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Optimization of the design and production process of stainless steel throughs

MASTER'S THESIS

to achieve the university degree of

Master of Science

Master's degree programme: Production Science and Management

submitted to

Graz University of Technology

Supervisor

Univ.-Prof. Dipl.-Ing. Dr. techn. Franz Haas

Institute of Production Engineering

Graz, 13th December 2019

AFFIDAVIT

I declare that I have authored this thesis independently, that I have not used other than the declared sources/resources, and that I have explicitly indicated all material which has been quoted either literally or by content from the sources used. The text document uploaded to TUGRAZonline is identical to the present master's thesis.

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Date

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Abbreviations

AC/DC: Alternating current/direct current
AGV: Automated guided vehicle
AISI: American Iron and Steel Institute
BOWA: Bodewanne - Floor tub
CO2: Carbon dioxide
DIN: The German Institute for Standardization
EWE: European Welding Engineer
IEC: International electrotechnical commission
ISO: International Standards Organization
KORA: Kombirinne - Combination channel
RVM: Randverstärkung Vollmaterial - Edge reinforcement solid material
Spa: Sanitarrinne - Sanitary channel
SRSA: Schlitzrinne - Slot channel
TTO: Tvornica Tehnoloske Opreme - Factory of technological equipment

Abstract

One of the main goals for every engineer is to find a proper solution that accomplishes a goal, not only based on the functionality of the product, but also to fit to the economic aspect of the organization.

In the cooperation with two companies, company ASCHL from Austria and company TTO from Bosnia and Herzegovina, the manufacturing opportunities for the production process of specified parts of a water drainage system had been observed, analyzed and evaluated. Improvement possibilities, not only regarding the production phases, but also based on customers' requirements and objectives on the design of the product and the behavior in the exploitation had been explained and evaluated and the final solution according to VDI 2222 had been made.

Although the results are the improvement indicators, the final contribution of this thesis should not only be them, but also the understanding and the knowledge about the manufacturing processes, it's important parameters, the process of search for possible improvement points, the analysis of the problems and the evaluation of explained results.

Abstrakt

Eines der Hauptziele für jeden Ingenieur ist es, eine richtige Lösung zu finden, die ein Ziel erreicht, nicht nur basierend auf der Funktionalität des Produkts, sondern auch passend zum wirtschaftlichen Aspekt des Unternehmens.

In Zusammenarbeit mit zwei Unternehmen, der Firma ASCHL aus Österreich und der Firma TTO aus Bosnien und Herzegowina, wurden die Fertigungsmöglichkeiten für den Produktionsprozess bestimmter Teile eines Wasserableitungssystems beobachtet, analysiert und bewertet. Verbesserungsmöglichkeiten, nicht nur in Bezug auf die Produktionsphasen, sondern auch basierend auf den Anforderungen und Zielen der Kunden an die Gestaltung des Produkts und das Verhalten bei der Nutzung, wurden erläutert und bewertet und die endgültige Lösung nach VDI 2222 erarbeitet.

Obwohl die Ergebnisse die Verbesserungsindikatoren liefern, sollte der endgültige Beitrag dieser Arbeit auch das Verständnis und das Wissen über die Herstellungsprozesse, seine wichtigen Parameter sowie den Prozess der Suche nach möglichen Verbesserungen Punkte, die Analyse der Probleme und die Bewertung der erklärten Ergebnisse beinhalten.

Table of Contents

Introduction

Introduction and motivation

Creative thinking in solution finding process is one of many tasks which an engineer should obtain. Designing product, realizing the sequence of the production flow, preparing needed documentation together with all of the drawings for a production and control are some of the main task which a production engineer should do on the daily basis.
This thesis should give a production overview of specified parts of a water drainage system and optimization of the parts and/or production processes.
Main goal of the thesis is not only to give a detailed *tour around the production* but also to solve problems in production or in exploitation and to reduce production costs while maintaining enviable quality.
Thesis is done within two companies located in Austria and Bosnia and Herzegovina.
Production is done in the company in the Bosnia and Herzegovina.

Thesis structure

Apart of the introduction and conclusion part, this thesis consists of chapters which represent:

- the overview of the companies within which the thesis is done,
- production processes in the companies with the corresponding documentation,
- the optimization of manufacturing processes and/or design of the products
- conclusion and explanation weather and why optimization had been obtained.

For an easier overview, the chapters will cover one product at a time.
Main reason for this approach is because each product has its own problematic parts and there is no *one fits all* solution. Another reason for this approach is because of the clearer flow of the information, introduction and explanation of products, manufacturing phases, problems which occurred in exploitation and/or in production followed by proper solution. This gives a better overview of products before and after the optimization with a possibility to rate the optimization and give a final decision on if the change is approved and why.

Every chapter will consist of:

- Theoretical framework

Covers introduction and brief explanation of the with drawings and pictures in the exploitation.

- Manufacturing

Overview of all manufacturing process with all phases and needed documentation.
Theoretical explanation of a different manufacturing methods and calculation which method provides the best end-result.
Preparation of the drawings and documentation for a production.

- Optimization part

As written in the beginning of this chapter, optimization can be made either in manufacturing processes or in the design of a product.

Ideas for an optimization are developed and elaborated together with a team of an engineers.

Reason for an optimization are:

1. Complexity of the production which seeks for a longer producing time which is directly affecting the costs.
   Goal is to design the production so that the complexity is reduced.
   Some of the ideas on how this problem can be solved is either by using other tools or by reconstructing the production flow.
2. Optimization of the design of a product because of the problems which occurred in the exploitation.

For every problem and corresponding solution, detailed explanation together with drawings and documentation will be given.
Goal of the thesis is to reduce production costs and complexity of the processes by solving given tasks.

1. Practical framework

Introduction of the companies

As stated in the previous chapters, thesis is done within two company.
Company ASCHL, based in Austria, is working for more than 25 years with >50 employees. ASCHL's two main department are engineering and sales department.
Engineering department is in charge of product design and optimization, while sales department fills in the database with new customers and suppliers.

Second company is one of ASCHL's suppliers, company TTO from Bosnia and Herzegovina. TTO is manufacturing company with around 60 workers who can roughly be separated into two departments. Production hall and managers office. According to F. W. Taylor [1], there should be no cooperation between workers (production hall) and managers (Project manages - engineers). Managers should supervise the workers; their task is to instruct and design work. Workers should be able to perform the work alone.

Production flow

For an easier understanding of the thesis and with a goal of focusing mainly on manufacturing tasks and specific requests, short organizational overview of the company TTO will be given in this chapter.

As explained in the previous chapter, company TTO is a supplier for a company ASCHL. Whole process begins company TTO accepts an order made by company ASCHL. With every order, drawings of the products with documentation and special requests are delivered.

Before accepting the order, it is important to check next points:

- If TTO can technologically respond to the request,
- If there are enough of the resources which are needed for the manufacturing (time, people, place),
- If requested material can be procured in given time manner,
- The requested deadlines can be observed.

Since company TTO is located in Bosnia and Herzegovina which is not part of an EU, it is important to note that special certificates and documents are needed to be able to work with companies located in the EU. TTO has a certificate ISO 9001:2015 which determines the organizational principles in the company.

After approving the order, first step is to check the dimensions, as well as weight of each single part of an order and to make a "Material order" which is forwarded to the procurement department. Procurement department will, based on the current inventory situation, provide the necessary material by ordering or by taking it from inventory. When material is provided, next step is to create a production flow and plan the production.

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[1] Taylor F. W. (1991) page 36f

Planning part is different and unique for every product.
Production flow is mainly based on the recourses of the company. Good planning of the production in crucial for a successful business. Production with a lot of gaps and pauses will cause a financially unstable state of the company. Goal in planning is to choose, create and calculate the best method for each specialized task with a main goal of reducing costs of the production. This topic will be covered later in the text.

After the production flow is defined, detailed drawings and documentation for a workshop with a sequence and priority in the production are delivered to the workers. Every order will be assigned to the main maser who is in charge of all phases and has to follow the production process, to control the order in the predefined phases and to send requests if something is not understandable or if they are not able to reach the given deadline.

In the next chapters, theoretical overview of the main processes in the production will be given.

2. Theoretical framework

Cutting

According to DIN 8580[2], manufacturing process can be split into next categories: primary shaping, forming, cutting, joining, coating and changing material properties. Cutting is furtherly split into three categories: mechanical, chemical and thermal. According to IEC[3] thermal cutting is defined as “parting of materials by burning or by local fusion, by means of a heat source, such as flame, an electric arc, a plasma arc or a laser beam.”
ISO 9013:2017[4] provides all needed information about the product specifications as well as quality regarding thermal cutting process.
Laser cutting, especially CO2 laser cutting can be counted as one of the most used and important types of gas laser. This type of laser had been invented by Patel in 1964 and is considered as one of the most powerful lasers which is still used today. [5] Thermal energy, which is generated in the nozzle is strong enough to be applied for almost whole range of materials. High variety of lasers which offer different quality of the cut and which are followed by different amount of operating costs depend of laser power. Laser power influences cutting speed, needed gas pressure, diameter of the nozzle, focus point and work-piece material.[6]

Light Amplification by Stimulated Emission of radiation (LASER) is widely used in the industry today and in the sense of cutting, it simplifies the process of different materials with different thickness and promises great surface finish. Laser beam is created in the resonator, it is then transported via mirrors in the cutting head where special lenses will focus it at a high power on small diameter. Then, laser beam is projected on the metal sheet and it will melt it according to the drawings. There are two types of laser sources: CO2 laser and fiber laser.

Main difference between CO2 and fiber laser is the source of laser beam. As the name says, in CO2 laser, gas mixture is used to create the beam. “Light from a CO2 laser is powerful enough to cut many materials, including cloth, wood and paper; the most powerful CO2 lasers are used for machining steel and other metals.” [7]

“Carbon dioxide lasers are the highest-power continuous wave lasers that are currently available.” [8] Metal sheet and laser system will not be in contact in the cutting process, but the material is cut with a light beam created by laser (see Figure 1). First step before the contours will be cut is the penetration of the material by the laser beam.

[2] DIN 8580:2003
[3] Cf. IEC Online source [5th December 2019]
[4] ISO 9013:2017, Online source [5th December 2019)
[5] M. W. Sigrist (2018), P.249
[6] Badoniya P. (2018), P.2103
[7] Badoniya P. (2018), P.2103
[8] Saravanakumar S./Sathishkumar T./Muthukumar A./Sivaraja M. (2015), P.94

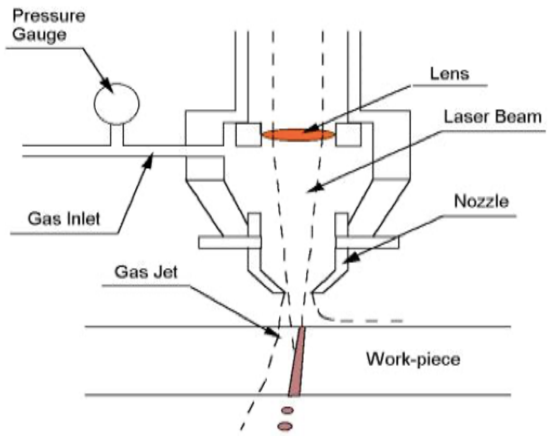

Figure 1 - Laser cutting process (Source: Badoniya P. (2018), P. 2103)

The piercing can be done either quickly (with full laser power) or slowly by using the ramp. As the laser output gradually increases, start hole in the ramp mode will begin to create. Then it is held constant unit the start hole has been formed. At the end, it will be slowly reduced. Together with the laser beam, cutting flow of gas will be emitted out of nozzle. It helps in removal of melting, and the material will be blown out of the kerf which is created by moving cutting head or the work piece.
High power allows heating, melting and partially vaporizing. By adding a gas to the process, cutting results can be adjusted to the requirements. Depending on the material, which is cut and required quality of surface required, cutting gas can be chosen.
Main factor which directly influence the costs of the production is length of the cut.
In the thesis, cutting is done on CO2 Bystronic Laser. Short overview of the machine is given in the text below.

Laser

"Bystronic By star 3015 with cutting are 3048 x 1524 x 170mm and a nominal sheet size of 3000 x 1500mm and maximum workpiece weight of 890 kg"[9] is used in the production. CO2 laser (see Figure 2) with a strength of 4000W offers precise sheet metal processing. Cutting process can be observed through the plastic window which keeps unpredicted dangerous bursts of material within the cutting area. Two changing tables offer fast change of working platforms and good time management. Sheet metal lager and a laser attached crane makes one-man job easier and allows the laser operator to be independent from other workers and reduce material handling time to a minimum.
Large sheets with thickness up to 15mm (stainless steel) can be cut precisely and economically with no need for post treatment. Drawings for the laser are sent by an engineer to a laser operator who will form cutting plan according to the priority of the project marked on the drawing.
Regular maintenance of the laser allows the work on the machine to be consistent and without any unpredicted production downtime.

[9] cf. Bystronic (2011), Online source [date 18th Nov 2019]

Figure 2 - Laser Bystronic (Source: Own picture)

Bending

According to DIN 8580[10], manufacturing process can be split into next categories: primary shaping, forming, cutting, joining, coating and changing material properties. Forming is furtherly split into next categories: pressure forming, tensile pressure forming, tensioning according, bending forming and shear forming. Bending forming is furtherly split[11] into bending with straight tool movement and bending forming with rotating tool movement.
In this thesis, bending with straight tool movement will be used for bending process.

Bending forming is according to DIN 8586[12], a category of forming process. In bending, the plastic changes (bending stress) are applied to the workpiece. One of the most important sheet metal forming processes is bending forming. During bending, workpiece is presented to the two types of stress. The inner area of the bend is compressed (cross-section is widened) and the outer area of the bend is stretched (cross-section is narrowed).

Some of the important words related to bending:

“Bend: A bend is a geometric feature associated with a given part that is created by straining a flat sheet of metal by moving it around a straight axis, which lies in a neutral plane. “ [13]

[10] DIN 8580:2003
[11] Engel B. (2003), Online source [5th December 2019)
[12] Forster A. (2018), P. 58
[13] Satyandra K. Gupta (2002), P.3

In order to get the final shape shown on the right side of the Figure 3, metal sheet shown on the left side should be bent along the dotted lines.

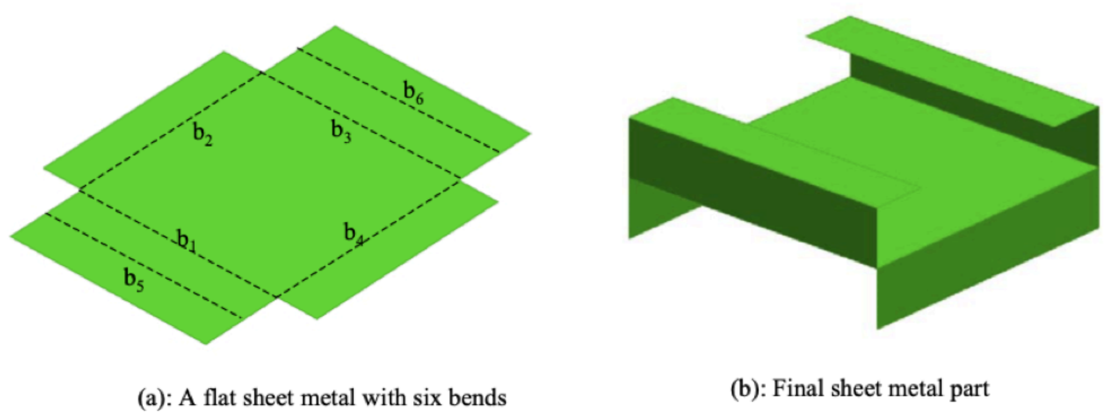

Figure 3 - Bend (Source: Satyandra K. Gupta (2002), P. 3)

Operation Sequences: For every bending operation, an engineer needs to observe the dimensions and angles of the tool and the bending sheen in order to create an adequate set of bending operations which are sorted into the sequence.

For the Figure 3, correct bending sequence would be b6, b3, b2, b5, b1, b4.

Punch and Die: Punch and die are two parts of the bending tool. The profile of both punch and die can be seen on the right part of the Figure 4. Die is a supporting part and punch is the striking and moving part which will push the material into die and crate a bend.

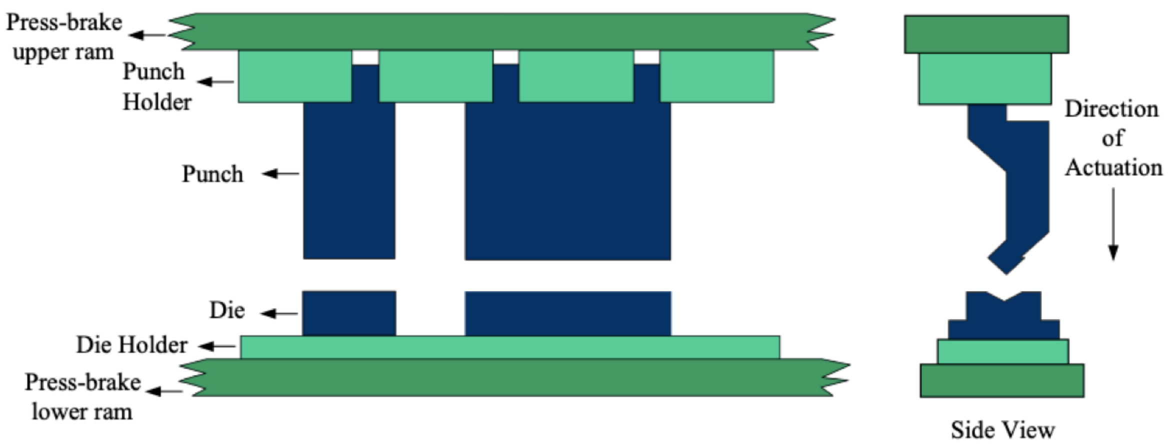

Figure 4 - Punch and Die (Source: Satyandra K. Gupta (2002), P. 3)

When planning the sheet metal bending process, an engineer should consider couple of factors which are important for the bending process. Factors which need to be considered are bending forces, blank length, selection of the tool. It is important to check the possible deformation based on the sheet material and tool used. At the end, he will define which tool will be used, a bending sequence and set up plan. “For small and medium lot sizes, the set-up time is one of the most important factors influencing the time in process and thereby influencing the cost effectiveness of this manufacturing stage. “[14]

Optimization possibilities for the bending process are always possible and should always be discussed prior the manufacturing. Optimization is to be done because of the possibility minimize the total production time which influences the costs of the production. When planning the production, it is also important to define it is for the single part planning and multi-part planning because the price of the product varies. Main factor which directly influence the costs of the production is number of the bends in the bending phase and number of the tools needed for the bending (mainly how many time should the tool be changed).

In the thesis, bending is done on Durma AD-S 3013. Short overview of the machine is given in the text below.

Durma AD-S 30135

Durma AD-S 30135 (see Figure 5) is one of the machines in Durma AD-S series which promise precise bending with minimalized tool change and adjustment time and maximized speed and safety. Some of the standard equipment of the press are 4 axes (Y1, Y2, X, R), CNC ModEva 15T control unit, servo motor back gauge & liner guided &ball screw system (X-R), CNC crowing, European style clamping system etc.
“The most important feature to achieve perfect bending is the stability and the design of the back gauge, which allows an impeccable and correct product to be produced. The high-speed ball screw back gauge system movement is also supported with linear guides, which helps the back gauge achieve long life, greater sensitivity and strengthens against any collisions. Special designed finger blocks with steps to achieve maximum stability can also be supplied for every kind of bending solution.”[15]

AD-S 30135 has a characteristics: “135 t bending force, 3050 mm bending length, 2600 mm distance between columns, 265 mm stroke, 530 mm daylight, 410 mm throat depth, 900 mm table height, 104 mm table width, 160 mm/sec Y rapid speed and 10 mm/sec Y working speed. “ [16]

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[14] Satyandra K. Gupta (2002), P. 3
[15] Cf. Durma, Online Source [date 13th Nov 2019]
[16] Cf. Durma, Online Source [date 13th Nov 2019]

Figure 5 - Durma AD-S 30135 (Source: Own picture)

Welding

According to the ISO[17] metal welding is an operation which unifies metal(s) by means of heat or pressure, or both, in such a way that there is continuity in the nature of the metal(s) which has (have) been joined.
Welding joint can be produces via force, heat and force and heat together. Arc welding is one of several fusion processes for joining metals. Fusion process uses only heat in the welding process. By applying intense heat, metal between two parts (joint) is melted and caused to intermix directly with an intermediate molten filler metal. Upon cooling and solidification, metallurgical bond a result. Since the intermixture consists of the substance of one part and the substance of the other part, the final weldment has the potential for exhibiting at the joint the same strength properties as the metal of the parts. In arc welding, the intense heat is produced by an electric. The arc is formed between the part which should be welded and an electrode which can be moved manually or mechanically moved along the joint. Most welding in the manufacture of steel products where filler metal is required, however, is accomplished with the second type of electrodes those that supply filler metal as well as provide the conductor for carrying electric current.

The basis arc-welding circuit is illustrated on Figure 6.

[17] ISO 857-1 (1998)

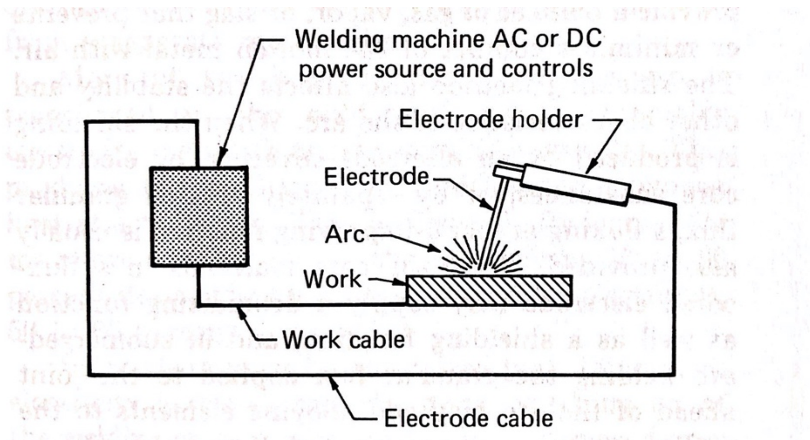


Figure 6 - Basic arc-welding circuit (Source: The James F. Lincoln Arc Welding Foundation, P. 1.3-1)

“An AC or DC power source, fitted with whatever controls may be needed, is connected by a work cable to the workpiece and by a “hot” cable to an electrode holder of some type, which makes electrical contact with the welding electrode.”[18]

An arc will be created when circuit is closed. Close circuit means that an electrode tip had touched the workpiece. The temperature at the tip of the electrode is about 6500°F. This temperature is more than adequate for melting most metals. The heat which had been produced will melt both, the base metal in the vicinity of the arc and a filler metal supplied by the electrode or by a separately introduced rod or wire. A common pool of molten metal is produced, and it is called a "crater." This crater will solidify behind the electrode, and as the electrode is moved furtherly, do crater will continue to solidify. The result of the process will be a fusion bond which is followed by a metallurgical unification of the workpieces which means that there will be continuity in the metals which are united.
Main factor which directly influence the costs of the production is the total length of the weld.

Welding machine which is used in the manufacturing process is Kemppi Minarc TIG Evo 200 which can be seen on the Figure 7 below the text. In the welding process, it is important to use defined and pre calculated wires, current and voltage. This is to be defined in the WPS lists (Welding Procedure Specification) which are made by an EWE engineer. More about the WPS lists will be found later in the thesis and WPS lists for all of the products can be found in the Appendix. The quality of the wire depends on the part material (AISI304 (V2) or AISI316 (V4)).

[18] The James F. Lincoln Arc Welding Foundation, P. 1.3-1

Figure 7 - Welding machine (Source: Own picture)

Cleaning phase

End product should appear clean and should have uniform flawless surface condition, which means free from welding residues or other imperfections made in the manufacturing phases. A fine surface condition which is a result of the surface treatment is not only aesthetic requirement, but it also provides good corrosion resistant which is necessary in order to increase serving life of the product.
"Stainless steel is protected from corrosion by its passive layer – a thin, impervious, invisible, surface layer that is primarily chromium oxide. The oxygen content of the atmosphere or of aerated aqueous solutions is normally sufficient to create and maintain ("self-heal") this passive layer. Unfortunately, surface defects and imperfections introduced during manufacturing may drastically disturb this "self-healing" process and reduce resistance to several types of local corrosion. Thus, as regards hygiene and corrosion, a final cleaning process is often required to restore an acceptable surface quality." [19]

The process of cleaning of the surface consists of:

- Grinding – grinding wheels are used for removing defects, welding bursts or uneven surfaces. It is important to use the right grinding (with the right proprieties, grain size and grain toughness) because if wheel is rougher than necessary, it can damage the material.
- Pickling - is the removal of a thin layer of metal from the surface of the stainless steel. Mixtures of nitric and hydrofluoric acids are usually used for pickling stainless steels. Pickling is the process used to remove weld heat tinted layers from the surface of

[19] Voestalpine (2019), P. 5

stainless-steel fabrications, where the steel's surface chromium level has been reduced. [20]

Summary: A final pickling/cleaning operation following a typical manufacturing process, according to the AvestaPolarity Welding AB, could be:[21]

- Grinding for removal of defects caused by welding. It is important that slag is removed after welding. Removal of organic contamination
- Pickling using a bath, paste or solution, possibly in combination with a careful mechanical treatment to break oxides.
- A thorough rinsing with water, preferably using a high-pressure water jet.

In the next chapter of this thesis, while explaining manufacturing steps for first products, cleaning steps according to the text above, results of each step in the cleaning phase will be shown on the pictures.

VDI 2222

In this chapter, the guideline VDI 2222 which deals with tasks of finding the principles and solutions which is used as a role model in the process of changing the product in the proper way. This guideline is called "Methodical Development of Solution Principles".

Solution for technical problems - First step is not to create a detailed design, but to understand the problem structure and to create first "basic solution". In this step, on the one hand, first determinations are made about the arrangement and the connection of data structures. The advantage of this abstraction is that the desired solutions are still very easy to manipulate, and the design is not complex but simplified, but the idea generate a kind of first descriptive coordinate system for the product or parts of a product. It is important to define a difference between "Principal solution" and "function". In praxis, the terms are often mistaken. Functions describe the behavior of parts which are analyzed. "Principal solutions" determining ideas for the realization of products.

Application of "basic solutions" for different types of construction - In different construction types, the term "Search for solution principles" is not equally weighted. Different construction types can be differentiated to the required modification, design occasion or according to the working area. If the construction is considered from the viewpoint of changing design features, essentially three design types can be distinguished:

- The entire product is reworked. Characteristic is that all steps are completed all the above design features can be changed.
- The product is configured as a combination of existing modules, which can be parameterized frequently. Examples for this are material variants. A special case is the "construction according to a fixed principle", in which only dimensions are changed.
- Customized, an existing product is modified to best suit the specific needs of a particular customer or changing market conditions. Here, however, individual sub-functions can be completely redesigned.

[20] Euro Inox (2007), P. 3
[21] AvestaPolarit Welding AB (1995), P. 5

When it comes to the new product ideas and new design tasks, the finding of suitable "principle solutions" is the decisive step of the entire problem-solving process. These design processes are usually unclear. For successful problem solving, therefore, an above-average level of care is required in the task clarification and the establishment of the functional structure. In general, it must be assumed that iterative steps are necessary.

The functional structure and the requirement list are analyzed in a first working section, resulting in insights into particularly important or particularly difficult subfunctions and critical requirements From these clues gained in this working sections further procedure must be planned (for example experts, suppliers or cooperation partners are to be consulted or which previous solutions can be used). Further planning factors can be the personnel planning (project management, team, composition) and the creation of computer-aided methods. Some of the next tasks is to find partial solutions for example with the help of brainstorming or some other methods. Often, at least a rough estimate of functional and geometric parameters is important. Next task is the analyzation of the overall solution variants (disturbing effects must be identified). This finally leads to an evaluation of the remaining alternatives.
In order to place the decision on the selection of "basic solutions" and their realization the starting point must be a more precise task, which contains both the main task of the product and all requirements that can be identified at this time.
It is very expedient to obtain clarity about the chosen function and the solution principles that have been found before a particular design is made. One additional step to clarify the task is resort to knowledge memories which very often consist of the constructor's wealth of experience, but also of existing collection lists or design catalogs.
"Principal solutions" are found methodically. Their functions can be realized by physical, chemical, biological. [22]

Optimal solution

According to the Methods of Choosing an Optimal Portfolio of Projects [23], effects which led to a significant reduction in costs are:

- Reduction of a production time,
- Reduction of the development costs,
- Reduction of number of various resources which are increasing the costs,
- Revision of the total number of projects led by the company,
- Increase in speed of the production,
- Increase of flexibility of the production,
- Change in the organizational structure,
- Reduction of the complexity of the production,
- Improvement of the distribution of resources (human, computer) to increase quality of the work.

According to the above-mentioned effects, the aim is to redesign current production plan or the product and to optimize the production process. Huang & Mak [24] define engineering changes

[22] VDI 2222 (1997)
[23] cf. Chernenko M. (2016), P. 34
[24] Huang GQ, Mak KL. (1999), P. 21–37

as a modification of components or product associated to forms, fits, materials, dimensions or functions.

According to the VDI, first crucial step is to understand the problem. This will be done by “5 why” root cause analysis [25]. The method is based on asking “why?” five times in a row, after which the final definition of the problem and root of the problem should be made. After defining what is the problem, it can be furtherly proceed with the optimization steps.
In this thesis, all problems are either in the production phase or on the part itself.
Depending on the problem, it will be focused on finding the right solution.
According to the VDI, there are 3 ways on how to optimize the product:

- whole product can be reworked,
- some parts of the product can be reworked,
- functions can be redesigned.

This principle will be modified and applied on the process:

- whole process can be reworked,
- some parts of the process can be reworked.

For each problem, after brainstorming the solutions, at least two ways for manufacturing and the evaluating criteria will be defined and explained.
As mentioned above, in each paragraph respectively, important factors which are evaluating criteria are:
- Length of the cut made on lase,
- Number of bends and the number of tool changes in the process,
- Length of the weld.

After discussing above mentioned parameters which influence time, costs, work force, complexity and organization of the production process, final conclusion on which way of manufacturing will be used in the future. The advantages of the chosen way of manufacturing will be listed and explain in each chapter.

[25] Liker J. (2004)

4. BOWA

Introduction

BOWA is shorten of Bodewanne (ger.) – floor tub.

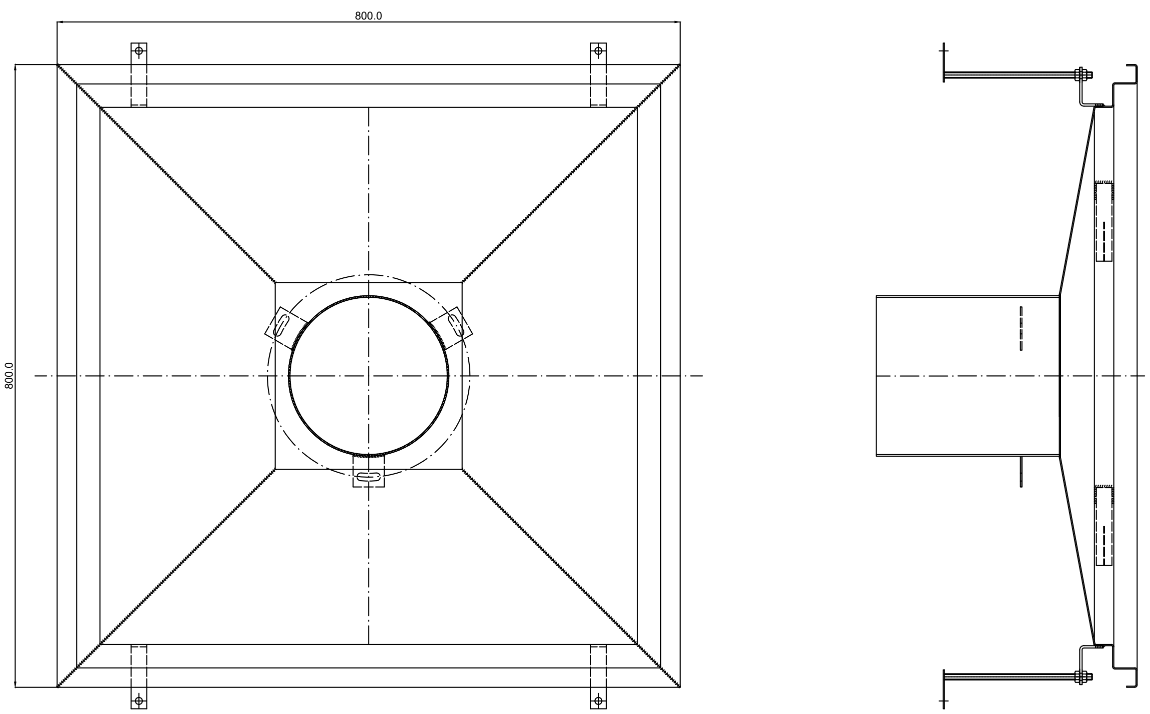


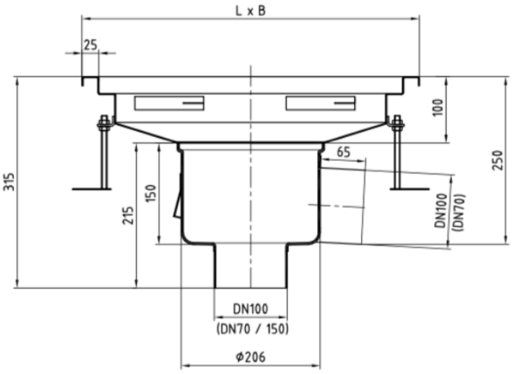
Figure 8 – BOWA (Source: Product drawings)

BOWA shown on the Figure 8 represents a floor tub which is suitable for surface drainage in many different areas of application. It consists of 2 main parts (main construction and grating cover) which can be seen on the picture below.

Standard BOWAs are offered in different dimensions shown in the Table 1. Custom made BOWAs with dimensions different in the table request special order.
BOWA which will be explained in this chapter is 900x900.

Table 1 - BOWA dimensions (Source: ASCHL (2013), P. 60)

L Länge in mm	*B* Breite in mm
400	400
400	600
500	500
500	800
500	1000
600	600
700	700
800	800
900	900
1000	1000



Standard BOWA is completely made of stainless steel V2A (1.4301) with a usual material thickness of 1,5 mm. Customization by means of height adjustments (by adjusting the screws), optional flange variants and optional wall anchor are possible. BOWA provides safe elevation, large tub slope, safe removal of dirt even with little water and easy cleaning, antibacterial hygienic form.
Depending on the area of application, BOWA can also be made of stainless steel V4A (1.4571) with a thickness of 2 mm. This material is resistant to aggressive substances, acids, salts. It is intended not only for working with drinking water, for the food industry, medicine, conditions where hygiene is more important, but also for working with more aggressive matrices, acids, sea water, etc.

Manufacturing

Main drawing for the product and special requests is delivered by the company ASCHL.
After accepting an order, an engineer checks the drawings and makes needed adjustment to fit the process and machines properly.
Dimension and weight of the material is calculated and sent to the procurement department which will provide needed material (by ordering or by taking material from inventory).
After, an engineer who is Project Manager for this order, will analyzing BOWA drawings and will define production flow and control milestones in the production. Production flow is:

1. Cutting
2. Bending
3. Connecting parts together/ Welding
4. Adding necessary accessories.

Production flow and control points are given to the main master. Main master is in charge of an order from this moment till the final control of the order and till the packing for transport.

1. Cutting

Based on the resources in the company TTO, cutting can be made either on Laser cutter Bystronic machine or on Plasma cutter.
Picture below shows cuts made on Plasma cutter and laser cutter, on the metal sheet (AISI316, thickness 1,5mm).

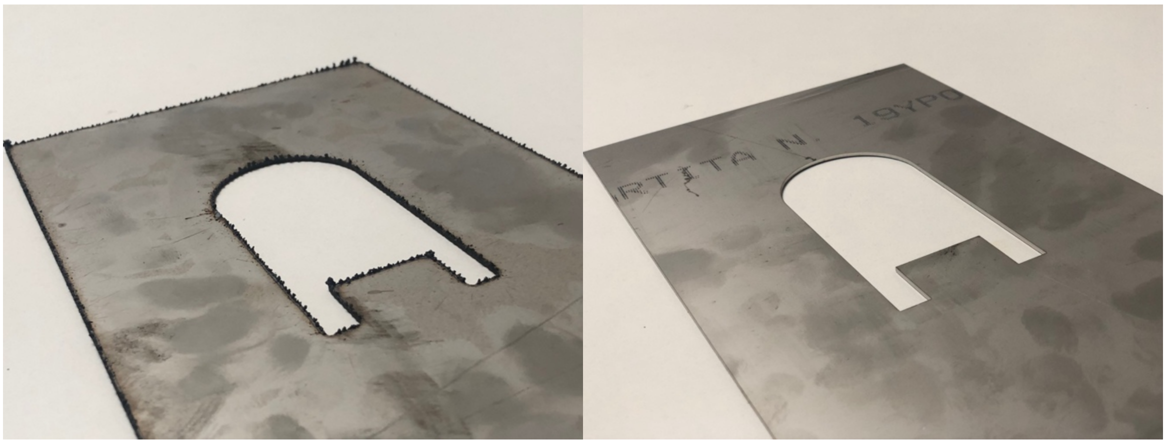


Figure 9 – Semple cut on plasma (left) and laser (right) cutting machine (Source: Own picture)

Table 2 - Laser and Plasma factors (Source: Own illustration)

	Post treatment	Time	Speed	Larger quantities	Quality	Final result
Plazma cutter	1	1	1	1	1	1
Laser cutter	5	5	5	5	5	5

Table 3 - Criterions for Table 2 (Source: Own illustration)

	1	5
Post treatment	Necessary	No need
Time	Long	Short
Speed	Slow	Fast
Larger quantities	Hard to obtain	No problem
Quality	Bad	Excellent

In the Table 2, important factors which are a result of a Laser cutting and Plasma cutting process are shown. In the Table 3, grading system of the evaluation criteria can be seen.
Post treatment – for plasma cutter, as it can easily be seen on the left side figure 9, post treatment is necessary. However, for laser cutter, post treatment is not necessary.
Time – Plasma cutter needed 73 s in total to cut piece shown on Figure 9. Laser cutter needed 44 s.
Speed – Based on the time needed for cutting, it can be concluded that laser is faster.

Larger quantities – after observing cutting process on both machines and after consulting with the operators on both machines, it is concluded that plasma cutter overheats and that it is necessary to plan brakes.
Quality – As it can be seen on Figure 9, quality of cut made on laser cutter is much better.

According to the evaluation criteria from the table 2, laser cutter will be used for the cutting process. Detailed information about the Laser cutter can be found in the previous chapter.

Drawings for a Laser machine are prepared and sent to the operator working on the laser cutter. Laser drawing consists of open positions with engravings and can be seen on the figure 10. Engravings are done due to addition help, with a goal of reducing time and minimizing chances for a failure in the next phases. For example, engravings will help to the operator on the bending machine to position the part properly and to make a bend on the right side.

On the drawing for every part which is send on laser it is necessary to define next points:

- Which material is used for this part,
- Thickness of the material,
- Number of pieces.

Figure 10 represent a drawing made by an engineer which is sent to the laser operator. BOWA has been split into 4 main parts which are all the same. After bending, the 4 parts will be welded (together with other parts) into one position.

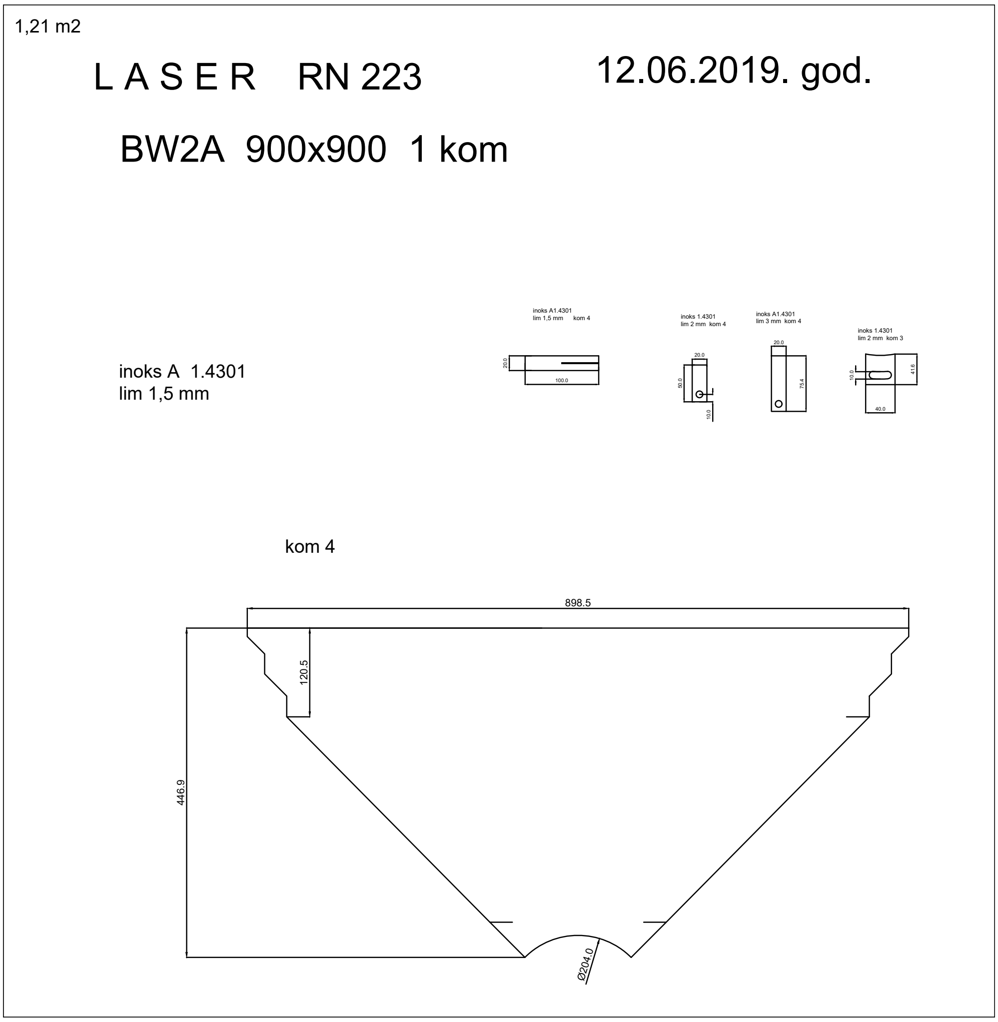


Figure 10 - BOWA drawing for laser (Source: Own drawing)

Before giving a command to cut the pieces, operator has a several tasks to preform and double check. The tasks are mentioned above and are written on the drawing which, as explained, has been sent by an engineer. Due to waste reduction, engineer guides the operator on how to position each piece which is to be cut out onto the metal sheet. Parameters for the process of laser cutting the BOWA and the optimal positioning of the pieces on the metal sheet can be seen in the Appendix A.

One BOWA requires a 50 s of works and length of the cut is 3,385 m in total.
After parts are cut, they are transferred to the bending press.

2. Bending

Bending process is done on Durma AD-S 30135. In the first chapter, theoretical overview of process and machine can be found.
Depending on the tools which company has, an engineer has to check if all bends can be performed and after analyzing important parameters, an engineer has to create a bending sequence. It is important to note which tool and which channel (punch and die) should be used for each bending step.

Bending flow for one part of the BOWA is shown on the figure below.

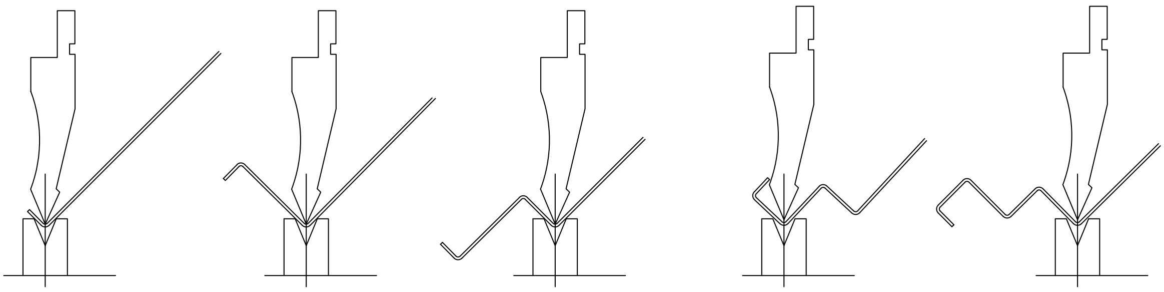


Figure 11 - Bending sequence for BOWA (Source: Own illustration)

Figure 12 - Bending of the BOWA (Source: Own picture)

Bending process can be seen on Figure 12.
Final result of the bending steps from figure 11 is shown on the Figure 13.

Figure 13 - One side of the BOWA bended (Source: Own picture)

As already mentioned, one BOWA consists of four main parts (all parts the same as a part on the Figure 13).
After bending, it is important to check all bends with digital measuring equipment, to check straightness and angles. Bending process can be seen on Figure 13.

When ordering bending sequence, an engineer has to make sure that tool can enter and exit a process without any obstacles. When reviewing bending steps on the Figure 11, it can be notice that an order in bending sequence has been created according the needs of the part. This can evidentially be seen on the bend no.4. If counting bends on the end product, bend no.4 is second bend from the beginning, but as seen on the picture above, it is on the fourth place in a sequence. This is because of the problems which occur in the further steps and obstacles which are faced in bending other parts of the product.

3. Welding

After bending, the positions are moved to the foreseen position and the main master for this order has to assigns a team that will start composing this part. The team consists of master and one welder who point weld all the parts together and add additional elements (legs, uprights, fasteners ...) to the construction. This position is now moved to the table of a welder who welds all parts position in the one position.

Welding tasks are defined by standard. Standard defines the necessity for making a WPS which is done by EWE engineer. WPS - Welding Procedure Specification is according to Weman [26] a document specifying the details of the required variables for a specific application in order to assure repeatability. WPS for BOWA can be found in the Appendix B.

[26] Weman K. (2003), P. 3

While designing the welding process, it is known that distortion and buckling [27] of the part after welding, especially of thin metal sheets, are possible due to high heat input. It is also common with larger positions, that positioning of the element represents a problem and it requires the attention of couple of workers. Because of this problem, an engineer prescribed that the position should first be tack welded. Tack welding [28] can be considered as a preparation of the position of the components which need to be welded. Components are held (point welded) in the right position and alignment.
This approach, tack welding and after complete welding of the position, is one of the ways time and money is saved in the production. Tack welding does not have to be done by the certified welder. Since the price for the certified welder is higher than for other workers, it is more profitable to tack weld and prepare the position by workers. Then position is ready, certified welder will weld the position according to parameters and suggestions from the WPS list. Based on requirements of the company and WPS lists made by an EWE engineer, different controlling methods are performed in order to check the welds. This position does not require any special welding checks.

One additional way on how to check the straightness (flatness) of the position is added to the control phase. Flatness is important because in the montage phase, metal grid will be inserted into the BOWA. When straightness is out of tolerances, it is not possible to position the grid properly. The tool which simulates the grid is created. After welding the BOWA, the tool should fit in without any problems. If it does not fit, if it moves and if it is not straight, position needs to be straightened and fixed.

Additional parts for BOWA

Every BOWA has couple of additional parts which will be explained below.

Position 1 - Concrete anchor
Concrete anchor which is used to enable the channel to be securely fixed into the concrete.
On the Figure 14 concrete anchor before the modification can be seen and on the Figure 15 is the new design for the anchor. The modification was necessary because the old design of the concrete anchor was not strong enough and it usually broke down due to the weight of the concrete. Every BOWA has 4 concrete anchors which are placed as shown on the Figure 16.

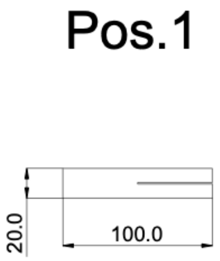


Figure 14 – Position 1 (before the modification) (Source: Product drawing)

[27] Gray T./Camilleri D./McPherson N. (2014), P. 16
[28] Gray T./Camilleri D./McPherson N. (2014), P. 34

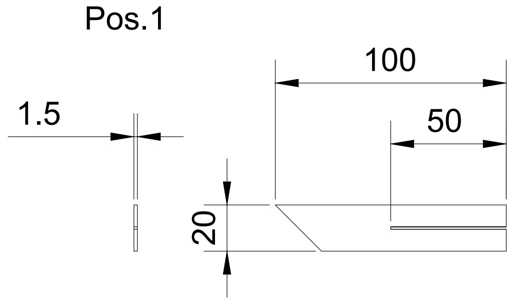


Figure 15 – Position 1 (after the modification) (Source: Product drawing)

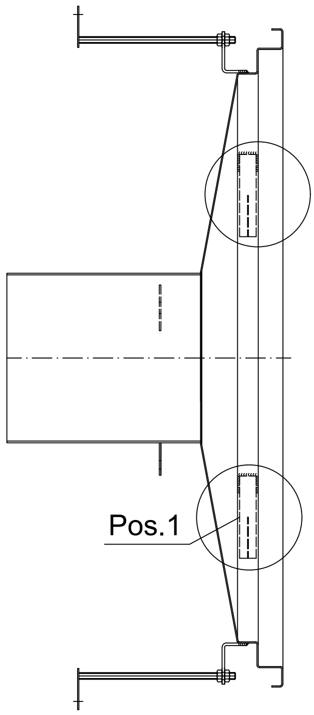


Figure 16 - Positioning of position 1 (Source: Product drawing)

With the new design, it is ensured that if concrete anchor starts to break down, it will not brake till the end and will still hold the part still. Main use of this part is to create a barrier to move the canal after the concrete has been poured around the BOWA. Assembly: two "wings" of the concrete anchor are opened and after the concrete is poured, BOWA will not be able to move.

Position 2 and 3 - Fixable leg
Position 2 is made of the threaded bar as it must be adjusted on uneven ground and is mounted on-site. Position 3 is welded onto the channel.
Both positions are shown on the Figure 17 and the positioning of the position is shown on the Figure 18.

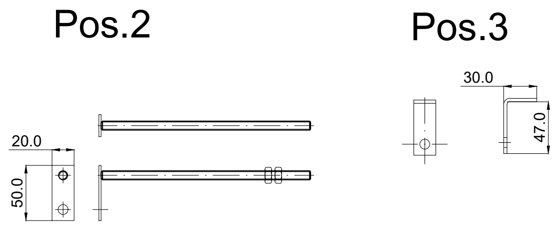


Figure 17 - Position 2 & 3 (fixable leg) (Source: Product drawing)

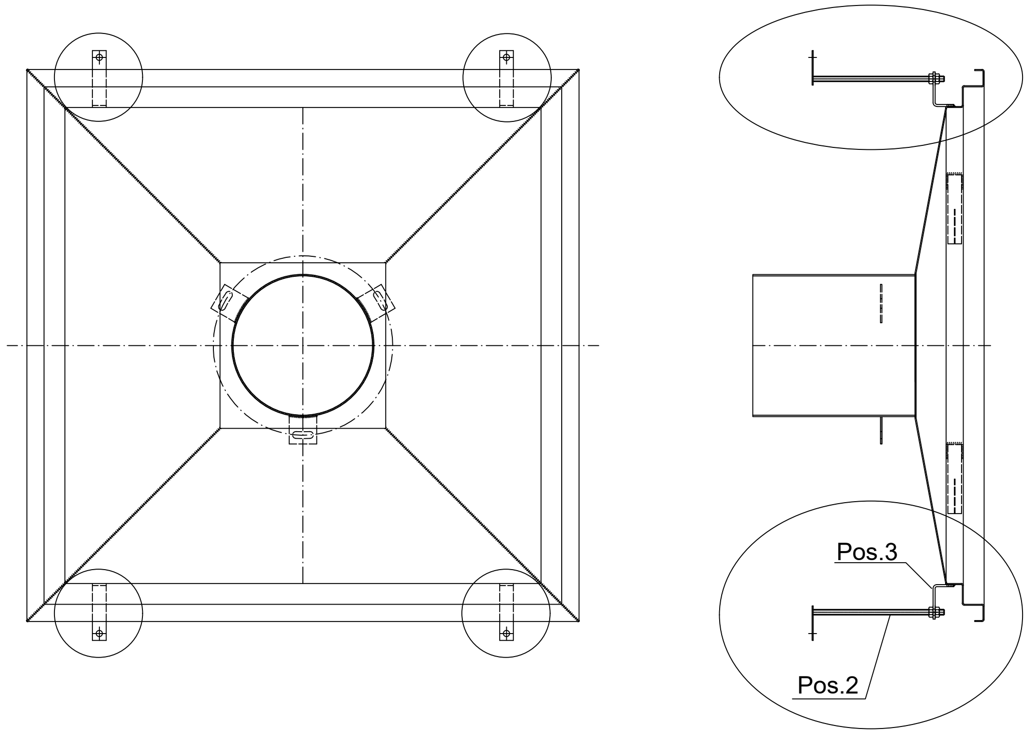


Figure 18 - Positioning of positions 2 & 3 (Source: Product drawing)

Pos 4 - Siphon holder
Position 4 is a holder for a plastic siphon.
Positioning of this position is shown on the picture below. Figure 19 shows the look of the holder and figure 20 the positioning of this position.

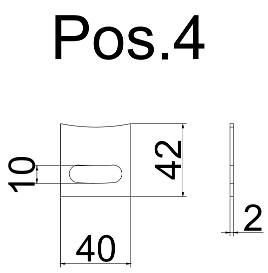


Figure 19 – Position 4 (Source: Product drawing)

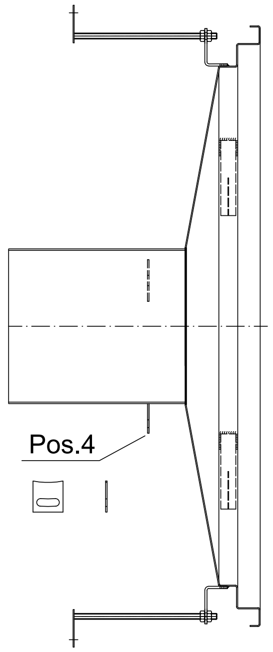


Figure 20 - Positioning of position 4 (Source: Product drawing)

An additional position is the RVM which is used to solidify the upper surface on the channel due weight (for example cars in the parking garages, AGVs in the warehouses).
RVM used to be made out of cast resin, but because of the short life cycle due to peeling off from the metal surface, new solution has been made.
New design of the RVM is small metal tile (dimensions20*8) which is inserted in the gap in the construction and it increases strength and loads which product can take.

Last step in the production, before packing and transport, is cleaning. Cleaning phase has been covered theoretically in the beginning of the thesis. Short explanation with pictures is given here. Cleaning consists of pickling and passivating, washing and grinding.

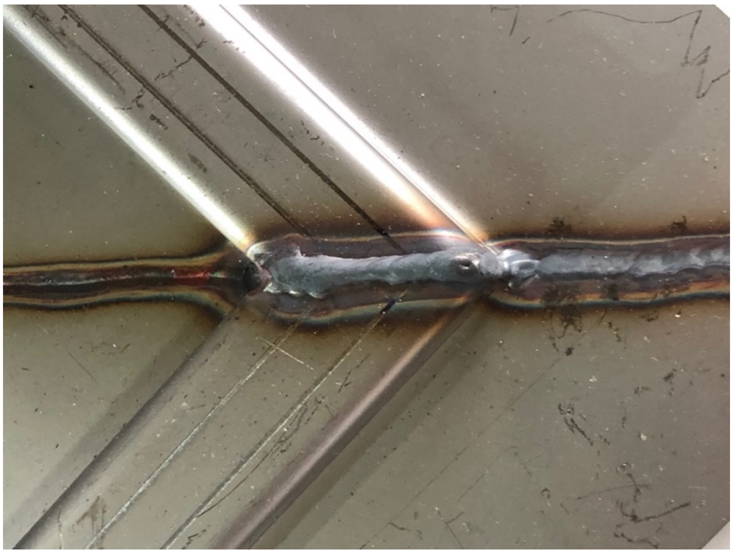


Figure 21 - Weld before cleaning phase (Source: Own picture)

Figure 21 shows how the weld looks before the cleaning phase. First step is to grind the weld. Figure 22 shows how the weld looks after the first step. Goal of this step is to even out the surface and to remove weld thickness.

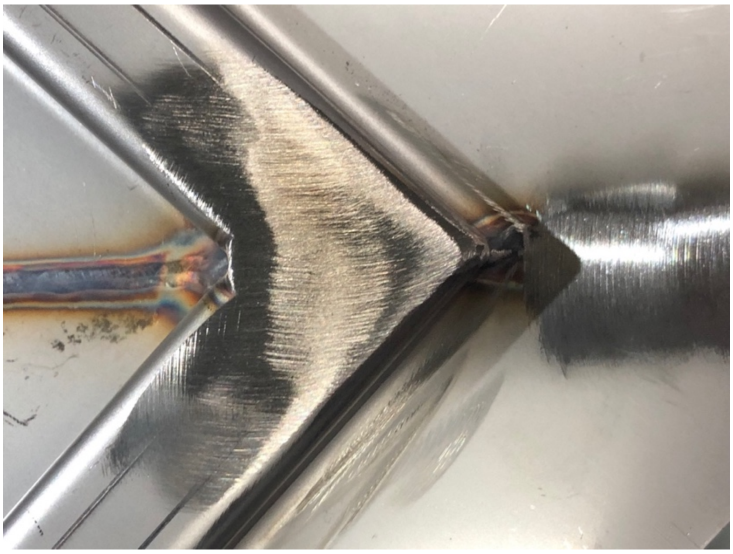


Figure 22 - Weld thickness removed (Source: Own picture)

Acid for pickling and passivating (shown on Figure 23) is used to coat the position or just one part of it, depending on the request for the final visual look.
Main purpose for the acid is to pull ferrite from the places where it can be stored.
Ferrite can be kept in welds or on the bends.
For the remaining ferrite in the bends we do not use acid for the removal, but we either clean the tool so that no material can be pressed into position while bending or we put protecting foils on the position while bending is performed.
As noted, main priority is to clean the welds.
After position is coated with the acid, it has to stay on the position for approximately 20-30 minutes. Later, acid is removed with the water and position should dry.

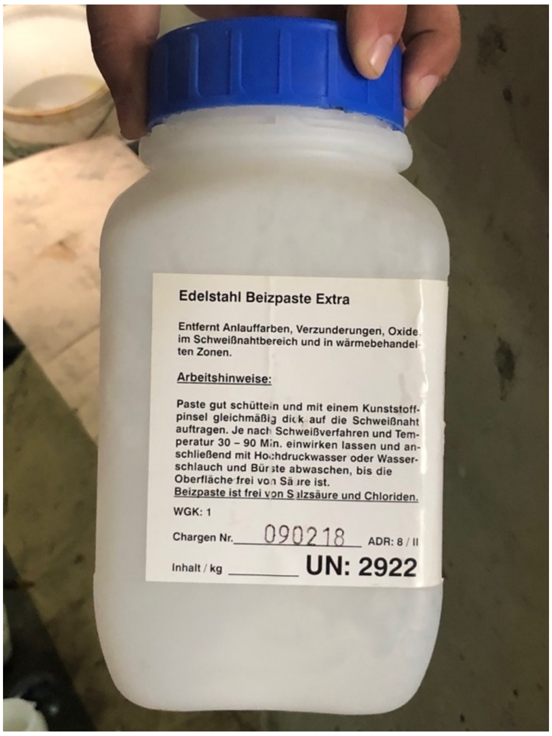


Figure 23 - Acid for picking and passivating (Source: Own picture)

Figure 24 shows how the acid looks when part is coated with it.


Figure 24 - Acid on the position (Source: Own picture)

After the acid has stayed on the position for 20-30 minutes it turns into the color green, this can be seen on Figure 25.

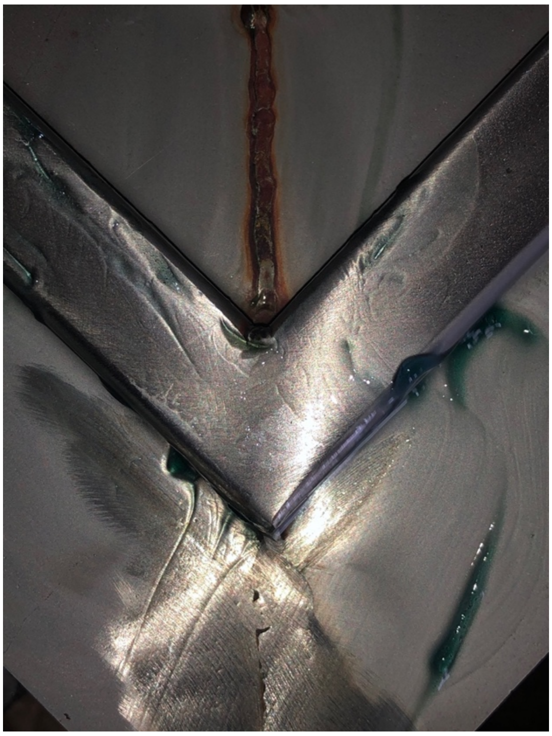


Figure 25 - Acid on the position after 20-30 min (Source: Own picture)

Figure 26 shows how the position looks when is the acid is cleaned and when the position is dried. It can be noticed that acid leaves white marks on the position. Marks can be seen on the picture below.

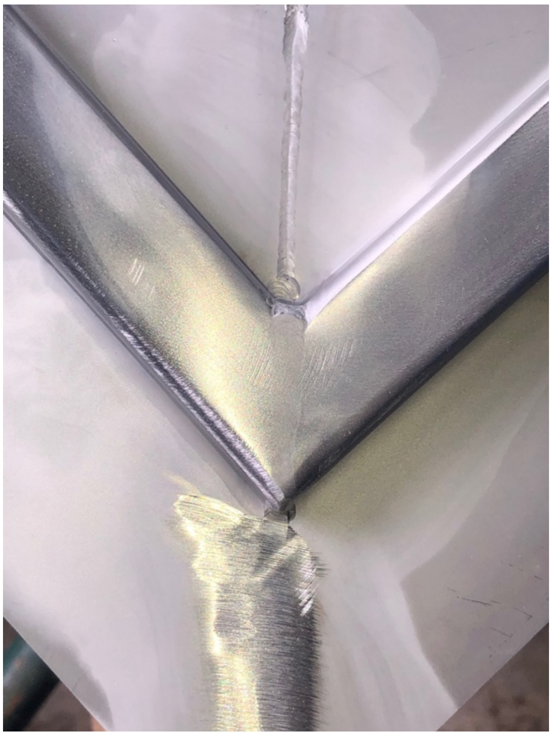


Figure 26 - Position after cleaning the acid (Source: Own picture)

For this position, it is not necessary to have uniformed surface because position will be montaged into the concrete and the aesthetic appearance is not that important (this would be avoided if sandblasting was done).
Note: product is not the same as on the previous pictures, but the process and the end results are the same.

Figure 27 - Acid marks (Source: Own picture)

Positions are then brought to the final stage - grinding and straightening.
This phase is done at the end of the production line, because during the washing (pickling, passivating and cleaning) positions are transferred and there is a possibility that the straightness of the position can be shifted.
First step is to check the flatness, possible damages and visual defects.
If there are major defects, positions are return to the repair and sent back to washing. If the defects are smaller, a rubber hammer is sufficient to correct the errors.
After damages and defects are removed and straightness is checked, visible surface of the position is grinded with the K220 (roughness quality).
Note: While grinding, the worker uses gloves; in the picture, the tool is only taken for the sake of photographing.

Figure 28 – Grinding (Source: Own picture)

After grinding, the positions are cleaned with an air compressor so that no dirt will remain in them after the process.
Figure 29 shows how the grinded position looks. This is end look of the position. It should have uniform, clean and even surface.

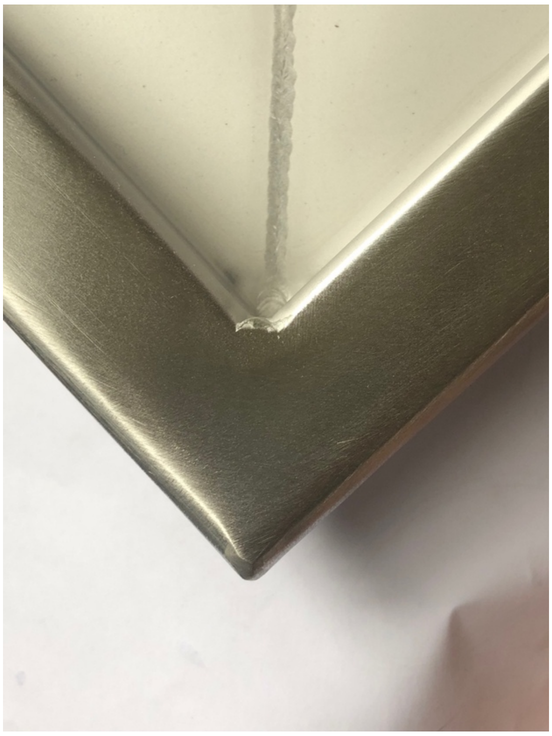


Figure 29 - Grinded position (1:2) (Source: Own picture)

One last control is done just before packing. Once again, it is checked if all additional parts are welded on the correct place, if all bends are on the right position and have the right angle, if products straightness is good, whether the acid retained in some of the parts, if the grid can be located within tolerance limits in the foreseen space etc.

When everything is according to the drawings, special protective residue-free adhesive tape is glued to the top of the products and it is stored in custom-made pallets and secured for the transport.
Note: This process is the same for the all products and will not be written again in the next chapters.

Problem and solutions

Problem with BOWA was in the use phase – exploitation.
The customer had reported that the liquid flow is not constant and that the small pools of liquid are being created at the bottom of the BOWA. This problem caused various scents and hygienic conditions were harmed, so customers have made a complain and asked for new design. On the Figure 30, it is shown where water had been held.

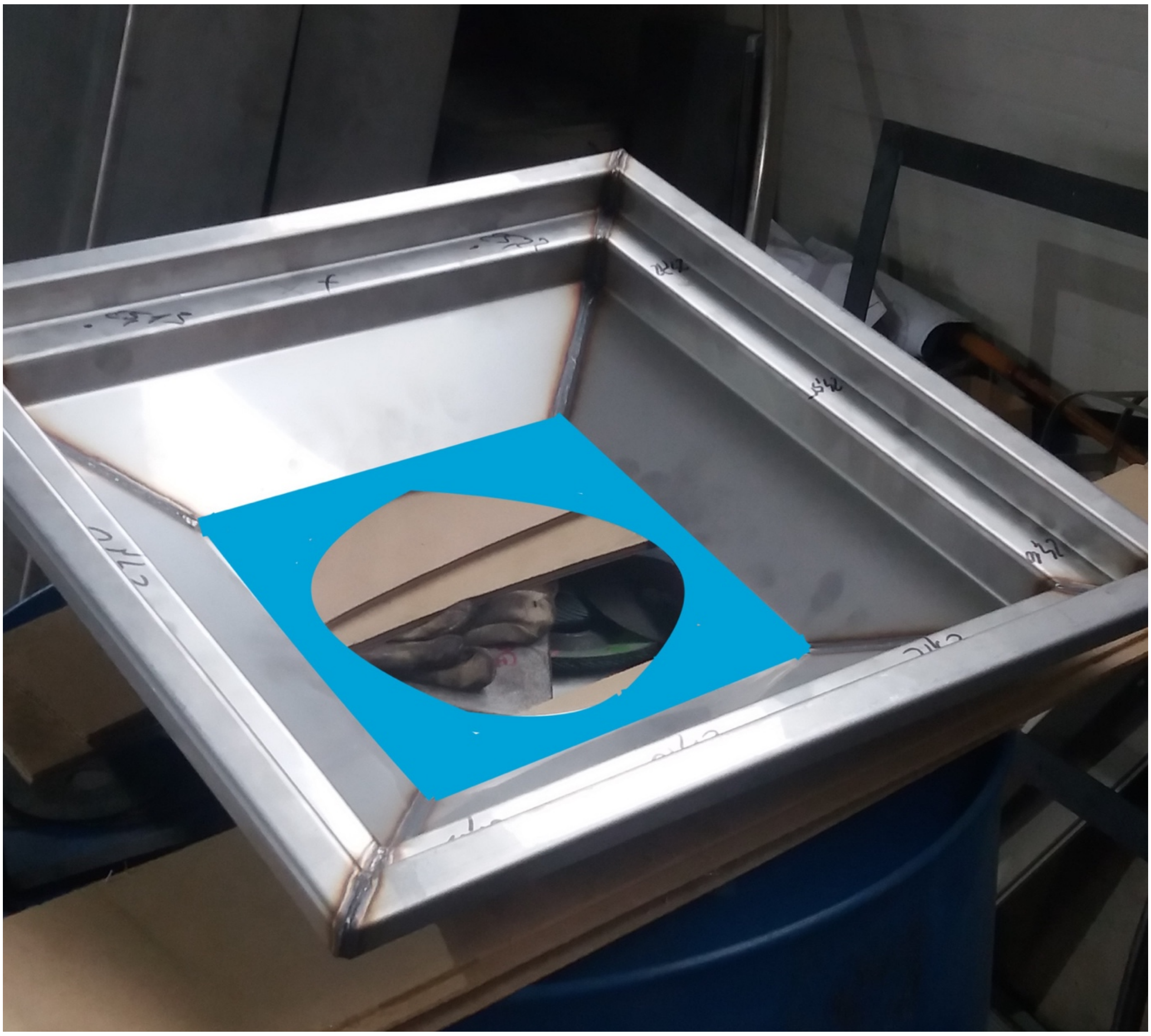


Figure 30 - Retained water on the BOWA (Source: Own picture)

After applying 5 why method, the problem had been defined.
Problem was the straight part at the bottom of the BOWA where constant flow of liquid was stopped. Due to the unpredictable assembly situation and due to the impact during the

positioning of the part on its place, straightness of the part on BOWA where liquid had been held was not checked and surface irregularities had been created. This is where small pools of liquid are held. In order to find a solution which would made it possible to safely avoid this problem in the future, even due to negligence during assembly, slight changes to the design had been made.

For the new design of the BOWA it is decided to eject the flat part on which the fluid is held, reduce the slope of the sides, and retain the frame of the original BOWA because of the additional positions and installation process. Design is just simplified and straight part where liquid was held was omitted. New design can be seen on the Figures 31 and 32.
It is important to note that this exact BOWA on which new design is preformed and explained, has addition to the design compared to the previous BOWA.
Addition is made due to requirements during assembly and consists practically of extension of the previously explained BOWA. This addition requests two more bending, which will be explained and shown on the picture later.

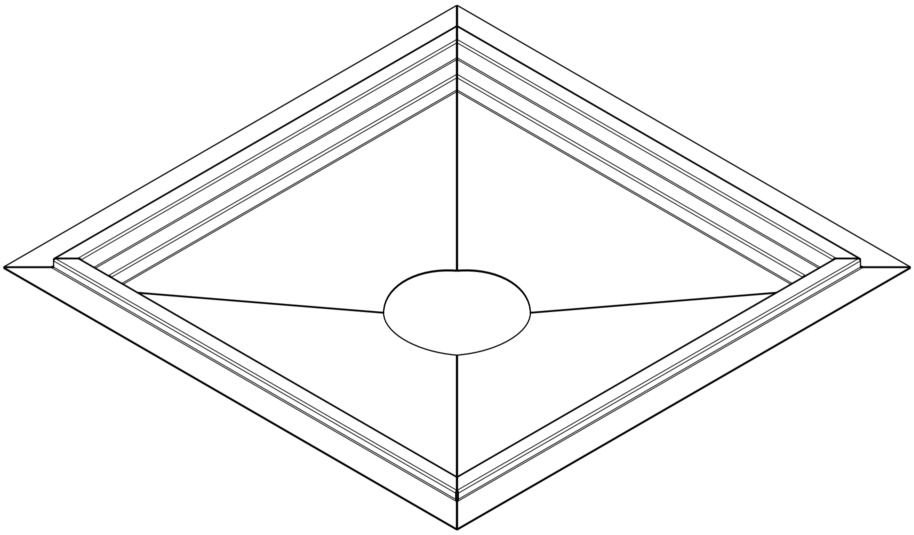


Figure 31 - New BOWA (Source: Product drawing)

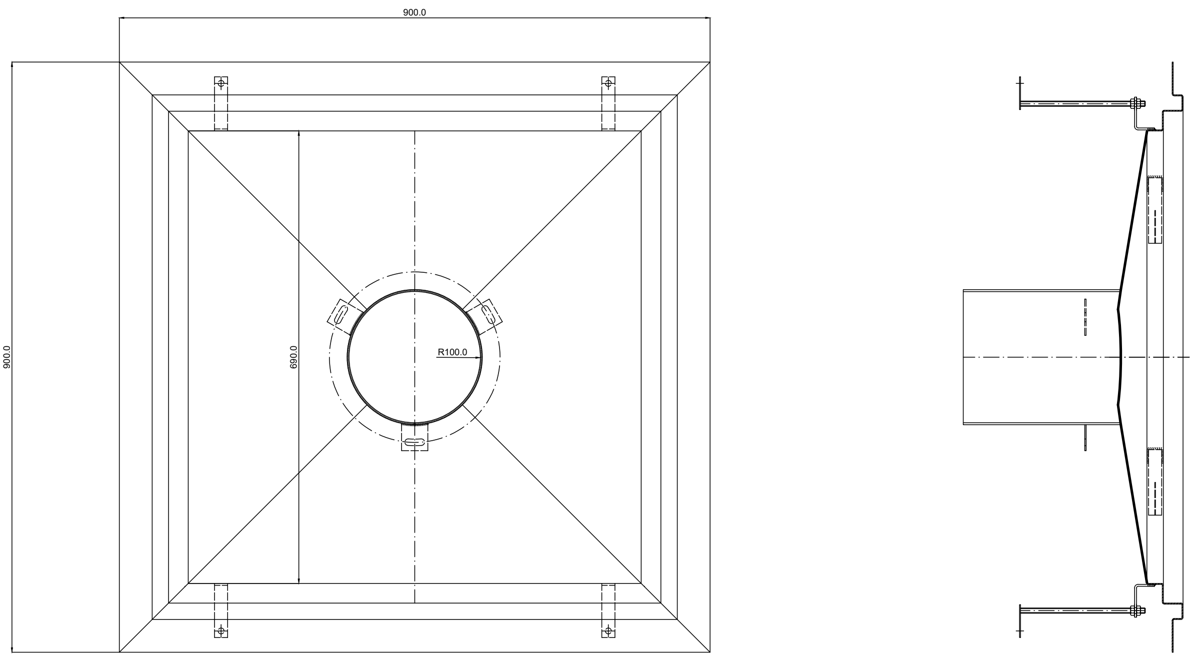


Figure 32 - New BOWA (Source: Product drawing)

Production flow has been defined:

1. Cutting
2. Bending
3. Connecting parts together/Welding
4. Adding necessary accessories.

Note: Since the layout of the process is almost similar as for the previous design, some of the explanations will not be explained again. This is valid for the theory for the laser cutter and bending press, welding, for all of the additional element and their position, and cleaning phase.

1. Cutting

Laser cutting drawing is shown on the Figure 33. For the parameter for the laser cutter for the new design of the BOWA, see Appendix C.

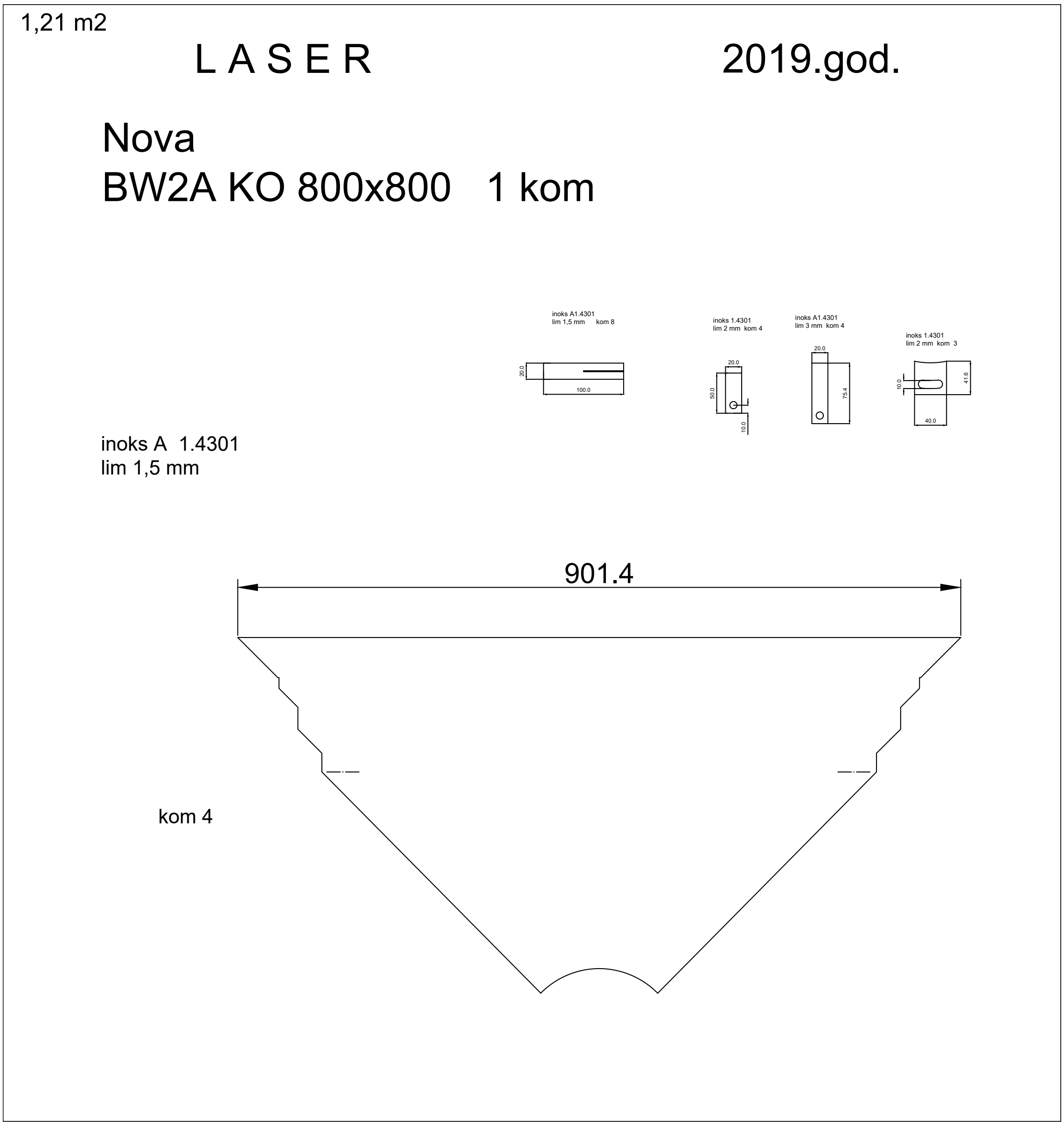


Figure 33 – Laser drawing for new BOWA (Source: Own drawing)

One new BOWA requires a 48 s of works and length of the cut is 3,345 m in total.

If we compare parameters for the old and new design of the BOWA, it can be notice that time is reduced by 2 seconds and cutting length by 0,004 m.
Even though the problem with BOWA was inability of constant liquid flow, it is positive that numbers for this specific task in the production show reduction of needed time, which is directly linked to the price.
However, as laser cutting task is not the only task in manufacturing of the BOWA, more on the topic of cost-effectiveness will be covered in the last part of this chapter.

2. Bending

Bending sequence for the new design of BOWA is shown on the Figure 34. As in the previous scenario, it was important to check if length of the tool and depth of the press are compatible and to create good bending sequence where all the bends can perform. For instance, bend no.5

is third bend if counting physically from the beginning of the piece but was done in the fifth step. If it was third step, later bends would not be possible.

Bend no. 7 is deepening of the bend no.4 because tool was not able to make the whole angle in one step. Same with bend no.8, it is just deepening of the bend no.3, because tool was not able to make the whole angle in one step.

One bending step can be seen on the Figure 35.

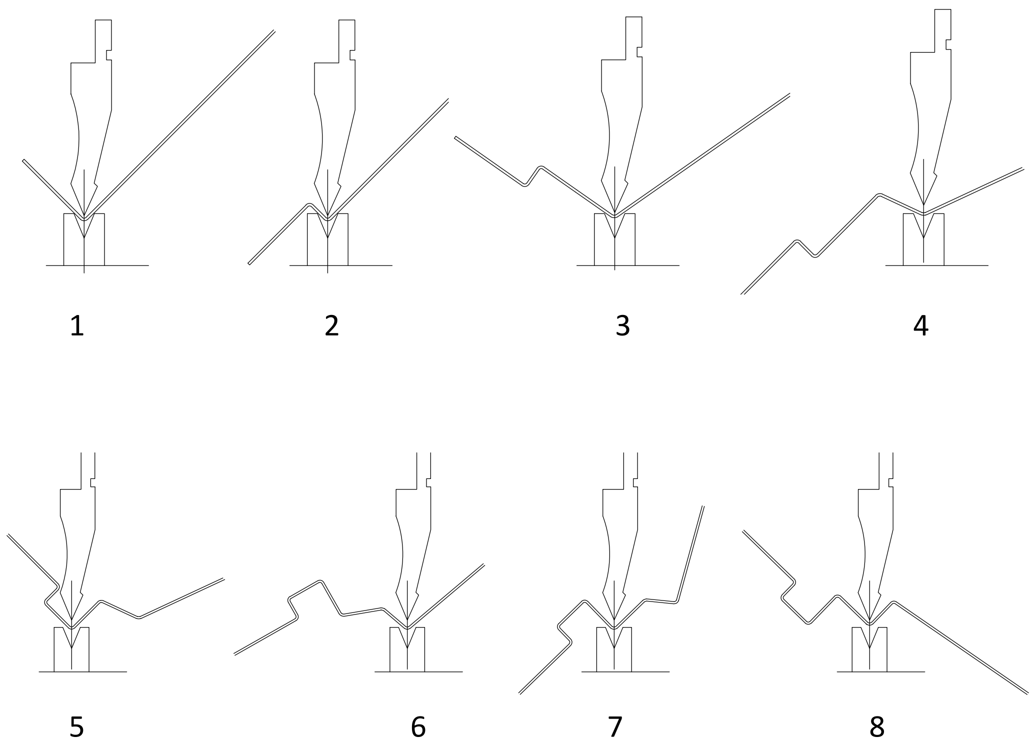


Figure 34 - Bending sequence for the new BOWA (Source: Own illustration)


Figure 35 - Bending of the new BOWA on press (Source: Own picture)

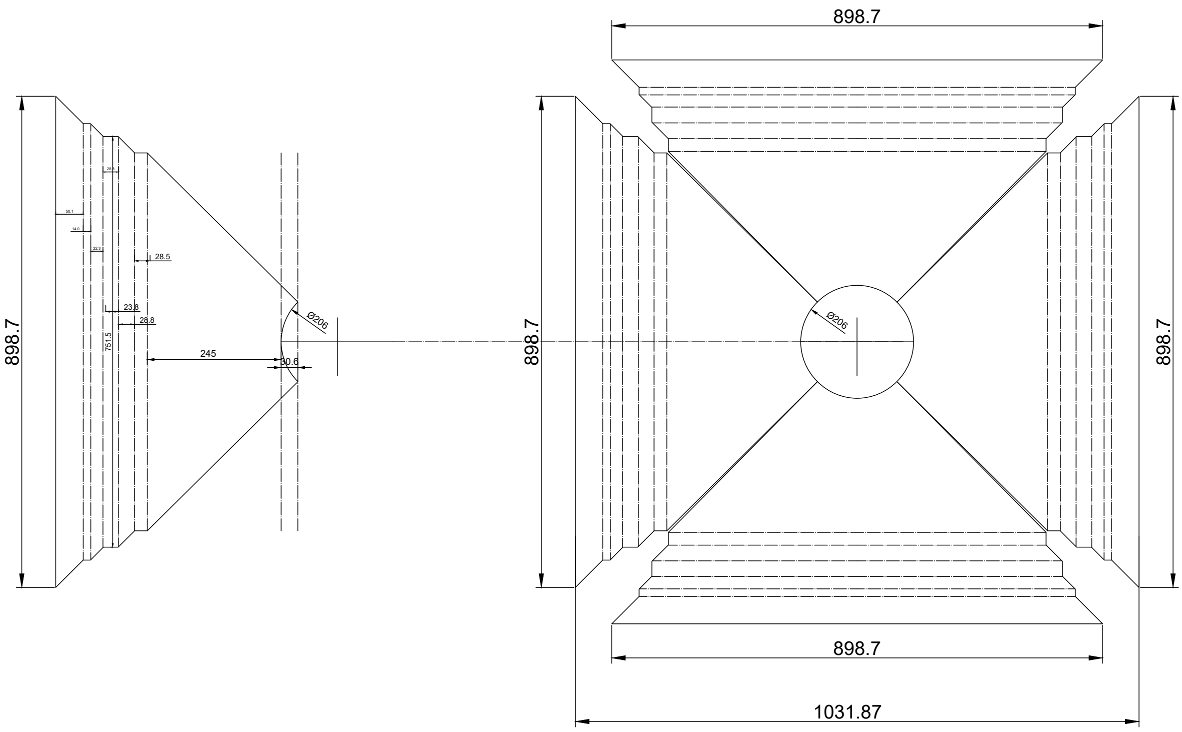


Figure 36 - Control drawing (Source: Own drawing)

However, there was one more problem which we encountered while producing BOWA with new design. Problem is that at the place where the upper part of the BOWA is connected to the tube below. The tube must be profiled so that it can fit in the construction.
For this problem, after brainstorming two different solutions on how to cut pipe had been made.

1. First solution

The problem of cutting the pipe could be easily solved if the company had the laser that could cut the pipes, but TTO does not have this machine right now. Because of the price for the laser which is not justified and cost effective and after consulting the customer and discussing future plans for the operation which can be performed on this machine, it has been decided that this machine will not be purchased in this moment.
After searching the market in the area of the company, one of the lasers which can cut pipes has been found at the cooperants and this job can be done by the cooperant in the future. Unfortunately, cooperant had not been able to do this for this order, so new solution was necessary to solve this problem now.

2. Second solution

The other solution which can be performed is to create a muster in scale 1:1 which will be glued on the tube, marked and then hand-cut. This solution request for more time, but space for failure is minimized. Muster is created in the program where diameter, angle and high of the pipe are defined, and the pipe is opened (1D view).

After analyzing 2 ways on how new BOWA can be produced and after comparing criteria from the chapter optimal solution, conclusion has been made.

The most effective method is to have this part made at cooperates as the time consumption is not big and costs are acceptable. Second acceptable method is second solution which has been described above and it is to hand cut the pipe. This second solution is used as a reserve, when the subcontractor is unable to accept the order.
Both solutions provide good quality and both of the solutions have proportional ratio in costs and price.

Conclusion

Regarding the new design on BOWA, main reason for a change was that constant flow of liquid was stopped. This problem had been solved.

Table 4 - Final parameters for BOWA (Source: Own picture)

	Old BOWA	New BOWA	
Laser (m)	3,347	3,345	↘ 0,002
Laser (s)	50	48	↘ 2
Bending steps	20	24 (32)	↗ 2

In the Table above, final parameters for old and new design of the BOWA can be seen.
Laser cutting process is reduced by 2 s and 0,002 m.
Regarding the bending for new BOWA, as explained, new BOWA had a special request which consisted of 8 additional bends. When additional request (additional bends) are not counted, one BOWA needs 24 bends. This means that number of bends had been increased by four.
As an addition to the parameters from the table, pipe problem discussed in the previous chapter is also a new addition to the new BOWA.
As all of the changes are minor, final price for old and new design of BOWA has remained the same. Main task for this chapter had been to enable constant flow of the liquid in the BOWA and to stop hold of the liquid in the down part of the BOWA and this request has been resolved.

5. KORA

Introduction

KORA (ger. Kombirinne translation: comping channel) is shown on the Figure 37, is completely made of stainless steel V2A (1.4301) with a material thickness: 1.5 mm.
KORA is suitable for surface drainage in many different areas of application. It has a channel gradient of 0.5% and a M load class (125 kN). It offers safe removal of dirt even with little water (easy cleaning) and has antibacterial hygienic form. Fixation to the surface is done every 500 mm with welded wall anchors or with height-adjustable screws.
KORA comes with a drain connection and connection element and can be made without edge reinforcement.
Depending on the environment and special requests, KORA can be completely made of stainless steel V4A (1.4571) and with a material thickness: 2 mm. [29]

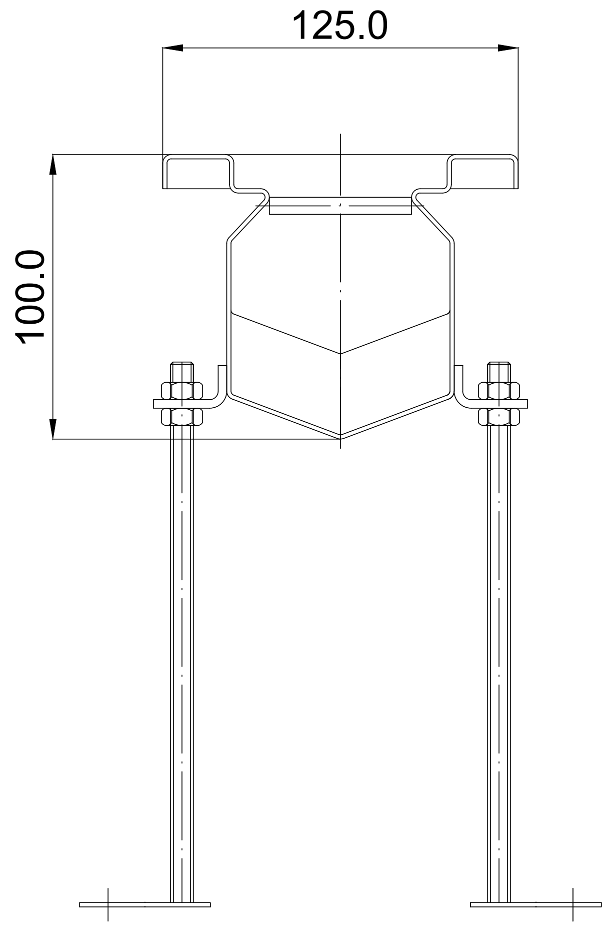


Figure 37 – KORA (Source: Product drawing)

[29] ASCHL (2013), Online source [date 13th Nov 2019]

Standard KORAs are offered in different dimensions shown in the table below. KORA which will be covered in this thesis has a length of 6 m.

Table 5 - Different dimensions KORA (Source: ASCHL (2013), P. 53)

		Art.Nr.	
	L *Länge in mm*	**ohne Randverstärkung**	**Edelstahl-Vollmaterial** *(randverstärkt)*
Belastungsklasse	-	L *(15 kN, begehbar)*	M *(125 kN, befahrbar)*
Rinne	1000	KORA1000	KORA1000RVM
	2000	KORA2000	KORA2000RVM
	3000	KORA3000	KORA3000RVM
	4000	KORA4000	KORA4000RVM
	5000	KORA5000	KORA5000RVM
	6000	KORA6000	KORA6000RVM
Verlängerung Typ B	6000	KORB6000	KORB6000RVM
Verlängerung Typ C	6000	KORC6000	KORC6000RVM

Manufacturing

Main drawing for the product and special requests is delivered by the company ASCHL.
After accepting an order, an engineer checks the drawings and makes needed adjustment to fit the process and machines properly.
Dimension and weight of the material is calculated and sent to the procurement department which will provide needed material (by ordering or by taking material from inventory).
After, an engineer who is Project Manager for this order, will analyzing KORA drawings and will define production flow and control milestones in the production. Production flow is:

1. Cutting
2. Bending
3. Connecting parts together/ Welding
4. Adding necessary accessories.

Production flow and control points are given to the main master. Main master is in charge of an order from this moment till the final control of the order and till the packing for transport.

1. Cutting

Based on the resources in the company TTO, cutting can be made either on Laser cutter Bystronic machine or on Plasma cutter. Analyze and discussion on which method will be used for cutting has been made in the first chapter and same solution will be used for this position. Laser cutter Bystronic is chosen for cutting the parts.

Drawings for a Laser machine are prepared and sent to the operator working on the laser cutter. Laser drawing consists of open positions with engravings and can be seen on the figure 39. Engravings are done due to addition help, with a goal of reducing time and minimizing chances for a failure in the next phases. For example, engravings will help to the operator on the bending machine to position the part properly and to make a bend on the right side.

On the drawing for every part which is send on laser it is necessary to define next points:

- Which material is used for this part,
- Thickness of the material,
- Number of pieces.

Note: As it can be seen on the drawing for the laser (figure 39), width on one side of KORA is 340mm and on the other side it is 309,99. This is because KORA is made with a slope, which is needed to facilitate the flow of fluid into the further drainage system.
The dimensions for the slope are taken from the main drawing. The main drawing shows the difference in the high which means that beginning and end of the KORA are not the same (shown on figure 38).
Dimensions given on the main drawing are for the bended position. The total dimension of the opened position should be calculated. The most important parameters for calculation are the inner length of the bended sides and the bending angles.
Since the front and the back of the KORA are not the same (because of the slope), the process of calculating opened length of the position needs to be calculated two times.
Dimension of beginning of the KORA is 340mm and of the end of the KORA is 309,99.

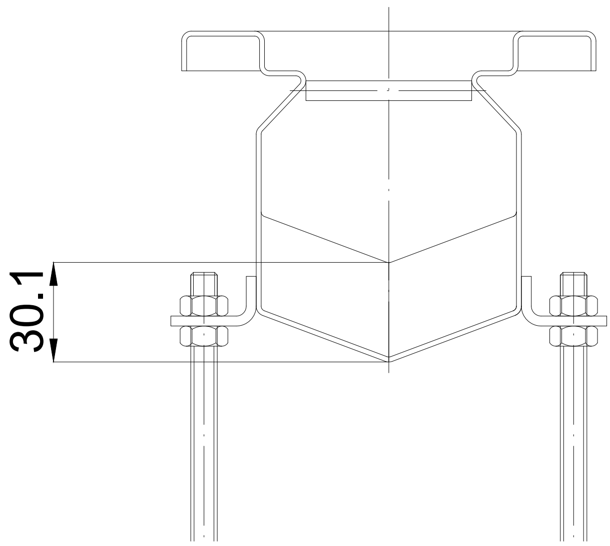


Figure 38 - High difference (Source: Own illustration)

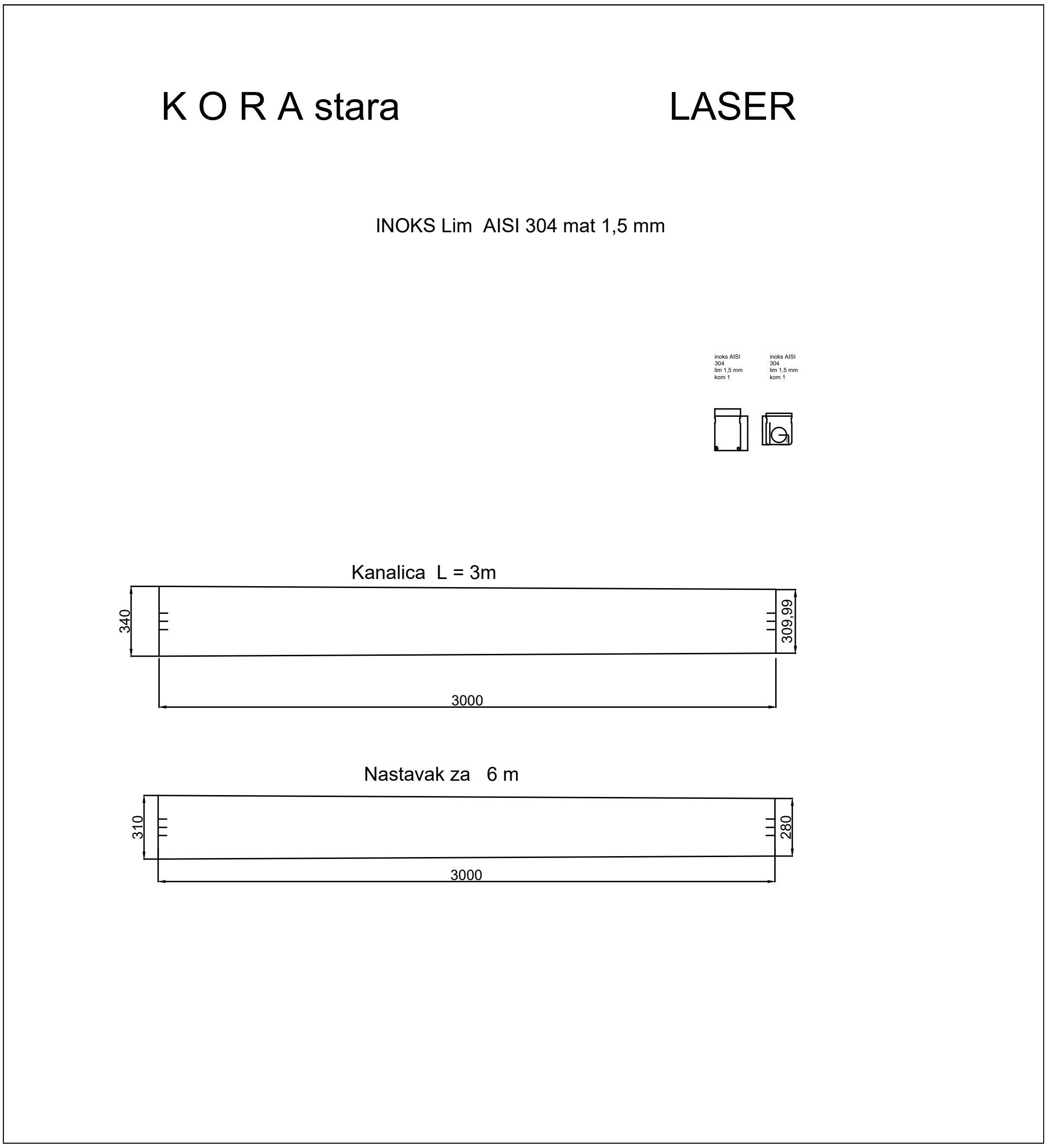


Figure 39 - Laser drawing for KORA (Source: Own drawing)

Before giving a command to cut the pieces, operator has a several tasks to preform and double check. The tasks are mentioned above and are written on the drawing which, as explained, has been sent by an engineer. Due to waste reduction, engineer guides the operator on how to position each piece which is to be cut out onto the metal sheet. Parameters for the process of laser cutting the KORA and the optimal positioning of the pieces on the metal sheet can be seen in the Appendix D.

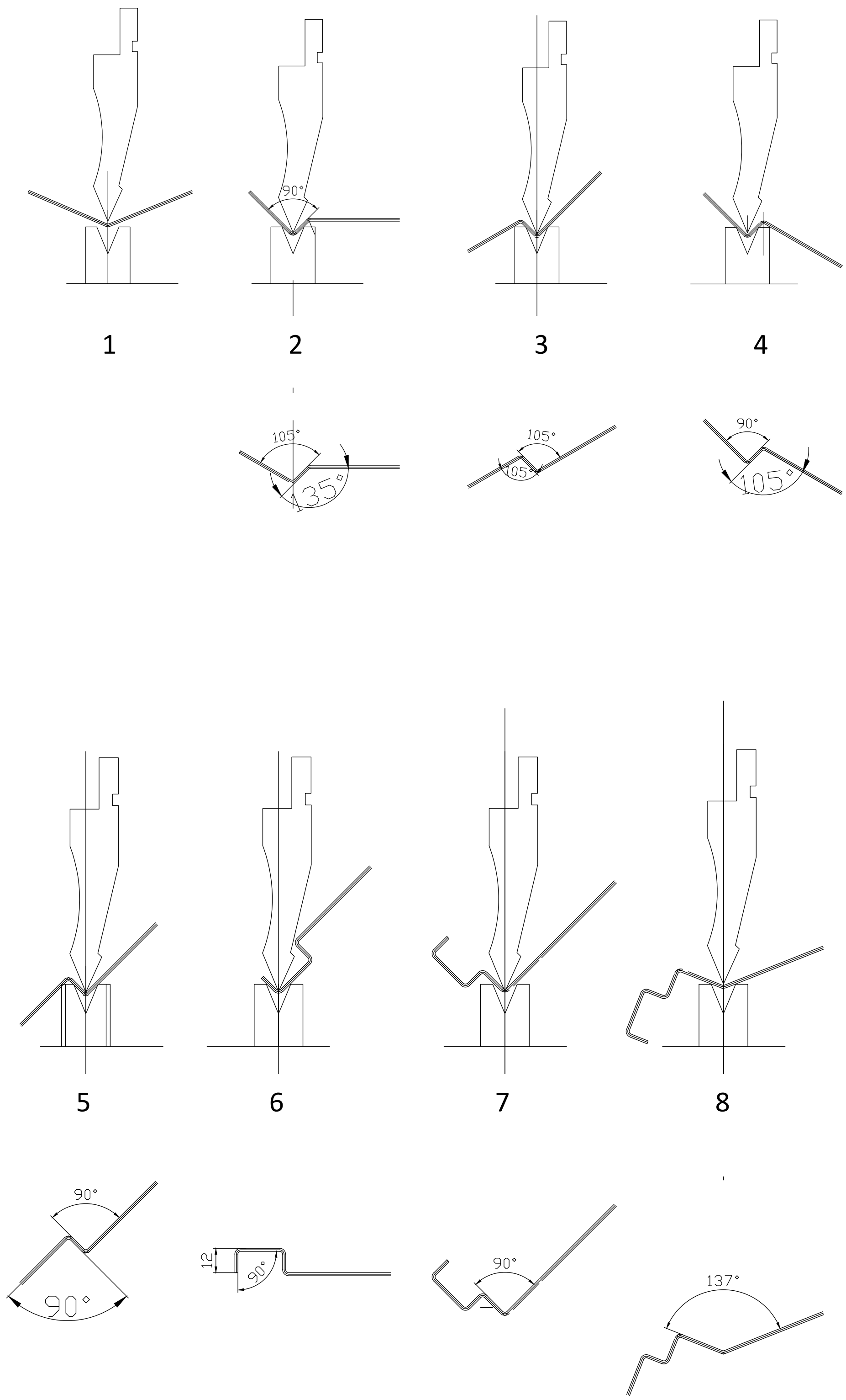
One KORA (3 m length) requires a 168 s of works and length of the cut is 15,155 m in total.

2. Bending

Bending process is done on Durma AD-S 30135. In the first chapter, theoretical overview of process and machine can be found.

Depending on the tools which company has, an engineer has to check if all bends can be performed and after analyzing important parameters, an engineer has to create a bending sequence. It is important to note which tool and which channel (punch and die) should be used for each bending step.

Bending flow for one part of the KORA is shown on the figure below.
When ordering bending sequence, an engineer has to make sure that tool can enter and exit a process without any obstacles, and an engineer has to make sure that bends will not affect one to another.
Bending steps 1-9 create needed form on one side of the KORA. Then all of the steps in the same sequence need to be repeated on the other side of the KORA.
At the end, final steps 10 and 11 can be performed.
Step 10 needs to be performed 2 times on the two sides of KORA.
Now, bending of the KORA is done and bending phase consists of 21 bending steps which are all performed by the same tool.
In the bending steps 1-5, only 2 bends close on to another with a 90° angle are made. Five steps were necessary because of the deformations which can be caused if this had been done only in 2 steps.
Bend step 9 had resulted in a lot of complications and was quite hard to perform. The reason was mainly problems with positioning of the tool due to long part. This bend step lasted 3 times longer than other steps.
After bending, it is important to check all bends with digital measuring equipment, to check straightness and angles.


1
2
3
4
90°
105°
135°
105°
105°
90°
105°
5
6
7
8
90°
90°
12
90°
90°
137°

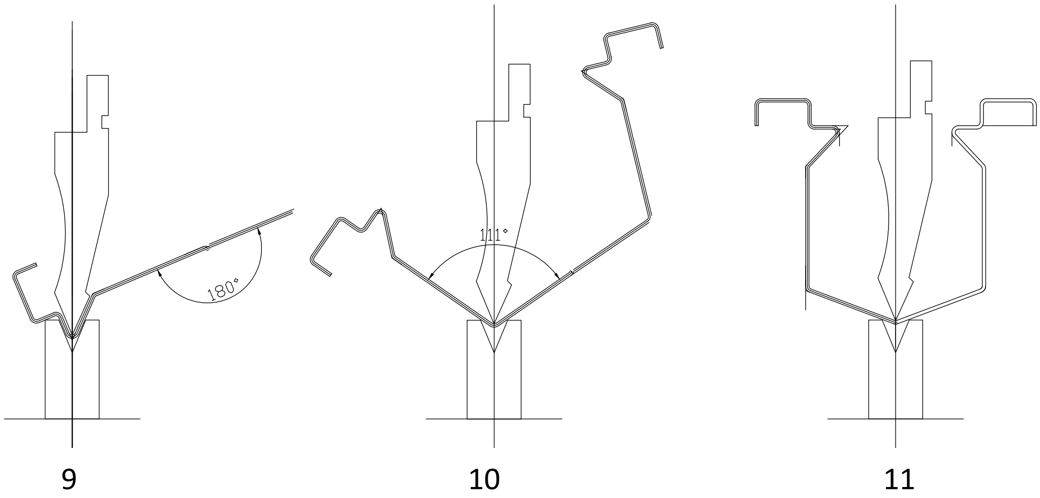


Figure 40 - Bending steps for KORA (Source: Own illustration)

Figure 41 - KORA (Source: Own picture)

Figure 41 shows how KORA looks after bending is done and cover is welded onto the position.

Additional parts

Position 1 - Concrete anchor

Concrete anchor is used to enable the secure fixing of the product into the concrete. Concrete anchor can be seen on the Figure 42 and positioning of this position can be seen on Figure 46.

Number of concrete anchors is defined in the table provided in the product drawings and can be seen in the table below.

Table 6 - Number of anchors (Source: Product drawing)

1m drain	4 adjustable feet
2m drain	6 adjustable feet
3m drain	8 adjustable feet
4m drain	10 adjustable feet
5m drain	12 adjustable feet
6m drain	14 adjustable feet
between variables	
> 500	round up
< 500	round down

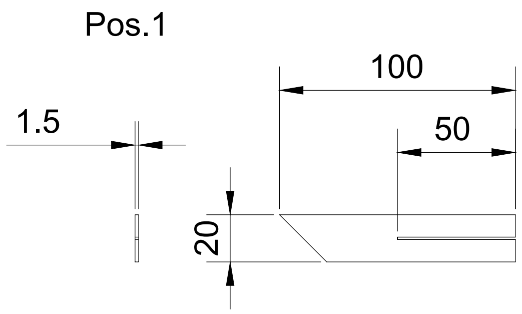


Figure 42 – Position 1 (Source: Own illustration)

Position 2 and 3 - Fixable leg
Position 2 is made of the threaded bar as it must be adjusted on uneven ground and is mounted on-site. Position 3 is welded onto the channel. Positions can be seen on Figure 43 and positioning of positions 2 and 3 can be seen on figure 46.

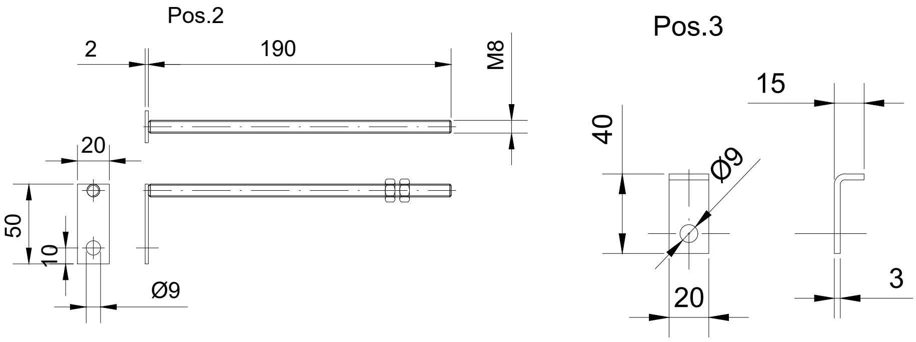


Figure 43 – Position 2 & 3 (Source: Own illustration)

Position 4 and position 5 - Side covers.
Position 4 has a welded tube on it and serves as an extension because a plastic tube is put into in. Position 5 is a classic cover that does not allow the liquid to move further. Both positions can be seen on Figure 44 and Figure 45. Positioning of positions 4 and 5, as well as of the all other additional positions can be seen on Figure 46.

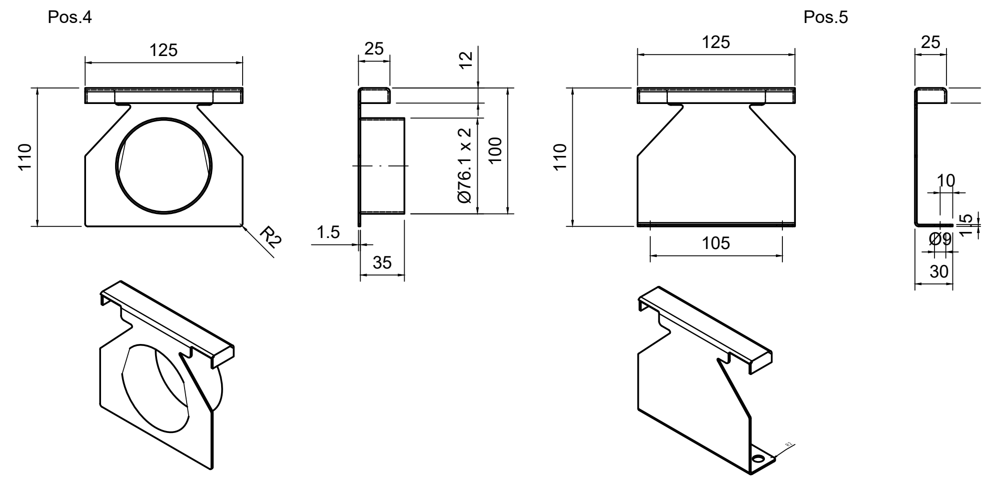


Figure 44 - Position 4 & 5 (Source: Own illustration)

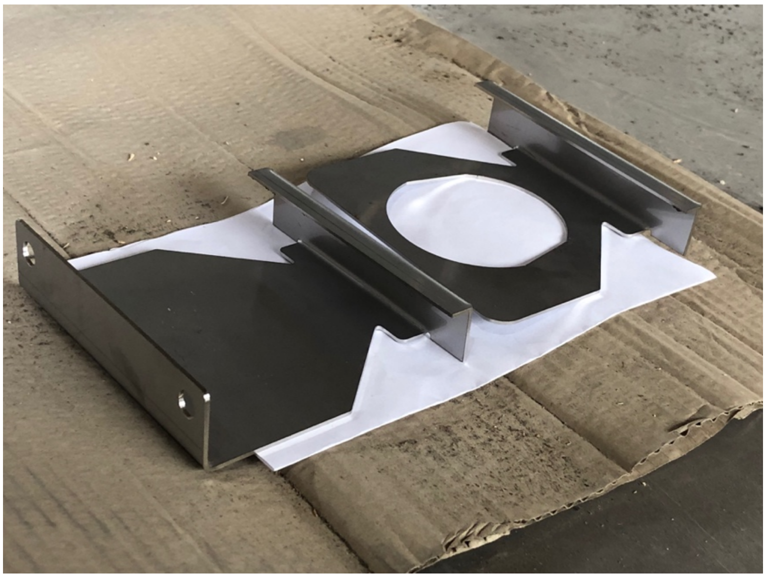


Figure 45 - Position 4 & 5 (Source: Own picture)

Positioning of the additional parts can be seen on the Figure below.

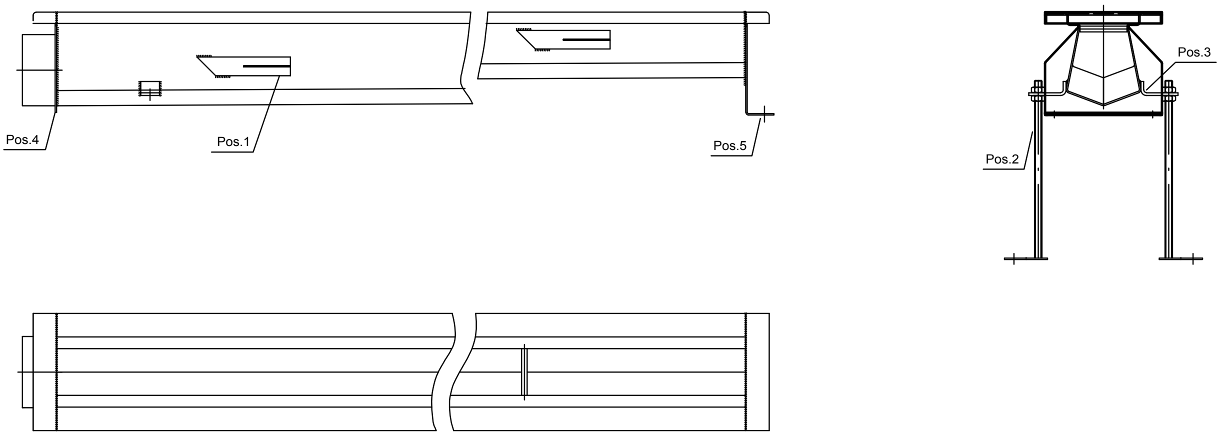


Figure 46 - Positioning of the additional parts (Source: Own drawing)

3. Welding

After bending, the positions are moved to the foreseen position and the main master for this order has to assigns a team that will start composing this part. The team consists of master and one welder who point weld all the parts together and add additional elements (legs, uprights, fasteners ...) to the construction. This position is now moved to the table of a welder who welds all parts position in the one position.

Welding tasks are defined by standard. Standard define the necessity for making a WPS which is done by EWE engineer. WPS - Welding Procedure Specification is according to Weman [30]

[30] Weman K. (2003) page 3

a document specifying the details of the required variables for a specific application in order to assure repeatability. WPS for KORA can be found in the Appendix B.
While designing the welding process, it is known that distortion and buckling [31] of the part after welding, especially of thin metal sheets, are possible due to high heat input. It is also common with larger positions, that positioning of the element represents a problem and it requires the attention of couple of workers. Because of this problem, as in the previous chapter, an engineer prescribed that the position should first be tack welded. Tack welding [32] can be considered as a preparation of the position of the components which need to be welded. Components are held (point welded) in the right position and alignment. The reasons for this approach had been explained in the previous chapter.
After welding, it is necessary to check straightness (flatness) of the position. Flatness is important because in the montage phase, top of the KORA needs to be aligned with the level of surface to which it is laid. Straightness is important, because if the KORA is placed in the garage and its flatness is not good, as the cars pass over the KORA, it may be distorted, and bursting may result. Simple tool that looks like a metal rectangle that has a notched dimension of the KORAs' internal slot is made. The tool is inserted into the KORA and shows whether whole part is straight, or it needs to be fixed. The tool can be seen in the figure below.

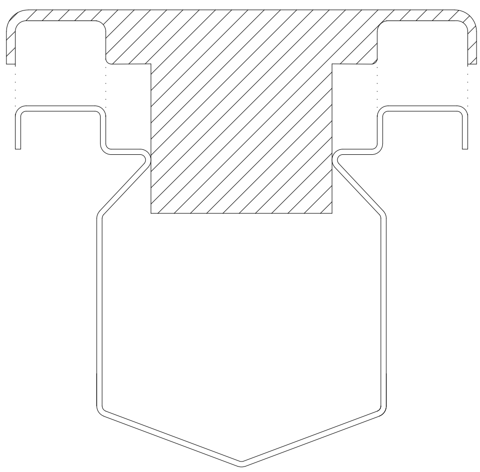


Figure 47 – Tool for KORA (Source: Own illustration)

Welding sequence as improvement

In the first order, while having no experience with this exact part, some problems were found in the welding phase of the positions 4 and 5 onto the KORA.
Welding was performed according to the delivered drawings. As it can be seen on the drawing (figure 49), the pipe was welded on both sides (Figure 48). Workers experienced problems while cleaning this weld because one part was not accessible. Due to thickness of the material, material was burned, constant water runoff was interfered and visually weld was not acceptable.

[31] T. Gray, D. Camilleri, N. McPherson (2014 page 16
[32] T. Gray, D. Camilleri, N. McPherson (2014 page 34

When consulting with an EWE engineer, it was concluded that welding on both sides is not necessary. According to the book "Control of Welding Distortion in Thin-Plate Fabrication"[33] for thin-plate materials, single side and single pass welding is acceptable.
Drawings have been corrected and checked by an EWE engineer. Furtherly, this part will only be welded prom the outside. Improvement on the drawing can be seen on Figure 50.

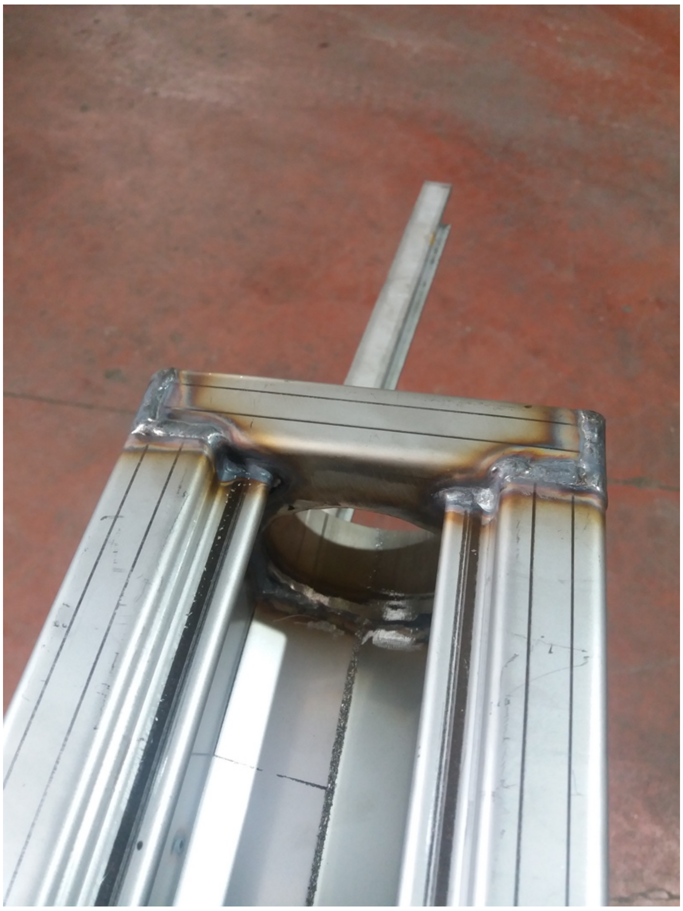


Figure 48 – Weld on both sides (Source: Own picture)

On the Figures below drawings before and after the improvement can be seen.

[33] Gray T./Camilleri D./McPherson N. (2014), P. 19

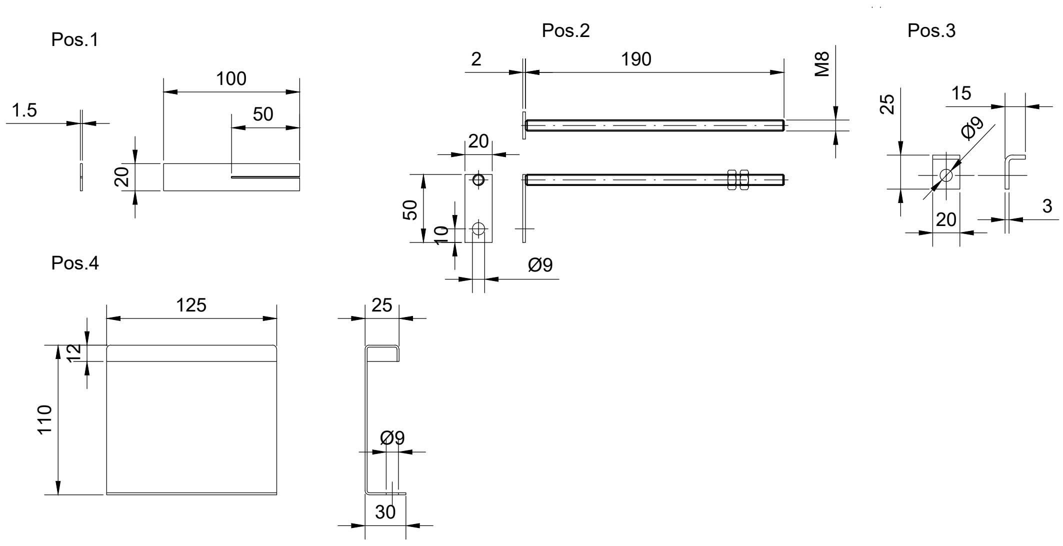


Figure 49 - KORA drawing without welding explanation (Source: Product drawing)

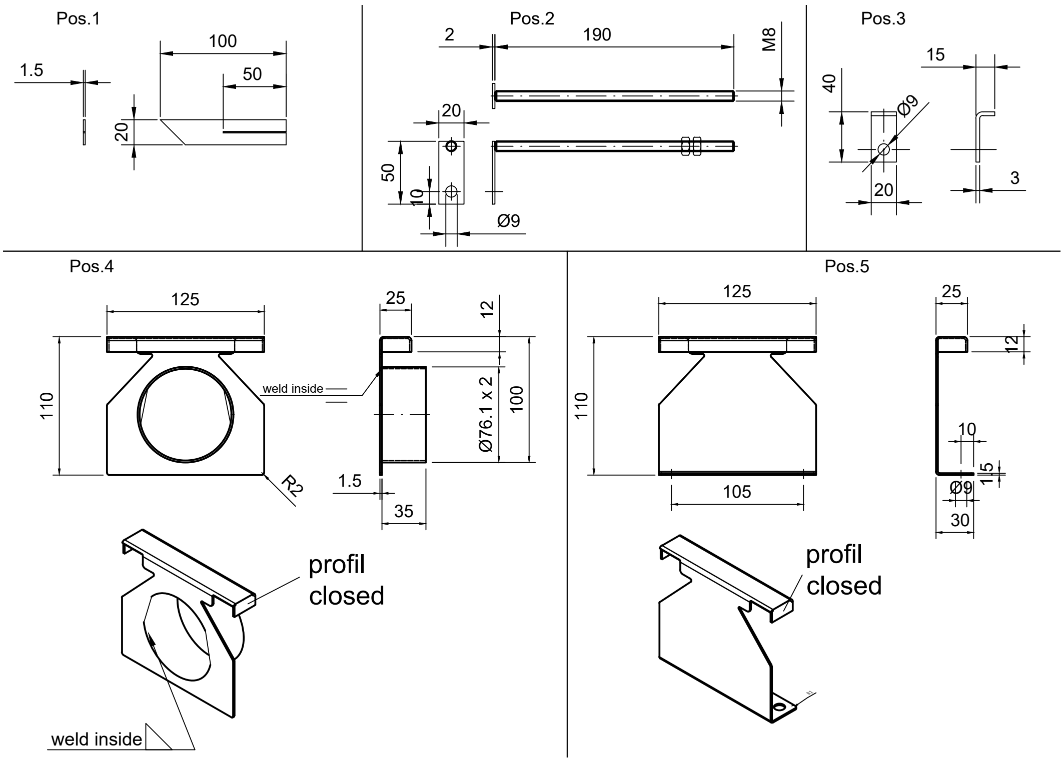


Figure 50 - KORA drawing with improvement (welding explanation) (Source: Own drawing)

Last step in the production, before packing and transport, is cleaning, washing and coating. This step was in detail explained in the first chapter and it is the same for this part.

Problem and solutions

Main task in this chapter is to reduce complexity for manufacturing KORA.
After applying 5 why method, main problem had been narrowed and it is concluded that the problem is found in the bending phase of the production.
Problematic bend is shown on the Figure below.

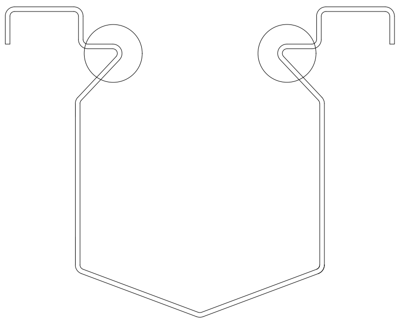


Figure 51 - Problematic bend (Source: Own illustration)

Two solutions were made for the problem described above.

1. First solution

First aim to solve this problem is to modify the production process for KORA. As already written, bending of this bend lasted 3 times longer than bending of the other bends. It is decided to split KORA into three pieces. The bending of the pieces will be done separately, and the pieces will be welded together into one unit after.
KORA would be split according to Figure 52.

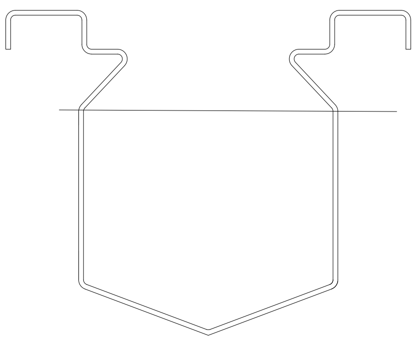


Figure 52 - KORA split (Source: Product drawing)

As it can be seen on the figure above, KORA is split into 3 pieces. Two pieces are the same and are called upper part. Third piece is KORAs' body.
On the Figure 53, bending steps for the upper part of the KORA are shown. It is needed to make two upper parts.

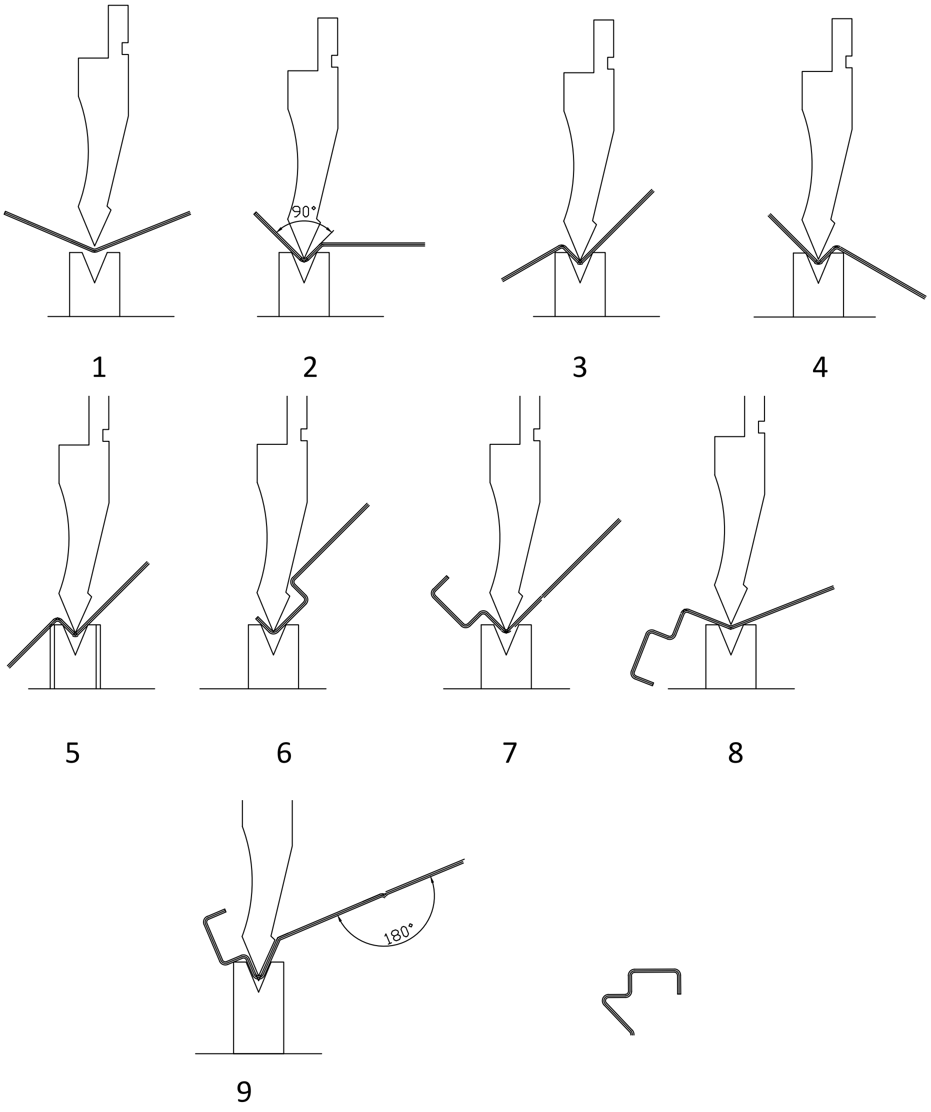


Figure 53 - Bending for ne part of KORA (Source: Own illustration)

Bending for the body is shown on the Figure below.

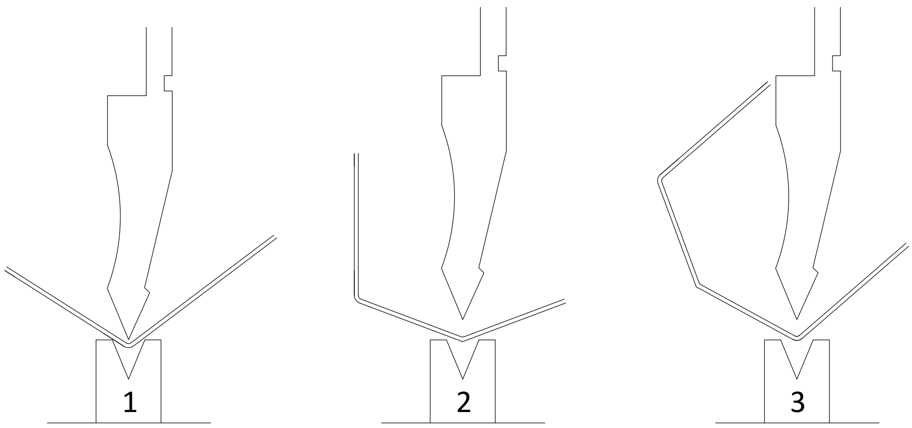


Figure 54 - Bending of the body part of KORA (Source: Own illustration)

After bending, parts need to be welded together. Because the positioning of the parts is hard, tools which should help in the welding process are built and can be seen on the Figure 55. First part of the tool (shown on left side of the Figure 55) consists of construction with legs, because of the uneven bottom of the KORA and with the aim to enable stable standing. Second part of the tool (shown on right side of the Figure 55) is a metal block which fit to the gaps of upper part. This part was built to simplify the holding and positioning of two pieces while welding.

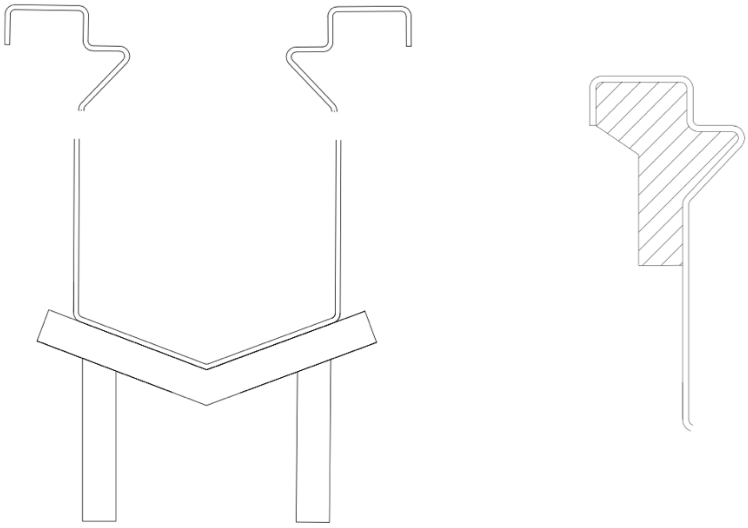


Figure 55 - Tools for KORA (Source: Own illustration)

It is important to note that additional welding performed for this task had a length of 12 m. This number will be taken into consideration in the conclusion on which solution is the best.

2. Second solution

After analyzing design of the KORA, it is decided that the problematic bend (Figure 42) has no special purpose and can be simplified, so this solution is based on modifications to the design of the KORA. Problematic bend had been ejected and the slope of the rest of the KORA was altered. It is important to emphasize that the bottom and the beginning have remained the same because of the additional positions and their positioning and because of the assembly process. Additional advantage of the new design is easier approach to all parts of the position in the cleaning phase. Picture of the new design of the KORA is shown on the Figure 56.

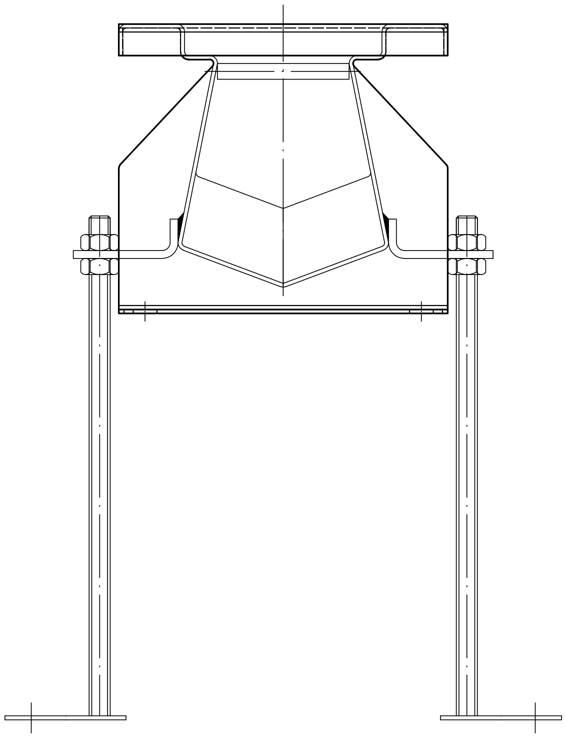


Figure 56 - New design of KORA (Source: Product drawing)

Drawings for a Laser cutter are changed with a new design and can be seen on the figure 57. and sent to the machine operator. Parameters for the laser cutter for new KORA, as well as the suggested positioning of the positions on the metal sheet can be found in an Appendix E.

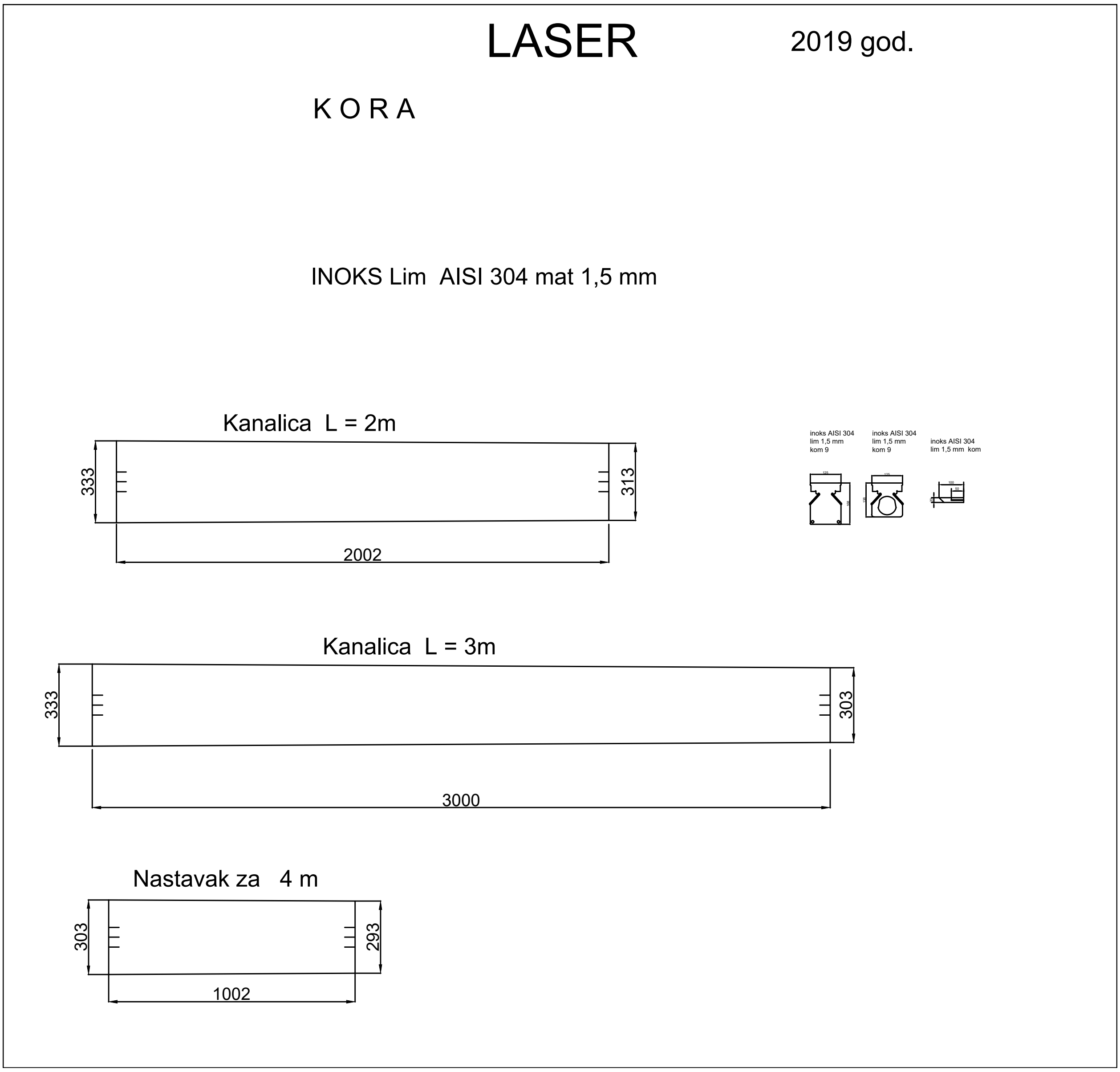


Figure 57 - Laser drawing for the new design of KORA (Source: Own drawing)

One new KORA (length 3 m) requires a 173 s of works and length of the cut is 15,488 m in total.

After parts are cut, they are transferred to the bending press. Bending flow for one part of the KORA is shown on the Figures 58 and a picture from the actual bending process is shown on the Figure 59. Bending steps 1-8 are needed bends for one top side of the KORA. Bending steps 1-8 need to be repeated on the other side of KORA. Final steps 9 should be repeated on the other side also. Final step 10 should be performed. KORA with a new design is now bended and has 19 steps in total.

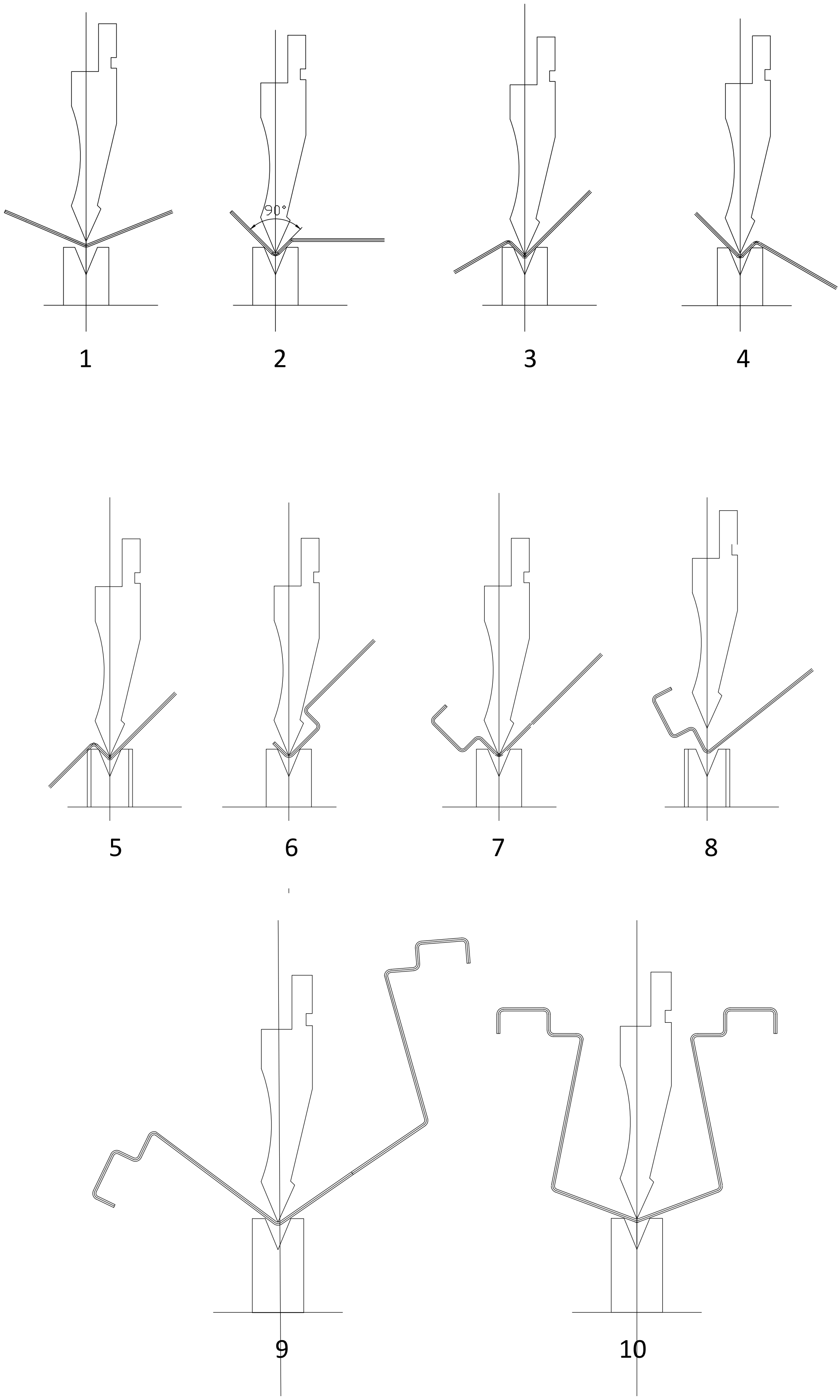


Figure 58 - Bending for new KORA (Source: Own illustration)

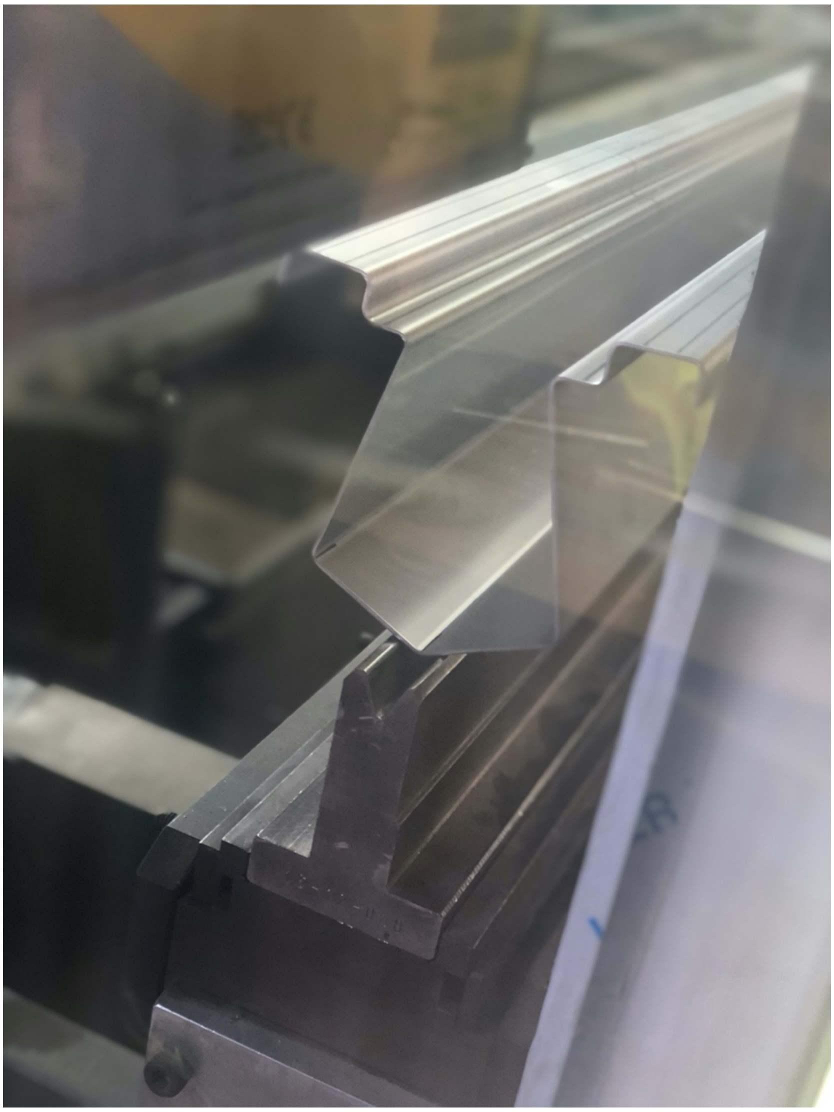


Figure 59 - KORA in the bending phase (Source: Own picture)

Before continuing with further processes in the production, conclusion which solution is the best should be made.

Conclusion

In the table below, final parameters for the solution 1 and 2 can be seen.
While performing first solution, KORA can be made but factors which can be seen in the table 5 are increasing costs for the production process and therefore are increasing the price tremendously. Costs are increased mainly because of the welding.
Second solution, the optimization of the design of the KORA simplified the production process while functionality of the product had been left unchanged.
After analyzing parameters from the Table 7 and the criteria from the chapter Optimal solution, it has been decided that due to effectiveness (time consumptions, people enrolled, complexity, final quality of the product and easier cleaning) it will be furtherly proceeded with the Solution 2.

Table 7 - Final parameters for solution 1 and 2 (Source: Own illustration)

	Solution 1	Solution 2	
Laser (m)	15 155	15 155	0
Laser (s)	168	168	0
Bending steps	21	19	↘ 2
Additional welding (m)	12	0	-

6. SPA

Introduction

Spa (ger. Sanitärrinnen means sanitary channel) can be seen on the figure 60.
The rimless channel integrates optically perfectly, almost invisibly, into the floor of bathing and wellness areas. An ideal solution in drainage technology. The Europe-wide patented design is manufactured in stainless steel V4A and can be walked on barefoot thanks to the slit width of 8 mm. The circumferential adhesive flange seals the upper drainage level optimally, the integrated channel slope and the V-edge secure the water and dirt drainage. Protection against odor nuisance is achieved by the addition of a sanitary drain with gutter connection. [34]

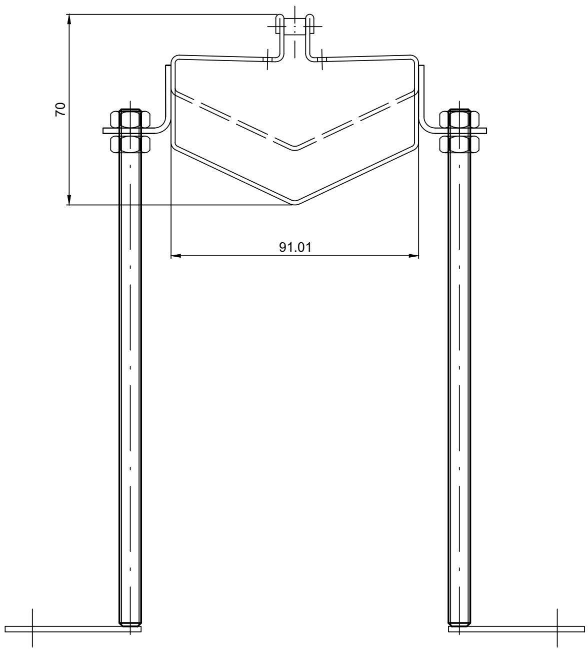
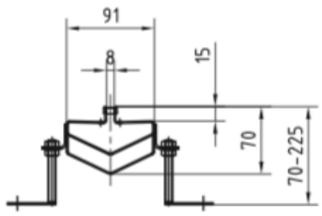


Figure 60 – SPA (Source: Product drawing)

SPA (shown on Figure 60), just like every other product can be delivered in different sizes. Table below shows standard sizes of the SPA [35]. In this thesis, SPA with the length of 2 meters will be covered.

[34] ASCHL, Online source [date 13th Nov 2019]
[35] ASCHL, Online source [date 13th Nov 2019]

Table 8 - SPA dimensions (Source: ASCHL (2013), P. 105)



L (in mm)	*randlos* Art.Nr.
1000	SPAA1000
2000	SPAA2000
3000	SPAA3000
4000	SPAA4000
5000	SPAA5000
6000	SPAA6000
6000 (Verlängerter Typ B)	SPAB6000

Manufacturing

Main drawing for the product and special requests are delivered by the company ASCHL. After accepting an order, an engineer checks the drawings and makes needed adjustment to fit the process and machines properly.
Dimension and weight of the material is calculated and sent to the procurement department which will provide needed material (by ordering or by taking material from inventory).
After, an engineer who is Project Manager for this order, will analyze SPA drawings and will define production flow and control milestones in the production. Production flow is:

1. Cutting
2. Bending
3. Connecting parts together/ Welding
4. Adding necessary accessories.

Production flow and control points are given to the main master. Main master is in charge of an order from this moment till the final control of the order and till the packing for transport.

1. Cutting

Based on the resources in the company TTO, cutting can be made either on Laser cutter Bystronic machine or on Plasma cutter. Analyze and discussion on which method will be used for cutting has been made in the first chapter and same solution will be used for this position. Laser cutter Bystronic is chosen for cutting the parts.

Drawings for a Laser machine are prepared and sent to the operator working on the laser cutter. Laser drawing consists of open positions with engravings and can be seen on the figure 61. Engravings are done due to addition help, with a goal of reducing time and minimizing chances for a failure in the next phases. For example, engravings will help to the operator on the bending machine to position the part properly and to make a bend on the right side.

On the drawing for every part which is send on laser it is necessary to define next points:

- Which material is used for this part,
- Thickness of the material,
- Number of pieces.

Note: As it can be seen on the drawing for the laser (figure 61), width on one side of SPA is 284mm and on the other side it is 263,97mm. This is because SPA is made with a slope, which is needed to facilitate the flow of fluid into the further drainage system.
The dimensions for the slope are taken from the main drawing. The main drawing shows the difference in the high which means that beginning and end of the SPA are not the same (shown on figure 62).
Dimensions given on the main drawing are for the bended position. The total dimension of the opened position should be calculated. The most important parameters for calculation are the inner length of the bended sides and the bending angles.
Since the front and the back of the SPA are not the same (see figure 62), the process of calculating opened length of the position needs to be calculated two times.
Dimension of beginning of the SPA is 284mm and of the end of the SPA is 263,97.
Beginning and the end of the SPA, shown on the figure 62, are also important for the design of the bending process. If an engineer only observes beginning of the SPA and creates bending process according to this side, there is possibility that the same bending process will not be possible for the end of the SPA – for the other side. Therefore, as the end of the SPA is tighter, bending process will be designed according to this side and it will fit the other side also.

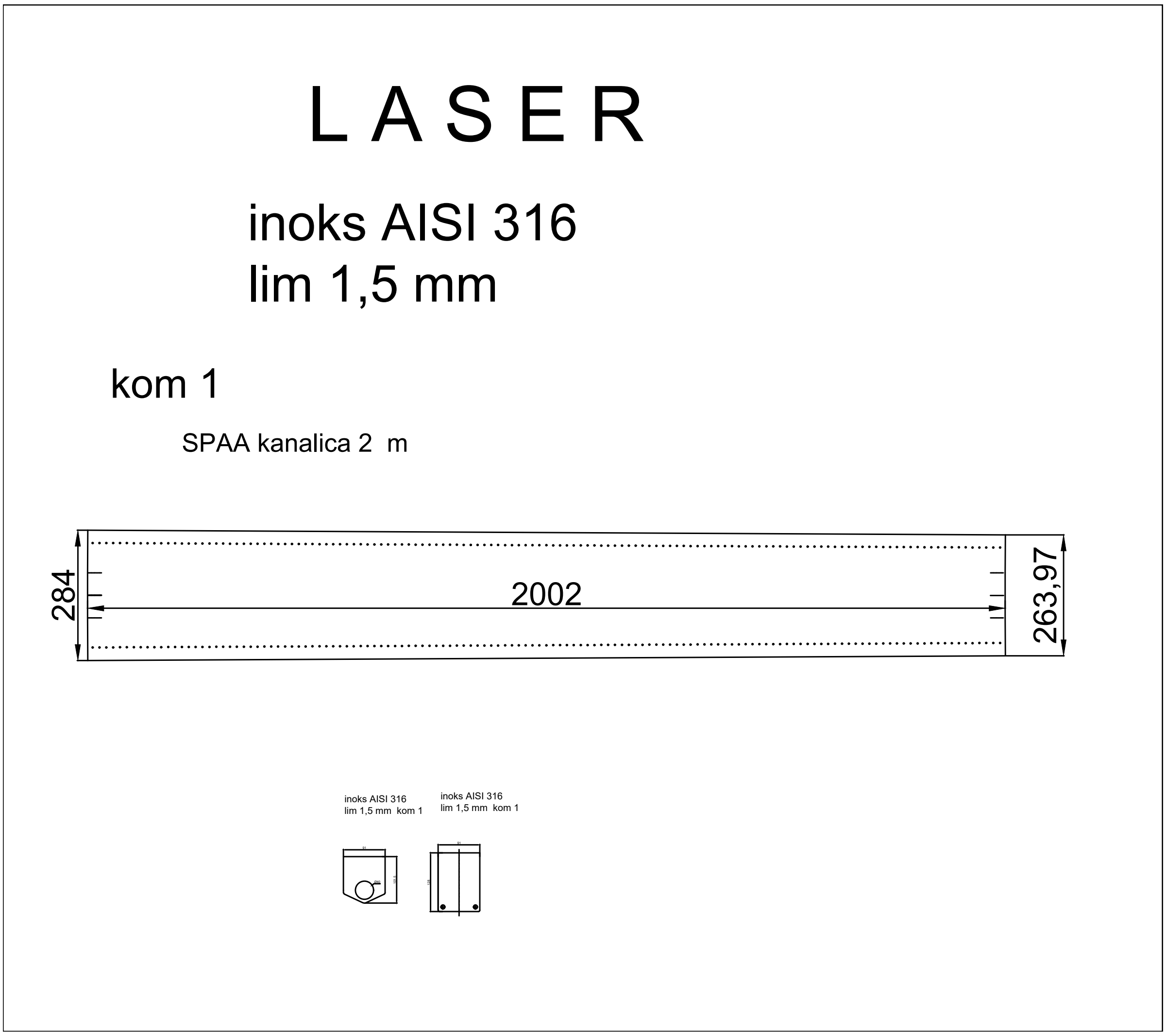


Figure 61 - Laser drawing for SPA (Source: Own drawing)

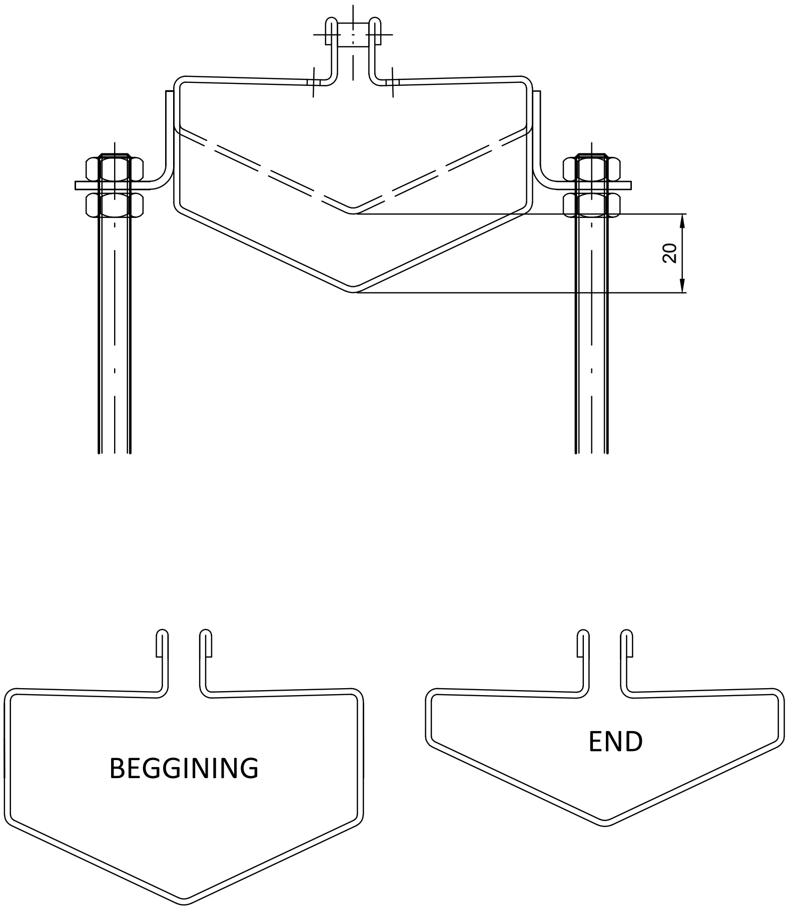


Figure 62 - SPAs' slope (Own illustration)

Before giving a command to cut the pieces, operator has a several tasks to preform and double check. The tasks are mentioned above and are written on the drawing which, as explained, has been sent by an engineer. Due to waste reduction, engineer guides the operator on how to position each piece which is to be cut out onto the metal sheet. Parameters for the process of laser cutting the SPA and the optimal positioning of the pieces on the metal sheet can be seen in the Appendix G.
One SPA (2 m length) requires a 381 s of works and length of the cut is 8,701 m in total.

2. Bending

After parts are cut in given order, they are transferred to the bending press where the problem had been found. Problems will be discussed in the next chapter.

Additional elements

Position 1 and 2 - Fixable leg
Position 1 is welded onto the channel. Position 2 is made of the threaded bar as it must be adjusted on uneven ground and is mounted on-site. Both positions can be seen on the Figure 63.

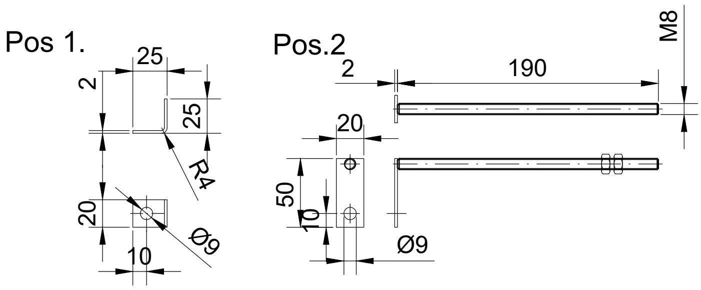


Figure 63 – Position 1 (Source: Own illustration)

Position 3, 4 and 5- Concrete anchor
Position 3 is used to securely fix the channel into the concrete. This position can be seen on Figure 64.

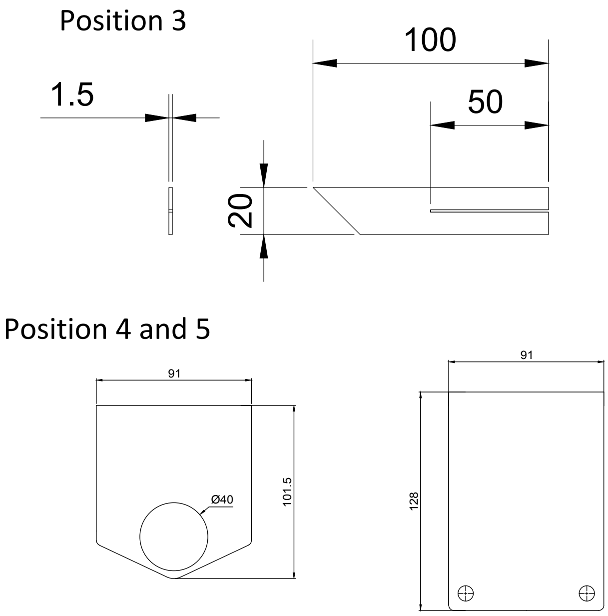


Figure 64 – Positions 3, 4 and 5 (Source: Own illustration)

Position 4 and 5 – Side covers
Position 4 and 5 will be welded on the end of the SPA. Side covers are used for the pipe from the drainage system. Positions can be seen on Figure 64.

Positioning of the additional parts

On the Figure below, positions of each additional part are shown.

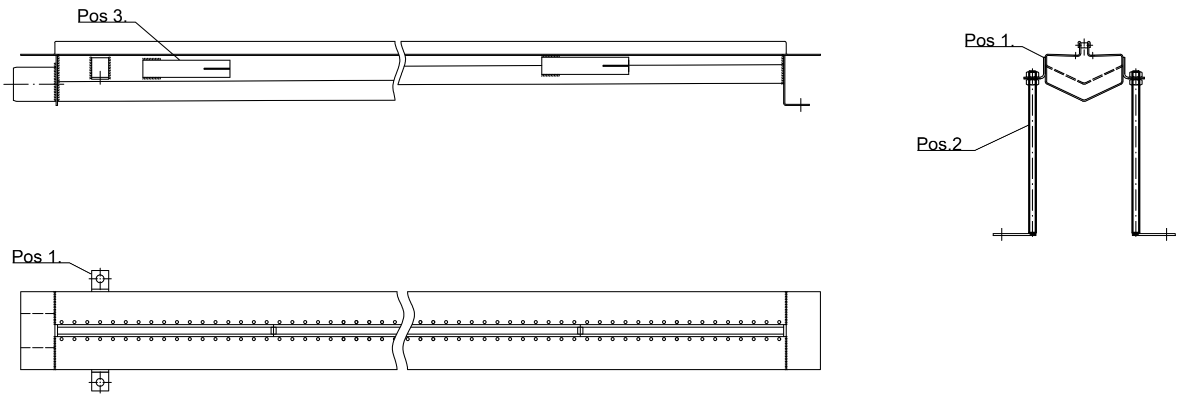


Figure 65 - Positioning of the additional parts for SPA (Source: Own drawing)

3. Welding

After bending, the positions are moved to the foreseen position and the main master for this order has to assigns a team that will start composing this part. The team consists of master and one welder who point weld all the parts together and add additional elements (legs, uprights, fasteners ...) to the construction. This position is now moved to the table of a welder who welds all parts position in the one position.

Welding tasks are defined by standard. Standard define the necessity for making a WPS which is done by an EWE engineer. WPS - Welding Procedure Specification is according to Weman [36] a document specifying the details of the required variables for a specific application in order to assure repeatability. WPS for SPA can be found in the Appendix G.

While designing the welding process, it is known that distortion and buckling [37] of the part after welding, especially of thin metal sheets, are possible due to high heat input. It is also common with larger positions, that positioning of the element represents a problem and it requires the attention of couple of workers. Because of this problem, as in the previous chapter, an engineer prescribed that the position should first be tack welded. Teck welding[38] can be considered as a preparation of the position of the components which need to be welded. Components are held (point welded) in the right position and alignment. The reasons for this approach had been explained in the previous chapter.

Figures 66 and 67 show how SPA looks after welding is performed.

[36] Weman K. (2003), P. 3
[37] Gray T./Camilleri D./McPherson N. (2014), P. 16
[38] Gray T./Camilleri D./McPherson N. (2014), P. 34

Figure 66 - Narrow top of the SPA (Source: Own picture)

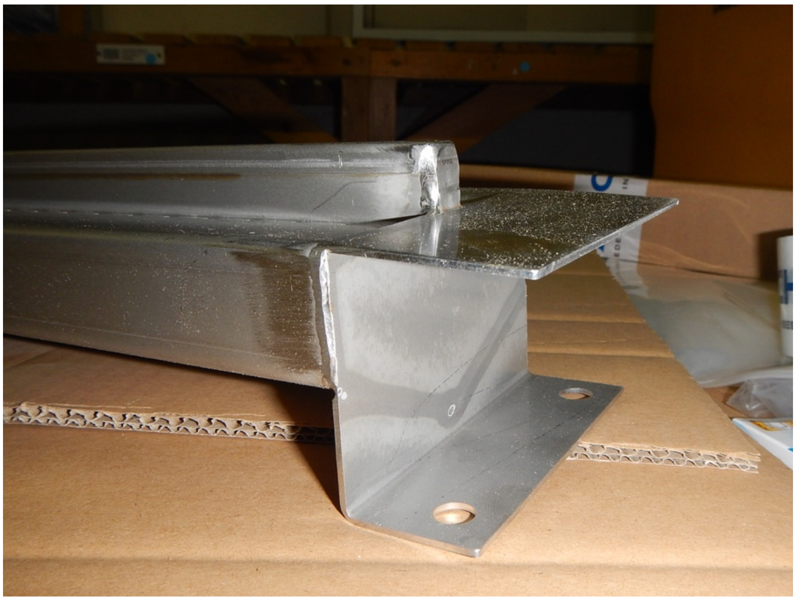


Figure 67 – SPA (Source: Own picture)

Last step in the production, before packing and transport, is cleaning, washing and coating. Cleaning phase is in detailed explained in the first chapter. The basics are the same for SPA. Due to the narrow top of the SPA channel, it has to be sink into the purpose-built tub. Figure 66 shows the narrow top. Problem with SPA is that brush cannot clean inside part of the position.

Problems and solutions

While analyzing the drawings for SPA, it was quite easy to see that with the current resources of the company, the process of making the SPA will be challenging. After applying 5 why method, the problems had been narrowed down to two bends.
One problem is to make position shown on the figure 68 which will be called top bend.
Second problem is shown on Figure 69. Current bending tool cannot perform one of the bends.

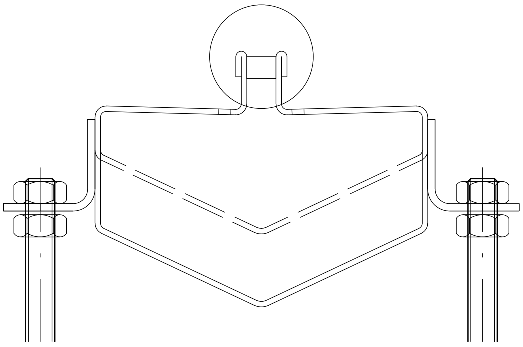


Figure 68 – Top bend (Source: Own illustration)

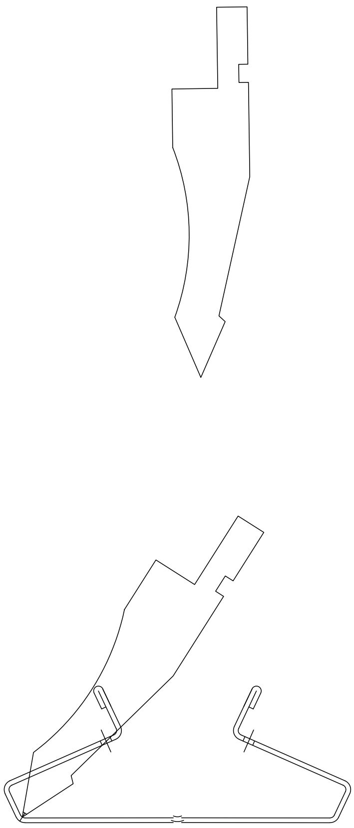


Figure 69 - SPA tool problem (Source: Own illustration)

While analyzing this problem, few of the solutions are made. Solutions are split into solutions for top bend (Solutions 1 &2) and solutions for whole piece (Solutions 3 & 4).

1. First solution

First solution is regarding the top bend. Since current tool is not eligible for bending of this part, catalog with a bending tool have been analyzed. In the catalog we found the tool especially made for this problem. Figure 70 represents a picture of an original tool from the catalog.

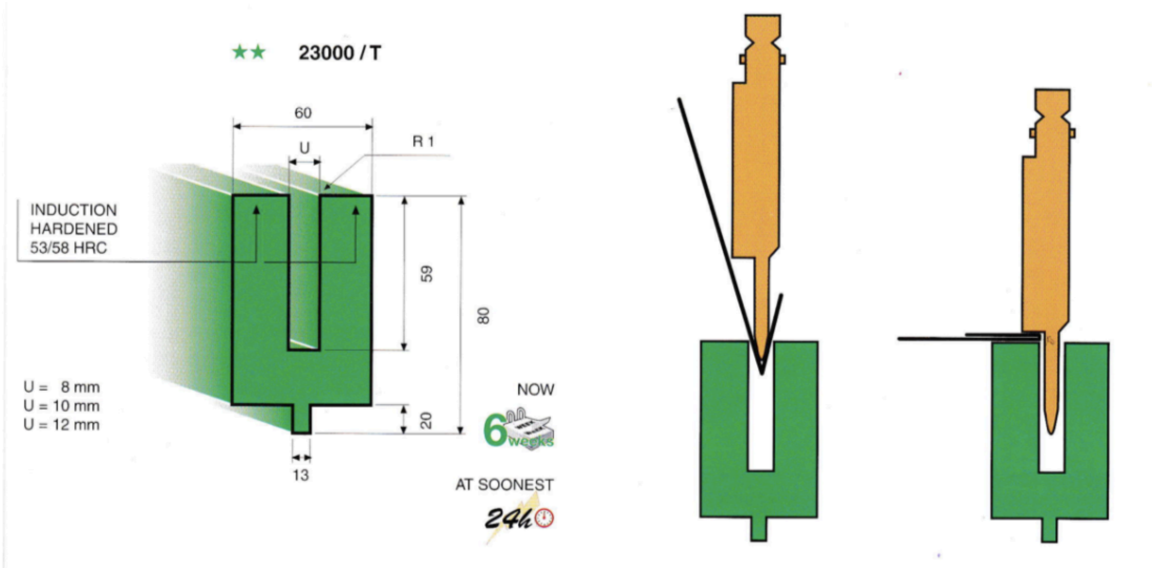


Figure 70 - Tool from a catalog (Source: EURAM (2004), P. 51)

2. Second solution

Second solution is also for the top bend. Since the tool mentioned and shown in the first solution looks simple and is easy to build, we decided not to buy this tool, but to make improvisation and make similar tool on our own. Figure 71 shows the tool made in the workshop and the bending process for top bend.

Top bend is made in a two-step process, where first, tip of the sheet is bended and in the second step it is pressed with a tool.

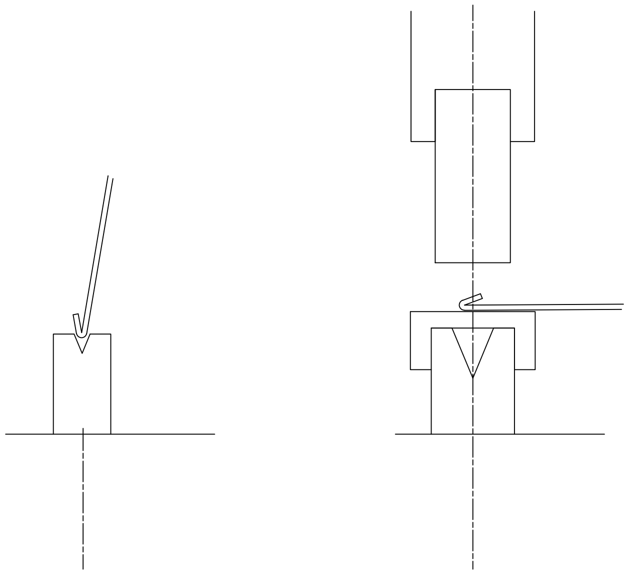


Figure 71 – Top bend bending (Source: Own illustration)

3. Third solution

Third solution is regarding the bending of the whole product. In this solution, idea is to redesign the manufacturing process for the SPA. The idea is to split SPA into three parts.

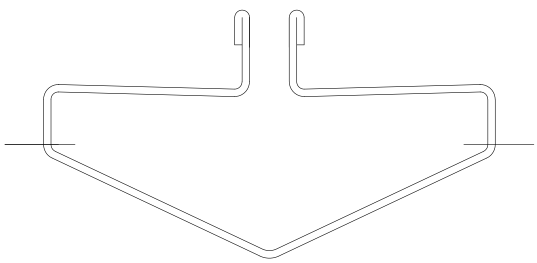


Figure 72 - SPA split into three parts (Source: Own illustration)

As seen on the picture above, 2 parts are the same and third part only has one bend. Parts will be bent separately and at the end all three parts will be welded into one unit.
Bending of the parts is shown on the figure 73. As it can be seen on the pictures, bending of the top bend is not shown as the conclusion on how to make the top bend is still not made. In the conclusion, all bending steps will be shown.
Bending steps 1 and 2, from the figure 73, need to perform two times on different sheets of metal. That is for the two parts of the SPA which are the same.
Bending step 3, from the figure 73, is the bend for the third part of SPA. This bend had been performed with thin custom-made tool.
All parts of the SPA are done now. Bending sequence in total has 5 steps.

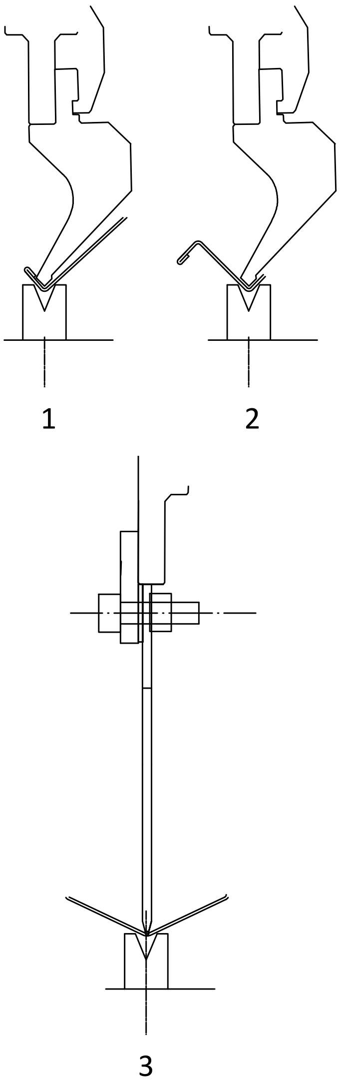


Figure 73 - Bending for SPA – Solution 3 (Source: Own illustration)

Figure below shows how the welding of parts will be performed.
As it can be seen on the Figure 74, holding structure had been made due to uneven bottom of the part.
It is important to note that all of the additionally made tools will also influence the price and final decision. In the next chapter, solutions will be analyzed and compared, and final decision will be made.

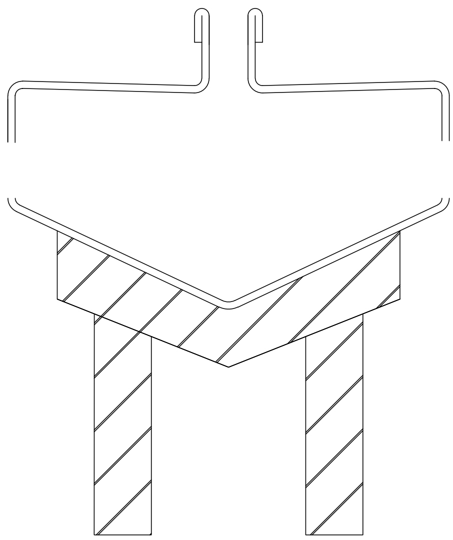


Figure 74 - Welding of parts into unit (Source: Own illustration)

4. Fourth solution

This solution is to modify the production process by using another tool. After analyzing tools from the catalog, we found the tool which, after small modification on the product, can fit in the production of this position.

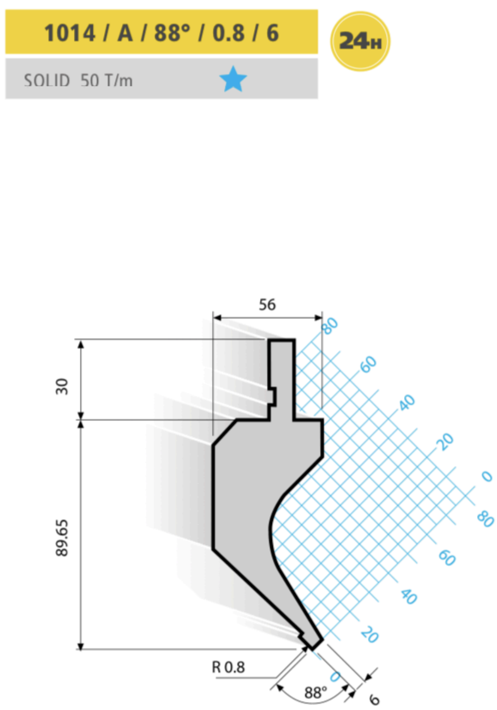
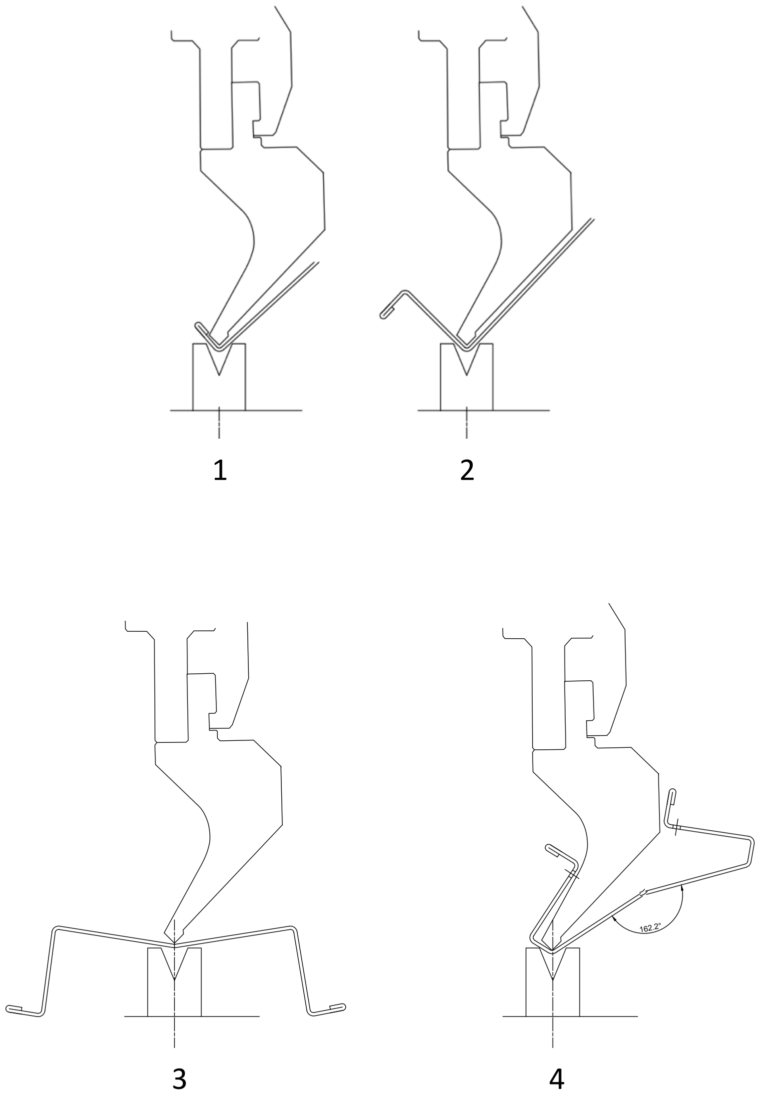


Figure 75 - New tool for SPA (Source: EURAM, P. 15)

Customer was informed about this and after discussing future plans about orders for this tool, we came to conclusion that it will be financially profitable to buy this tool. Figure of the new tool from the catalog (1014/A/6) is shown on the Figure 75.
After observing bending process, especially bend 3 and 4, it can be seen that there are still some adjustments on the part in order to perform bending process. Although it was possible to find a tool which can bend this position without any modification, it is also important to think about the future use of the tool and to analyze if it is financially acceptable and if the tool will pay out itself. Hence, this tool has been chosen. SPA can be made with minor adjustments to the process, and tool will be useful in the future applications.
Bending steps with the use of new tool are shown on the Figure 76. As it can be seen on the pictures, bending of the top bend is not shown as the conclusion on how to make the top bend is still not made. In the conclusion, all bending steps will be shown.

Bending steps 1 and 2 need to be performed also on the other side of the metal sheet.
Regarding the bending steps 3-4-5, solution is to open (bend the position so that it looks opened) while problematic spot is bended and then to close (to bring the position to the initial position) the product. Bending step 5 had been performed with thin custom-made tool.
SPA is now done, and it requires 7 bends in total.



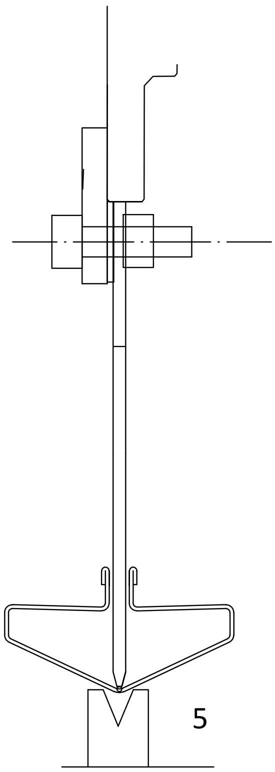


Figure 76 – SPA bend solution (Source: Own illustration)

Conclusion

As the solutions have been split into solutions for the top bend (Solutions 1&2) and solutions for the whole part (Solutions 3&4), conclusions will also be split.

- Top bend

After discussing criterions from the paragraph optimal solution and after discussing parameters of the production, further decisions have been made. In the table below, important criterions, grading system and grades for each solution respectively are given.

Table 9 - Solution 1 & 2 (Source: Own illustration)

	1	5
Costs	Expensive	Free
Post treatment	Necessary	No need
Speed	Slow	Fast
Quality	Bad	Excellent

	Costs	Post treatment	Time	Quality	Final result
Solution 1	1	5	5	5	4
Solution 2	5	5	5	5	5

As it can be seen from the table 9, Solution 2 is better. Main reason why solution 2 had been chosen is because it is significantly cheaper from the solution 1.
Explanation of the grades:
Costs – In the solution 1 it is decided that the tool will be bought. This option is much more expensive than in the solution 2 where tool had been made.
Post treatment – both solutions do not require any post treatment.
Time – as the solution 2 consists of two steps, and solution 1 only of one step, grade for the solution 2 is smaller.
Quality –quality of the part is the same, so the grade is the same.

- Whole part

In the Table 10, final parameters for old and new design of the SPA can be seen.
Laser cutting process is reduced by 189 s and 4000 m, bending process had been increased for 2 steps, but additional welding had been skipped.

Table 10 - Solution 3 & 4 (Source: Own illustration)

	Solution 3	Solution 4	
Laser (m)	12701	8701	↘ 4000
Laser (s)	570	381	↘ 189
Bending steps	5	7	↗ 2
Additional welding (m)	4	0	-

With the new solutions, Solution 2 & 4, whole flow of the bending with new made tools and new bought tool can be seen on the Figures 77.

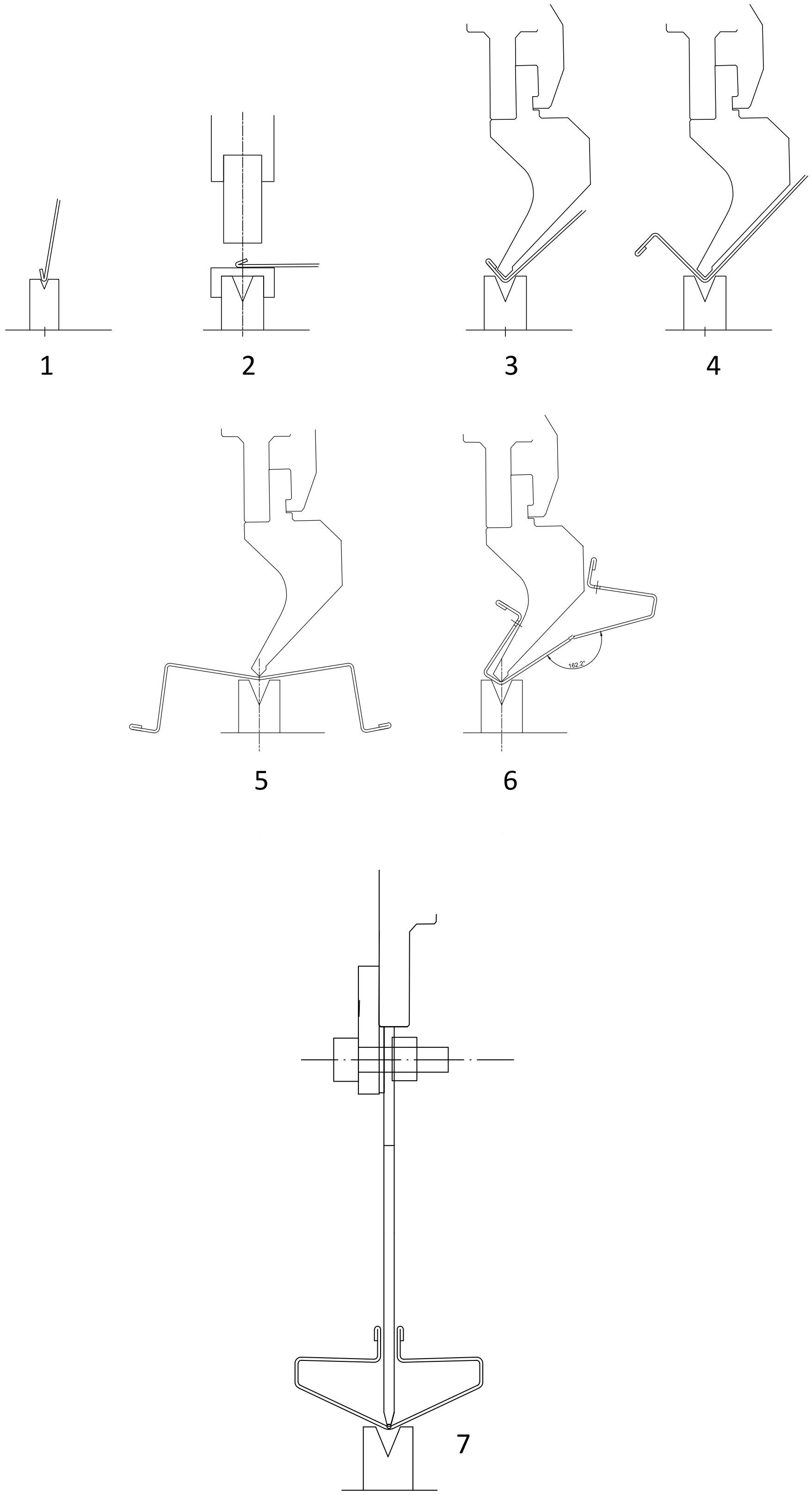


Figure 77 - Bending sequence for SPA (Source: Own illustration)

Bending steps 1-4 show only how the bending on one side is performed. The same steps need to be performed on the other side. At the end, steps 5-6-7 will be performed.
SPA is done, a bending sequence for SPA consists of 11 bends and 3 different tools. Figure 78 shows how SPA looks after the bending.

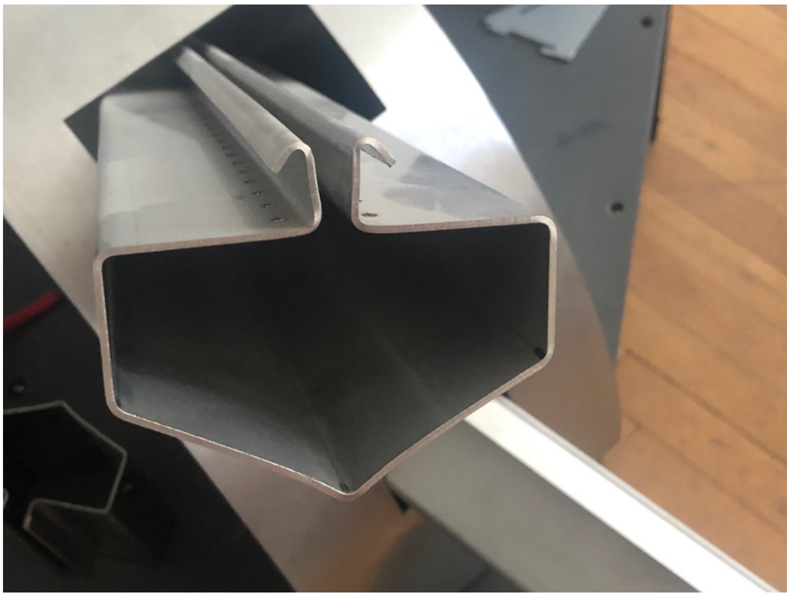


Figure 78 – SPA (Source: Own picture)

7. SRSA

Introduction

SRSA (ger. Schlitzrinne means slot channel) which can be seen on the Figure 72 and 73 is completely made of stainless steel V2A (1.4301) with a material thickness: 1.5 mm. Gradient od the channel is 0.5% and it has a M load class (125 kN).
It promises safe removal of dirt even with little water (easy cleaning) it has antibacterial hygienic form. It is fixed on the surface every 500 mm with welded wall anchors or with height-adjustable screws. It comes with a drain connection and connection element, but it can be made without edge reinforcement
Depending of the environment and special request, SRSA can be completely made of stainless steel V4A (1.4571) and with a material thickness: 2 mm.[39]

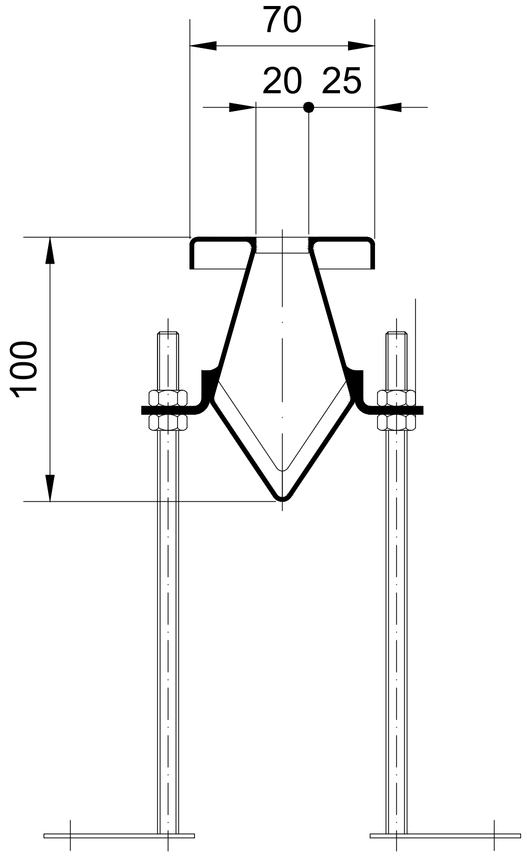


Figure 79 – SRSA (Source: Product drawing)

[39] ASCHL (2013) Online source [date 13th Nov 2019]

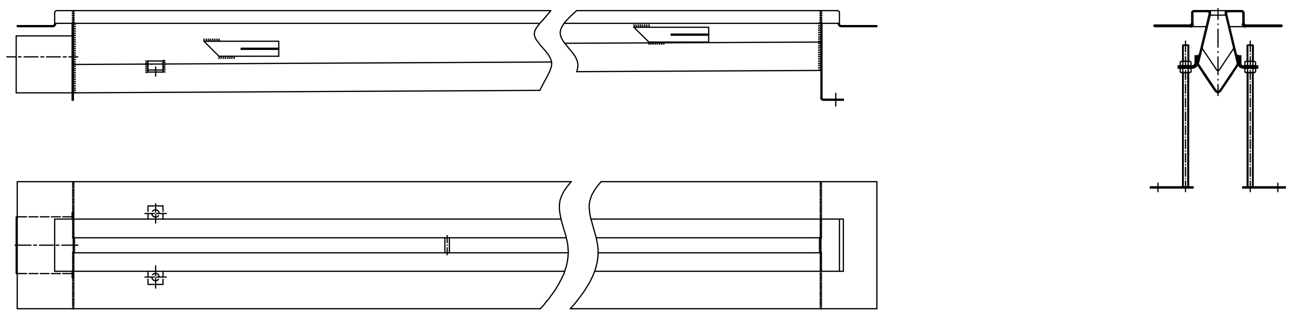


Figure 80 – SRSA (Source: Product drawing)

Standard SRSAs are offered in different dimensions shown in the table 11.
In this thesis, SRSA with the length of 1 meter will be covered.

Table 11 - Different dimensions SRSA (Source: ASCHL (2013), P. 51)

		Art.Nr.	
	L *Länge in mm*	*Kunstharz* *(randverstärkt)*	*Edelstahl-Vollmaterial* *(randverstärkt)*
Belastungsklasse	-	M *(125 kN, befahrbar)*	M *(125 kN, befahrbar)*
Rinne	1000	SRSA1000RV	SRSA1000RVM
	2000	SRSA2000RV	SRSA2000RVM
	3000	SRSA3000RV	SRSA3000RVM
	4000	SRSA4000RV	SRSA4000RVM
	5000	SRSA5000RV	SRSA5000RVM
	6000	SRSA6000RV	SRSA6000RVM
Verlängerung Typ B	6000	SRSB6000RV	SRSB6000RVM
Verlängerung Typ C	6000	SRSC6000RV	SRSC6000RVM

Manufacturing

Main drawing for the product and special requests are delivered by the company ASCHL.
After accepting an order, an engineer checks the drawings and makes needed adjustment to fit the process and machines properly.
Dimension and weight of the material is calculated and sent to the procurement department which will provide needed material (by ordering or by taking material from inventory).
After, an engineer who is Project Manager for this order, will analyzing SRSA drawings and will define production flow and control milestones in the production. Production flow is:

1. Cutting
2. Bending
3. Connecting parts together/ Welding
4. Adding necessary accessories.

Production flow and control points are given to the main master. Main master is in charge of an order from this moment till the final control of the order and till the packing for transport.

1. Cutting

Based on the resources in the company TTO, cutting can be made either on Laser cutter Bystronic machine or on Plasma cutter. Analyze and discussion on which method will be used for cutting has been made in the first chapter and same solution will be used for this position. Laser cutter Bystronic is chosen for cutting the parts.

Drawings for a Laser machine are prepared and sent to the operator working on the laser cutter. Laser drawing consists of open positions with engravings and can be seen on the figure 81. Engravings are done due to addition help, with a goal of reducing time and minimizing chances for a failure in the next phases. For example, engravings will help to the operator on the bending machine to position the part properly and to make a bend on the right side.

On the drawing for every part which is send on laser it is necessary to define next points:

- Which material is used for this part,
- Thickness of the material,
- Number of pieces.

Note: As it can be seen on the drawing for the laser (Figure 81), width on one side of SRSA is 282mm and on the other side it is 250,4mm. This is because SRSA is made with a slope, which is needed to facilitate the flow of fluid into the further drainage system.
The dimensions for the slope are taken from the main drawing. The main drawing shows the difference in the high which means that beginning and end of the SRSA are not the same (shown on Figure 82).
In the main drawing, the dimensions of the piece, when it is bent, are given. The total dimension of the opened position should be calculated. The most important parameters for calculation are the inner length of the bended sides and the bending angles.
Since the front and the back of the SRSA are not the same (because of the slope), the process of calculating opened length of the position needs to be calculated two times.
Dimension of beginning of the SRSA is 282mm and of the end of the SRSA is 250,5.

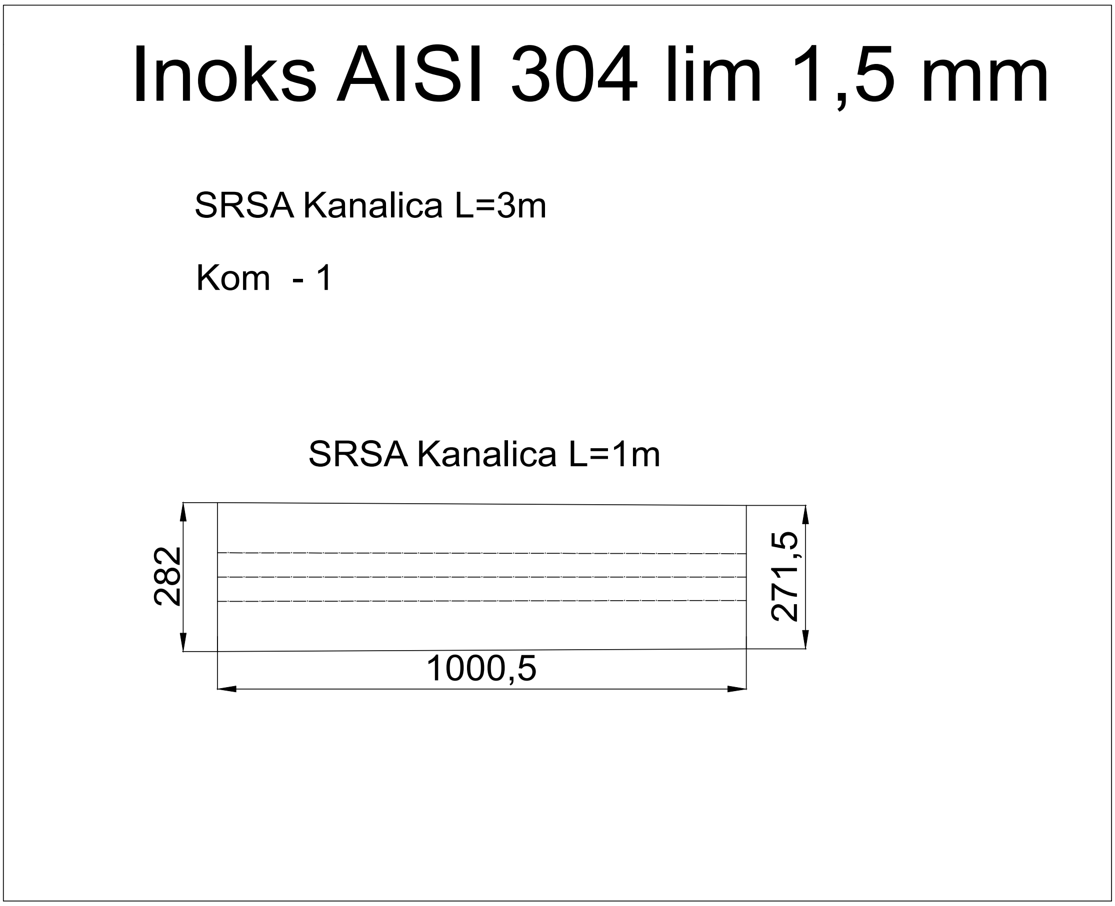


Figure 81 - Laser drawing for SRSA (Source: Own drawing)

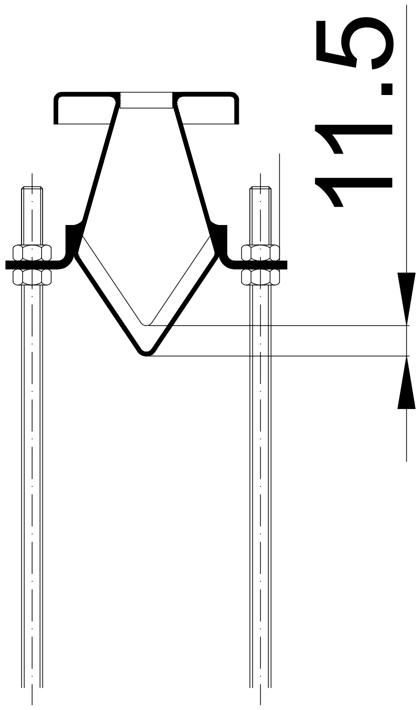


Figure 82 - SRSAs' slope (Source: Own illustration)

Before giving a command to cut the pieces, operator has a several tasks to preform and double check. The tasks are mentioned above and are written on the drawing which, as explained, has been sent by an engineer.

The length of the laser cut for one SRSA (1 m length is 3001 m.

2. Bending

Bending process is done on Durma AD-S 30135. In the first chapter, theoretical overview of process and machine can be found.
Depending on the tools which company has, an engineer has to check if all bends can be performed and after analyzing important parameters, an engineer has to create a bending sequence. It is important to note which tool and which channel (punch and die) should be used for each bending step.
Solutions on how to bend SRSA will be explained and evaluated in the next chapter.

Additional elements

Position 1 and 2 - Fixable leg
Position 1 is welded onto the channel. Position 2 is made of the threaded bar as it must be adjusted on uneven ground and is mounted on-site. Both positions can be seen on the Figure 83.

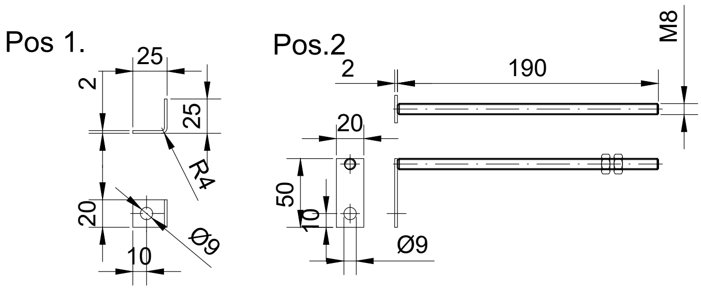


Figure 83 – Positions 1 & 2 (Source: Own illustration)

Position 3 - Concrete anchor
Position 3 is used to securely fix the channel into the concrete. This position can be seen on figure 84.

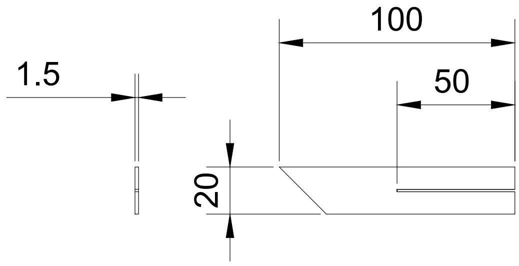


Figure 84 – Position 3 (Source: Own illustration)

Position 4 and 5 – Side covers
Side covers which can be seen on figure 85 are welded on each side of the SRSA according to the drawing. Plastic pipe which will connect SRSA to the drainage system will be connected on position 4. Position 5 will be welded on the other side.

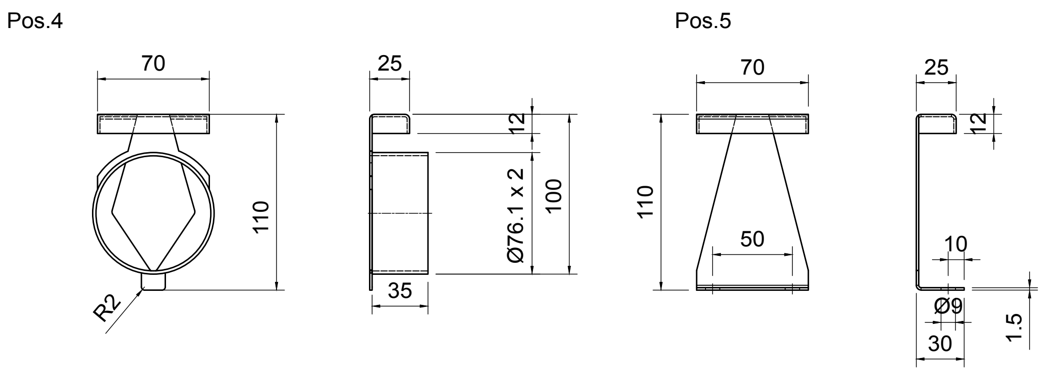


Figure 85 – Positions 4 & 5 (Source: Own illustration)

3. Welding

After bending, the positions are moved to the foreseen position and the main master for this order has to assigns a team that will start composing this part. The team consists of master and

one welder who point weld all the parts together and add additional elements (legs, uprights, fasteners ...) to the construction. This position is now moved to the table of a welder who welds all parts position in the one position.
Welding tasks are defined by standard. Standard define the necessity for making a WPS which is done by EWE engineer. WPS - Welding Procedure Specification is according to Weman [40] a document specifying the details of the required variables for a specific application in order to assure repeatability. WPS for SRSA can be found in the Appendix B.
While designing the welding process, it is known that distortion and buckling [41] of the part after welding, especially of thin metal sheets, are possible due to high heat input. It is also common with larger positions, that positioning of the element represents a problem and it requires the attention of couple of workers. Because of this problem, as in the previous chapter, an engineer prescribed that the position should first be tack welded. Tack welding [42] can be considered as a preparation of the position of the components which need to be welded. Components are held (point welded) in the right position and alignment. The reasons for this approach had been explained in the previous chapter.

Welding order as improvement

Same improvement as for the KORA and SPA had been performed on SRSA.
In the first order, while having no experience with this exact part, some problems were found in the welding phase of the positions 4 and 5 onto the SRSA.
Welding was performed according to the delivered drawings. As it can be seen on the drawing (Figure 87), the pipe was welded on both sides (Figure 86). Workers experienced problems while cleaning this weld because one part was not accessible. Due to thickness of the material, material was burned, constant water runoff was interfered and visually weld was not acceptable.
When consulting with an EWE engineer, it was concluded that welding on both sides is not necessary. According to the book “Control of Welding Distortion in Thin-Plate Fabrication“[43] for thin-plate materials, single side and single pass welding is acceptable.
Drawings have been corrected and checked by an EWE engineer. Furtherly, this part will only be welded prom the outside. Improvement on the drawing can be seen on Figure 88.

[40] Weman K. (2003), P. 3
[41] Gray T./Camilleri D./McPherson N. (2014), P. 16
[42] Gray T./Camilleri D./McPherson N. (2014), P. 34
[43] Gray T./Camilleri D./McPherson N. (2014), P. 19

Figure 86 - SRSA before cleaning phase (Source: Own picture)

On the pictures below drawings before (Figure 87) and after (Figure 88) the improvement can be seen.

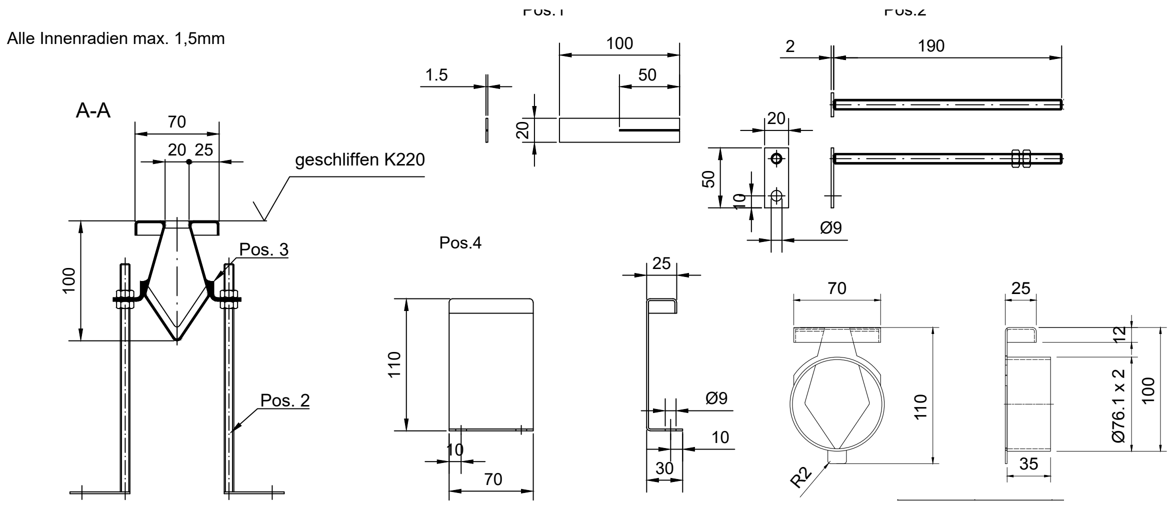


Figure 87 - Drawing without welding explanation (Source: Picture drawing)

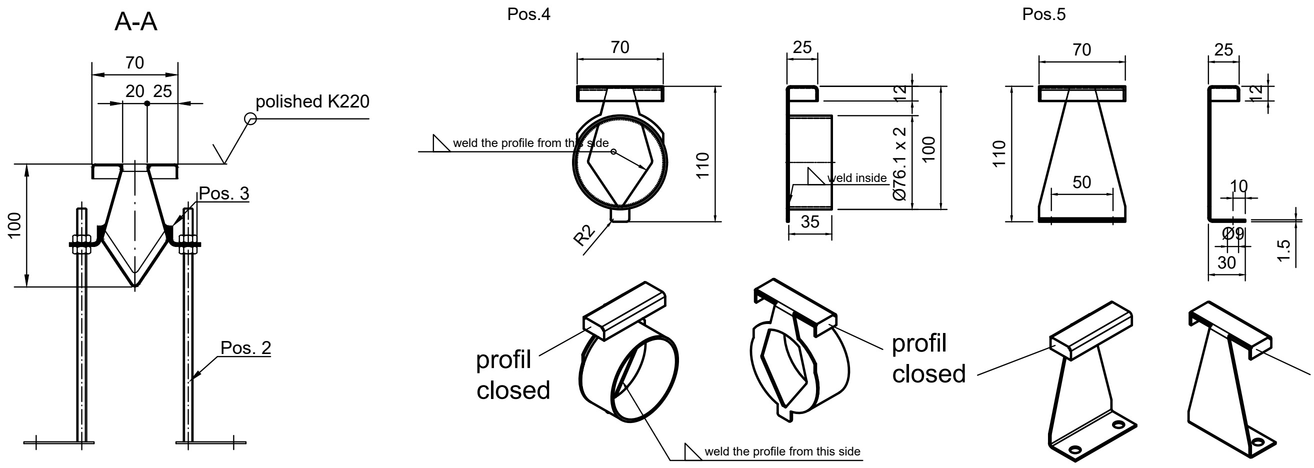


Figure 88 - Drawing with improvement (welding explanation) (Source: Own drawing)

Figure 89 - SRSA welding (Source: Own picture)

Problem and solutions

The problem in this chapter was in the bending phase of the SRSA. After applying 5 why method, problem had been narrowed to the one bend. Problematic bend is shown on the figure below. SRSA has a thigh opening at the top and deep sharp bend at the bottom (see Figure 86). Current tools which company owns are not long and thin enough for the bending process of SRSA.

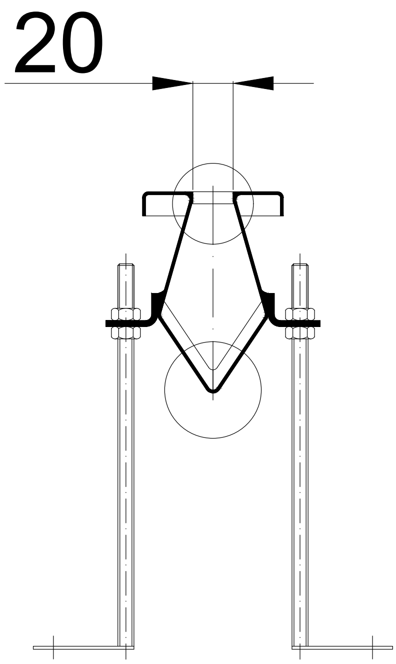


Figure 90 - Problematic part on SRSA (Source: Own illustration)

There were couple of solutions which were considered while finding the perfect solution on how to produce SRSA.

1. Solution one

Solution one is based on the modifications of the manufacturing steps. The idea is to make SRSA's body out of 2 parts which will be cut, bent and welded together. SRSA will be split in two same parts, as shown on the figure 91.

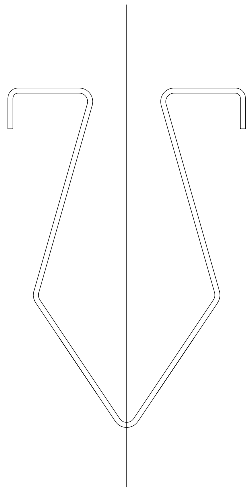


Figure 91 - Solution 1 for SRSA (Source: Own illustration)

Cutting and bending part of this task were simple and without any unpredicted ongoing. Bending can be seen on the Figure 75. Bending steps 1-2-3 need also to be performed on the other metal sheet, for the other part of the SRSA.

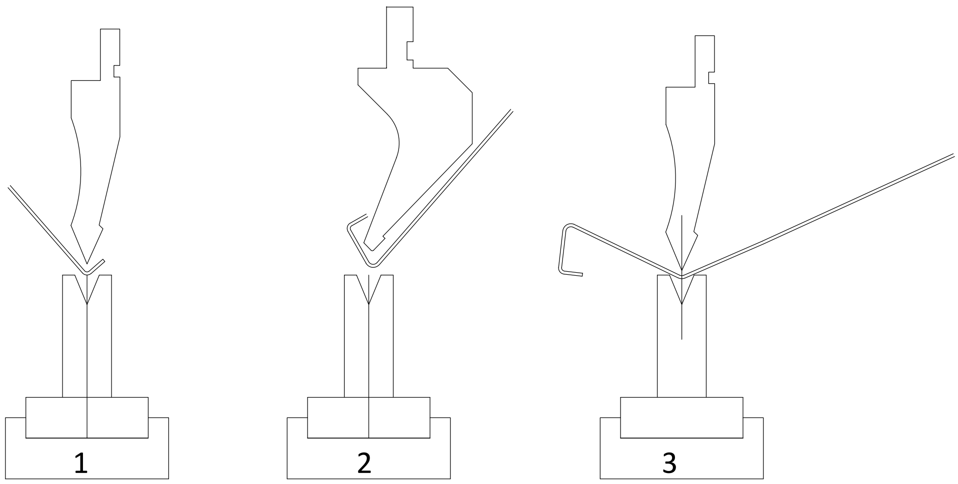


Figure 92 - Bending for SRSA (Source: Own illustration)

Welding part has been challenging and time consuming. Two extra tools, shown on the Figure below, have been made and this task had been performed. Tools simplified the welding process because of the uneven bottom of the SRSA and unstable construction, 3 workers needed to enroll in welding of this position. One welder and two workers who had to hold the position and help welder. If we compare this SRSA (length 1 meter) with longer SRSAs, it can be concluded that welding task would be time consuming and complicated.

Tool which holds the two SRSA's parts in the right angle while welding is preformed and tool which is fixed on the top of the SRSA so that is keeps both positions in the right place.

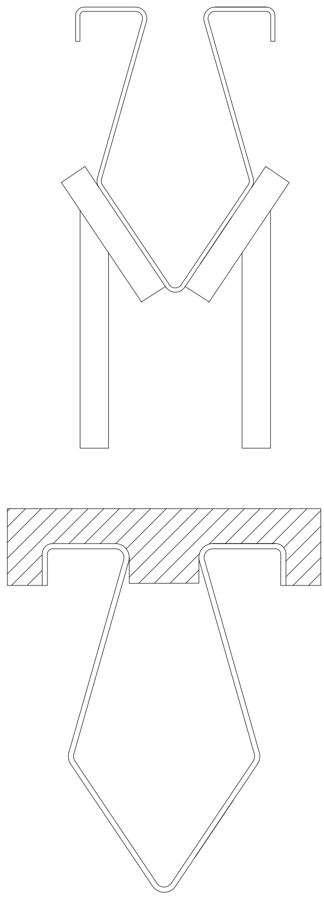


Figure 93 - Tools for SRSA (Source: Own illustration)

2. Solution two

As concluded with 5 why method, it was aimed to find the solution for the problematic bend shown on the Figure 94.

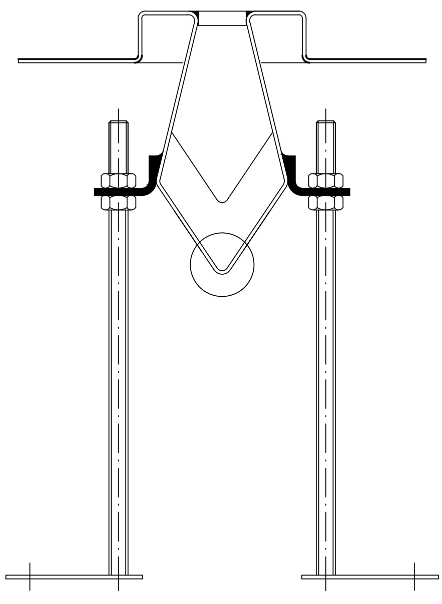


Figure 94 - Problematic part (Source: Own illustration)

After discussing this problem with the customer, it was decided that the design of the product cannot be changed due to the customer design requirements. Slight modification in the production had to be made. It was decided that in order produce this part, it is mandatory to building or buy new tool for the bending press which will enable the bending of the problematic part. As the tools main requirement is to be long and thin in order to be enable unproblematic removing of the tool after the bending is done, it is decided that the tool can be built in the company. Tool can be seen on the figure below. As it can be seen on the figure below, at the bottom of new tool, pipe with a diameter 3 mm is welded because the bottom of the SRSA is not sharp but oval.

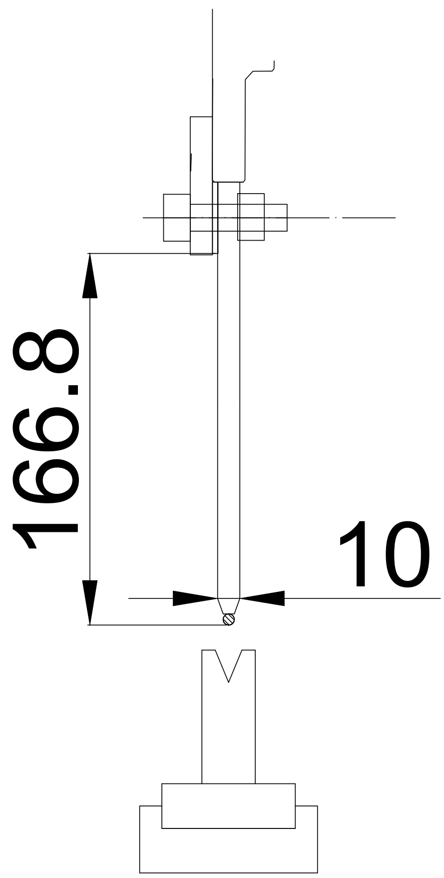


Figure 95 - Custom made tool for SRSA (Source: Own illustration)

Bending sequence for SRSA is shown on the Figure 96. For the bending of SRSA, 3 different tools are used and bending sequence consist of 7 bends in total.

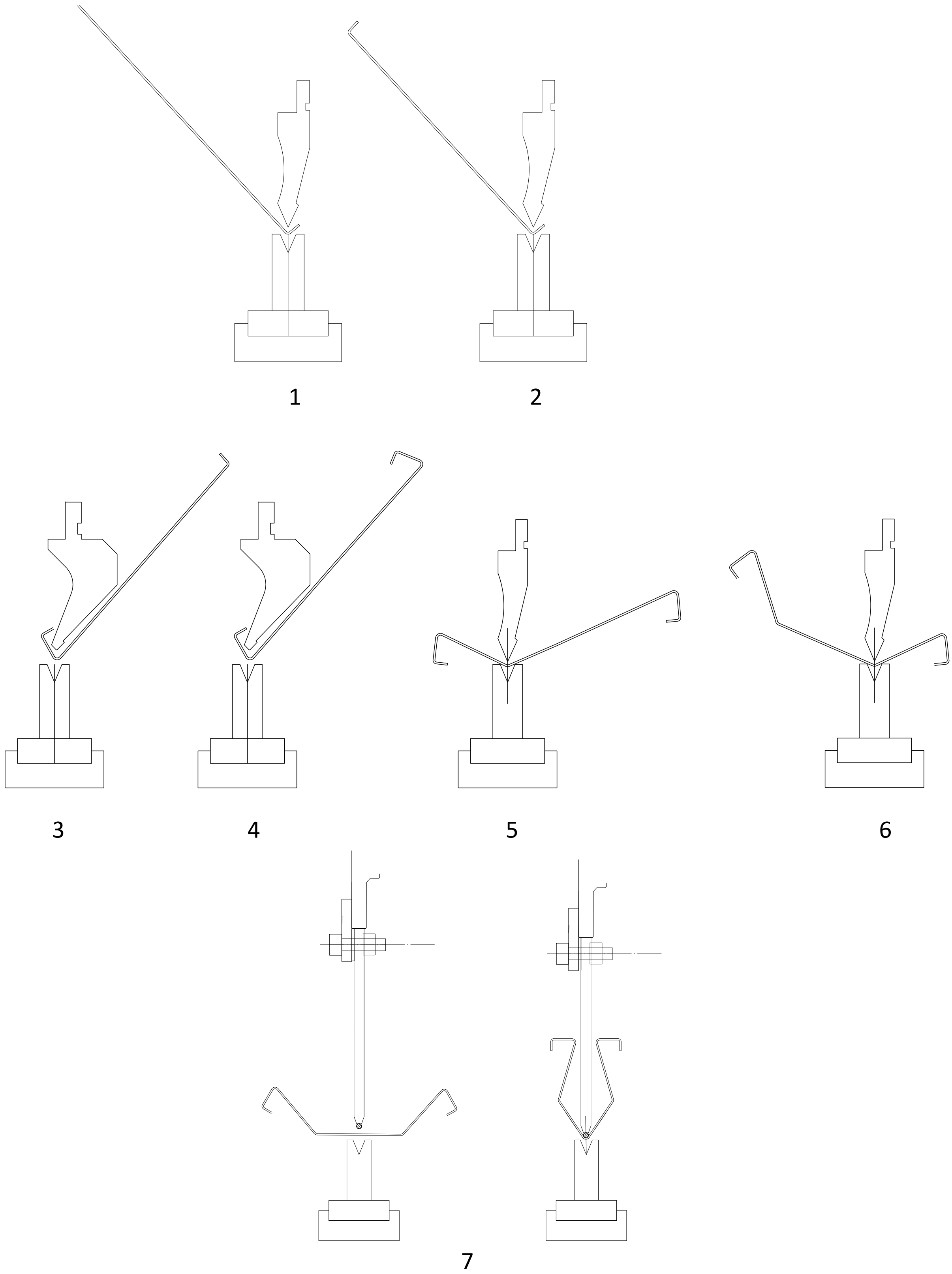


Figure 96 - Bending steps for SRSA (Source: Own illustration)

Figure 97 - SRSA bended (Source: Own picture)

Solution

Parameters for Solution 1 and 2 can be seen in the table below.

Table 12 - SRSAs solutions (Source: Own illustration)

	Solution 1	Solution 2	
Laser (m)	3001	2001	↘ 1000
Bending steps	6	7	↗ 1
Additional welding (m)	1	0	-

It is important to note that in the table above, given solutions are for SRSA 1 m. For future use and for SRSAs longer than 1 m, laser length and welding length will be increased.

As marked in the table, Solution 2 has better parameters. It requires no welding and the quality of the final product is better.
Regarding solution 1, this method had couple of the downsides.

The first and the main flaw is that the costs are not proportional to the price of the product which means that the price does not justify the production. Time spent on production, amount of the people needed for the production and extra costs of welding are increasing the price which is not acceptable for the customer.
The second flaw is that for a longer SRSAs (for example with length of 6m), the straightness of the product is not easy to obtain due to the welding heat input in the material.
The third flaw, which is the outcome of the second flaw, is that the customer was not satisfied with the appearance of the product and reported errors in the visual look of the product.
According to the factors listed above and the parameters from the table 10, this method will not be taken into further future application.

Table of Figures

Table of Tables

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Appendix:

Appendix A

BYWORK **Job list**

Designation	:	**Waste**	: 77.52 %
Technology	: Laser cutting	**Number of elements**	: 8
Customer name	:	**Created**	: 30.12.1899
Units	: mm	**by**	:
Sheet weight	: 52.99 kg	**altered**	: 30.12.1899
Cutting time	: 0h2min16sec	**by**	:
Final deadline	: 30.12.1899	**OID**	: 0

Machine parameters : D:\Cni stik 4gb\MCParam\Parameter_up_to_CNC_96\Bylaser_4000\P6110\STAR3015\INOX\14301015.X5N

Group code : 0 **Group designation** : /Job database section

Material

Code	: 1.4301	**Densit**	: 7.85 kg/dm³
Designation	: inox X5CrNi 18 9	**Thickr**	: 1.50 mm
Material number	: 1.4301		

Group code : 0 **Group designation** : /Materials database section

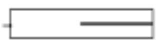
Machine

Code	: 100	**Controller type**	: BYSTAR
Designation	: 3015	**Control version**	: P6110
Additional info	:		

Material data

Code	:	**Dimension**	: 3000 x 1500 mm
Article No	:	**Number needed**	: 1
Designation	: User-defined raw material		

Flat part data



Part No.	: 1	**Fill part**	: no
Code	: ADNA bowa stara spr	**Dimension**	: 105.00 x 20.00 mm
Designation	:	**Debit/Quant**	: 4 / 4
Job No.	:	**Cutting time**	: 0h0min5sec
OID	: 4773	**Cutting ways**	: 0.345 m
Customer	: Laser	**Weight**	: 0.023 kg
Rotation	: 1	**Area**	: 1950 mm²
Common Cut	: no		
Additional info	:		

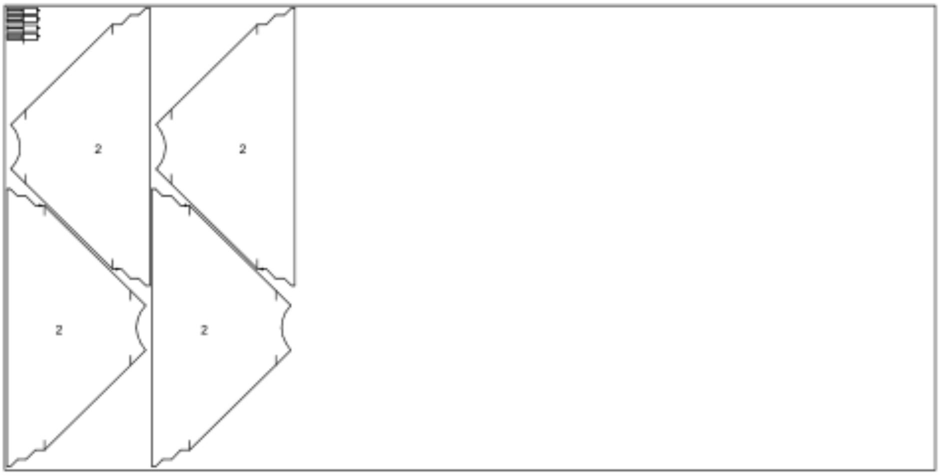
Part No.	: 2	**Fill part**	: no
Code	: ADNA bowa stara	**Dimension**	: 898.50 x 446.87 mm
Designation	:	**Debit/Quant**	: 4 / 4
Job No.	:	**Cutting time**	: 0h0min28sec
OID	: 4772	**Cutting ways**	: 2.388 m
Customer	: Laser	**Weight**	: 2.955 kg
Rotation	: 1	**Area**	: 250966 mm²
Common Cut	: no		
Additional info	:		

Figure 98 - Laser cutting parameters – old BOWA (1) (Source: Own document)

BYWORK **Job list**

Plan data

File name	:	**Cycles**	: 1
Designation	:	**Cutting time**	: 0h2min16sec
Plan dimension	: 937 x 1492 mm	**Waste**	: 77.52 %
Sheet dimension	: 3000 x 1500 mm	**Number of parts**	: 8



Flat part data

Part No.	: 1	**Dimension**	: 105.00 x 20.00 mm
Code	: ADNA bowa stara spr	**Number**	: 4
Designation	:	**Cutting time**	: 0h0min5sec
Article No	:	**Weight**	: 0.023 kg

Part No.	: 2	**Dimension**	: 898.50 x 446.87 mm
Code	: ADNA bowa stara	**Number**	: 4
Designation	:	**Cutting time**	: 0h0min28sec
Article No	:	**Weight**	: 2.955 kg

Figure 99 - Laser cutting parameters– old BOWA (2) (Source: Own document)

BYWORK # Job list

Designation	:	**Waste**	: 99.70 %
Technology	: Laser cutting	**Number of elements**	: 11
Customer name	:	**Created**	: 30.12.1899
Units	: mm	**by**	:
Sheet weight	: 105.98 kg	**altered**	: 30.12.1899
Cutting time	: 0h1min33sec	**by**	:
Final deadline	: 30.12.1899	**OID**	: 0

Machine parameters : D:\Cni stik 4gb\MCParam\Parameter_up_to_CNC_96\Bylaser_4000\P6110\STAR3015\INOX\14301030.X5N

Group code : 0 **Group designation** : /Job database section

Material

Code	: 1.4301	**Densit**	: 7.85 kg/dm³
Designation	: inox X5CrNi 18 9	**Thickr**	: 3.00 mm
Material number	: 1.4301		
Group code	: 0	**Group designation**	: /Materials database section

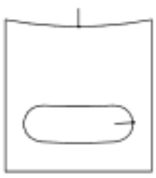
Machine

Code	: 100	**Controller type**	: BYSTAR
Designation	: 3015	**Control version**	: P6110
Additional info	:		

Material data

Code	:	**Dimension**	: 3000 x 1500 mm
Article No	:	**Number needed**	: 1
Designation	: User-defined raw material		

Flat part data



Part No.	: 1	**Fill part**	: no
Code	: Adna bowa stara 3mm-2	**Dimension**	: 40.00 x 44.60 mm
Designation	:	**Debit/Quant**	: 3 / 3
Job No.	:	**Cutting time**	: 0h0min6sec
OID	: 4776	**Cutting ways**	: 0.245 m
Customer	: Laser	**Weight**	: 0.031 kg
Rotation	: 1	**Area**	: 1331 mm²
Common Cut	: no		
Additional infc	:		

Part No.	: 2	**Fill part**	: no
Code	: Adna bowa stara 3mm-1	**Dimension**	: 20.00 x 80.40 mm
Designation	:	**Debit/Quant**	: 4 / 4
Job No.	:	**Cutting time**	: 0h0min6sec
OID	: 4775	**Cutting ways**	: 0.229 m
Customer	: Laser	**Weight**	: 0.034 kg
Rotation	: 1	**Area**	: 1444 mm²
Common Cut	: no		
Additional infc	:		

Part No.	: 3	**Fill part**	: no
Code	: Adna bowa stara 3mm	**Dimension**	: 20.00 x 55.00 mm
Designation	:	**Debit/Quant**	: 4 / 4
Job No.	:	**Cutting time**	: 0h0min5sec
OID	: 4774	**Cutting ways**	: 0.178 m
Customer	: Laser	**Weight**	: 0.022 kg
Rotation	: 1	**Area**	: 936 mm²
Common Cut	: no		
Additional infc	:		

Figure 100- Laser cutting parameters– old BOWA (3) (Source: Own document)

BYWORK **Job list**

Plan data

File name	:	**Cycles**	: 1
Designation	:	**Cutting time**	: 0h1min33sec
Plan dimension	: 88 x 1492 mm	**Waste**	: 99.70 %
Sheet dimension	: 3000 x 1500 mm	**Number of parts**	: 11

Flat part data

Part No.	: 1	**Dimension**	: 40.00 x 44.60 mm
Code	: Adna bowa stara 3mm-2	**Number**	: 3
Designation	:	**Cutting time**	: 0h0min6sec
Article No	:	**Weight**	: 0.031 kg

Part No.	: 2	**Dimension**	: 20.00 x 80.40 mm
Code	: Adna bowa stara 3mm-1	**Number**	: 4
Designation	:	**Cutting time**	: 0h0min6sec
Article No	:	**Weight**	: 0.034 kg

Part No.	: 3	**Dimension**	: 20.00 x 55.00 mm
Code	: Adna bowa stara 3mm	**Number**	: 4
Designation	:	**Cutting time**	: 0h0min5sec
Article No	:	**Weight**	: 0.022 kg

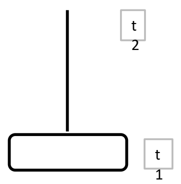
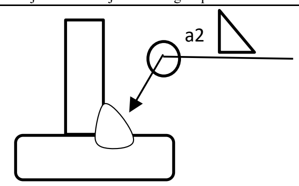
Figure 101 - Laser cutting parameters– old BOWA (4) (Source: Own document)

Appendix B

TTO	SPECIFIKACIJA POSTUPKA ZAVARIVANJA (SPZ) *WELDING PROCEDURE SPECIFICATION (WPS)*	WPS broj: 204/19 WPS No.: WPQR br.:IZBH-12/18 WPQR No:	Strana: 1/1 page:

Naručilac: *Customer:*	ASCHL	WPQR Ispitivač/Ustanova: *WPQR Certification Body:*	Institut za zavarivanje Tuzla Institute of welding Tuzla
Namjena: *Purpose:*	BOWA, KORA, SRSA	Crtež: *Drawing.*	ABA1107403, ABA1105890, SRSA

Osnovni materijali: Parent material:	t1 = t2=AISI 304	Postupak zavarivanja: welding	141 TIG	Izrada prema: According to:	EN ISO 5817-C
Dimenzije: *Dimensions:*	t1 = 1,5-3 mm t2 = 1,5-3 mm	Položaji zavarivanja: *welding*	Horizontalno (PB)	Vrsta šava: Joint type:	Ugaoni (FW)
Dodatni materijal Aditional material	TIG 308	Oznaka po EN, DIN ili AWS/ASME: according to	AWS A5.9/A5.9 M	Vrsta i promjer žice: *Type and diameter of wire*	Ø=2.0 mm
Zaštitini gas: *Gas shield:*	ISO 14175:I1 (Ar)	Prečnik cilindra: *Nozle diameter:*	/	Tip postupka Process type:	Ručno Manual

Priprema spoja / Join design:	Redoslijed zavarivanja / Welding sequence
	

U slučaju toplog rezanja (za pripremu) površine zavarivanja moraju biti obrušene do čiste površine metalnog sjaja.
Korodirane površine moraju biti obrušene do metalnog sjaja / po potrebi očistiti od masnoća i prljavština.

PARAMETRI ZAVARIVANJA (po WPQR) / *WELDING PARAMETERS (as in WPQR)*

Debljina Thickness [mm]	Broj slojeva *Number of runs*	Visina zavara a *weld height a*	Jačina struje Current [A]	Napon Voltage [V]	Polaritet *Type of current*	Protok gasa *Gas flow* (L/min)	Brzina žice Wire speed : m/min	Brzina zavarivanja *Welding speed* cm/min	Unos toplote *Heat input* kJ/cm
t1=1.5-3, t2= 1.5-3	1	2	80-110	9-12	DC-	9	/	8	~6

INSPEKCIJA ZAVARA

Predgrijavanje [^{0}C]: *Preheat:*	Međuslojna T [^{0}C]: *Interpass*	Temperatura naknadne TO [^{0}C]: *Post weld heat treatment T:*	Vrijeme držanja na TO [h]: *Holding time*	Brzina zagr./ hlađenja at TO[^{0}C/h]: *HT Cooling/ heating speed*
/	/	/	/	/

Kontrola kvaliteta zavarenog spoja / *Quality control weld:*

Vizuelna *Visual*	Radiografsk *Radiograp*	Ultrazvučna *Ultrasonic*	Penetrantska *Penetrants*	Magnetna *Magnetic particle*	Tvrdoća *Hardness*
100%					

Atest zavarivača: *Welder certificate:*	Grupa čelika: *Steel group:8.1*	Specifikacija termičke obrade br.: / *Heat treatment specification No.*

Napomene / *Remarks:*-

Prilozi / Supplements:

Izradio / *Made by:*	Odobrio / Approved:
Selim Dautović, dipl.ing.maš., IWE	Selim Dautović, dipl.ing.maš., IWE

Figure 102 - WPS for BOWA, KORA and SRSA (Source: Own document)

Appendix C

BYWORK **Job list**

Designation	:	**Waste**	: 78.31 %
Technology	: Laser cutting	**Number of elements**	: 8
Customer name	:	**Created**	: 30.12.1899
Units	: mm	**by**	:
Sheet weight	: 52.99 kg	**altered**	: 30.12.1899
Cutting time	: 0h2min26sec	**by**	:
Final deadline	: 30.12.1899	**OID**	: 0

Machine parameters : D:\Cni stik 4gb\MCParam\Parameter_up_to_CNC_96\Bylaser_4000\P6110\STAR3015\INOX\14301015.X5N

Group code : 0 **Group designation** : /Job database section

Material

Code	: 1.4301	**Densit**	: 7.85 kg/dm³
Designation	: inox X5CrNi 18 9	**Thickr**	: 1.50 mm
Material number	: 1.4301		

Group code : 0 **Group designation** : /Materials database section

Machine

Code	: 100	**Controller type**	: BYSTAR
Designation	: 3015	**Control version**	: P6110
Additional info	:		

Material data

Code	:	**Dimension**	: 3000 x 1500 mm
Article No	:	**Number needed**	: 1
Designation	: User-defined raw material		

Flat part data

Part No.	: 1	**Fill part**	: no
Code	: adna bowa nova	**Dimension**	: 901.40 x 443.10 mm
Designation	:	**Debit/Quant**	: 4 / 4
Job No.	:	**Cutting time**	: 0h0min26sec
OID	: 4777	**Cutting ways**	: 2.348 m
Customer	: Laser	**Weight**	: 2.850 kg
Rotation	: 1	**Area**	: 242060 mm²
Common Cut	: no		
Additional infc	:		

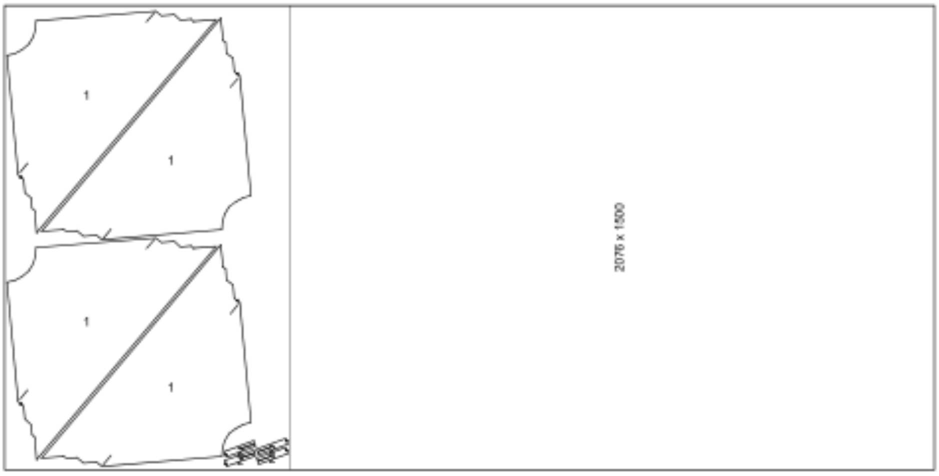
Part No.	: 2	**Fill part**	: no
Code	: ADNA bowa stara spr	**Dimension**	: 105.00 x 20.00 mm
Designation	:	**Debit/Quant**	: 4 / 4
Job No.	:	**Cutting time**	: 0h0min5sec
OID	: 4773	**Cutting ways**	: 0.345 m
Customer	: Laser	**Weight**	: 0.023 kg
Rotation	: 1	**Area**	: 1950 mm²
Common Cut	: no		
Additional infc	:		

Figure 103 - Laser cutting parameters– new BOWA (1) (Source: Own document)

BYWORK **Job list**

Plan data

File name	:	**Cycles**	: 1
Designation	:	**Cutting time**	: 0h2min26sec
Plan dimension	: 915 x 1481 mm	**Waste**	: 78.31 %
Sheet dimension	: 3000 x 1500 mm	**Number of parts**	: 8



Flat part data

Part No.	: 1	**Dimension**	: 901.40 x 443.10 mm
Code	: adna bowa nova	**Number**	: 4
Designation	:	**Cutting time**	: 0h0min26sec
Article No	:	**Weight**	: 2.850 kg

Part No.	: 2	**Dimension**	: 105.00 x 20.00 mm
Code	: ADNA bowa stara spr	**Number**	: 4
Designation	:	**Cutting time**	: 0h0min5sec
Article No	:	**Weight**	: 0.023 kg

Figure 104 - Laser cutting parameters– new BOWA (2) (Source: Own document)

BYWORK

Job list

Designation	:	**Waste**	: 99.70 %
Technology	: Laser cutting	**Number of elements**	: 11
Customer name	:	**Created**	: 30.12.1899
Units	: mm	**by**	:
Sheet weight	: 105.98 kg	**altered**	: 30.12.1899
Cutting time	: 0h1min33sec	**by**	:
Final deadline	: 30.12.1899	**OID**	: 0

Machine parameters : D:\Cni stik 4gb\MCParam\Parameter_up_to_CNC_96\Bylaser_4000\P6110\STAR3015\INOX\14301030.X5N

Group code : 0 **Group designation** : /Job database section

Material

Code	: 1.4301	**Densit**	: 7.85 kg/dm³
Designation	: inox X5CrNi 18 9	**Thickr**	: 3.00 mm
Material number	: 1.4301		

Group code : 0 **Group designation** : /Materials database section

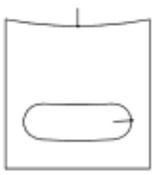
Machine

Code	: 100	**Controller type**	: BYSTAR
Designation	: 3015	**Control version**	: P6110
Additional info	:		

Material data

Code	:	**Dimension**	: 3000 x 1500 mm
Article No	:	**Number needed**	: 1
Designation	: User-defined raw material		

Flat part data



Part No.	: 1	**Fill part**	: no
Code	: Adna bowa stara 3mm-2	**Dimension**	: 40.00 x 44.60 mm
Designation	:	**Debit/Quant**	: 3 / 3
Job No.	:	**Cutting time**	: 0h0min6sec
OID	: 4776	**Cutting ways**	: 0.245 m
Customer	: Laser	**Weight**	: 0.031 kg
Rotation	: 1	**Area**	: 1331 mm²
Common Cut	: no		
Additional info	:		

Part No.	: 2	**Fill part**	: no
Code	: Adna bowa stara 3mm-1	**Dimension**	: 20.00 x 80.40 mm
Designation	:	**Debit/Quant**	: 4 / 4
Job No.	:	**Cutting time**	: 0h0min6sec
OID	: 4775	**Cutting ways**	: 0.229 m
Customer	: Laser	**Weight**	: 0.034 kg
Rotation	: 1	**Area**	: 1444 mm²
Common Cut	: no		
Additional info	:		

Part No.	: 3	**Fill part**	: no
Code	: Adna bowa stara 3mm	**Dimension**	: 20.00 x 55.00 mm
Designation	:	**Debit/Quant**	: 4 / 4
Job No.	:	**Cutting time**	: 0h0min5sec
OID	: 4774	**Cutting ways**	: 0.178 m
Customer	: Laser	**Weight**	: 0.022 kg
Rotation	: 1	**Area**	: 936 mm²
Common Cut	: no		
Additional info	:		

Figure 105 - Laser cutting parameters– new BOWA (3) (Source: Own document)

BYWORK **Job list**

Plan data

File name	:	**Cycles**	: 1
Designation	:	**Cutting time**	: 0h1min33sec
Plan dimension	: 88 x 1492 mm	**Waste**	: 99.70 %
Sheet dimension	: 3000 x 1500 mm	**Number of parts**	: 11

Flat part data

Part No.	: 1	**Dimension**	: 40.00 x 44.60 mm
Code	: Adna bowa stara 3mm-2	**Number**	: 3
Designation	:	**Cutting time**	: 0h0min6sec
Article No	:	**Weight**	: 0.031 kg

Part No.	: 2	**Dimension**	: 20.00 x 80.40 mm
Code	: Adna bowa stara 3mm-1	**Number**	: 4
Designation	:	**Cutting time**	: 0h0min6sec
Article No	:	**Weight**	: 0.034 kg

Part No.	: 3	**Dimension**	: 20.00 x 55.00 mm
Code	: Adna bowa stara 3mm	**Number**	: 4
Designation	:	**Cutting time**	: 0h0min5sec
Article No	:	**Weight**	: 0.022 kg

Figure 106 - Laser cutting parameters– new BOWA (4) (Source: Own document)

Appendix D

BYWORK **Job list**

Designation	:	**Waste**	: 59.28 %
Technology	: Laser cutting	**Number of elements**	: 4
Customer name	:	**Created**	: 30.12.1899
Units	: mm	**by**	:
Sheet weight	: 54.75 kg	**altered**	: 30.12.1899
Cutting time	: 0h3min23sec	**by**	:
Final deadline	: 30.12.1899	**OID**	: 0

Machine parameters : D:\Cni stik 4gb\MCParam\Parameter_up_to_CNC_96\Bylaser_4000\P6110\STAR3015\INOX\14301015.X5N

Group code : 0 **Group designation** : /Job database section

Material

Code	: 1.4301	**Densit**	: 7.85 kg/dm³
Designation	: inox X5CrNi 18 9	**Thickr**	: 1.50 mm
Material number	: 1.4301		

Group code : 0 **Group designation** : /Materials database section

Machine

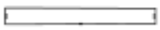
Code	: 100	**Controller type**	: BYSTAR
Designation	: 3015	**Control version**	: P6110
Additional info	:		

Material data

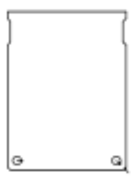
Code	:	**Dimension**	: 3100 x 1500 mm
Article No	:	**Number needed**	: 1
Designation	: User-defined raw material		

Flat part data

Part No.	: 1	**Fill part**	: no
Code	: adna kora stara 1,5mm-3	**Dimension**	: 3000.00 x 310.00 mm
Designation	:	**Debit/Quant**	: 1 / 1
Job No.	:	**Cutting time**	: 0h1min13sec
OID	: 4781	**Cutting ways**	: 6.835 m
Customer	: Laser	**Weight**	: 10.421 kg
Rotation	: 1	**Area**	: 885000 mm²
Common Cut	: no		
Additional info	:		

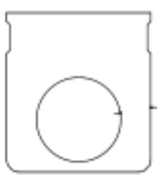


Part No.	: 2	**Fill part**	: no
Code	: adna kora stara 1,5mm-2	**Dimension**	: 3000.00 x 340.00 mm
Designation	:	**Debit/Quant**	: 1 / 1
Job No.	:	**Cutting time**	: 0h1min14sec
OID	: 4780	**Cutting ways**	: 6.895 m
Customer	: Laser	**Weight**	: 11.481 kg
Rotation	: 1	**Area**	: 975000 mm²
Common Cut	: no		
Additional info	:		



Part No.	: 3	**Fill part**	: no
Code	: adna kora stara 1,5mm-1	**Dimension**	: 127.66 x 170.66 mm
Designation	:	**Debit/Quant**	: 1 / 1
Job No.	:	**Cutting time**	: 0h0min11sec
OID	: 4779	**Cutting ways**	: 0.661 m
Customer	: Laser	**Weight**	: 0.244 kg
Rotation	: 1	**Area**	: 20729 mm²
Common Cut	: no		
Additional info	:		

BYWORK **Job list**



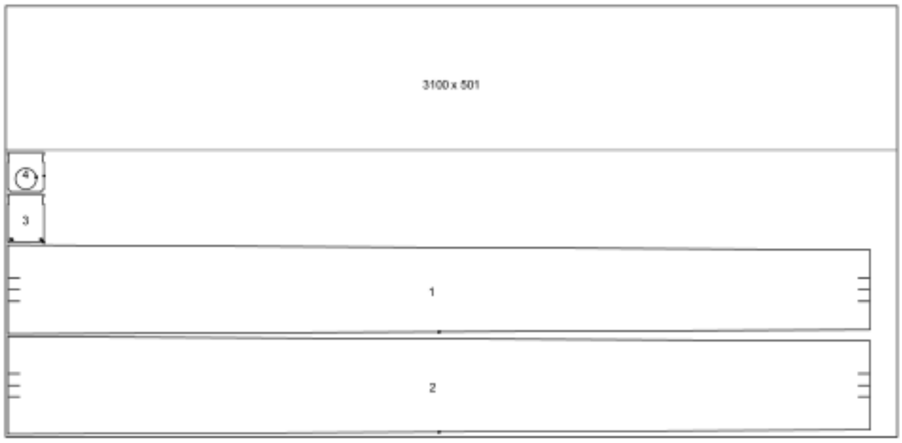
Part No.	: 4	**Fill part**	: no
Code	: adna kora stara 1,5mm	**Dimension**	: 130.00 x 138.00 mm
Designation	:	**Debit/Quant**	: 1 / 1
Job No.	:	**Cutting time**	: 0h0min10sec
OID	: 4778	**Cutting ways**	: 0.764 m
Customer	: Laser	**Weight**	: 0.152 kg
Rotation	: 1	**Area**	: 12870 mm²
Common Cut	: no		
Additional info	:		

Figure 107 - Laser cutting parameters– old KORA (1) (Source: Own document)

BYWORK **Job list**

Plan data

File name	:	**Cycles**	: 1
Designation	:	**Cutting time**	: 0h3min23sec
Plan dimension	: 3008 x 990 mm	**Waste**	: 59.28 %
Sheet dimension	: 3100 x 1500 mm	**Number of parts**	: 4



Flat part data

Part No.	: 1	**Dimension**	: 3000.00 x 310.00 mm
Code	: adna kora stara 1,5mm-3	**Number**	: 1
Designation	:	**Cutting time**	: 0h1min13sec
Article No	:	**Weight**	: 10.421 kg

Part No.	: 2	**Dimension**	: 3000.00 x 340.00 mm
Code	: adna kora stara 1,5mm-2	**Number**	: 1
Designation	:	**Cutting time**	: 0h1min14sec
Article No	:	**Weight**	: 11.481 kg

Part No.	: 3	**Dimension**	: 127.66 x 170.66 mm
Code	: adna kora stara 1,5mm-1	**Number**	: 1
Designation	:	**Cutting time**	: 0h0min11sec
Article No	:	**Weight**	: 0.244 kg

Part No.	: 4	**Dimension**	: 130.00 x 138.00 mm
Code	: adna kora stara 1,5mm	**Number**	: 1
Designation	:	**Cutting time**	: 0h0min10sec
Article No	:	**Weight**	: 0.152 kg

Figure 108 - Laser cutting parameters– old KORA (2) (Source: Own document)

Appendix E

BYWORK **Job list**

Designation	:	**Waste**	: 58.90 %
Technology	: Laser cutting	**Number of elements**	: 14
Customer name	:	**Created**	: 30.12.1899
Units	: mm	**by**	:
Sheet weight	: 54.75 kg	**altered**	: 30.12.1899
Cutting time	: 0h4min16sec	**by**	:
Final deadline	: 30.12.1899	**OID**	: 0

Machine parameters : D:\Cni stik 4gb\MCParam\Parameter_up_to_CNC_96\Bylaser_4000\P6110\STAR3015\INOX\14301015.X5N

Group code : 0 **Group designation** : /Job database section

Material

Code	: 1.4301	**Densit**	: 7.85 kg/dm³
Designation	: inox X5CrNi 18 9	**Thickr**	: 1.50 mm
Material number	: 1.4301		

Group code : 0 **Group designation** : /Materials database section

Machine

Code	: 100	**Controller type**	: BYSTAR
Designation	: 3015	**Control version**	: P6110
Additional info	:		

Material data

Code	:	**Dimension**	: 3100 x 1500 mm
Article No	:	**Number needed**	: 1
Designation	: User-defined raw material		

Flat part data

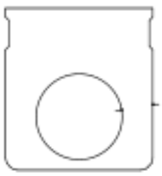
Part No.	: 1	**Fill part**	: no
Code	: adna kora stara 1,5mm-3	**Dimension**	: 3000.00 x 310.00 mm
Designation	:	**Debit/Quant**	: 1 / 1
Job No.	:	**Cutting time**	: 0h1min13sec
OID	: 4781	**Cutting ways**	: 6.835 m
Customer	: Laser	**Weight**	: 10.421 kg
Rotation	: 1	**Area**	: 885000 mm²
Common Cut	: no		
Additional info	:		

Part No.	: 2	**Fill part**	: no
Code	: adna kora stara 1,5mm-2	**Dimension**	: 3000.00 x 340.00 mm
Designation	:	**Debit/Quant**	: 1 / 1
Job No.	:	**Cutting time**	: 0h1min14sec
OID	: 4780	**Cutting ways**	: 6.895 m
Customer	: Laser	**Weight**	: 11.481 kg
Rotation	: 1	**Area**	: 975000 mm²
Common Cut	: no		
Additional info	:		

Part No.	: 3	**Fill part**	: no
Code	: adna kora stara 1,5mm-1	**Dimension**	: 127.66 x 170.66 mm
Designation	:	**Debit/Quant**	: 1 / 1
Job No.	:	**Cutting time**	: 0h0min11sec
OID	: 4779	**Cutting ways**	: 0.661 m
Customer	: Laser	**Weight**	: 0.244 kg
Rotation	: 1	**Area**	: 20729 mm²
Common Cut	: no		
Additional info	:		

Figure 109 - Laser cutting parameters– new KORA (1) (Source: Own document)

BYWORK **Job list**



Part No.	: 4	**Fill part**	: no
Code	: adna kora stara 1,5mm	**Dimension**	: 130.00 x 138.00 mm
Designation	:	**Debit/Quant**	: 1 / 1
Job No.	:	**Cutting time**	: 0h0min10sec
OID	: 4778	**Cutting ways**	: 0.764 m
Customer	: Laser	**Weight**	: 0.152 kg
Rotation	: 1	**Area**	: 12870 mm²
Common Cut	: no		
Additional info	:		

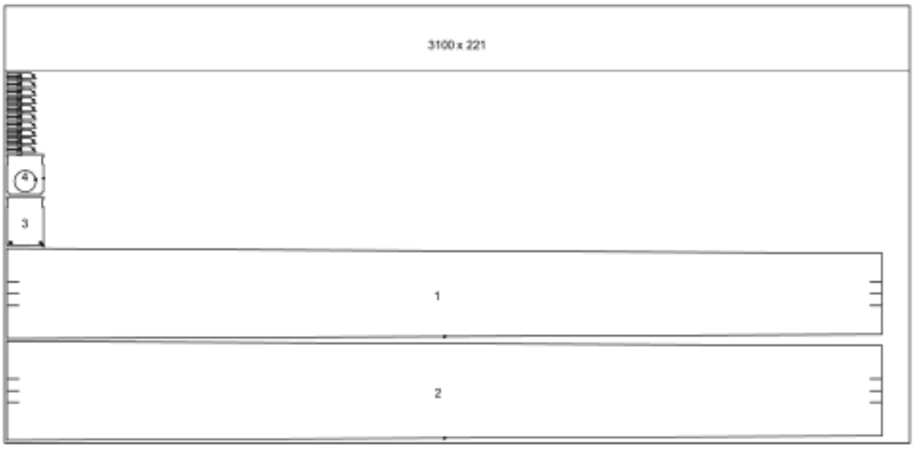
Part No.	: 5	**Fill part**	: no
Code	: Adna kora nova 1,5mm-4	**Dimension**	: 100.00 x 20.00 mm
Designation	:	**Debit/Quant**	: 10 / 10
Job No.	:	**Cutting time**	: 0h0min5sec
OID	: 4786	**Cutting ways**	: 0.333 m
Customer	: Laser	**Weight**	: 0.021 kg
Rotation	: 1	**Area**	: 1750 mm²
Common Cut	: no		
Additional info	:		

Figure 110 - Laser cutting parameters– new KORA (2) (Source: Own document)

BYWORK **Job list**

Plan data

File name	:	**Cycles**	: 1
Designation	:	**Cutting time**	: 0h4min16sec
Plan dimension	: 3008 x 1270 mm	**Waste**	: 58.90 %
Sheet dimension	: 3100 x 1500 mm	**Number of parts**	: 14



Flat part data

Part No.	: 1	**Dimension**	: 3000.00 x 310.00 mm
Code	: adna kora stara 1,5mm-3	**Number**	: 1
Designation	:	**Cutting time**	: 0h1min13sec
Article No	:	**Weight**	: 10.421 kg

Part No.	: 2	**Dimension**	: 3000.00 x 340.00 mm
Code	: adna kora stara 1,5mm-2	**Number**	: 1
Designation	:	**Cutting time**	: 0h1min14sec
Article No	:	**Weight**	: 11.481 kg

Part No.	: 3	**Dimension**	: 127.66 x 170.66 mm
Code	: adna kora stara 1,5mm-1	**Number**	: 1
Designation	:	**Cutting time**	: 0h0min11sec
Article No	:	**Weight**	: 0.244 kg

Part No.	: 4	**Dimension**	: 130.00 x 138.00 mm
Code	: adna kora stara 1,5mm	**Number**	: 1
Designation	:	**Cutting time**	: 0h0min10sec
Article No	:	**Weight**	: 0.152 kg

BYWORK **Job list**

Part No.	: 5	**Dimension**	: 100.00 x 20.00 mm
Code	: Adna kora nova 1,5mm-4	**Number**	: 10
Designation	:	**Cutting time**	: 0h0min5sec
Article No	:	**Weight**	: 0.021 kg

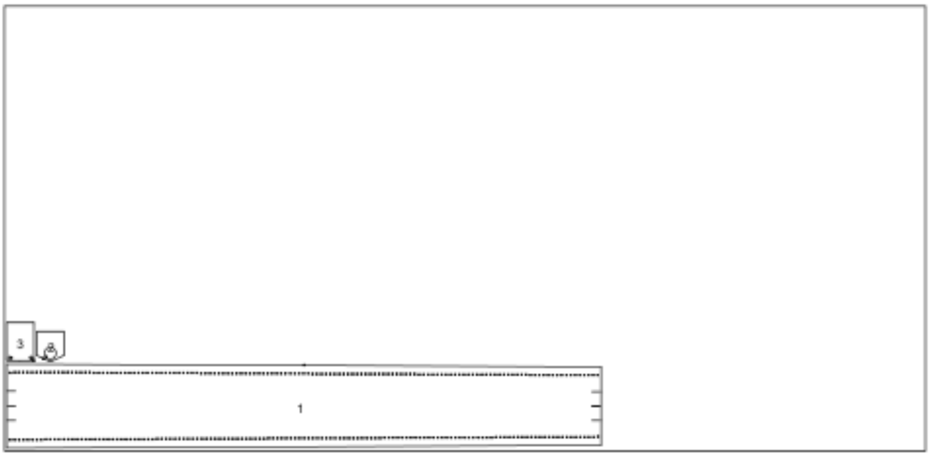
Figure 111 - Laser cutting parameters– new KORA (3) (Source: Own document)

Appendix F

BYWORK **Job list**

Plan data

File name	:	**Cycles**	: 1
Designation	:	**Cutting time**	: 0h6min22sec
Plan dimension	: 2010 x 431 mm	**Waste**	: 87.85 %
Sheet dimension	: 3100 x 1500 mm	**Number of parts**	: 3



Flat part data

Part No.	: 1	**Dimension**	: 2002.43 x 284.00 mm
Code	: Adna spa 1,5mm	**Number**	: 1
Designation	:	**Cutting time**	: 0h6min6sec
Article No	:	**Weight**	: 6.436 kg

Part No.	: 2	**Dimension**	: 91.00 x 101.50 mm
Code	: Adna spa 1,5mm-1	**Number**	: 1
Designation	:	**Cutting time**	: 0h0min7sec
Article No	:	**Weight**	: 0.083 kg

Part No.	: 3	**Dimension**	: 93.66 x 130.66 mm
Code	: Adna spa 1,5mm-2	**Number**	: 1
Designation	:	**Cutting time**	: 0h0min8sec
Article No	:	**Weight**	: 0.136 kg

Figure 112 - Laser cutting parameters– SPA (1) (Source: Own document)

BYWORK **Job list**

Designation	:	**Waste**	: 87.85 %
Technology	: Laser cutting	**Number of elements**	: 3
Customer name	:	**Created**	: 30.12.1899
Units	: mm	**by**	:
Sheet weight	: 54.75 kg	**altered**	: 30.12.1899
Cutting time	: 0h6min22sec	**by**	:
Final deadline	: 30.12.1899	**OID**	: 0

Machine parameters : D:\Cni stik 4gb\MCParam\Parameter_up_to_CNC_96\Bylaser_4000\P6110\STAR3015\INOX\14301015.X5N

Group code : 0 **Group designation** : /Job database section

Material

Code	: 1.4301	**Densit**	: 7.85 kg/dm³
Designation	: inox X5CrNi 18 9	**Thickr**	: 1.50 mm
Material number	: 1.4301		

Group code : 0 **Group designation** : /Materials database section

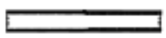
Machine

Code	: 100	**Controller type**	: BYSTAR
Designation	: 3015	**Control version**	: P6110
Additional info	:		

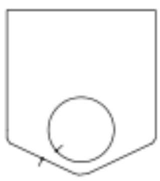
Material data

Code	:	**Dimension**	: 3100 x 1500 mm
Article No	:	**Number needed**	: 1
Designation	: User-defined raw material		

Flat part data



Part No.	: 1	**Fill part**	: no
Code	: Adna spa 1,5mm	**Dimension**	: 2002.43 x 284.00 mm
Designation	:	**Debit/Quant**	: 1 / 1
Job No.	:	**Cutting time**	: 0h6min6sec
OID	: 4787	**Cutting ways**	: 7.707 m
Customer	: Laser	**Weight**	: 6.436 kg
Rotation	: 1	**Area**	: 546578 mm²
Common Cut	: no		
Additional info	:		



Part No.	: 2	**Fill part**	: no
Code	: Adna spa 1,5mm-1	**Dimension**	: 91.00 x 101.50 mm
Designation	:	**Debit/Quant**	: 1 / 1
Job No.	:	**Cutting time**	: 0h0min7sec
OID	: 4788	**Cutting ways**	: 0.488 m
Customer	: Laser	**Weight**	: 0.083 kg
Rotation	: 1	**Area**	: 7091 mm²
Common Cut	: no		
Additional info	:		

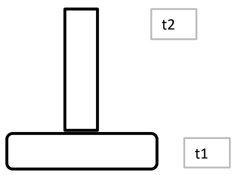
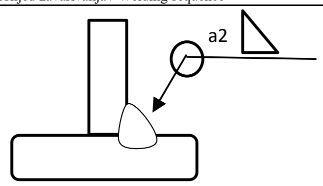
Part No.	: 3	**Fill part**	: no
Code	: Adna spa 1,5mm-2	**Dimension**	: 93.66 x 130.66 mm
Designation	:	**Debit/Quant**	: 1 / 1
Job No.	:	**Cutting time**	: 0h0min8sec
OID	: 4789	**Cutting ways**	: 0.506 m
Customer	: Laser	**Weight**	: 0.136 kg
Rotation	: 1	**Area**	: 11517 mm²
Common Cut	: no		
Additional info	:		

Figure 113 - Laser cutting parameters– SPA (2) (Source: Own document)

Appendix G

TTO	**SPECIFIKACIJA POSTUPKA ZAVARIVANJA (SPZ)** ***WELDING PROCEDURE SPECIFICATION (WPS)***	WPS broj: 205/19 WPS No.: WPQR br.:IZBH-12/18 WPQR No:	Strana: 1/1 page:

Naručilac: *Customer:*	ASCHL	WPQR Ispitivač/Ustanova: *WPQR Certification Body:*		Institut za zavarivanje Tuzla Institute of welding Tuzla	
Namjena: *Purpose:*	SPAA	Crtež: *Drawing.*		SPAA Production	
Osnovni materijali: Parent material:	t1 = t2=AISI 316	Postupak zavarivanja: Welding process:	141 TIG	Izrada prema: According to:	EN ISO 5817-C
Dimenzije: *Dimensions:*	t1 = 1,5-2 mm t2 = 1,5-2 mm	Položaji zavarivanja: *Welding position:*	Horizontalno (PB)	Vrsta šava: Joint type:	Ugaoni (FW)
Dodatni materijal Aditional material	TIG 316	Oznaka po EN, DIN ili AWS/ASME: according to	AWS A5.9/A5.9 M	Vrsta i promjer žice: *Type and diameter of wire*	Ø=2.0 mm
Zaštitini gas: *Gas shield:*	ISO 14175:I1 (Ar)	Prečnik cilindra: *Nozle diameter:*	/	Tip postupka Process type:	Ručno Manual

Priprema spoja / Join design:	Redoslijed zavarivanja / Welding sequence
	

U slučaju toplog rezanja (za pripremu) površine zavarivanja moraju biti obrušene do čiste površine metalnog sjaja.
Korodirane površine moraju biti obrušene do metalnog sjaja / po potrebi očistiti od masnoća i prljavština.

PARAMETRI ZAVARIVANJA (po WPQR) / *WELDING PARAMETERS (as in WPQR)*

Debljina Thickness [mm]	Broj slojeva *Number of runs*	Visina zavara a *weld height a*	Jačina struje Current [A]	Napon Voltage [V]	Polaritet *Type of current*	Protok gasa *Gas flow* (L/min)	Brzina žice Wire speed : m/min	Brzina zavarivanja *Welding speed* cm/min	Unos toplote *Heat input* kJ/cm
t1=1.5-2, t2= 1.5-2	1	2	70-100	9-11	DC-	9	/	8	~6

INSPEKCIJA ZAVARA

Predgrijavanje [^{0}C]: *Preheat:*	Međuslojna T [^{0}C]: *Interpass T:*	Temperatura naknadne TO [^{0}C]: *Post weld heat*	Vrijeme držanja na TO [h]: *Holding time*	Brzina zagr./ hlađenja at TO[^{0}C/h]: *HT Cooling/ heating speed*
/	/	/	/	/

Kontrola kvaliteta zavarenog spoja / *Quality control weld:*

Vizuelna *Visual*	Radiografska *Radiographic*	Ultrazvučna *Ultrasonic*	Penetrantska *Penetrants*	Magnetna *Magnetic particle*	Tvrdoća *Hardness*
100%					

Atest zavarivača: *Welder certificate:*	Grupa čelika: 8.1 *Steel group:8.1*	Specifikacija termičke obrade br.: / *Heat treatment specification No.*

Napomene / *Remarks:-*

Prilozi / Supplements:

Izradio / *Made by:* Selim Dautović, dipl.ing.maš., IWE	Odobrio / Approved: Dautović, dipl.ing.maš., IWE

Figure 114 - WPS for SPA (Source: Own document)