Simulation of a Work Cell in the IGRIP Program

Isaac Braña Veiga
Master’s Thesis

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Preface

I would like to express my gratitude to my supervisor Torbjörn Ilar, Division of Manufacturing Systems Engineering, Luleå University of Technology, Sweden, for providing me in this work, for his advice and supervision throughout this Master’s Thesis. I am also grateful for his continuous help and kindness when I had difficulties to start and develop this project. Thank you very much.

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Finally, I would like to give my most sincere gratitude to my friends and family, and especially, to my parents and my brother for their love and unconditional support.

Isaac Braña Veiga

Luleå, April 2006
Abstract

Nowadays, robots are extremely important instruments in factories that it is unusual to find a business without any robot. Robots can perform complicated and dangerous tasks, and currently most production companies use them. On the other hand, we need to know if it is possible and effective to set a robot into the production line. Furthermore, we have some tools to understand its behaviour and the advantages we can get.

A very common cheap tool is simulation. Simulation is a good tool for engineers to build virtual spaces, check information about robots and discuss about the best position and the best work the robot can do. This way, it is not necessary to stop the production and it is possible to try different ways to get the most efficacious and efficient solution so as to save money and time.

This thesis discusses how robotic simulation answers these questions. So, the thesis involves the use of IGRIP program. Firstly, we will build the work cell and then we will try to answer if it is feasible, and even if it is a good economic solution.
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Chapter 1: Introduction

1.1 Purpose

Currently, the enterprise Ferruform produces side members. In this production, two operators are in charge of all the manual tasks in the welding-grinding process. Nevertheless, Ferruform can take into advantage of new automatic solutions such as welding-grinding robots so that only one operator is necessary for the tasks.

In this thesis we will try to prove that we can make the side members with ABB robots. For this, we will use IGRI P software to design the work cell and estimate the movements of the robots, the best locations and the time and space necessary.

Also, we will see if it is a good idea from an economic point of view. Thus, we will demonstrate if money can be saved and if the robot is a profitable solution.

At the end, we hope to get the correct answers and prove that the introduction of two robots is a good idea from all points of views.

1.2 Background

Nowadays, simulation is a very important tool for designing new processes and making changes in production lines. Almost all companies take advantages of its benefits in order to improve their facilities.

This thesis will use the advantages of the IGRI P program so as to design a new work cell and try to save time and money in our production line.
Chapter 2: Ferruform, the enterprise

2.1 The Company

Ferruform is a big company that makes chassis components and axles for trucks and buses. It has two factories, one in the south of Sweden, in Konga, and the other one in Luleå. It is a big enterprise with 750 workers and an annual turnover of 88 million Euros. [1]

2.2 Its Location

Luleå is a city situated in the province of Norbotten in the North of Sweden (See Fig 1)

Fig 1: Luleå’s situation [2]
2.3 The city

Luleå has a population of about 71,000. It has a big trade in northern Sweden and northern Scandinavia. Also, it has an expansive market and industrial infrastructure, with strong primary industries and leading IT companies.

This city is the metallurgical centre for the famous Swedish steel group SSAB. Luleå has one of the Sweden’s biggest harbours for bulk goods and is open for shipping year-round. Luleå is the centre for transports of ore, steel, oil and freight for trans-shipping via sea, rail and road, and a major junction for passenger traffic to and from northern Sweden. [3]

The airport of Luleå is one of the Swedish biggest in terms of total passenger volume, where flights can reach a lot of number of international destinations without intermediate landing. [1, 3]

On the other hand, Luleå’s port is open for shipping all the year round due to the cooperation with modern state-run and locally ice-breakers.

2.4 The enterprise

The enterprise is a supplier and co-operative partner with many years of experience of cost-efficient manufacturing and the development of more than 1,500 different chassis components and frame sections for the world’s best trucks, coaches and buses. [1]

Currently, they are investing 33 million Euro in leading-edge technology, which will strengthen their position on the world market. Investments include a new roll-forming and surface finishing plant, and a unique axle project whereby they will be first in the world to use laser welding in the production process.
Mainly, production operations include:

- Pressing power up 4,200 tons.
- Pressing, single presses and automated 2- and 3-press lines.
- Robotic and manual welding with MIG, MAG, TIG, resistance and friction welding.
- Machining operations in flexible manufacturing cells.
- Surface treatment and powder-coating.

The 3-press line has a high capacity ensures competitive production. It has three separate presses, each with a pressing power of 1,250 tons. Work pieces are loaded and moved by robots between the three pressing stages. The 3-press line guarantees a rapid production flow with less need for warehousing and shorter cycle times.

The company has a pressing power of 4,200 tons and is one Europe’s biggest. It is part of a fully-automated line for side members and reinforcement beams that are stamped and formed in two strokes. In 2003 this press was replaced by a new roll-forming process [1].

Fig 2: A manufacture piece of Ferruform [1]
2.5 Their politics

Ferruform is a member of the northern Swedish engineering network EVONET, which increases their competitiveness. It has a production process that is regulated by customer orders. They are specialists in forming and finishing flat sheet and steel plate up to 30mm in thickness.

Ferruform has techniques of continuous improvement, whereby each worker is committed to an ongoing effort to systematically improve quality, cost-efficiency and productivity.

They work with coupled and visual production flows and inventory control methods such as Kanban and Reorder-point. Order processing and invoicing are mainly done with the aid of EDI (Electronic Data Interchange).
The enterprise is constantly refining its operations to be able to ensure the best possible delivery assurance and precision “just in time” delivery.

Their products are shipped several times daily to customers throughout Scandinavia, Europe, North and South America. Therefore, thirty fully-loaded tractor-trailer units leave the factory of Ferrurform each working day, all year-round.

Also, it has been ISO 9001 certified since 1994 and we are now accredited according to QS 9000. Quality assurance is implicit in everything we do, and all of our employees, in all facets of production, are committed to a systematic quality effort. This means that we are constantly measuring various parameters of production, conducting quality audits, evaluations and new training programmes.

The enterprise conducts programmes of development and research in close co-operation with Luleå University of Technology, customers and partners. R&D is carried out, in among other areas:

- Hydro-forming.
- Blow moulding.
- Forming of high-strength materials.
- Roll-forming hardening.
- Form fixture hardening.
- Laser welding.
- Development of a component lab for developing and testing prototypes.
The enterprise has been ISO 14001 certified since 1998. They have adopted a life-cycle approach, and they have implemented more efficient ways of recycling water and solvents and managing waste products. [1]
Chapter 3: Off–Line Programming (OLP):

3.1 History of Robots

Currently, robotic has a role so important in the world industry that now we cannot think of a world without it. But the beginning of robotic was the result of three technologies born after or during the World War II. First, servo-mechanisms theory (it was unknown before WW II). Second, digital computation came into its own after WW II, and finally, solid state electronics made it all economically feasible. [5]

But, we had to wait until 1961 to find the first industrial robot by Unimation Inc’s. It was 75% electronic and 25% hydromechanical (today, that cost is just reversed). That prototype worked quite well, and it would start a fast grown in this matter. Japanese executives watched a good future in that. The Japan Industrial Robot Association (JIRA) started out with an opening membership of 46 companies and with representatives having personal clout in the industrial community. [6]

![Fig 5: The first industrial robot by Unimation Inc’s][7]

From mid-1970s a lot of different robot applications were under constant testing and evaluation including cleaning of castings, gluing and polishing. [8]
As a result, many of the experimental tasks in those laboratories, in the early to mid 80's the robot industry grew very fast due to large investments by the automotive industry. [9]

![Fig 6: Robots in the automotive industry [30]](image)

### 3.2 Benefits of robots

Robots have a lot of benefits. If introduced correctly, industrial robots can eliminate labours dirties, borings and dangerous. Maybe, it is true that robots can cause unemployment but also can create jobs such as, robot technicians, salesmen, engineers, programmers and supervisors. The benefits of robots to industry include improved management control and productivity and high quality products. Industrial robots can work night and day on chain of production without a loss in performance. So, they can reduce the costs of goods. As a result of these industrial benefits, countries that effectively use robots in their industries will have an economic advantage on world market. [9]
3.3 The beginning of Off-Line Programming (OLP)

Off-Line Programming was developed in the 1980s. This technique allows object oriented programming and manipulation and detailed analysis of robot tasks, and provides a platform for optimization of robot operations impossible by other methods. It is also an important tool in analysis of robot structures in general. This technique was gradually introduced in the automotive industry in the early 1990s. [8]

![Fig 7: Off-line programming][27]

3.4 Advantages of OLP

Before use of computer simulation, layout and reach studies were calculation-intensive tasks that required a hard work. Manual calculations made multiple design iterations and work cell layout scenarios difficult, time-consuming, and extremely expensive. Even that hard work does not ensure that the robot system works correctly, because a small calculation error could be disastrous. [10]

In fact, Off-Line Programming (OLP) can minimize, if not eliminate, cost and required to program robotic cells manually. Simulation verifies that a robot can reach all of the positions required to complete a particular task and that the robot and tool will not collide with fixtures or other objects. [10]
Thus, as simulation has become more powerful, robot manufacturers have integrated actual robot motions planning within their own simulation software. Due to that, customers can now to verify and predict cycle time before a robot cell is assembled, using dynamic computer simulation tools. [29]

Fig 8: Industrial robots [11]

Off-line programming of robotic cells was a natural next step in the use of simulation software. Though, the same tools that make off-line programming possible and effective also add value to the process of design-to-manufacture. [10, 24]
3.5 Uses of OLP

For instance, without off-line programming, a customer who plans to launch production of a new product using an existing robotic cell might introduce changes to the product design that simply cannot be manufactured using the existing robot cell. Even now, the general approach to resolving this issue is to make changes in the layout and configuration of the robot cell. [9,10]

Simulation software allows design engineers to evaluate several designs. Therefore, if the designer can simplify the part geometry to some degree, it might be possible to simplify the robot path, thus allowing faster cycle time. Moreover, robotic simulation tools allow the designer to quantify the amount of time savings gained based on each change to surface geometry. Therefore, design department must be communicated with marketing department to select an optimum design for a new product, knowing its related throughput and accurate manufacturing cost. [10]

3.6 Trends simulation

Nearly ten years ago, Realistic Robot Simulation (RRS) was introduced (at the insistence of automotive customers) and the payoff expanded in two ways: delivering both a means to verify cycle time/process capability, as well as a means to generate quality robot programs off-line. [12]

Over the past few years, the focus on increasing payoff of simulation has evolved to include an extension of the RRS standard to add robot syntax, simulation of PLC (Power Line Communications) commands and timing, external axes, and calibration, all of which offer value to off-line programming as they minimize interruption of the production line.
However, there is another emerging trend, the reduction of the amount of investment required to perform robot simulation. In this manner the use of libraries of standard modules/components is having significant impact on the use of simulation in robotic applications.

In the beginning of simulation, an operator needed to use CAD tools to create all components for the work cell, before even beginning to consider how to attack the robot programming effort itself. Also, there was significant risk of error (fixtures/clamps were placed in the wrong location or had the wrong dimension) that was only detected when the cells were built.

So, simulation programs have libraries of standard simulation modules that minimize cost of simulation to complete robot cells. Hence, the end user of the simulation tool needs only import CAD data and begins the off-line programming process. The user can be confident that locations/dimensions of cell components are correct.
With the use of standard simulation modules, engineers now are able to create complete work cell simulations and also accurately represent throughput that a particular process can achieve. So, when the robot cell simulation is easily built, everyone is better able to visualize and understand the benefits of a process concept. [12, 26]
Chapter 4: IGRIP Program

4.1 IGRIP Overview

In order to test if it is possible to add a robot in the side member production line, this thesis will use the IGRIP program. The Interactive Graphics Robot Instruction Program (IGRIP) software, a product of Deneb Robotics, Inc., is a user-friendly computer based robotic simulation package for robotic work cell layout design, simulation and offline programming. [14]

With this program, designers can study the best solutions to design and evaluated alternatives. Also, as modifications are made to a work cell design, incorporating modifications into the corresponding work cell simulation models is easier and faster compared to making changes to a real work cell. Finally, robotic simulation packages provide designers a safe design environment. Whether designing a new work cell, optimizing its performance, or making modifications to an operational work cell, developing and testing required programs can be safely carried out.

Fig 10: IGRIP screen shot [31]
4.2 Creating parts models and building device models

If we want to create three-dimensional visual representation of part models, we will use the IGRIP CAD Context. It also has a world Cartesian coordinate system that works as the common reference point for dimension measurements of Part models.

A device model in IGRIP such as robot, table, conveyor, part, end-effector, and so on, represents an actual work cell component. These one-part models are usually called non-robotic Device models. If an IGRIP Device model consists of multiple Part models that are connected by a series of joints, the Device model is called a manipulator model or robotic model that may have the complex geometry of motions. All industrial robots are represented as manipulator models in IGRIP. For a Device model with multiple Part models, the Part models play the roles of structural elements that compose joints of the Device model for generating motions between Part models. Usually, an independent motion generated by a joint of a manipulator or robotic Device model defines a “degree of freedom” (DOF) of the Device model. [14]

So, if we want to create an IGRIP Device model, we will start with the base Part model that is the first Part model retrieved from the IGRIP Part library and placed in the Device Context. The base coordinate system of the base Part model is used by IGRIP as the base coordinate system of the Device model.
Then, the second Part model is to be selected and attached to the base Part model. As a rule of attaching Part models for constructing a Device model, an available coordinate system of the selected Parent Part model on the Device model must be selected to attach to the base coordinate system of the Attached Part model.

Besides the structural construction of a Device model using Part models, we can define the programmability and communicability of a Device model when the Device model is created. The programmability determines whether or not a Device model can be programmed via IGRIP’s GSL, and the communicability specifies the capability of a Device model to send and receive signals via its input/output (I/O) ports.

### 4.3 Positioning device models in IGRIP layout

When a Device model is retrieved from IGRIP Device library and placed in the work cell, the Device model first superposes onto the world Cartesian coordinate system of the layout Context, therefore we will need to put where we want. [28]
4.4 Defining devices motion destinations in IGRIP layout

In the IGRIP layout, the motion destination position of a Device model is represented by a tag point in a Cartesian coordinate frame with n, o, and a (or x, y, and z) axes. To calculate the position of a tag point in the layout, a Part model of a Device model in the layout must be used to attach the tag point. With the attachment, the position of a tag point can be determined with respect to the base coordinate system of the Part model of the Device model to which the tag point is attached. In the database, all tag points in the layout are stored with different names [14].

Fig 12: IGRIP screen shot where we can see the tag point of the robot

4.5 Device behaviour and programming in IGRIP layout

The behaviour of a Device model in the simulation is represented for three types of movements: motion, manipulation and action. In IGRIP, the GSL program of a Device model control the Device model for performing a series of movements in the work cell. In order to cause the best behaviour of a Device model in the layout, the Device’s GSL program also realizes the interlock conditions through the signal passing on the Device’s input/output (I/O) ports. [14]
4.6 Executing IGRIP work cell simulation and analysis

If we have one or more Device models and we want to program, the behaviour of each one in the work cell can be simulated over time. We will need to follow some steps to run the work cell model.

- Step 1: Load all GSL programs of the Devices. In this step, the developed program for a device model can be selected from the IGRIP program directory and downloaded into the Device model in the layout.
- Step 2: Active each Device model that has a loaded GSL program.
- Step 3: Set simulation step size. Tool for understanding the behaviour of the work cell. A simulation step can be best described as a time slice of the simulation in work cell time. For example, if there is great concern about collisions at some tag point during a simulation run, the step size should be set to a relative small value to assure that the collision-checking algorithm does not miss a collision display between steps.

Fig 13: Screen shot where we can see a collision between the weld torch and the item
• Step 4: Conduct a simulation run. In this step, the initial configuration of Device models in the layout can be set before simulation begins. Also, there are “Run” types of simulation to determine how the simulation stops. For instance, a simulation run may continue until it finishes, discovers an error, or obtains the modeler-specified stop time.

![Fig 14: An example of a workcell [15]](image)

When the simulation runs, the GSL program of the device can be altered, and the data can be recorded and displayed. The more typical performance date are cycle times, joint values, collisions, joint speeds and accelerations, TCP values and speeds, I/O values, and so on. [14]
4.7 Conclusion

The use of advanced software tools such as IGRIP for off-line programming gives some advantages compared with traditional programming, such as:

- We can simulated programmed and tested more complex work items and weld cases, because there are no restrictions to use any work item geometry.
- To study the design of weld jigs
- Programs are in general more consistent and parts of programs can be reused. Better documentation and reuse of data gives in general better quality of the programs.
- Simulation, testing and programming can be done using a virtual model of the work item before it exists, providing short lead time in preparing the production.
- The programming method gives a safe way to produce programs. This is very important in complex industrial robotic systems including those with integrated gantry systems, servo tracks, etc. Manual on-line programming should otherwise force the programmer to work within the system which, especially in complex systems, demand great resources both with respect to personnel safety and the machine system.[15]
Chapter 5: Welding

In the description of the enterprise Ferrufor m, we mentioned the types of welding that they use. Now, we are going to explain them briefly:

5.1 Robot welding

In the robot welding, there are different kinds of welding processes which all use different sources of heat; for instance arc welding uses an electric arc as a heat source. Another one commonly used welding process is spot welding (resistance welding). [17] There are two popular types of industrial welding robots.

- Rectilinear robots that move in line in any of three axes (X, Y, Z). Also, they have a wrist attached to the robot to allow rotational movement.
- Articulating robots that use arms and rotating joints. These robots move like a human arm with a rotating wrist at the end. Hence, it creates an irregularly shaped robotic working zone.

![Fig 15: Robots are very commonly in the welding industry [16]](image-url)
On the other hand, as the welding process contains repetitive tasks on similar items, robot welding can be used in automated applications. The most popular, used in perhaps 80 percent of applications, is the solid wire GMAW process. This process is usually the best because it does not need to clean the item afterwards. [16]

5.2 Types of welding used in Ferruform

5.2.1 GMAW welding

Gas Metal Arc Welding (GMAW) has two subtypes, Metal Inert Gas (MIG) welding or Metal Active Gas (MAG) welding. They are a semi-automatic or automatic arc welding process in which a continuous and consumable wire electrode and a shielding gas are fed through a welding gun. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used. [18]

Fig 16: MIG welding [19]
MIG Welding Benefits [17]

- Allow all positions
- More depositions than SMAW
- Less operator skill required
- Long welds without starts and stops
- Minimal post weld cleaning is required

MIG Welding Problems [17]

- Heavily oxidized weld deposit
- Irregular wire feed
- Burn back
- Porosity
- Instable arc
- Difficult arc in the beginning

5.2.2 GTAW welding:

Gas Tungsten Arc Welding (GTAW), more famous like Tungsten Inert Gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode for welding. The weld area is protected from atmospheric contamination by a shielding gas (usually an inert gas such as argon), and a filler metal is normally used. Also, it needs a constant-current welding power supply that produces energy which is conducted across the arc through a column of highly ionized gas and metal vapours known as a plasma. [18]
TIG Welding Benefits [17]

- More quality welds
- Welds can be made with or without filler metal
- Very precise
- Does not spatter

TIG Welding Problems [17]

- Erratic arc
- Electrode consumption excessive
- Exits a deposit of oxidize
- Porosity
- Difficult arc starting
5.2.3 Resistance welding:

In the resistance welding, small pools of molten metal are created at the weld area as high amounts of current (1000–100 000 Amperes) is passed through the metal.

Fig 18: Diagram of resistance welding [17]

Resistance Welding Benefits [17]

- Fast
- Easily automated
- Suitable for high rate production
- Economical
- Little pollution
Resistance Welding Problems [17]

- Cracks
- Electrode deposit on work
- Porosity or cavities
- Little holes
- Deep electrode indentation
- Improper weld penetration
- Weld size
- Irregular shaped welds

5.2.4 Friction Welding:

The most common, is Friction Stir Welding. It uses heat generated through mechanical friction between a moving work piece, with the tool who rotates and add pressure. [18, 20]

![Image of Friction Stir Welding](image.png)

*Fig 19: Image of Friction Stir Welding [22]*
Friction Welding Benefits [22]

- No widespread softening of the assembly
- Can join dissimilar materials
- Very fast
Chapter 6: IGRIP Work cell

6.1 Current situation

Currently, the situation in the company Ferruform to make the side member is this way:

Firstly, a crane picks up the item in order to fabricate the side member and places it in a buffer, before going to the welding work cell.

Then the crane picks up once again the item, and puts it on the welding table so as to set the right position. Currently the operators need 25 minutes to finish the task.

Afterwards, the crane takes the side member and transports it to the second buffer. When the second work cell is available the crane takes the item and moves it to the grinding work cell. The operators need another 25 minutes as well, and after this, the side member is finished.

Thus, currently the production line involves a lot of manual processes that means that it is necessary a lot of time to perform all tasks. Regarding the latest trends in robotic arc welding, we have considered the introduction of two robots into the line that would improve cycle times and increase the production.

This thesis had already described the advantages of the suggested robots. Furthermore, in order to check the feasibility, we will take advantage of the Off-Line Programming (OLP) by using the IGRIP software.

On the other hand, there are some ergonomic problems in the current layout. The work place is quite uncomfortable and the work table is too high. Nowadays, ergonomics have an important role and a good design provides a lot of advantages in terms of production. Thus, it is extremely convenient to set the robots in the right place into the production line.
6.2 Suggested situation

In order to check the feasibility of the suggested layout, a work cell will be designed with IGRIP software. This software will help us to choose the suitable robots in order to prove that the side members can be produced in our work cell.

Firstly, it is necessary to choose the robots that can perform the welding-grinding tasks. ABB website provides a wide range of robots.

<table>
<thead>
<tr>
<th>Robot</th>
<th>Payload</th>
<th>Reach</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRB 6600</td>
<td>125 kg, 225 kg</td>
<td>2.55 m, 2.8 m</td>
</tr>
<tr>
<td>IRB 580</td>
<td>10 kg</td>
<td>2.2 m, 2.6 m</td>
</tr>
<tr>
<td>IRB 1600</td>
<td>5 kg, 7 kg</td>
<td>1.2 m, 1.45 m</td>
</tr>
<tr>
<td>IRB 2400</td>
<td>5 kg, 16 kg</td>
<td>1.5 m, 1.8 m</td>
</tr>
<tr>
<td>IRB 540</td>
<td>5 kg</td>
<td>1.7 m, 2.6 m</td>
</tr>
<tr>
<td>IRB 660</td>
<td>180 kg, 250 kg</td>
<td>3.15 m</td>
</tr>
<tr>
<td>IRB 7600</td>
<td>150 kg, 500 kg</td>
<td>2.3 m, 3.5 m</td>
</tr>
<tr>
<td>IRB 5400</td>
<td>25 kg</td>
<td>3.1 m, 15 m</td>
</tr>
<tr>
<td>Robot</td>
<td>Payload Capacity</td>
<td>Reach</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>IRB 4400</td>
<td>10 kg, 60 kg</td>
<td>1.95 m, 2.55 m</td>
</tr>
<tr>
<td>IRB 6650S</td>
<td>125 kg, 200 kg</td>
<td>3.0 m, 3.5 m</td>
</tr>
<tr>
<td>IRB 140</td>
<td>5 kg</td>
<td>0.81 m</td>
</tr>
<tr>
<td>IRB 6600</td>
<td>170 kg, 185 kg</td>
<td>2.55 m, 2.75 m</td>
</tr>
<tr>
<td>IRB 4450S</td>
<td>30 kg</td>
<td>2.74 m</td>
</tr>
<tr>
<td>IRB 260</td>
<td>30 kg</td>
<td>1.52 m</td>
</tr>
<tr>
<td>IRB 6400RF</td>
<td>100 kg, 120 kg, 150 kg, 200 kg</td>
<td>2.5 m, 2.8 m, 3.0 m</td>
</tr>
</tbody>
</table>

In ABB website we can choose the right robots by application, payload and reach of the robot.

In our case of study we have chosen an arc welding robot with a payload capacity of 7 - 16 kgs and a reach up to 1.8 m. Thus, the most suitable robot we found is IRB 2400.

In the same way, it is posible to select the grinding/polishing robot, too. The payload capacity is 7 to 16 kgs and the reach up to 1.8 m. For these requirements the right robot will be IRB 2400 as well.
The description of this robot can be found in ABB website:

“The IRB 2400 in its different versions and best accuracy gives excellent performance in material handling, machine tending and process applications. IRB 2400 offers you increased production rates, reduced lead times and faster delivery for your manufactured product.

![Fig 20: Picture of the ABB robot IRB 2400 [23]](image)

- **Reliable – High production up time**
  
  IRB 2400 is the world’s most popular industrial robot. The robust construction and use of minimum parts contribute to high reliability and long intervals between maintenance.

- **Fast – Short cycle times**
  
  Thanks to the ABB’s unique motion control of the robot optimizes the acceleration and retardation, which results in shortest cycle time possible.

- **Accurate – Consistent parts quality**
  
  Best in class regarding path accuracy and position repeatability (RP = 0.06 mm)

- **Strong – Maximized utilization**
  
  Payload options are between 5 -16 kg. Max reach 1.810 m.
• **Robust – Harsh production environment**
  
  *IP 67 classified, steam washable, clean room (class 100) and “Foundry Plus” optional.*

• **Versatile – Flexible integration and production**
  
  *All models offered with inverted mounting capability.” [23]*

Moreover, this robot is designed for tasks such as: arc welding, grinding/polishing, assembly, cleaning of casting, cutting of casting, die casting, gluing/sealing, injection molding, machine tending, material handling, packing,

Thus, the robot is suitable for our production line. We chose the robotic arc welding, because this type of weld offers our many benefits. These benefits include: consistency of quality welds, repeatability, reduction of production costs, fewer scrapped parts, and increase our return on investment (ROI). [10]
6.3 Creating the work cell in the IGRIP program

In order to create the work cell, two robots IRB 2400 are used. It is possible to find them in the library of the IGRIP program.

Also, we need to build the side member and the work tables in CAD World (see Figures 21 and 22), a tool integrated in IGRIP.

![Fig 21: Side member in the IGRIP program](image1) ![Fig 22: Work table in the IGRIP program](image2)

Subsequently, these items are inserted into the work cell. A crane is used to move the side member next to the robots so it is necessary to find a similar one in the library of IGRIP. At this point, we have now everything to create the work cell.

On the other hand, when creating the work cell it is necessary to take into account the best layout for the robots so that they can be easily used and perform the tasks in an efficient way.
In the suggested situation the disposition of tasks does not change. In first place the side member goes through the welding station and then through the grinding station.

To create the welding work cell, it is necessary to attach the welding gun on the robot arm. Otherwise, we put the suitable tag points on the side members for the accurate weld.
Subsequently, we introduce the speed of the weld robot in the program. The usual speed is 400 mm/min. This way we enter this value into the robot program.

Afterwards, it is necessary to do the inspection. The following picture shows how an operator makes the inspection beside the welding table. After this, he uses the crane to move the item to the grinding table.

![Fig 25: The operator is close to the welding table](image)

When the welding is finished, the crane transports once again the side member until the grinding table.

Here, we need to build the grinding work cell with the same as the weld work cell. Firstly, attaching the grind gun and then putting the suitable tag points. On the another hand, we introduce the suitable speed of the robot (300 mm/sec).
Afterwards, the operator needs to do the inspection the grinding work cell.

![Fig 26: The operator with the grinding robot](image)

After this task, he attaches the item again and move it to the last buffer.

![Fig 27: The operator close to the last buffer](image)
In order to complete the work cell, it is necessary to enter the speed of the crane. It moves at 100 mm/sec, but when the side member is attached the crane slows down to 50 mm/sec.

In the next picture, we can see the final work cell in the IGRIP program.

Fig 28: The worker in the final work cell

With that speed of the welding robot, the robot takes about 375 sec (6.25 min), because it needs to weld 750 mm both sides (1500mm in total).

Fig 29: Cycle time of the welding robot
The grinding robot requires 586 sec (9.7 min) to grind the side member.

![Fig 30: Cycle time of the grinding robot](image)

The accuracy of this work cell is difficult to know since there are a lot of external factors that are not taken into account. For instance, the crane is not exactly the same as the one used in Ferruform. As a result, speeds and work cell locations may vary. The movements of the robots may vary as well, so the accuracy of the model may be a matter of opinion.
6.4 Results

Reports can be obtained from IGRIP in order to draw some conclusions. First we can claim that the suggested situation is feasible by using the automated work cell. Besides, we can obtain the cycle times necessary to perform all the tasks.

IGRIP tools are used in order to calculate the total times. The necessary time to make the side member is 1403 sec, (23,4 min), thus; the cycle time. (See Fig 31)

![Fig 31: Total time of the production of the item](image)

Now, if we compare the current time with the new time, we can estimate the time saved.

<table>
<thead>
<tr>
<th></th>
<th>Current line</th>
<th>Suggested line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding</td>
<td>25 min</td>
<td>6,25 min</td>
</tr>
<tr>
<td>Grinding</td>
<td>25 min</td>
<td>9,7 min</td>
</tr>
<tr>
<td>Total time</td>
<td>50 min</td>
<td>15,95 min</td>
</tr>
</tbody>
</table>
We can also estimate the time that the crane needs to move the side members in the production line. The total cycle time is 23.4 minutes, but the necessary time for welding and grinding is 16 min. Thus, the time needed for the crane to move the items is 7.4 min. If we study the case in more detail, it could be possible to reduce this time by calculating the best positions on the work tables.

In order to move the item, a crane and only one operator are necessary. Beside, the manual processes cycle times may vary more than the automated processes times. All in all, the new cycle times estimated in the suggested layout are more accurate and precise than in the current situation. Thus, we can estimate the necessary time to produce side members and use them in order to increase the profitability.

The suggested layout created with IGRIP is very similar as the one in Ferruform. Nevertheless, different layouts can be analysed so as to find a more efficient solution. To achieve this it would be necessary a more detailed study of the different processes, the locations of the picking up place and intermediate buffers, the amount of space available, etc.

Besides, it would be convenient to take into account that when one item is in the grinding work cell another item can enter the welding work cell. This way both stations could work in parallel. Thus, the number of items produced a day would increase, and we could improve the profitability of the line.

6. 5 Investment

The investment necessary to set up the production line will be discussed now. In the first place the most important investment will be done the first year. In addition to the costs regarding the welding-grinding robots it is important to take into account costs regarding fixtures and pressing tools, installation, training, etc.
Besides, as a result of the implementation of the new production line it is possible to reduce the number of operators. In the suggested layout only one operator is necessary to perform the manual processes. Thus, the wage of this operator is saved. Since there are two working shifts, it is possible to save two labour costs.

The following table shows the investments and profits of each year.

<table>
<thead>
<tr>
<th>First year</th>
<th>Profit (SEK)</th>
<th>Cost (SEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour cost 350.000</td>
<td>Welding robot</td>
<td>-550.000</td>
</tr>
<tr>
<td>Labour cost 350.000</td>
<td>Grinding robot</td>
<td>-450.000</td>
</tr>
<tr>
<td>Fixture and pressing tools</td>
<td></td>
<td>-200.000</td>
</tr>
<tr>
<td>Installation, training, etc</td>
<td></td>
<td>-150.000</td>
</tr>
<tr>
<td>700.000</td>
<td></td>
<td>-1350.000</td>
</tr>
<tr>
<td><strong>Total First year</strong></td>
<td></td>
<td><strong>-650.000</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Year</th>
<th>Profit (SEK)</th>
<th>Cost (SEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour cost 350.000</td>
<td>Maintenance</td>
<td>-100.000</td>
</tr>
<tr>
<td>Labour cost 350.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>700.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Second year</strong></td>
<td></td>
<td><strong>-50.000</strong></td>
</tr>
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<table>
<thead>
<tr>
<th>Third Year</th>
<th>Profit (SEK)</th>
<th>Cost (SEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour cost 350.000</td>
<td>Maintenance</td>
<td>-100.000</td>
</tr>
<tr>
<td>Labour cost 350.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>700.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Third year</strong></td>
<td></td>
<td><strong>550.000</strong></td>
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<table>
<thead>
<tr>
<th>Fourth Year</th>
<th>Profit (SEK)</th>
<th>Cost (SEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour cost 350.000</td>
<td>Maintenance</td>
<td>-100.000</td>
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<tr>
<td>Labour cost 350.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>700.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Fourth year</strong></td>
<td></td>
<td><strong>1,150.000</strong></td>
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<table>
<thead>
<tr>
<th>Fifth Year</th>
<th>Profit (SEK)</th>
<th>Cost (SEK)</th>
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<tbody>
<tr>
<td>Labour cost 350.000</td>
<td>Maintenance</td>
<td>-100.000</td>
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<tr>
<td>Labour cost 350.000</td>
<td></td>
<td></td>
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<tr>
<td>700.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Fifth year</strong></td>
<td></td>
<td><strong>1,750.000</strong></td>
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To sum up, we can say that the capital invested is totally amortized over three years. Moreover we had proved that the new cycle times are lower and the production can be increased. This way it is possible to make more side members a day and get more profits.

### 6.6 Conclusions

IGRIP software is an efficient tool to create and analyze work cells. Likewise, we have created a work cell that enabled us to simulate a hypothetic situation in order to check the feasibility of the introduction of robots into our current production line. On the other hand, IGRIP enable to make changes and verify results. Comparing the different situations it is possible to find the most efficient scenario for the company Ferruform.

Besides, we had proved that with the introduction of the robots the total production time is reduced. If we compare the new times with the old ones, we can claim that cycle times are reduced: 34,05 min per item. So, now we can use that time to use it in other tasks or to make more side members per day.

Moreover, from an economic point of view the investment is not quite high if we compare it with the benefits we can achieve. Thus, the investment will be amortized by the third year, regardless of cycle time reductions. As of the third year, we will earn 600.000 SEK per year, even with a cost of 100.000 SEK per year.

This way the final conclusion is that this new automatic work cell is economically and technically feasible.

On the other hand, some difficulties had been found during the study of the work cell. For instance, the movements of the robots had been difficult to simulate. As a result, cycle times may vary a little bit in this case of study.
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