Development of an automated system for assembling cold pressed segments – industrial application of a degree project

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Abstract—In this paper a successful final project work, done at Linnaeus University (LNU), is presented as a result of cooperation between the company and the students group, which will find its industrial application in making the production process of the company more efficient.

In the presented paper the emphasis is on the process followed during the design project and on the continuous and fruitful cooperation between the company providing the project, the student’s design team and the University itself.

Keywords: design methodology, engineering education, industrial projects, industrial application.

I. Introduction

In Sweden as a whole and in LNU particularly is a tradition that product development courses and degree theses are based on industrial projects, where students work in groups. This good practice gives to the student the opportunity to work in real projects, to accumulate experience of working in real industrial environment and brings benefits not only to the company providing the project work but also adds value to the quality of education.

This paper will present an example of successful cooperation between the higher education and the industry. In this case the two students in mechanical engineering at Linnaeus University carried out a degree project, together with Husqvarna Construction Products Sweden AB. The final thesis was done by Johan Kooiker (exchange student from Windesheim University, Netherland) and Kashira Roil Beto (program student from Linnaeus University), supervised by Valentina Haralanova and examined by Samir Khoshaba during the spring term 2014.

The topic of the degree project was “product development” and the task was to develop an automated system for assembling cold pressed segments.

Nowadays, Husqvarna assembles cold pressed segments manually, where the cold pressed segments are made of metal powder and synthetic diamond. The segments are brittle and can easily crack therefore the segments are assembled into a frame manually by an operator. Husqvarna want to develop a system that can assemble the cold pressed segments into the frame without breaking the segments.

The project began with studying the current situation to get a clearer picture of the problem and finding out the requirements for the system. The requirements were studied, translated and implanted in the behaviour description of the system. Later on, ideas and concepts were generated, which through rating and screening led to the final concept.

II. Theory and application in the degree project

For defining the problem and the project the project group started with studying the current situation.

As shown in Fig.1 the manufacturing process starts with pressing metal powder with synthetic diamonds into segments; all the segments are stored in boxes for; the next step is to assemble all the segments and the graphite parts. An operator does the assembling handleings manually.

Husqvarna Construction Products want to automate the assembling process. By automating this process the

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Fig. 1. Manual assembly of the segments
efficiency will increase and this will lead to lower costs for every produced segment. Placing the graphite and isolation plates are not included in the automating process, neither is the aluminium frame. The problem is that it takes too long time to assemble all the segments. When all these handlings can be automated the operator’s work can be much more efficient.

There are around 20 shapes and 300 different dimensions; every shape has a unique assembly process. Table 1 shows the shape variations of the different segments, graphite and metal parts.

<table>
<thead>
<tr>
<th>Segments</th>
<th>Graphite parts/metal parts</th>
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<tr>
<td><img src="image" alt="Image of segments and graphite parts" /></td>
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</table>

TABLE 1. Shape variations of segments, graphite and metal parts

After clarifying the problem and for to provide clear guidance for the product development, the team formulated the target and the assumptions under which the design group will operate. The mission statement is “to automate the assembling process of the segment production for Husqvarna Construction Products”.

The biggest challenge in industrial projects like this is to satisfy both the company and the university. The company is interested in the results and the university is interested in application of the theory and the structure of the project. The structure of the project is determined by the process of product design. In this case the students and the company selected the most applicable steps of product development process. (Fig. 2)

The process was based on the knowledge from the course Product development. One of the most used reference was the textbook Getting design right: a system approach, by Peter L. Jackson. [3] Except that students studied also Systems engineering technique by Karas and Rhodes; Kvalitet från behov till användning by Bergman; Produktutveckling by Johannsson et al.; Primärkonstruktion by Olsson.

The results of the concept generation were 5 alternative concepts. The comparison between the concepts is an assumption based on the project groups experience together with Husqvarna. The “decision-matrix method” also called “Pugh’s method” was used to select the most promising concept. In the first screening each one of the alternative concepts were weighted against the main product objectives (Table. 2). In the second scoring step the weights of the product objectives were taken in consideration. The weights of the attributes were defined already in the second step of the process.

<table>
<thead>
<tr>
<th>Attribute name</th>
<th>Robot with flexible gripper</th>
<th>Robot with robotic arm</th>
<th>Manual handling</th>
<th>Mechanical reliability</th>
<th>Reliability</th>
<th>Handling</th>
<th>Flexibility</th>
<th>Capacity</th>
<th>Durability</th>
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TABLE 2. Performing an initial screening of alternatives

After the second step of scoring the concepts the first concept, called “Robot with flexible gripper” was selected as the winning one (Fig 3).

At this point, all information is collected to begin the embodiment design of the system. The next step of the process is “developing the architecture”. Here a system view of the product is taken, it’s broken into its subsystems, and developed thorough understanding of how each subsystem works with the other subsystems within the context of the system to achieve the desired behaviour of the overall system. The goal is to describe each subsystem with sufficient clarity that detailed design work can precede in each subsystem independently of the design work on other subsystems.
In this step the method presented by Olsson [4] is used, where the components are divided into “standard components” and “unique components” (Fig. 4). Standard components are products/parts that already exist and are available on the market. Unique components are custom built parts that don’t exist on the market. Both the standard and the unique components are split up into subcategories, “routine” and “special treatment”. Routine selected standard components are well proven product parts and their function is well known. Selecting a part by routine will decrease the engineering time and cost. Standard components can go through special treatment, which helps the engineer to find the ultimate product part that fits in the system.

The project group did not have any working experience and the system is custom built therefore the selection or design of the subsystems went more through the special treatment and less through routine. The product summary includes 3D CAD-models, technical component specification and detailed descriptions of the subsystems.

The robot was set as a standard component because there are already existing and well-proven robots. The robot went through the special treatment process and was not selected by routine because it has to fulfil specific requirements. The material supply and the gripper are unique components, they may not be found on the market that is why they were not designed by routine because there was lack of knowledge about them. By following the special treatment process for the unique components, other solutions could be found on the market or this may provide useful information for further design. The frame and the table were designed by routine because their functions are simple and well known.

After detailed behavioural description of subsystems the derived requirements for each one of them were defined and the systems were developed.

A. Robot
The robot was considered as a standard component and as it was mentioned the robot went through the special treatment process. After defining the derived requirements for the robot a benchmark analysis on the existing available robots were performed. The “Universal Robots” model UR-5 was selected, because it was the only robot that doesn’t need a safety screen around it, and it’s the only robot that fulfils the safety requirements.

B. Gripper
The vacuum gripper was designed. The gripper consist of several parts, some of them were selected and some - designed. Figure 5 shows a principle sketch of what the gripper looks like and it identifies the different parts.
requirements therefore some compromises were made. The crown shaped segments have the smallest surface to pick the segments. Based on this segment the maximum vacuum cup diameter should be 5mm. Some assumptions about the material of the vacuum cups were also made.

The maximum amount of assembled parts in one time is 5, therefore the gripper consists of 5 blocks. The middle block is fixed on the robot. The function of the blocks is to hold the vacuum cups and to open/close. In the opened condition, the gripper will pick the material parts and in the closed condition, the gripper will move the material parts together. Figure 6 illustrates the opening and closing mechanism.

The mounting blocks for vacuum cups are connected together with levers, therefore the parts are moving simultaneously. The vacuum cups are adjustable for different shapes of segments. The levers are fixed in the middle of the block to prevent the blocks from self-locking.

The mechanism can be driven by different kinds of devices, pneumatic rotating cylinder or pneumatic horizontal cylinder or electrical motor. A rotating pneumatic cylinder was selected because of its simplicity and because it makes the gripper robust compared to the other two devices.

3D CAD-models, technical component specification were made (Fig. 7).

C. Material Supply Device

A material supply was designed and while the focus was on its simplicity. The main functional requirements to the material supply are to: hold, secure and detect that the material is in proper position because of the shape. It distributes and supplies the materials to the gripping position because of the slope. The graphite parts can also be sticky (from the voice of the customer). Therefore in the design of the material supply (Fig. 8) the red bar on the right side is added for the separation of the graphite parts. On the two sides of the bar, slot holes are added to make the separation gap adjustable for different thicknesses. The other two red bars have big slot holes for adjusting the side plates for the needed width of the segments and graphite.

D. Frame and table

Husqvarna construction already has working frames, which are made from welded steel parts and they are not standardized. The scope was not on designing a new frame with new functions. There was a routine design. The new frame looks like the current frame the only differences is that all the frames have same dimensions what increases the simplicity and reliability. Figure 9 shows how the frame will look like. The yellow base plate is the standard design for all the assemblies. The blue support on the right side holds the green plate in place with the pins on the downside of the support, the support is removable.
A table is needed for the system, on which all the subsystems will be placed. A table with high load capacity is required. Husqvarna Construction Products already have industrial tables that can handle high loads therefore a routine selection will be made because of the well-known properties.

Before building the prototype for validating the design some critical requirements should be verified. Two requirements were to be verified “supply the material in proper position” and “grip the segments without breaking them” by building a simple scaled model. Both the vacuum gripper and the material supply were made from wood, because it’s the easiest and fastest way to build and test it (Fig.10)

The model for the experiment was loaded manually and the material was supplied to the proper position by a slope, where the material slides and stops in front of the picking position, then the vacuum gripper grips the material and lifts it up, the bar that is mounted on top of the side walls is to avoid picking two pieces at the same time.

The experiment proved that air leakage in vacuum cups can be ignored if the air pressure is high enough. The model of the material supply shows that the slope angle is critical for the best result. A large angle provides high sliding capacity but it damages the segments when the gripper lifts the front segment. The segment behind, slides with high speed and hits the front wall with high force. An angle between 18 – 22 degrees provides the best result, depending on which material is used for the material supply.

The tests have been successful, both the vacuum gripper and material supply fulfil the requirements. The validation of the main requirements have a big impact on further development of the system because it was proven that the vacuum gripper doesn’t destroy the segment and that the material is supplied in the easiest way, by a slope. The reliability of the two main subsystems is really high and Husqvarna Construction Products decided to invest in more advanced prototypes.

III. Conclusions

The relation between students and Project Company should be very close and continuous during the project time, so that each decision step will be taken with active contribution from the customer.

In this case it was really fruitful cooperation between the Student project group from LNU and Husqvarna Construction Products. It leaded not only to successful final project, which proposed a conceptual design for solving a problem for the company. But Husqvarna Construction Products developed this concept in further.

After an iterating design step performed by the company’s designers and some simplifying of the proposed concept an investment for a real prototype was decided.

The vacuum gripper was build and the proposed robot in the project was borrowed from a supplier for a period to perform tests (Fig. 11)

In the further tests some issues will be taken in consideration. Some recommendations about this are made in the project report as well.

The experiment model of the material supply was built in wood. The slope angle depends on the friction of the material that is used for the material supply. The best result for wood is an angle between 18 – 22 degrees. A big angle with low friction can damage the segments and a small angle makes the segments tilt instead of sliding.

The gripping force from the testing of the prototype is generated by a vacuum cleaner. A vacuum cleaner has a high air flow and low vacuum resistance. If the air pressure is low and the vacuum resistance is high then air leak can be critical.
The final result from the project was satisfying for the company. According the expectations of the university and the requirements to a final thesis there are some steps to be added and some of them could be applied in a better way, but it was appraised like a very good project team work.

References


[2] Kooiker J. and Roil Beto K. An automated system for assembling cold pressed segments – Degree project, Linnaeus University, 2014...
