Design of a Process Plan for Automatic Integration

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ABSTRACT

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ABSTRACT

The objective of the thesis was to follow up the experiment performed at HAMK Robotics Laboratory and create an industrialized solution for unpackaging a bearing from its package. The aim of the project was to enhance the manual and hazardous process by using collaborative robots and propose a possible industrial solution scenario. This thesis work was commissioned by Konecranes. The experiment for the thesis was performed by HAMK Tech Research Unit; one of the Research & Development departments of Häme University of Applied Sciences, situated in Riihimäki.

The project was started based on an experiment performed at HAMK Tech Research Unit. A course about simulation in visual component's was completed to create an industrial simulation. Several ideas were proposed and improvised during the process to develop a practical process plan design. Regular communication with the commissioning party was conducted to ensure the work was done as per requirements. A 3D model for the required unit was made in Solidworks. The components which were included into the process plan were selected and their cost estimates were made. Thus, the general design approach; background research, ideation, concept-design, analysis, and documentation were implemented for the completion of the thesis work.

This thesis contains details of the design layout, a list of components, a cost estimate and the details on assembly design which will be used as a reference for production. This thesis work can also be a helpful reference for further amendment and optimization of the design.

Keywords Automatic Integration, Laser system, Process plan, Research, Robot.

Pages 44 pages + appendices 28 page

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LIST OF APPENDICES

List of abbreviations:

HAMK	Hämeen Ammattikorkeakoulu
IRB	Industrial Robots
Fanuc	Factory Automation Numeric Control
2D	2(Two) Dimensional
3D	3(Three) Dimensional
mm	Millimeter
g	Gram
kg	Kilogram
min	Minute
sec	Second
hr.	Hours
Qty	Quantity
Mrad	Milliradians

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1 INTRODUCTION

1.1 Background

New renovation, inventions have made the most difficult and impossible process a piece of cake. Few years ago, while huge number of personnel were required for completion of a process, while today it has been more automated, simpler, clean, precise, and economic with the use of new inventions. Taking the inspiration how innovation has changed the present and coming future, in this thesis I have tried to make the automation project simple, applicable, and reliable. Konecranes unpack about 600 bearing per day using manual operators. The objective of the thesis is to upgrade the manual and injury prone process by using collaborative robots and propose possible industrial solution scenario. The level of unpacking is shown below in Figure 1.

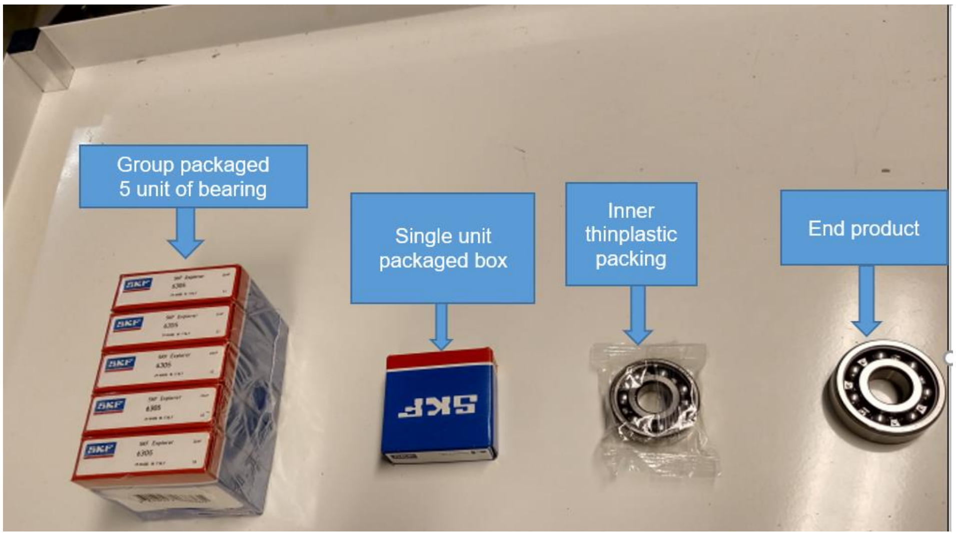

Figure 1 Level of unpackaging (HAMK Tech, 2019, p. 4)

Observation were made on the current practice at the factory premises. For the manual work the following notable observation was made:

- The rate of opening of the bearing was not consistent with the workers as shown in Table 1.

Table 1 Unpackaging rate of bearings

Worker type and timing	No. of bearings	Time
Trainee and morning time (8-8:30)	57	30 minutes
Experienced employee (11:45-11:52)	50	7 minutes

Table 2 shows the quantity of bearings that are unpacked in a single day.

Table 2 Unpackaging per day

Bearing Type	Approximate per day bearing removal
6304	500
6310	200

1.2 Commissioning party and goals

HAMK Tech Robotics Research Group is one of the 'Research and Development' departments of HAMK University of Applied Sciences which is actively carrying out research and project related to industrial application of robot ranging from product packaging to product manufacturing. The main aim of this group is to provide flexible learning and research environment to engineering students with maximum use of collaborative robots present at the research lab.

This group has been carrying out experiment on how to make the process automatic with use of robots. My responsibility is to broaden the research on the topic and if necessary, make a suitable design for the process. Layout of the process, timespan, cost calculation is also required.

1.3 Proposed idea

The industrial solution to unpack the bearing fully by removing paper package and plastic wrap is the main goal of the thesis. With co-ordination from the Konecranes representors, it was proposed to develop the existing practice in HAMK Robotic. For the operation to succeed, few main components were considered applicable which are listed below with their operation in brief:

- Robot: to pick and place and for cutting operation
- Laser cutter: to cut plastic wrapper of the bearing
- Conveyer: to convey the bearing for operation.
- Sensors: for detection of objects

Asides from these components it was proposed to design the tool or unit that can:

- Cut the outer and inner cartoon
- Separate the plastic wrap from bearing

2 MECHANICAL DESIGN PROCESS

Most engineering designs can be described as an invention of devices or systems or improvising a current practices or design. New inventions or design does not appear from nowhere. They are the outcome of a continuous effort of bringing together technologies to meet human requirements or to solve problems. The engineering design process is a highly iterative process which is interlinked by the common series of the steps that engineers applies to create a product or a process. Figure 2 shows the process cycle. The cycle is followed for designing the process plan.

Figure 2 Design Process (Engineering process, 2020)

Engineering design is the process of devising a system, component, or process to meet desired. It is a decision-making process (often iterative) in which the basics sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective needs (Introduction to Design Process, 2020, s. 1) . Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing and evaluation. The basic nine steps of design process are normally applied for problem-solving. Initial step in the process is identifying the problem or a requirement. Background research, study and solution concerning the problem are gathered. Requirement needed for the possible solution are analysed and multiple solution are presented. With the best possible solution, prototype for the product is built followed by proper testing. There is always a place for possible improvement. Repetitive redesign for the better solution is a key in design process. Finally, after the completion of the project the process is documented and presented.

2.1 Definition of problem

In the initial phase problems were identified. Problem identification is one of the crucial process for planning further task. Konecranes has been unpackaging around 700 bearings per day. The plastic wrap bearing comes with small square package which is further packed in bigger rectangular package by plastic wrap. Konecranes, by using some hand tools has been using manual effort from worker to remove the bearings from the package. The process of unpackaging bearing was quite hectic, inconsistent, time-consuming and hazardous. HAMK Tech Research Unit as well as customer recognised the problem.

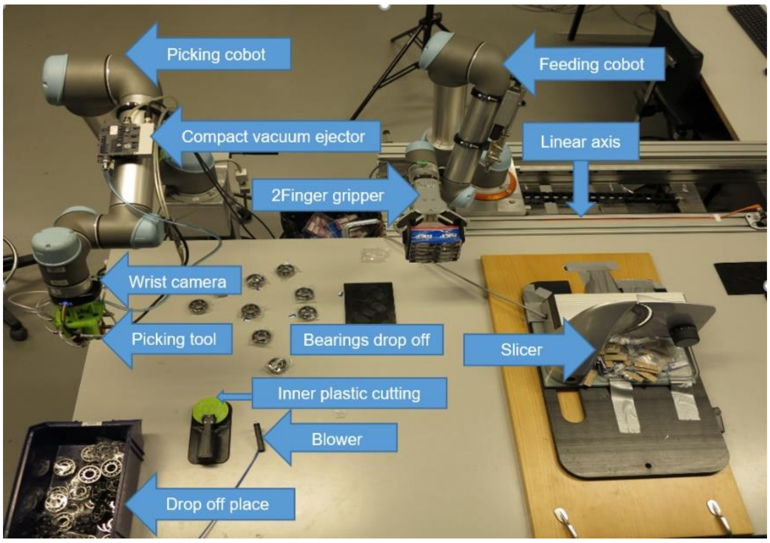

Figure 3 HAMK Tech Research Unit experiment (HAMK Tech, 2019, p. 3)

Considering this challenge, HAMK Tech Research Unit performed an experiment. Two cobot, linear track motion meat slicer, inner plastic cutter was used in the experiment. The experiment was conducted to proof the idea that the process could be automated. The issue with the experiment was poor handling of bearing, problem for wrist camera to reach bearing location. Bearing was dropped into the table which created stress in bearing causing the bearings to scatter unwantedly. Thus, industrial solution was sought to make the operation efficient, convenient, faster, and systematic. Possible goals and ideas are than set to overcome these problems. Figure 3 shows how the experiment was performed in HAMK Tech Research Unit.

The experiment was the base to support the idea that the process can be automized. The experiment did not only proof the concept but also provided huge assist on further research.

2.2 Design specifications

In this phase, the requirements of the commissioning party were carefully analysed, and the scope of design was set. The utmost aspects of design specifications, like design function, size, components, cost, safety were considered.

While designing the layout various specifications were analysed as per the requirements set by HAMK Tech Research Unit and commissioning party which are illustrated in Table 3;

Table 3 Design Specification

Aspect	Specifications
Function	The basic requirement was to design an applicable layout for the unpackaging process.
Size	The perimeter about 4914x3558mm was agreed with the commissioning party.
Aesthetics	The layout should be as small as possible. Layout requires at least one collaborative robot.
Components	The Layout needs to have various components like robots, sensors, conveyers, cutter, Laser cutter robot end effector, etc. Components and materials shall be chosen taking care of market availability, robustness, and cost.
Safety	Robots movements, arm movements, Laser cutting and paper cutting process were selected considering the safety factors.
Customer	Accessories are sought from nearby markets for ease availability and accessibility.
Accessories	Minimal number of accessories is considered as priority.
Manufacturability & assembly	The components for the process were chosen taking care of market availability while some of them are idealized as well as roughly designed.

2.3 Research and scope of design

In the second stage background research for the successful design was considered important. The components required, market availability, and space limitations were all discovered. A former experiment made at HAMK Robotics is used as a foundation for the research.

Before designing the layout all the necessary components were considered. Conveyers, laser cutter, sensors, robot, end effector, as per requirement were available in the market. A non-commercial unit was designed as per customer requirements. Before deciding the structure of the layout, the following factors were considered:

- Is there a real need for a new layout?
- What are the existing problems?
- What advantages does the existing solution have?
- What features can be used from the existing solution into the new solution?
- What are the economic constraints?
- What are the safety factors that need to be considered?
- What problems may be encountered during the manufacturing & assembly process

All these queries were considered and given proper care that helped on creating applicable and reasonable layout design. Figure 4 shows current Konecranes process.

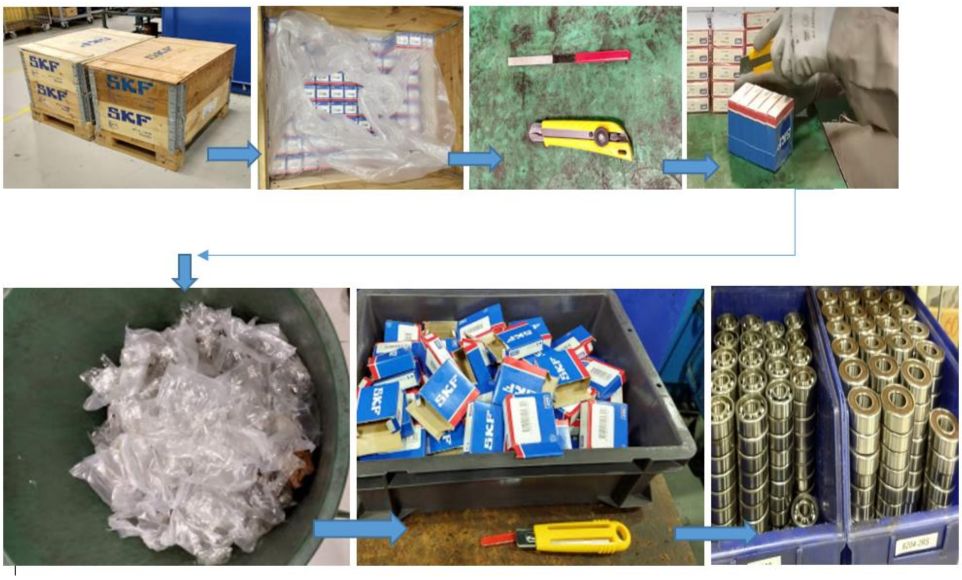

Figure 4 Current Process (HAMK Tech, 2019) (HAMK Tech, 2019, p. 11)

Downsize of current practice on Konecranes as well as the experiment performed in Hamk Robotics was analysed. Which is than utilized to search for design solution.

Experiment were performed to proof the design ideas and the rough layout for the process were carried out and simulated in Visual Components. Upon several phases the design idea was further improvised for better results and applicable design.

2.4 Design solution/ideas

During design process multiple ideas were created and proposed. For a better industrial solution, the combination of all the findings can be utilized and carefully analyzed

With experts of devices and tools as the whole process must be running uninterruptedly. The scope of system and quantity of bearing should be considered and time for operation of such system must be defined. Instead of looking simply for rapid bearing opening solution system, the solution can be made so that demand is met all the time for bearing and machine is not idle without any work and inventory cost for storing unpacked bearing should not be raised. The bearing unpacked on large number are considered. SKF 6304 and SKF 6310 bearing are the minimum and maximum diameter bearing, respectively. Selection of robot, conveyer, laser, and end effector was performed on the basic of these bearings. The properties of this bearings are shown in Table 4.

Table 4 Bearing Properties

	Mass/bearing	Row in package	Mass/ package	Outer diameter	Width of package
6304	0.14 kg	2	1.6 kg	52 mm	80 mm
6310	1.08 kg	1	5,60 kg	110 mm	155 mm

.

The logistic part of the solution was not studied in the HAMK experiment, but an industrial solution must comprise of incoming logistic of bearing package.

The ideas were analyzed, and the most applicable and reliable idea is further explored and researched in detail. Explanation of the ideas proposed are discussed below

2.4.1 Ideation one

In Figure 5 we can see a rough sketch of the idea on how the process can be carried out. The main difference between two ideas was related to how the position of the bearing will passed through the station during the whole procedure. The bearings were separated from package and allowed to move vertically through conveyer without any impact.

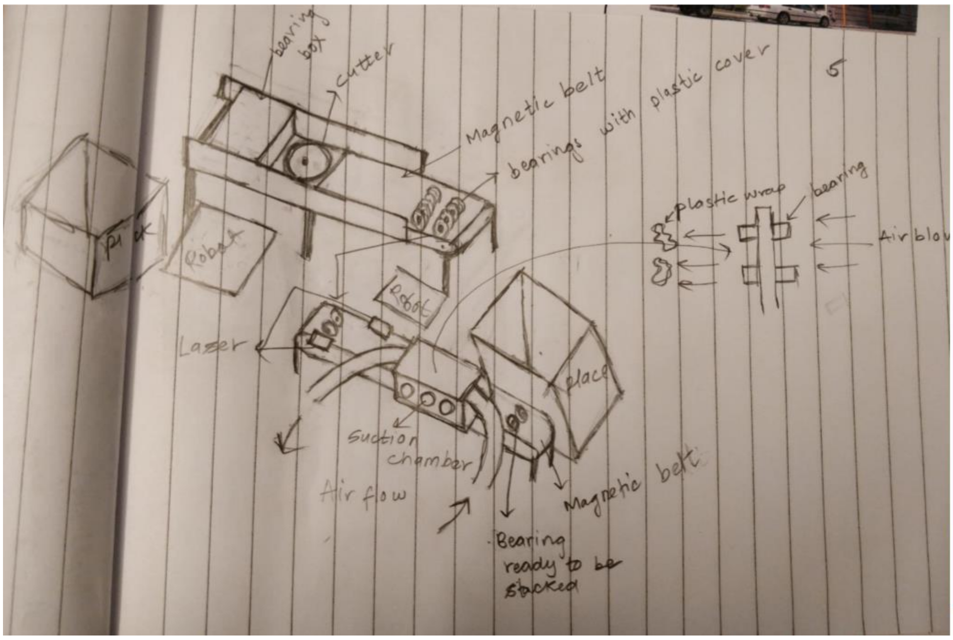

Figure 5 Ideation 1 sketch

Basic requirements:

- Robots
- Magnetic conveyer
- Scrap removal unit
- Slicer
- Mini laser cutter
- Linear actuator
- Sensors and PLC units

Robot one picks the bearing box, slices it, and places scrap into boxes. Bearing are passed through magnetic conveyors. Robot 2 picks the bearing and places to another magnetic conveyor for laser cutting and plastic scarp removal. A linear actuator inside the suction chamber lifts the bearings for ease of removal from scrap. After scrap removal the bearing passes on conveyor for pick up. Finally, robot 2 picks the bearing and places it for pelleting.

2.4.2 Ideation two

Figure 6 represents the scratch idea of how the unpackaging process can be carried out. The bearings were dropped in the table after the bearing package was sliced. This idea is a follow up of how the bearings are separated from bearing package and then collected by robot using optical sensors. Because bearings were dropped in the table, there is an impact in bearings.

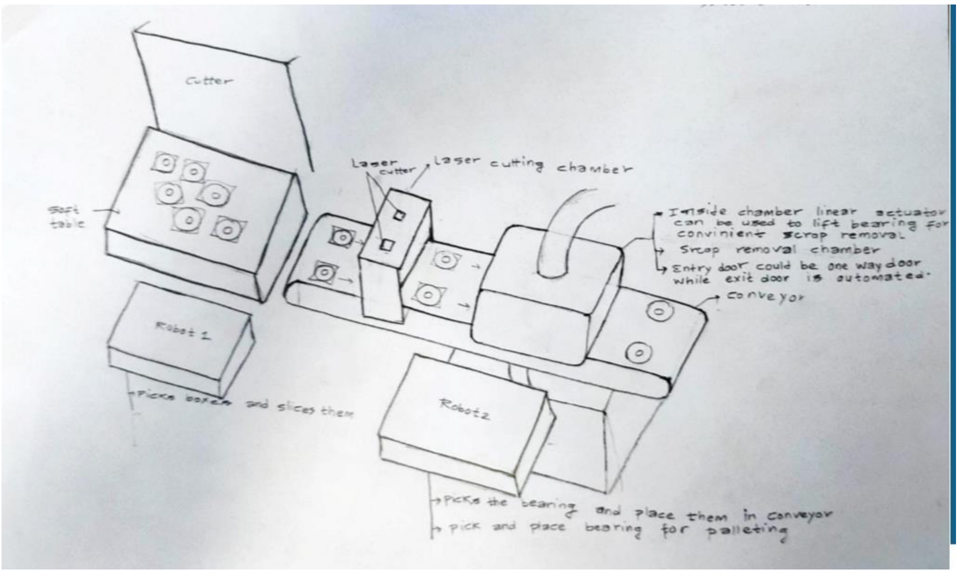

Figure 6 Ideation 2 sketch

Basic Requirements:

- Robots
- Conveyers
- Table
- Scrap removal (suction) chamber
- Slicer
- Mini laser cutter
- Linear actuator
- Sensors and PLC units.

Robot one picks bearing box, slices it, throws the bearings in soft table and place scrap boxes. Robot 2 picks the bearing and places to conveyor for laser cutting and plastic scarp removal. Linear actuator inside suction chamber lifts bearings for ease removal of scrap. After scrap removal bearings were passes on conveyor for pickup. Finally, robot 2 pick bearing and places it for pelleting.

2.4.3 Package removal Idea

The package itself were in different size for different size of bearing dimensions as shown in figure. Altogether there were five different bearing types with either 10-unit bearings package or 5-unit bearing package. Two types of main bearing package are shown in Figure 7.

Figure 7 Types of package (HAMK Tech, 2019) (HAMK Tech, 2019, p. 4)

There were several variables in the package removing process from the mixture of material of plastic and paper. The idea of taking out each unit of paper box packed bearing after removing the thin layer of wrapped plastic from combined single package was not optimal. Following the current manual process in Konecranes factory premises helped to shape how to remove the outer layer. It was identified that the access to inner package should be made straight out from thin film wrapped surface.

2.4.4 Plastic removal idea

The thin plastic wrap was a challenging part of the package to be removed. After the laser test with fiber laser, it was observed through experiment that laser is one of the most prospective area to look forward for the solution to remove inner plastic cover as it was the most challenging phase. For the more knowledge on the laser device case, Konecranes laser supplier Apricon Oy personnel was contacted and consult on the use of laser device were taken. From their perspective, Low power CO2 laser might be the best to suit for bearing opening scenario and suggested some testing on such system. The Fenix 25-watt CO2 laser marking system shown in Figure 8 was used to perform the testing.

It is generally used to mark different shapes, pattern and required info into different types of material. The operator created a circular profile for laser cutting process according to the bearing size on a windows-based system and the cutting program was ready in couple of minutes. Figure 8 demonstrate the laser cutting experiment performed by HAMK Tech.

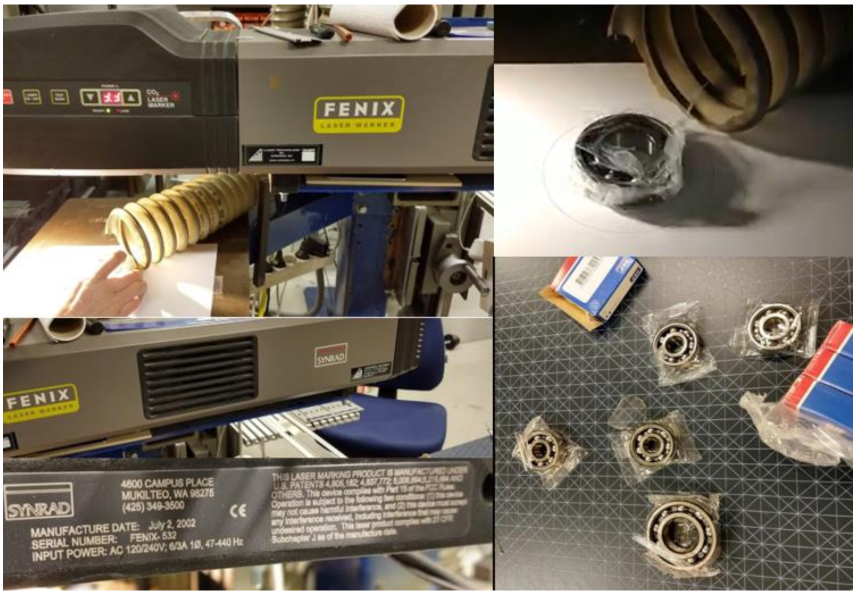

Figure 8 Laser cutting experiment (HAMK Tech, 2019, pp. 20-21)

The possibility of eradicating laser system with some mechanical unit were also considered. Brief description on the ideas is explained below:

<u>Option 1:</u> One of the options was to pass the bearing with the plastic wrap which has been laser cut through suction chamber. The bearing will be lifted by telescopic rod inside the bearing chamber while the plastic wrap will be blown away in the container. Figure 9 provides insight about the idea.

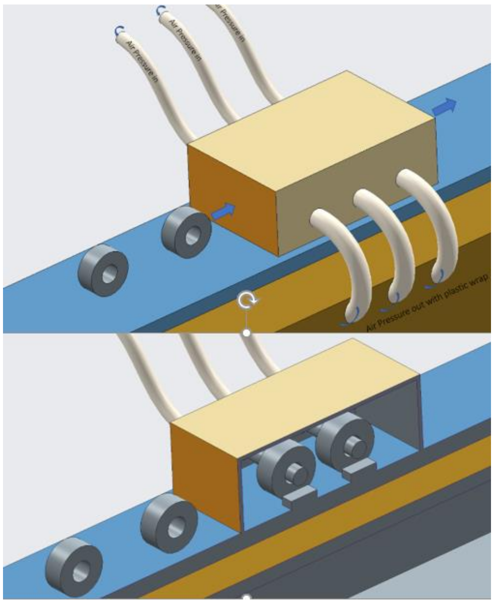

Figure 9 Plastic wrap removal idea design

<u>Option 2:</u>

Since we were using cobot in the process another option was to use cobot to make the plastic wrap apart from the bearing. But the problem was how to make it automated without any other mechanical assistant. Replacing the laser by applying pushing force in the bearing was also one of the options.

It was agreed to further work with second option and the 3D model to perform the experiment was made. Experiment can be observed from Figure 10.

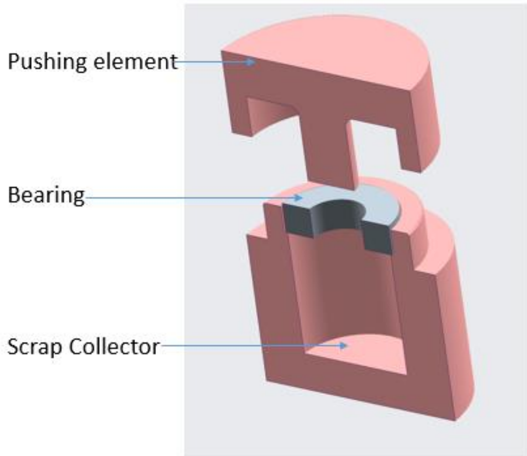

Figure 10 Wrap removal design idea

Following the ideation and with some experiment, it is found that there would be some challenges to remove the plastic wrap from the bearings. As shown in Figure 11 the plastic wrap got trapped in the side wall. After the experiment, it is observed that cutting the plastic wrap with laser and dropping them to the pushing element as in Figure 12 makes it much easier to separate plastic wrap from the bearing.

Figure 11 Wrap removal experiment

Figure 12 Wrap removal experiment result

Picking and placing the bearing and the plastic scrap can be performed with the help of robot.

2.4.5 Final idea for the process plan

The ideas were discussed with the commissioner party and analyzed properly. The ideas were analyzed and ideation one was chosen for further research. Few changes on design were made. First conveyer is will be magnetic while the second will be slate conveyer. Bearings will travel horizontally on the surface of slate conveyer. Laser cutting will be performed vertically. Suction chamber will be replaced with plastic removal unit. Block sketch of the final idea is shown in Figure 13.

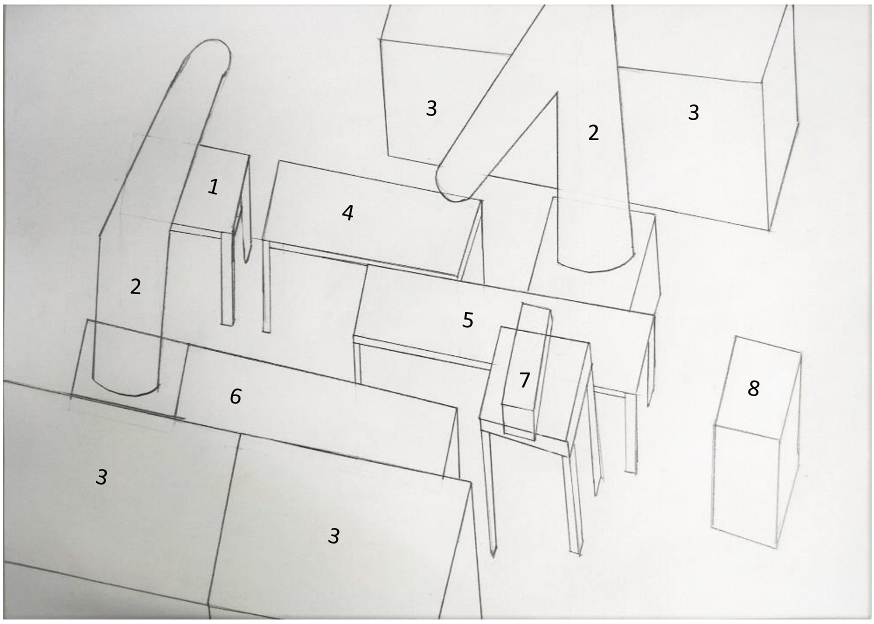

Figure 13 Final Idea

Figure 13 shows the sketch for two robot process. The process is similar with single robot process. The difference is single robot uses one robot for all operation. 3D demonstration of the design layout can be found in page17 and the Design process is further explained from page 14. Naming of the components in Figure 13 is shown in Table 5.

Table 5 Name of components

1	Package cutting unit (for cutting outer and inner package
2	Robot (for picking and placing package bearings, and plastic scrap/ for cutting package)
3	Containers (for pelleting package, scrap, and bearings.)
4	Magnetic Conveyer (for ease movement of bearings moving in row. Magnetic conveyers allow the bearing to stay vertical in conveyer)
5	Slate Conveyer (for conveying single bearing)
6	Linear track motion (for movement of robot one)
7	laser cutter (for creating circular cut in plastic wrap)
8	Scrap removal unit (for removing plastic scrap from the bearing)

3 DESIGN PROCESS

Next step in design process is the detail design where the 3D model is created, 2D drawings are drawn, materials are finalised, specifications are met, and cost is figured out. Although the detail design was not the basic requirement of the thesis, it was made for better visualization of how the system operates. It also allows us to roughly estimate the cost of the tool. The design and drawing for package and plastic removal is made. Material selection, manufacturing process and cost calculation is carried out.

3.1 Cartoon removal

During the experiment performed in the HAMK, Meat slicer was used as an option for cutting out the package cover and an individual bearing's cover. The idea was than considered to build more rigid, sustainable, and industrial unit to perform regular operation in the industry.

3.1.1 Design idea

The idea about the tool is taken straight out from meat slicer. The meat slicer is normally held on angle which was the reason bearing were dropped on the table during HAMK Tech experiment. The idea was to make the blade horizontal to the conveyer, which will allow to move the bearing without any disturbance right after it is separated from the cartoon.

3.1.2 Design

The design is a follow up to the design idea. Blade that is used in meat slicer and other component of meat slicer are used in the design. From Figure 14, we can get insight of the Package cutting unit. Two table one fixed and other with height adjustable feature are used. Fixed table contains blade, blade cover, tool sharpener and motor unit to operate blade. Height adjustable table provide us required gap between the table and blade to cut the package. Scarp of package can be collected in the box which is placed under the blade. Blade cover allows free movement of bearings without any obstacle. Tool sharpener can be to sharpen the blade automatically.

Fixed table can be machined with milling tools. Angle profile and square profile are either screwed or welded. Base support square can also be screwed with the help of I-profile or welded. Aluminium plate on the top will be screwed with angle bar. Drawing for the unit can be found from Appendix 19. Other components for the unit are detailed in Appendix 2.

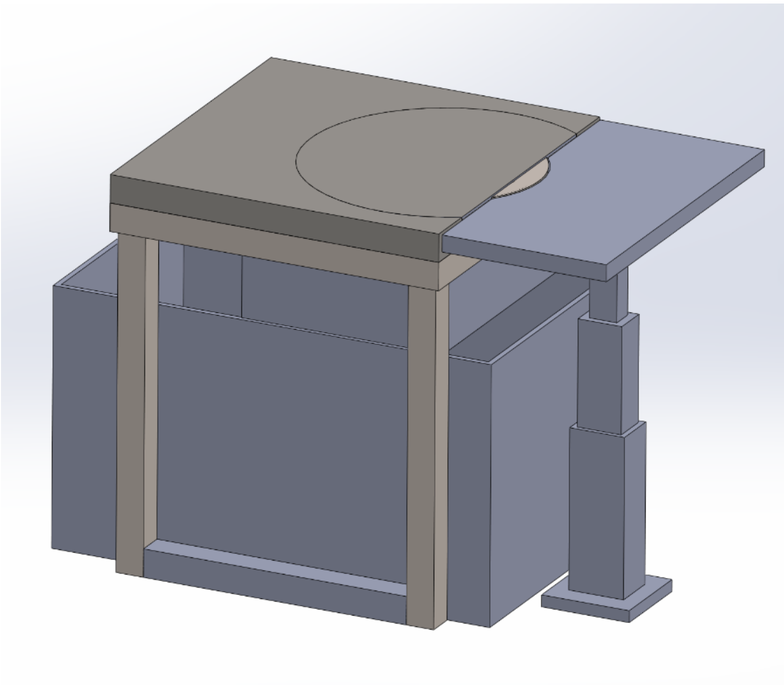

Figure 14 Package cutting unit

3.1.3 Material selection

Material selection is one of the crucial process in Engineering design process. Considering the application of the product, weight, other mating parts, material for the components are selected. L profile stands and the upper frame need to be rigid enough to provide support for the unit. Considering the payload stainless steel could be suitable material. Aluminium 6061 can be used for table plate. More information about the material can be found from Appendix 3.

3.2 **Scrap removal**

3.2.1 Design idea

After the experiment on how the plastic wrap should be removed, further process for the design in carried out. It was proposed that the use of laser cutter to make opening cut would be suitable. After the opening the bearing along with plastic scrap is dropped into a scrap removal unit by use of robot. To apply this concept in our process, design consideration for the indexing table is carried out. Figure 15 in the right is the design idea for the indexing table.

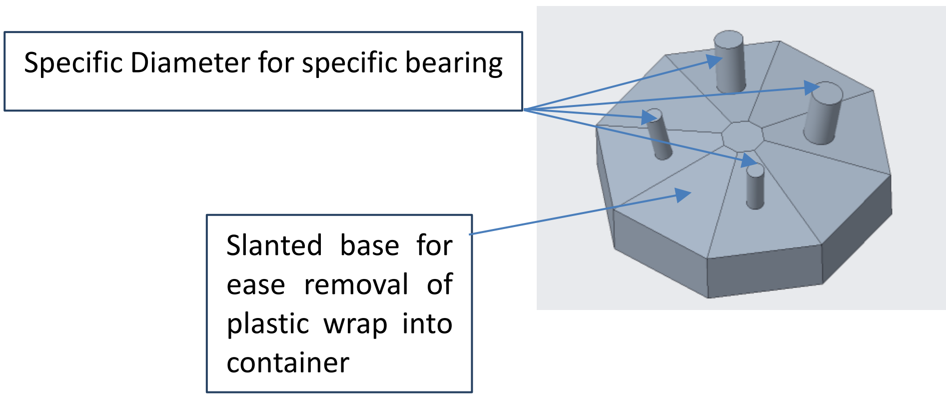

Figure 15 Plastic wrap removing table

Slanted base can be casted while another circular bar can be screwed on the base. Agreement was made with commissioner party that the idea was enough, and no detail design is further needed for scrap removal unit. The unit is also not included in cost calculation. Package cutting unit is the one which is further studied with detail design for manufacturability.

4 DESIGN LAYOUT

4.1 Single robot

Single robot is used with a longer guide rail. This will reduce the initial investment, but it might increase the time spam thus increasing cost during unpackaging process. Design of the system was created in Visual Component which gave us visual idea of how the process plan will look like. Figure 16 shows different position of bearing from P_1 to P_{10}. Drawing of the layout is in Appendix 16 to Appendix 18

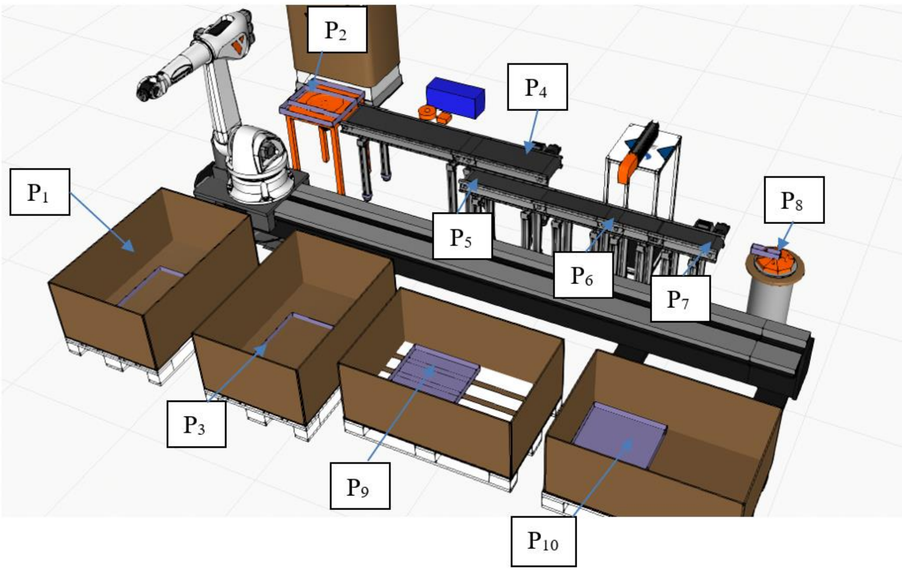

Figure 16 Design layout for one robot

4.2 Two robots

Two robots are used in this layout. Design of the system was created in Visual Component which gave us visual idea of how the process plan will look like. Figure 17 shows the position of bearing from P_1 to P10. Drawing of the layout can be found from Appendix 13 to Appendix 15.

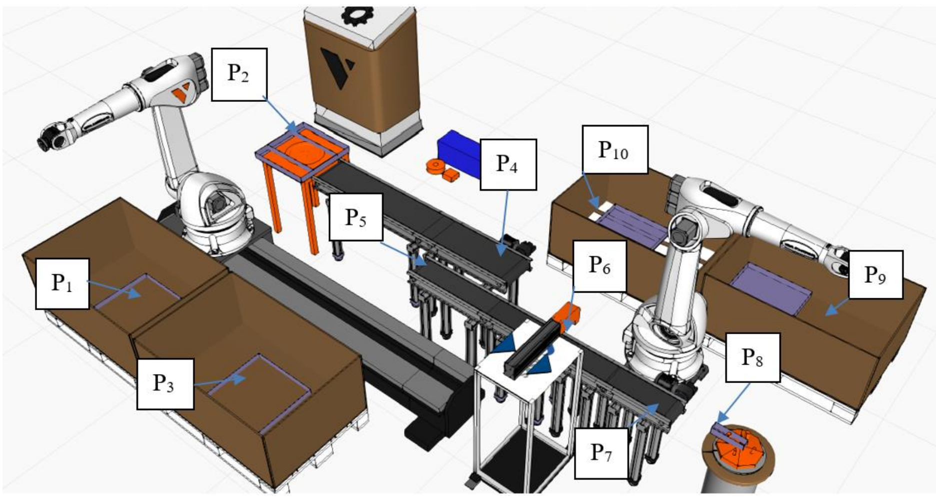

Figure 17 Design layout for two robots

5 DESIGN PROCESS

5.1 Single robot

Step 1:

The package is picked using vacuum gripping with Leneartec Maxcap end effector. In Figure 18 it shows the position of end effector in P_1. The waste produced is collected under the package slicing unit.

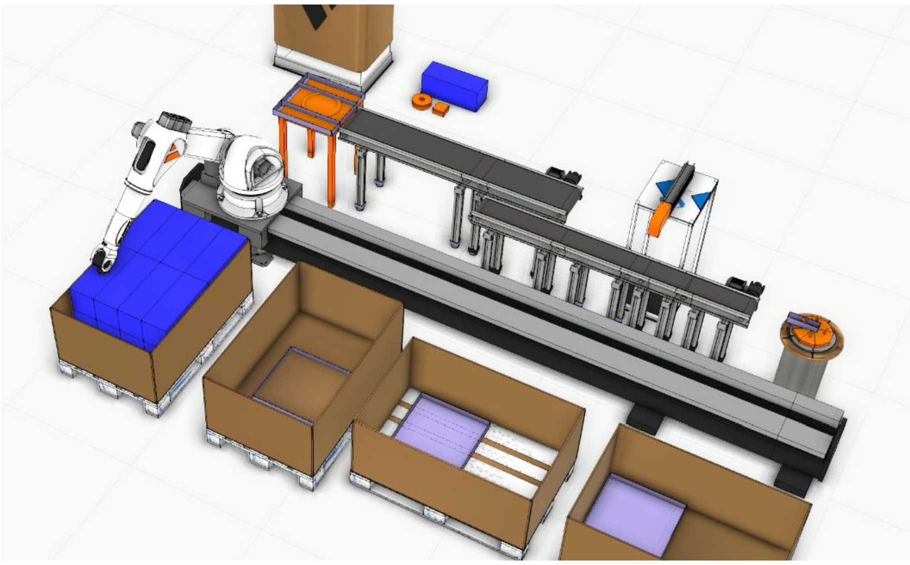

Figure 18 Single robot step 1

Step 2:

The package is picked and placed to package cutting unit where the paper packages would be cut off and separated. Figure 19 shows the position of bearing on position P_2. Proximity sensor detects bearing on conveyer one and sends the command to star the conveyer. Approximate virtual time from step 1 to step 2 is 6 sec.

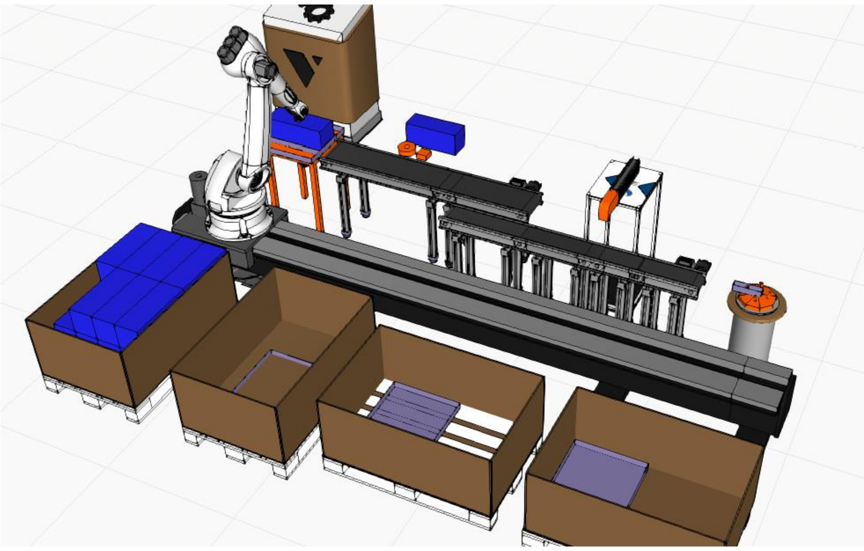

Figure 19 Single robot step

Step 3:

Figure 20 shows the sliced package placed in second container. The package is sliced and placed from position P_2 to P_3. Approximate virtual time from step 2 to step 3 is 6 sec.

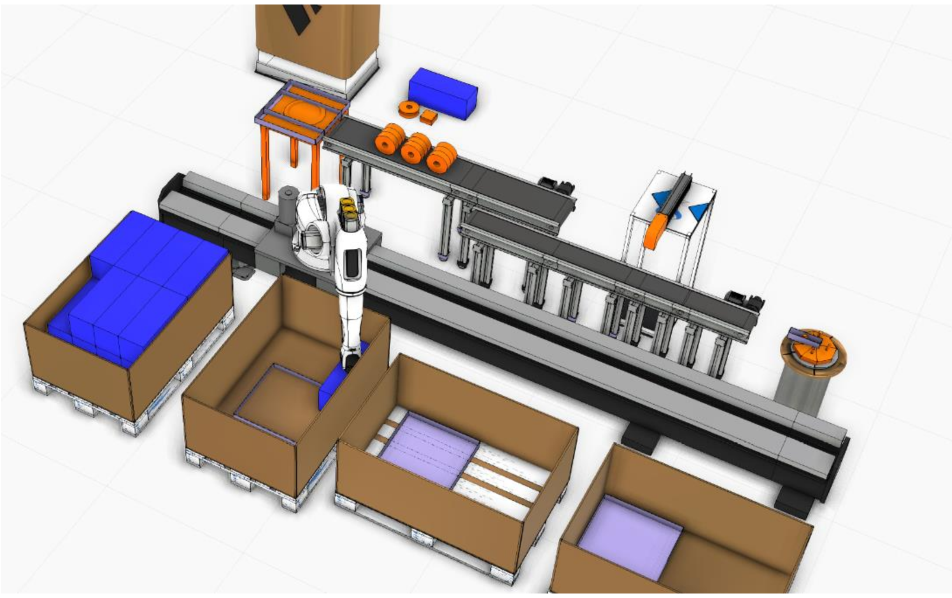

Figure 20 Single robot step 3

Step 4:

After step one robot one changes the end effector. Figure 21 shows the position of bearing at P_4 from where it will be picked by goldsmith magnetic gripper and placed to another conveyer. Proximity sensor detects bearing on P_4 and stops conveyer one. Approximate virtual time from step 3 to step 4 is 14 sec.

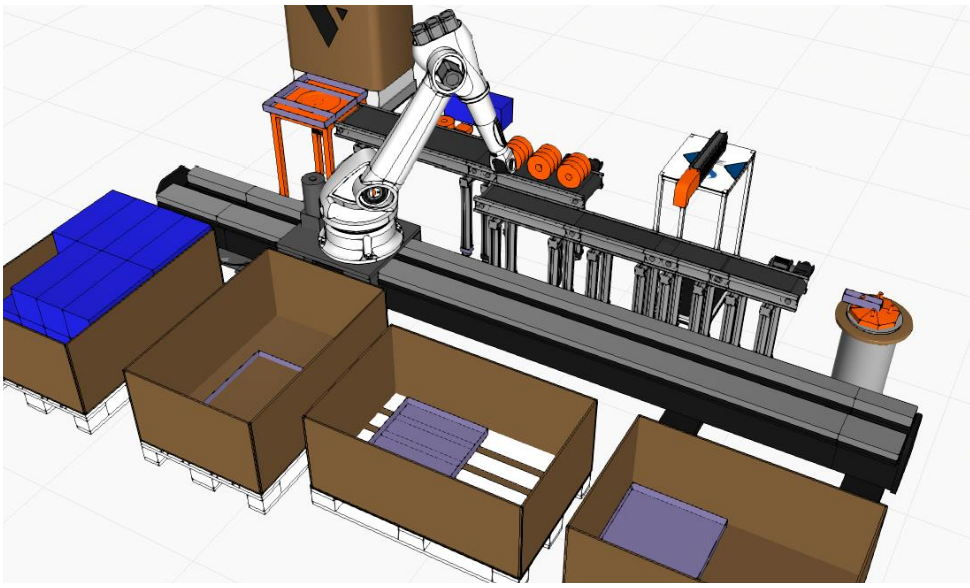

Figure 21 Single robot step 4

Step 5:

As in Figure 22 bearing with plastic wrap is placed on position P_5. Proximity sensor detects the bearing on P_5 which sends the command to start conveyer 2. Approximate virtual time from step 4 to step 5 is 4 sec.

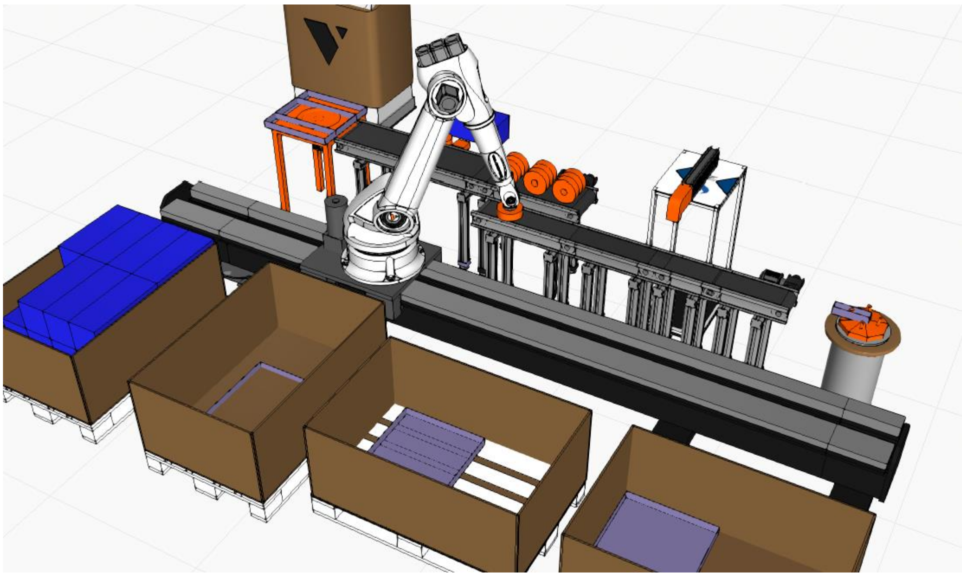

Figure 22 Single robot step 5

Step:6

Proximity sensor will be used to detect the bearing. As in
Figure 23 Laser unit will operate cutting process around the bearing to cut plastic wrap. As an experiment performed by HAMKtech Laser penetration will create and opening in the bearing wrap. Approximate virtual time from step 5 to step 6 is 6 sec.

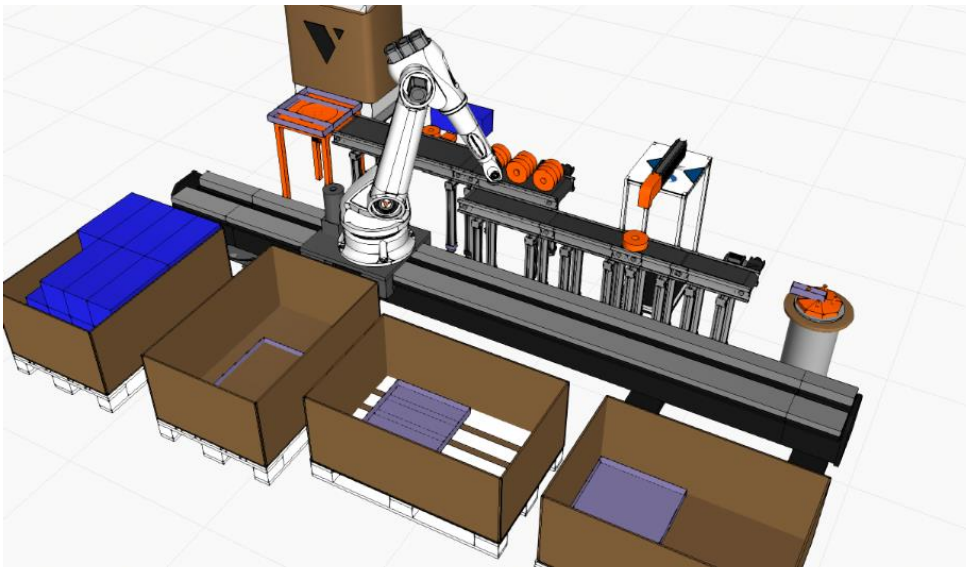

Figure 23 Single robot step 6

Step:7

After step 6 robot changes the end effector. As in Figure 24, bearing with wrap that has been penetrated from laser will be picked by robot on position P_6. Robot gripper 2F-85 will be used to pick the bearing. Sensor detects presence of bearing at position P_6 and halt the motion of conveyer. Approximate virtual time from step 6 to step 7 is 15 sec.

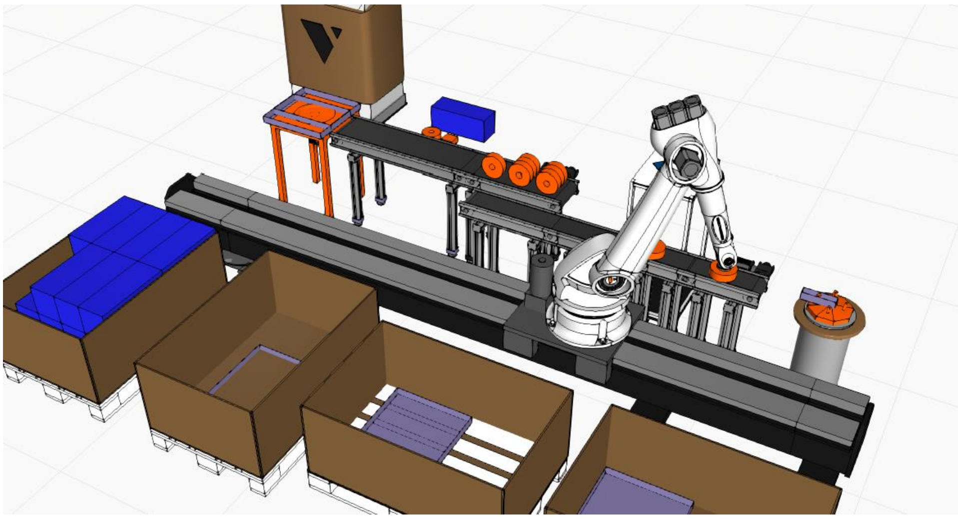

Figure 24 Single robot step 7

Step 8:

Figure 25 shows position of bearing at P_7. The bearing with the wrap is picked and placed to the scrap removal unit by facing the opening toward the unit. This will help to remove the plastic wrap from the bearing. Approximate virtual time from step 7 to step 8 is 4 sec.

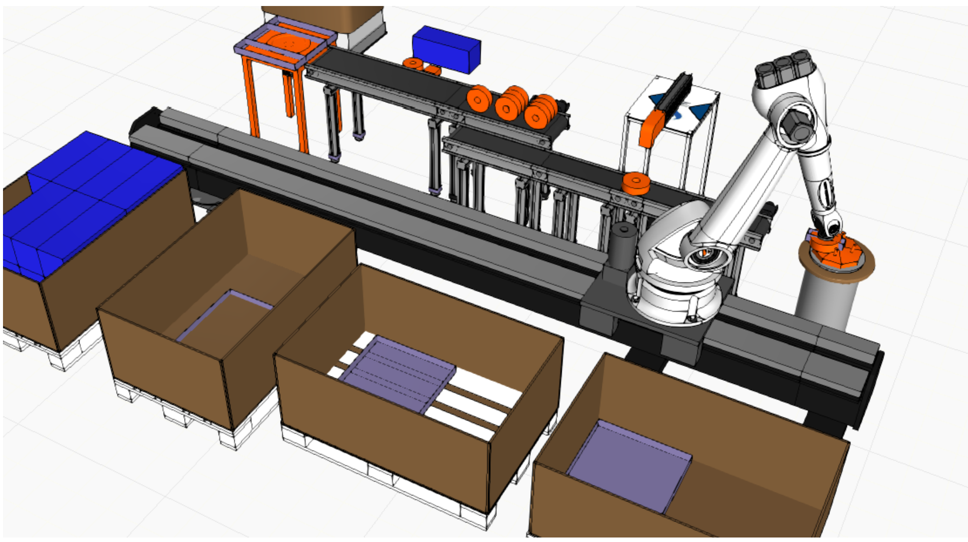

Figure 25 Single robot step 8

Step9:

The plastic wrap that might be stuck on the surface of circular bar of scrap removal unit is picked by robot with robot gripper 2F-85.
Figure 26 shows the position of bearing wrap at P_7. Approximate virtual time from step 8 to step 9 is 4 sec.

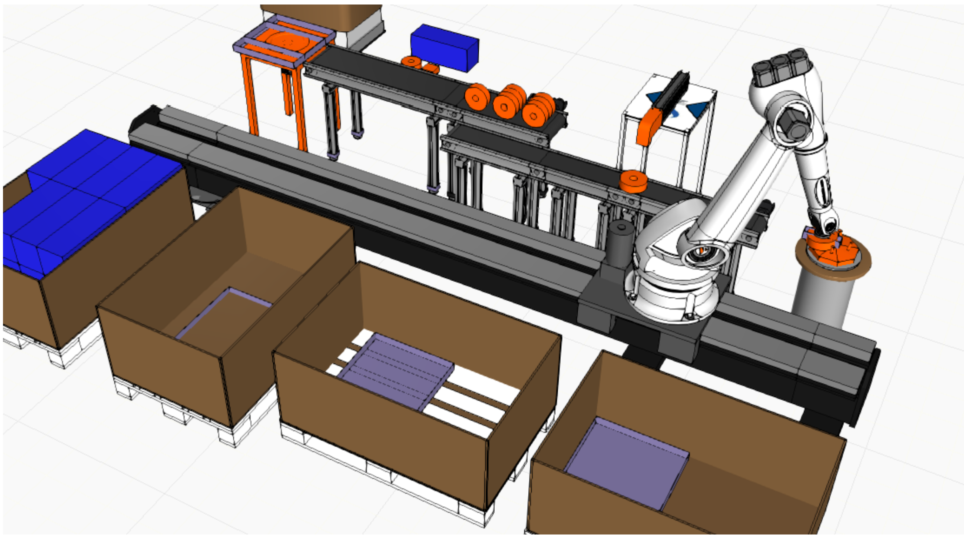

Figure 26 Single robot step 9

Step 10:

As in Figure 27 the scrap that is picked from scrap removal unit is placed inside last container. Approximate virtual time from step 9 to step 10 is 6 sec.

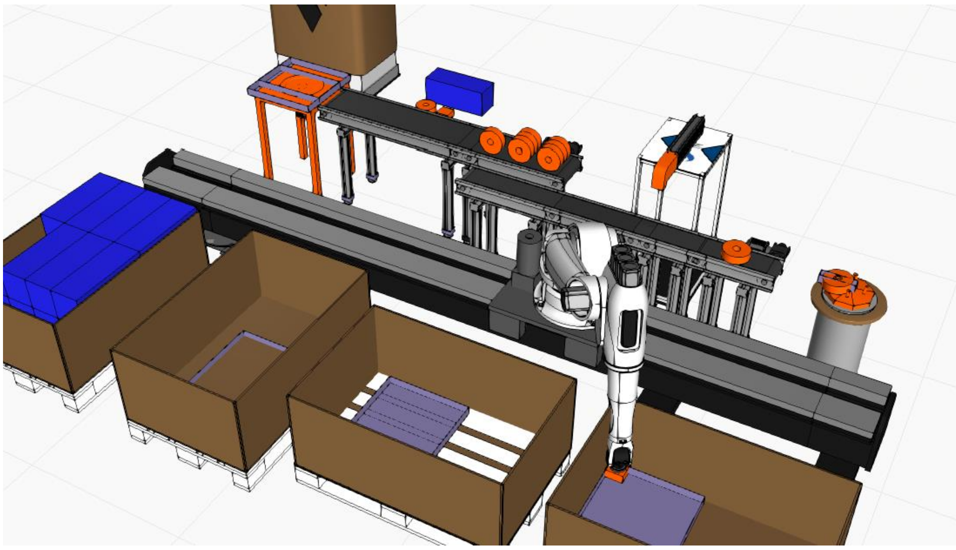

Figure 27 Single robot step 10

Step:11

After step 10 robot changes end effector. The bearing without scrap is than finally collected from the scrap removal unit. Figure 28 shows the position of bearing on P_7 with end effector goldsmith magnetic gripper. Approximate virtual time from step 10 to step 11 is 5 sec.

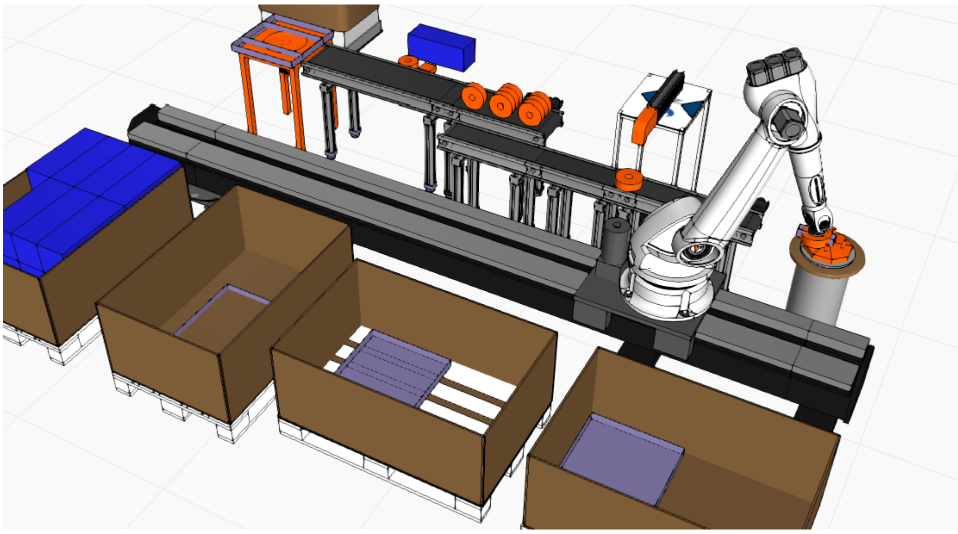

Figure 28 Single robot step 11

Step 12:

The bearing is finally palleted by robot using goldsmith magnetic gripper and placed in the third container. Goldsmith magnetic gripper is used to minimise the interference robot might cause around palleted bearings. Approximate virtual time from step 11 to step 12 is 7 sec.

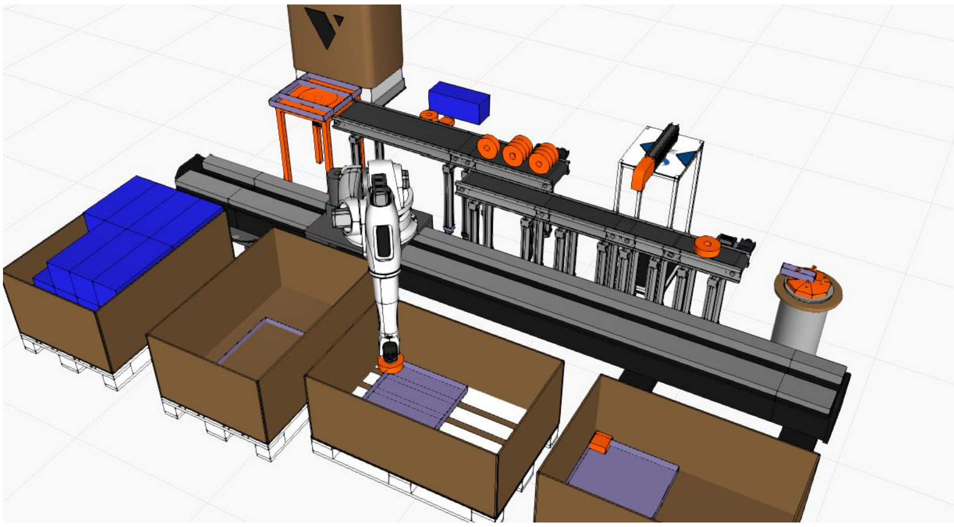

Figure 29 Single robot step 12

Time span:

The simulation is carried out for the process until the container is filled up. Times loss for changing end efector, cutting the package, lazer cutting is not considered. The time recorded is a virtual time spend to unpack 216 bearings. The process is carried out after the bearing package that are required to be unpack are placed for the robot to be picked. The time period for single robot process can be seen in Figure 30 which is 2 hours fourtyone minutes and thirtysix seconds.

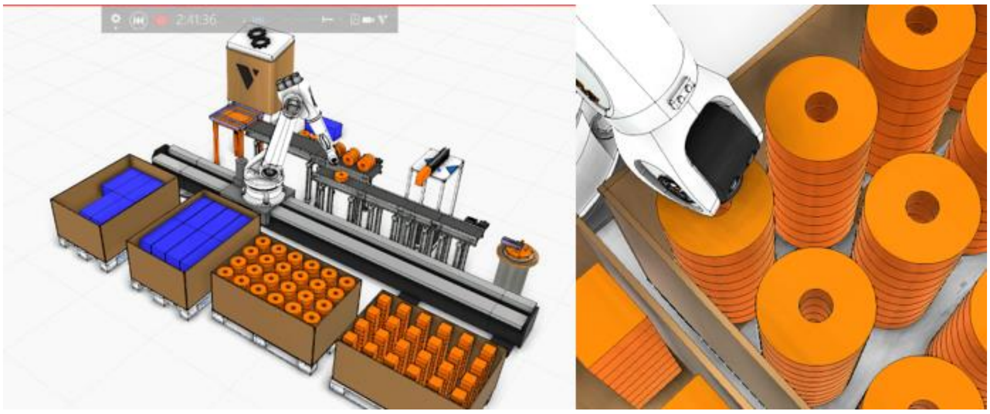

Figure 30 Time span for process

Time span for first bearing on each station is shown in Table 6. Ignoring the time for changing tools according to simulation every second bearing is palleted approximately in time difference 45 sec to first bearing.

Table 6 Time span per station

Position	Timespan
P_1- P_2	5 sec (transition time)
P_2	4 sec (for cutting)
P_2- P_4	7 sec (on Conveyer first)
P_4	8 sec (on Conveyer first waiting for robot)
P_4-P_5	4 sec (transition time)
P_5-P_6	10 sec (on Conveyer second)
P_6	3 sec (on Conveyer first during laser cutting)
P_6- P_7	4 sec (on Conveyer second)
P_7	10 sec (on Conveyer first waiting for robot)
P_7-P_8	4 sec (transition time)
P_8	16 sec (on Scrap removal unit)
P_8-P_9	7 sec (transition time)
Total	1 min 23sec

5.2 **Two Robot**

Step 1:

The bearing package palleted in the container one is bring on the pheriphery of robot. Vacuum gripping Lineartec Maxcap end effector will be used. As in Figure 31, robot gets the command and picks the bearing package from position P_1.

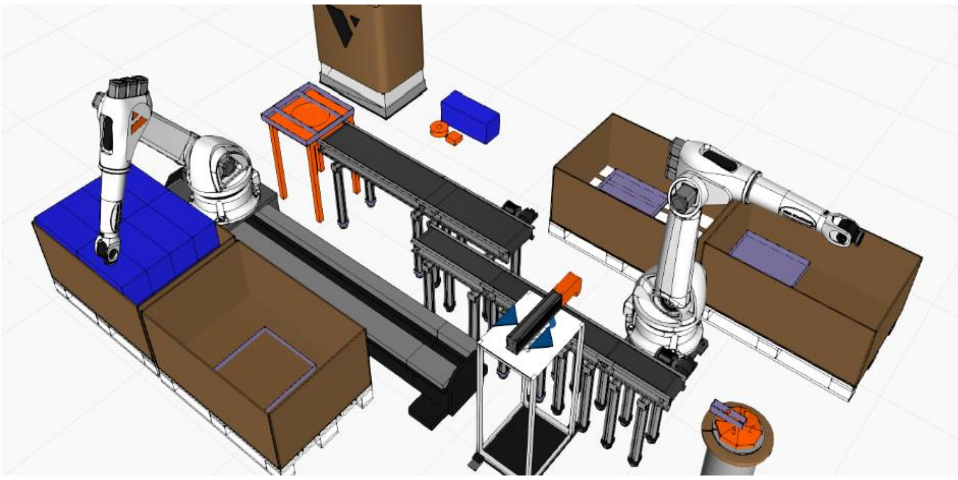

Figure 31 Two robot step 1

Step 2:

Figure 32 shows the position of bearing at P_2. The bearing package is placed onto bearing package slicing unit where the bearings with plastic wrap are separated from the paper package. The waste produced is collected under the package slicing unit. Approximate virtual time from step 1 to step 2 is 6 sec.

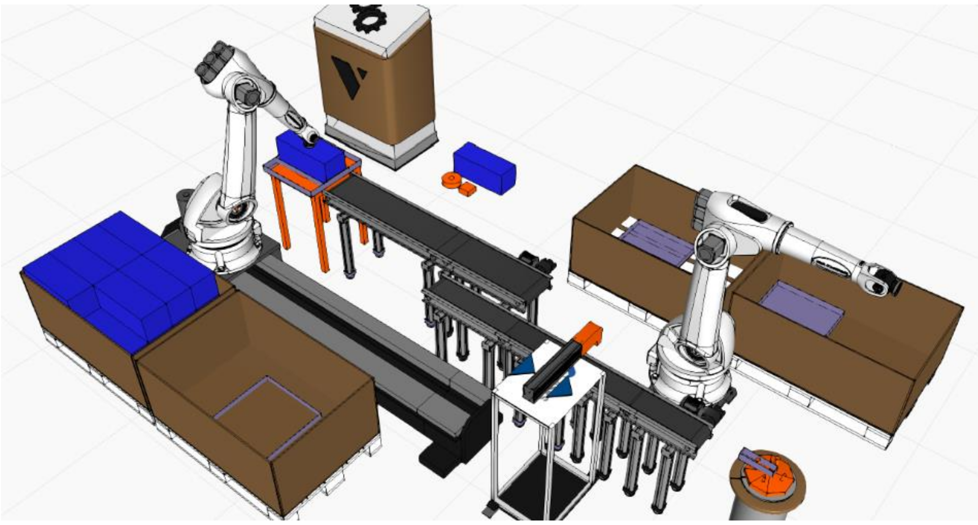

Figure 32 Two robot step 2

Step 3:

As in Figure 33, the package without bearing is gripped by robot and palletized into second container for disposal. Figure 33 shows the position of bearing package. Approximate virtual time from step 2 to step 3 is 6 sec.

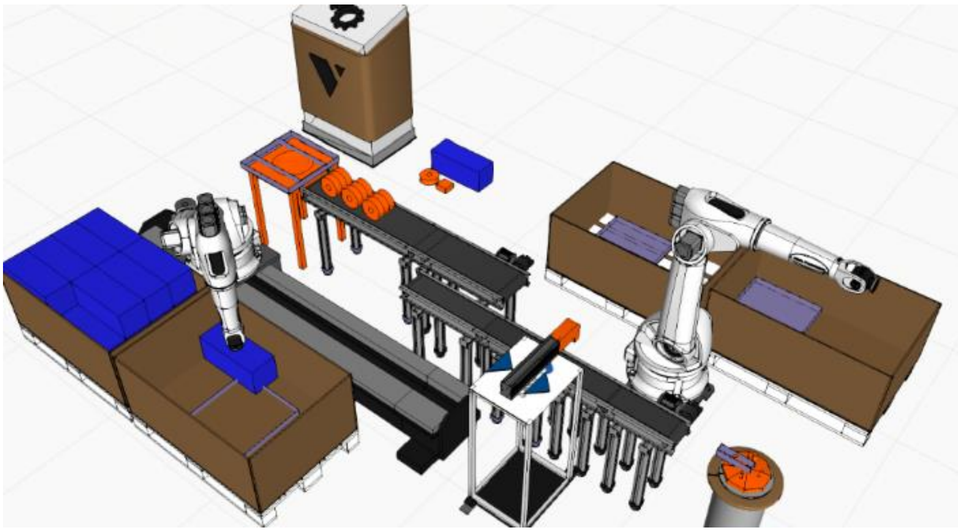

Figure 33 Two robot step 3

Step:4

After step 3 Robot changes end effector to Goldsmith magnetic gripper. As shown in Figure 34 bearings with plastic wrap are conveyed to position P4 which is picked by robot 1 with goldsmith magnetic gripper. Approximate virtual time from step 3 to step 4 is 14 sec.

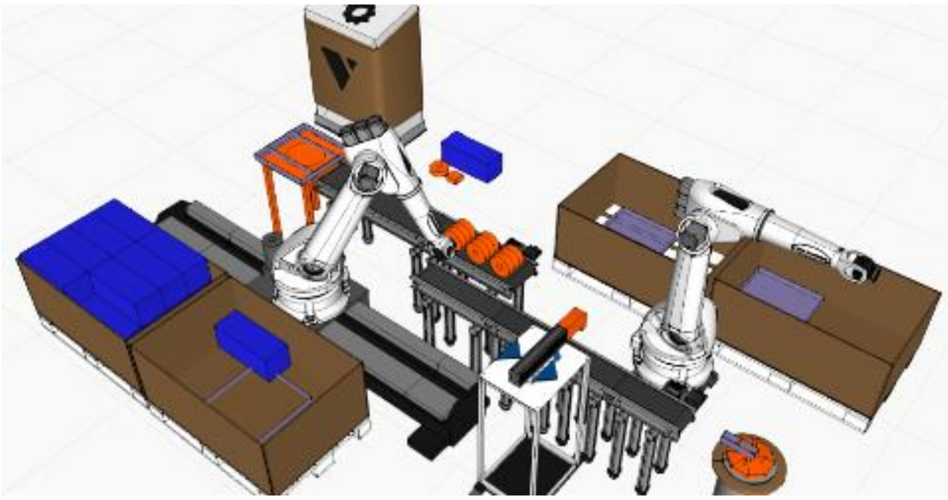

Figure 34 Two robot step 4

Step 5:

The bearing with wrap is picked from position P_4 with goldsmith magnetic gripper. As shown in Figure 35, the robot place bearing to second conveyer. Sensor detect the presence of bearing and operate the conveyer. Approximate virtual time from step 4 to step 5 is 4 sec.

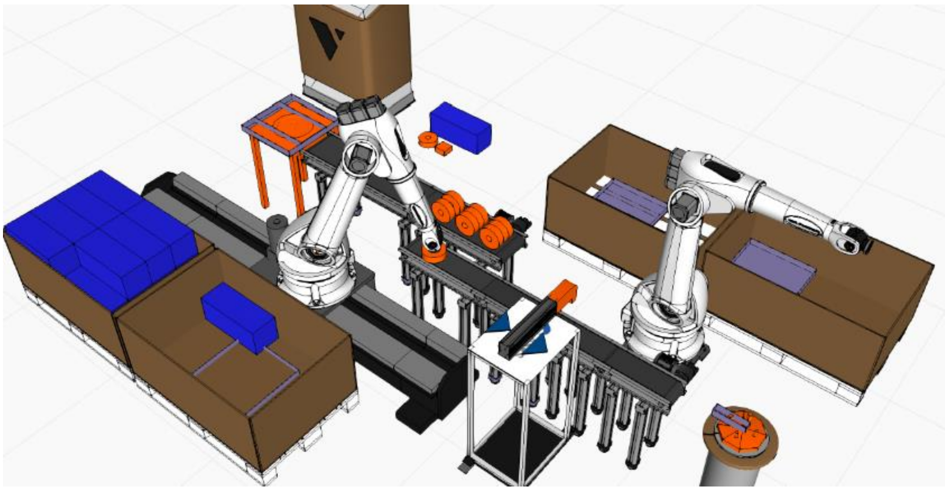

Figure 35 Two robot step 5

Step 6:

The bearing in conveyer two is conveyed to laser cutting area, where an opening around the plastic wrap is created. As in Figure 36, the bearing reaches at position P_6 where the bearing wrap is penetrated by the laser. Approximate virtual time from step 5 to step 6 is 10 sec.

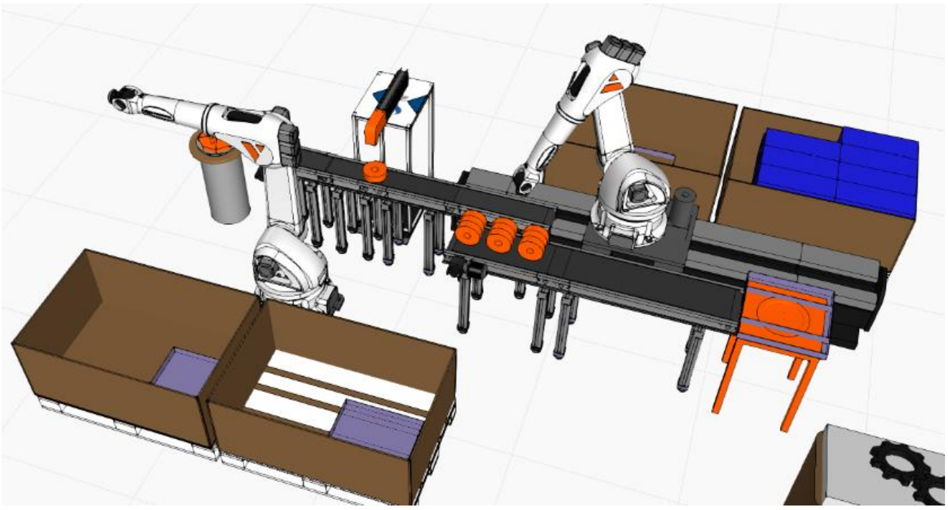

Figure 36 Two robot step 6

Step 7:

As shown in Figure 37, the bearing with plastic wrap is than picked form P_7 by Robot 2 with robotic gripper 2F-85. Sensor detect the presence of bearing at this position which then sends command to halt the conveyer. Approximate virtual time from step 6 to step is 9 sec.

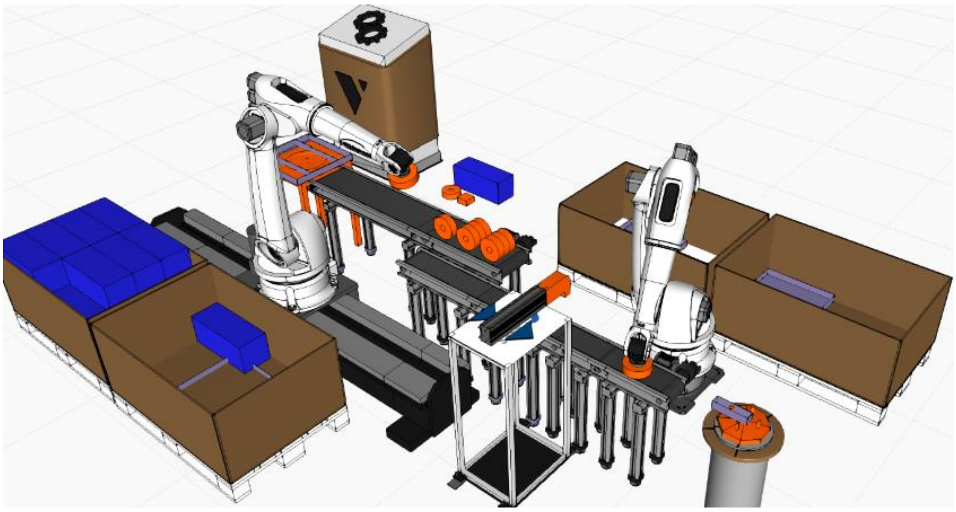

Figure 37 Two robot step 7

Step 8:

The bearing with plastic wrap is placed into plastic wrap removal unit while facing the opening toward the unit. The position of bearing at P_8 is shown in the Figure 38. This separates the bearing from plastic wrap. Approximate virtual time from step 5 to step 6 is 10 sec.

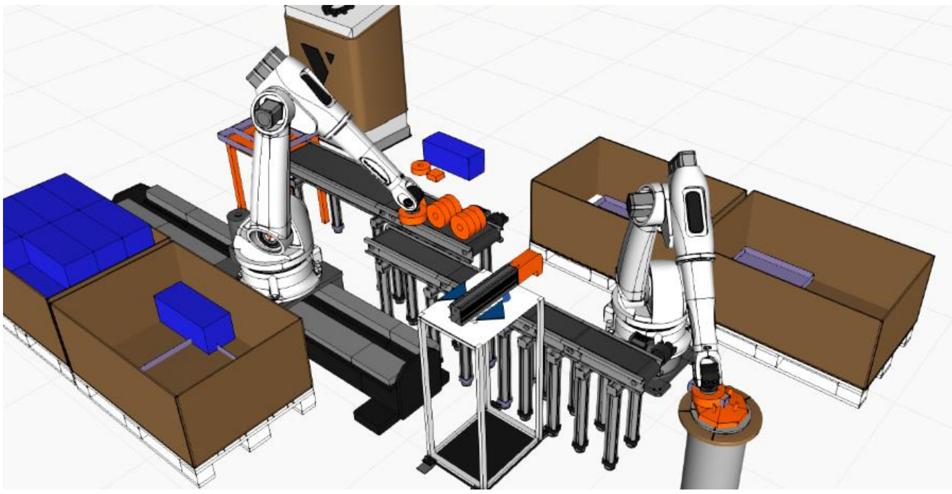

Figure 38 Two robot step 8

Step 9:

The plastic wrap that might have been stuck in plastic wrap removal unit is picked from the unit by robot 2 with robotic gripper. The position of robot arm is shown in the Figure 39.
Figure 26 shows the position of bearing wrap at P_7. Approximate virtual time from step 8 to step 9 is 4 sec.

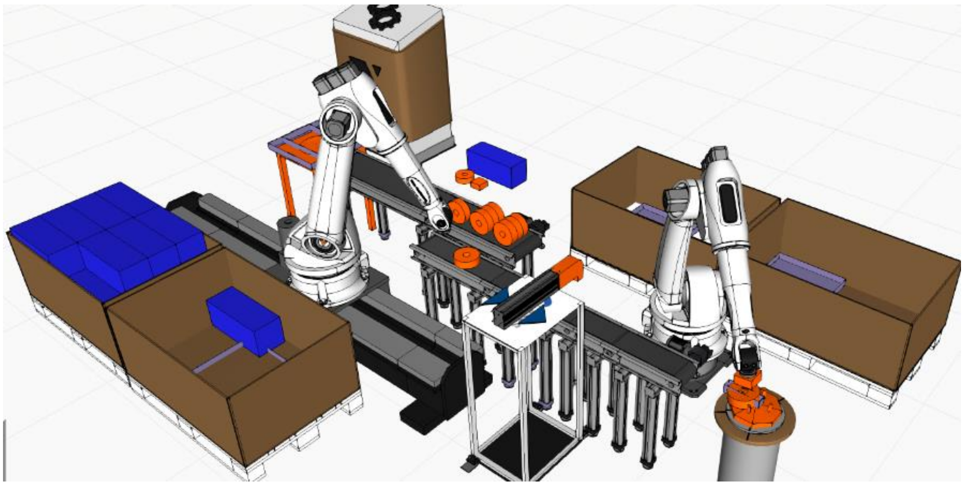

Figure 39 Two robot step 9

Step:10

Robot two changes the end effector to Goldsmith magnetic gripper. The bearing stuck around the cylindrical part of plastic wrap removal unit is than picked by robot 2 .As shown in the Figure 40 the scrap plastic wrap is collected in container for disposal. Figure shows the position of bearing wrap at P_7. Approximate virtual time from step 8 to step 9 is 6 sec.

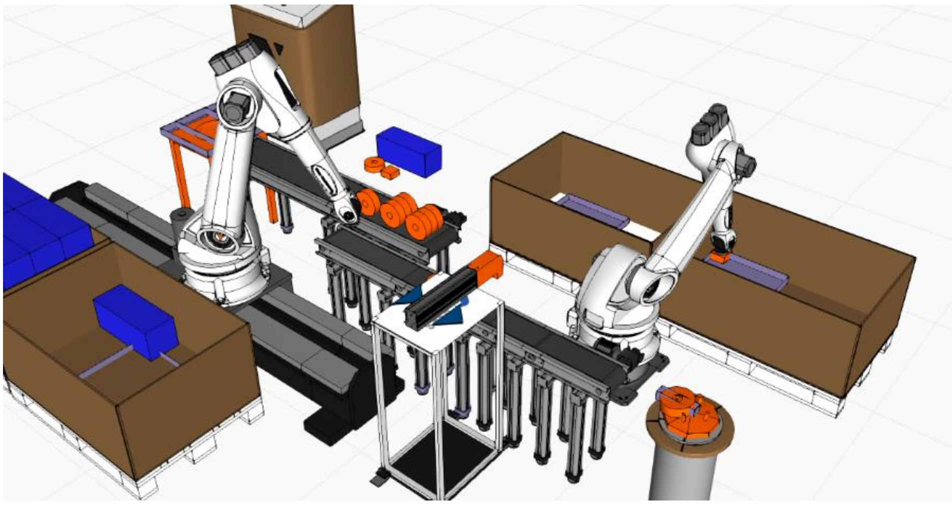

Figure 40 Two robot step 10

Step 11:

Before step 11 robot changes gripper to goldsmith magnetic gripper. The bearing without plastic cover is finally picked from plastic removal unit. The position of the bearing can be found from Figure 41.
Figure 26 shows the position of bearing wrap at P_7. Approximate virtual time from step 10 to step 11 is 5 sec.

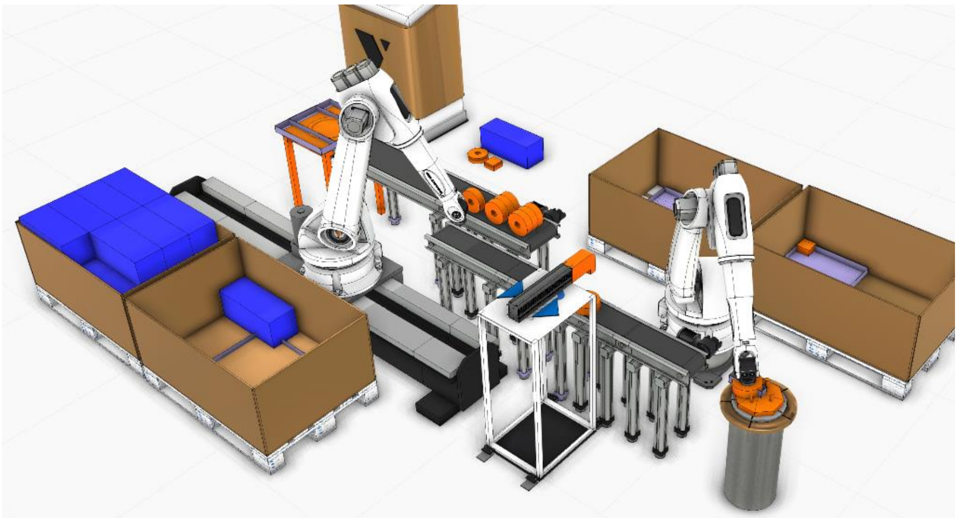

Figure 41 Two robot step 11

Step12:

Finally, the bearing without plastic wrap is palletized into container 4 by robot 2. Position of the robot arm can be seen in Figure 42.
Figure 26 shows the position of bearing wrap at P_7. Approximate virtual time from step 8 to step 9 is 7 sec.

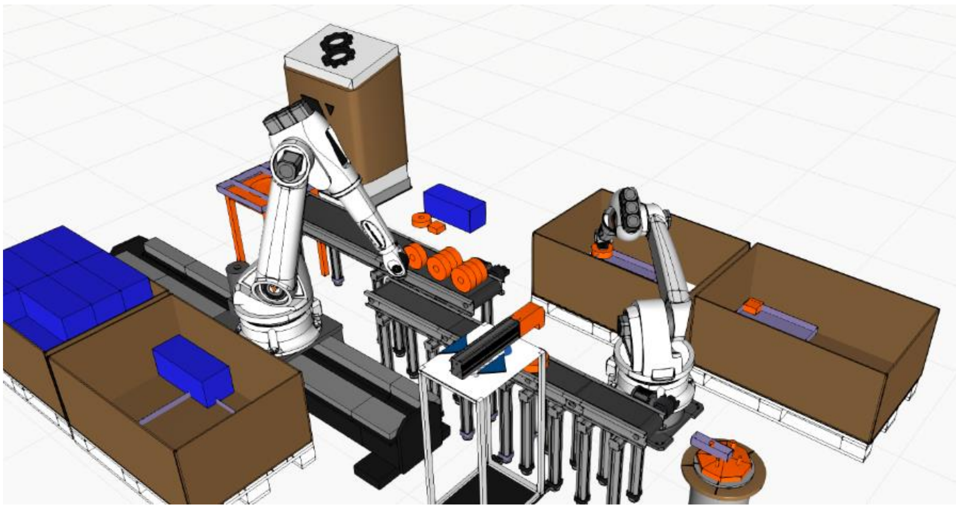

Figure 42 Two robot step 12

Time span:

The simulation is carried out for the process until the container is filled up. Times loss for changing end efector, cutting the package, lazer cutting is not considered. The time recorded is a virtual time spend to unpack 216 bearings. The process is carried out after the bearing package that are required to be unpack are placed for the robot to be picked. The time period for two robot process can be seen in the Figure 43, which is one hours sixteen minutes and fourtysix seconds.

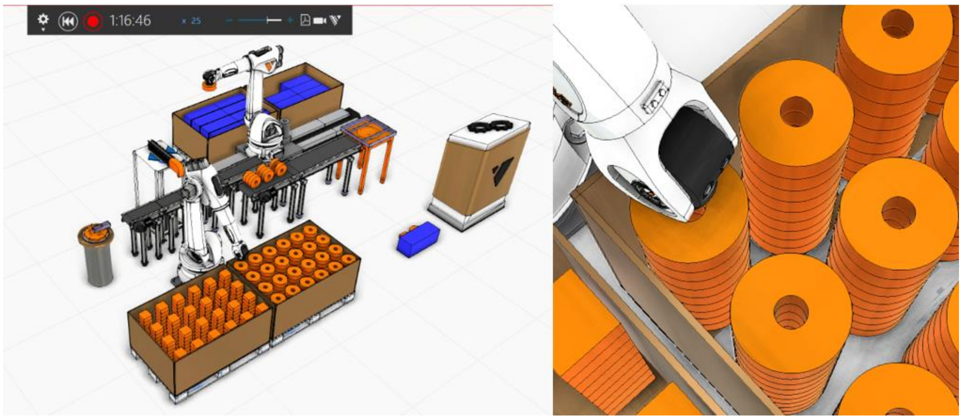

Figure 43 Time span for two robot process

Time span for first bearing on each station is shown in Table 7. Ignoring the time for changing tools according to simulation every second bearing is palleted approximately in time difference 25 sec to first bearing.

Table 7 Time span per bearing

Position	Timespan
P_1- P_2	5 sec (transition time)
P_2	4 sec (for cutting)
P_2- P_4	7 sec (on Conveyer first)
P_4	8 sec (on Conveyer first waiting for robot)
P_4-P_5	4 sec (transition time)
P_5-P_6	10 sec (on Conveyer second)
P_6	3 sec (on Conveyer first during laser cutting)
P_6- P_7	4 sec (on Conveyer second)
P_7	3 sec (on Conveyer first waiting for robot)
P_7-P_8	4 sec (transition time)
P_8	16 sec (on Scrap removal unit)
P_8-P_9	7 sec (transition time)
Total	1min 16 sec

6 COMPONENTS SELECTION

6.1 Robotics

6.1.1 Robot

In Figure 44, The slender FANUC M-10iA simplifies applications and floor plans as it is more compact than other robots in its class while maintaining the highest axis speeds and best repeatability in its class. It is truly a small but mighty robot, weighing in at a mere 130 kg while also providing some of the highest write moments and inertia in its class.

In addition, the FANUC M-10iA has a short, standard, and long arm available, and two different types of wrists, hollow or high-inertia. The hollow wrist, dress-out and the routing of cables simplifies the robot, improves the reliability, and reduces the overall system cost. Also, the M-10iA robot can be mounted at any angle on the floor, wall, or ceiling. The work envelope is also increased as J3 can flip over backwards. the robot is controlled using ethernet Ip protocol. (Fanuc M10iA/10M , 2020). The R-30iB Plus controller is used as a controller for the robot (R-30iB Plus controller, 2020). Appendix 5 contains detail specification and workspace of the robot.

Figure 44 Fanuc M-10iA/10M robot (M-10iA/10M, 2020)

Table 8 Fanuc M-10iA/10M Capacity

Axis Robot	Reach	Load capacity
6	1422 mm	10 Kg

6.1.2 End effector

End effector is the tool that is connected to the end of the robot arm which grips the object or workpieces. Different operation acquires different types of end effector to perform process efficiently and conveniently.

In our design process there are two types of workpieces. One is rectangular box containing bearings and other is bearing itself. For gripping and holding bearing package during package cutting process higher grip and the end effector with higher payload is necessary. In Figure 45, Vacuum gripper form Leneartec Maxcap is the perfect example for this operation. use of external vacuum generator and manufactured by 3D printing the gripper weigh only 460 g. Table 9 provides an insight about the capacity of the gripper.

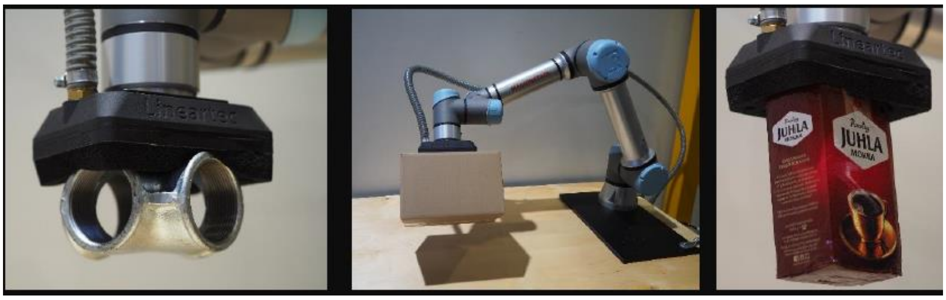

Figure 45 Vacumm Gripper ((Lineartec MaxCap, 2020)

Table 9 Leneartec Maxcap Gripper Capacity

Weight	Gripping Dimension	Payload
460 g	155x114x36 mm	16 kg

Smooth operation is required for passing bearing from conveyer one to conveyer two. It is also similar for pelleting bearing in the container. While pelleting bearing it is highly important that the robot arm will not hit any other bearing that has already been palleted. For such operation Goldsmith magnetic gripper as in Figure 46 would be the best option.

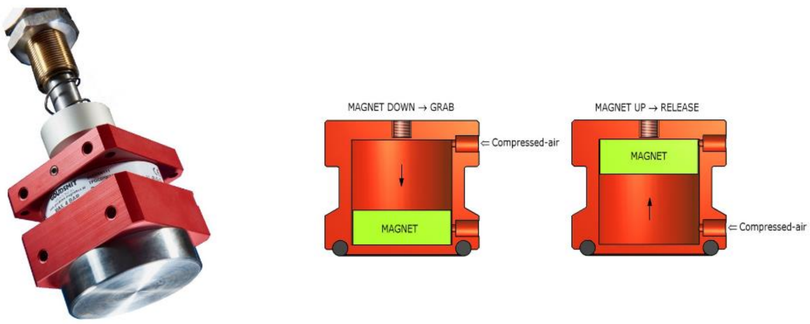

Figure 46 Goldsmith Magnetic Gripper (Goudsmit Magnets Gripper, 2020)

Figure 47 Two finger gripper (2F-85-140 Grippers, 2020)

For griping bearing which plastic wrap has been just penetrated by laser, end effector capable of rotating bearing in opposite position is required. End effector should also be capable of inserting bearing on cylindrical rod of plastic wrap removal unit. After the plastic is separated, it must be moved to the container for disposal. All this operation can be efficiently performed by the 2F-85. Considering the maximum diameter of our bearing to be around 60 mm two finger gripper as shown in Figure 47 could be one of the best options. Appendix 9 contains specification of the grippers.

6.1.3 Robot guide

Modular drive axes with rack-and-pinion drive are use in various applications such as welding, plasma-arc cutting, mechanical processing, pouring, packing, etc. Track motion drive axes are well-proven in applications such as logistics, aerospace, and in the automotive industry. By optimal graduation of the individual sizes, the best possible drive axis could be offered for each type of robot. As in Figure 48 carriage plates, gearboxes, and energy chains are customized specifically for your type of robot and application.

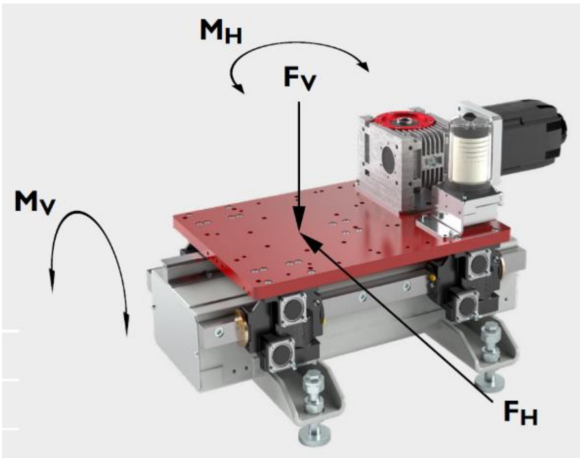

Figure 48 Gudel TMF Trackmotion

The elevated installation (TMO-E) is an extension to the classical mounting on the floor (TMF). The raised installation above the floor permits a significantly better use of the production areas and an optimal access to processes and machines. Trackmotion drive axes can also be employed without robots to carry payloads from 100kg up to 5200kg for universal use. (Trackmotion Floor TMF, 2020). Specification of the robot guide can be found from Appendix 8.

6.2 **Conveyer**

Conveyors are automated tracks that move bulk material or discrete products from one area to another. They are the backbone of myriad material-handling applications to improve efficiency and throughput. Recent advances in materials, controls, and modular subcomponents have spurred new large conveyors for bulk material transport, miniature conveyors for discrete sorting, and everything in between. (Eitel, 2019). Any products like metal, box, food, medical supplies, plastics are conveyed through conveyer from one station to another station. With various purpose conveyors comes with different shape, sizes, and types

On contrary of types moving product, surrounding environment, weight of the products, and speed required the selection of conveyer types is determined. Conveyer one conveys 5 bearing standing vertical along with bearing package. Considering the 6310-Z bearing the width of the package is around 150mm. Similarly, conveyer 2 conveys single bearing standing horizontally. Again, considering the diameter of 6310-Z bearing the diameter is 110 mm. Mass of bearing and package is approximately 1,08 kg and 5,6 kg. The mass and width are used for the biggest bearing type.

For transferring bearings along with package in Conveyer one low profile magnetic conveyer can serve well. Converyer is selected considering the width and payload. For conveying small component as bearing slate conveyer with stainless steel belt is selected. Stainless steel belt will have negligible effect with the laser station. Detail about the selection, specification of the conveyer cab be found from Appendix 10.

Conveyer one:

Figure 49 Magnetic Belt Conveyers (Magnetic Belt Conveyers, 2020)

Eriez' Magnetic Belt Conveyors provide an effective way to move and elevate ferrous materials such as parts, stampings and containers. (Magnetic Belt Conveyers, 2020). As shown in Figure 49 no side guide are required, and the magnetic conveyer could hold the bearings firmly in vertical position.

Conveyer two:

Slate conveyors use a slat and chain system to move components along an assembly line. They are often used where production operations are performed with the parts located on the conveyor. For handling small components like bearings slate conveyer is one of the best option available (Slay Conveyer Systems, 2020). The chain is operated by an electric motor and gearbox. Special chain attachment is used to attach steel panels.

Figure 50 DL2 Slate Conveyer (Modu Stainless steel Structure System DB, 2020)

Upon researching DL2 (145mm) Plastic Chain Conveyer from modu (Modular Conveyer Components, 2020) is selected. The conveyer has 140mm width with thermoplastic chain and stainless-steel frame. Figure 50 and Table 10 shows the DB-Structural System and technical characters of Dl2 Slate Conveyer. Appendix 11 contains detail specification of conveyer 2.

Table 10 Technical Characters of Conveyer two. (Modular Conveyer Components, 2020)

Chain width		140 mm
Chain Pitch44		44,5 mm
Chain Weight		2,5 kg/m
Max Tension		1000 N
Max Product weight		25 kg
Drive Unit Capacity		1200 N
Item Width		25-320 mm

6.3 Sensors

Object detection is an important task in the automation industry. Industrial controls engineers and software developers need to know when an object or target has arrived at a location.

Depending upon task and object properties and the location of the target different types of sensors are required. Diameter from 3-30 mm can be found. Since we are dealing with ferrous material inductive sensor can be the better choice.

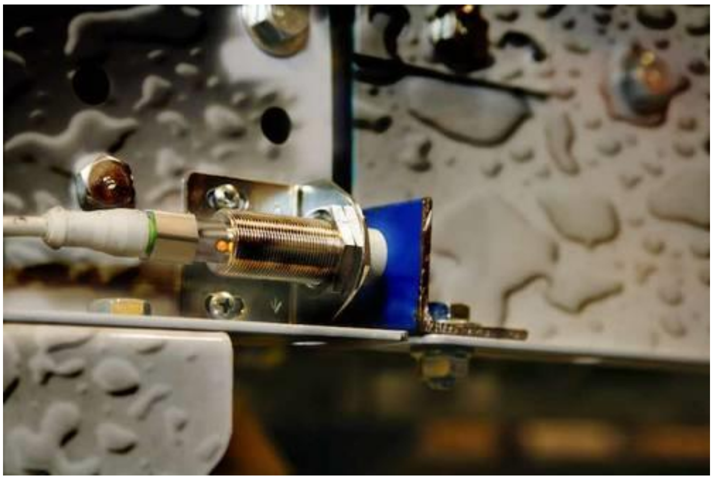

Figure 51 Inductive sensor with housing (Control Engineering, 2020)

The proximity sensors sense a disruption caused in its' electromagnetic field by metallic objects. This helps detecting the metallic object. The variation of distance for detection depends on the metal type and mass of the metal within the sensor's range. Sensors are available in many shape and sizes. Proximity sensors are reliable and cost effective. they are widely used in automation and process equipment. The two vital, co-related selection criteria are the diameter of the proximity switch, and its sensing distance, which is defined as the distance from the sensor face to the target. For our purpose inductive proximity sensor, tubular, 30mm diameter x 60mm body is selected. The specification of the sensor can be found in Appendix 12.

6.4 **Laser cutter**

Higher precision levels and edge quality achieved with laser cutting machine has outcast many other traditional cutting methods. Laser cutting is comparatively efficient, fast, accurate which does not require any cutting tools. With capacity of making complex cut within a second, this method this technology makes lesser contamination with workpiece. Laser cut is widely used for cutting small diameter holes which also provide good edge quality even in a thin sheet, paper, and plastic. Hamk Tech had performed an experiment using 48 series Synard laser cutter for cutting plastic wrap of the bearing. With promising result, further study on Synard laser cutter is conducted. 48-2 Series with 25 W is selected for the operation.

48 Series lasers emit a laser beam with a wavelength of 9, or 10.6 microns depending on model. The laser beam diverges due to diffraction at a full angle of 4 mrad (milliradians), with the beam waist at the output aperture of the laser. (48 Series Operator's Manual, 2019). The beam shape which is initially square at laser output aperture turns to circle when placed one to one and half meter away from laser. Further detail about the laser can be found in Appendix 6 and Appendix 7.

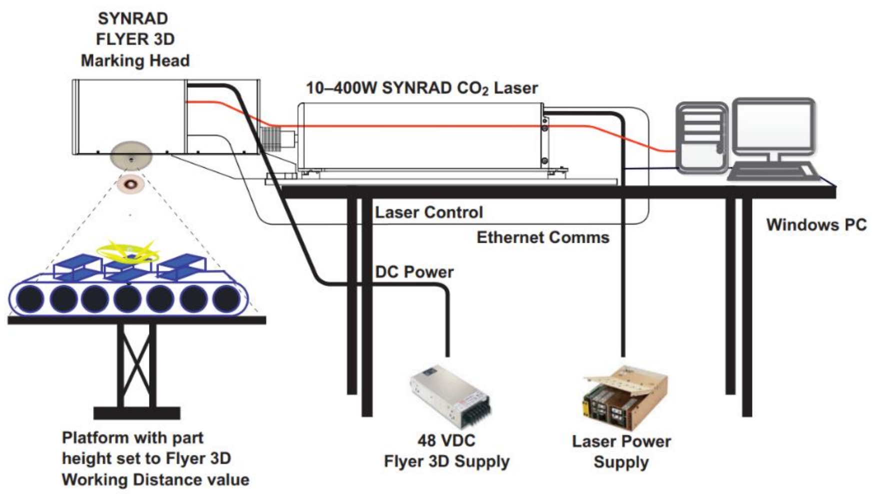

Figure 52 Typical Flyer 3D Head Marking setup. (Flyer 3D Head Manual, 2020)

7 COST ESTIMATE

After all material are selected, cost calculation can be made. In our design, L profile for frame and the aluminium plate needs machining which add up machining as well as labour cost. The cost of material, machining cost, labour cost, and the cost for components like blade, blade cover, tool sharpener, motor, motor controller, cost for joints and adjustable table is roughly calculated. Cost for motor casing is not calculated. The cost estimation is divided into two parts.

7.1 Cost of materials and accessories

The number of components were in significant number thus, the exact cost of all component could not be confirmed. Research are made and list of material and accessories cost are detailed in Table 11.

Table 11 Component Cost

Part/Component	Qty	Price per unit (euros)	Total price (euros)
Fanuc M-10ia/10M with R-30iA Controller	2	17853.06	35706
Lineartec vaccum end effector	1	N/A	-
Goldsmith magnetic gripper	1	420	420
2F-85 Finger gripper with all controllers	1	4700	4700
Magnetic conveyer	1	N/A	-
Slate Conveyer	1	N/A	-
Robot Linear trackmotion	1	18900	18900
48 series synard laser cutter	1	1115.87	1115.87
Flyer head for laser cutter	1	N/A	-
Inductive sensor	5	30,75	153.75
Total price for package cutting unit accessories from Howard from Appendix 2.		3410.10	3410.10
Square profile bar 50x50x8		94.23	94.23
Square profile bar 50x50x6		161.28	161.28
Angle profile 50x50x5		67.05	67.05
Aluminum 6061 plate		55	55
Total		46807.34	64660.4

Cost difference between single and two robot system is the cost of one robot, its' control unit, and tool changer. Other cost like manufacturing, maintenance, assembly, and labour cost are not included.

8 COMPARISON

The main idea of the thesis was to create an industrial process plan and layout for unpackaging the bearing package. Single robot and double robot layout were proposed and studied. Simulation for each layout is performed as well as rough calculation of equipment cost is created. Comparison between two layouts are made.

8.1 Cost comparison

The cost estimation for both single and two robot process are calculated according to the market cost. More accessible supplier was considered in priority. Some of the customer did not respond to the quotation, therefore they are not included. The Table 12 below can give rough estimation of cost.

Table 12 Cost Comparison

Single robot	Two robot
46807.34 euros	64660.4 euros
Flyer head for laser cutter (N/A)	Flyer head for laser cutter
Lineartec vacuum end effector (N/A)	Lineartec vacuum end effector (N/A)
Magnetic conveyer (N/A)	Magnetic conveyer (N/A)
Slate Conveyer (N/A)	Slate Conveyer (N/A)

8.2 Table comparison

A comparison on the basis of a time span for a single robot and a two robot process was determined from the simulation and detailed into in Table 13. Time loss during changing tools is not included.

Table 13 Time comparison

	Time span for first bearing	Time for 216 bearing	Time difference between two bearing
Single Robot	1 min and 23 sec	2 hr. 41 min and 36 sec	45 sec
Two Robot	1 min and 16 sec	1 hr. 16 sec and 46 min	25 sec

9 RECOMMENDATION

The process plan in the thesis satisfied the requirements of the commissioner party. The idea was to design a process plan capable of unpackaging the bearing package. The idea with a single and double robot for the process was proposed and evaluated.

The cost and time estimation were carried out for each process. After the evaluation it was stated that although the two-robot process requires an extra budget for the robot, it is quite efficient and comparatively faster. Thus, my recommendation is to use a two-robot process.

The process consists of package cutting unit. The unit contains components from Hobart slicer. The idea is to make a station where the blade will rest horizontally on the surface of table. Separate station is designed to make the assembly of the component as desired. Most of the commercial and industrial slicers are set in angle. This angle does not allow ease movement of bearing. Besides most of the slicer, Leonardo 350 EVO BS2 has the blade aligned vertically to the table. The specification of the slicer can be found in Appendix 1
Appendix 1 (Sirman, 2013). It is possible to mount the slicer horizontally on the table. With proper height adjustment it is possible to transfer the bearing undisturbed to the first conveyer. If we can use the meat slicer, it can replace package cutting unit making the cost less expensive. It also reduces time for manufacture and assembly of the unit.

10 CONCLUSION

The HAMK Tech Research Unit has been actively conducting research work and projects related to robotics. This thesis work was conducted as a part of this process.

The main aim of this thesis work was to design an industrial process plan capable of unpackaging the bearing package. An earlier experiment and research also provided some foundation for the design. All the requirements set were achieved in this project. The process plan without any disturbance was simulated and evaluated.

All the necessary background research was done prior to starting the design of the process and a systematic design approach was followed until the end. All the possible solutions were discussed with the supervisor and the commissioning party and the best solution was always chosen to proceed further. The design was the most time-consuming phase in the project followed by a study of simulation and simulation. A separate course was taken for learning about visual components for simulation. Simulation and analysis helped to achieve the design. Due to the huge numbers of components, a selection of the best components and cost calculation was another challenge. Suitable components were chosen, and a cost evaluation was finally made. Therefore, this project was successful.

This thesis work contains a pictorial representation of the 3D design, the process plan simulation, the assembly line, the parts list, and the cost breakdown of the product which can be further used to develop the process. All the relevant information retrieved online are attached as references or appendices here. Thus, this thesis work will work as a guidebook for Konecranes.

However, there is still room for improvement in the design, as product design is such a field which always demands improvement. Thus, this thesis work could work as a helpful reference to Konecranes for further design amendments.

To conclude, this thesis project was a great experience to me as a designer. I have learnt various technical skills and broadened my knowledge about process plan design. I got an opportunity to explore new fields of mechanical engineering, such as work simulation, laser cutting, robotics, process plan and automation integration. This experience and knowledge gained will be helpful for me as a future mechanical engineering professional.

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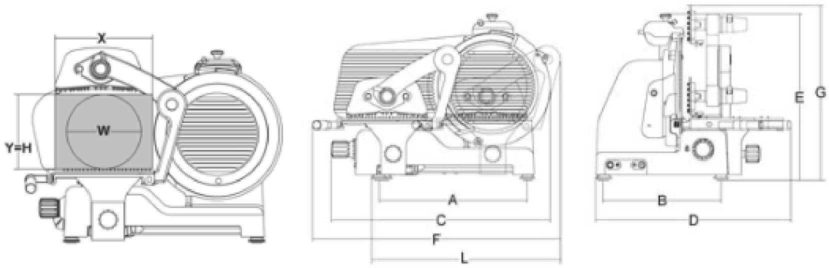
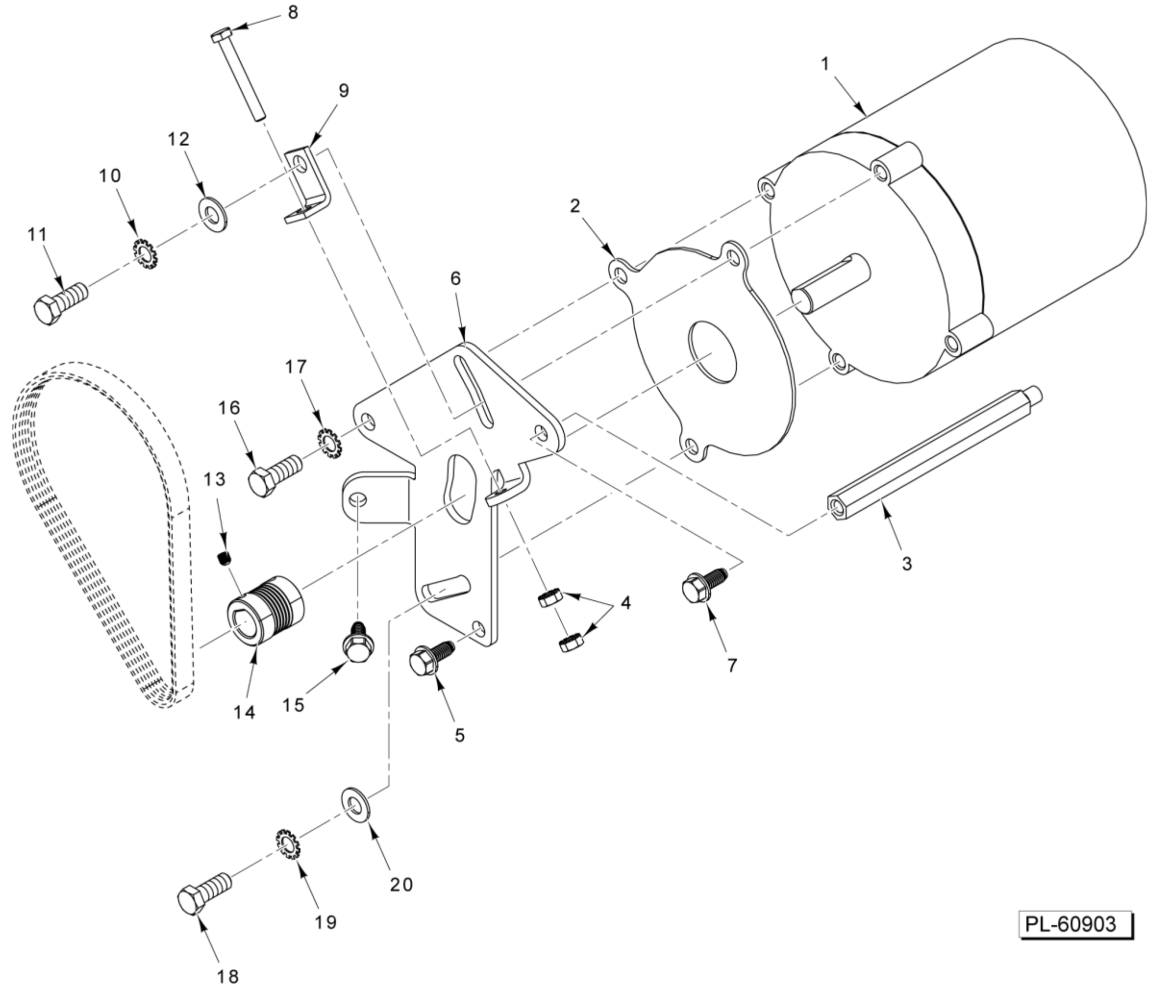
Appendix 1 Data Specification for Meat Slicer



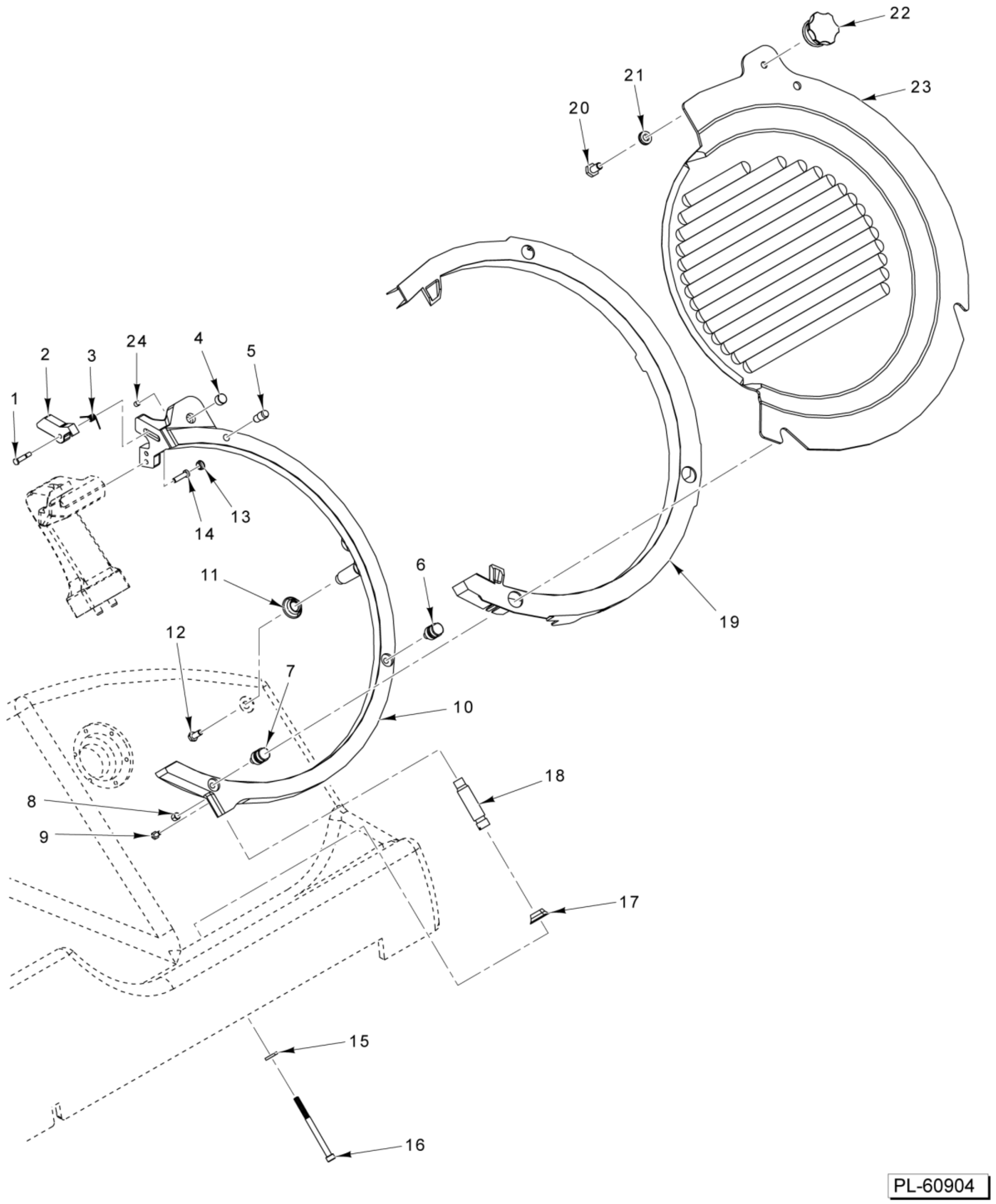
Dati Tecnici:

Modello	Leonardo 350 Evo BS2
ø Lama:	mm 350 - inch 14
Motore:	watt 380 - Hp 0,52
Spessore di taglio:	mm 25
Corsa carrello:	mm 370
Piatto:	mm 350x330
A:	mm 515
B:	mm 410
C:	mm 750
D:	mm 676
E:	mm 567
F:	mm 887
G:	mm 635
L:	mm 677
X:	mm 330
Y:	mm 250
H:	mm 250
W:	mm 250
Peso netto:	kg 59
Dimensioni imballo:	mm 870x840x830
Peso lordo:	kg 75
HS-CODE:	84385000

Appendix 2 Specification for accessories for Package cutting unit



N.O.	PART NO.	NAME OF PART	AMT	PRICE($)
1	00-438846-00001	Motor (60 Hz.)	1	403.38
2	00–439032	Gasket - Motor	1	3.78
3	00–438984	Standoff.	1	94.10
4	NS-044-14	Nut 1/4–20 Hex KEPS	2	N/A
5	SD-038-18	Self-Tapping Screw 5/16-18 x 3/4 Hex Washer Hd., Type RL	1	1.23
6	00-477760	Plate – Motor	1	56.57
7	SD-038-18	Self-Tapping Screw 5/16-18 x 3/4 Hex Washer Hd., Type RL	1	1.23
8	SC-118-98	Cap Screw 1/4-20 x 2 Hex Hd	1	1.44
9	00-477532	Bracket - Tensioner Adjustment	1	5.70
10	WL-007-25	Lockwasher 3/8 External	1	0.10
11	SC-037-73	Cap Screw 3/8-16 x 1 Hex Hd	1	0,71
12	WS-018-22	Washer	1	1,05
13	SC-123-65	Set Screw 1/4-28 x 3/8 Hex Hdls., Flat Pt. (SST).	2	1,39
14	00–438844–00002	Sheave - Poly "V"	1	81,67
15	SD-038-18	Self-Tapping Screw 5/16-18 x 3/4 Hex Washer Hd., Type RL	1	1,23
16	SC-037-73	Cap Screw 3/8-16 x 1 Hex Hd	1	0.71
17	WL-007-25	Lockwasher 3/8 External	1	0,10
18	SC-037-73	Cap Screw 3/8-16 x 1 Hex Hd	1	0.71
19	WL-007-25	Lockwasher 3/8 External	1	0.10
20	WS-018-22	Washer	1	1.05


1
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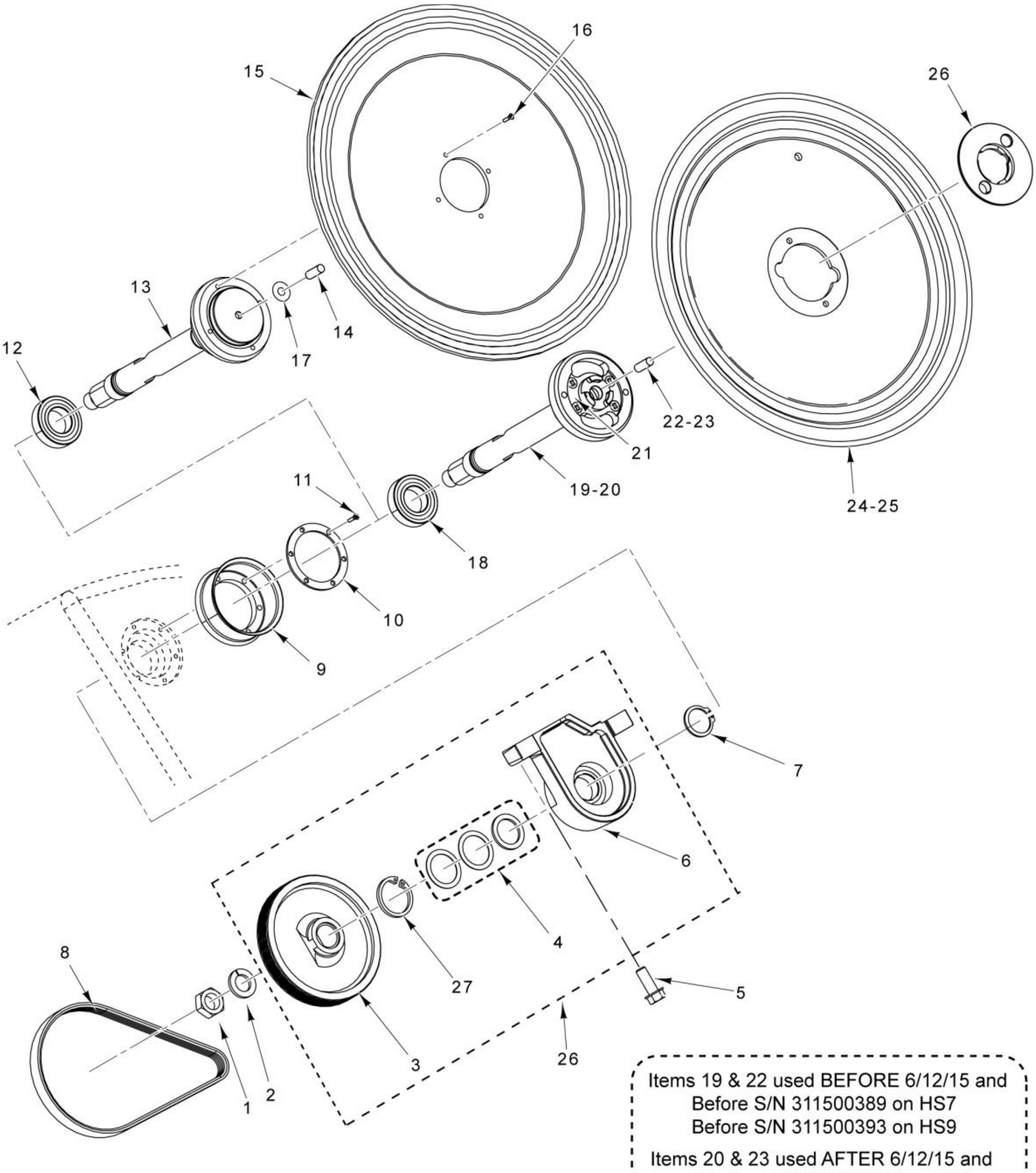
PL-60904

N.O.	PART NO.	NAME OF PART	AMT	PRICE($)
1	00-914411	Pin - Lock.	1	3.78
2	00-914409-00003	Lock - Knife Edge Protector	1	26,26
3	00-914425	Lock - Torsion Spring	1	2
4	00-915319	Magnet	1	10.75
5	00-915299	Pin - Top Cover	1	2.98
6	00-915378	Pin – Tapered	1	4.92
7	00–915378	Pin – Tapered	1	4.92
8	00–914634	Magnet - Product Deflector.	1	2.75
9	SC-130-21	Mach. Screw 6-32 x 5/16 Hex Hd. (SST)	1	0.32
10	00-915390	Ring Guard Assy. (Incls. Items 1 thru 9 & 24)	1	408.18
11	00-914429	Boot - Ring Guard	1	12.81
12	SC-037-80	Mach. Screw 10-24 x 1/2 Hex Hd	1	11.35
13	00–914430	Plug	2	2.50
14	SC-129-78	Cap Screw 8-32 x 5/8 Hex Socket Hd	2	0.45
15	WS-031-78	Washer	1	0.65
16	SC-131-56	Cap Screw 10-24 x 2-1/2 Hex Socket Hd	1	1.17
17	00–914429	Boot - Ring Guard	1	12.81
18	00–915300	Post - Ring Guard	1	10.06
19	00–914408	Cover - Ring Guard	1	15.62
20	SC-131-80	Cap Screw 1/4-20 x 1/2 Hex Hd. (SST)	1	2.86
21	WS-031-80	Washer	1	0.72
22	00–915297	Knob - Top Cover	1	23.25
23	00–915391	Top Cover Assy. (Incls. Items 20, 21, & 22)	1	485.38
24	SC-131-63	Set Screw 1/4-20 x 1/4 Hex Hdls., Flat Pt. (SST)	1	0.25

Length: 5.2 in / 13.21 cm
Width: 5.7 in / 14.48 cm
Height: 3.85 in / 9.78 cm
Weight: 1.9 lbs / 862 g

N.O.	PART NO.	NAME OF PART	AMT	PRICE8($)
1	00–914571	Hobart 00–914571 Knife Sharpener Assembly	1	364.18



Items 19 & 22 used BEFORE 6/12/15 and
Before S/N 311500389 on HS7
Before S/N 311500393 on HS9

Items 20 & 23 used AFTER 6/12/15 and
Starting S/N 311500389 on HS7
Starting S/N 311500393 on HS9

PL-60905

N.O.	PART NO.	NAME OF PART	AMT	PRICE($)
1	NS-017-41	Jam Nut 5/8–18 Hex (SST).	1	0,85
2	WL-004-17	Lockwasher 5/8 Light	1	0,95
3	00–937968	Sheave – Poly "V" Large 6 Groove *See Note	1	58,96
4	00–937970	Washer Assy. *See Note	1	12,50
5	SC-123-50	Cap Screw 3/8-16 x 1 Hex Washer Hd	2	0,69
6	00–875180–00002	Retainer - Lower Hub & Bearing	1	57,16
7	RR-009-07	Retaining Ring	1	2,23
8	00–438845	Belt - Poly "V"	1	33
9	00–915341	Boot - Knife Shaft.	1	5,19
10	00-915342	Ring – Boot	1	5,88
11	SC-131-62	Cap Screw 8-32 x 7/8 Hex Socket Hd. (SST).	6	0,14
18	BB-021-66	Bearing – Ball	1	14,94
19	00–915421	Knife Shaft Assy. (Removable) (Ajustable Rulan Screw) (Incls. Item 18).	1	405
20	00-915421-00002	Knife Shaft Assy. (Removable) (Non Ajustable Rulan Plug) (Incls. Item 18)	1	504,91
21	00-915137	Plunger - Spring 8–32 Thread	1	25
22	00-914561	Screw – Rulon	1	26
23	00-915308	Plug – Rulon	1	7,59
24	00-914753	Knife - Slicer Pack (Removable).	1	577,87
26	00–914422	Plate - Knife Removal Clamp	1	104,84
27	RR-012-48	Retaining Ring *See Note	1	13,97
28	00-937969	I-Kit, Lower Hub and Bearing (Includes items 3, 4, 6 & 27)	1	110,27

Appendix 3 Specification of aluminum plate and bars

6061 ALUMINUM PLATE

Designed for use in aerospace, fittings, valves, drive shafts, couplings, structural, signs, and marine applications.

Categories: Aerospace, Aluminum, Automotive, Furniture, Marine, Mold Alloy, Oil & Gas, Plate, Railroad, Truck.

REQUEST A QUOTE

More Information | Tech Specs | Additional Resources & Downloads

Thickness	Min: 0.25 Max: 12
Length	Max: 240
Width	Min: 48 Max: 96
Other (Wall, Etc...)	Min: Max:
Tolerances	Thickness: Width: Length:

Square bars

Material standard: EN 10025
Material certificate: EN 1024/ 2.1 S235JR, EN 10204 / 3.1 S355J0
Dimensional standard: EN 10059

Length: 6 m

Size	kg/m	S235JR	S355J0
6 x 6	0,28	•	
8 x 8	0,5	•	
10 x 10	0,78	•	
12 x 12	1,13	•	
16 x 16	2,01	•	
20 x 20	3,14	•	
25 x 25	4,91	•	
30 x 30	7,07	•	
35 x 35	9,62	•	
40 x 40	12,56	•	•
50 x 50	19,63		•

Equal angle bars

Material standard: EN 10025
Material certificate: EN 10204 / 2.2
Dimensional standard: EN 10056-2

Length: 6/12 m

Size	kg/m	S235JR	S355J2
20 x 20 x 3	0,88	•	
25 x 25 x 3	1,12	•	
30 x 30 x 3	1,36	•	
30 x 30 x 4	1,78	•	
35 x 35 x 4	2,1	•	
40 x 40 x 4	2,42	•	
40 x 40 x 5	2,97	•	
50 x 50 x 5	3,77	•	
50 x 50 x 6	4,47	•	

Appendix 4 Properties of height adjustable table.

Specifications

- Recommended Table Top Size: 20" x 20" (minimum) to 36" x 36" (maximum)
- Minimum Table Thickness: 3/4"
- Material: Solid Steel
- Control Panel Type: Button Control Panel
- Base Dimensions: 19.4" x 19.4"
- Height Range: 25.5" to 51.5"
- Power Input: 100 to 240V
- Max Speed: 38 mm/s
- Weight Capacity: 110 lbs

Appendix 5 Data Specification of Fanuc Robot

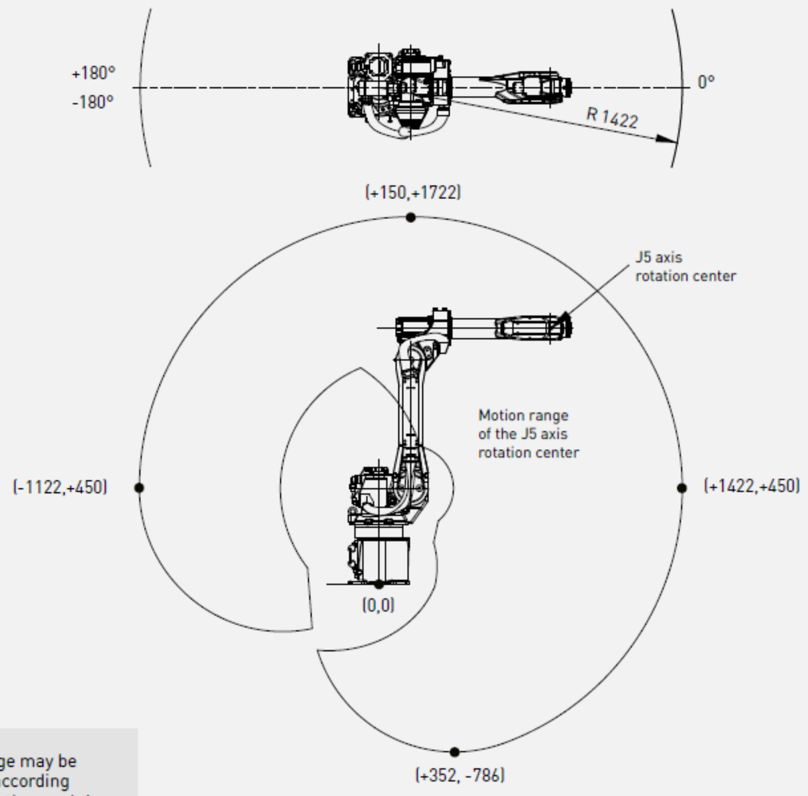
M-10*i*A/10M (High inertia version)

Max. load capacity at wrist: **10 kg**

Max. reach: **1422 mm**

Controlled axes	Repeatability (mm)	Mechanical weight (kg)	Motion range (°)						Maximum speed (°/s)						J4 Moment/ Inertia (Nm/kgm2)	J5 Moment/ Inertia (Nm/kgm2)	J6 Moment/ Inertia (Nm/kgm2)
			J1	J2	J3	J4	J5	J6	J1	J2	J3	J4	J5	J6			
6	± 0.03*	130	340(360)	250	445	400	280	720	225	205	225	420	420	700	26.0/0.9	26.0/0.9	11.0/0.3

Working range



Motion range may be restricted according to the mounting angle!

Robot	**M-10*i*A/10M**
Robot footprint [mm]	283 x 283
Mounting position Floor	•
Mounting position Upside down	•
Mounting position Angle	•
Controller	**R-30*i*B Plus**
Open air cabinet	-
Mate cabinet	○
A-cabinet	•
B-cabinet	○
*i*Pendant Touch	•
Electrical connections	
Voltage 50/60Hz 3phase [V]	380-575
Voltage 50/60Hz 1phase [V]	-
Average power consumption [kW]	1
Integrated services	
Integrated signals on upper arm In/Out	8/8
Integrated air supply	1
Environment	
Acoustic noise level [dB]	< 70
Ambient temperature [° C]	0-45
Protection	
Body standard/optional	IP54/IP55
Wrist & J3 arm standard/optional	IP67

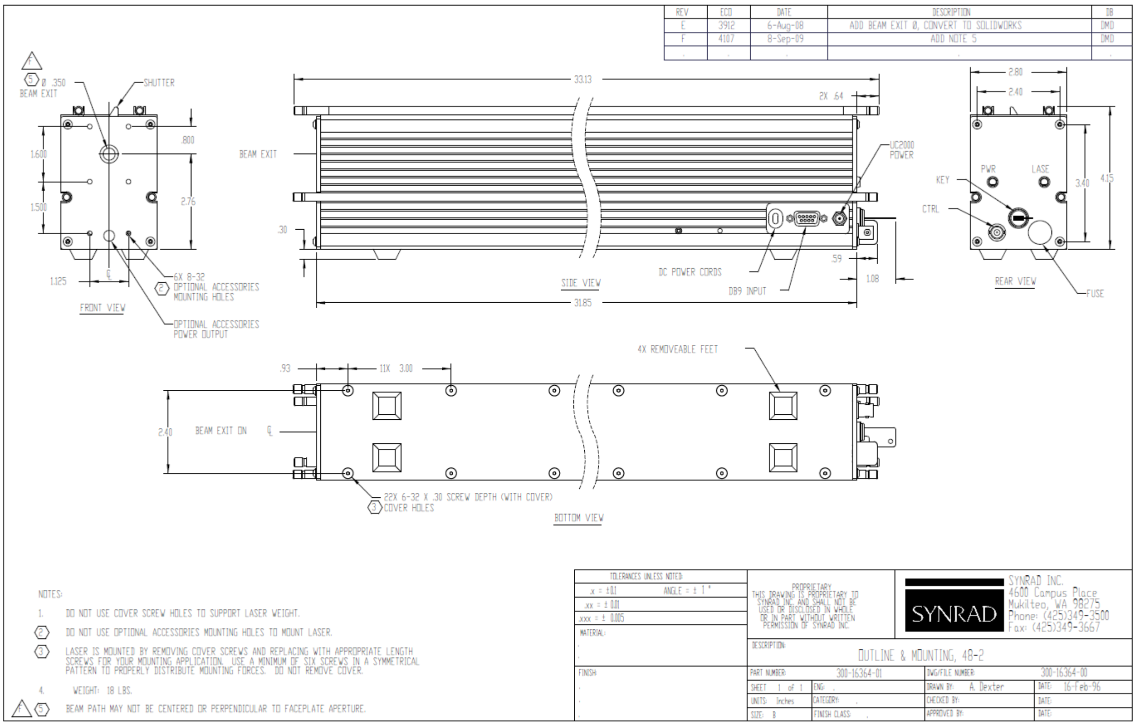
Appendix 6 Specification of laser cutter

series48

• Specifications

Model	48-1(S)	48-1(S)W	48-2(S)	48-2(S)W	48-5(S)W
Output Power	10W		25W		50W
Mode Quality	TEM_{00}, 95% Purity M^2<1.2		TEM_{00}, 95% Purity M^2<1.2		TEM_{00}, 95% Purity M^2<1.2
Ellipticity	<1.2		<1.2		<1.2
Rise Time	<150μsec		<150μsec		<150μsec
Beam Diameter	3.5mm		3.5mm		3.5mm
Beam Divergence (full angle)	4mR		4mR		4mR
Wavelength	10.57-10.63μm*		10.57-10.63μm*		10.57-10.63μm*
Power Stability, from cold start (guaranteed)	±10		±5%		±5%
Polarization	Linear (Vertical)		Linear (Vertical)		Random
Cooling	Air	Water	Air	Water	Water
Heat Load (max)	300W		500W		800W
Flow Rate, Air	250 CFM x 2	N/A	250 CFM x 4	N/A	N/A
Flow Rate, Water (18-22°C)	N/A	0.5 GPM	N/A	0.8 GPM	1.5 GPM
Input Voltage / Current	30 VDC / 7A		30 VDC / 14A		30 VDC / 28A
Dimensions (in)	16.9 x 2.8 x 4.2		31.9 x 2.8 x 4.2		34.9 x 5.3 x 4.5
(mm)	429 x 71 x 107		810 x 71 x 107		886 X 135 X 114
Weight	9 lbs / 4.1 kg		18 lbs / 8.2 kg		44 lbs / 20 kg

(S) in the model number designates OEM configuration (does not include keyswitch or shutter switch).
Beam specifications measured at $1/e^2$.
*Typical. Actual wavelength range may vary from 10.2-10.8μm
Specifications subject to change without notice.

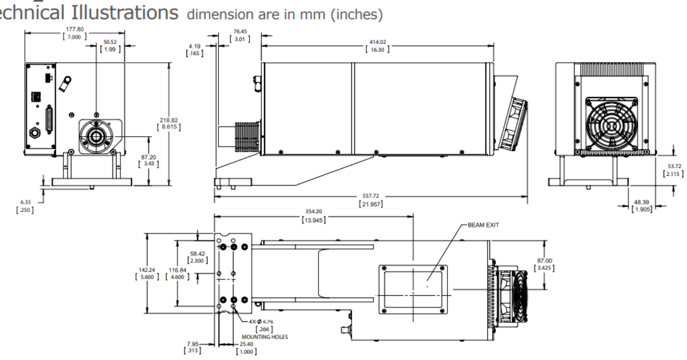


Appendix 7 Specification for flyer head for laser cutter

Performance	
Field Size mm (inches)	269 x 227 to 914 x 833 (10.6 x 8.9) to (36 x 33)
Spot Size 1/e² (µm)	165 - 688
Working Distance Range mm (inches)	268 - 1101 (10.5 - 43.3)
Scan Speed, mm/s (inches/s)	7620 (300) - 15240 (600)
Operation	
Operating Temperature Range	0 to 40° C
Humidity	0 - 95%, non-condensing
Electrical Input	48 VDC ± 2.0 VDC, 6.7 A, 20 A Peak
Heat Load, generated by the head	320 W nominal, 400 W max
Inbput Beam Wavelength	9.3 µm - 10.8 µm
Continuous Beam Input Power	500 W
Physical	
Dimensions w/ mounting bracket LxWxH inches (mm)	558 x 191 x 280 (21.9 x 7.5 x 11.1) - all others 580 x 191 x 280 (22.8 x 7.5 x 11.1) - p Series
Weight kg (lbs.)	9.7 (21.45)
Communication	
Tethered: PC control and mark file creation	WinMark, ActiveX
Standalone: allows API, PLC, PC or I/O control	ActiveX, Modbus I/P, Master Control File
I/O	8 inputs/8 outputs Built-in user accessible 15 V power source

Flyer 3D Scan Head

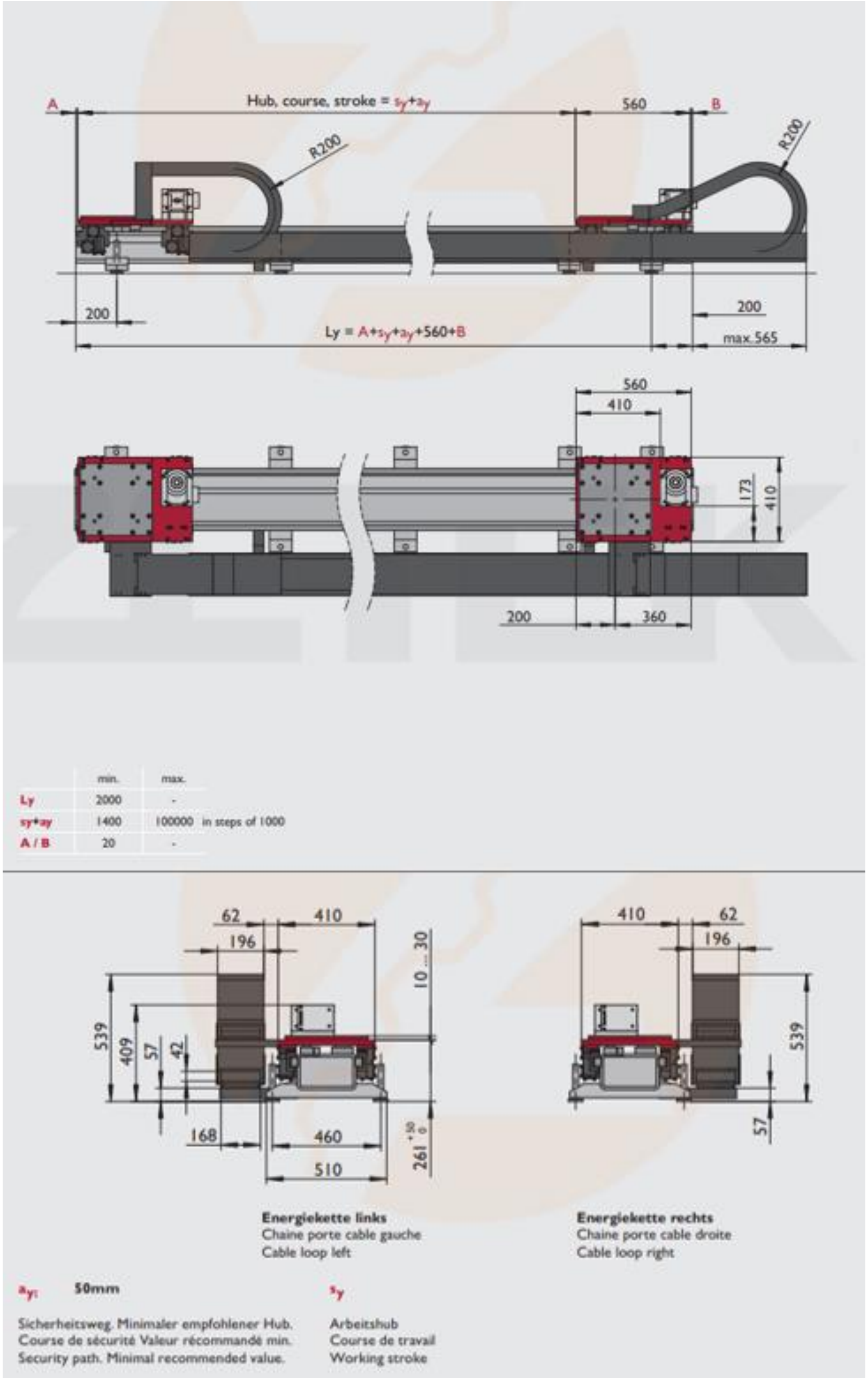
Technical Illustrations dimension are in mm (inches)



Dimensions Marking head, Synrad CO_2 laser (30 - 400 W) and mounting rail

Dimensions for Flyer 3D System Pairings - mm (inches)							
	v30	ti Series	p100	p150	p250	f201	i401/p400
L	1022.21 (40.24)	1250.01 (49.21)	1272.75 (50.11)	1481.58 (58.33)	1913.28 (75.33)	1913.28 (75.33)	1914.08 (75.36)
W	203.20 (8.00)	241.30 (9.50)	241.30 (9.50)	241.30 (9.50)	355.60 (14.00)	355.60 (14.00)	355.60 (14.00)
H	231.52 (9.12)	231.52 (9.12)	293.24 (11.55)	293.24 (11.55)	263.40 (10.37)	263.40 (10.37)	429.54 (16.91)

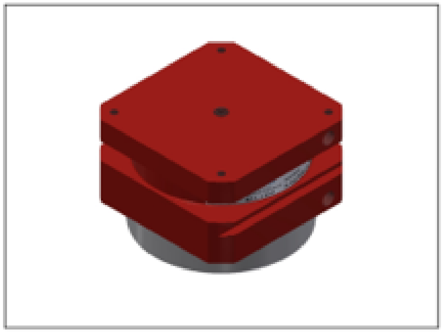
Appendix 8 Specification for robot guide



Appendix 9 Specification for Robot end effector

SPECIFICATIONS

	Hand-E	2F-85	2F-140
Stroke (adjustable)	50 mm	85 mm	140 mm
Grip force (adjustable)	20 to 130 N	20 to 235 N	10 to 125 N
Form-fit grip payload	5 kg	5 kg	2.5 kg
Friction grip payload	3 kg	5 kg	2.5 kg
Gripper mass	1 kg	0.9 kg	1 kg
Position resolution (fingertip)	0.2 mm	0.4 mm	0.6 mm
Closing speed (adjustable)	20 to 150 mm/s	20 to 150 mm/s	30 to 250 mm/s
Communication protocol	Modbus RTU (RS-485), RS-485, RS-232		
Ingress protection (IP) rating	IP67	IP40	IP40



Magnetic grippers

HGR-SQ-100-FL-R-G-S

SKU: TPGC100078

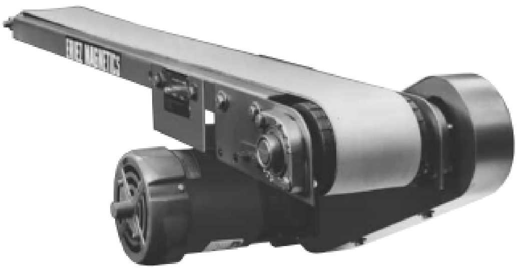
Product Features

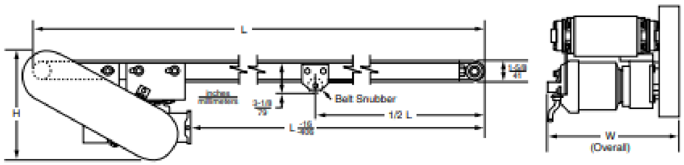
Description	Magnetic gripper
SKU	TPGC100078
Product key	HGR-SQ-100-FL-R-G-S
Size	100 mm
Switching	Pneumatic
Advised working load	500 N (under ideal conditions - with safety factor 3 acc. EN13155)
Max. tear off force	1500 N (under ideal conditions - Graph: see Document tab - Factors influencing lifting capacity: see<nbsp;>/goudsmit/en/knowledge-base/about-magnetic-lifting.html)
Min. advised sheet thickness	3 mm
Interface/connection dim's	Threaded hole M6 (8x),Threaded hole M10
Connections	Pneumatic: G1/8" (2x)
Material housing	Aluminium,AISI316L (SS 1.4404) (screw cap)
Surface treatment/finishing	Anodized
Colour	Red
Min./max. ambient temperature	0 to 70 °C
Switching pressure	Max. 4 bar
Magnetic system	8 Permanent magnet poles
Magnet quality	Neodymium GSN-45, Br 13,700 gauss (at 20 °C), Tmax. 80 °C
Depth	100 mm
Width	100 mm
Height	70 mm
Weight	1.5 kg
Type	Basic
Air consumption	1.352 l/cycle (1x up, 1x down)

Appendix 10 Specification for Conveyer

LOW-PROFILE MAGNETIC BELT CONVEYOR FEATURES

- Motor can be side mounted, top mounted or mounted beneath the conveyor.
- Sturdy 11-gauge steel frames are light enough to be moved easily.
- 3-1/2" (89 mm) diameter steel-drive pulley is grooved to dissipate oil and improve tracking.
- Sealed bearings eliminate the need for lubrication.
- Three standard lengths and four widths (with custom sizes available to meet specific applications).
- Standard belt speed of 60 fpm (18.3 mpm) can be varied by changing sprocket ratios.





MODEL NUMBER	L		W (BELT)		W (FRAME)		W* (Frame at Belt Snubber)		W (OVERALL)		H*		WEIGHT	
	in.	mm.	in.	mm.	in.	mm.	in.	mm.	in.	mm.	in.	mm.	lb.	kg.
456	66	1676	4	102	6	152	7	178	12-5/8	321	11	279	94	43
656			6	152	8	203	9	229	12-5/8	321			130	58
856			8	203	10	254	11	279	14-3/8	365			164	74
1056			10	254	12	305	13	330	16-3/8	416			196	88
476	90	2286	4	102	6	152	7	178	12-5/8	321	11	279	130	58
676			6	152	8	203	9	229	12-5/8	321			178	80
876			8	203	10	254	11	279	14-3/8	365			227	102
1076			10	254	12	305	13	330	16-3/8	416			276	125
4106	126	3200	4	102	6	152	7	178	12-5/8	321	11	279	180	81
6106			6	152	8	203	9	229	12-5/8	321			247	112
8106			8	203	10	254	11	279	14-3/8	365			315	142
10106			10	254	12	305	13	330	16-3/8	416			385	174

* W (Overall) and H based on standard 1/6 hp gearmotor.

LOW-PROFILE MAGNETIC BELT CONVEYOR SPECIFICATIONS

Belt: Oil-resistant PVC

Belt Speed: 60 fpm (18.3 mpm)

Frame:
One-piece 11 gauge stainless steel

Pulleys:
Drive pulley: 3-1/2" (89 mm)
Tail pulley: 1-1/4" (32 mm) C.R.S.

Bearings: Sealed

Drive:
1/6 to 1/2 hp, 115V, 60 Hz
TEFC gearmotor

Dimensions and specifications are subject to change without notice.

Note: Some safety warning labels or guarding may have been removed before photographing this equipment.

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Appendix 11 Technical Specification and Accessories for Conveyer two.

Drive Units DL2

Item Code Guideline For Drive Units

Gearmotor size (SEW)
S20 = WA20
S30 = WA 30
S37 = SA37
S47 = SA47

Gearmotor type (Motovario)
M40 = NMRV 040
M50 = NMRV 050

Transfer Device
NIL = Basic Unit
TR = Free Roller
DR = Driven Roller

Gearmotor position: L or R

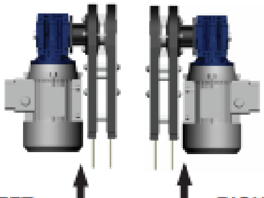
D: Front Drive
T: Combined Drive
C: Catenary Drive
S: Suspended Drive
I: Intermediate Drive
W: Wheel Bend Drive

Clutch
NIL = Basic Unit
C = With Clutch

DL2 DD L S20 TR C

Front direct drive unit, motor on left side for 0.55kW SEW geared motor, with Free Roller and Clutch.

Motor Orientation Guideline



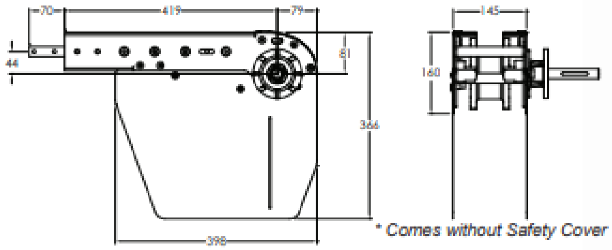
LEFT RIGHT

* Drive comes without gearmotor,
Please refer TR-13 for gear motor options.

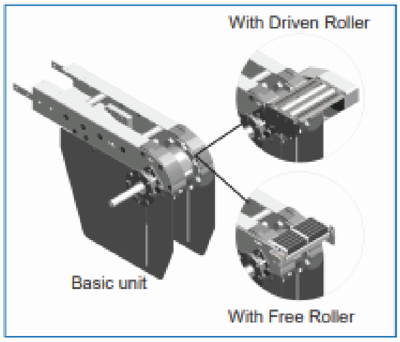
eg. Code for Basic unit; DL2 DT R M50 => Combined drive unit, motor on right side for Motovario NMRV 050 geared motor.

Front Drive Unit

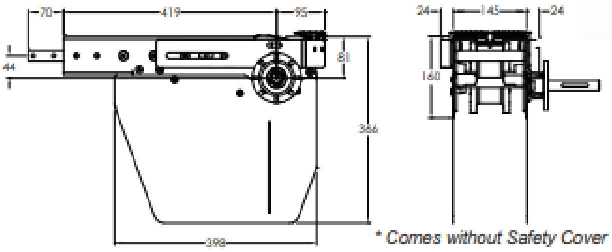
Basic Front Drive



* *Comes without Safety Cover*

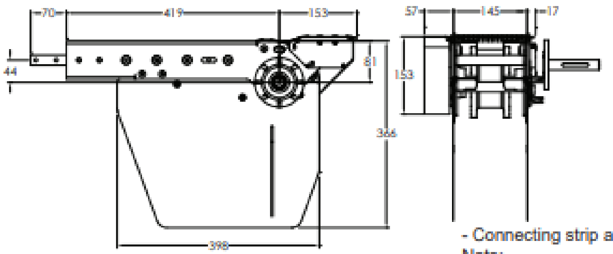


Front Drive with Free Roller



* *Comes without Safety Cover*

Front Drive with Driven Roller



* *Comes without Safety Cover*

- Driven Roller speed is approximately 10% higher than conveyor speed.

Effective track length: 1.16m
Traction force: 1200N

Item Code	*Weight*	*Supply*
DL2 DD R/L S/M	6.4 kg	1 unit
DL2 DD R/L S/M TR With free roller	8.1 kg	1 unit
DL2 DD R/L S/M DR With driven roller	9.9 kg	1 unit

- Connecting strip and screw included.

Note:

- Safety Cover comes as an option.
- Recommended maximum chain elongation is 366mm from top conveyor and chain slack.
- Refer TR15 for chain effective track length calculation.
- Cleated Chain is not possible to use on drive with Free Roller or Driven Roller.

Please consult MODU representative for further information and assistance.

Units: Dimension (mm)

Lubricant For Chain

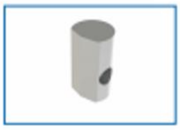
Silicone-based lubricant, 400ml

Item Code	Weight	Supply
MA SL	0.35 kg	1 pc

Stainless Steel Pin

Item Code	Weight	Supply
ML2 PN M4x73	0.07 kg	10 pcs/pkt

Chain Pivot



Item Code	Weight	Supply
ML2 PV	0.07 kg	10 pcs/pkt

Chain Pin Insertion Tool

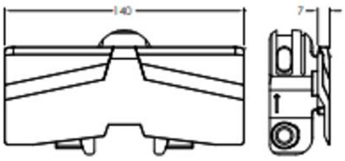
Chain pin insertion tool shown without attachment & specific drive pin

Item Code	Weight	Supply
TR CP 1	1.2 kg	1 pc

Attachment For Chain Tool

Chain attachment & drive pin

Item Code	Weight	Supply
ML2 AC	0.3 kg	1 set



Safety Chain

- Suitable for conveyor configuration with incline/decline up to 5˚.
- Accumulation possible.

Item Code	Material	Colour	Weight	Supply
ML2 CP 5S	POM	White	12.4 kg/roll	5m/roll

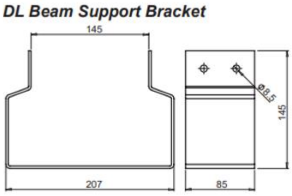
DB 2

Bipod

Material:
- Foot cap in stainless steel AISI 303.
- Two-point foot in Polyamide, glass fibre reinforced, PA 6 GF30%.
- Beam support bracket in stainless steel AISI 303.
- Ornamental pipe in stainless steel AISI 303.

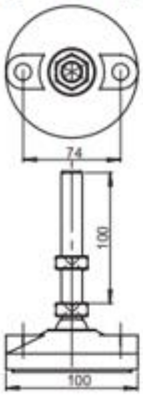
Supply:
- Items are supplied individually.

DL Beam Support Bracket



Item Code	Weight	Supply
DL2 BS 100	1.1 kg	1 pc

Adjusting Foot Cap, M16



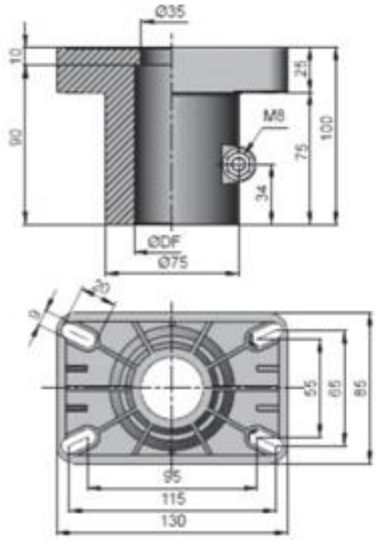
Item Code	Weight	Supply
MB FP 16x100S Stainless Steel	0.4 kg	1 pc
MB FP 16x150S Stainless Steel	0.4 kg	1 pc

Polyamide Foot, 2-point

Bore Diameter: 63.5mm

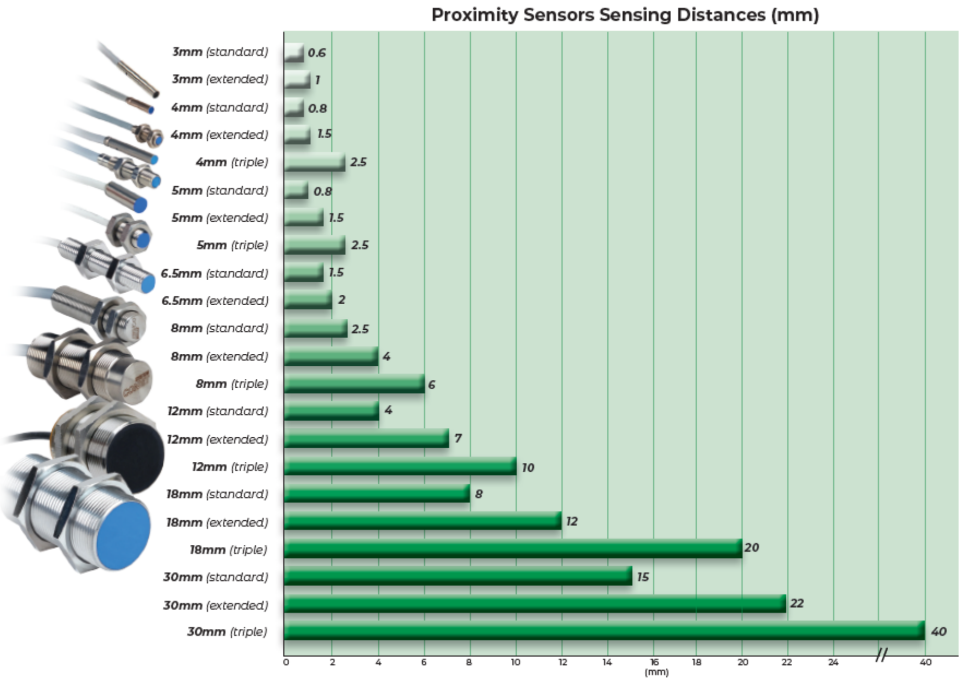
Item Code	Weight	Supply
DB FB	2.4 kg	1 pc

Support Head



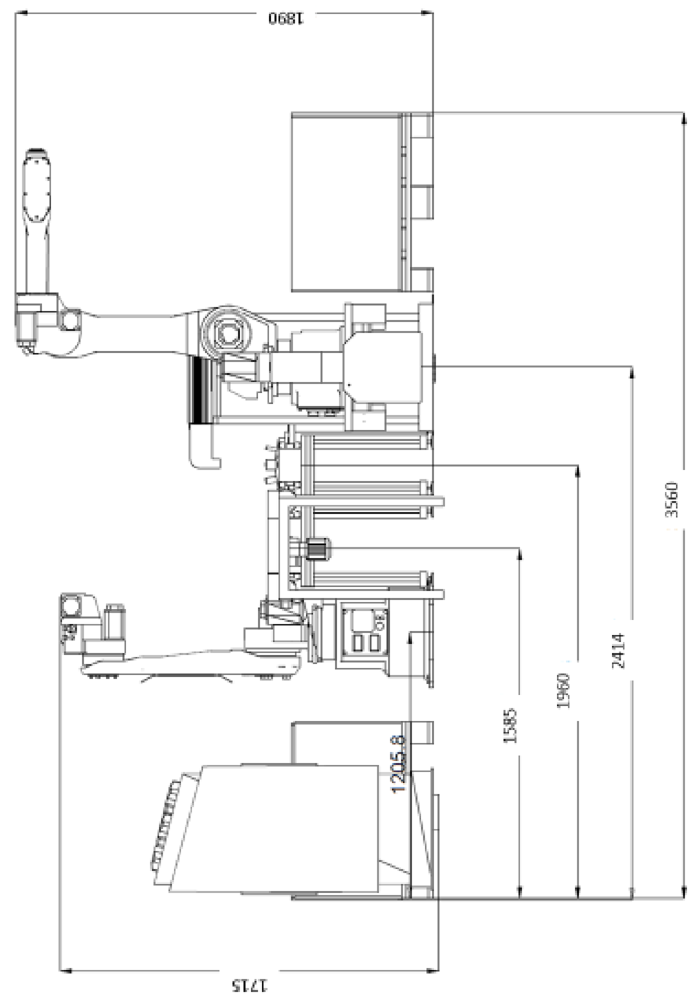
Item Code	Weight	Supply
DB HS	0.3 kg	1 pc

Appendix 12 Sensor Specification

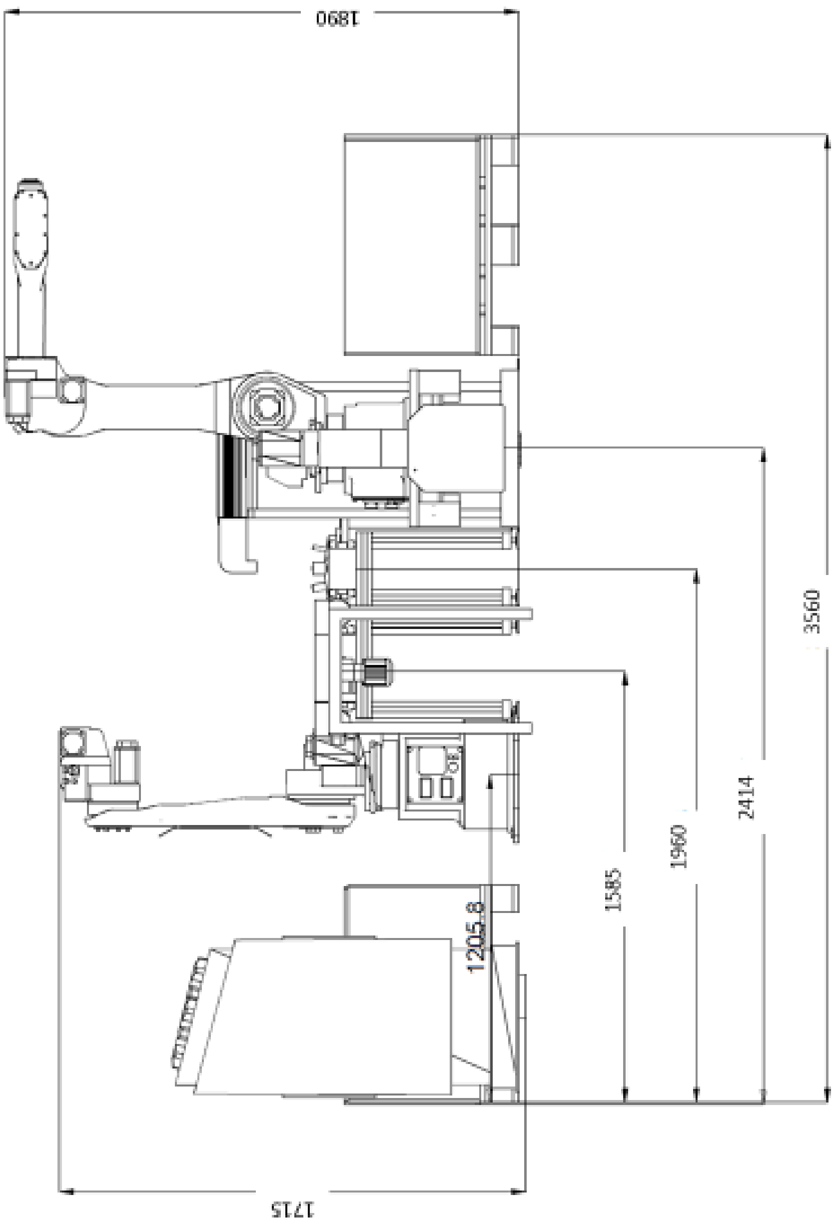


Technical Attributes	
Item	Proximity sensor
Sensor Type	Inductive
Shape	Tubular
Housing Size	30mm diameter x 60mm body
Housing Material	Nickel-plated brass
Barrel Type	Threaded
Sensing Method	Standard sensing
Adjustable	No
Number of Wires	2
Switching Output	NPN/PNP
Operation Mode	N.O. output
Sensing Distance	10mm
Mounting Type	Flush
IO-Link Compatible	No
Switching Frequency	150 Hz
Operating Voltage	10-30 VDC
IP Rating	IP67
Connection	Pigtail
Conductor Size	21 AWG
Cable Length	6.5ft/2m
Includes	Mounting hardware

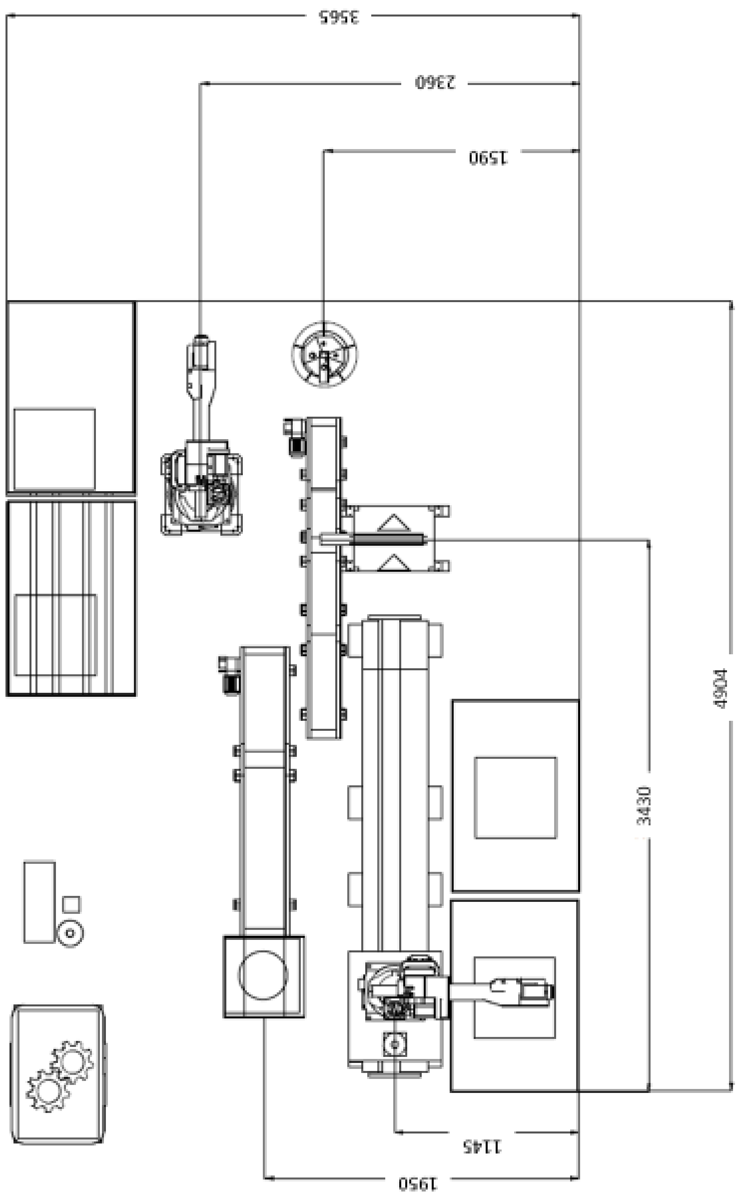
Appendix 13 Front view drawing for two robot operation



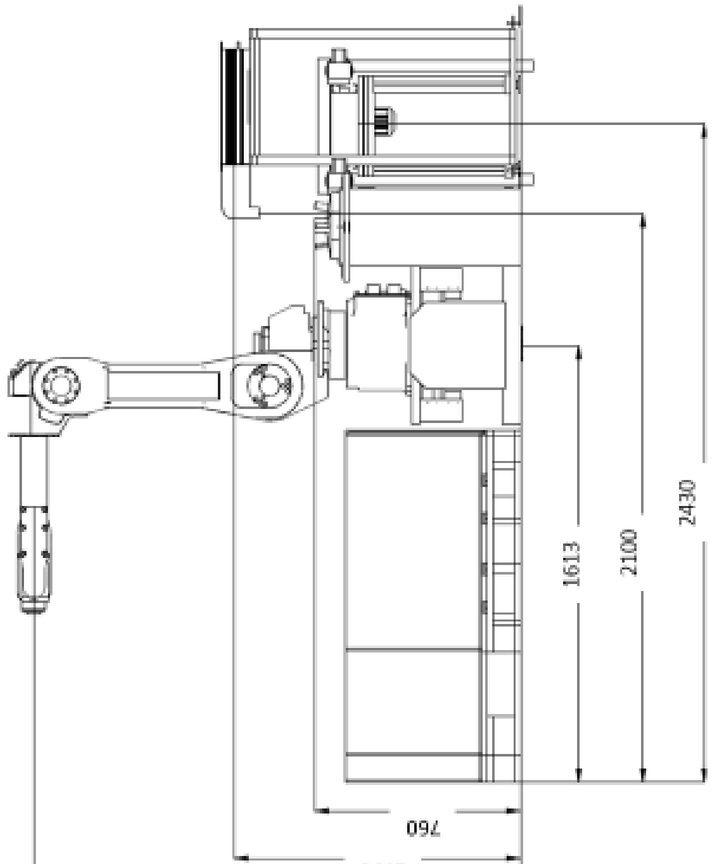
Appendix 14 Side View drawing for Two robot operation



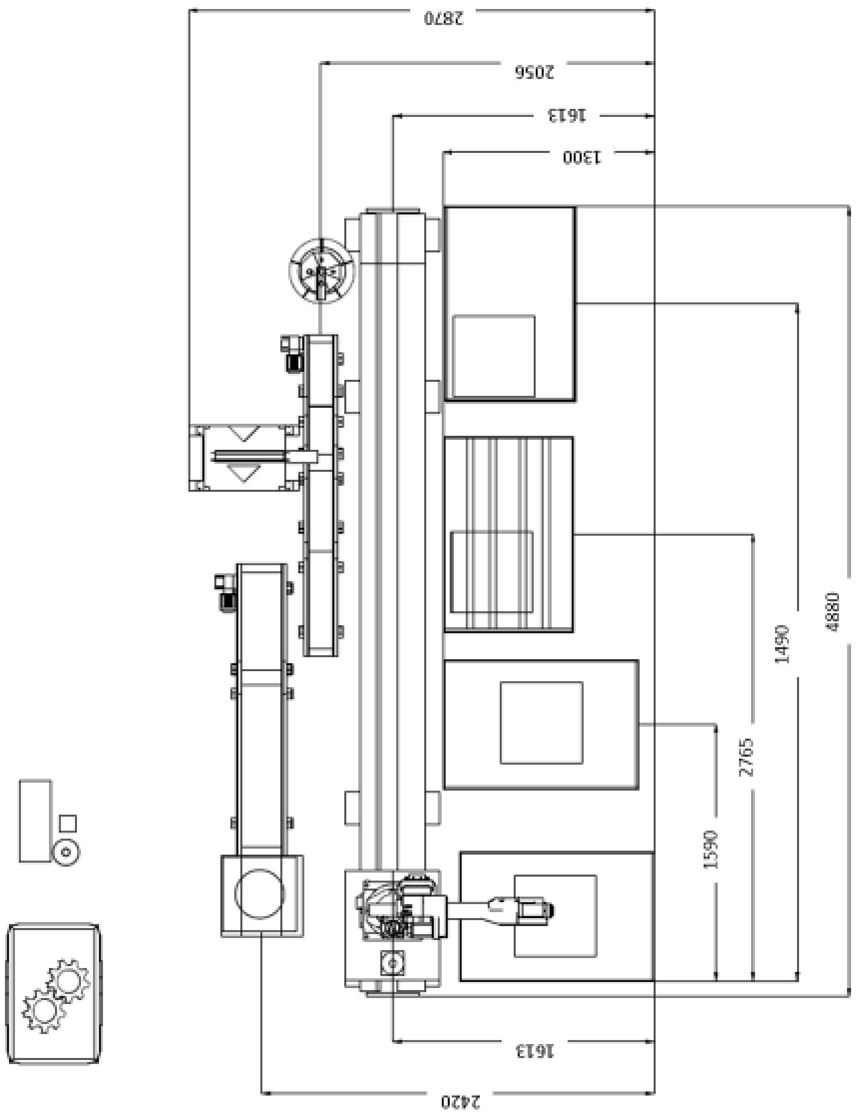
Appendix 15 Side view drawing for two robot operation



Appendix 16 Front view drawing for single robot operation

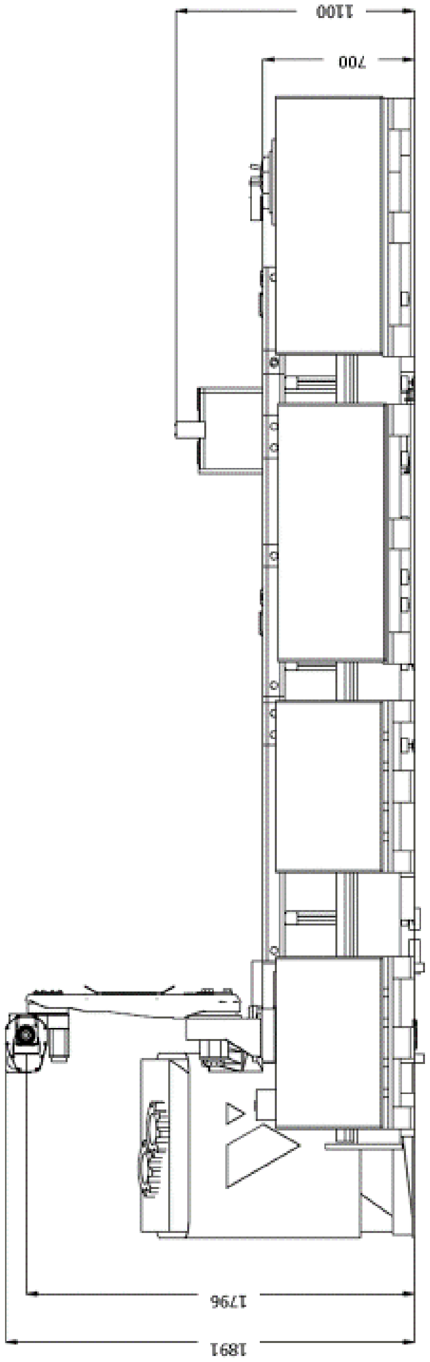


Appendix 17 Top view Drawing for single robot operation

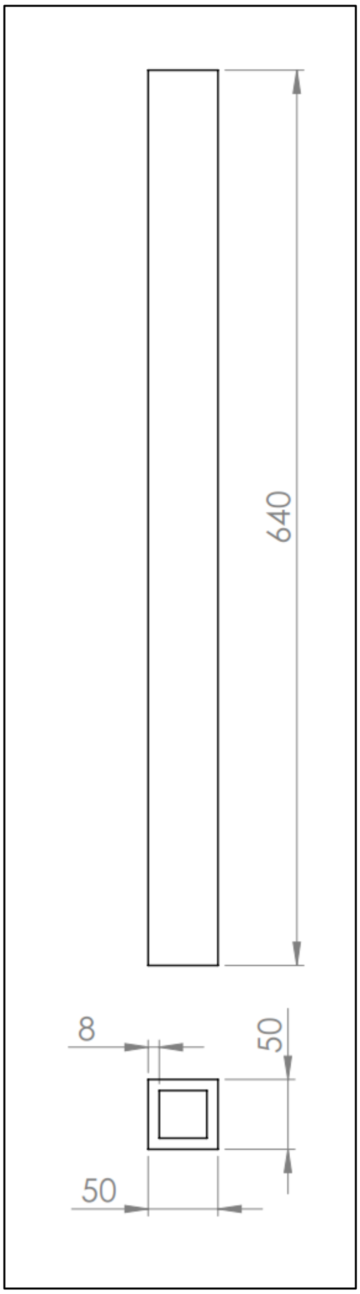


Appendix 18

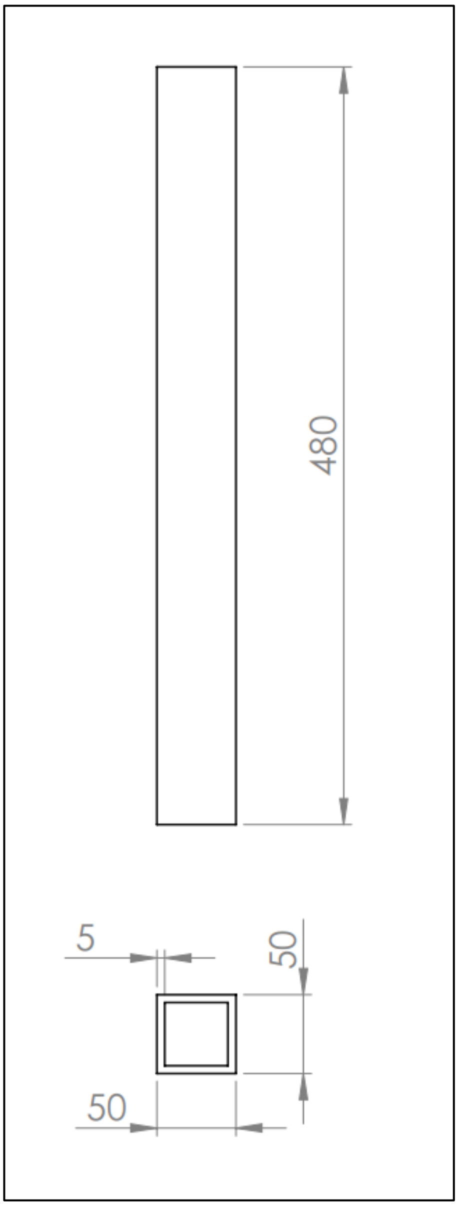
Appendix 18 Side view drawing for single robot operation



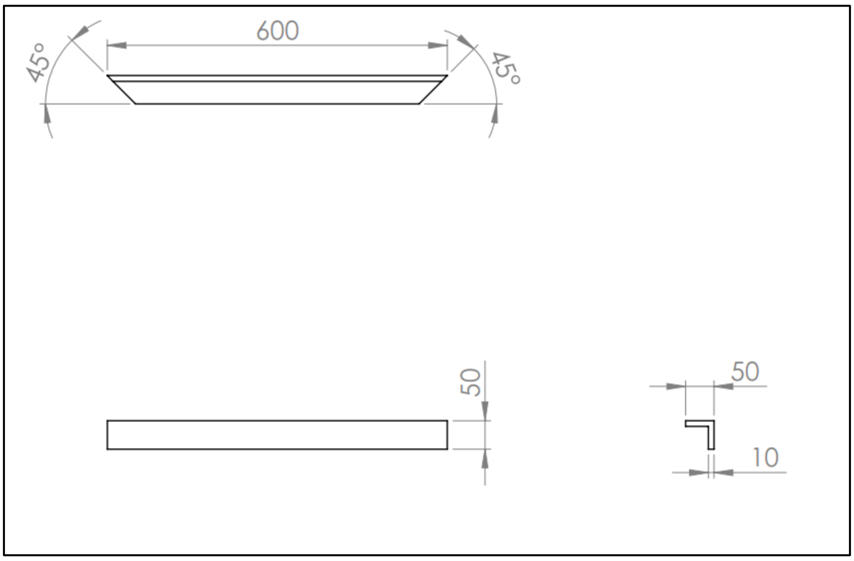
Appendix 19 Drawing for components and assembly of Package cutting unit.



Square Profile Leg

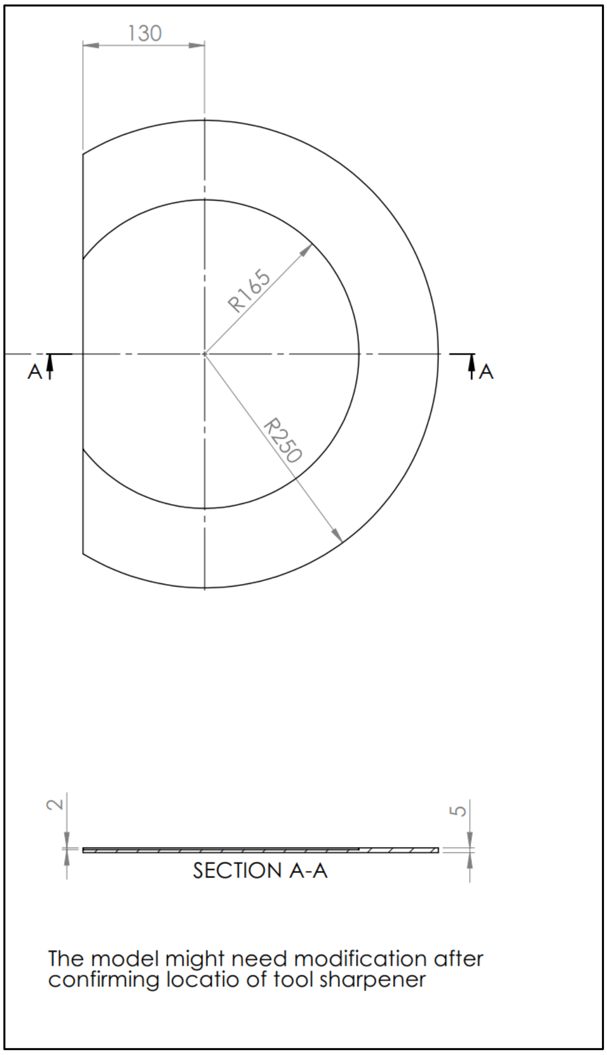


Square Profile Base Support

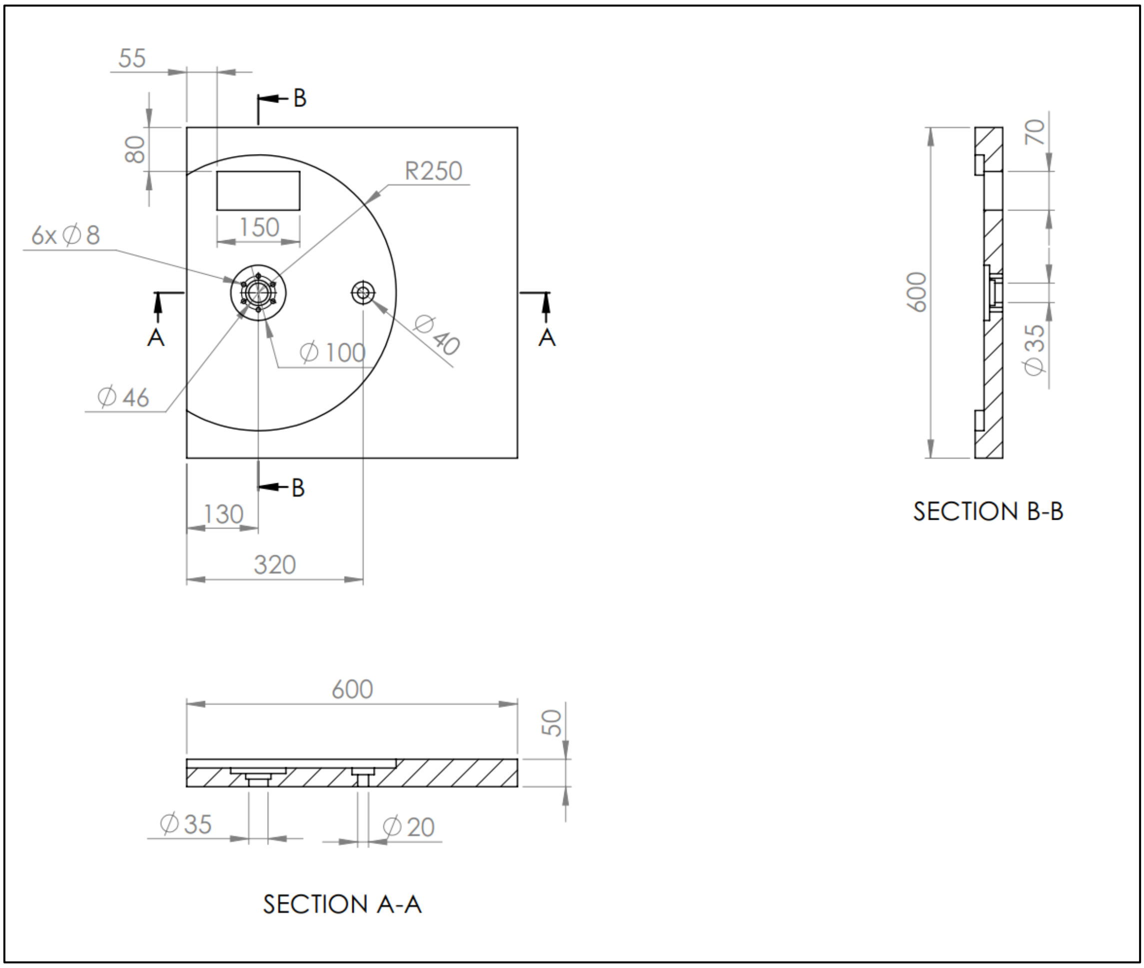


Upper Frame Angle Profile

https://www.gyscoal.com/index078a.html?page_id=27



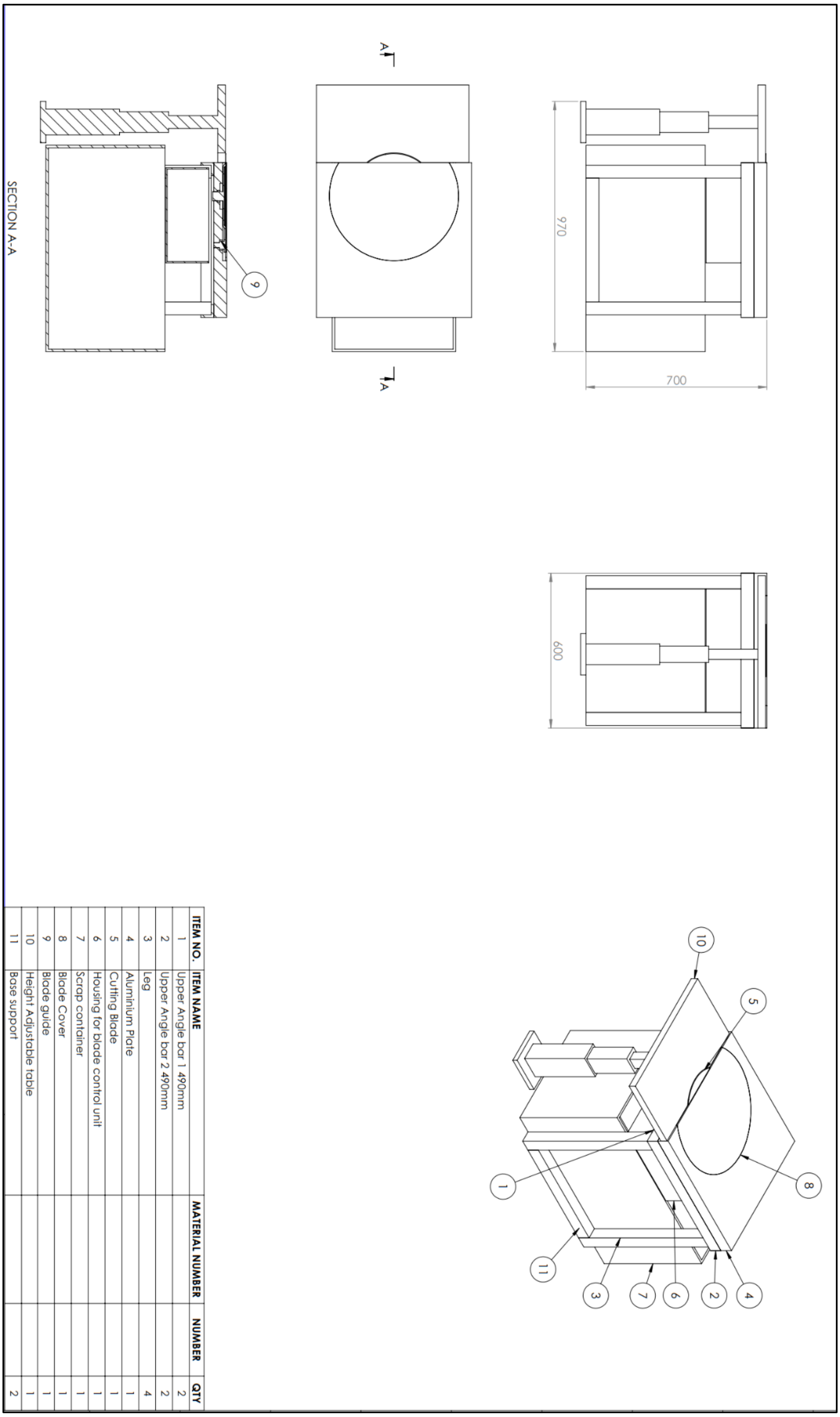
Blade Cover



Blade Support Aluminium Plate

https://www.clintonaluminum.com/product/6061-aluminum-plate/

Appendix 19 (page 3)



ITEM NO.	ITEM NAME	MATERIAL NUMBER	NUMBER	QTY
1	Upper Angle bar 1 490mm			2
2	Upper Angle bar 2 490mm			2
3	Leg			4
4	Aluminium Plate			1
5	Cutting Blade			1
6	Housing for blade control unit			1
7	Scrap container			1
8	Blade Cover			1
9	Blade guide			1
10	Height Adjustable table			1
11	Base support			2

Package Cutting unit