YRKESHÖGSKOLAN NOVIA

Implementation of weighing equipment at a motor production line

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Degree Thesis for Bachelor of Engineering

Degree Programme in Mechanical and Production Engineering

Vaasa 2024

DEGREE THESIS

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Specialization: Operation and Energy Technology
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Title: Implementation of weighing equipment at a motor production line

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Date: 22.05.2024 Number of pages: 40 Appendices: 0

Abstract

This thesis was carried out for ABB IEC LV Motors in Vaasa. The factory manufactures IEC low-voltage motors in various sizes.
The purpose of the work was to implement scales at the production line to weigh the assembled motors as a port to automate the production line.

The background to the work is that customers have complained about delivered motors because their weight does not match the weight on the motors type plate, transport companies have also reported that the weight mentioned when ordering transport did not match the actual weight during transport. The work is part of a project, where the project goal is to automate the production line with industrial scales, and a laser printer that prints the motor-type plates at the production line.

The work consisted of getting to know the motor production line at the factory and finding different types of scale solutions for the production line. To achieve the result, I started by following the production process in the factory, reading up on the theory of scales, interviewing the foreman and the workers on the production line, and keeping meetings with project participants. From the information obtained, was able to decide where in the process the scales could be placed and what types of scales could be used.

In the result of the work, layout images are shown of where the scales could be placed and what types of scales are profitable. Also, the most suitable scale is chosen.

Language: English
Key Words: scale, low-voltage motor, production line, weight

EXAMENSARBETE

Författare: Max Nyholm
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Handledare: Samu Tuomainen (ABB), Leif Backlund (Novia)

Titel: Implementering av vågutrustning vid motorproduktionslinje

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Datum: 22.05.2024 Sidantal 40 Bilagor 0

Abstrakt

Detta examensarbete utfördes åt ABB IEC LV Motors i Vasa. Fabriken tillverkar lågvoltsmotorer i olika storlekar. Syftet med arbetet var att implementera vågar som väger de ihopmonterade el-motorerna vid produktionslinjen för automatisering av produktionslinjen.

Bakgrunden till arbetet är att kunder reklamerat levererade motorer för att deras vikt inte stämmer överens med vad vikten som står på motorns typbricka. Transportföretagen har också rapporterat att den vikt som anmälts vid transportbeställning inte stämt överens med verkliga vikten vid transport . Arbetet är en del av ett större projekt där målet är att automatisera produktionslinjen med industrivågar och en laserprinter som skriver ut motortypbrickorna vid produktionslinjen.

Arbetet bestod av att bekanta sig med motorproduktionslinjen vid fabriken, olika typer av vågar för industribruk och att hitta olika lösningsalternativ. För att uppnå resultatet började jag med att följa med produktionsprocessen i fabriken, läste in mig på teori om vågar och vilka olika typer det finns på marknaden. Förmannen och arbetarna vid linjen intervjuades och möten med projektdeltagare hölls. Av informationen som fåtts utifrån detta kunde jag besluta om var i processen vågarna kunde placeras och vilka typer av vågar som kunde användas.

Resultatet blev layoutbilder på var vågarna kunde placeras, möjliga vågtyper och lösningen för hela projektet. Även den mest passande vågen är vald.

Språk: Engelska
Nyckelord: våg, lågvoltsmotor, produktionslinje, vikt

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Päivämäärä:22.05.2024 Sivumäärä 40 Liitteet 0

Tiivistelmä

Tämä opinnäytetyö tehtiin ABB IEC LV Motorsille Vaasassa. Tehdas valmistaa erikokoisia pienjännitemoottoreita.
Työn tarkoituksena oli selvittää, onko mahdollista toteuttaa tuotantolinjalla täysin koottuja moottoreita punnittavia vaakoja tuotantolinjan automatisointiin.

Työn tausta on, että asiakkaat ovat valittaneet toimitetuista moottoreista, koska niiden paino ei vastaa moottorin tyyppikilvessä olevaa painoa, kuljetusyritykset ovat myös raportoineet, että kuljetuksen tilauksessa ilmoitettu paino ei vastannut todellista painoa kuljetuksen aikana. Työ on osa suurempaa projektia, jossa tavoitteena on automatisoida tuotantolinja teollisuusvaaoilla ja lasertulostimella, joka tulostaa moottorin tyyppikilvet.

Työ koostui moottorin tuotantolinjaan tutustumisesta tehtaalla, erilaisiin vaaoihin teolliseen käyttöön ja erilaisten ratkaisuvaihtoehtojen etsimiseen. Tuloksen saavuttamiseksi aloitin seuraamalla tuotantoprosessia tehtaalla, lukemalla vaakojen teoriaa ja erilaisia markkinoilla olevia tyyppejä, haastattelemalla työnjohtajaa, linjalla olevia työntekijöitä ja palaveria projekti ryhmän kanssa. Tästä saaduista tiedoista pystyin päättämään, mihin prosessissa vaakoja voidaan sijoittaa ja minkä tyyppisiä vaakoja voidaan käyttää.

Työn tuloksena esitetään layout-kuvia siitä, mihin vaa'at voitaisiin sijoittaa ja millaiset vaa'at ovat kannattavia. Myös eniten sopiva vaaka valitaan niistä.

Kieli: Englanti
Avainsanat: vaaka, pienjännitemoottori, tuotantolinja, paino

Table of Contents

Abbreviations / Shorthand expressions

SAP	Enterprise Resource Planning (ERP)
ABB	Asea Brown Boweri
MES	Manufacturing Execution System
Bar code	A barcode is a method of showing data in a visual form or machine-readable form
Overhead crane	An overhead crane is a crane used in industrial environments.
Wireless connection	Computer networks that are not connected by cables of any kind are used as connections between different equipment locations.
Remote control	Electronic device that can operate other devices from a distance
VAT	A value-added tax
QMS	Quality Management Standard
Roller conveyor	Roller conveyor is used in material handling systems to move supplies, materials, and boxes

List of Figures

1 Introduction

1.1 Background

ABB IEC LV MOTORS sells IEC LV MOTORS worldwide for applications and industrial use. Currently, ABB IEC LV MOTORS orders its motor-type plates from a subcontractor before the motors are fully assembled and all equipment is installed. The final weight of the motors is calculated in the SAP system according to what parts are to be assembled into them. Customers often make changes during the assembly process, or the SAP system may miscalculate. This means that the weight of the motor type plates does not match the actual weight of the motor and the transport companies are notified of the wrong weight for the logistics. This causes dissatisfied customers, complaints, and high costs for transport. The transport companies may also have to weigh the motors again and invoice more for logistics or give fines.

1.2 Objective

The thesis is to figure out where at the production line the weigh measuring equipment could be implemented to weigh the assembled IEC LV Motors. My task is part of a bigger project where the main goal is to automate the motor-type plates manufacturing process at the AL2 production line at the ABB IEC LV MOTORS factory in Vaasa. The project solution idea contains scales, electronic devices, and a computer system with a wireless data transfer connection to a laser printer, that will print its motor-type plates at the production line.

Through this thesis, I seek to explore various solutions for the motor weighing process at the production line AL2, determine the most suitable types of scales to be used, and recommend the most appropriate locations for their installation. The work also includes getting offers from scale manufacturers and choosing the most suitable scale out of them.

1.3 Delimitations

This work focuses on the motors weighing equipment solution, and possible scale placements at the production line. The IT team in the project will be responsible for weight data transfer from the scale device to the computer.

The scales are planned to present the factory layout, so the production line or assembly positions are not redesigned. In this work, there is no extra space in the factory layout for a new united solution. The time the weighing operations take is not considered for how much assembly time is lost, because other stages in the project process are not known yet.

1.4 ABB

ABB got its start in 1889 under the name Strömberg, they made DC machines in Helsinki. In 1983 Kymi-Kymmenen merged with Stromberg and then became Kymi-Stromberg. Then in 1986, Strömberg was transferred to Asea. The ABB Group was formed in 1988 when Asea and Swiss Brown Boveri merged their electrotechnical businesses, (ABB, 2023).

Today ABB has 105000 employees in over 100 countries around the world. ABB focuses on four different business areas which are: electrification, process automation, motion, robotics, and discrete automation, (ABB , 2024).

ABB in Finland has around 5000 employees and operates in over 20 locations. ABB is hereby one of the largest industrial employers and the largest in the Helsinki capital. The factories are located in Vaasa, Porvoo, Helsinki Pitäjänmäki, and Helsinki Vuosaari, (ABB, 2024).

ABB IEC LV MOTORS develops and produces customized IEC low-voltage motors. The motors are made for applications and industries worldwide. Around 600 professionals work at a factory in Vaasa, (ABB, 2024).

Figure 1. ABB logo. (Wikipedia, 2007)

1.5 Disposition

Below is a brief description of what the chapters of this work will contain.

Chapter 2. Pre-study

This chapter includes prework for the thesis, how the process is today, and what the current problems in the process are.

Chapter 3. Theory,

This chapter presents the theoretical part of the work. This part will go through the necessary theory to understand the thesis and what was considered to reach the desired result.

Chapter 4. Method,

In this chapter, the method is presented for the work, which methods are used to reach the results, and the best possible solution.

Chapter 5. Results

This chapter presents the workflow, production line with scales, what kind of scales could be suitable for the solution, where they will be placed, and which of the solutions is the best. Also, recommended future works are mentioned.

Chapter 6. Discussion,

In this chapter, self-reflection is done. What could have been done differently in the work process and what did go well in the work.

2 Pre-study

2.1 Process today

Currently, the motor-type plates have been ordered from subcontractors for the IEC low-voltage motors. Before and during the assembly process the customer often wants to install extra equipment on the motor like a gearbox, brake, or other heavy equipment that is not included in the weight. The given weight is calculated in the SAP system after what parts have been added to it.

The motor's net weight formation process is influenced by the motor's type. The motors are divided into a 3G product family, which has been ordered with extra equipment or features, and a static product family which is the basic model. A variant can be a component, modification of a component, or other additional option for the motor. The weight data for static motors comes from the systems. There are two ways of how the net weight is given for the motors in the 3G product family.

Substantially SAP system tries to configure the weight of the 3G motor, by searching the combinations of the variant codes of the ordered additional features for the appropriate entity for the motor. Adding the weight of the additional parts of the variants to the weight of the basic motor. If the system does not find a suitable set of additional parts, the motor will be transferred to the planning process where the correct additional parts for the motor are determined from the ordered variants, then the weight for the motor is calculated out of that. Which causes the weight to often be wrong.

After the painting process, the motors come out of the oven on a roller conveyor to the AL2A final assembly line. As the motor arrives from the paint oven the line operator checks the motor assembly manual for what kind of motor model it is, depending on the model they know at which assembly location it must be assembled. Every motor has its own manual that follows with the motor at the whole production line and shows what parts should be added to the motor at the assembly stages. The manual also has a bar code that operators scan to see in the MES system if there have been any changes to the part assembly list.

There are four different final assembly locations where they could be moved at the AL2 production line, depending on the different motor models and modifications. They are the following: AL2A final assembly, AL2B final assembly, AL2B forge, and AL2P dock. The mentioned assembly positions can be seen in Figure 2 down below. The assembly process at different positions will also be described.

In Figure 2 below all final assembly positions are mentioned and marked as boxes in different colors. The four red transverse objects are overhead cranes used for lifting motors and parts at the factory.

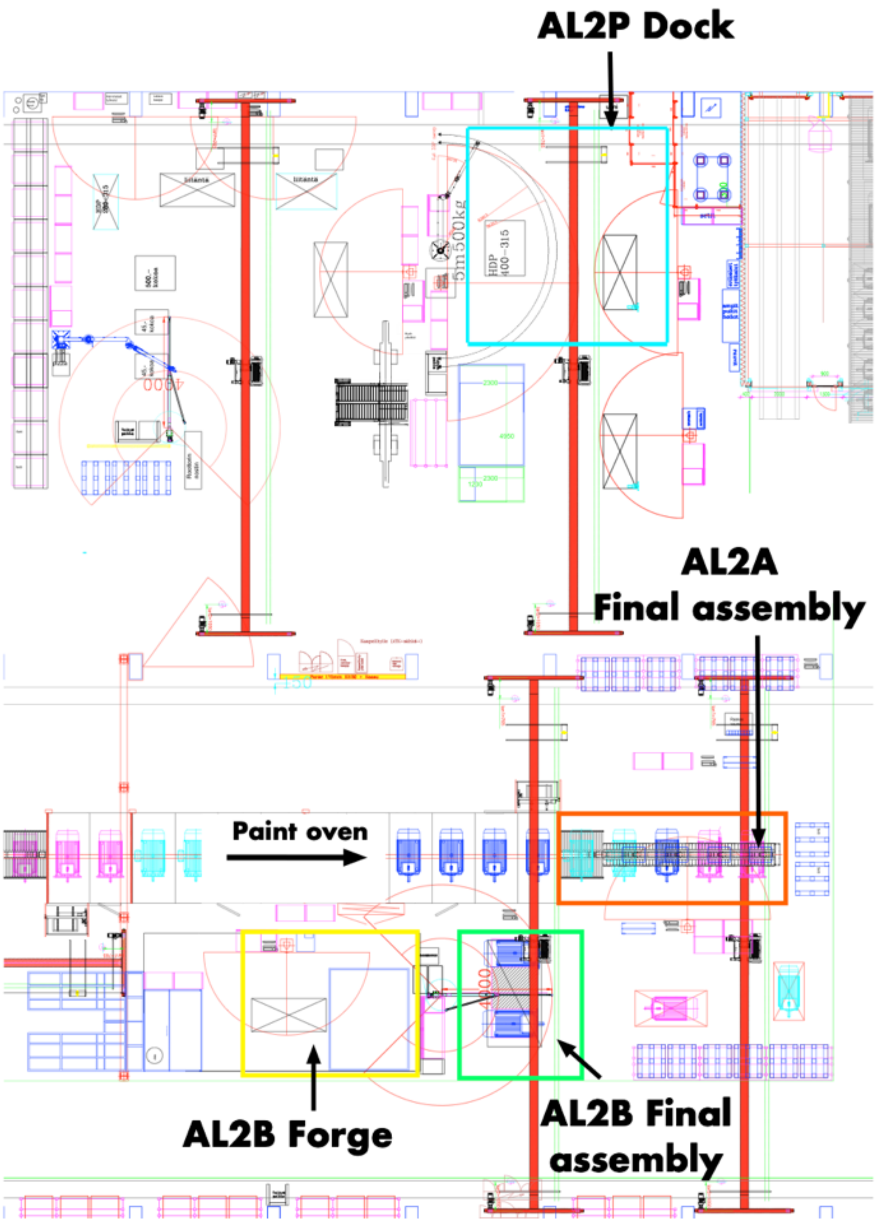

Figure 2. Assembly places AL2 production line

2.1.1 Al2A final assembly

At the AL2A final assembly the 315, 355, and 400 motor models are assembled before final check and transport. When they come out of the oven they assemble motor type-plate, information stickers, fan, fan shield, mounting screws, main junction box, and a special box. The whole assembly process at AL2A final assembly is done at the roller conveyor seen in Figure 3. After motors have gone through the assembly process there, they lift them on to transport pallet for final inspection and transport. If it is not a motor that must go to ALP dock.

Figure 3. AL2 final assembly line

2.1.2 AL2P dock

After the AL2A final assembly line, a few motors are modified after the customer needs them at the AL2P dock. The motors that are moved to the AL2P dock will first be assembled with everything at AL2A final assembly and after that lifted to a transport pallet and moved by forklift operator to the AL2P dock.

At the special modifications at AL2P dock main parts in the motors can be changed, the rotor or stator or the hole motor, depending on what the customer wishes to get done to it after the original deal. A picture of the AL2P dock can be seen in (Figure 4).

Figure 4. AL2P Dock

2.1.3 AL2B Final assembly

At the AL2B final assembly, they do the final assembly of the 355-400 motors. After the painting oven some of the 355 depending on the equipment, and all 400 motors are lifted to a working table at AL2B final assembly with the overhead crane.

There they assemble special fans, fan covers, brakes, couplings, and silencers. So heavier and bigger parts and motors than at AL2A final assembly. After assembly, they lift motors onto transport pallets, and they are moved to inspection before delivery to the customer. A picture of the AL2B final assembly is shown in (Figure 5).

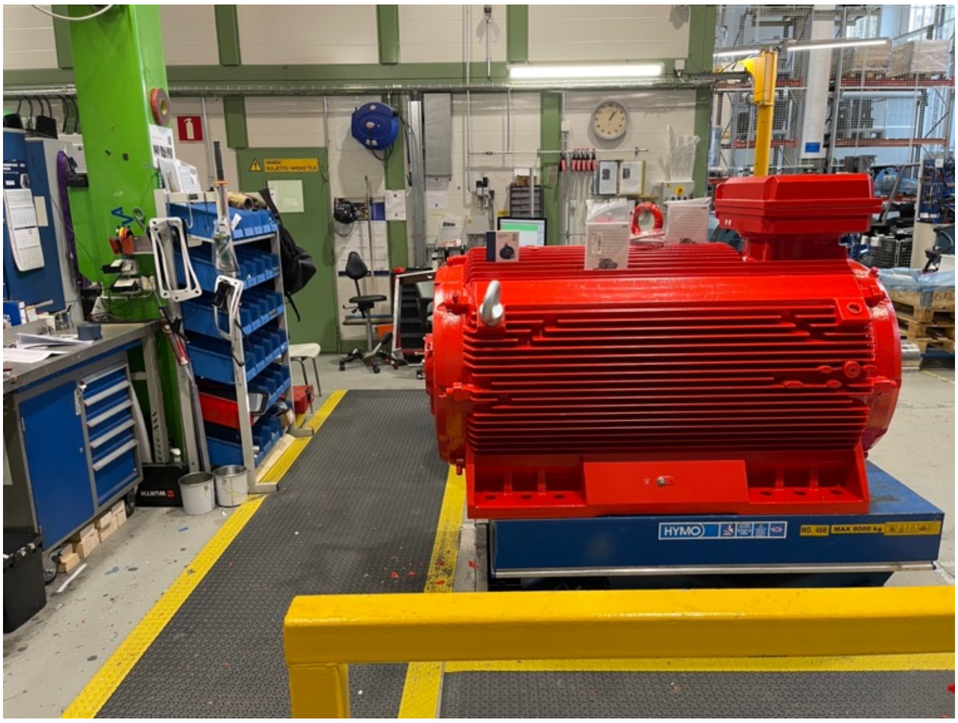

Figure 5. AL2B final assembly

2.1.4 AL2B forge

At the AL2B forge they do the final assembly of the 450, HDP, and 500 motors. These are the heaviest motors that are assembled at the line and weigh up to 7300kg. As the mentioned motor models comes out from the paint oven to the AL2A final assembly, they are directly lifted to this assembly location by the overhead crane. There they assemble the same equipment as at the AL2B final assembly, but the assembly forge is made for bigger motors. After assembly there they also lift the motor from the table to transport pallets for inspections and transport. A picture of AL2B forge see (Figure 6).

Figure 6. AL2B forge

Almost every part that is assembled at the different locations has a huge impact on the final weight, whether it is or is not included in the calculation for the final weight in the SAP system. The heaviest parts like silencers can weigh up to 200kg. When the heaviest motors weigh 7300kg there is a difference of $\pm$ 4% in the final weight and even more difference in lighter motors. In (Figure 7) below a flowchart of the final assembly process can be seen.

Figure 7. Flowchart for Final assembly process AL2 production line

3 Theory

The theory part contains theory and research to get the thesis done. This part will go through the possible scale types for the industry and include theory about their standards for industry use. The theory part also includes information about scale procurement for industry and production use.

3.1 Industrial Scales

A scale is an equipment that was invented to measure mass. The force measuring scale has its origin back to the 18th century, (Wikipedia, 2024).

Industrial scales have an important role in manufacturing, logistics processes, and production, serving as weighing equipment for measuring the load of materials and products. They are used in a wide range of industries, ranging from pharmaceuticals and chemicals to food, construction, and automotive. The industrial scales are designed to withstand industrial environments, accuracy, and versatility for different weighing needs. (ScalesPlus, 2024).

In production processes, the industrial scales have a crucial role, in ensuring accuracy and precision in the measurements of final products and raw materials. Today the industrial world is developing fast, manufacturers continuously seek ways to improve the production processes to go ahead in competition with competitors. They have proved to be game changers to manufacturers, as they provide real-time insights and data enabling factories to make leads to better results, (AWM, 2023).

There are many advantages of using industrial scales in manufacturing. Increasing efficiency as they help to automate weighing processes, which reduces effort and time to weigh products and materials. Improving accuracy as they provide accurate measurements, that remove human errors and maintain quality standards. Saving in costs, scales help manufacturers to improve quality and increase efficiency. Over time it could lead to significant savings in outlays. Industrial scales can be integrated with manufacturing systems, like MES and SAP systems. As mentioned earlier, this brings real-time insights and data to the manufacturing process and helps manufacturers make decisions that lead to better results, (AWM, 2023).

3.2 Load Cells

A load cell is a sensor or a transducer that converts a load acting on it, or a force into an electrical signal by strain gauges inside of the body. They are often used in industrial applications to measure force, weight, or torque. The most common load cells are strain gauge load cells, hydraulic load cells, pneumatic load cells, and capacitive load cells, (Medium, 2018). The design idea with load cells is to convert the kinetic energy of a force, tension, pressure, compression, or torque to an electrical signal that is measurable, (Load Cell Central, 2024).

The most common load cell in industrial use is a strain gauge load cell. They consist of a spring element or a solid metal body like steel, aluminum, or stainless steel, that provides minimal elasticity and durability for industrial use. Which the strain gauges are attached to. As force is applied to the body it undergoes a slight deformation, if it is not overloaded the body returns to its original shape. As the body undergoes deformation it causes changes in the strain gauges.

Strain gauges work with DC electricity, and it is important that the electricity source is stable (FINLANDS REGLERINGSTEKNISKA SÄLLSKAP rf, 1981).

Resistance in strain gauges is set apart in tension load cells vs compression load cells. A tension force causes the strain gauge to become longer and thinner, which increases resistance. This can be seen in (Figure 8) down below. A compression force causes the strain gauge to become shorter and thicker, which decreases the resistance. The strain gauge load cell is on the right side in Figure 8, (IQSdirectory, 2024).

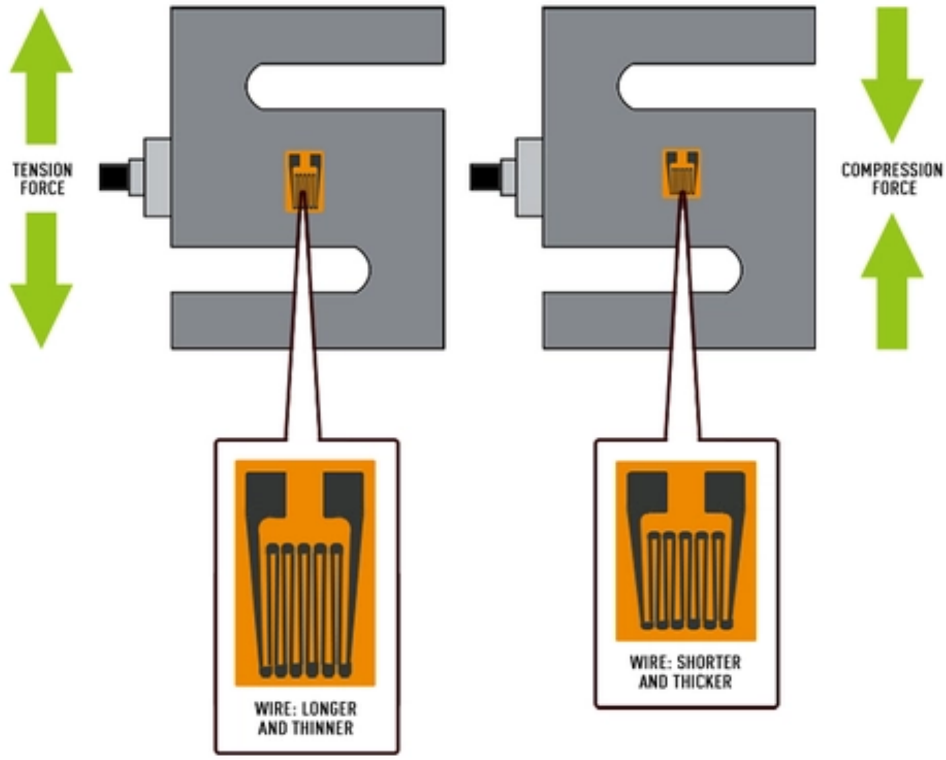

Figure 8. Tension load cell and Compression load cell. (Load Cell Central, 2024)

3.2.1 Tension load cells

The tension load cells are named or categorized by how their sensor deflects when it is exposed to strain. Models of tension load cells are tension link load cells, S-type load cells, crane scales, canisters, and pancakes. This theory focuses on S-type load cells and tension link load cells, they can be seen in (Figure 9), (Load Cell Central, 2023).

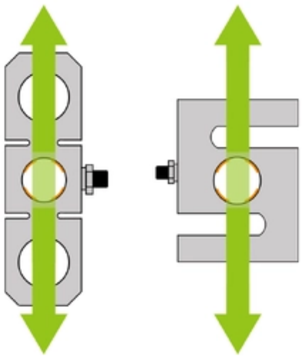

Figure 9. Tension link load cell & S-type load cell. (Load Cell Central, 2023)

A crane scale often uses a S-type load cell. The S-type name comes from its shape, see (Figure 10). They can be mounted between items to weigh the lower mounted object, for example in a crane scale, (Load Cell Central, 2023).

Figure 10. S-type load cell. (Load Cell Central, 2023)

The tension link load cell is a good option for a lot of tension applications, including crane scales. They are made of stainless steel or steel to outstand the harshest environments. Tension links have the shape of Figure 8, and they can be linked between ropes, chains, or cables, see (Figure 11). To measure the loading strain, the loading axis is vertical with the strain gauges placed parallel to each other, (IQS Articles, 2024)

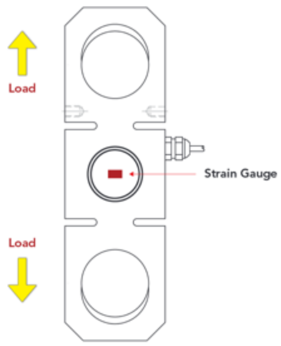

Figure 11. Tension load cell. (ANYLOAD, 2024)

3.2.2 Compression load cell

The compression load cell is named and categorized by how the sensor deflects when experiencing a strain. The compression load cell is compressed or bent compared to tension load cells which are pulled apart. The compression load cell technology is used in a wide range of industrial applications. Because they have a low-profile button or design, they are excellent for use where the overhead or side space is limited.

Compression load cells convert the force applied to it into an electrical signal. There are many different compression-type load cells: canister, beam, shear web, single point, and pancake, (Load Cell Central, 2024). In this thesis, the focus will be on pancake-type compression load cells, because the other models are not relevant for the implementation at the production line.

Pancake-type load cells are used in a wide range, of hydraulic press applications, multi-point weighing, in-line force measurement, and off-axis loading. It has holes around it, located at half of the radius from the center seen. Into the holes shear strain gauges are mounted with a 45-degree angle set to the loading axis, see (Figure 12). They are very useful in tight spaces and can be used in tension or for compression, (IQSdirectory, 2024).

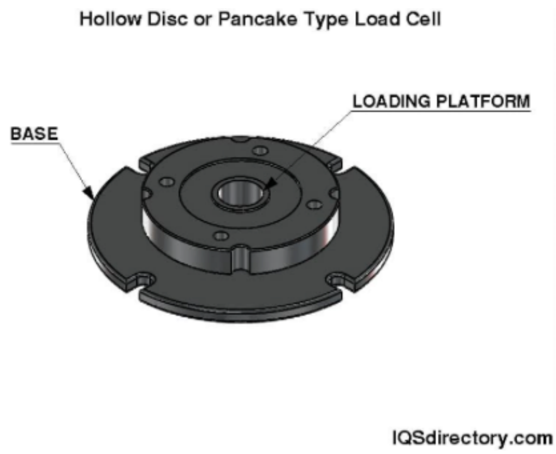

Figure 12. Pancake load cell. (IQSdirectory, 2024)

3.3 Strain gauges

The first strain gauge was developed in 1940 (Medium, 2018). It is a device that measures change in electrical resistance as a force is applied to it. Strain gauges are often used in a tandem system with more strain gauges to increase the accuracy. The parallel wires in (Figure 13) are fasted to a metal body's surface. As the body is exposed to stress, it causes the wires to deform and resist the affecting stress. That makes it measurable because the resistance is proportional to the stress that the force causes, (IQSdirectory, 2024).

Strain gauges work with DC electricity, and it is important that the electricity source is stable (FINLANDS REGLERINGSTEKNISKA SÄLLSKAP rf, 1981).

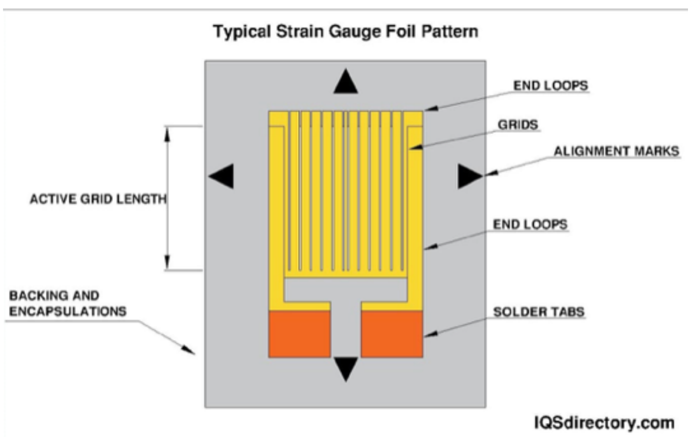

Figure 13. Strain gauge. (iqsdirectory, 2023)

There are seven types of strain gauges, can be seen in (Figure 14): Linear strain gauge (number 1), Double linear strain gauges (number 2), shear strain gauges (number 3), tee rosette strain gauge (number 4), half-bridge strain-gauges (number 5), full-bridge strain gauges (number 6), and rosette strain gauge (number 7), (Load Cell Central, 2020).

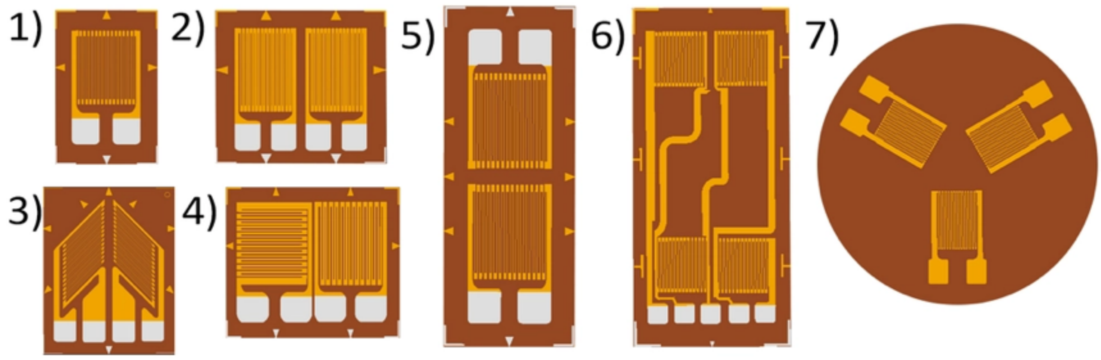

Figure 14. Strain gauge types. (Load Cell Central, 2020)

3.3.2 Double parallel strain gauge

Double parallel strain gauges are made of two linear strain gauges mounted parallel to each other as seen in (Figure 15). An example is a bending full bridge circuit where two double parallel strain gauges are placed on different sides of the structure, but they can also be used with different bridge circuit solutions, (IQSdirectory, 2024). This type of strain gauge is used in crane scales or tension load cells.

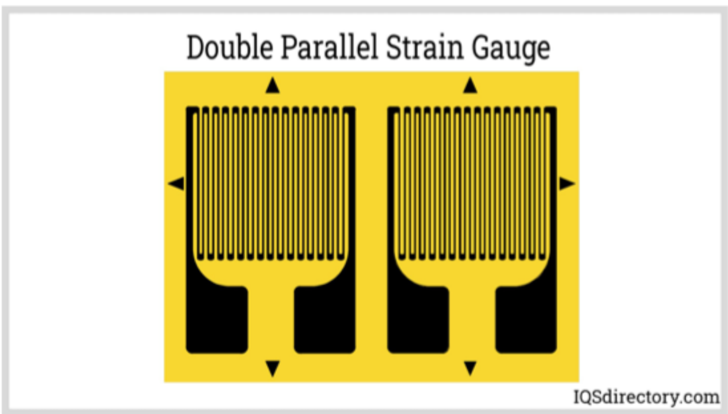

Figure 15. Double Parallel Strain Gauge. (IQS Articles, 2024)

3.3.2 Shear strain gauge

They are used to measure shear strain caused by torsional loading or torque. They have one or two measuring grids connected to a single carrier. The single strain gauge is aligned at a 45-degree angle to the center of the shaft, can be seen in (Figure 16). They are used in pancake load cells, (IQSdirectory, 2024).

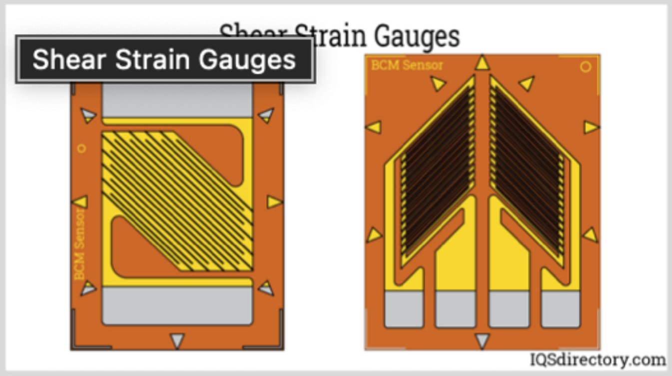

Figure 16. Share strain gauge. (IQSdirectory, 2024)

A single strain gauge measuring resistance is extremely small, a good solution for the small changes into a more measurable value is to connect them as a Wheatstone bridge, (Load Cell Central, 2024).

3.4 Wheatstone bridge

A strain gauge load cell works according to the piezo resistivity. The strain gauge is exposed to voltage within the gauge scale, when weight is applied the strain gauge senses a change in piezo resistivity, which creates changes in voltage output. In a single strain gauge the change in resistance is very small. That makes it difficult to measure it and to get an accurate load of the measurement.

This is a solution by combining four strain gauges in a set of a circuit and was invented back in the 19th Century by Samuel Hunter Christie, (Medium, 2018). Below is an application of a Wheatstone bridge (Figure 17).

A Wheatstone bridge consists of four resistors R1, R2, R3, and R4, it uses a stable DC voltage source.

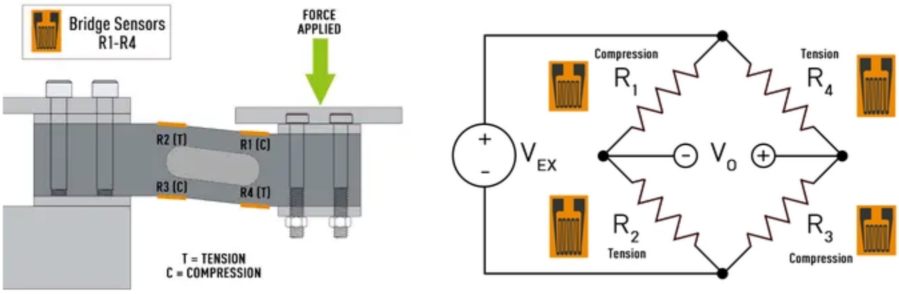

Figure 17. Wheat stone bridge circuit from. (Load Cell Central, 2024)

When force is applied to the load cell, the structure of the strain gauge changes as seen in the annex below. This changes the resistance in the strain gauges and V_0 is being measured. This can be seen in the formula down below (1):

$$V_0 = (\frac{R3}{R3+R4} - \frac{R2}{R1+R2})V_{EX} \quad (1)$$

3.5 Crane Scale

Crane scales or hook scales are used to weigh items by lifting them from a fixed position rather than setting the load on a weighing platform, (MARSDENGROUP, 2020). They are equipped with hooks above and under to attach an object, see (Figure 18). The main parts of crane scales are a load cell, a scale frame, and a weighing indicator. Crane scales take up little space compared to a platform scale and can be used to move items and at the same time weigh them. Hanging scales are mostly used in industrial environments like factories and warehouses to weigh fruit and vegetables or packages to know the weight for transport or sale.

To ensure an accurate load of the weighed object it needs to be placed on a level surface before measuring. A digital hanging scale measures and calculates the weight of a display with a load cell. (Arlynscales, 2024).

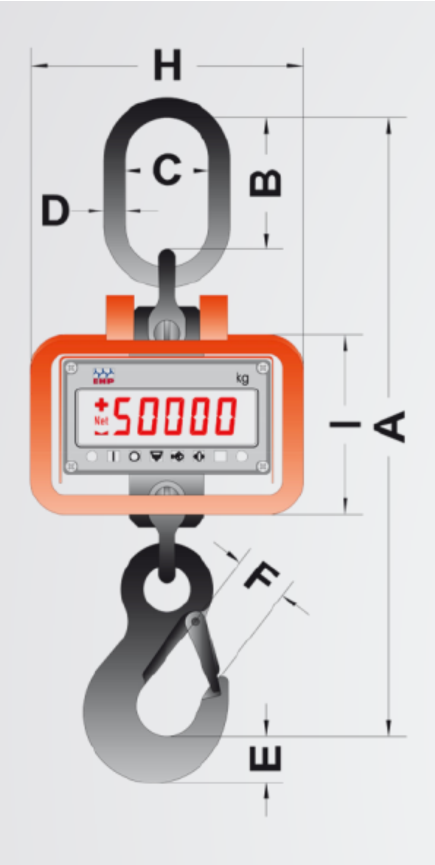

Figure 18. EHP Crane Scale. (EHP, 2021)

A crane scale consists of four resistive elements that are tied to the strain gauge surfaces. When a weight is attached to the scale, two of the resistive elements are stressed (shortened) and two of them are strained (lengthened). These four elements are connected in a Wheatstone Bridge that was described in the preview heading, (Torbal, 2023).

3.6 Electronic mechanical Scale

An electronic mechanical scale is a load weighing equipment that transforms the weighed gravity affecting mass with one or more electric mechanical converters into an electronic weigh message, that can be expressed on a display or printer. (FINLANDS REGLERINGSTEKNISKA SÄLLSKAP rf, 1981).

The object weight acts on a strain gauge through the load cell, the strain gauge gives out an analog voltage signal which is sent to the data acquisition board, where it is amplified, filtered and A/D converted into a digital signal. Next, the processing board of the instrument processes the weight into the scale's main display in the desired weight unit. The scale can also be connected wirelessly then it is instead able to send the weight data further, (HiWeigh, 2019). In (Figure 19) the electronic mechanical scale function is shown.

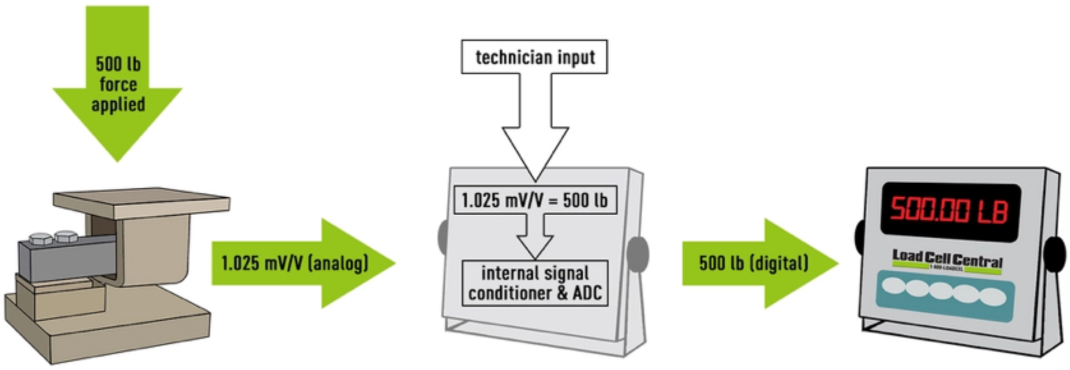

Figure 19. Electronic mechanical scale function. (Load Cell Central, 2023)

3.7 EN13155 Standard

When choosing a scale for factory use it must fulfill a few scale standards. The EN13155 is a European Standard that specifies safety requirements for non-fixed load lifting attachments for manually operated load devices, hoists, and cranes. (EN13155, 2009) It is applied to the following crane lifting attachments: lifting beams, C-hooks, and clamps. This standard describes if the scale is allowed to be used when moving objects around that are attached to the scale.

3.8 ISO 9001 Standard

The ISO 9001 standard is the most used quality management standard in the whole world. It specifies requirements for quality management systems and is an international standard. Companies use the standard to show that they consistently provide services and products that can meet most of the highest industry quality standards in the world.

The ISO 9001 calibration is a process that makes sure the measuring devices and other measuring equipment fulfill the requirements of the ISO 9001 standard. It includes they are reliable, consistent, and accurate. The ISO 9001 standard requires that the company has a documented procedure to calibrate all measuring devices used in their QMS. The calibration is important for QMS maintenance. A regular calibration helps prevent problems further in time, like customer complaints, (GNW Instrumentation, 2024).

ABB is ISO 9001 standard certified, so the calibration schedule for scales will be decided by them when scales are bought, (ABB, 2024).

3.9 Commercial scale

When crushed rock or steel is sold in industry, the material price is determined by the weight. When the weighing result is used like this, it is in commercial use. The accuracy of the scale must be verifiable and the scale in use must be certified for commercial use. In industry, it has been cases where a standard scale has been used for commercial purposes without the company realizing that the business, they run requires to have a weighing instrument that must be approved for commercial use, (TAMTRON, 2023).

Any scale is not suitable for commercial use, the operation and design of the weighing instrument must meet certain criteria. They are determined by directives, laws, and many other standards. All scales should be regularly serviced and calibrated, commercial scales must be legally certified every three years. The weighed motor weight will be used as transport weight (determines the price) and that means the scales have to be commercial, (TAMTRON, 2023).

3.10 SAP

SAP is an ERP (Enterprise Resource Planning). It offers systems for different business areas, sales, production, materials management, finance, and human resources, (SAP, 2024).

3.11 MES

MES is a manufacturing execution system, it is a dynamic software that tracks, monitors, documents, and controls the manufacturing process from raw materials to finished products. MES is used with an ERP and makes the plant floor more efficient and optimizes production, (SAP, 2024). At ABB production line system is used to track motors through the assembly process and show which parts should be assembled into the motor.

3.12 Choose of scale

When deciding on the right kind of weighing system to get, you must go through some important steps. Area of use for the scale, what type of objects will the scale be weighing? Is the scale fulfilling the standards that are required for the environment it will be used? Where will the scale be used, is the scale moved around or is it stationary? If not, an electricity source is needed in some way to charge the scale, a battery, or a permanent cable, (Quality Scales Unlimited, 2018).

The scale capacity, decide on what the largest total load will be to know how much weight the scale has to handle. Accuracy is important in the procurement of a scale, by the time of use it loses its calibration and is faster if it is moved around or exposed to variations in temperature.

The connection options are important when buying a scale. They are often needed to be connected to computer systems, devices, and printers, (Quality Scales Unlimited, 2018). A few other points to have in mind when buying a scale are how smooth it works, data transfer, working time, investment cost, and the working speed (FINLANDS REGLERINGSTEKNISKA SÄLLSKAP rf, 1981)

Weighing range and precision. Which standards it must fulfil for the area of use. Deciding about how protected the scale must be set to in which conditions it will be used what materials it will be used with, will it be exposed to heat, dust, or liquids.

3.13 IEC low voltage motor

The ABB IEC LV motor is an electric motor. They are used in applications and industries all over the world. It runs by using electric power to rotate the rotor in it. The main parts of the motor are the stator, rotor, shaft, bearings, and frame. The named parts can be seen in (Figure 20) below.

The motors are available in aluminum or cast iron, (ABB, 2019). In the Figure, the silencer, brakes, and other extra equipment are not installed.

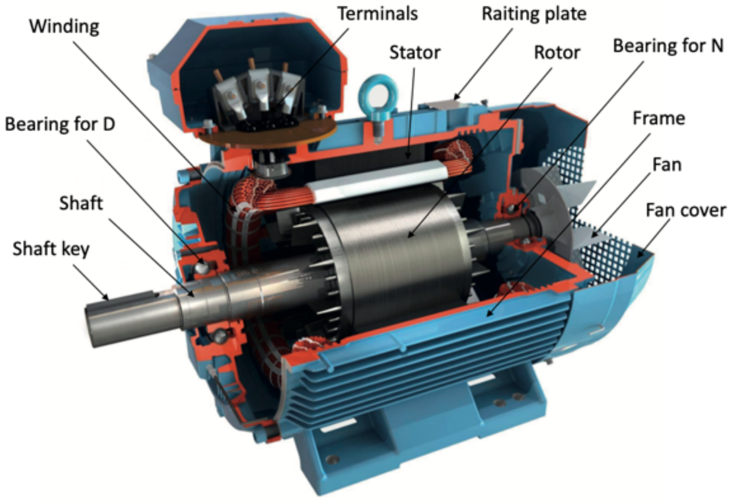

Figure 20. ABB IEC Low Voltage Motor. (ABB, 2019)

3.14 Motor type-plate

A motor type-plate contains information about a product, like a manufacturer, product name and type, VIN number, and year of manufacture. In the figure below an ABB motor-type plate for an IEC low-voltage motor is seen. In the bottom right corner, the weight for the motor is marked, (MAWDSLEYS, 2024). In (Figure 21) an ABB IEC LV Motor type-plate can be seen.

Figure 21. ABB IEC LV Motor type-plate

4 Method

There are three types of research methods you can use when doing a thesis, qualitative research, quantitative research, and mixed methods research. The qualitative research method focuses essentially on interviews, literature reviews, and groups. The Quantitative research method focuses essentially on surveys, data collection, and data analysis.

Mixed-method research methods use both qualitative and quantitative methods. If the problem is difficult and not just only one method is enough to get a deep understanding of the research problem, (Researcher.Life, 2021). To carry out this thesis a mixed method is chosen to reach the best possible results.

The qualitative research method has contained the following stages.

- Interviews with production operators, production line supervisor, and project team members to see what they think of the possible solutions, what problems it could cause, and their expectations for the project, to reach a handy solution.
- Observed production line assembly stages to get an insight into how scales could be placed at the line and what types could be used.
- Interviews with scale manufacturers to widen knowledge of their weighing solutions and their pros and cons.

The quantitative research method has contained the following stages.

- Made a flowchart of the current state of the production line and a layout figure to identify the steps in the process.
- Analysed where all the different motors went after the paint oven.

5 Results

In this part of the thesis, the workflow, the results, the new process, and a conclusion of the results are presented. In the end, suggestions for further work will be given.

5.1 Process following

I started the project by reading two older theses that had been done by other students a few years backwords. The first thesis was done to figure out why the weights are not right for the motors and what a possible solution to the problem could be, (Halmenpää, 2019). The second thesis was done to find a printing solution for the motor type plates at the production line that included a laser printer and a robot that moves the printed type plates to boxes, (Markkula, 2023).

Following the motor assembly process, keeping interviews with the line operators and the line manager, gave a good perspective of the process. With them, we went through the whole process at different assembly locations after painting the oven. Where the extra parts are assembled into the motors, where the different motors are assembled, and where they are ready to be weighed after full assembly. The line operators had insightful opinions and points where the scales should be positioned. The operators' opinions are important because they have a lot of experience in the part of the production where the scale is coming, so it is not set in a bad position in the process or in the way of their work. Their points are good overall but are not always the best. Safety is very important in this part too, that does not always come first to mind because they often rather get things done fast or as it always has been done.

5.2 Interview with production line supervisor

I started this work by speaking with the line supervisor and introducing the project goal with the scales at the lines. Then I interviewed him to get an overall picture of the manufacturing process. With the supervisor we discussed the different models on the motors, and that almost every motor is different from the other set to what it will be equipped with. He explained and showed to which three workshops the different motors were going after the painting oven and which parts would be added to them at the final stages. The supervisor had good points and reflections on where the scales should be placed at the lines and where it is not in the way of production logistics and work.

5.3 Interviews with line operators

After the interview with the line supervisor, I followed the motor assembly process after the oven. I spoke with the line operators in different shifts and told them what the idea was with the scales. Then I kept interviews with operators at the different work stages to get a deeper understanding of what is added to the motors what affects their weight, and where a possible weighing measurement could be done. They also had important points where the final parts are assembled and what kind of solution it would need to be so it won't slow the assembly process. We discussed the possible scales that could be used and which of them fits best into their working stage.

5.4 Meetings

Took part in meetings with the production development team regularly that participated in the project. Kept meetings with the project manager continuously to give updates on my part of the project and what he thought about it. Kept discussions with the information transfer team at the factory that handled the information transfer between scale and computer, to understand which scale offered the best wireless transfer solution for the computer and SAP system. We went through all the possible scales and rated them overall set to data transfer solution, accuracy, price, standards, and other features.

5.5 Offers

In this part, the method for the offers is described.

5.5.1 Crane scale offers

Asked for nine different offers from crane scale manufacturers all over the world. The scales had to meet the standards for EN13155 to be allowed to move the attached loads and have a wireless connection option for a computer. To get the weighing data transferred easily from scale to computer. ABB also required 3 offers from different retailers to get a competing offer. The offers were made for AL2B forge, AL2P dock, AL2B final assembly, and AL2A final assembly.

5.5.2 Conveyor roller offers

For the AL2A final assembly position, a solution could be to modify the supporting legs or change them into load cells, to weigh the motors at the final conveyor, the AL2A final assembly can be seen in Figure 3.

Kept meetings with the two design companies that could possibly redesign the roller conveyor with load cells. The companies had to have the knowledge and rights of how to design a commercial roller conveyor scale, so that it fulfils the standards for industry use. They also had to include a solution to get the weighed data from load cells into the computer.

Arranged meetings with both possible design companies, where I explained the project idea and showed pictures of the production line, and detailed drawings of the roller conveyor that the manufacturer had drawn. Explained what it has to fulfil, weighing range, wireless solution idea, and accuracy. After the meetings, the design companies counted on offers for the conveyor roller load cell design solutions.

5.6 Scale positions

In the picture below the positions for the scales are marked as 1. Crane scale, 2. Crane scale, 3. Solution A, and 4. Solution B. The paint oven is marked with an arrow in which direction the motors move. In (Figure 22) below the different scale solutions are marked.

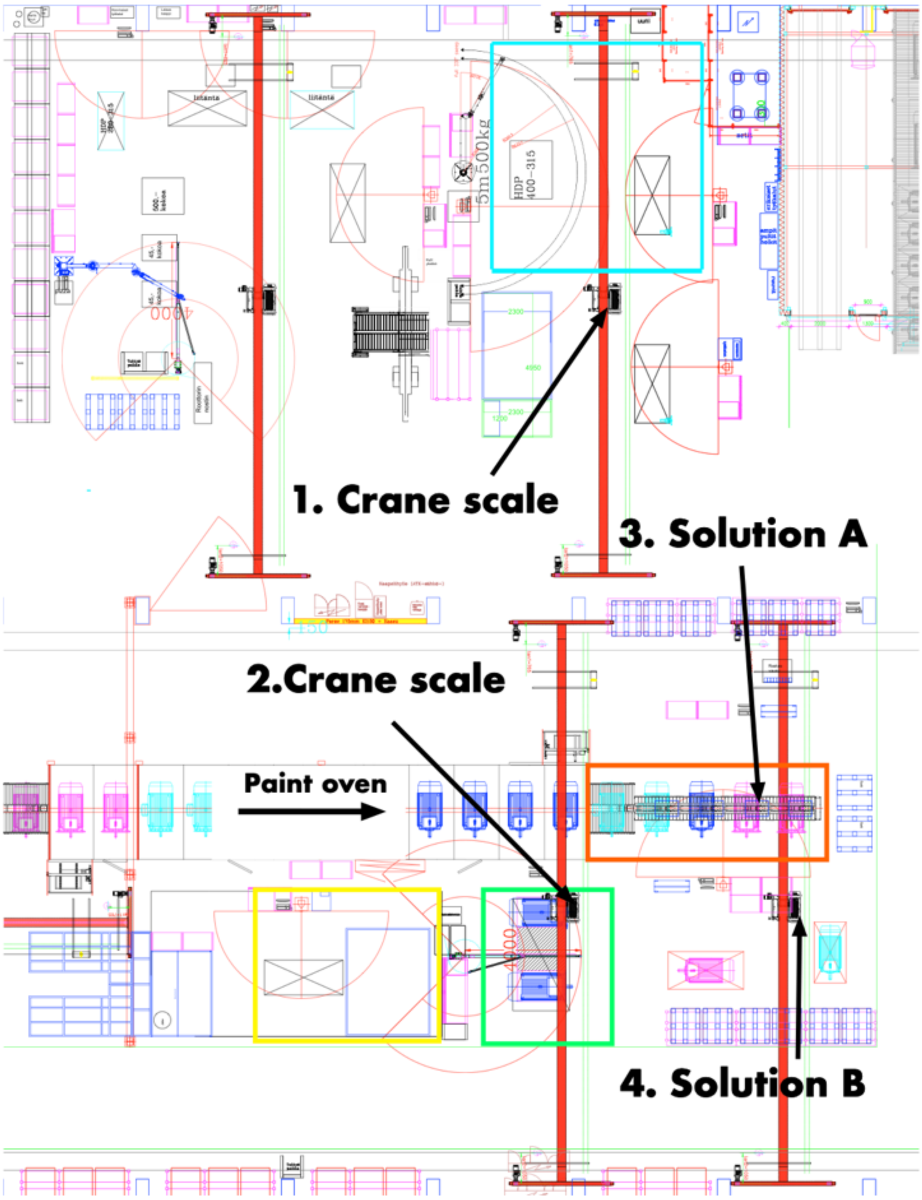

Figure 22. AL2 factory layout with scale positions

5.6.1 Solution for AL2P dock

Solution for Al2P dock a crane scale mounted to the overhead crane permanently, marked as (1. Crane scale) in (Figure 21). The ALP2 dock needs its own scale because when motors have been modified, heavy parts have been changed and after the modification, they leave directly for inspection. When the motors are reassembled, they will be lifted back to the transport pallet from the mounting table. At the same lift, the operator will weigh the motor again.

5.6.2 Solution for AL2B final assembly

The AL2B final assembly will have a crane scale and will be fitted to an overhead crane, which can be seen in Figure 22 marked with (2. Crane scale). The same overhead crane will be used in the AL2B forge and AL2B final assembly which can be seen in (Figure 22). The crane scale will be permanently attached to the overhead crane also when moving the motors from the AL2 final assembly roller conveyor to the two assemblies.

At these two final assembly positions, the only solution was crane scales because there was no extra room for other scale types that could be attached to the floor. As the crane scale will be attached permanently to the overhead crane, it won't affect its use to move other objects because it will fulfil EN 13155 standards. One crane scale is enough for the two assembly positions because they only assemble 10-15 motors a day in the two shifts, so they won't need it at the same time.

5.6.3 Scale solution A for AL2A final assembly

Solution A for the AL2A final assembly could be a roller conveyor load cell. The solution would be to modify the support legs for the conveyor with a pancake compression load cell package under the roller conveyor. This solution won't take up any more space at the production line.

In (Figure 23) below the support legs are marked with red arrows. On the opposite side, there are two at the same position. The supporting legs would be exchanged for pancake compression load cells.

Figure 23. Solution A roller conveyor

Got two different offers for this solution from companies that could fulfil the commercial scale requirement.

The first offer included roller conveyor control measuring, redesign of support legs with loadcells, sizing, and typing. The offer landed on 8100€ but the price did not include a solution for the weight data transformation to the computer.

The second offer for the AL2A final assembly roller conveyor included loadcells, mounting kits, a scale terminal for weight data transfer, and a box for the load cell connections. This offer was in total 10577,20€. Offers did not include VAT or transport.

The scale had to be a commercial scale because it is used for the pricing of transport. When the motor has been driven to the final conveyor part At AL2A final assembly and are completely assembled. The operator pushes a button on a remote control that makes the roller conveyor load cell weigh the motor and send the weighted data to the computer, where it will be handled for further use.

5.6.4 Scale solution B for AL2A Final Assembly

Solution B for the AL2A final assembly would be a crane scale mounted to the overhead crane. Location can be seen in (Figure 22) marked with an arrow and (4.Solution B). The overhead crane would be used by the operators, and they lift the motor from the last roller conveyor part onto the transport pallet as before. But now in the middle of the lift, they weigh the motor by scanning the motor barcode from the manual as in other assembly places.

5.7 Crane scale offers

In this part the best scale will be introduced and what features they offer.

In this chapter two crane scale offers are presented, because the other ones were filtered away because they did not fulfil EN 13155 standards or did not have a solution for wireless connection. VAT and transport outcomes are not included in the offers presented. Both scales are constructed with a tension link load cell and strain gauges to reach top accuracy.

The first crane scale offered is a digital crane scale made in Germany by manufacturer EHP. This scale fulfils the following standard, 13155 which allows the scale to be used when moving the motor or parts with an overhead crane, it also has an easily changed battery, battery time of up to 90 hours, a three-year guarantee on load cells, and scale, and a measuring accuracy of 0,03%.

They also offered a smart automation solution on the wireless connection for the weighed data transformation between scale and computer. When a motor is connected to the scale and in the right weighing position. The solution was to scan the barcode of the motor manual. When scanning, the weight data could be pulled with their device to the computer for future integration in programs.

The scale also had a confirmation feature, so you could get confirmation text sent in to display when weighing data had been pulled to the computer. The operator then knows the data has been sent and the motor can be lifted to transport the pallet.

The price for the crane scale was 2580€, plus the wireless device for data transformation was 1095€, so in total 3675€ for the whole package.

Figure 24 EHP crane scale, (EHP, 2021)

The second offer was a Dini Argeo MCW09. This scale also fulfills the following standard, 13155 which allows the scale to be used when moving the motor or parts. The main features it has are 30 hours of battery time, an exchange battery, a wireless connection solution to the computer, a remote control, and a display. The wireless solution they could offer included a remote control for the data transfer. When the motor is in the weighing position the operator pushes a button on the remote control, which makes the scale send the weight data to the computer. The offer landed on 2650€, lower hook 365€, and process card 425€. In total 3440€.

Figure 25, Dini Argeo MCW09 crane scale, (Dini Argeo, 2024)

5.8 Conclusion

In the end after rating the different scales set to prices and options. The crane scales would be an overall better solution for the assembly locations at the AL2 production line. This is because the roller conveyor load cell can only be used at one location and set to the weighing data solutions it could cause problems and outcomes when the other scales do not use the same systems.

At the other assembly tables, a loadcell solution or floor scales were not possible to use. The load cells or floor scales could easily be damaged when lifting the motor to the table and off, as the overhead cranes are not so smooth. They have a little delay in connection between the remote control and the lift motor in up and down moves. The hits they could take would possibly damage function and accuracy in load cells. The crane scales are not in the way in the factory either when they are connected to overhead cranes and can be used to move objects around set to the EN13155 standard. The motor lift hooks are placed in a centred position already in the beginning of the assembly process, so it won’t make the weighing difficult for the operator.

The roller conveyor load cell offers were 3 times more expensive than the crane scale, and in the price, they did not include the data transformation solution.

The better crane scale manufacturer offers of the two was the German-manufactured scale from EHP. Most of its features were better than the Dini Argeo crane scale and the end price for the whole package. The battery time was an important thing for the production line, as the work is done in two shifts. The battery must last all day and the change of battery can’t be too difficult or take too long. The data transfer solution where also a main point which is why the EHP crane scale was a better option. The EHP crane scale doesn’t require calibration, but the calibration is done after the ISO 9001 standard in the company, see theory Chapter 3.8.

The operator has hooked the motor to the crane scale and it is ready to be weighed. The solution the EHP manufacturer could offer, included the scanner that is already in use at the line, an EHP wireless receiving device that is sold with the scales, and a computer that is already in use at the line. When operators scan the motor bar code from the motor manual, the device reacts and pulls the weight data from crane scale to computer. As it has pulled the weight it confirms it with a confirming light in the scale. From there it can be handled for future use in the SAP system and so on.

5.9 The assembly process with scales

The assembly process with scales doesn’t deviate that much from today’s process. After the motor has been fully assembled at the final locations the operators will connect the crane scale to the motor with a hook, lift it up with the overhead crane and weigh the motor. After that they lift them onto the transport pallets. The difference from today’s process is that the motor-type plate will be mounted to the motor when it has been lifted onto to the transport pallet, before they were mounted at the assembly table or roller conveyor.

In (Figure 26), the change in process can be seen where the weighing process has been added to the first flowchart, see the first flowchart in (Figure 7).

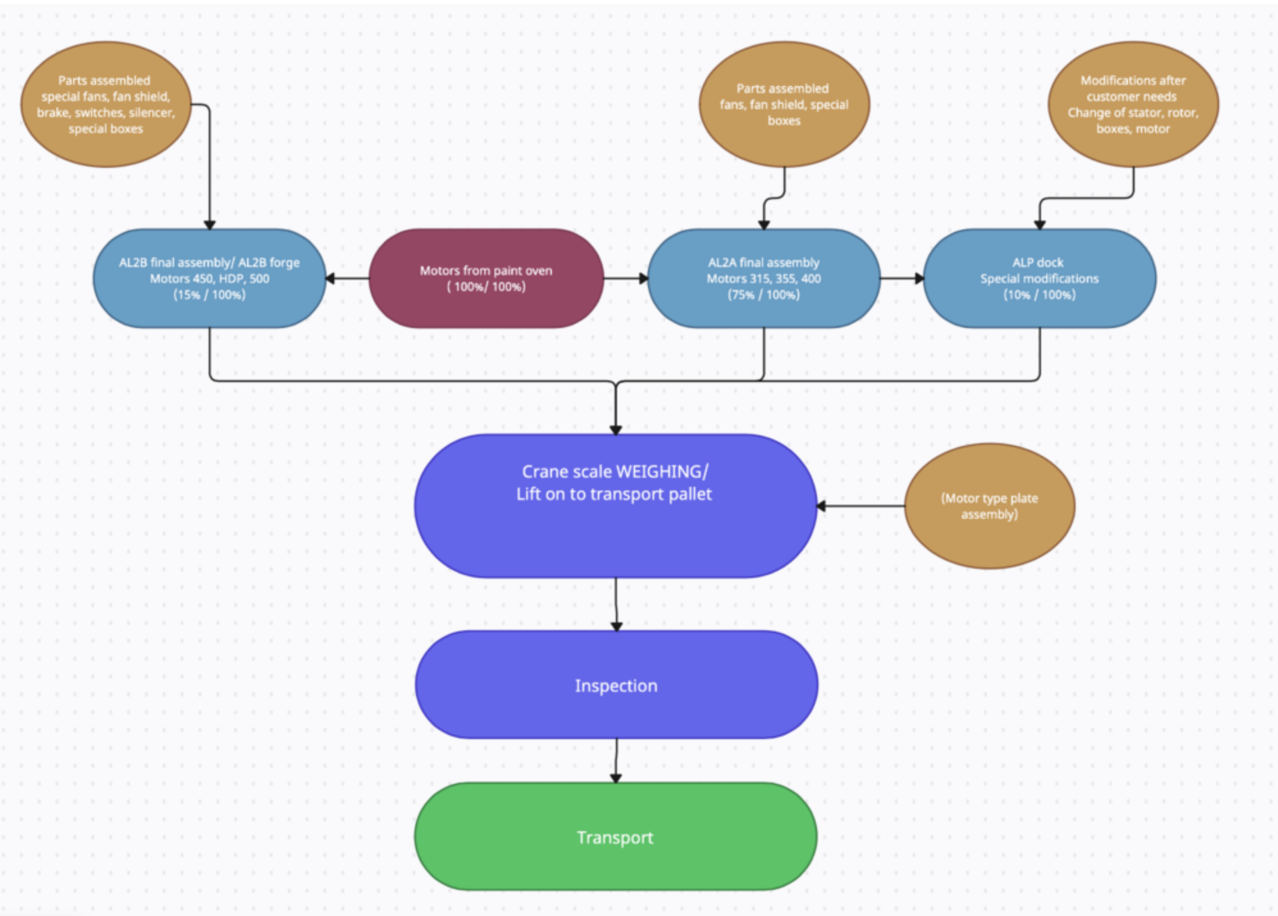

Figure 26, Flow chart for Final assembly process at AL2 with scales

5.10 Recommended future work

During the project, many thoughts came up about future work. The positions of the laser that prints the motor-type plates could be optimized to find the best position for it to save more time for operators picking up the plates.

Another future work could be to investigate if a united mounting location could be used where all the motor-type plates could be mounted. It could possibly save installation time when they don’t have to wait at the production lines for the motor-type plates to be printed and be in the way of line operators assembling the next motor. Also, a backup plan is needed if a technical issue happens at the line and the type plates can’t be printed.

6. Discussion

At the beginning of the work, I underestimated how much research work I should have done to get the work done in the right way. The standard EN 13155 which allows you to move objects with scales came up a little late over me. As I had got 9 crane scale offers from different manufacturers, most of the manufacturers could not fulfil the standard. I then had to filter them away although they had smart wireless solutions for weight data transfer. As the project is still at step one, possibilities to widen the work came up all the time so it was important to put up delimitations.

Under this project, I have learned a lot. Hearing many people's views about the possible solutions has given me new perspectives myself. Another learning is how important it is to do proper research about a product that has to be procured for industry use so it fulfils all standards, and to get offers from different manufacturers because they can have big price differences. Also, the importance of clarity when explaining solutions and ideas to other project participants or production operators so you don't misunderstand and waste time on the wrong thing.

Overall, I am satisfied with the result achieved. I want to thank ABB IEC LV MOTORS for this opportunity to do the final thesis for them. I also want to thank the project team who guided and supported me through the project and the other participants in this project. Specially I want to thank my final thesis guiders Samu Tuomainen from ABB and Leif Backlund from school.

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