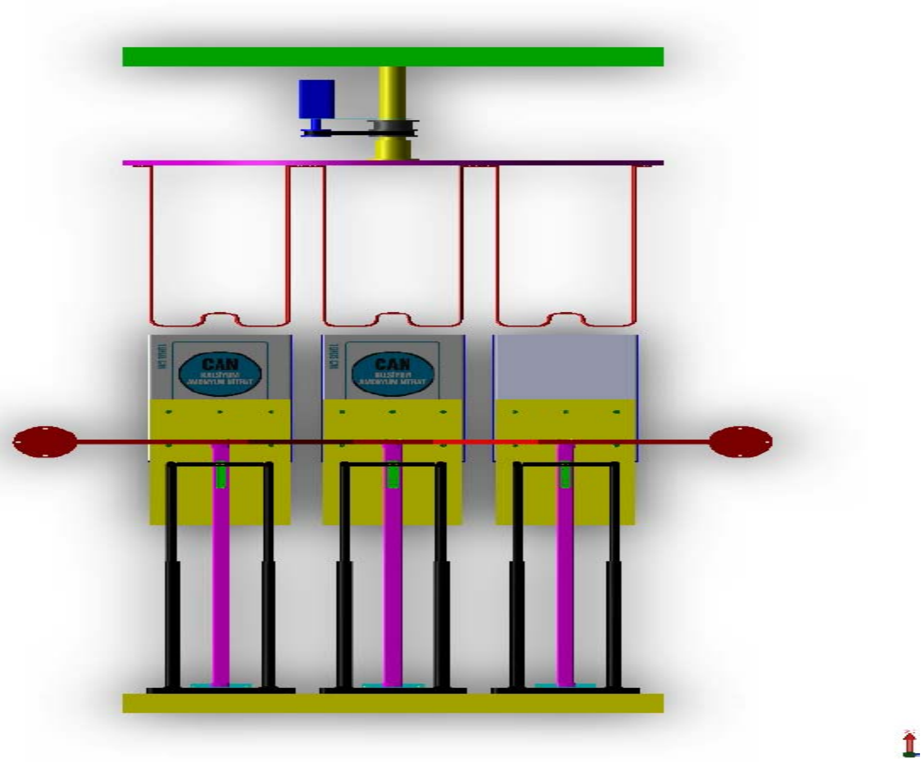
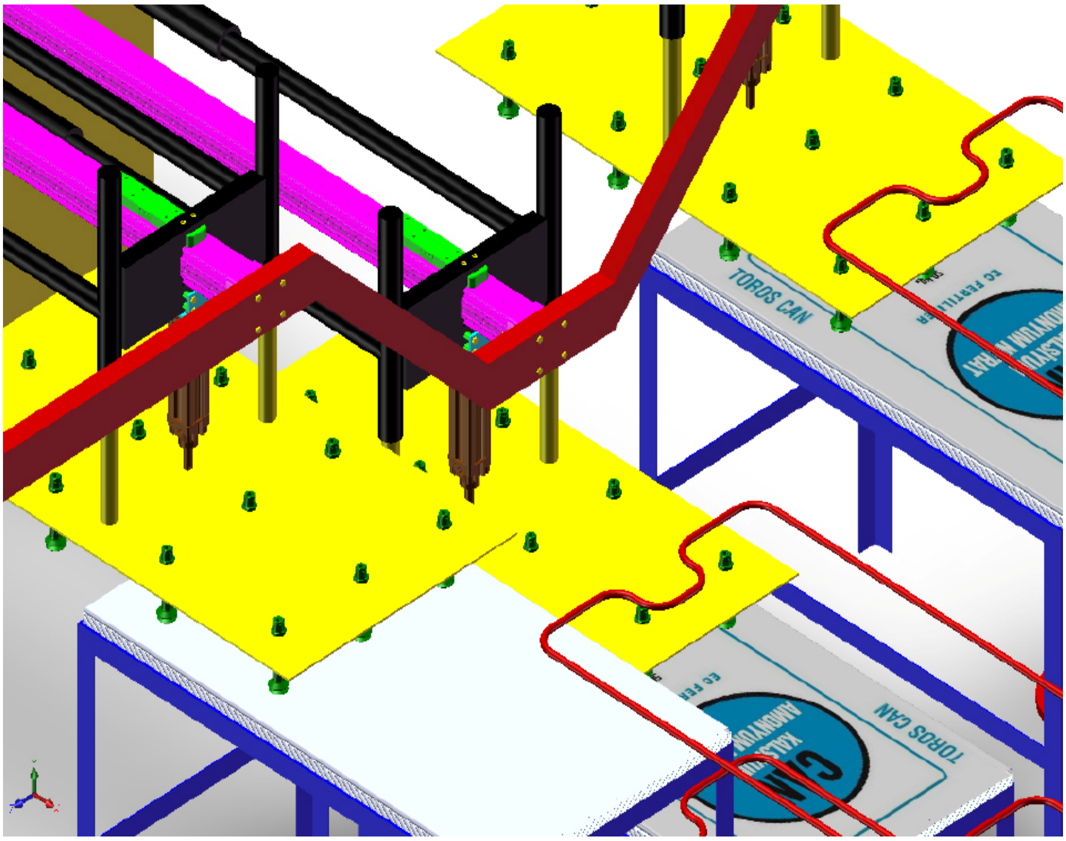


Figure 2.20. An isometric view for vertical sack placing mechanism (2^{nd} Model)



(a) A top view of vertical sack placing mechanism (2nd Model)



(b) A view of vertical sack placing mechanism (2nd Model)

Figure 2.21. Different views for vertical sack placing mechanism (2nd Model)

2.5 Evaluation for Final Design

There are two different alternative designs for the sack inserting mechanism. All of the mechanisms can carry out the turn of the Sack-Turret and manage the required inserting process.

The first model consists of six sack inserting platforms, six Horizontal and Vertical Pneumatic Cylinders-Vacuum Systems and a Horizontal Sack-Turret and this Sack-Turret must run horizontally. The Horizontal and Vertical Pneumatic Cylinders-Vacuum Systems must run in sequence. So, the first model is balanced and the control of it may not be difficult. It could perform insertion of two final sacks at the specified unit of time.

The second model consists of six sack inserting platforms, three Horizontal and Vertical Pneumatic Cylinders-Vacuum Systems and a Vertical Sack-Turret. The Sack-Turret must run vertically. The Horizontal and Vertical Pneumatic Cylinders-Vacuum Systems must be installed on different parts and must run in sequence. So, the control of the second model may be difficult. A final sack can be completed at a specified unit of time. The design of the inserting platform of the Vertical Sack-Turret is more difficult due to its position to the ground. If its inserting platforms' positions are not horizontal, then the Horizontal-Vertical-Vacuum Systems could not properly work to place the sacks on the inserting platforms.

The cuff form of sack cannot be performed by either alternatives; the PE sack is 7 cm. longer than that of PP in operation to help keep them together. However, it is not necessary at the moment. The PE sack length can be shortened 7 cm. by canceling the cuff form. So, this can be utilized in an economical point of view.

The main goal of this evaluation is to make a comparison between the alternative models. Two sack inserting mechanisms providing the inserted-sack are developed in this thesis. These models are compared in terms of the following criteria; functional requirement, compact structure, easy manufacturing, layout, better controllability, sack removability, and inserted sack output .

A comparison between the alternative models is given in Table 2.1 where the first row shows the alternative models and the first column shows the criteria.

Table 2.1 Comparison between the alternative sack inserting models

Criteria	***The First Model (Horizontal Sack-Turret)***	***The Second Model (Vertical Sack-Turret)***
Functional Requirement	+	+
Compact Structure	+	-
Easy Manufacturing	+	+
Layout	+	+
Better Controllability	+	-
Sack Removability	+	-
Inserted Sack Output	+	-
Target	**+ 7**	**+ 3**

All models satisfy the function of inserting the sacks theoretically. However, the first model (Figure 2.13) is the most simple and compact in size with respect to the second model. And the final sack removal is easily performed by the first model. The second model must be stopped while the sacks are put on storing tables and removed from the final sack storing table. The inserted sack output is two sacks/cycle for the first model whereas one sack/cycle for the second model. As a result, the first model given in Figure 2.13 is decided as an acceptable solution for the sack inserting mechanism.

CHAPTER 3

DRIVE SYSTEMS AND CONTROL OF INSERTING MECHANISM

3.1. Introduction

The motion coordination and the actuation of the mechanisms are explained in this chapter. The inserting system consists of four different mechanisms; the sack-turret, the sack-turret actuator, the horizontal and vertical pneumatic cylinders and the vacuum system. Each mechanism has a different function and structure which makes the system difficult to operate with others.

The above mechanisms can be driven by using an electrical actuator, servo motor, vertical and horizontal pneumatic cylinders, sensors or vacuum systems. There are numerous types of motors: servo motors, pneumatic, hydraulic actuators and so on [27-29]. They are studied and the drive systems for sack inserting mechanism are proposed in the following section.

3.2 Operation of Sack Inserting System

Figure 3.1 shows the mechanism of the sack inserting system with a block diagram. A DC servo motor is used to drive the sack-turret mechanism. A vacuum system is used to hold the sack. The Horizontal and Vertical Pneumatic Cylinders are used to transport the vacuum systems which hold the sacks and to place the sacks on the sack-turret inserting platforms and finally, to transport the final sacks to the storing tables. As the first part of the motion cycle, the motor adjusts the location of the positioning mechanism, which can carry all the mechanisms to place the sack. The motion profile of the servo motor is designed using the trajectory available to the location of the PE sack, the PP sack and the final sack. Here the servo motor operates at a 60^{o} angle, and stops to perform the required operation.

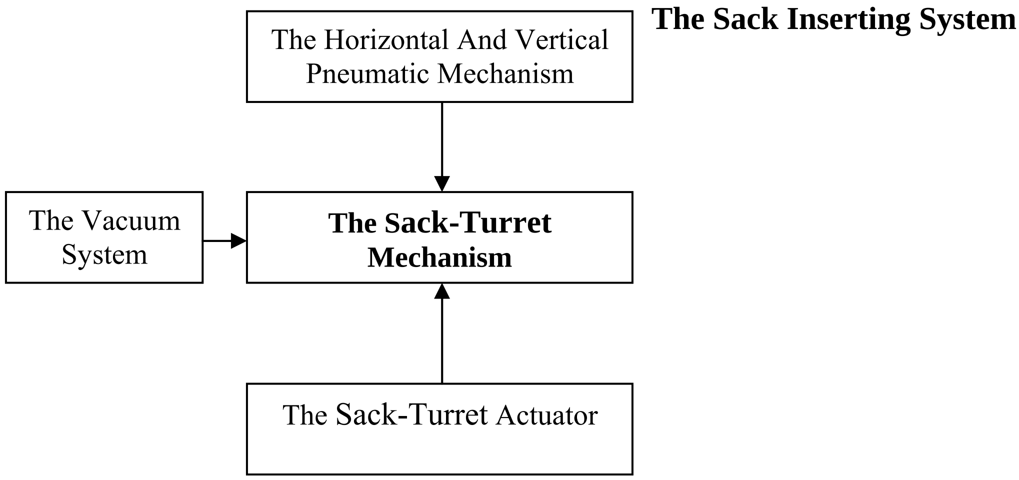


Figure 3.1 The sack inserting mechanism

The basic structure of the controller is given with a PC, I/O interface and software as shown in Figure 3.2.

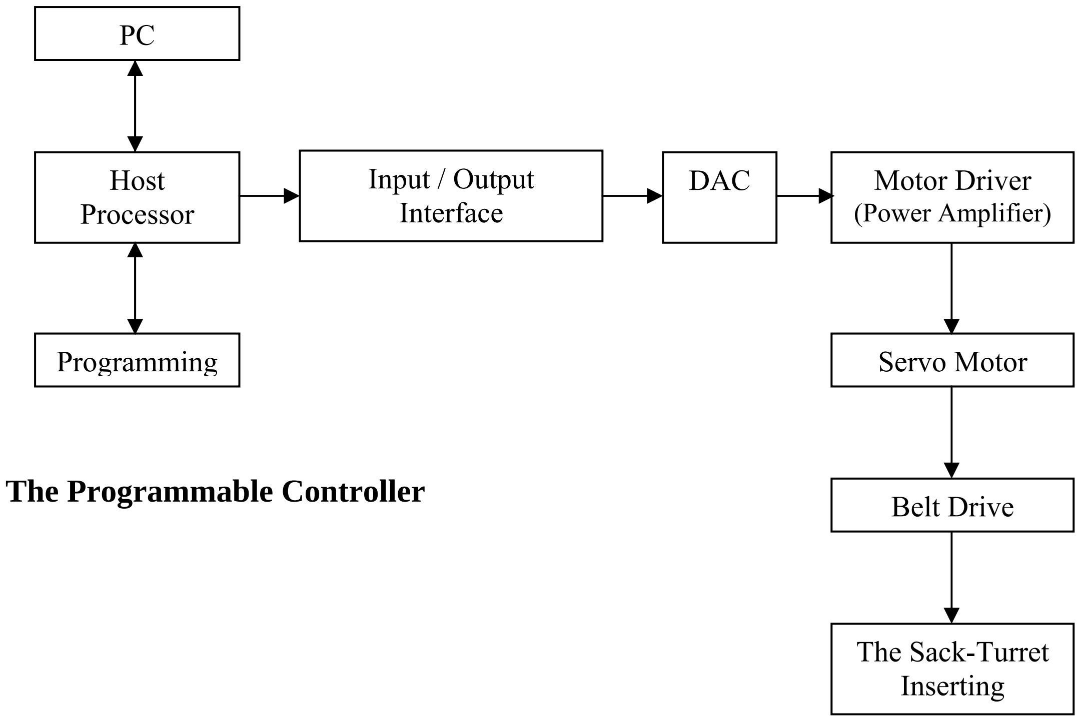


Figure 3.2 The motor control system with mechanism

3.3. Servo Motors

Servo motors are available as AC or DC motors. Early servo motors were generally DC motors because for many years the only type of control for large currents was through SCRs. As transistors became capable of controlling larger currents and switching the large currents at higher frequencies, the AC servo motor became more common. One of the most usable types of motors in servo systems is the permanent magnet (PM) type motor. The PM motor has an encoder or resolver built into the motor housing. This ensures that the device will accurately indicate the position or velocity of the motor shaft. The brushless servo motor is designed to operate without brushes. This means that the commutation that the brushes provide must be provided electronically. Electronic commutation is provided by switching the transistors on and off at appropriate times [30].

Servo motor controllers have become more than just amplifiers for a servo motor. Today servo motor controllers must be able to make a number of decisions and provide a means to receive signals from external sensors and controls in the system, and send signals to host controllers and PLCs that may interface with the servo system. Figure 3.3 shows operation of a servo system [30].

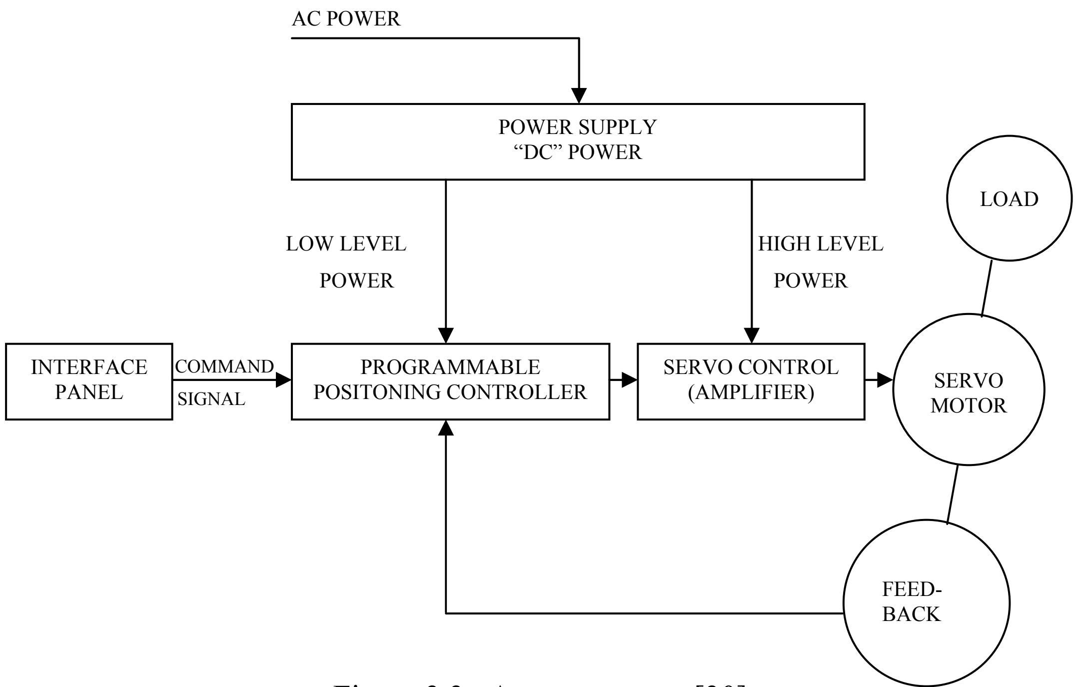


Figure 3.3. A servo system [30]

A command signal given from the user's interface panel comes into the servo's "positioning controller". It is the device which stores information about various jobs or tasks. It has been programmed to activate the motor/load, i.e. change speed/position. The signal then passes into the servo control or "amplifier" section. The servo control takes this low power level signal and increases, or amplifies the power up to appropriate levels to actually result in movement of the servo motor/load. These low power level signals must be amplified: higher voltage levels are needed to rotate the servo motor at appropriate higher speeds; higher current levels are required to provide torque to move heavier loads. This power is supplied to the servo control (amplifier) from the "power supply" which simply converts AC power into the required DC level. It also supplies any low level voltage required for the operation of integrated circuits. In this study, XBR 4250 brushless DC motor (Electrocraft) is chosen. Motor mechanical and electrical data are given in Table 4.1. ACE 1300 (Electrocraft) is used for the high voltage digital servo drive.

Table 3.1. Specifications of encoder

Code	....	Incremental Plus Commutation and once / rev. Pulse Marker
Pulses Per Revolution	....	2.000
Supply Voltage	....	5,0 VDC, Single Supply
Current	....	300 ma AV

3.4. Pneumatic System

Pneumatic systems are an important part of a control loop and they are an integral part of the industrial world. For a long time [31, 32], they have been simple to use as a readily available working medium. The main idea in most pneumatic systems is the availability of the converting the power of compressed air into mechanical energy to perform different kinds of work. Pneumatic systems are used when lighter loads are encountered, where an air supply is available and where fast response required.

Consequently, pneumatic actuators are considered suitable drivers for some mechanisms which will be driven at high speeds such as the sack inserting mechanism, vacuum system, or the horizontal and vertical pneumatic mechanism. The parts of the pneumatic system considered in this system may be given as:

- Air compressor system
- 5/3 way solenoid valve
- Rodless pneumatic cylinder (magnetic)
- Profile pneumatic cylinder (magnetic)
- Sensor (photoelectric proximity switch)
- DC power supply
- Vacuum Generator
- Suction Pad
- 3/2 way vacuum valve

Specifications of each components of the pneumatic system are given in Table 3.2.

Table 3.2. Specifications of pneumatic system

Air Compressor System: (Atlas Copco GA37 VSD)	
Motor:	
Electrical Power	37 kW
Input Voltage	380 V
Rpm	600 - 4.000 rpm
Compressor and Tank:	
Type	49492-1 (Atlas Copco)
Air Pressure	8 bar
Tank Capacity	2.000 Lt.
Flow Rate	7.000 Lt/min
Pneumatic Cylinders:	
Profile Pneumatic Cylinder (magnetic):	
Type	DNC-32-600-PPV-A (Festo)
Diameter Rod	6 mm
Stroke	600 mm
Operating Pressure	1-8 bar

Continued on specifications of pneumatic system:	
Rodless Pneumatic Cylinder (magnetic):	
Type	M/146025L31600 (Norgren)
Cylinder Diameter	25 mm
Maximum Stroke	1.600 mm
Operating Pressure	1-8 bar
Speed	Up to 2 m/s
Operation Temp	-30o C to +80o C max.
Solenoid Valves:	
5/3 way Solenoid Valve:	
Type	MFH-5/3E-1/4 B (Festo)
Pressure Range	2-10 bar
Input Voltage	24 VDC
3/2 way Solenoid Valve:	
Type	MFH-3/2-1/4 (Festo)
Pressure Range	2-10 bar
Input Voltage	24 VDC

Table 3.3. Specifications of vacuum system

Bellow Suction Pads:	
Type	FSGA 33 HT1-60 G1/4-IG (Schmalz)
Diameter	33 mm
Number of Folds	1,5
Suction Pad Material	High temp material HT1 60±5Sh
Vacuum Connection	G1/4" - F
Suction Force	13.6 N
Pull-off Force	39,6 N
Volume	4,75 cm^3
Min. Curve radius (convex)	40,0 mm
Recom. internal hose diameter d	6,0 mm

Continued on specifications of vacuum system:

Dust Filter:

Type .... STF G1-1/4-IG N (Schmalz)

Connection .... Thread G1-1/4"-F

Nominal flow rate .... 96 m^3/h (1.600 l/min)

Max. Vacuum .... -950,0 mbar

Multi-Stage Ejector (controllable):

Type .... SEM-C 100 SD NC AS VD (Schmalz)

Size 100

with .... Silencer

Suction rate .... 673 l/min

Air consumption .... 246 l/min

Vacuum .... -800 mbar

Control .... Normally closed

Shape .... With blow-off system

with .... digital vacuum switch

Operating pressure .... 5 bar

Degree of evacuation .... 81,0 %

Air consumption during evacuation .... 14,8 m^3/h

Air consumption during evacuation .... 246,0 l/h

Maximum suction rate .... 40,3 m^3/h

Maximum suction rate .... 673,0 l/h

Recommended internal hose diameter, compressed-air side .... 6,0 mm

Recommended internal hose diameter, vacuum side .... 32,0 mm

3.4.1. Pneumatic Circuit

The main components of an open loop pneumatic system include sensor (input), solenoid valve (controller), air compressor system, pneumatic cylinder, DC power supply, and the mechanical system as shown in Figure 3.4.

The compressed air is routed to solenoid valves controlling the direction of the air flow, air flow control valves which control the amount of power produced by the pneumatic cylinders to convert the potential energy of the compressed air into kinetic energy at the output by means of a mechanical system.

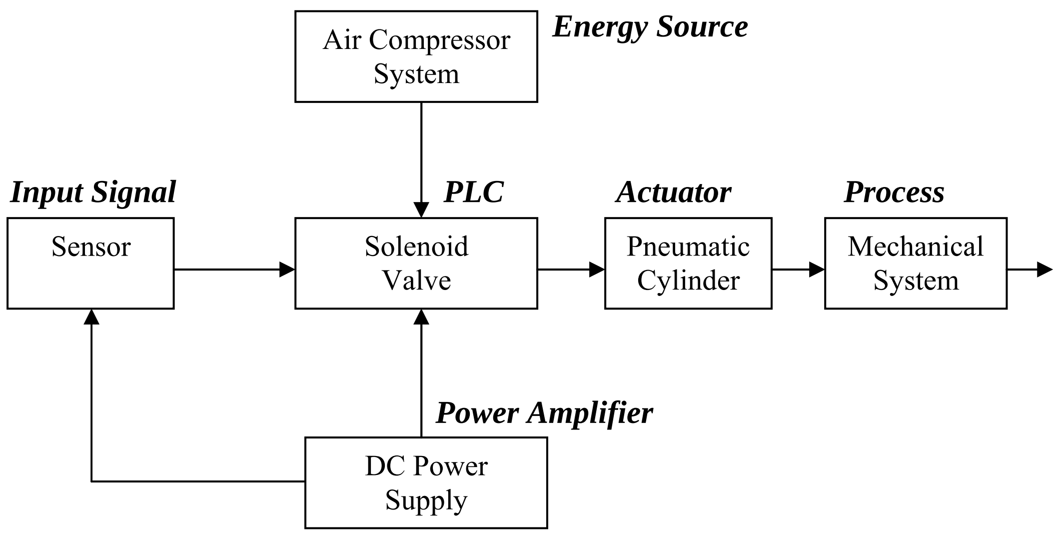
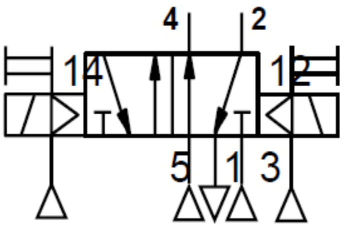


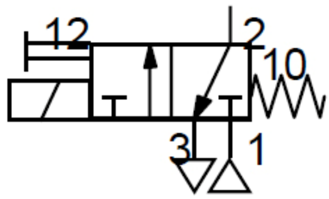
Figure 3.4 The pneumatic control system

(i) Solenoid Valves

In pneumatic systems solenoid valves are used as a controller element being a hardware piece of equipment that employs pneumatic energy to perform system operation. Solenoid valves can make use of the respective advantages of pneumatic and electrical energy and are referred to as electro-pneumatic converters. They consist of a pneumatic valve for the signal output and an electrical switching element, the magnetic coil. When an electrical current flows through the coil, an electro-magnetic field is generated that acts on the coil armature connected to the valve. The magnetic energy is only present as long as current is flowing through the coil. The return spring then switches the valve back to its normal position. In this study, 5/3 way solenoid valves and 3/2 way vacuum valves are used for actuating the pneumatic cylinders and vacuum ejector as seen in Figure 3.5. In addition, 5/3 way valves are generally used for applications such as the control of double acting cylinders. These valves are also implemented as spool valves. A symbolic picture of 5/3 way solenoid valve is shown in Figure 3.5 (a) [33]. The 3/2 way solenoid valve is used to control vacuum ejector as shown in Figure 3.5 (b). Specifications of these valves are presented in Table 3.3.



(a)



(b)

Figure 3.5 The solenoid valve [33]

(ii) Air Compressor

This component is the energy source of the pneumatic system. Atlas Copco compressor specifications are given in Table 3.3. An air compressor system is specified according to its delivery volume and their delivery pressure. Air is pumped through a non-return valve into a strong metal tank called a receiver. When the air inside in receiver reaches the required pressure, the pump switches off. A safety valve is fitted to the receiver so that if a dangerous pressure level is reached the safety valve opens to allow air to escape, reducing the pressure in the receiver.

(iii) DC Power Supply

DC power supply is the amplifier of the pneumatic system. It has some features such as twin power output with tracking function for automatic selection of parallel or serial connection, short circuit protection against external input while providing constant voltage and constant current and 5V/5A constant voltage output. This power supply is used to feed the sensors and solenoid valves with 24 VDC electrical signal specifications shown in Table 3.3.

(iv) Pneumatic Cylinder

The pneumatic cylinders and vacuum ejectors are actuators for the pneumatic system. Two different pneumatic cylinders are used for the sack inserting system: the vertical pneumatic mechanism, the horizontal pneumatic mechanism. The vacuum ejector supplies air suction for holding and inserting the sack by the horizontal and vertical pneumatic mechanism. The pneumatic cylinders and vacuum ejector specifications are given in Table 3.2 and Table 3.3.

3.5 Sensors Used In Pneumatic System

A Sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact [34]. The sensor plays an important role in determining the overall performance of the control system, due to the impression of the dynamic and static characteristics of it. Two different sensors are used for the sack inserting system: a capacitive sensor for the plastic target, and that of inductive proximity for the metal target.

In this project two types of photoelectric proximity switch as sensors are used which are WTB12-3P2431 (Sick) and WL11-2P2430 (Sick). Specifications of each component of the sensors are given in Table 3.4.

Table 3.4. Specifications of sensors

Type : WTB12-3P2431 Photoelectric proximity switch

Product Features:

Sensing range	20 mm. – 350 mm
Relating to	object with 90 % remission
Adjustment	Potentiometer
Light source	LED
Type of light	Red light
Wave length	640 nm
Light spot diameter	Ø 6.0 mm at 200 mm distance

Technical Data:

Design	cuboid
Dimensions (W x H x D)	15.6 mm x 48.5 mm x 42 mm
Supply voltage (min .. max)	DC 10 ... 30 V
Ripple	≤ 5 Vss
Power consumption	≤ 45 mA
Switching output	PNP antivalent
Signal voltage PNP HIGH / LOW	> Vs - 2.5 V / approx. 0 V
Output current max.	100 mA
Response time	≤ 330 µs
Switching frequency	1,500 Hz
Connection type	Connector, M12, 4-pin
Enclosure rating	IP 66, IP 67, IP 69K
Ambient operation temperature, min ... max	-40 °C ... +60 °C
Weight	ca. 120 g
Housing material	die-cast zinc

Continued on specifications of vacuum system:
Type : WL11 -2P2430 Photoelectric proximity switch   ***Product Features:***   Scanning range max. Typ. .... 0.15 ... 10 m   Scanning range .... recommended 0.15 ... 8 m   Relating to Reflector .... PL80A   Light source .... LED   Type of light .... red light   Wave length .... 640 nm   Light spot diameter .... Approx. 50 mm at 3 m distance   Relating to .... object with 90 % remission   ***Technical Data:***   Dimensions (W x H x D) .... 15.6 mm x 48.5 mm x 42 mm   Angle of dispersion .... Approx. 2.2°   Polarisation filter .... yes   Supply voltage min...max. .... DC 10 ... 30 V   Residual ripple .... ≤ 5 Vpp   Current consumption .... ≤ 30 mA   Switching output .... PNP antivalent   Signal voltage PNP HIGH / LOW .... > VS - 2.5 V / approx. 0 V   Output current Ia max .... ≤ 100 mA   Response time .... 2.5 ms   Switching frequency .... 200 Hz   Connection type .... Connector, M12, 4-pin   Enclosure rating .... IP 67   Ambient temperature operation .... –30 °C ... +60 °C   Weight Approx. .... 120 g   Housing material .... ABS, PMMA

3.6 Synchronization With Other Systems

This section describes the synchronization all of the actuators in the system to insert PE sack into the PP. The operation steps of actuators are sequential, in a defined order for the purpose of synchronization. Twenty-one (21) operations (18 independent and 3 dependent) are needed to perform a sack insertion. Three dependent operations are performed by the servo motor. Eighteen independent operations are carried out by three horizontal and vertical pneumatic cylinders and vacuum systems. The six of them are performed by horizontal and vertical pneumatic cylinders and vacuum systems. The initiations of the operations are carried out by vertical pneumatic cylinders whereas the terminations are performed by that of the horizontal.

The total time of all the operations is accepted as a specified unit of time to get the final sack – or when the PE sack is inserted into the PP. All the operations are explained in the following sections. Since two different design alternatives are considered, the operations are specified for each one separately to automize the manual inserting procedure. They are given in the following sections as sequence of operations involved.

3.6.1 First Sack Inserting Mechanism

Manual inserting procedure is given in Chapter 2 with Figures 2.1 to 2.9, performed by an operator. When the automatic inserting is considered, the 1st sack inserting mechanism is given in Figure 2.13 as an overall view. Remembering this figure, the procedure of automation can be summarized as the following steps.

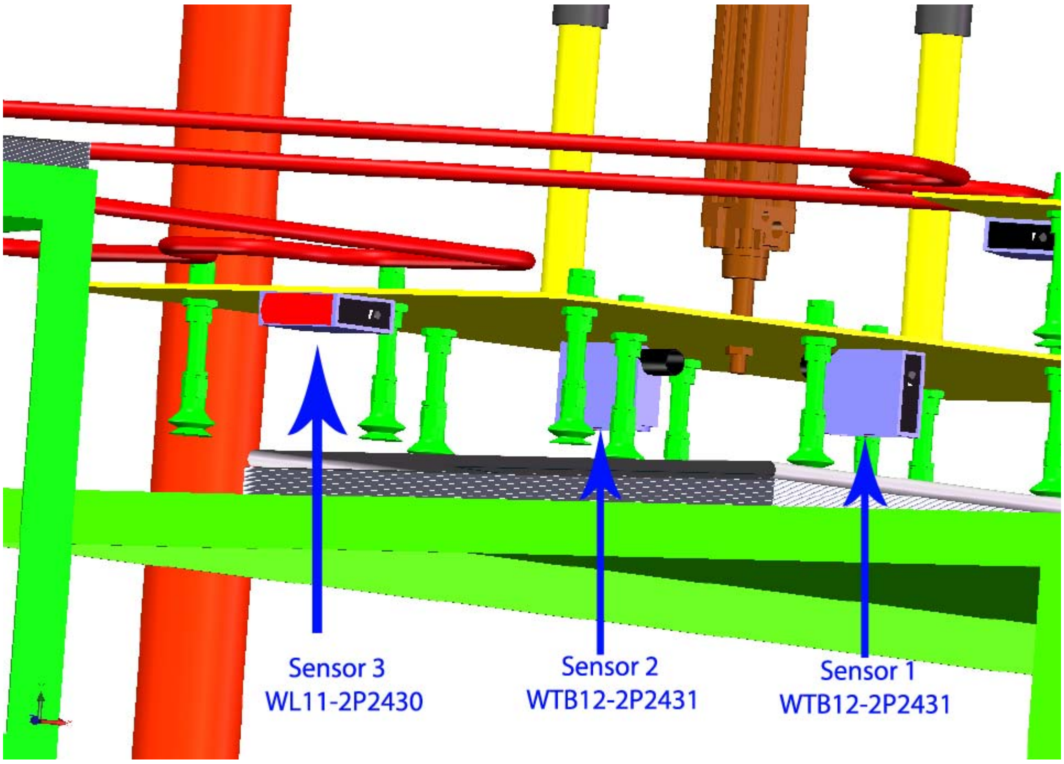


Figure 3.6 A view of sensors of the first sack inserting mechanism

The sensors (Sensors 1, 2 and 3) placed on the 1st vacuum system of the first sack inserting mechanism are showed in Figure 3.6. The sensors of the other vacuum systems (2nd, 3rd, 4th, 5th and 6th) are placed in the same manner.

Sensors 1, 4, and 7 are WTB12-2P2431 type; sensors 2, 5, and 8 are WTB12-2P2431 type; sensors 3, 6, and 9 are WL11-2P2430 type.

Step-1 Positioning of Vertical Pneumatic Cylinder for PE Sack

The vertical pneumatic cylinder is moved down for positioning the vacuum system close to the PE sack via sensor 1. The sensor 1 is used to position the vertical pneumatic cylinder which holds the vacuum system. The other steps (step 2 - step 7) are dependent on this step.

Step-2 Vacuum On

The vacuum system is initiated to hold the PE sack via sensor 2. The vacuum is become on and then the upper part of the PE sack is sucked by vacuum and the bottom side of it is opened by gravitational force.

Step-3 Positioning of Vacuum

The vertical pneumatic cylinder is moved up for positioning the vacuum system until it reaches the same height of the sack-turret inserting platform via sensor 3.

Step-4 Placing PE Sack

After positioning the vacuum system height to the same with the sack inserting platform, the horizontal pneumatic cylinder is moved through the sack inserting platform until the pre-determined distance is reached.

Step-5 Vacuum Off

The vacuum is then terminated. The vacuumed PE sack is placed on the sack-turret inserting platform in this way.

Step-6 Positioning of Horizontal Pneumatic Cylinder for the PE Sack

The horizontal pneumatic cylinder is moved back until the vacuum system reaches the top of the PE storing table and then it is terminated.

Step-7 Positioning of Sack-Turret Inserting Platform of the PE Sack

The sack-turret inserting platform which has already inserted PE sack is turned 60^o clockwise (CW) by the servo motor.

Step–8 Positioning of Vertical Pneumatic Cylinder for the PP Sack

The vertical pneumatic cylinder is moved down for positioning the vacuum system close to the PP sack via sensor 4.

Step-9 Vacuum On

The vacuum ejector system is initiated to hold the PP sack via sensor 5. The vacuum is become on and then the upper part of the PP sack is sucked by vacuum and the bottom side of it is opened by gravitational force.

Step-10 Positioning of Vacuum

The vacuum system is moved by the vertical pneumatic cylinder up to reach same height as the sack-turret inserting platform via sensor 6.

Step-11 Placing PP Sack

The horizontal pneumatic cylinder is moved through the sack inserting platform until the pre-determined distance is reached. The PP sack is placed in this way.

Step-12 Vacuum Off

The vacuum is terminated. The PP sack is placed on the sack-turret inserting platform which has already held the PE sack.

Step-13 Positioning of Horizontal Pneumatic Cylinder for the PP Sack

The horizontal pneumatic cylinder is moved back until the vacuum system reaches the top of the PP storing table and then it is terminated.

Step-14 Positioning of Sack-Turret Inserting Platform of the PE Sack Inserted into the PP

The sack-turret inserting platform which holds the PE sack inserted into the PP is turned 60^o clockwise (CW) by the servo motor.

Step-15 Positioning of Vertical Pneumatic Cylinder for the Final Sack

The vertical pneumatic cylinder is moved down for positioning the vacuum system close to the final sack via sensor 7.

Step-16 Vacuum On

The vacuum ejector system is initiated to hold the final sack via sensor 8. The vacuum is become on and then the upper part of the final sack, which is the PP sack, is sucked by the vacuum. The bottom side of it is become loose due to gravitational force.

Step-17 Positioning of Vacuum

The horizontal pneumatic cylinder is moved through the final sack storing table via sensor 9.

Step-18 Vacuum Off

The vacuum is terminated on the final sack storing table for delivery of the final sack.

Step-19 Positioning of Vertical Pneumatic Cylinder

The vertical pneumatic cylinder is moved up for and returns the vacuum system to its starting position.

Step-20 Positioning of Horizontal Pneumatic Cylinder

The horizontal pneumatic cylinder is moved back until the vacuum system reaches its starting position.

Step-21 Positioning of Sack-Turret Inserting Platform

The sack-turret inserting platform, which has already removed the final sack, is turned 60^{o} clockwise (CW) by the servo motor. The first final sack is obtained and the sack-turret is ready for the next inserting operation.

3.6.2 Second Sack Inserting Mechanism

The second design alternative for the inserting mechanism is already given in Figure 2.20. There are differences in design, but the manual procedure is again imitated here to perform the sack inserting operation. The steps to be performed are given as the following.

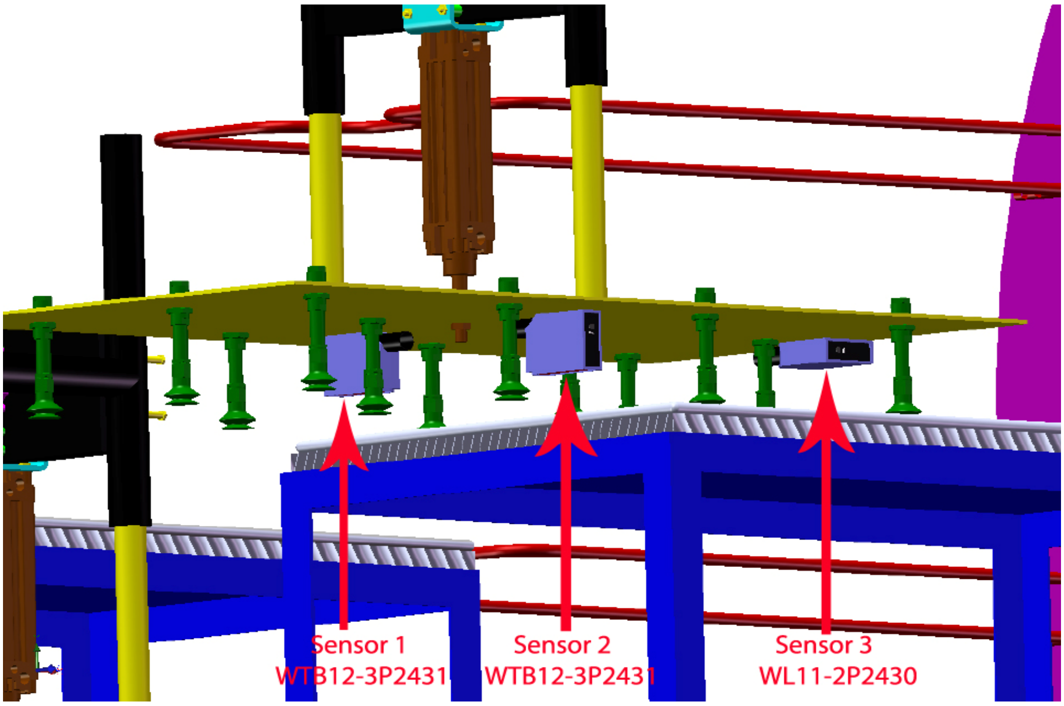


Figure 3.7 A view of sensors of the second sack inserting mechanism

The sensors (Sensors 1, 2 and 3) placed on the 1st vacuum system of the second sack inserting mechanism are showed in Figure 3.7. The sensors of the other vacuum systems (2nd and 3rd) are placed in the same manner.

Sensors 1, 4, and 7 are WTB12-2P2431 type; sensors 2, 5, and 8 are WTB12-2P2431 type; sensors 3, 6, and 9 are WL11-2P2430 type.

Step-1 Positioning of Vertical Pneumatic Cylinder for the PE Sack

The vertical pneumatic cylinder is moved down for positioning the vacuum system close to the PE sack via sensor 1. The sensor 1 is used to position the vertical pneumatic cylinder which holds the vacuum system. The other steps (step 2 - step 7) are dependent on this step.

Step-2 Vacuum On

The vacuum system is initiated to hold the PE sack via sensor 2. The vacuum is become on and the upper part of the PE sack is sucked by the vacuum and the bottom side of it is opened by gravitational force.

Step-3 Positioning of Vacuum

The vertical pneumatic cylinder is moved up and positions the vacuum system at the same height as the sack-turret inserting platform via sensor 3.

Step-4 Placing PE Sack

After positioning the vacuum system, the horizontal pneumatic cylinder is moved through the sack-turret inserting platform to the pre-determined distance.

Step-5 Vacuum Off

The vacuum is then terminated. The vacuumed PE sack is placed on the sack-turret inserting platform.

Step-6 Positioning of Horizontal Pneumatic Cylinder for the PE Sack

The horizontal pneumatic cylinder is moved back until the vacuum system reaches the top of the PE storing table and then it is terminated.

Step-7 Positioning of Sack-Turret Inserting Platform of the PE Sack

The sack-turret inserting platform, which holds already the inserted PE sack, is turned 60^o counterclockwise (CCW) by the servo motor.

Step-8 Positioning of Vertical Pneumatic Cylinder for the PP Sack

The vertical pneumatic cylinder is moved down and positions the vacuum system close to the PP sack via sensor 4.

Step-9 Vacuum On

The vacuum ejector system is initiated to hold the PP sack via sensor 5. The vacuum is become on and then the upper part of the PP sack is sucked by the vacuum and the bottom side of it is opened by gravitational force.

Step-10 Positioning of Vacuum

The vertical pneumatic cylinder is moved up and positions the vacuum system at the same height as the sack-turret inserting platform via sensor 6.

Step-11 Placing PP Sack

The horizontal pneumatic cylinder is moved through the sack-turret until the pre-determined distance is reached. The PP sack is placed in this way.

Step-12 Vacuum Off

The vacuum is terminated. The PP sack is placed on the sack-turret inserting platform which already holds the PE sack.

Step-13 Positioning of Horizontal Pneumatic Cylinder for the PP Sack

The vacuum system is moved to the height of the PP storing table by the horizontal pneumatic cylinder and then it is terminated.

Step-14 Positioning of Sack-Turret Inserting Platform for the Final Sack

The sack-turret inserting platform which holds the PE sack inserted into the PP is turned 60^{o} counterclockwise (CCW) by the servo motor.

Step-15 Positioning of Vertical Pneumatic Cylinder for Final Sack

The vertical pneumatic cylinder is moved down and positions the vacuum system close to the final sack via sensor 7.

Step-16 Vacuum On

The vacuum ejector system is initiated to hold the final sack via sensor 8. The vacuum is become on and then the upper part of the final sack, which is PP, is sucked by the vacuum and the bottom side of it is loosen due to gravitational force.

Step-17 Positioning of Vacuum

The horizontal pneumatic cylinder is moved through the final sack storing table via sensor 9.

Step-18 Vacuum Off

The vacuum is terminated on the final sack storing table for delivery of the final sack.

Step-19 Positioning of Vertical Pneumatic Cylinder

The vertical pneumatic cylinder is moved up and returns the vacuum system to its starting position.

Step-20 Positioning of Horizontal Pneumatic Cylinder

The horizontal pneumatic cylinder is moved back and returns the vacuum system to its starting position.

Step-21 Positioning of Sack-Turret Inserting Platform

The sack-turret inserting platform, which has already removed the final sack, is turned 180^o counterclockwise (CCW) by the servo motor. The 1^{st} final sack is obtained and the sack-turret is ready for the next inserting operation.

3.7 Automation Of Inserting System

Automation is the use of control systems (such as numerical control, programmable logic control, and other industrial control systems), in concert with other applications of information technology (such as computer-aided technologies [CAD, CAM, CAx]), to control industrial machinery and processes, reducing the need for human intervention [35]. In the scope of industrialization, automation is a step beyond mechanization. Whereas mechanization is provided by human operators with machinery to assist them with the muscular requirements of work, automation greatly reduces the need for human sensory and mental requirements as well. Processes and systems can also be automated.

Many roles for humans in industrial processes presently lie beyond the scope of automation. Human-level pattern recognition, language recognition, and language production ability are well beyond the capabilities of modern mechanical and computer systems. Tasks requiring subjective assessment or synthesis of complex sensory data, such as scents and sounds, as well as high-level tasks such as strategic planning, currently require human expertise.

Specialized hardened computers, referred to as programmable logic controllers (PLCs), are frequently used to synchronize the flow of inputs from (physical) sensors and events with the flow of outputs to actuators and events. This leads to precisely controlled actions that permit a tight control of almost any industrial process. Human-machine interfaces (HMI) or computer human interfaces (CHI), formerly known as *man-machine interfaces*, are usually employed to communicate with PLCs and other computers, such as entering and monitoring temperatures or pressures for further automated control or emergency response [36].

The main advantage of automation can be given as replacing human operators in tedious tasks, replacing humans in tasks that are done in dangerous environments such as fire, nuclear facilities, under water, etc,; making tasks that are beyond human capabilities such as handling heavy loads, large objects, extremely hot or cold substances or economy improvement. The main disadvantages of automation can be counted as technology limits, unpredictable development costs, and high initial costs [37].

Different types of automation tools exist:

- ANN - Artificial Neural Network
- DCS - Distributed Control System
- HMI - Human Machine Interface
- SCADA - Supervisory Control and Data Acquisition
- PLC - Programmable Logic Controller
- PAC - Programmable Automation Controller
- Instrumentation
- Motion control

3.7.1 PLC Operated Pneumatic Cylinders

In this thesis, the PLC is thought of as an automation tool, Figure 3.8 shows the basic elements of PLC.

A PLC-operated system consists of a power supply, an input device such as a limit switch, push button, sensor etc., an input module, which is part of the PLC, a logic unit, which is the ‘brains’ within the PLC, an output module, which is also part of the PLC, and an output device such as a solenoid valve, lamp, relay, motor starter etc.

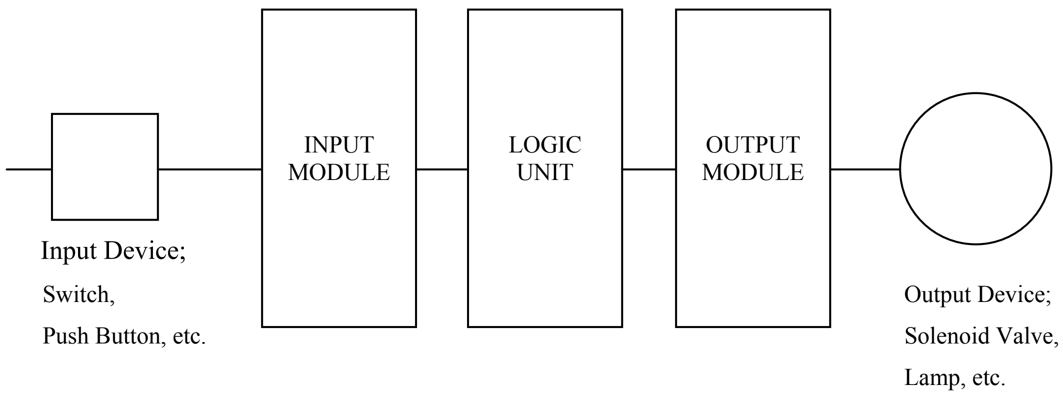


Figure 3.8 The basic elements of PLC [38]

The PLC is in essence a device that is specifically designed to receive input signals and emit output signals according to the program logic. PLCs come in many shapes and sizes from small, self-contained units with very limited input/output capacity to large, modular units that can be configured to provide hundreds or even thousands of inputs/outputs. The PLC requires inputs from sensors and responds with outputs according to a set of instructions called the program in order to control a machine [38].

The steps involved in using a PLC are:

i. Determine the program specification.
ii. Define the inputs and outputs and assign a unique number to each
iii. Design the ladder diagram.
iv. Enter the program into the PLC memory using a programming terminal (also called coding).
v. Test the PLC program 'off line'.
vi. Integrate the tested PLC into the plant or machine control system and check for correct operation.

Steps 1 to 3 are general for all PLCs but steps 4 to 6 are PLC specific.

3.7.2 Routine Application with PLC

In the following paragraph, an example is presented to realize routine applications of PLC. In this example, one rodless pneumatic cylinder, one profile cylinder, two 5/3 solenoid valves and one 3/2 solenoid valve are used. The cylinders A and B are repetitively operated in a sequence of A(+) B(+) B(-) A(-). The circuit is controlled by reed-contacts. This type of circuit is presented in Figure 3.9.

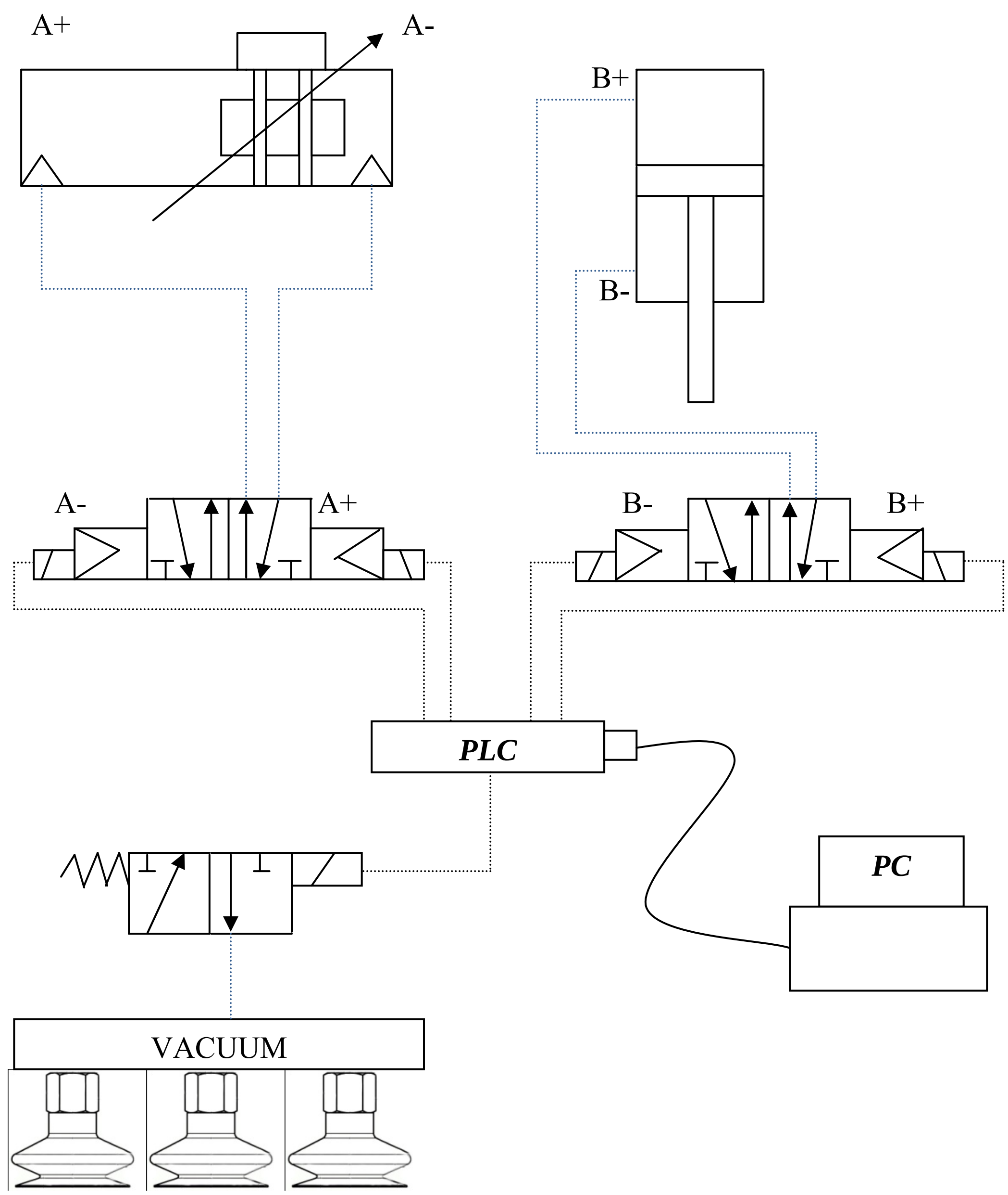


Figure 3.9 Two pneumatic cylinders and vacuum system with PLC control

CHAPTER 4

MODELING AND ANALYSIS OF SACK INSERTING MECHANISM

4.1. Kinematics of Mechanisms

Automated production systems commonly use two types of motion: intermittent and continuous. Intermittent motion is characterized by a sequence of motions and dwells. Many applications are available in machinery performing intermittent motion. Different mechanisms performing intermittent motion include the Geneva Mechanism, Rachet and pawl mechanism, Cam and follower, for example [39]. The Geneva Wheel is a commonly applied one. It provides intermittent rotary motion and is widely used in both low- and high-speed machinery. It is extensively used in automatic machinery, for example, where a spindle, turret, or worktable must be indexed.

The kinematics of mechanisms can be performed in four parts: functional synthesis, type determination, kinematic analysis and synthesis. *Functional synthesis* determines the mechanisms which can realize a given or implied set of functional requirements. The mathematical formulation of these requirements and the theory is a present field of research. One way is to analyze and compare the known mechanisms in terms of functions they can perform. *Type Determination* refers to investigation of the known mechanisms for their topological characteristics such as the degree-of-freedom, number of rigid bodies, number of joints, etc. *Kinematic Analysis* is the study of the motion characteristics of a known mechanism. The displacement, velocity and acceleration of a point on a moving body in a mechanism are found. *Kinematic Synthesis* is the determination of the mechanism parameters such as the link dimensions for example [40, 41].

This chapter presents details of the sack inserting mechanism with its available trajectory. The manual sack inserting procedure is observed many times, and a model trajectory for the system is built and discussed. This motion is given in rectangular coordinates, X-Y. This motion is provided by a servo driven system. A mathematical model is derived for motor driven horizontal sack inserting mechanism with turret configuration. Simulation results are presented for intermittent motion representing a second order system model with the actuator and the load.

4.2 Trajectories on Inserting Mechanism

The manual sack inserting mechanism has a trajectory like Figure 4.1. The first step of the manual sack inserting process is to place the PE sack. The trajectory of the PE sack is drawn by the green line and arrow (Number 1). After placing the PE sack, the PP is placed on it and the trajectory of the PP sack is drawn by the blue line and arrow (Number 2). The final sack, which is the PE sack inserted into the PP sack, is removed outside of the sack inserting platform. Its trajectory is drawn by the red line and arrow (Number 3).

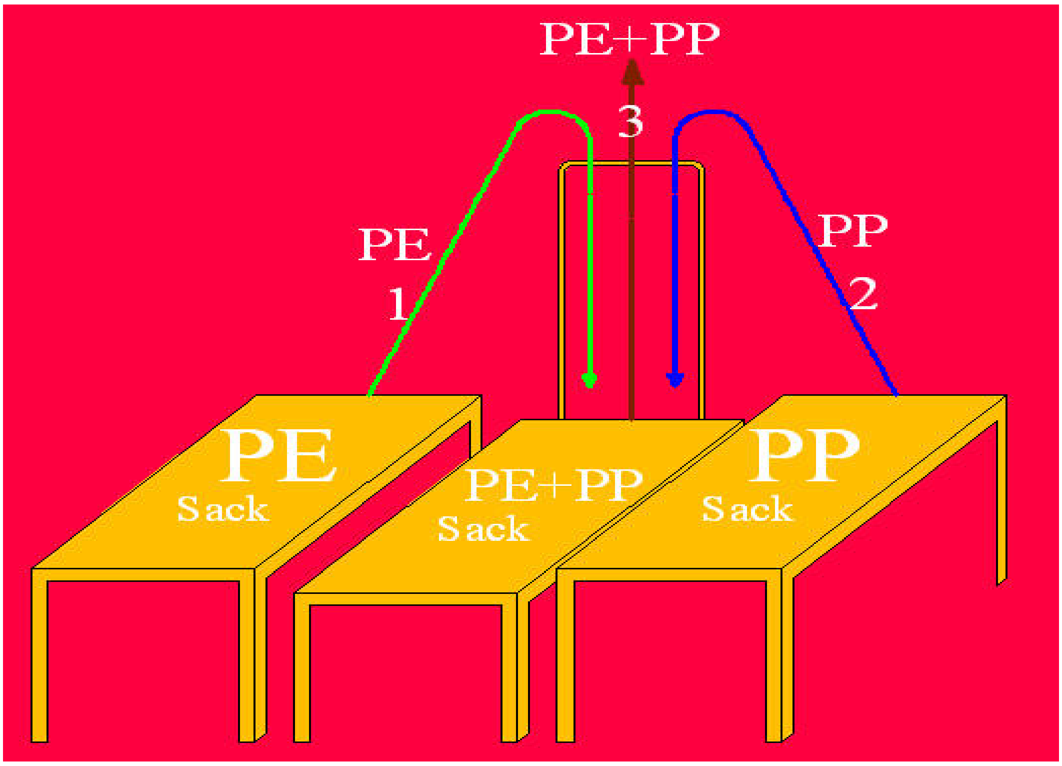


Figure 4.1 Manual sack inserting mechanism trajectories

Motion design refers to the adaptation of motion before implementation into a real system. The trajectory for each sack insertion can be represented by motion of segments and also with a mathematical function; for example polynomials. Its initial conditions are determined by looking at the manual inserting procedure in an X-Y coordinate system. Figure 4.2(a) and (b) show representation of trajectories for both the PE and PP sacks in X-Y coordinate. Inserting trajectory for completed inserting procedure is given in Figure 4.2(c). There is a similarity between the trajectory of the manual sack inserting mechanism, the first sack inserting mechanism and that of the second seen in Figure 4.2.

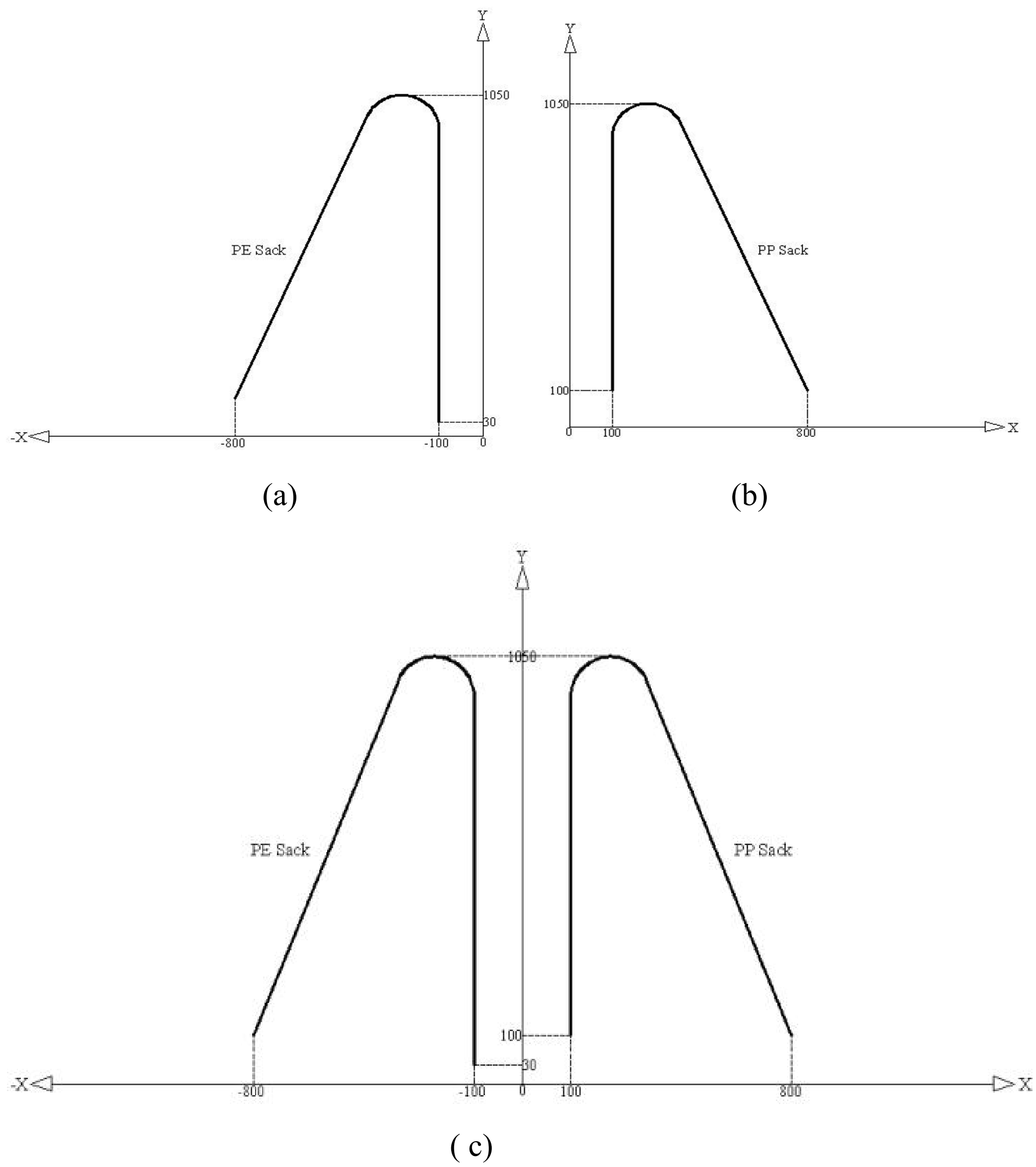


Figure 4.2. Representation of trajectory in X-Y coordinates

4.3. Mathematical Model of Horizontal Sack Inserting Mechanism

There are different actuators – either AC, DC, stepper electric motors, hydraulic or pneumatic ones – in use. In this study, DC servo motors are considered. Permanent magnet DC motors are found in two different designs: brushed (PMDC) and brushless structure (BLDC). A brushless motor has been developed to eliminate mechanical commutation and brushes. The dynamic characteristic of a BLDC motor are similar to PMDC motors [42, 43]. Since commutation is electronically achieved with Hall Effect sensors, the structure offers less rotor inertia. In this structure, the coils are the stator and the rotor is the permanent magnet. These motors also have several advantages such as high reliability, quiet operation, high speeds (up to 10,000 rpm) and high peak torques (more than 20 times compared to conventional ones). BLDC motors can be used with an incremental encoder. In this application, preferably a BLDC motor should be chosen for rotary motion output as indexing and pneumatic action is necessary for other purposes of inserting.

This section presents a mathematical model for a horizontal sack inserting mechanism given in Figure 2.13. The dynamic characteristic of the actuator is studied by using the mathematical model available. Here an inserting turret is used; an inserting is performed by 60˚ indexing at the output. This is provided by a servo motor as a servo mechanism in the application.

4.3.1. Electromechanical Modeling

Referring to the 1st alternative mechanism, a horizontal sack inserting system, a mathematical model is developed. The system consists of a BLDC motor with an incremental encoder for positional feedback. A horizontal turret is attached indirectly to the motor via a belt drive. System representation is schematically given in Figure 4.3.

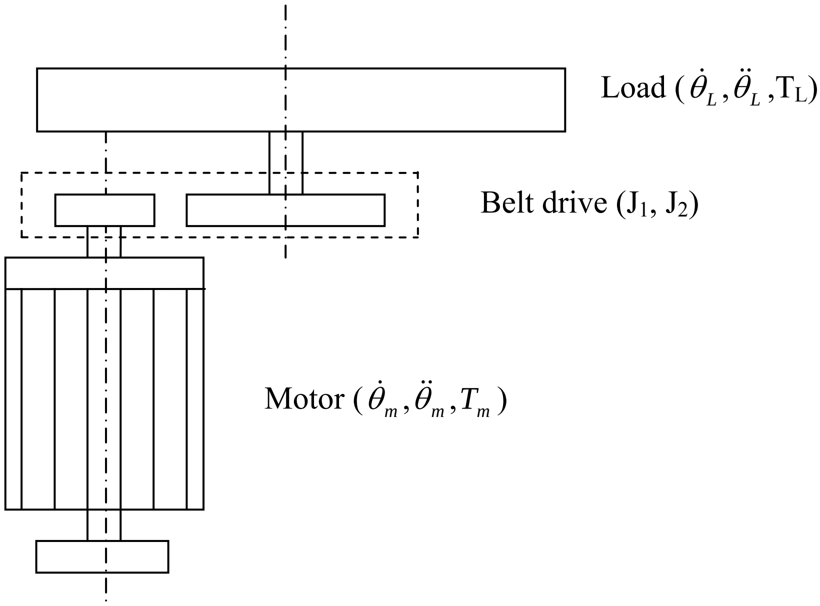


Figure 4.3. Schematic representation of motor-load system

Since a Brushless DC motor is chosen, the equations can be written by looking at a representative system as [43, 44]

$$L\frac{di(t)}{dt} + Ri(t) + V_{emf}(t) = V_{app}(t) \tag{4.1}$$

$$J\frac{dw(t)}{dt} + Dw(t) - T(t) = T_L \tag{4.2}$$

Where $V_{app}(t)$ is the applied voltage, w(t) is the motor angular velocity, i(t) is the motor circuit current, R is the motor resistance, L is the motor inductance, and D is the motor viscous coefficient. J refers the total inertia referred to motor shaft and the rotary actuator, motor as

$$J = J_m + J_1 + \frac{J_2}{N^2} + \frac{J_L}{N^2} \tag{4.3}$$

J_m is the motor inertia, J_1 and J_2 are the inertias of pulley 1 and 2, J_l is the load inertia, calculated from the horizontal turret configuration. A belt drive model contains the belt ratio (ratio of pulley diameters), the efficiency (η). [45, 46] Thus

$$N = \frac{\theta_m}{\theta_L} = \frac{w_m}{w_L} = \frac{d_2}{d_1} \tag{4.4}$$

The applied voltage in equation (4.1) is calculated using PID control which combines P (Proportional), I (Integral) and D (Derivative) control action producing the necessary voltage from the amplifier. This control takes the past, current and future error [44]. It can be represented as

$$V_{app}(t) = K_p e(t) + K_v \dot{e}(t) + K_i \int_0^t e(t)dt \qquad (4.5)$$

Here P control is the simplest type of control and always tried first in a control system. Other types of control are considered to improve the system performance. The damping action is introduced by D control providing stability. Finally integral control reduces the steady state error. In the application e(t) refers to the positional error. It is fed back to the system to get proper indexing after reduction. In equations (4.1) and (4.2); $V_{emf}(t) = K_e w(t)$ and $T(t) = K_t i(t)$ representing K_e is the motor back emf constant, K_t is the motor torque constant. These equations can be represented as first order ones as

$$\begin{bmatrix} L_a & 0 \\ 0 & J \end{bmatrix} \begin{bmatrix} \dot{i}_a \\ \dot{w} \end{bmatrix} + \begin{bmatrix} R_a & K_e \\ -K_t & D \end{bmatrix} \begin{bmatrix} i_a \\ w \end{bmatrix} = \begin{bmatrix} V_{app}(t) \\ T_L \end{bmatrix} \qquad (4.6)$$

4.3.2. PID Controller Implementation

Tuning a servo system is necessary in that the input signal is followed as closely as possible. When the system is properly tuned, the fastest response can be obtained with little or no overshoot. Since PID is simple in structure and easily applicable, many studies can be found on PID design and tuning methods. Tuning methods can be given as Heuristic, frequency response based, analytical, numerical optimization and also adaptive. Effects of P, I, and D tuning on closed loop response are also studied by many researchers [48, 49]. The system used here is given with a PID controller schematically in Figure 4.4.

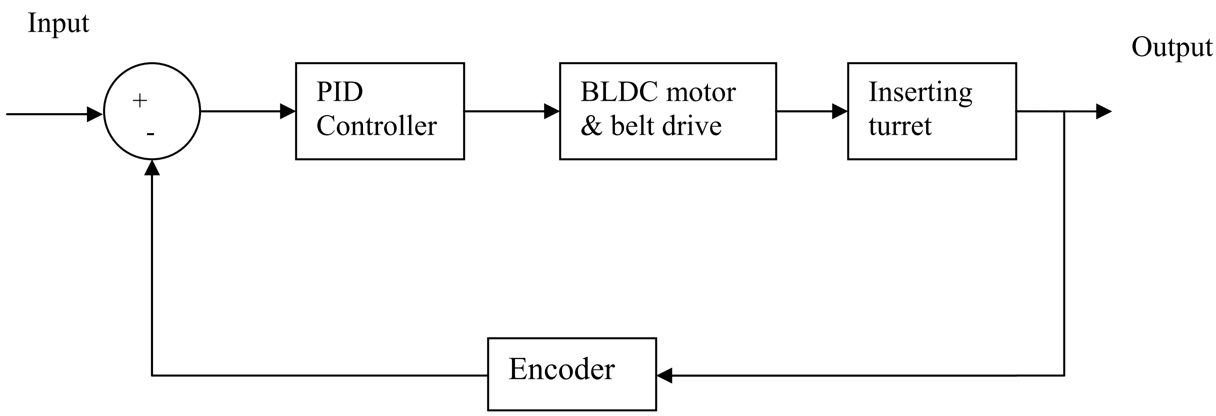


Figure 4.4. Structure of position control

The electro mechanical characteristics of the motor are given in Table 4.1.

Table 4.1. Motor parameters [47]

Parameter Description	***Value***
Motor inertia	J_m=0.000813 kg.m^2
Motor torque constant	K_t=0.745 Nm/A
Motor back emf constant	K_e=86 (V/krpm)
Motor resistance	R=1.35 Ω
Motor inductance	L=7.3 mH
Electrical time constant	t_e=5.92 ms
Mechanical time constant	t_m=1.80 ms
Maximum speed (no load)	w=3000 rpm
Static friction torque	T_f=0.113 Nm

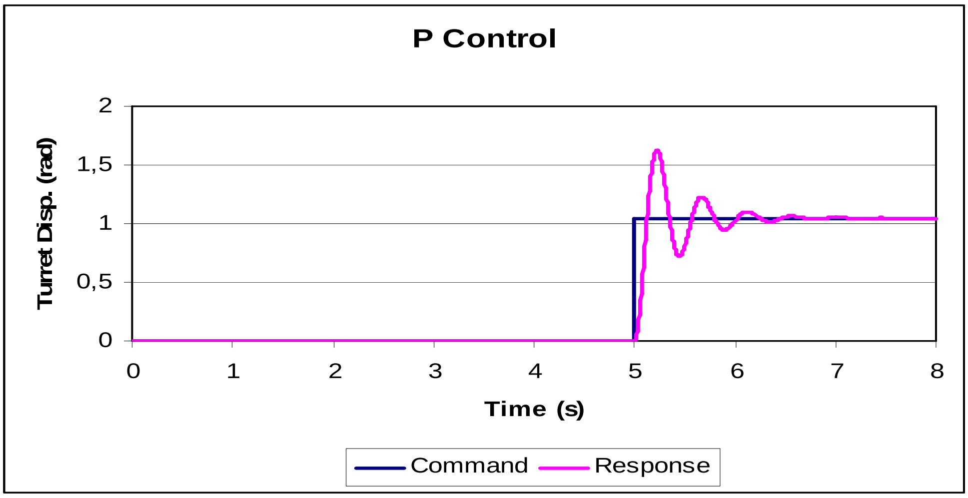
4.3.3. Numerical Simulation

There are different packages to solve equations of interest. Here Simulink and Pascal are used successively. Simulink is a software package which is graphical and interactive. It is mainly used for modeling, simulating and analyzing dynamics systems whether linear or nonlinear in character [50, 51]. Block diagrams are built to represent the system. Having obtained equations for the inserting mechanism and the horizontal turret, the 4th order Runge Kutta method is applied for solutions. The time interval taken for integration is Δt=0.01 sec. The system equations (4.1) and (4.2) are linear in character. They are represented in state space for and solved with initial conditions given as motor current, motor displacement and motor velocity. For optimum performance, K_p, K_v and K_i must be tuned properly by looking at the closed loop performance of the system.

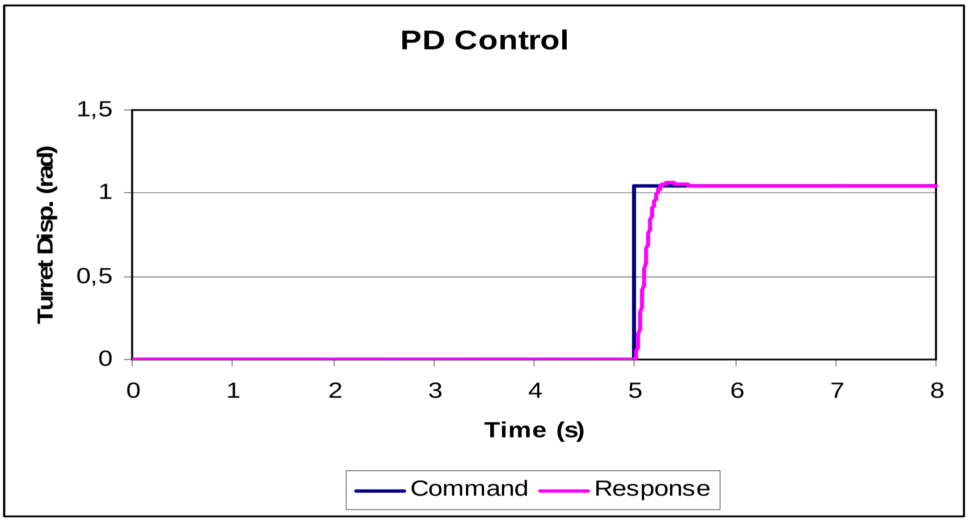
4.4. Simulation Results for Sack Inserting Mechanism

The dynamic model equations; (4.1) and (4.2) are solved to simulate system behavior. The response of the horizontal sack inserting mechanism is dependent on specified inputs. Here a step input is given, with N=6 belt-pulley ratio. The motor is required to turn 360˚, resulting 60˚ angular indexing at the end. Load inertia is calculated using the figures given in Chapter 2, horizontal turret configuration as J_L=2.52 kg/m^2. Many observations are taken by running simulations independently. Three basic observations are given here corresponding to P, PD and PID control system performance.

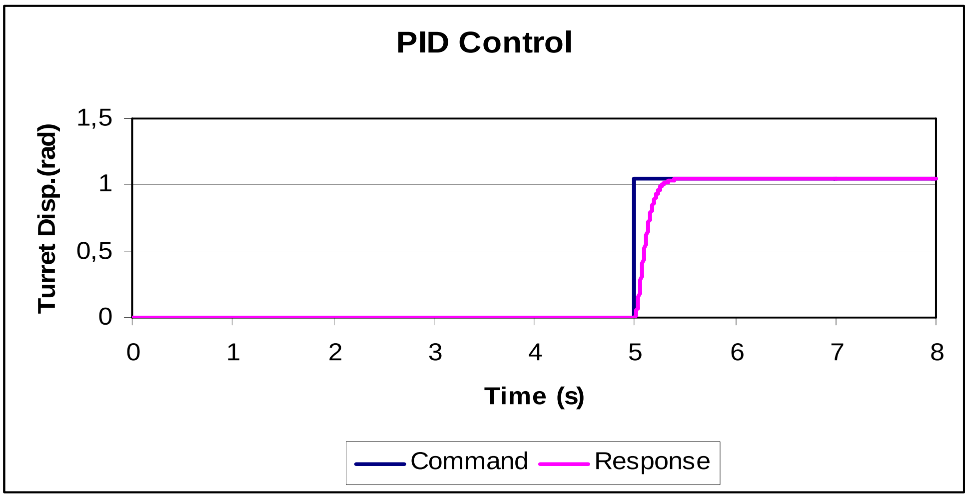
Step responses of BLDC motor are given in Figures 4.5. (a), (b) and (c) with P, PD and PID action. The period of motion is taken as 8 seconds. The dwell motion is 5 seconds where the pneumatic action for holding the sack is performed. Rotation of turret for proper positioning is performed in 3 seconds to stay ready, in front of other table for sacks. Here the load is taken as a hexagonal turret made of galvanized steel. During successive runs, P action is performed K_p=30, PD action is applied using K_p=30.0 and K_d=2.0 and finally, K_p=30.0, K_d=2.0 and K_i=1.0 with PID. Motor response is improved by applying control actions properly. Acceptable system responses are obtained.



(a)



(b)



(c)

Figure 4.5. Step responses for different controllers (Horizontal turret)

CHAPTER 5

CONCLUSIONS

5.1. About Present Work

Machine design is an interdisciplinary process such that kinematic and dynamic analysis, selection of actuators and transmission elements, system integration and control must be considered together. In this study, an introduction with basics on packaging and materials used PP and PE, later PP and PE sack production are given in Chapter 1. The design of the inserting mechanism is included in Chapter 2 with the criteria to be held during design. The manual inserting procedure is given. Two inserting mechanism alternatives are designed: the horizontal turret and the vertical turret configurations. Both designs are compared and one is chosen for application. In Chapter 3, the control of the inserting mechanism is discussed. Control issues and actuators necessary for the system are explained. Control alternatives are included. Chapter 4 contains the mathematical framework for analysis, modeling and simulation. A brushless DC motor is driven by belt and pulley arrangement. A mathematical model is built with included actuator dynamics. Machine performance for integrated motion is determined with different controllers as, P, PD and PID.

5.2. Discussions on Proposed Design

This work presents a comprehensive study for inserting PE sack into that of PP, the basic sack placing type used in the manual sack inserting procedure by means of an electromechanical system. The system referred to as the sack inserting system was designed and controlled by benefiting from technological developments of computers, actuators, etc. Development in technology has made it possible to design very complicated machines, equipment and computer controlled machines in several industries and are the examples of today’s technological developments.

During the design of the whole system the function of the sack inserting system and its decomposition were firstly considered. The function was broken down into the sub-mechanisms and components, and then assemblies were developed to provide these functions. The sack inserting system involves different mechanisms: the sack-turret, the sack-turret actuator, the horizontal-vertical pneumatic cylinders and the vacuum system. The main mechanism was the sack inserting mechanism. The others were accepted as auxiliary mechanisms to be developed and designed referring to the sack inserting mechanism. The design studies on each mechanism, which depended on the functional requirements, design criteria, assumptions and general properties of the sacks, were realized.

In this study; rodless and profile pneumatic cylinders (Norgren), solenoid valves (Festo), vacuum equipments (Schmalz), photoelectric proximity switches (Sick), brushless DC motor and servo driver (Electrocraft) were used.

5.3. Recommendations for Further Work

Having completed simulation of the system with real system data with an available fertilizer filling procedure, there will be a chance of applying this design in the future. This will eliminate the need for individual human effort as the process will be done automatically. Of course, production and integration of parts will take some time. Inserting procedure will be quicker and no time loss will happen in the operating system.

Building a prototype inserting system will definitely need financial support. When a firm is found to sponsor the project, an inserting mechanism will be built and field tested. Studies and personal contacts are still continuing in this effort.

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APPENDIX A

A 1. *Chapter 1- Introduction*

A 2. *Chapter 2- Design Of Inserting Mechanisms*

Figure A.2.1. Manual inserting platform dimensions

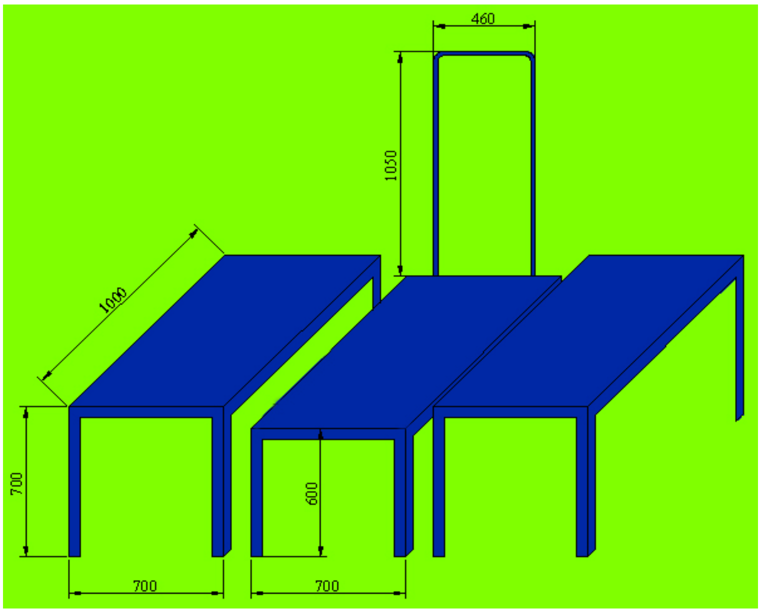


Figure A.2.2. The PE sack and PP sack storing table dimensions

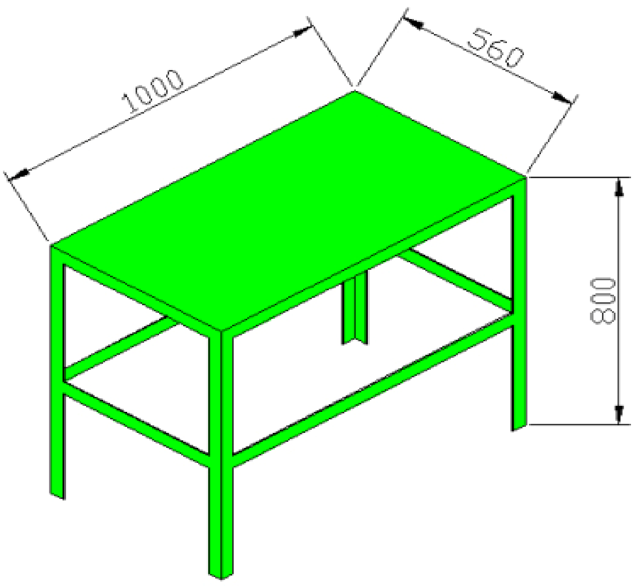


Figure A.2.3. The horizontal sack-turret design dimensions

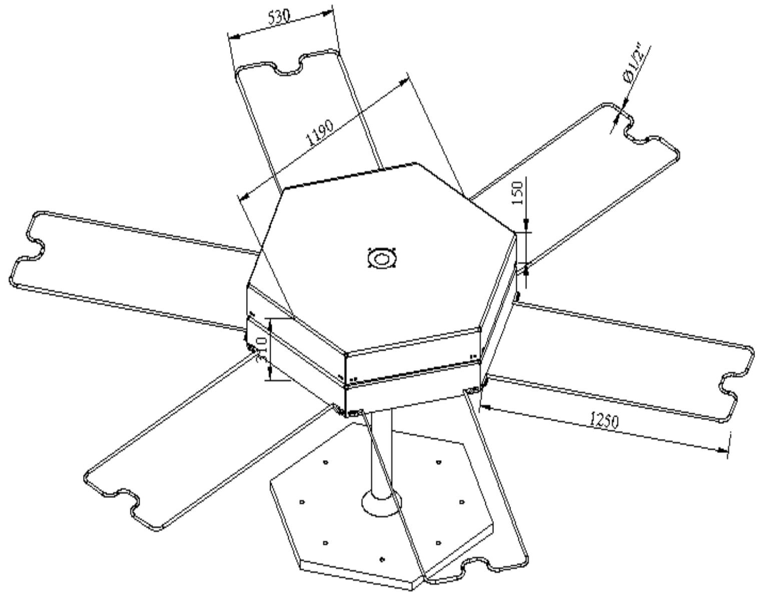


Figure A.2.4. The horizontal sack-turret stand dimensions

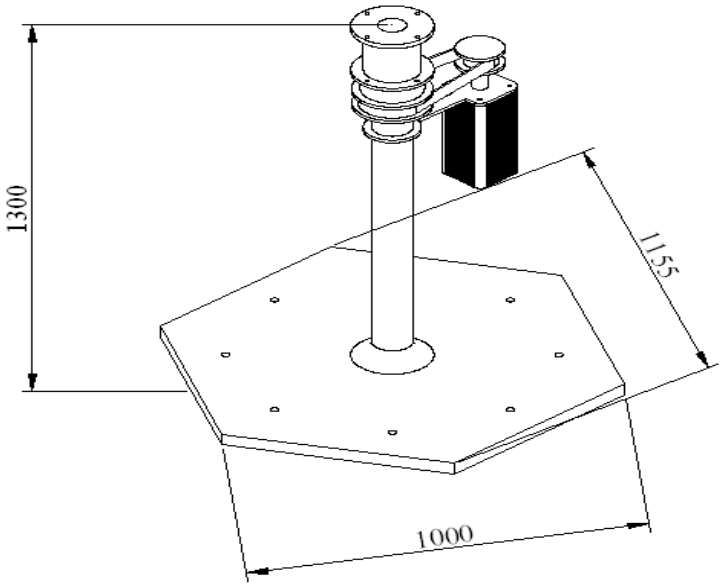


Figure A.2.5. The horizontal-vertical pneumatic cylinders, and vacuum system dimensions.

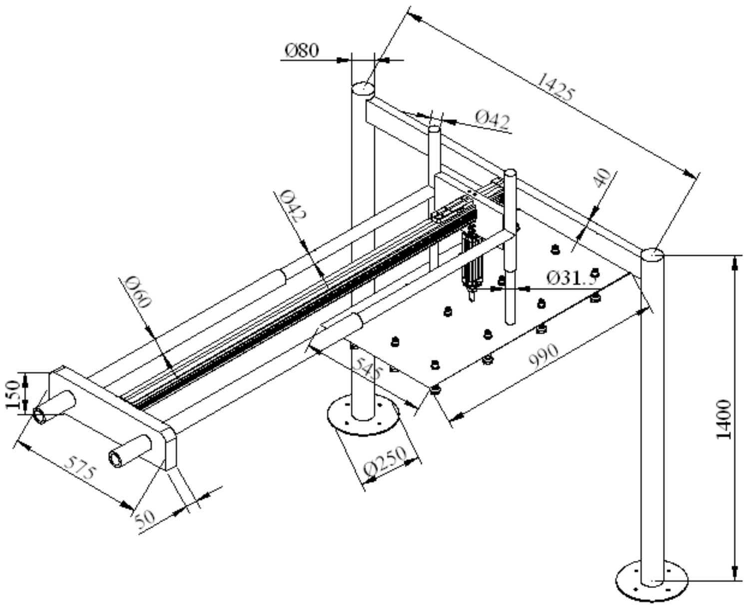


Figure A.2.6. Final sack storing tables dimensions

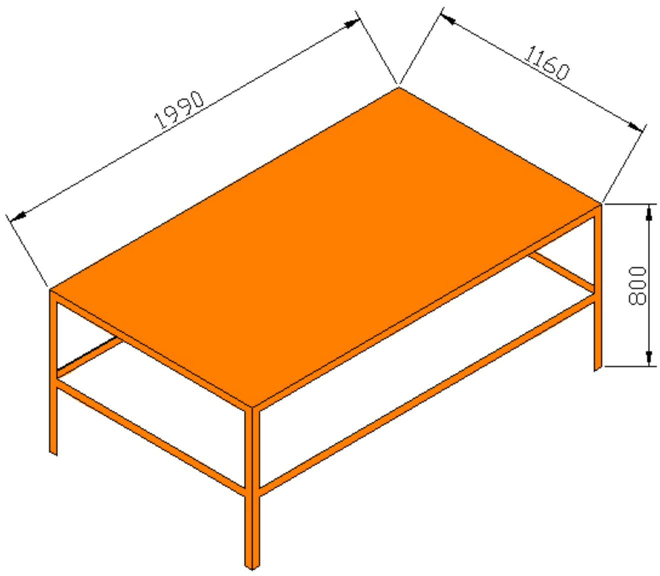


Figure A.2.7. The horizontal sack placing mechanism (1st model) dimensions

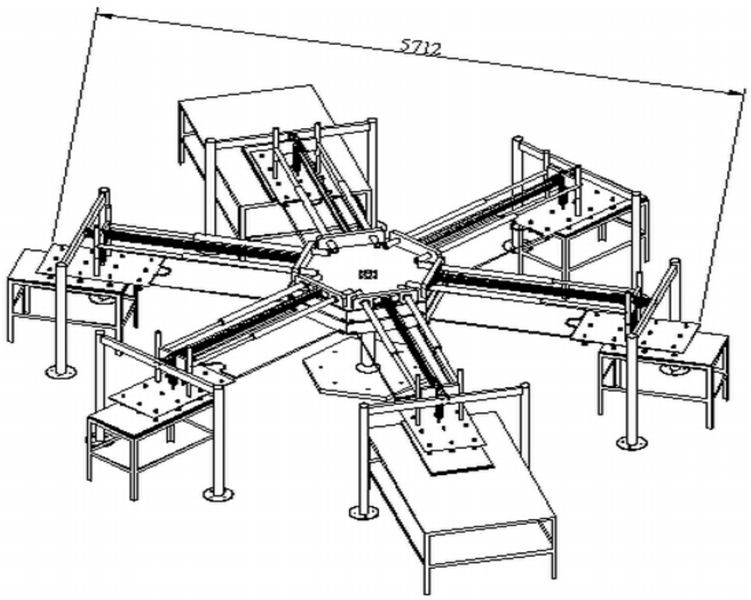
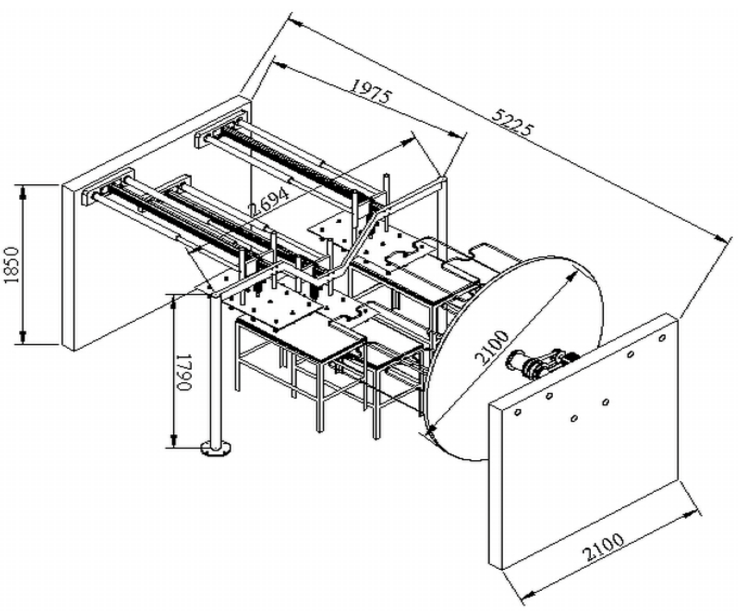


Figure A.2.8. The vertical sack placing mechanism (2nd model) dimensions



A 3. *Chapter 3- Drive Systems and Control Of Inserting Mechanism*

A 4. *Chapter 4- Modeling and Analysis Of Sack Inserting Mechanism*

A 5. *Chapter 5- Conclusions*