SAVONIA

THESIS - **BACHELOR'S DEGREE PROGRAMME**
TECHNOLOGY, COMMUNICATION AND TRANSPORT

DEVELOPING AN E-CIGARETTE TRAY-BASED PRODUCTION SYSTEM DURING A STUDENT EXCHANGE PROGRAM

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SAVONIA UNIVERSITY OF APPLIED SCIENCES | THESIS
Abstract

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Abstract

The subject of the thesis was to develop a design for an e-cigarette tray-based production system during a student exchange program. 13 students from the Technical Department of Windesheim University of Applied Sciences took part in a development project, which was made for TDC Kampen. The thesis was made for the Savonia University of Applied Sciences. The purpose of the thesis was to create a design for a new type of technology and gather thoughts and experiences of doing the project while taking part in a student exchange program.

Windesheim University of Applied Sciences offered a course called Project, which was used for the thesis. The project was done abroad in the Netherlands for a student exchange program. The project started from scratch to only give an idea of a tray-based system for the group of students. In the beginning ideas and solutions were gathered for a couple of weeks which included a guided brainstorm session about the whole production system. The group of 13 students was divided in different areas of the process and this thesis includes a closer view for Quality Control group´s work. The tray-based production system includes multiple products in one tray which goes through the assemby sections. The concept from Festo was used for testing the tray. The product, which was used for tests, contained separated parts. These parts needed to be sorted out and assembled. The Quality Control group made solutions for checking that everything has gone well at each section of the process. Machine vision, resistance checks, weighing and laser sensors were used for controlling the quality of the product.

As a result of this thesis, a combination of each group´s designs with the test results and discussion about working abroad was obtained. Solutions that came up with this project were mostly successful and usable for the process. Because TDC is a machinery provider, options were suggested with the assignment. These options are crucial for TDC, because their customers will decide the investment for building the machine. The results of the project can be used in the future for building a machine. As a result, a discussion about doing the thesis for a student exchange program was obtained, too. Thoughts and experiences could be used for the future students that are willing to write their thesis in the same way.

Keywords
Tray-based, E-cigarette, student exchange, Savonia

CONTENTS

1 INTRODUCTION

The subject of this thesis is creating a design for a tray-based process and gather thoughts of doing the thesis abroad. The product used for the process is e-cigarette. The design was created for ITMGroup, TDC. The project was carried out in the Netherlands and it was provided by Windesheim University of Applied sciences. The exchange program was provided by Erasmus.

This was a new way of doing a thesis for an Electrical Engineering student at Savonia University of Applied Sciences. This could open possibilities for future students to go abroad to find a subject to their thesis.

1.1 Development project abroad

Windesheim offered a course called Project as a part of minor Industrial Automation and Robotics to all its students. The school has partners all over the Netherlands, which offer different kind of projects related to industrial automation and robotics.

Students of the minor had to apply for these offered projects in a group, which included at least one of each major from the Technical Department: Electrical Engineering, Mechanical Engineering and Information and Communications Technology.

1.2 Building a design

ITMGroup was looking for students to create a new type of technology in industry. Running a tray full products through the production sections is the idea of a tray-based system. This makes the production more efficient and faster than a normal production line with one product at the time.

The tray-based system was only an idea for the company at the time when a group of 13 students started working on it. Ideas and innovation is a huge part of creating something new which is not purchasable publicly.

2 ITM GROUP

ITMGroup is a machinery provider for the tobacco industry, located in Kampen in the Netherlands. Figure 3 shows the front door of ITMGroup in Kampen. ITMGroup was found in 1912, when Van der Sluis family started a cigar manufacturing company in Kampen. Over the years the company grew bigger and became a wider tobacco industrial provider. ITMGroup consists of production sites, regional offices and service centers worldwide with total of 700 employees.

Today ITMGroup is divided into different departments: ITM, TDC, SCM, IMAtec, Tricas, Gemba Solutions, Eme-Engel and PMP. These departments include the manufacture of different products of tobacco industry, packing and machinery. Figure 1 shows the logo of ITMGroup. (ITMGroup 2017.)

FIGURE 1: ITMGroup logo (ITMGroup 2017).

2.1 TDC

TDC, Technical Development Corporation is a part of ITMGroup. TDC was found in 1997 and is a machinery supplier for the tobacco industry in the OTP (other tobacco products) segment. TDC's portfolio covers the dosing and packing of roll-your-own, make-your-own and expanded tobacco's into pouches, different type of cans, stand-up bags, special packs and also new, reconditioned and used machinery. Figure 2 shows the logo of TDC. (ITMGroup 2017.)

FIGURE 2: TDC logo (ITMGroup 2017).

FIGURE 3: Front door of the ITMGroup department (Google 2017).

2.2 Innovation Centre

Innovation centre is an area in TDC which is used for working with innovations and the difficulties that can appear to the organizations of the customer. TDC can work on those types of projects together with clients in the Innovation centre. It can start with feasibility studies, the groundwork to understand the specifications of all materials used in the final product and the possible impact it has on current known and available technologies or the need for new yet to discover solutions. Figure 4 represents Innovation centre located in TDC.

The OTP innovation centre brings following operations:

- From concept to final production launch.
- Production site for test market.
- Faster from start to finished project. (ITMGroup 2017.)

FIGURE 4: Presentative image of Innovation centre (ITMGroup 2017).

3 PROJECT

The project was a development work in TDC in Kampen and the main goal was to create a design for a tray-based process line for the company to use in the future. The product used in the testing was an e-cigarette cartridge. The group included 13 students from different areas of Technical Department at Windesheim University of Applied Sciences and engineers from TDC to work with the group. The design had restrictions of its own:

- 250-300 products per minute
- tray-based system

The design was a hand-in assignment for the company.

3.1 Brainstorm

The project started by gathering ideas and solutions for different areas of the process. The process line included four different main subjects:

1. Filling the tray

   Because all the parts of the cartridge come separated, they needed to be sorted out in the wanted way for filling the tray.

2. Assembly

   All the parts needed to be assembled in the way that the product is well assembled at the end.

3. Track and trace

   All the products wanted to be traced even afterwards. Track and trace works ideas of transporting the tray through the process line.

4. Quality control

   Quality control made a check after each part to ensure that each section went well.

In the first week, a controlled brainstorm session was held by a professional brainstorm person. The goal of the brainstorm was to open minds and fade the limitations of the group´s thoughts. Some ideas that came up were even utopian, but it was a part of the exercise. Working on the ideas and solutions was the main subject for few weeks before the groups separated in four different smaller groups of students. These four groups started working on their own area of the main subjects.

3.2 Tray-based production system

The design of the tray-based production system is a new kind of method to run multiple products in a single tray through assembly segments. This technology allows production to get faster compared to the production lines that run one product at the time. The filling of the tray and assembly is done simultaneously with more than one product.

3.3 Product

The product used for testing is the cartridge part of the e-cigarette. The cartridge has curved and round shapes, which makes assembling, inspecting and moving of it difficult. The cartridge contains five parts that were named to make working with them easier:

- shell
- vent seal
- inner frame
- main seal (heat element)
- end cap

The cartridge contains liquid that is filled in one part of the production.

3.4 Design

The design of each group sums the whole design of the tray-based production system. There were various solutions for each section of the process. These solutions make up the whole design, which give options for customer to choose from.

The process has an order to follow:

- Feed the shell to the tray
- Assemble the inner frame with the main seal
- Assemble the inner frame with the vent seal
- Assemble the inner frame to the shell
- Check resistance of the heating element
- Fill the liquid
- Weigh the liquid filled
- Assemble the cap
- Final quality check
- Warehouse

The order of the process became clear after running tests. All the parts are sorted in the way that the assembly with them is possible. Various machines were tested with the product and the successfulness of them was reported. The design got its form from the test results.

The tray is designed to hold 21 products with a shape of 3x7 as Figure 5 shows. The shapes of the holes are made for e-cigarette cartridge that was used for testing.

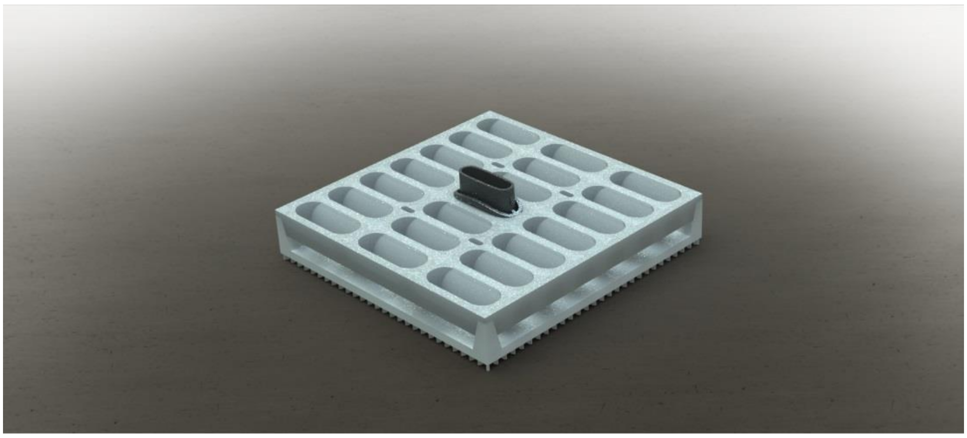

FIGURE 5: Model of the tray and one mouth piece in the middle of it (ITMGroup 2017).

The tray is transported with the Festo 2D move concept. 2D move allows the tray to move from one platform to another. 2D move was tested with the tray at a slow slow speed and worked fine. 2D move allows to track individual trays with a sensor installation.

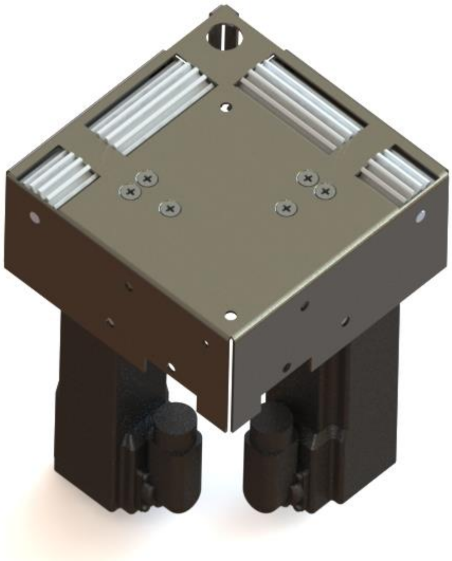

FIGURE 6: Festo 2D-move with motors underneath (Festo 2017).

Because the process is meant to be fully automated, robots are used for filling the trays and assembling the products. Festo Gantry 2D robot was tested with assembly of the product which achieved succesful results. The speed of the gantry robot is enough to assemble the demanded amount of products. The assembly can be done with the robot that figure 7 shows.

FIGURE 7: Festo 2D Gantry robot (Festo 2017).

The pick and place robot is successful solution for filling the tray. The used pick and place robot was provided by Fanuc, which is shown in figure 9. The speed needed for the process is not enough with one Fanuc -robot but installing multiple pick and place robots will fix the gap.

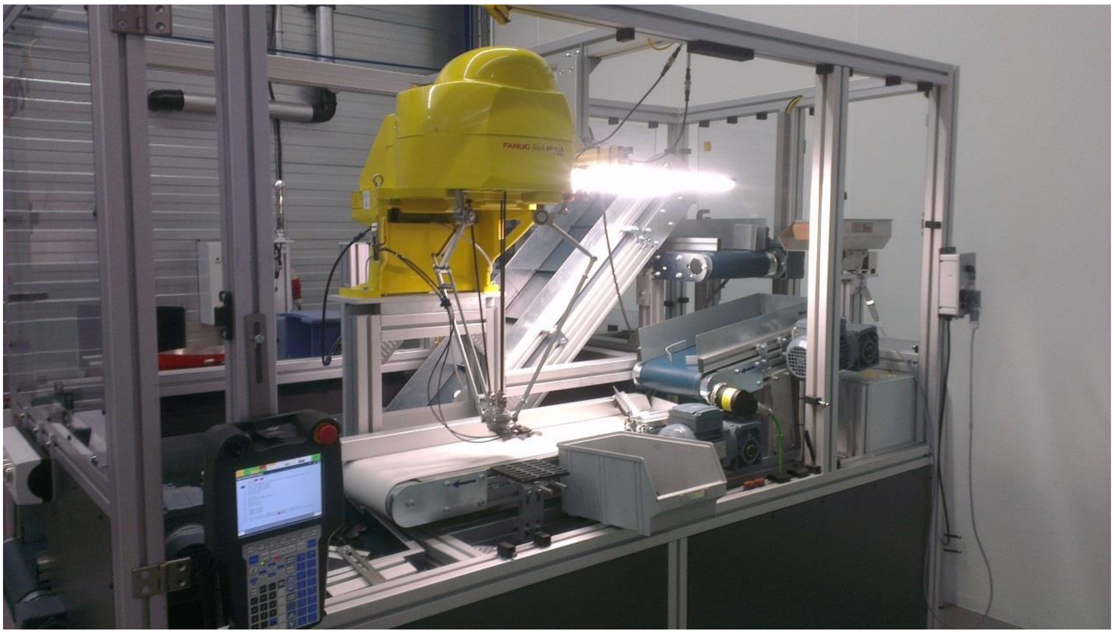

FIGURE 8: Fanuc pick-and-place robot setup with conveyor loop (ITMGroup 2017).

Omron Lynx is a self-tracking robot that can be set to do paths or jobs. The Omron Lynx could be used at warehousing. The Omron Lynx is compact and modern looking robot that is presented in figure 9.

FIGURE 9: Omron Adept Lynx robot (Adept 2017).

The bowl feeder works with resonance. Parts are dropped in the bowl and the motor starts to vibrate with the set frequency. This makes the parts move by the sides of the bowl. By building obstacles to the sides of the bowl, the orientation is done at the same time as feeding. The bowl feeder is separated from the process line as Figure 10 shows.

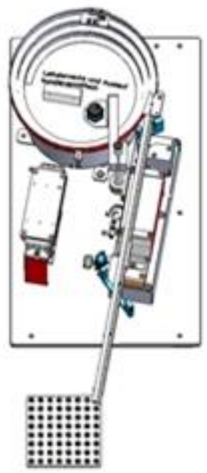

FIGURE 10: Bowl feeder model (ITMGroup 2017).

These are some solutions that were tested and part of the design. Each group worked with their own ideas and main subjects, so these solutions were tested in various ways.

3.5 Quality control

Minimum standards of quality were required from quality control. Quality control group's task is to find solutions for each necessary inspection and to generate deliverable information for product traceability. TDC made research questions for each group and for quality control those questions were:

- What possible solutions are available to weigh every product?
- How can we do a vision inspection on all products in a tray?
- Track and trace, how is this database adjusted after every quality check?
- How do we perform simple checks on the products with sensors? Do we use multiple or just one sensor?

Quality could be checked after every single step in the process, but it is time consuming and expensive. The group must decide in which section to make inspections. Areas are detailed below:

- Filling trays

  To inspect infeed parts, the customer can decide the level of inspection and critical features.
  Tray inspection guarantees the full amount and position of parts.

- Assembly

  Define correct assemble position in the tray
  Weigh without liquid
  Check resistance of heat element

- Weigh with liquid and compare it to determine liquid level

  Integrity inspection in order to reach quality requirements of the customer and guarantee that only good products go to storage.

- Rejection

  Withdraw damaged or failed parts and products from the tray.

(Autio, Medeiros and Keizer 2017, 2-3.)

3.5.1 Solutions

Machine vision system is a way to make the quality inspection for each product in a tray. The main problem is to find angles of view to see wanted objectives. Because of materials of the cartridge, lights of different wavelength needed to be tested for detecting insides of cartridge. Camera with different lenses are part of the machine vision system. The system is ran with special computer built for machine vision systems. Used lights for detecting the product are infrared light with different wavelengths, red light and flat diffuse light. (Autio etc. 2017, 4-7.)

Weighing unit was made for each individual product to be weighed. The weighing unit contains loadcell with accurate and precise enough to work with few grams in total and a mount for the product. Weighing is done with PLC (Autio etc. 2017, 7).

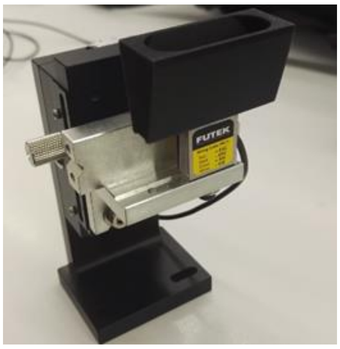

FIGURE 11: Weighing unit without product (Autio etc. 2017).

Resistance inspection makes sure that the heating element, which contains a coil, has a demanded resistance. Inspection of it is done with connection pins with a springs and the measurement is done with PLC. (Autio etc. 2017, 7-8.)

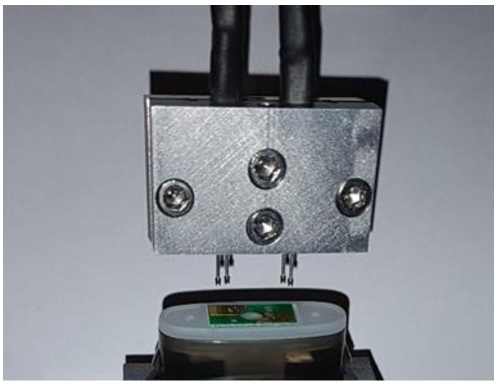

FIGURE 12: Connection block with 4 pins, where connection is made with metal sections of the electrical part (Autio etc. 2017).

Laser sensor inspection is performed because of silicone parts of the product (vent seal and main seal). A distance laser sensor is used for this solution. The inspection shows whether the laser sensor can detect the silicone parts or not. (Autio etc. 2017, 9.)

FIGURE 13: Laser sensor pointed on top of main seal (Autio etc. 2017).

3.5.2 Setup

The setup was built for the machine vision system. The other inspections were tested at the same area. The test bench contains an Omron machine vision system, PC, conveyor belt with frequency changers, mechanical structure for adjusting angle of the camera and a rack for Beckhoff PLC and terminals. (Autio etc. 2017, 4.)

Field of view can be affected by adjusting the height and angle of the camera. Different kind of lights can be set under white platform to make different results with machine vision (Autio etc. 2017, 4, Figure 6). The tray can be set to run on conveyor belt by frequency converter either front or back and height of the led lights can be adjusted. Camera is mounted in the middle of the led lights and the height is affecting to field of view (Autio etc. 2017, 4, Figure 5).

3.5.3 Test results

Machine Vision System inspections are separated in two categories: a tray inspection with products and a single product inspection.

The inspection for a full tray is performed with a diffuse light system, which is presented in figure 18. This inspection makes it possible to inspect every product in the tray. The inspection allows to measure each object individually and do different kind of inspections for them. Inspections are detailed below:

- Missing a product in the tray
- Inspect the inner frame in the shell
- Inspect main seal in the shell
- Count products in the tray
- Provide information on the position of Good and Not Good products

With FZ Panda software a tray inspection including products can be set to show missing products, amount of products, well assembled products and failed products (Autio etc. 2017, 10).

The infrared backlight system was used with a single product inspection. By placing the infrared light under the cartridge, it gives an option to inspect the insides of it. Following inspections were done for the product:

- Inspect if the product is leaking
- Inspect the position of the inner frame in the shell
- Inspect if there is a vent seal in the shell
- Inspect if there is an endcap on the product

(Autio etc. 2017, 10.)

The weighing unit had to be tested for accuracy. The measurement was done with 10 different products and the 11. measurement was done with the first product. Test shows that accuracy of the load cell is good and stable enough. Because of demanded speed of 250-300 products per minute, the measurement time had to be tested. Figure 15. shows that it takes approximately one second to get steady and this is fast enough for production line. (Autio etc. 2017,11.)

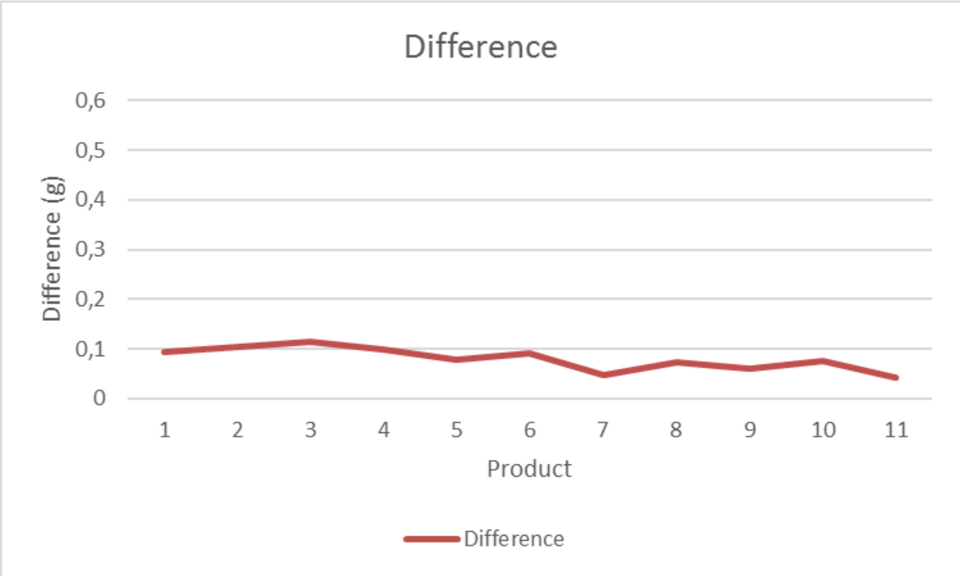

FIGURE 14: The measurement difference between the weighing unit and a precision scale (Autio etc. 2017).

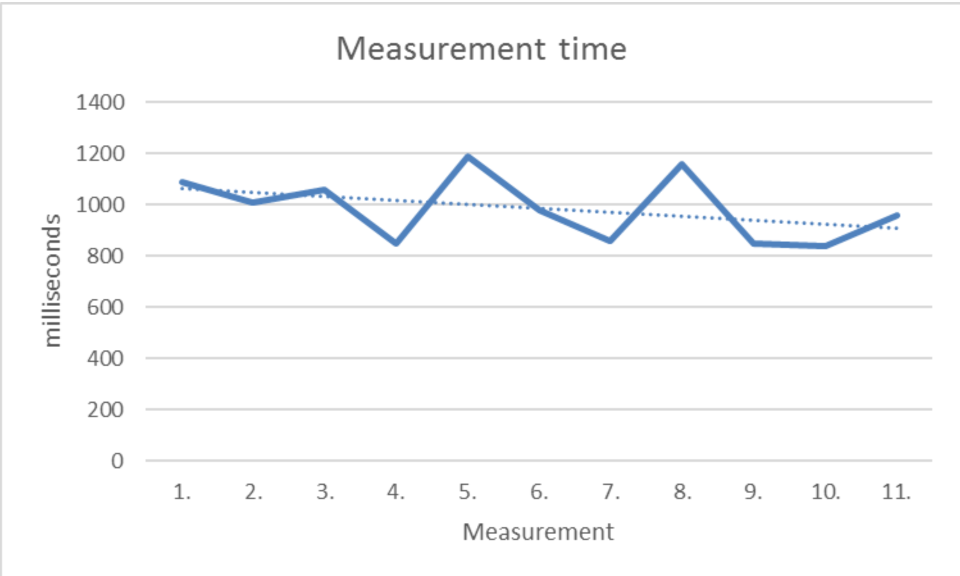

FIGURE 15: Time taken for weighing (Autio etc. 2017).

The resistance check can be done with different methods. The tests were done with each method. Methods are detailed below:

- 2-wire method
- 4-wire method with 2 pins
- 4-wire method with 4 pins

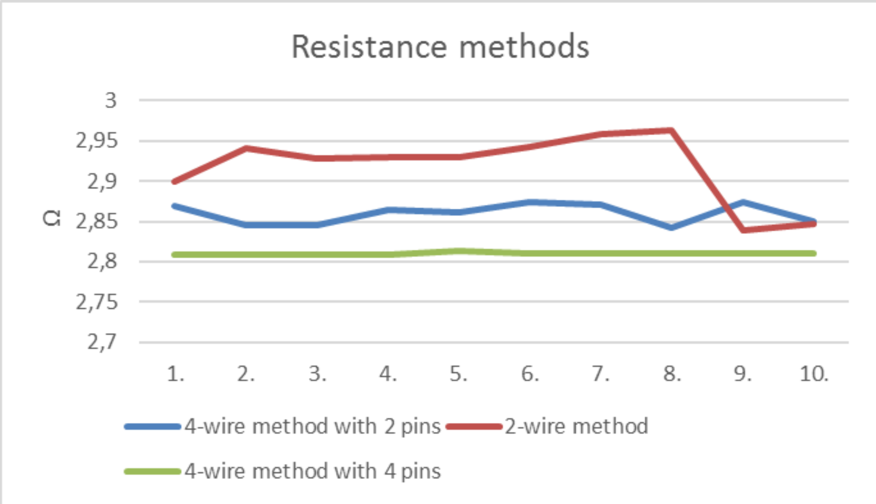

FIGURE 16: Measurements with 10 different products by each method (Autio etc. 2017).

The accuracy of each method can be calculated. The standard deviation shows the average dispersion of the measurement compared to the average value. This can be calculated with the formula:

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

TABLE 1: Table of resistances, difference from average and range of all methods (Autio etc. 2017).

Measurement	R_4	$(x_i - \bar{x})^2$	R_5	$(x_i - \bar{x})^2$	R_6	$(x_i - \bar{x})^2$
1.	2,899969	0,000314	2,869655	0,000101	2,808528	0,000002
2.	2,941096	0,000548	2,845577	0,000194	2,808646	0,000002
3.	2,927911	0,000105	2,845984	0,000183	2,808717	0,000001
4.	2,929056	0,000130	2,86381	0,000018	2,80898	0,000001
5.	2,929127	0,000131	2,860565	0,000001	2,813942	0,000016
6.	2,942717	0,000626	2,873245	0,000188	2,809595	0
7.	2,958143	0,001637	2,870506	0,000121	2,80977	0
8.	2,962828	0,002038	2,842041	0,000305	2,81	0
9.	2,838516	0,006268	2,87378	0,000203	2,810173	0
10.	2,847517	0,004924	2,849993	0,000091	2,810878	0,000001
Average	2,917688	-	2,8595156	-	2,8099229	-
Sum	-	0,016721	-	0,001405	-	0,000023
Range ($R_{MAX} - R_{MIN}$)	0,124312	-	0,028203	-	0,005414	-

Using sums to calculate standard deviation:

$\sigma_{R4} = \sqrt{\frac{1}{10} * 0,016721} = 0,040891\ \Omega$ // 2-wire method

$\sigma_{R5} = \sqrt{\frac{1}{10} * 0,001405} = 0,011853\ \Omega$ // 4-wire method with 2 pins

$\sigma_{R6} = \sqrt{\frac{1}{10} * 0,000023} = 0,001517\ \Omega$ // 4-wire method with 4 pins

Standard deviation shows the accuracy of each method. The most accurate method to measure resistance of this product is by using 4-wire method with 4 pins. This can be determined from standard deviation and range. Most inaccurate method is 2-wire. 2-wire method is usually used on higher values of resistance and it is not so useful in this measurement. (Autio etc. 2017, 12-16.)

Laser sensor inspection was used for two measurements: product in the tray while moving on conveyor belt and test successfully assembled and failed products

The laser could detect product in moving tray by using a main seal as a target. The direction of the movement did not affect to the result. Nevertheless, the laser could not make accurate measurement from shapes of the tray, while moving on the conveyor belt. (Autio etc. 2017, 17.)

4 DISCUSSION

4.1 Development from zero

The subject of building a design for a tray-based process felt bit odd at first and it was difficult to approach. Creating something new from a scratch was the main idea of the project. A group of technical department students from Windesheim sat in the Innovation Centre and they were given a job to use their imagination and write down everything that came up to their minds. These ideas were taken into inspection and some of them were picked up to the testbench. Ability to work with the latest automation technology was helping a lot the throught the process.

Building up the test setups was a step forward to work with the ideas. Working with smaller groups combining mechanical engineering, electrical engineering and IT, made the group share the information and knowledge with each other. Everyone learned something new, like handwork, programming and also the innovation was always part of the job. The research questions was main goal to keep in mind while building up a test setup.

The quality control group came up with solutions to weight each individual product, to make a vision inspection to all products in the tray, came up with ideas on how to adjust the database after each quality check and tested different kind of sensors with the product and parts of it. Other groups also answered their questions and this made the design for the process line that was requested.

For quality control the biggest impact for the design was vision inspectation. Machine vision is not the cheapest solution, but it is capable of doing the quality check for most parts of the assembling. Mechanical solutions are not so easy to do, but they could make the process simpler and more cost efficient.

The process can be divided in to four different areas from aspect of quality control: filling trays, assembly, weighing the amount of liquid filled and rejection

These areas had to be taken apart and find solutions for each part. The e-cigarette contained difficult parts and fillings to work with. Materials were plastic, silicone, electrical parts and liquid. The solutions that quality control group came up with detecting each individual part of the cartridge was the hardest part of the development. The tested solutions were functional with the product, in which makes assignment successful.

Quality control is a part of a manufacturing process in which manufacturer should take a closer look. It is a huge investment to be made in the process, but it also plays a huge role on the brand. If the quality fails while manufacturing the product, the brand could became wounded. End-customer will avoid products with bad quality.

The tray-based system could be emerging way of building process lines in the future. It is still a new concept-like technology, which could make industry more efficient speed- and costwise. By the time trays can become much bigger and could be used in heavier industries. Tray-based system faces the problems with doing same job or moving every product simultaneously with robot or other automation device.

Because TDC is a machinery provider and not the manufacturer, it is important to give options for the customer. Low-cost machinery probably cannot produce with the expected speed or guaranteed quality. It always depends on the manufacturers' requirements on, which type of machinery is required.

The created design is modifiable for different products also. That gives TDC an option to use tray-based system in many different ways too, for example in different machinery. Therefore this assignment was complited with required terms.

4.2 Thesis out of exchange program

The idea of doing the thesis abroad became when I was told that it is possible to take part in an exchange program. Few conversations with my teacher led to the point that I was looking for offered programs from another universities abroad. My exchange coordinator told me that University of Applied Sciences Windesheim in Zwolle, Netherlands had a course called Project, size of enough ETC to adapt my thesis on it. Windesheim and Savonia are members of the Erasmus program, which made the exchange much easier. Erasmus as well as Kela supports students, which makes the departure easy.

The exchange program started and it contained a minor called IAR (Industrial Automation and Robotics). IAR was about the same as the degree in Savonia, so it was not so hard to get into it. While taking courses in Windesheim, I had to seek for the workplacement for Project course. Teachers of Windesheim reminded the student from the beginning of the exchange program to seek for a workplace. It was organized well by the Windesheim teachers.

By the start of the project, I kept in mind that I am doing my thesis from it otherwise than my colleagues. For my colleagues that project was only a course to finish. I wrote down everything that we did and discovered. By the end of the project it was also easy to combine all the work in one file, which worked as an assignment for the company.

Working abroad was a new thing for me. Daily morning traffic and using English all the time were kind of a shock first. Using English daily had a huge impact on my English skills. When you are forced to use English in every situation, you slowly start to think with that language and it makes learning much faster and easier. My special terminology grew a lot and it will be useful in the future as well as in Finnish companies.

Cultural differences made me to question my working methods and routines, but I think it was mindopening experience. Netherlands considered as welfare state still has similar industrial working methods as in Finland. Dutch people like to have a cup of coffee here and there and I found it cosy.

Students from all over the world took a part in IAR. In TDC there were students from Brazil and Spain besides me and of course Dutch. This factor brought different ways of thinking in our group and it made the working comfortable. We shared experiences of our home countries and those opened my mind on other cultures.

Doing the work for thesis abroad is not different than doing it in Finnish company. It is just workplacement, which is in other country and you have to use other than your mother-language. By doing the work during the exchange program is the main thing. You get experience of your life by taking a part in exchange program, meet people around the world and the most important factor, you get working experience abroad. Nowadays when globalization is growing effect at industry, it is important to get working experience abroad, if you are willing to work outside of Finland.

The help from Savonia and its teachers made the exchange easy. By doing the thesis from another school's course was bit harder and I had to be independed. Basicly I did the same process abroad as my colleagues in Finland. Hopefully in the future for future students there will be more this kind of possibilities. From my experiences this will give a seed for more open way of co-operation between universities around the world. Savonia could make more coordinated and specified exchange program for future students, that are looking for subjects of a thesis. Exchange program could be designed only for doing thesis in another university. This could give information and knowledge for staff of Savonia.

5 SUMMARY

The goal of the thesis was to create a design for an e-cigarette tray-based production system by concept ideas and test results, which could be used in the future within construction of production machines. The group of 13 students were divided in four different areas of the process to create solutions and the thesis contains closer view for quality control. Quality control had to take a look for weighing, resistance check, quality of the parts and assembly of the products. With testing the resistance check and weighing solutions were built up for enough of speed and precision. Checking bad quality parts and making inspection after each assembly step has multiple solutions. Each part could be done with a machine vision system. Test results of the machine vision system shows that with proper lights and angles it is possible to check all wanted issues with the product. Because the machine vision system is expensive, quality control group had to find cheaper solutions for some of the inspections. Mechanical solutions could be used, which are cheaper. As a result, all four groups combined their solutions and test results into one hand-in assignment. This assignment is being used for future constructions of production lines. Tray-based production is a new kind of technology, which makes production faster and therefore more costefficient.

The thesis includes thoughts and experiences of doing the work of thesis abroad too, which could be helpful for future students who are willing to do thesis the same way. The knowledge of doing thesis during a student exchange program, which was a new way of doing it, could help the future students that are interested on going abroad. The thesis could improve universities relations and create more coordinated system for studies in another country. Experiences and way of looking the world expands by working with people from another cultures.

The thesis improved my knowledge with electronics and the latest automation technology. Vocabulary of mine have vastly expanded. By doing the thesis abroad opens the mind and I have learned about cultural differences.

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