Concept and simulation of robotized assembly application

Hanna Tullock
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Assa OEM is a manufacturer of locks and fittings for windows, doors and cabinets. To be more competitive, automating the production is an advantage. Assa assembles six different types of left and right reversible hinges. One product stands for 80% of the assembly time on the line. For this product Assa wants to implement a robotized assembly solution in one of the three assembly stations. The remaining 20% still needs to be assembled manually. The aim of this study is to investigate three assembly stations, select one assembly station to automate, give three concepts at half-time of the project for the selected assembly station and simulate one final automated concept.

The assembly line produces approximately 2000 reversible hinges each day. For the stations in the assembly line the cycle time is around 16 seconds. In the three assembly stations the assembly tasks are similar, it is the number of rivets or parts that differ. In assembly station three there is one additional task that is not included in the first two assembly stations. In this task the arm is lifted and turned 180 degrees, and then placed over three rivets. This is more complex for a robot to perform and will require more equipment. There are similarities between assembly station one and two and therefore concepts for both stations will be given.

Three layout concepts are presented for the first assembly station and for the second assembly station one concept is presented. Also, two concepts of combining assembly station one and two are presented. On April 17th, 2018, a meeting at Assa was held to discuss the different concepts and layouts. The discussion led to the conclusion that a further investigation on implementing a robot will be carried out for the concept in assembly station two.

The main result is that the cycle time of 16 seconds is difficult to accomplish. The path must be well planned to achieve this with a collaborative robot. To attain the cycle time the end-effector must be designed so that no tool change will be necessary. The rivet is small and therefore a gripper would have difficulty gripping the rivets. Therefore, other methods such as ferromagnetic or vacuum are recommended. The feeder system of the rivet is suggested to have a vibrating bowl feeder due to the orientation of the rivets. The frames’ feeder system needs to be designed for the purpose in assembly station two.

The frame that is to be assembled on to the fixture exposes a risk for an operator if working beside the robot. To minimize the risk area from the frame, relocation of the frame feeder and planning the path differently is suggested. The layout will require safety equipment and the suitable safety equipment depends on the flexibility Assa requires.
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This master degree report, *Concept and simulation of robotized assembly application*, was written as part of the master degree work needed to obtain a Master of Science with specialization in Robotics degree at University West. All material in this report, that is not my own, is clearly identified and used in an appropriate and correct way. The main part of the work included in this degree project has not previously been published or used for obtaining another degree.

Signature by the author

Hanna Tullock

June 4, 2018

Date
Preface
SUMMARY .................................................................................................................. III
PREFACE .................................................................................................................. IV
AFFIRMATION .......................................................................................................... V
CONTENTS ............................................................................................................... VI

Main Chapters
1 INTRODUCTION ..................................................................................................... 1
  1.1 PROBLEM DESCRIPTION .............................................................................. 1
  1.2 AIM .................................................................................................................. 2
  1.3 LIMITATIONS ............................................................................................... 2
2 THEORY .................................................................................................................. 3
  2.1 MATERIAL HANDLING ................................................................................. 3
  2.2 ISO STANDER ............................................................................................... 7
  2.3 METHODOLOGY ........................................................................................... 12
3 METHOD ............................................................................................................... 14
4 ASSEMBLY LINE ................................................................................................... 15
  4.1 ASSEMBLY STATION ONE ............................................................................ 16
  4.2 ASSEMBLY STATION TWO .......................................................................... 17
  4.3 ASSEMBLY STATION THREE ....................................................................... 17
  4.4 ANALYSIS OF ASSEMBLY STATIONS ........................................................... 18
5 CONCEPT ............................................................................................................. 20
  5.1 ASSEMBLY STATION ONE ............................................................................ 20
  5.2 ASSEMBLY STATION TWO .......................................................................... 22
  5.3 CONCEPT COMBINED STATION ONE AND TWO ....................................... 22
  5.4 CONCEPT DISCUSSION .............................................................................. 24
6 RESULTS ............................................................................................................. 26
7 CONCLUSION AND DISCUSSION ...................................................................... 29
  7.1 DISCUSSION ................................................................................................. 29
  7.2 CONCLUSION ................................................................................................ 32
  7.3 FURTHER WORK ........................................................................................... 32
8 REFERENCES ....................................................................................................... 33

Appendices
A. LAYOUT MEASUREMENTS
B. DISCUSSIONS MATERIAL FOR CONCEPT MEETING ON APRIL 17, 2018
1 Introduction

Assa OEM (Original Equipment Manufacturer) is a company within Assa Abloy group and located in Eskilstuna and Gothenburg. In June 2007 the company was formed by a merger of the three companies ASSA Industri AB, AB FAS Låsfabrik and FIX AB. Assa OEM is a manufacturer of locks and fittings for windows, doors and cabinets and a market leader in Scandinavia. [1] To be more competitive, automating the production is an advantage. Reasons to automate can be that the tasks are tedious and repetitive or that the environment is dangerous for workers. Today it is most common to automate when the throughput is high, and the variety of products is low. Assembly tasks are seldom automated in industry. Case studies in the Swedish industry show that 90% of the assembly is still being done by human workers [2]. The main reason for this is that it is still difficult to achieve the desired flexibility to meet the customer's demands of variety.

There are two basic types of assembly configurations. The first is an automated line with a special purpose. The robots are located along a transfer line and each robot has its purpose and task to do. When the task is fulfilled the parts proceed to the next station on the transfer line. The second one is a single station assembly; the robot has one or more tasks to do and then the part is moved to the next station. For a single station assembly there are four types of tasks: (1) The picking and placing of parts which cause the robot to have a low load and insertion force; (2) Mechanical fastening such as riveting, screwing and crimping that requires significant power and high force; (3) Fastening of parts such as welding or soldering, operations categorized by the effect they have on the surrounding environment. When automating an assembly task with a robot, problems might occur if the assembly task contains small pieces that need to be mounted with high accuracy. (4) The robot will have problems to do the intersection of parts such as gaskets or O-rings, which is typical manual assembly work. [3]

1.1 Problem description

Today Assa is interested in investing in a solution with robotized assembly. At the line in Gothenburg, where Assa produces reversible hinges, the assembly is being executed by manual work. The line consists of three manual assembly stations. Between the assembly stations there are machines for rivets and grease. After the assembly, there are several more rivet machines to complete the assembled products. Assa assembles six different types of left and right reversible hinges. Product A stands for 80% of the assembly time on the line. For this product Assa wants to implement a robotized assembly solution in one of the three assembly stations. The remaining 20% still needs to be assembled manually, due to the required high flexibility and low batch sizes of these products.
1.2 **Aim**

The aim of this study is to:

- investigate three assembly stations.
- select one assembly station to automate.
- suggest three concepts at half-time of the project for the selected assembly station.
- simulate one final automated concept.

1.3 **Limitations**

This study does not include:

- concept of assembly station without economical calculations.
- study of material flow excluded.
- any recommendation of brand for production equipment.
- evaluation on automation will be on product A.
2 Theory

2.1 Material handling

Should an assembly task be automated with a robot, the parts that the robot will use for the assembly task must be delivered to the cell. Redford [3] presents four material handling requirements that the assembly system has to fulfil to be automated, (See Figure 1) the first being the handling of parts to the assembly cell. These parts are categorized in two sections: the parts that can be handled and those which cannot be handled by automatic part feeders. The second requirement is the removal of parts from the assembly cell. The third requirement is the removal of products to external operations. Not all products can be assembled by automation due to technical specifications or other reasons. The fourth requirement is the transportation of partly finished products. These are products that are almost done but need to be reworked. This chapter will describe different ways to supply the robot with parts.

Figure 1: Material handling requirements listed by Redford.

2.1.1 Feeder

A feeder should fulfil the function of storing and feeding, and have a good size so that the re-stocking has manageable time intervals. The use of a correct feeder is mainly determined by two factors, the quality and the kind of the products the feeder handles. In relation to the part the feeder handles, it can be categorized in three main groups. Feeders can only organize the part by one arrangements property. These are parts with a clear centre of gravity formation such as screws and rivets, which always fall in a particular order. Feeders of this sort are hoppers and inclined conveyers. The second group are feeders, which can arrange parts in different arrangement features, such as vibrating bowl feeders. The latter group of feeders have additional sorting equipment. [4]

To be able to channel the parts to the robot’s picking position the orientation of the parts needs to be correct. This can be achieved by generating vibration and the parts orientation is dependent on the method used to move the parts. In the industry the most common feeder is the vibration bowl feeder. (See Figure 2) A vibration bowl
forces the parts upwards in a spiral track. These tracks have obstacles that force the parts, which are not traveling in the right orientation, to fall down into the bowl again. [5]

The reason for the vibration bowl feeder being the most common one is its availability and versatility. A vibratory bowl feeder is not effective in the space it requires, and it is not easy to re-configure. With a vibratory bowl feeder there are costs that may be expensive depending on which products the feeder is built for, such as the bowl and outlet of the feeder need to be special configured to match the part. Re-configurating the vibratory bowl feeder usually means that the bowl and outlet need to be replaced. [3] The vibrations cause noise, and therefore the vibratory bowl feeders are coated with nose cancelling material or constructed with soundproofing material [5].

Another type of feeder are the hoppers, and there are different types of hopper feeders. The book “Manufacturing assembly handbook” describes the scoop segment, a hopper with an edge wheel and one with a discharging system of magnetic plate. A hopper with a scoop segment functions so that the segment in the hopper swings back and forth and only the part with the right orientation follows the scoop segment to a delivery channel. The design of the top blade and width of the scooper depend on the part the hopper is to orientate. (See Figure 3) The swinging motion of the scoop needs to be smooth and not uneven, and to generate the smooth motion crank or cam drive is

![Figure 2: Typical design of a vibrating bowl feeder.](image)

![Figure 3: Design of a hopper with a segment scooper.](image)
preferred. Because of the smooth motion, this type of feeder is preferable with a sensitive material such as glass or ceramic. The capacity depends on the part the hopper is handling, the length of the scoop segment and the time a movement cycle for the scoop segment takes. [4]

A hopper with blade wheel is suitable for parts that are larger and simpler and only need to be aligned in one direction. A wheel rotates in the hopper and correctly oriented parts follow the wheel around to an outlet for the parts. This hopper is not adequate for parts that are easily deformed. The wheel design is dependent on the geometry of the parts. The capacity of hoppers with an edge wheel depends on the parts and the rotation speed of the wheel. [4]

A hopper with a magnetic plate is suitable for orientating parts that are flat and simple, such as plates, rings and discs. Using this hopper, the parts must be ferromagnetic. Since the hopper consists of a plate with magnetics inside on a proper placement. When the plate rotates, the parts are rotated with the plate and forced to leave the plate at the delivery outlet. If the level of parts in the hopper is low, the parts move to the rotated plate due to gravity and the slope of the front on the hopper. (See Figure 4) The diameter of the magnetic plates, numbers of magnets and rotating speed determine the capacity of the hopper. [4]

![Figure 4: Hopper with a slope designed to make the parts falls throw the bottom.](image)

An inclined conveyer is a hopper with a conveyer system that only allows parts in the right orientation to reach the discharge rails. If the parts are in the wrong orientation they will fall to the hopper. (See Figure 5) An inclined conveyer is appropriate for feeding parts that are cylindrical flat and has a high capacity. Another advantage is its high of parts in the storage and in the conveyer. Its limitation is if the parts are cylindrical flat and large. Depending on the centre of gravity on the part the degree of inclination to the conveyer belt is decided. It is the design of the conveyer belt that sorts the parts to the right orientation. The conveyer belt extracts parts from the container and incorrectly oriented parts fall down into the container again. [4]
2.1.2 Bin picking

Bin picking is a method of supplying the robot with parts by delivering a bin, in which the parts are not placed in a certain order. Then different methods are used to let the robot calculate how to grip and pick the parts from the container.

Overall the method of bin picking contains five steps. First an image of the part and container is created. In the next step objects are separated from the background, while the third step is to calculate the objects’ position relative to the robot. The fourth step is to generate a trajectory for the robot to be able to pick the part up, and the last step is the motion of transferring the part from the picking location to the desired location. [6]

Using the method of bin picking has the benefits of reducing the costs and improving efficiency since manual and mechanical sorting has been eliminated. The speed can also increase, which generates a higher throughput and production volumes also create system flexibility. The calibration of the bin picking system can be difficult to do, due to the need for specialised software. Which type of system to use when using a bin picking method depends on the characteristics of the parts such as the shape, size, geometry and the arrangement of the parts in the bin. [6]

Depending on which system is used, different problems might occur. If a method of laser vision system is used, the limitation of the sensing range can occur since the system calculates the pose only from the area that the laser is scanning. If a stereovision system is used, the system needs reference points on the part, for example holes, to be able to calculate the orientation of the part. Other problems that might occur, depending on the method, is the reflection from metallic parts and the lack of comparable models. [7]
2.1.3 Pallets
Using pallets is another method to handle transportation of material in an out of the assembly hall. An advantage of handling material with pallets is that much of the material handling can be done at the same time as the assembly work is done within the assembly cell. Also, the distance for the robot arm between the picking and placing of all the parts will be minimized since the different parts are at the same place. (See Figure 6) Problems that might occur when using a pallet with many different parts is that this pallet needs to move in and out of the assembly cell at the same time. This can be done by letting the pallet follow the system in a loop, although this can be both costly and time consuming. Another method can be to let the system be reversible. Using pallets requires a well-thought-out design as to how the pallet should be best suited to accomplish the desired task. When developing the pallet there are two conflicting issues to consider. While larger pallets require larger storage space, they will also carry more parts, and therefore less transportation is needed. In order to reduce transportation between the storage and the assembly cell, it is desirable to stack pallets during transportation. One method of storing pallets is to have two places to stack them, one stack with pallets that hold material and one stack with empty pallets. The disadvantage with this method is the storage space it requires. The stacks need to be within reach so that operators are able to unload them. [3]

![Figure 6: Layout of a pallet with different components.](image)

2.2 ISO Stander
When designing a robot cell, consideration must be given to standards and legislation. This section covers three standards regarding the risk assessment, safety requirements for implementation of an industrial robot and the complimenting standard regarding the implementation of collaborative robot system.
2.2.1 Safety requirements for industrial robots - robot systems and integration, ISO 10218-2:2011

In the Standard ISO 10218-2:2011 [8] requirements for safety regarding the robot system and the integration are described. Regarding the layout of the robot cell, it is important to eliminate the risk and hazard by establishing the cell’s physical limits including other parts and larger cells and systems. The workspace access should be easy and safe, which means there should be no cables on the floor etc. The layout of the robot cell should be designed so that manual tasks can be done from the outside of the cell, for example loading or unloading parts or changing tools. [8]

No safety equipment related to the robot system shall fail due to environmental conditions. If controls or equipment, such as valves or weld controllers, are to be accessed during the automatic mode of the robot, the equipment needs to be located outside of the robot cell. The robot cell shall be designed so that operators have a clear view of the robot’s restricted space. A robot system shall not respond to external remote commands or conditions. Safety equipment shall be around the safety space of the robot and it shall be designed in regard to the locations and layouts of machines and hazards within the safety space. If limiting devices are to be used, there are two types of limiting devices, 1) Mechanical limiting devices that physically prevent the robot from going further than the restricted area allows, for example safety fences. 2) Non-mechanical limiting devices that do not prevent the robot from going further than allowed. They indicate a stop function of the system and if these are to be used, the stop distances of the robot shall be taken into account when establishing the restricted space of the robot. The maximum speed and load of the robot shall be established through the restricted space of the robot. [8]

Material entering or exiting the robot cell shall have an entrance that does not allow individuals to enter the robot cell, which means that the entrance shall have the minimum dimensions that the material allows. The fence shall be designed so that it is not possible to reach over, under, through or around the safe guard and it shall have a minimum height of 1400 mm from the walking surface. If the safe guards are fixed the removal of the guard shall only be possible through the use of tools and the assembly equipment for the guard shall remain either on the machinery or on the guard. [8]

A collaborative robot operation is an operation between a human and a robot in the same workspace. This is only allowed for predetermined tasks when all required protective measures are activated and with robots specifically designed for collaborative operations. A risk assessment shall be done and the space where the robot and operators can interact shall be clearly marked and defined. If a failure is detected in the safety system chosen for the collaborative operation, it shall result in a stop and shall not be resettable within the collaborative workspace. When an operator enters the collaborative workspace, the robot shall stop moving in automatic mode and maintain a safety-rated monitored stop. For hand guided robots, the system needs to meet a number of demands. At the hand over position the robot must have a safety rated monitored stop and the operator must have a guiding device to move the robot to the intended position. In addition, a clear view of the entire collaborative workspace is necessary. Parameters such as force, speed, minimum distances, power and ergonomics shall be determined through the risk assessment. [8]
2.2.2 Robots and robotic devices - collaborative robots, ISO 15066:2016

The ISO Standard 15066:2016 is a complimenting standard to the ISO Standard 10218 and it describes the safety requirements for collaborative industrial robot systems and its work environment.

When designing a collaborative robot system and the design of the cell there are some important factors to take into consideration, such as the limitations of the cell’s three dimensions. Furthermore, the work shall be free from obstacles or have a clearance, to ensure the safety of the operator working in the area. The interface between the worker and the equipment needs to be considered and, factors such as unexpected behaviour, sudden reflexes, misuse or fatigue and lack of concentration shall not endanger the worker. The consequences of repetitive or single interaction with the robot will be estimated. Workers that interact with collaborative robots need training and the number of workers with accessibility to the robot should be limited. [9]

When identifying risks and hazards, the robot’s characteristics such as its payload, speed and force must be considered. Other factors that need to be examined is the robot’s position in relation to the operator, the design of the end-effector, the material and workpiece design, the workers’ positions and movement with respect to the parts that will be handled within the workspace. The limitation of the protective equipment and the fixture design are two additional factors that need to be considerate when identifying risks and hazards. [9]

An operator’s task within the collaborative work space needs to be clearly identified. This identification must be done in consultation with the user of the collaborative robot system. The tasks’ characteristics are the frequency and duration of an operator within the collaborative workspace and the contact between the operator and collaborative robot. When identifying hazards within the collaborative work area, a number of tasks must be taken into consideration such as the transition between the collaborative and non-collaborative operation, the start or restart of a collaborative robot system, operations with more than one worker and additional tasks within the workspace. [9]

Before taking measures to reduce the risks and hazards they shall be assessed according to the order of: 1) eliminating the risks by safe design; 2) preventing workers to access the hazard or bringing the system to a safe state for example stopping or limiting speed and force; 3) giving information such as training or signs. When implementing a conventional industrial robot, safety is achieved using safety equipment that separates the workers from the robot system. These risk reductions are mainly addressed through the design and application of the collaborative robot system. [9]

When designing the collaborative workspace, it shall be thought through so that the worker can execute all tasks safely. This means that risks associated with equipment and its placement and risks associated with crushing or trapping shall be mitigated and not introduce additional hazards. This is either done by the elimination of the risks or by the use of safety controls of the robot system. The operator shall have the ability to stop the collaborative robot at any given time either by an enabling device, emergency stop or by stopping the robot with the hand. [9]

The transition between the non-collaborative operation and the collaborative operation shall be designed so that it does not pose any danger for the operator during the transition. The pendant control must have an emergency stop and an enabling device according to ISO 10218-1:2011. However, these functions are not necessary if a risk assessment for the collaborative robot system can establish that safety is achieved through safe design or by safety-rated limiting functions. [9]

For a collaborative operation one or more of the following four methods may be used;
1) A method that permits the robot to be in a non-collaborative operation is a safety-rated monitoring stop. This function will stop the robot and allow an operator to be within the collaborative work space, for example to finish the current task. To have a collaborative operation with the safety-rated monitoring stop method, the requirements, the limitation of the robot’s motion and the equipment of a function for protective stop in ISO 10218-1:2011 must be fulfilled. [9]

The robot system is only allowed to be in a non-collaborative state when there is no operator within the collaborate work space. To allow an operator within the collaborative work space, the robot system or hazards are not allowed to be present within the collaborative work area. The robot system is allowed to be within the collaborative work space if the system is in a safe-rated monitoring state or in a stop state. [9]

2) A method that allows an operator to use a hand guiding device to transmit motions to the robot system is hand guiding. It is allowed when the robot has achieved a safe-rated monitoring stop. [9]

3) A method that allows an operator to be within the collaborative work space as the robot system is executing tasks is speed and separation monitoring. This is accomplished by a protective separation distance between the operator and the robot. If the protective separation distance decreases, the robot must stop performing its tasks and is not allowed to re-start before the operator has moved away from the area. The protective separation distance corresponds to the speed of the robot, and if the speed decreases, the acceptable protective separation distance decreases. If the protective separation distance decreases below the allowed limit, the robot system must activate the protective stop and safety functions. [9]

If this method is used, the robot is required to have safety-rated monitoring speed and stop functions. Also, all individuals within the collaborative work space shall be protected. The number of people allowed within work space should be clearly stated and in case the number is exceeded the protective stop function shall be activated. [9]

4) A method that allows the operator and robot to have physical contact, either by intention or unintentional interaction is through power and force limiting. It is achieved by the use of a robot that is specially designed for that purpose. [9]

A risk assessment must be conducted regarding the contact between the operator and the robot. The assumption that the operator is not using any protective measurements is to be made, including personal protection equipment. For the potential contact, the following criteria shall be considered: the contact area, speed, force and pressure, as well as the form of contact, the occurrence probability and frequency, the intentional or unintentional interaction and in which body region the contact will be in. Sharp and pointed objects, for example knives or needles, are not allowed within the area of contact. [9]

The risk assessment is done by first identifying the conditions for when the contact might occur, and then evaluating the risk associated with that contact and also designing the robot system so that the interaction will occur less frequently or is prevented. The last step is to use risk reduction measurements to limit the contact under the threshold value. [9]

2.2.3 Safety of machinery - risk assessment and risk reduction, ISO 12100:2010

The standard ISO 12100:2010 provides methods of conducting a risk assessment and reduction in the design and implication of machines. When conducting a risk assessment and reduction, the constructor shall follow a series of actions in a specific
The actions are: 1) determining the machine’s limitations, its use and potential misuse of the machine; 2) identifying the source of the risk and any associating risks; 3) assessing the risk for each source of risk and situation; 4) evaluating the risk and deciding on appropriate risk reduction; 5) eliminating the source of risk or reduce the risk by the help of safety equipment.

The document of the risk assessment must contain necessary information, for example related documentation to the machinery, standards and regulations and also information such as ergonomic principles, relevant experiences and history of accidents.

To determine the machinery’s limitations, all its phases need to be considered i.e. transportation, installation, commissioning, usage of the machine, dismantling and scrapping. Other limitations to consider are the movability around the machine, the interface between the human and the machine, the equipment used and the maintenance, for instance cleaning and repairing. People who lack information about the machine and its potential hazards, risk encountering problems with the machine. It shall be thought through who, where and how the machine will be used.

The risk associated to a certain situation depends on how severe the damage might be and the probability for the damage to occur. The estimation of the seriousness to a risk includes an analysis of whether it is light seriousness, hard seriousness or deadly, and whether there will be one or more people affected by the risk.

When estimating the exposure to a risk, the following factors should be considered: the time spent within the risk area, the number of people that need access to the area, the frequency of the access to the area, and the type and need to access the area.

The estimation of the possibility to avoid or limit a risk consists of the following questions; who will be exposed, how quickly can the risk situation lead to damage and to what extent are people aware of risks and the human capability to avoid or limit the damage.

The estimation of the occurrence of a risk is done by the use of historical data, for example the history of accidents. In addition, the estimation of the conjunction between the effect and the exposure to a risk needs to be calculated. These factors include the human factor, the safety equipment adequacy and the possibility to uphold or disable the safety equipment.

To eliminate or reduce a risk, the three-step method shall be used. The first step is to design the machine so that risks are limited. This means that the machine must be designed so that it does not harm the surroundings. This is accomplished through choosing the appropriate technology, minimizing the probability for faults in safety equipment, considering the ergonomic principles and the geometric and physical aspects. Other steps include limiting the risk exposure through reliable equipment, using automated or mechanical work equipment and placing the work area outside of the risk area. Further to build the machine with stability, serviceability and take the general technical knowledge under consideration.

The second step to reduce risks is to design the layout with appropriate safety measurements. If the machine can not be designed to eliminate the risks, the layout where the machine will be used should be appropriately designed so that risks are eliminated.

Adequate safety equipment shall be used depending on the circumstances such as if there are moveable parts or moveable transitions parts. If the area is not accessed through normal processes, the choice of safety equipment should be of the following types: fixed protection, preventive protection with or without locking functions, self-
closing or sensing protection, for instance electrical sensing devices. If there is a need to access the area through normal operation, then safety equipment such as preventive protection with or without locking functions, self-closing protection or sensing protection such as electrical or pressure sensing devices, adjustable protection, tow-hand actuators and preventive protection with a start function shall be chosen. [10]

When deciding which type of sensing protection to use, the following aspects should be considered: the size of the area and the location and its characteristics, as well as the device’s reaction time, its detection ability, the variation over time and the possibility to set the device out of function. The safety equipment that is implemented must be designed so that it allows minimum interference in the environment. The design shall also prevent the user from setting it out of function. [10]

The third step to reduce risks is to provide information to the user if the risk remains after the first and second steps. Then the risk must be identified for the user through information, for example safe working methods or signs. The information shall contain all the instructions and information necessary to guarantee a safe handling of the machine. Depending on the risk, when the user needs the information and how the machine is constructed, the information shall be placed or given either on the machine, in a document, on the packaging or through signals, lights and warnings outside the machine. [10]

2.3 Methodology

When developing a product there is a developing process of six phases. The first phase is the planning, and it is closely connected to research and technology development. This phase is often ongoing before the project formally has begun. The output from this phase is the project description. [11]

The second phase is the conceptual development. A concept is a description of a product’s function, form and properties. In this phase, the needs from the market are identified and alternative product concepts are generated and one or more are chosen for further development and testing. [11]

The third phase is the development on a system level, which includes the creation of the product’s architecture, subsystems and components and initial planning for the production and the assembling process of the product. The output of this phase is a functional specification for each subsystem and a preliminary process flow for the final assembly. [11]

The fourth phase is the product development. In this phase, a specification of the product’s geometry, material and tolerances is created. The output is an number of control document, for example drawings. [11]

The fifth phase is the testing and further development and it contains building and evaluating the product to ensure that the requirements are fulfilled. [11]

The sixth phase is the product launch, the product is produced with the intended production system. The purpose is to train the operators and to solve possible problems that might still be there. Products in this phase are usually delivered to specified customers to evaluate if there are still problems with the product. The transition to full scale production often occurs gradually from this phase. [11]

The concept development process consists of the following seven activities:
1) Identifying customer needs. In this activity, it is important to understand the needs of the customers and the output becomes a series of tasks which are sorted by relevance.
2) Establishing target specification: Here a specification is created from customer needs that are translated into technical terms. This specification consists of measurable product characteristics that are based on expectations and ambitions before any knowledge of the product's limitations exists. [11]

3) Concept generation: The goal of concept generation is to thoroughly examine the number of appropriate concepts that can satisfy the customer needs. In order to generate concepts, external and internal searches, creative problem solving, and systematic exploration of different sub-solutions are made, the output usually is 10-20 concepts, and these are often presented by a sketch and a shorter description. The concept generation method consists of five steps: 1) Clarify the problem and break it down in sub systems, 2) Collect information from external sources, for example, patents, experts and related products, 3) Retrieve information from knowledge within the company, 4) Systematically explore using classification tree and combination tables to organize thoughts, 5) Reflect on the process and results.[11] Concept generation is a creative process and it is important during this process not to stop at one concept, but instead try to create as many concepts as possible that would more or less fulfill the requirements. It is also important in the concept generation to not only think of the good properties in an ideal environment. [12]

4) Concept selection: Analytically and methodically eliminate concepts to find the most promising. This is done through a concept screening matrix where the concepts are scored and ranked. Furthermore, the concepts can be improved and combined and then one or more concept are chosen to proceed with.

5) Concept testing: selected concepts are tested for verification against customer needs. [11]

6) Establishing final specification: The previous target specification is converted into the final specification. The measurable values of the product properties are committed. [11]

7) Project planning: A detailed development plan has been created and a plan for continued work is created and identification of the resources required. [11]
3 Method

A literature study was conducted regarding the system to feed and orient the parts to the robot and also regarding the ISO standards of implementation of robot system and on the risk assessment analysis. This study was done to obtain necessary information regarding the different possibilities to handle material to the robot appropriately. The literature on the ISO standards provides knowledge on how to design a layout for a robot and on how to conduct a risk assessment for the layout.

To obtain knowledge on how the line works, visits to Assa OEM in Gothenburg were made. During these visits observations of the performed assembly tasks were conducted and the assembly tasks at each assembly station were performed. The executions of the assembly tasks were done to gain understanding of the movement required for each part to be placed and fitted to the fixture on the line. Information gathering such as drawings and measurements was also conducted during the visits to Assa. To understand the workers’ views regarding the assembly tasks, discussions with the workers were held.

Simpler simulations of concepts were simulated in the software Robot studio. The reason for using a simulation program instead of drawing the concept on paper was because it provides a clearer view of the layout and its proportions. The concepts were discussed between supervisor from, Assa OEM and University West at a meeting on April 17, 2018. During the meeting the advantages and disadvantages of each concept were discussed as well as the differences between a conventional industrial robot and a collaborative robot. At the end of the meeting one concept to move forward with was chosen.

The chosen concept was simulated in the Robot studio. To achieve a simulation, the line was modelled in the Robot studio and parts are imported CAD models given from Assa. To investigate the cycle time and how that is changed between different simulations runs, the concept was simulated with different speeds, target zones and paths.
4 Assembly line

The assembly line consists of one ink printer, one greasing station, two vision stations, three manual assembly stations and five riveting stations. (See Figure 7). The assembly line produces approximately 2000 reversible hinges each day. For the stations in the assembly line the cycle time is around 16 seconds. At the line Assa assembles six different types of reversible hinges. Product A stands for 80 % of the total amount of reversible hinges and has seven sizes and each size can be made either for the left or the right side. Each product can be produced with minor differences for example long or short rivets.

![Figure 7: Layout of the assembly line for the reversible hinges.](image)

![Figure 8: The finished reversible hinge when the fixture arrives in the first assembly station.](image)
4.1 Assembly station one

For assembly station one there are four different components that are assembled on to the fixture at the line, one arm and three various types of rivets which are the same for both the right and the left hinge. The three rivets are: a stop rivet, an adjustment rivet which is eccentric (See Figure 9 number 6) and a sash rivet that either is short or long. The sash arm consists of seven right and seven left arm types and it is mainly the sizes of the arms that separate them from each other. When the fixture arrives to the assembly station the assembled reversible hinge is left on the fixture (See Figure 8). It will be manually controlled, and the operator will check the rivets and ensure that the force required to open or close the reversible hinge is not too high or too low. There are eight assembly steps at this station; (See Figure 9) 1) Placement of one sash rivet either long or short; 2) Placement of the sash arm; 3) Manual control of rivets on the assembled reversible hinge; 4) Manual check of the assembled reversible hinge and its inertia to open and close; 5) Placement of the assembled hinge back on the fixture. 6) Placement of one adjustment rivet; 7) Placement of one stop rivet; 8) Push of the button to let the fixture go to the next station.

The layout of assembly station one is the line in front of the operator and behind the operator there is a fixture stand to the left and pallets with material to the right (See Figure 7). The length of the line is 2250 mm and the width is 360 mm, from the line to the end of the material pallets the length is 1880 mm. For measurements of the line see Appendix A.

Figure 9: Positions for the parts on to the fixture in assembly station one.

1 According to layout drawing
2 Measurements from the line at Assa OEM
4.2 Assembly station two

At assembly station two there are two different components assembled; one rivet that is the same for both the left and the right reversible hinge and four left and five right types of the frame bracket. When the fixture arrives at the second assembly station the controlled reversible hinge from assembly station one is placed in the middle of the fixture. The operator picks off the reversible hinge and places it in a pallet for finished reversible hinges. At assembly station two there are four assembly steps done; (See Figure 10) 1) Picking up and placing the finish reversible hinge in a pallet; 2) Placing two rivets; 3) Placing the frame bracket; 4) Pushing the button to send the fixture to the next station.

The line is placed in front of the operator and the assembled reversible hinge pallet is placed behind the operator to the left. On the operator’s right side there are material container (See Figure 7). The length of the line is 2500\( \text{mm} \) and the length from the line to the end of the material pallets on the left side is 1750\( \text{mm} \) and on the right side the length is 1880\( \text{mm} \). For measurements of the line see Appendix A.

![Figure 10: Parts and their placements on to the fixture assembly station two.](image)

4.3 Assembly station three

There are three parts assembled at assembly station three, one rivet which is the same for the right and the left hinge. Two different types of arms are placed at assembly station three, a long and a short type. The long arm consists of twelve types for the left hinge and six types for the right hinge. The short arm consists of six types for the right hinge and five for the left hinge. It is mainly the sizes that differ between the arms, but the difference also depends on whether there is a child lock or not to the hinges. In assembly station three there are five steps of assembly; (See Figure 11) 1) Placing two rivets; 2) Placing the short arm; 3) Placing the long arm; 4) Lifting and turning the arm placed in assembly station one and placing it over the short and the long arm; 5) Pushing the button to send the fixture on to the next station.
The line in assembly station three is placed in front of the operator. Behind the operator to the right-side containers with material for the two arms are placed. (See Figure 7) The length of the line is 1500$^1$ mm and behind the operator, to the right, the length is 1750$^2$ mm. On the right side there is a walkway past the operator. For measurements of the line see Appendix A.

![Image](image.png)

Figure 11: Positions of the parts to the fixture at the third assembly station.

### 4.4 Analysis of assembly stations

In the three assembly stations the assembly tasks are similar, it is the number of rivets or parts that differ. For assembly station three there is an additional task that is not included in the first two assembly stations. It is the task of lifting the sash arm which is placed in assembly station one on to the two arms placed in assembly station three. In this task the arm is lifted and turned 180 degrees, and then placed over three rivets. This manoeuvre is more complex for a robot to perform and will require more equipment. The space to place a robot for the three assembly stations is approximately the same area as for assembly station one and two. In assembly station three the area is less and the footpath to the right will increase the number of people that move within the robot area. Therefore, no concepts will be given for the third assembly station. At the first assembly station, rivet one (See Figure 9) has two variants, a long and short type. This can increase the number of feeding systems depending on what type of availability is necessary for that rivet.

In the first assembly station the sixth assembly step contains an adjustment rivet that has an eccentric form. This rivet has a mark on the top and needs to be aligned with a mark on the fixture. Today, this alignment is done either in station one, two or three. (See Figure 12) To automate one of these assembly stations, this alignment should be performed in the previous station. As for the first assembly station, the robot must perform this task or else the operator in the second assembly station has to align the rivet with the fixture.
In assembly station two the number of part and task are fewer than in assembly station one and therefore it may not be economically justifiable to implement a robot system for those tasks. Today the assembled reversible hinge is returned to the assembly stations for quality checks and placement in a pallet. This quality check and placement will complicate the implementation of a robot system in assembly station one or two. As a result, more equipment will be required and the cycle time for the stations may be affected due to the need of tool change. There are similarities between assembly station one and two and therefore concepts for both station will be given.

The area in the assembly stations is not large and to have a conventional industrial robot with the safety equipment such as fences will be more difficult to implement, and possibly larger reconfigurations are needed to the line. Since not all products will be assembled by the robot, the availability of the line for manual work will decrease with a conventional industrial robot. For this reason, a collaborative robot is to be used in the concepts.
5 Concept

5.1 Assembly station one

To be able to implement a robot to perform the assembly tasks in assembly station one, the assembled reversible hinge needs to be picked off and quality checked at the end of the line. Feeding the robot with material requires three to four feeding systems for the different rivets, and for the arm one feeding system is required.

5.1.1 Concept one

The robot is placed behind the line and therefore it will have a fixed position and the robot will not need to be calibrated each time it has not been used. The feeding systems for the parts are placed along the right and the left side in front of the line. (See Figure 13) If the feeding systems are placed along the side, an operator will be able to stand in front of the line to perform the manual assembly task of the products that will not be assembled by the robot. It will require some flexibility in the outlets from the feeding system to the position that the robot can reach the material.

![Figure 13: Arrangement of the robot and feeding system for concept one in station one.](image)

5.1.2 Concept two

The robot is placed behind the line, so it will have a fixed position and the robot will not be calibrated each time it has not been used. The feeding systems for the rivets are placed along the line and has a fixed position. (See Figure 14). The outlet from the rivets feeders are fixed. The feeding system for the arm is placed in front of the line between two feeders. The arm feeding system will be moveable to allow an operator to perform manual work to the product that is not within the automation solution.
5.1.3 Concept three

The robot is placed on the right side and the feeding system for the rivets surrounds the robot. The arms’ feeding system are moveable and placed in front of the robot. (See Figure 15) With this concept the reach area for the robot is smaller than for concept one and two, because there are no reaching movements over the line. Because of the moveable arm feeding system, manual work is possible at the line. The fixed position of the robot does not require calibration of the robot when it has not been used.

Figure 14: The arrangement for the robot and feeding systems for concept two in station one.

Figure 15: The layout of the third concept.
5.2 Assembly station two

To implement a robot at assembly station two will require one feeding system for the arm and one feeding system for the rivet. It will be possible to check the assembled reversible hinges at the first assembly station and then picking it off in the second assembly station.

5.2.1 Concept one

The robot is placed behind the line, the feeding system for the rivet to the right and the arm feeding system in front of the line. (See Figure 16) On the left side there is a container for assembled products removed by the robot. The possibility of having the robot placing the assembled reversible hinges in a container depends on the robot’s reachability. This task will also need reconfiguration of the fixture to have a fixed position for the reversible hinge, which makes it possible for the robot to pick it up from the fixture. The robot and the feeding system for the rivet are fixed and therefore calibration of the robot will not be needed when manual work has been done at the line. The arm feeding system is movable, which makes it possible to carry out manual work at the line.

![Figure 16: Concept layout for assembly station two.](image)

5.3 Concept combined station one and two

To combine assembly station one and two, the assembled reversible hinges products need to be picked off and quality checked at end of the station. When combining two stations more resources are available, and an operator can therefore handle the quality check and the refilling of material. The combination of the two stations requires more equipment, two feeding systems for the arms and four to five feeding systems for the rivets.
5.3.1 Concept one
The robot is placed behind the line in assembly station one and the feeding systems for the rivets are grouped together in front of the line and the arms feeding system is placed on the left and the right side of the feeding systems for the rivets. (See Figure 17)

The robot and the feeding system are fixed and therefore calibration is not necessary when the robot has been stopped. To be able to have manual work when combining the two stations, an investigation of the possibility to move the rivet and vision systems towards the second assembly station needs to be conducted. This is because one rivet is being riveted in the first station after assembly station one. (See Figure 7) If there are standards rivets used in the other 20 % of products the robot can assist during the manual assembly work. A further investigation if this is the case needs to be conducted.

![Figure 17: Concept one for the combination of the assembly station one and two with the rivet and vision system moved towards the second assembly station.](image)

5.3.2 Concept two
The robot is placed behind the line and is therefore in a fixed position and calibration of the robot is not necessary when it has not been used. The feeding system for the tow arms is placed on the left and right side and the feeding system for the rivets is placed behind the arms in a line outwards. (See Figure 18) This requires flexibility in the outlets from the feeding system so that the robot will reach the positions of the rivets.

An investigation needs to be done regarding the rivet and vision system and its possibilities to move toward the second assembly station. This is for the ability to do manual work beside the robot and before the first rivet station. In this way, there can be two workers at the line doing manual assembly but the robot can not assist during manual work if standard rivets are used in the other 20 % of the products.
5.4 Concept discussion

On April 17th, 2018 a meeting at Assa was held to discuss the different concepts and layouts, for the discussion material used see Appendix B. All concepts have an implementation of a collaborative robot and no concepts are given with a conventional industrial robot. For this reason, the advantage and the disadvantage for each robot type were discussed. Some advantages and disadvantage that were deliberated at the meeting were the larger area required for the conventional industrial robot when comparing to the collaborative robot. The impact the robot types have on flexibility when carrying out manual work at the assembly station and its differences were also discussed. The conclusion of the discussion was that Assa does not desire an industrial robot.

The discussion of the concepts concerning assembly station one, (See section 5.1) was mainly regarding the numbers of feeding systems required to implement a robotic solution to the assembly station. Another topic concerned the issue on how to solve the quality checking and the picking off the assembled reversible hinge from the line. These tasks had to be accomplished at the end of the line at the second vision station (See Figure 7) and had therefore required additional operators performing these tasks. Because of the number of feeding systems required and the issue of picking off and quality checking the assembled reversible hinge, the decision was made not to further investigate the concepts for the first assembly station.

For the discussion regarding the concept in assembly station two, (See section above5.2) the amount of feeding systems required for this concept were deliberated and how the robot would be able to pick up and place the assembled reversible hinge in to the container since the reach of the robot will be limited. This gave rise to the discussion of having the assemble reversible hinge be picked off and placed in a container at the first assembly station. A decision was made to move the picking off to assembly station one, and Assa will investigate further, how this will be solved.

Assa in Gothenburg is today in an early stage of development of implementing robotics solutions to their factory. Therefore, by initiating with a minor concept such as the concept for the second assembly station, the introduction of robotic within the assembly environment is done in smaller steps. This implementation can therefore argue for the benefits of having robotics in the manufacturing process as a tool.
When introducing new equipment to the manufacturing process there is a risk that this equipment will affect the production through unexpected problems. Through the implementation of the concept in assembly station two, manual work will still be possible if such unexpected problem would occur.

If Assa would be interested in increasing their implementation of robotics to the assembly line, for instance combining station one and two, the same equipment that would be used for implementing robot to assembly station two can be used.

Since the picking off is moved to the first assembly station and the low amount of feeding system required to implement this concept, the benefits of implementing a minor concept as a start of Assa’s development of the use for robots in their production, a further investigation on implementing a robot will be carried out for assembly station two.

The discussion regarding the two concepts for the combination of the first and second assembly station (see section 5.3) primarily concerned the possibility to move the rivet and the vision stations after assembly station one. It was also discussed how many feeding systems would be required and the possibility to have assistant from the robot during manual work, because it is an old line which makes it harder to find spear parts to use and the number of feeding systems that are required for these concepts. Also, if the robot will encounter an unexpected stopped, it would be difficult to use the line with manual work and therefore the two concepts was excluded.
6 Results

The chosen concept to simulate is the concept in assembly station two. The robot used in the simulation is an ABB 1200, which has a payload of 5 kg and a reach of 901 mm and it is placed behind the line. The material handling for the rivets is placed to the right side and is visualized with a vibrating bowl feeder. A feeder for the frames is placed to the left (See Figure 19) This allows an operator to have access to the line when necessary. The part used in the simulation is a left side model of the second largest size.

![Image of the simulated concept layout for assembly station two.](image)

The first program for the robot to execute the picking and placing of parts to the fixture has the following flow: go home, pick and place the two rivets, go home, pick and place a frame then go home and wait for the next fixture. (See Figure 20). The cycle time is measured between the initial state ‘go home’ and the ending state ‘go home’. During this simulation the cycle time of 16 seconds was not achieved. (See Table 1) The closest cycle time was 18.71 seconds and had a speed of V400. The standard speed for a collaborative robot is V250 and with the speed closest to use in simulation V200 the cycle time is 30.99. (See Table 1) After modifying the first path by removing the go home motion between picking and placing the rivet and picking and placing the frame, the cycle time was reduced to 26.58 seconds. (See Table 1) These cycle times were far from the desired 16 seconds, and therefore a new path was programmed.

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3 ABB Web page
The second program for the robot has the following flow: pick a rivet, wait for fixture, place and pick rivets and then pick and place the frame. (See Figure 21) The cycle time was measured between the operation ‘place and pick rivets’ and ‘place the frame’. At a speed of V200 the cycle time was measured to 17.58 seconds. (See Table 1) By increasing the speed to V300 the desired cycle time is achieved.

Furthermore, it is necessary to have a lower speed when picking or placing the parts than it is between the different non-working operations such as movements between the feeder and fixture. Simulating this with a speed of V100 at picking and placing operations and a speed of V200 at movements between the operations, the required cycle time was not achieved. Increasing the speed from V200 to V300, the cycle time was reduced to 15.98 seconds. (See Table 1)

By changing the time, the robot waits for the attachment and detachment of parts to the end-effector from one second to 0.2 second. The targeted cycle time was achieved with speeds of V100 at picking or placing operations and V200 at the non-working operations (See Table 1)
### Table 1 Result and changes for the different simulations runs.

<table>
<thead>
<tr>
<th></th>
<th>Speed mm/s</th>
<th>Number of Fixtures</th>
<th>Average s/Fixture</th>
<th>Other Changes</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>V100</td>
<td>50</td>
<td>19.73</td>
<td></td>
<td>V100 for approaching and departing pick and place targets. V500 for joint movements between targets</td>
</tr>
<tr>
<td></td>
<td>V500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>V300</td>
<td>50</td>
<td>24.15</td>
<td>Increased the zones for passing the targets in the path</td>
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<tr>
<td>3</td>
<td>V400</td>
<td>50</td>
<td>18.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>V200</td>
<td>50</td>
<td>30.99</td>
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<tr>
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<td>26.58</td>
<td>Path change</td>
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<td>Path change</td>
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<tr>
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<td>13.54</td>
<td></td>
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</tr>
<tr>
<td>8</td>
<td>V500</td>
<td>50</td>
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<td>V100 for approaching and departing pick and place targets. V500 for joint movements between targets</td>
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<td>V100</td>
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<td>V200</td>
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7 Conclusion and discussion

This chapter contains a discussion regarding the simulation, the feeder systems and a discussion regarding the safety around the robot during operational state. Further the conclusions are given that where obtained thru the work and finely recommended further work is suggested.

7.1 Discussion

7.1.1 Simulation

The robot is able to pick both the frame and the rivet. Nevertheless, when the robot is to pick the frame the reach range of the robot is on its limit. Consequently, the frame is not picked in between two holes on the frame. Depending on the model, and if the reversible hinge is a left side or a right side, components might be added to these holes. This can interfere with the end-effector when picking the frame.

After the picking of the frame from the feeder, the robot makes a movement towards the area where an operator might work. This movement eliminates the possibility to have an operator working beside the robot. If the frame feeder is moved and placed along the line and if the path is planned, this movement can be performed from the feeder over the line and to the fixture. This should also minimise the risk area since the risk of the robot going the wrong way is slim. However, the measures taken will affect the cycle time.

The rivets are small and do not have a large area to grip around, and therefore the simulation has an end-effector that simulates another possible way of picking the rivets instead of using a gripper, for example using a ferromagnetic or vacuum tool.

It is difficult to achieve the desired cycle time in the simulation. The first path did not achieve the preferred cycle time even if the speed was increased to V400 at all targets. By changing the path, the required cycle time was achieved for a speed of V300, but not at a speed of V200. The cycle time is changing linearly when increasing the speed. (See Figure 22). Therefore, the cycle time would be achievable at a speed of V250. However, it is necessary to have a slower speed when picking and placing the parts.

When simulating V100 for picking and placing parts and a higher speed of V200 for movements in between the targets, the cycle time is not achieved. Increasing V200 to V300, the cycle time is accomplished. (See Table 1) By changing the time frame for the robot to detach and attach parts to the end-effector, the desired cycle time is accomplished with the speed of V200 and V100. But the time frame to use when implementing the concept depends on the equipment. Therefore, it is highly possible that this time frame will increase and therefore the cycle time will increase.

Throughout the simulation the presumptive wiggling to place the frame over the three rivets is not considered. This will affect the cycle time but depends on a number of parameters, for example tolerances between the parts and the design of the end-effector. The time for an eventual tool changing operation is not simulated and to accomplish the cycle time tool changing operations are not possible. However, changes
to the simulation indicate that there are parameters to change in order to achieve the desired cycle time.

The model size used in the simulation is the second largest and for the left side, which means that the placements of parts are the worst possible to simulate. For the first rivet the placement varies between the different sizes. Since the robot picks this rivet and then moves to the approaching target for the rivet and waits for the fixture to arrive, the cycle time will not be affected. The second rivet is at the same position on the fixture regardless of which sizes are assembled, and therefore it will not affect the cycle time. If it would be a right side reversible hinge the path for rivet two would be shorter. Also, the distance for the frame is the longest and there for will not affect the cycle time by increasing it if changing side to assemble.

![Average cycle time at different speed](image)

**Figure 22: Average cycle time at different speed.**

7.1.2 Feeding system

The feeder system for the rivets is simulated with a vibratory bowl feeder. This is a possible way of feeding the robot with parts. Another way would be to use a segment hopper or rotated wheel hopper. Segment hoppers or rotated wheel hoppers are for parts that are only needed to be oriented in one arrangement property while the vibratory bowl feeder may handle more arrangement properties. If a segment hopper or rotated wheel hopper are to be used additional orientation equipment to the hopper might be necessary due to the orientation of the rivet. (See Figure 23) Nevertheless, the vibratory bowl feeder is not efficient in the space it requires and will require some soundproofing material. Because of the orientation needed for the rivet, a vibratory bowl feeder might be the solution to orient the rivet with.
Figure 23: The orientation for the rivet in assembly station two.

The orientation to the frame depends on whether the reversibal hinge is assembel for the right side or the left side. For both sides it is necessary to orient the frame with the front side up. (See Figure 24.) The frame is therfore oriented in two directions, a feeding system for the frame should be able to handle the orientations and handling the different sizes. A solution to this, is to use a bin picking system. This system would then be able to handle the different orientations without having to restock the frames from a container to another system. However, a bin picking system will add time to the cycle time and is a source to cause interuption to the assembly process. Since the manufacturing plant is in its early stage of developent regarding robots in the assembly proces, a bin picking is not to preferred. The frame feeder must be specially designed, to handle both sides and all the different sizes or designed in a simpler form for each of the sizes and sides.

Figure 24: Left side orientation to the frame.

7.1.3 Safety analyses

The frame has sharp edges and might cause serious damage if a human is colliding with it during operation as in path one and two. Therefore, it is not possible to work beside the robot while it executes the operation. This requires safety equipment such as light beams, carpet or floor scanner that will indicate to the robot that no person is in the working area. The area has to be large enough so that it is not possible to reach the operation without braking the safety.

However, if the frame is moved, as mentioned above, (See Section 7.1.1) and the path is planned, the risk area for collision with the frame will be minimized. If the speed is lower and the risk assessment determines that the force and pressure during a potential collision to the arms and hands are lower than 180 N/cm² of pressure and 140 N of force [9] there will be the possibility to work beside the robot. If this is not possible but the opportunity to still work beside the robot during this movement is desired. Then safety equipment such as safeball for two-handle grip can be used. This will indicate to the robot that there is no human in the frame path and therefore the risk of collision is removed.

Refilling the frames to the robot would require the robot to stop or decrease the speed considerable, because of the risk to be injured by the frame meanwhile it is in operation mode. This is achievable by safety systems such as light beams, light scanners or carpets.
By using a safety carpet or scanners on the floor, the safety system will not activate until it is pressured on the carpet or the light is interrupted. Therefore, if something or someone is to fall in to the safety area, the robot will not stop until it hits the carpet or the floor light scanner. This means that the area that needs to be covered by safety equipment is larger than when using light beams or light scanners.

If light beams are used, they can be placed at different heights. Therefore, the robot will stop faster if someone or something falls in to the safety area. However, the light beams require attachments. Another way of achieving a smaller area is to use light scanners, because then there is no need for attachments.

The rivet feeding system is to be placed at a lengthier distance from the picking position of the rivets. In this way it is possible to refill the feeder system without interrupting the assembling process. Since the distance between the outlet of the vibrating bowl feeder and the picking position of the rivet an extended outlet is necessary. This should be designed in such way that it does not cause harm or injury.

The motion to move the rivet from the feeder to the fixture is, in path one and two over the area that an operator can work within. The rivet has no properties of sharp or pointy edges. Therefore, the rivets will not harm an operator if it is in a collaborative state. Nevertheless, the robot will be stopped by the operator. Because of this, if it is desirable to have a collaborative state of the robot, the path must be planned differently.

7.2 Conclusion

The robot should have a reachability over 901mm. The parts the robot handle does not weigh considerably, therefore the payload of the robot will be dependent on the end-effector’s weight.

If the path is well planned the cycle time of 16 seconds are achievable. There will not be time for tool change during the operation therefore the end-effector shall be designed in such a way that this is not necessary. Also, the end-effector must be able to handle parts through ferromagnetic or vacuum option.

For the feeder system a vibratory bowl feeder is recommended for the feeding of rivets. The frame feeding system should be designed to fit the purpose of feeding parts to assembly station two. Requirement for flexible feeders is not necessary.

The safety system around the robot and feeder system should be designed depending on the required flexibility Assa requires. The layout of the concept fulfilled the requirement of the visibility over the robot area.

7.3 Further work

A further investigation of the cycle time is recommended, this investigation shall contain the intendent robot and end-effector. Also investigate all the different types of parts, that they are able to be assemble within the desirable cycle time. Also, confirm if or if not, a wiggling motion is necessary for placing the part over the three rivets.

If the system is to be implemented a proper risk assessment of all the different implementation stages must be conducted.

The correct safety system to used is depending on the flexibility Assa requires around the assembly cell. Also, on the material flow requirement and the space required around the line for the material. Therefor an analysis of these requirements is proposed.

When the established three-dimensional working space are established an analysis of the allowed speed are recommended.
8 References


A. Layout measurements
B. Discussions material for concept meeting on April 17, 2018

Concept for the reversible hinge line

Todays layout

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Analyze of assembly stations

- Similar working area in station 1 and 2.
- Less working area in station 3.
- Similar assembly task in station 1 and 2.
- Complex task for robot in station 3
- Footpath at right side in station 3.
- Time for each station are depending on the operator.

Concept to discuss

- Three concept for station one
- One concept for station two
- Two concept for merge of station one and two
Assembly station one
Concept one

Advantages
- No calibration of robot when not been used.
- Fix placement of the feeding system.
- Manual assembly possible at the line.

Requires
- Collaborative robot.
- Flexibility in the outlets from feeding system to reach point for the robot.
- Finished products picked and quality checked at the end of the line.
- Four feeding system.
- Changing type of rivet in one of the feeders or one more feeder.

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Assembly station one
Concept two

Advantages
- No calibration of robot when not been used.
- Fix placement of the feeding system for the rivets and robot.
- Manual assembly possible at the line.
- Assistance from robot during manual assembly

Requires
- Collaborative robot.
- Moveable feeding system for the arm
- Finished products picked and quality checked at the end of the line.
- Four feeding system.
- Changing type of rivet in one of the feeders or one more feeder.

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Assembly station one
Concept three
Advantages
• No calibration of robot when not been used.
• Fix placement of the feeding system for the rivets and robot.
• Manuel assembly possible at the line.
• Easy to reach components for the robot.

Requires
• Collaborative robot.
• Moveable feeding system for the arm
• Finished products picked and quality checked at the end of the line.
• Four feeding system.
• Changing type of rivet in one of the feeders or one more feeder.

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Assembly station two
Concept one
Advantages
• No calibration of robot when not been used.
• Fix placement of the feeding system for the rivets and robot.
• Manuel assembly possible at the line.
• Easy to reach components for the robot.
• Possibility to quality check the product in station one and lift it of in station two.

Requires
• Collaborative robot.
• Moveable feeding system for the arm
• Two feeding system

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Concept combined station 1 and 2

Advantages
• No calibration of robot when not been used.
• Fix placement of the feeding system and robot.
• Manuel assembly possible at the line.
• Assistant from the robot when assembly the rest 20% of the products.
• Free more resources.

Requires
• Collaborative robot.
• Investigate if it is possible to move vison and rivet station.
• Finished products picket and quality cheeked at the end of the line.
• Six feeding system.
• Changing type of rivet in one of the feeders or one more feeder.

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Collaborative vs Industrial

Collaborative robot
• Risk analysis define the level of safety equipment needed.
• Possibility to work with the robot.
• Less work area.

Industrial robot
• Safety equipment necessary.
• No possibility to work with the robot.
• Space limitation at the assembly stations.
• Larger reconfiguration of the line.

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Decision meeting 17/4-2018

- Assembly station two will be further investigated.
- Finished reversible hinges will be picked of in assembly station one.