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Implementation of Mechanization into the Welding Process

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The article is focused on the investigation of the impact of the implementation of mechanization into the welding workplace, for the production of cylinders from austenitic X5CrNi18 10 chromium nickel steel. The welds are assembled into a production line for the processing of puff pastry. In addition to the technical improvement of the process and the verification of the sufficient quality of the welds, calculations were used to prove that after the implementation of the change, there was a significant reduction in the production time. By introducing a higher level of mechanization and necessary technological changes, the production time was reduced by up to half, compared with the original technological procedure, including an increase in quality parameters and it led to a reduction in the production costs of the welding workplace. A significant consequence of the proposed change was connected with its impact on workplace safety.

Keywords: Austenitic chromium nickel steel, Implementation, Mechanization, Welding process, Positioner

1 Introduction

With the rising prices of energy and raw materials, today's society strives to lower manufacturing costs by investing in the discovery of new technologies and technological procedures or establishing modern digital technologies while utilizing artificial intelligence to lower the demand for manufacturing processes so that the production time, expenses and effort decrease. Ultimately, this minimizes the necessity of seeking skilled labor. Relating to material, wages or raw materials, the cost saving is significant benefit and represents an opportunity for the company to invest free capital into other areas in order to increase competitiveness in a high globalized and competitive environment. In the food industry, characteristic with specific quality requirements and high energy consumption, without which the food cannot be processed in a hygienic and sterile environment, competitiveness is fundamental phenomenon. In addition, it is narrowly specialised and depends on the specific properties of materials, the prices of which are crucial for manufacturing companies. The material has to meet strict standards, such as resistance to water, water vapour, humidity, weak organic and inorganic acids, etc. The quality of the material is the basic aspect and the production lines have to withstand the regular temperature loading during all the time, mostly continuous production. For many years, the governments have been making pressure on food marketing chains to lower food prices and thus there is also the pressure on food producers. This leads to the efforts of manufacturers to optimize production and look for possible alternatives, by investing into production technologies with lower consumption, price, or with other production advantages. Manufacturers of equipment and production lines for the food industry are forced to come up with innovative solutions that make it possible to sustain the price of the equipment, despite the increase in the cost of semi-finished products, the price of labour, and moreover, there is the effort to meet the increasing hygiene requirements and emission standards. One of them is an increase of the mechanization level that leads to a reduction in production times and at the same time to the minimization of imperfections and other undesirable phenomena leading to unnecessary costs. The company for which the proposal was created is one of the world-renowned companies with a leading position in world markets on the field of production lines manufacturing for the food industry. In order to keep this position, it is constantly forced to optimize, search, analyse and solve possible losses not only in the technological process. After a thorough analysis, the potential for improvement in the efficiency of the welding technology of the type part of the line was discovered. It showed deficiencies leading to significant downtime, which automatically led to losses, and to the need to employ high qualified workers at the welding workplace. The proposal to improve the welding technology required verification in practice. First, the impact of the future changes on product quality was analysed and it was followed by analysis of production times and possible rationalization. Finally, the verification whether the investment into technological improvement and the necessary technological equipment is profitable for the company was performed.

2 Characteristics of the type part

The subject of the research was a typed structural part for the food production line for the production of puff pastry called "Laminator line". One such line needs 20 of such parts in average. From the design aspect, it is a cylinder, the purpose of which is to reduce the thickness of the puff pastry in the individual steps of the production process and it also serves to guide the puff pastry correctly along the conveyor belt and to ensure the drive of the belt itself. For this reason, the cylinder, its quality and production duration represent an important factor in reducing costs and production time. It is a key component used in other types of lines that the company produces. It is the part of a pair of cylinders, located in the upper and lower parts of the line assembly. Figure 1. shows a cross-sectional diagram of the cylinder structure showing the individual items, namely 1-the shaft, 2-connection flange and 3-the tube.

The cylinder consists of a shaft with a length of 1230 mm and is connected to other parts of the cylinder as shown in the diagram by means of welds. The shaft passes through a tube with a length of 820 mm and a diameter of 250 mm. The hole through which the shaft passes has a diameter of 73 mm. The tube and the shaft are connected on both sides with fronts, with a thickness of 19 mm and a diameter of 234 mm. A fillet weld is used on each side of the part to create the joint (Figure 1 - part in red oval). The tube is connected to the front by a butt weld (Figure 1 - part in the green oval). In total, 2 butt and 2 fillet welds are used for cylinder. Figure 2 shows the individual parts of the cylinder in a real version before welding.

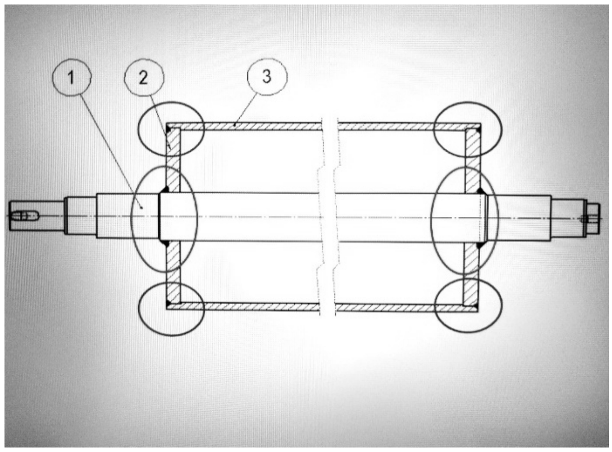

***Fig. 1** Diagram of the cylinder cross-section*

***Fig. 2** Final products of individual cylinder parts*

The justification for the implementation of mechanization in the production of this part can be found in its historical background. The company had previously revealed manufacturing flaws that resulted in the need to change the material and later the design. As it was found that the rollers were overloaded during continuous operation, the porosity of the chrome surface layer led to the formation of corrosion on the roller front sides, which were in contact with the puff pastry and could lead to contamination of the puff pastry that is unacceptable in the food industry. Therefore, since 2008, the S235JRG material has been stopped to be used for its production, and it has been replaced by X5CrNi18 10 steel. These changes turned out to be beneficial for the company due to the reduction of the very high costs of the original material, which had much worse properties. These were reflected in the costs of ensuring the necessary actions associated with the surface treatment of the part. In addition, the change had to be made due to strictly given hygiene requirements in the food industry. Another factor was related to increasing the production volume to approximately 350 and even 400 pieces per year. Austenitic X5CrNi18 10 chromium nickel steel is the most commonly used type of stainless steel due to its highly desirable mechanical properties for the food industry, such as heat and corrosion resistance and it also meets all required hygiene standards. In addition, it is well cold-mouldable and well weldable with an electric arc. It maintains resistance against the intercrystalline corrosion after welding sheet metal up to 6 mm thickness even without the need for any additional heat treatment due to the fact that it has a low carbon content. Its chemical composition is shown in Table 1 [6], [7], [8], [9].

***Tab. 1** Chemical composition of X5CrNi18 10 steel (weight %) [6]*

	C	Cr	Mn	Ni	P	S	Si
min:	–	17,00	–	9.000	–	–	–
max:	0.070	20.000	2.000	11.500	0.045	0.030	1.000

Its use has been approved up to working temperatures of around 300 °C and it has good polishability. Thanks to its price, it seems to be very advantageous for the company. It has a tendency to strengthen that needs to be considered, especially during its processing [6], [8], [10].

3 Analysis of the original welding technological procedure and its shortcomings

In the manufacturing and fabrication industries, fusion welding is among the most broadly utilized joining mechanisms and methods. The fusion welding process characteristics which influence majorly weld joints are the heat source intensity, the heat input rate, the methods used, and effectiveness of shielding gas to protect the weld from atmospheric contaminations [1]. Before the implementation of the new proposal of the cylinder welding technology, it was necessary to assess the old technological welding procedure which showed significant deficiencies. These lengthened the production time and led to complications during production. One of the problems turned out to be a workplace that was not prepared for increased production volumes and did not have the necessary equipment to ensure trouble-free and uninterrupted production without unnecessary downtime. It was not equipped with the necessary fixtures, positioners or a sufficiently powerful welding source to ensure the required increase in production volume. In the cylinder production process, any form of automation that would speed up and make the whole process more efficient was absent. As it turned out, the welding process was unnecessarily complex, inefficient, very laborious and demanding of skilled labour. The prepared parts of the cylinder had to be first prepared by chipping, and then another worker placed the parts on the wooden pallets. The welder had to re-stitch and arrange the parts so that they corresponded to the technical documentation. Without the necessary equipment, procedures and mechanization, the welder had to use cranes to handle the cylinder. Since in order to ensure the correct root welding procedure using the TIG method, it was necessary to first turn the cylinder from a horizontal to a vertical position, and only then continue welding and fill the beads weld using the MAG method. The result was connected with the unnecessary complications, increased physical effort of the worker and extension of production time. During welding, the welder had to go around the entire part from several sides and it negatively affected the accuracy of the torch's movement and caused weld imperfections. It was also necessary to interrupt welding process in order to go around the part again and it resulted in inaccuracies in feeding the beads weld. Figure 3 shows the unsatisfactory environment of the welding workplace before the implementation of mechanization.

***Fig. 3** Preparation of the butt weld before the welding operation*

As it is evident from Figure 3, part of the welding technological procedure did not meet the requirements for occupational safety and health protection due to insufficient fixation of the part during welding. There was a risk of loosening the weld and causing an occupational accident, or damage to the weld itself. This would mean an increase in costs for the company, or problems with securing an adequate replacement for an experienced welder. The whole technological process was not satisfactory at all. Based on the mentioned above, it is possible to claim that the welder had to be able to estimate, based on experience whether the individual stages of the welding process were correctly performed and complete as well as he also had to have physical fitness. Moreover, the given welder had to have a high level of professional competence, skill and many years of experience. During the welding of filler tracks, the torch, which did not have sufficient power, was overheated. Therefore, it was necessary to divide the welding process into two phases. Firstly, it was necessary to perform the welding of the root, using the TIG method, and then, the filling tracks using the MAG method was carried out. With two different types of welds on one cylinder, this was a non-negligible problem and wasted production time and costs. In order to illustrate the waste of production time, it is important to point out the fact that it is necessary to provide two beads weld on a butt joint, and for a fillet weld, there are up to five such beads. The insufficient welding power of the welding source resulted in a reduction in the lifetime of the dies. In the case of fillet welds, the multi-layer weld was often insufficiently welded because it was necessary to ensure subsequent repairs in order to prevent the multiplication of bacteria in the unmolten part of the weld and to keep the hygienic demands on the cylinder. There was sometimes a large splash of metal along with sticking to the surface of the part. Problems arose when turning the surface and front surfaces of the cylinder. This was the main reason of increased frequency of changing cutting tools and costs. The new proposal of the technological procedure for cylinder welding is intended to contribute to the efficiency of the production process and to reduce the demands on skills, physical effort of the worker while keeping the same level of weld quality, reducing the production time and costs in order to ensure a sufficient level of safety and health protection at work.

4 Implementation of mechanisation and changes in the technological procedure

As a part of the solution as well as the first step of mechanization to improve the the production process, a table rotary positioner of SPS 75 S HC type from the manufacturer Automa, modified with the three-jaw chuck was used and it is shown in Figure 4 [3].

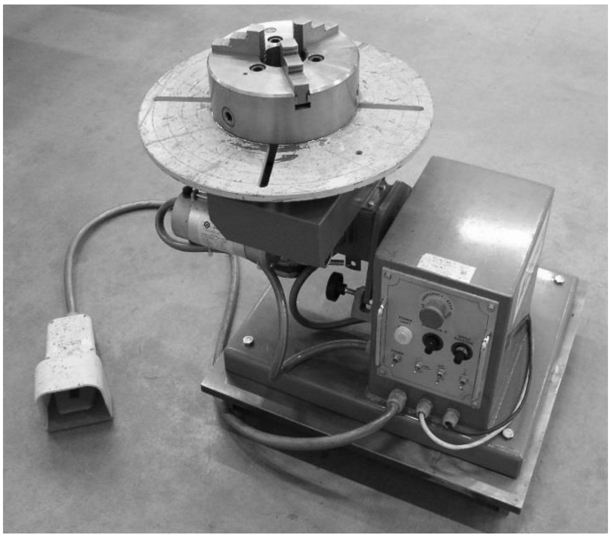

Fig. 4 *Positioner SPS 75 S HC [3]*

The positioner has a load capacity of 75 kg and enables vertical rotation of parts with the possibility of manual tilting by 90° to a horizontal position with a rotation speed of 7 revolutions per minute. Among its functions, there is a pulse sampling for controlling the welding source, precise clamping, and setting the initial position of the stitched weld. Clamping the support shaft will ensure precise guidance to the torch and increase the overall accuracy of the weld. By setting the optimum and uniform welding speed to the wire, the positioner can reduce the shortcomings caused by uneven speed during manual adjustment. At the same time, the possible loosening of the welded part is prevented by reliable and safe positioning [3]. The next step of mechanization is the implementation of a torch holder, which can reduce the inaccuracies caused by welding without fixing the torch, thereby ensuring a constant distance between the torch nozzle and the weld pool. As a part of the design, we used a holder that allows simple and quick adjustment of the height, working radius and inclination of the burner. In addition, it allows changing its working height depending on the length of the cylinder, the radius of the welded diameter and the inclination of the torch, which are changed during butt and corner welding [3]. Since welding required the use of two welding methods, two types of welding sources were needed. A welding source of TIG μP 161H type, from the STEL company, was used for welding the root. A FORMICA welding source of For - MIG 289 type [3], was used for welding filler tracks. The trial runs were carried out to determine the operating ranges of all selected factors by varying one factor while maintaining the others constant. The operating ranges are determined by assessing the welding process for a smooth appearance and the absence of apparent flaws such as porosity and undercut. The wire feeding angle was set at 60°, the arc length, L, is 8.5 mm, and h is approximately 1 mm less than L to obtain a smooth metal transfer of wire. The single weld bead was deposited with 100 mm length to determine the optimal process parameter and evaluate the relationship between input parameters and the response variable [2]. The change in technology eliminated the need to weld the root and tracks separately, using two methods, and this operation was performed in just one step. For this reason, it was necessary to provide a suitable welding source with the necessary welding power. In relation to the welding source, after buying a new suitable one an addition of powerful KEMPACT PULSE 3000 type was further enhancing solution because it increased and improved the welding speed and made it possible to use different types of modes and parameters [6]. The mechanization was mainly based on creating an assembly consisting of a welding source, a positioner and a torch holder, which are illustrated in Figure 5.

This was followed by changes at the workplace to make it suitable from a safety and technical aspect. The workplace was divided into two separate parts where two different types of operations were performed. There was the part for stitching and the part for welding filler tracks that was manifested by an increase in the flow of production. Moreover, the technological procedure of the production of the part was also proceeded to change [7], [8]. Logistically, after stitching, the cylinder is moved to a workplace for welding filler tracks. After clamping, the torch holder is adjusted to the desired welding position. After igniting the arc of the welding source, the positioner starts to rotate, making one revolution. Subsequently, the setting of the torch nozzle and the parameters for fillet weld welding can be changed [7], [8].

Fig. 5 *Mechanized welding assembly*

4.1 Characteristics of the change in the butt weld welding procedure

For the purposes of the experiment, a welding procedure was proposed. The blunt V-shaped circumferential weld was performed with a raised surface and a diameter of 235 mm with a bevel angle of the welded surfaces in the range of 30° and a dimension of a = 6 mm. A sketch of the butt weld that connects the face to the tube, according to the new proposed welding procedure, can be seen in Figure 6.

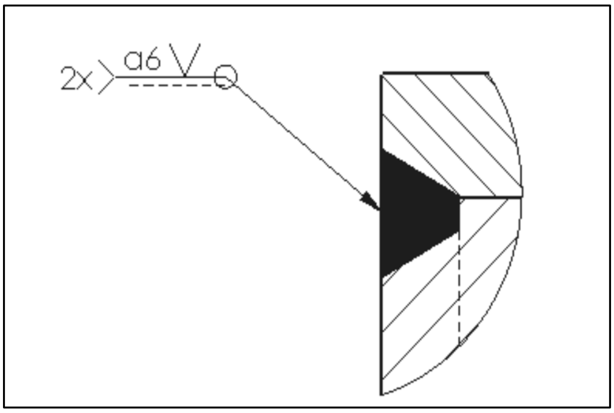

Fig. 6 *Butt weld sketch*

The KEMPPI KEMPACT PULSE 3000 welding source was used for welding. The joint was prepared by turning, stitching, and the weld metal was transferred by pulse method. The welding design, indicating the sequence of weld creation and individual dimensions, is shown in Figure 7.

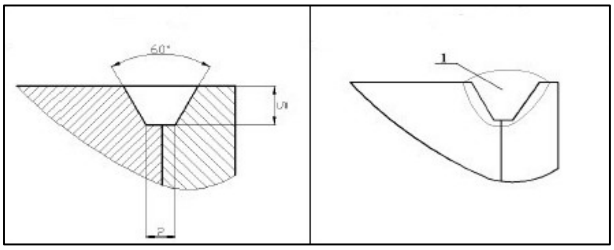

Fig. 7 *Joint design and butt weld welding sequence*

According to STN EN ISO 14343, G 19 9 L Si with a diameter of 1 mm was used as an additional material. A suitable protective and active gas (Ar 97.5 % + CO2 %) with a flow rate of 22 litres per minute and a nozzle diameter of 14 mm was used to protect the weld from the air atmosphere. The contact nozzle was 15 mm away from the surface of the welded part. A current of 180 A and a heat input of 10.8 kJ.cm-1 were used for welding with a table rotation speed of 0.3 revolutions per minute. Ragavendran and Vasudevan [11] stated that higher heat input produces coarser grains, smaller grain boundaries, and larger heat affected zone, while finer grain structure, larger grain boundaries, and excellent mechanical properties could be achieved by rapid cooling rate. Shangren et al. [12] also added that weld defects, such as porosity, distortion and hot cracking, easily occurred when arc welding with a high heat input and a low welding speed were used. Moreover, a slightly convex weld profile surface with lower heat input prevents surface shrinkage cracking, which tends to occur in weld zones with higher heat input and concave profile surfaces, because the former surface is subject to lower tensile forces [5], [13]. Therefore, it is necessary to pay close attention to the setting of welding parameters and not to change them.

4.2 Evaluation of the formed butt weld after the implementation of mechanization

In order to check the appropriateness of the proposed welding technology, it was necessary to carry out tests, using a test sample. The welds were carefully examined macroscopically (Figure 8) and subjected to a hardness test.

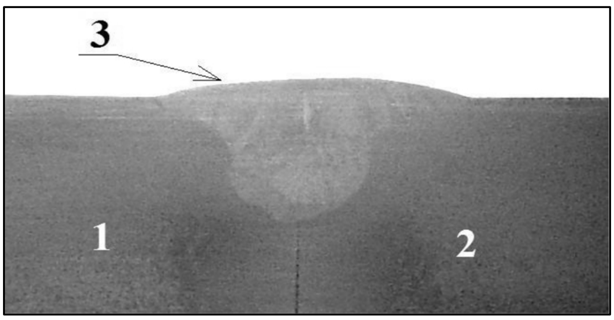

Fig. 8 *Macroscopic image of a butt weld cross-section (1 face, 2 tube, 3 weld)*

A butt weld sample was taken by cutting a portion of the weld across the weld joint. Subsequently, it was necessary to sand the butt weld sample using a plane sander and sandpaper. Then, the surface of the weld sample was etched, using ferric chloride. This chemical compound was used to reveal the structure of austenitic chromium nickel steels in the weld sample. After the structure became visible, an image of it was taken, using a digital camera. Since, as a part of the change in the technological procedure, the TIG welding method was removed, it was necessary to verify whether the proposed technological procedure led to its welding. Figure 8 clearly shows that the root of the weld was sufficient even after the technological change. No visible cold joints, no unwelded spots or cracks are observed in relation to the sample. Figure 8 also shows the dendritic structure of the weld metal in the direction of solidification.

4.3 Evaluation of the hardness of the butt weld by the HV method

After the butt weld had been observed and analysed, it was necessary to verify its hardness in accordance with the STN EN ISO 6507-1 standard. A BRIVISKOP device, BVR 250 H type was used for the measurement, according to Vickers. Sampling was carried out in the same way as in the previous case. During this test, it was determined whether there were inadequate hard structures or other phenomena in the weld site that could decrease the required quality of the weld because would show the inappropriateness of the proposed technological welding procedure. From the macroscopic aspect (Figure 9, 10 and 11) it is possible to see the course of the hardness measurement in the root line and the lines below the surface of the butt weld.

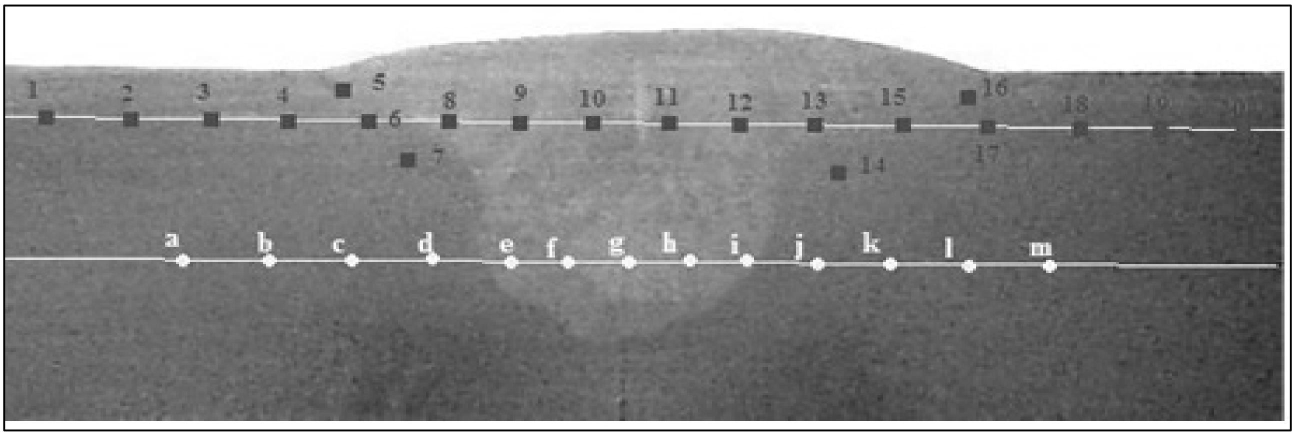

Fig. 9 *Macroscopic image of a butt weld cross-section*

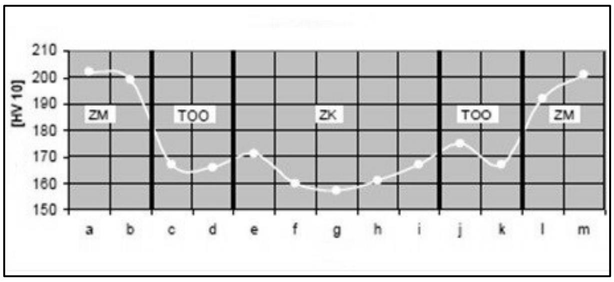

Fig. 10 *Course of hardness measurement – the root line for a butt weld*

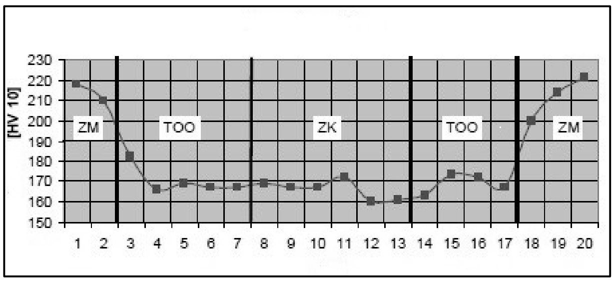

Fig. 11 *Course of hardness measurement – the line under the surface for a butt weld*

From the macroscopic image of the cross-section of the test butt weld, as well as from the course of the hardness measurement, there are not any negative changes in the area of the completed weld and any the appearance of inadequate hard structures in the area of the joint because it could lead to problems in operation. Neither the occurrence of extreme values of hardness, indicating the inappropriateness of the change in mechanization, nor other negative phenomena were observed. From Figure 10 and 11, it is clearly visible that the measurements confirmed the decrease in values in the heat-affected areas of the welded metals.

4.4 Characteristics of the change in the fillet weld welding procedure

For the purposes of the experiment, to verify the quality of the execution of the fillet weld, a welding procedure was proposed where a multilayer circumferential fillet weld was made with a central diameter of 80 mm and dimension: a = 8 mm, a structural offset of 4 mm depth for a diameter of 85 mm and a bevel in the range of 45°. In accordance with the new technological design, after turning the weld, it was necessary to leave an edge of 10 x 45° size to be knocked off. A sketch of the circumferential fillet weld connecting the shaft to the face can be seen in Figure 1.

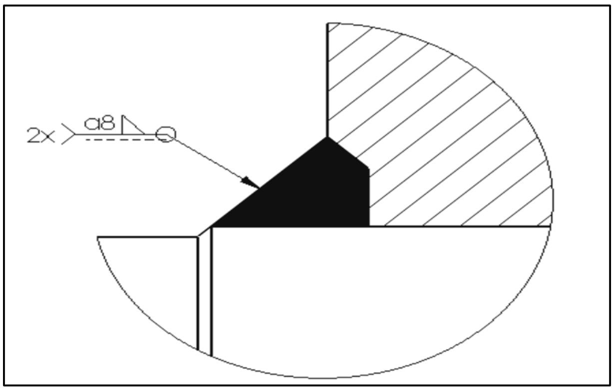

Fig. 12 *Sketch of a multilayer, circumferential fillet weld*

The same welding source as in the first case was used for welding, i.e. KEMPPI KEMPACT PULSE 3000. The weld was made in the PA position. The joint of the part was prepared by turning and stitching. The weld metal was transferred in a pulsed manner during welding. The design of fillet weld welding is shown in Figure 13.

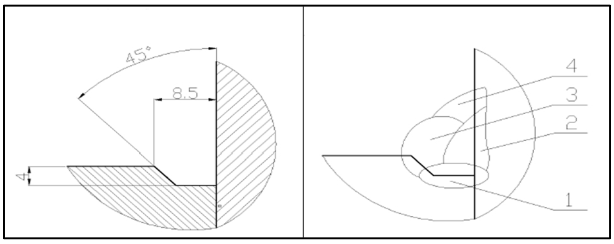

Fig. 13 *Design of the joint and its welding sequence for a fillet weld*

According to STN EN ISO 14343, the G 19 9 L Si type with a diameter of 1 mm was used as additional material. Protective and active gas (Ar 97.5 % + CO2 % CRONIGON 2) with a gas flow of 22 litres per minute and a nozzle diameter of 14 mm was used for protection from the air atmosphere. The contact nozzle was 15 mm away from the surface of the welded part. A current of 180 A and a heat input of 10.8 kJ.cm-1 were used for welding with a table rotation speed of 1 revolution per minute. The mentioned process was applied to all four beads of the fillet weld.

4.5 Evaluation of the fillet weld after the implementation of mechanization

In order to verify whether there were any negative phenomena that could lead to a decrease in the quality of the fillet weld or its parts, a change in technological procedure was verified by making test for fillet welds. These welds were made in accordance with the proposed technological procedure and it was monitored whether the process of making the weld led to negative impacts on the weld. The fillet weld test specimens were subsequently subjected to the destructive tests, during which the weld joints were observed macroscopically, as it can be seen in Figure 14. The purpose was to detect the presence of negative structures or phenomena within the formed weld.

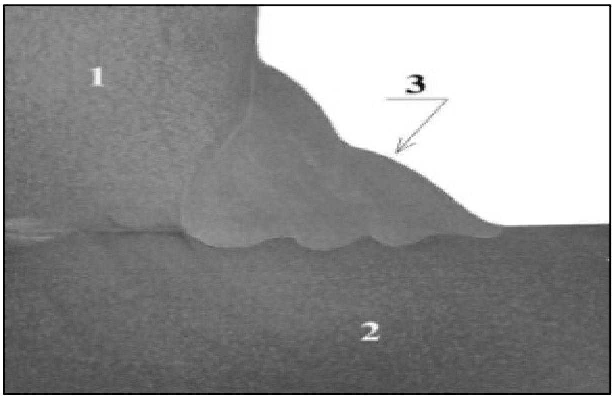

Fig. 14 *Macroscopic image of a fillet weld cross-section (1 flange, 2 shaft, 3 weld)*

Due to the fact that the fillet weld is multi-layered, its root must be welded sufficiently. For this reason, it was important to verify that it was welded to the desired level. The Figure 14 shows that the required quality parameters for the weld root filling have been fulfilled. The test verified that during welding, there were no cracks between its individual layers as well as there was not any formation of unwelded areas in the weld. From the observed image, it was possible to observe all four visible beads welds of the joint and their placement in accordance with the prescribed technological procedure. The image in Figure 14 shows that the new technological welding procedure does not stand for the creation of any inclusion or an incomplete joint. In this weld, the dendritic structure is not visible at each bead weld in comparison with a butt joint, because this type of weld is influenced by the technology of its execution. And thus, the thermal effect of the execution of each layer affects the next layer during welding.

4.6 Evaluation of the hardness of the fillet weld by the HV method

After verifying the weld suitability, it was also necessary to verify the hardness of the fillet weld which was formed after the changing the technological procedure and it was carried out in accordance with the specifica-tions for hardness measurement in the STN EN ISO 6507-1 standard. The BRIVISKOP device, BVR 250 H type, was used for the measurement. The sizes of heat-affected zones were measured. Mechanical properties were determined by HV0.1 hardness testing, the test according to Vickers [4]. During this test, it was de-termined whether there were inadequate hard structures in the joint area and whether the weld has the required quality. Microstructures of the welded specimens were examined using optical and scanning electron microscopy. The sizes of heat-affected zones were measured [4]. The macroscopic image and the course of the hardness measurement for the root line and the line below the surface of the fillet weld are shown in Figure 15, 16 and 17.

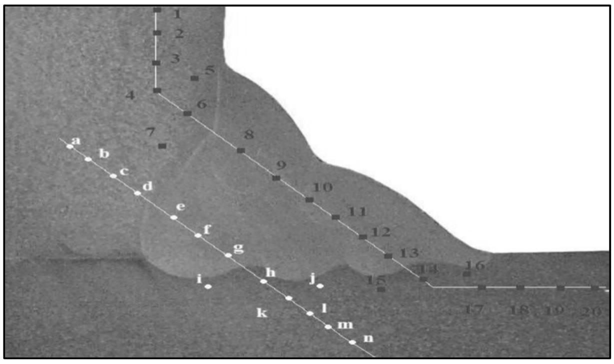

Fig. 15 *Macroscopic image of a fillet weld cross-section*

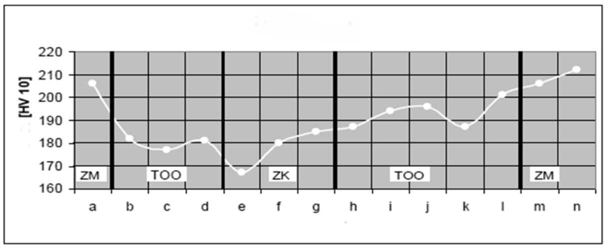

Fig. 16 *Course of hardness measurement – the root line for a fillet weld*

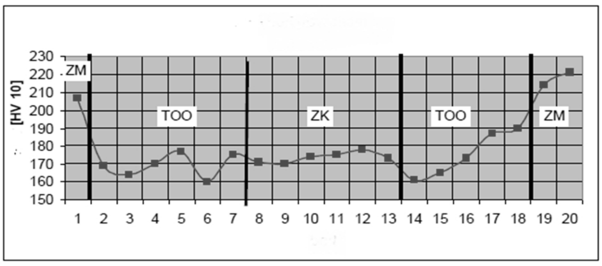

Fig. 17 *Progress of hardness measurement – line below the surface for a fillet weld*

From the macroscopic image of the cross-section of the test bead weld (Figure 15) as well as from the course of the hardness measurement, it follows that there were not undesirable negative changes in the area of the performed weld and there was not the occurrence of inadequate hard structures in the area of the joint because it could lead to problems in operation standing for reduced joint quality. The investigation did not show that there were any extreme hardness values that would indicate the inappropriateness of changes in the technological procedure. From Figure 16 and Figure 17, it is clearly visible that the measurement results confirmed the decrease in values in the heat-affected areas of the welded metals.

5 Effect of proposed changes on production times

In addition to technical advantages, based on the results obtained from individual changes, it is possible to assess whether the given changes brought economic improvement and increased work productivity. If these designs did not appear in the production process and the production time remained the same, further calculations would be unnecessary. Due to the fact that it is a welding technology, the calculation was based on the production time of welding. Equations were used to calculate the time of root welding and welding of filler beads weld. [7]:

1) The equation for calculating the production time relating to welding of the root of the weld for the cylinder (t_{zk}):

$$t_{zk} = \frac{l_z}{v_z} \quad (1)$$

Where:

l_z…The total length of the weld (mm),

v_z…Welding speed (mm.min^{-1}).

The total length of the weld (l_z) can be calculated:

$$l_z = 2.(l_{zoh} + l_{zscr}) \quad (2)$$

Where:

2x…The multiple for the two sides of the weld,

l_{zoh}…Weld length for the shaft circumference (mm),

l_{zscr}…The length of the weld of the joint for the side of the flange and the tube (mm).

2) Equation for calculating of the production time for welding the filler beads (t_{zv}):

$$t_{zv} = \frac{l_{zh}}{v_z} \quad (3)$$

Where:

l_{zh}…The total length of the weld for welding the filler beads weld (mm),

v_z…Welding speed (mm.min^{-1}).

The total length of the weld for welding the filler beads weld l_{zh} can be calculated on the basis of the equation:

$$l_{zh} = 2.(.\,l_{szch} + n_{zvtz}.\,l_{zscr}) \quad (4)$$

Where:

2x…The multiple for two sides of the weld,

n_{zvkz}…The number of fillet beads weld,

l_{szch}…Average length of the weld of the flange - shaft connection (mm),

n_{zvtz}…The number of beads weld of a butt weld,

l_{zscr}…The length of the weld of the joint in the side of the flange and the tube (mm).

5.1 Calculation of production time before implementation of changes

In the original welding procedure, the production time was calculated from (1) to (4) equations as follows [7]:

1) Calculation of the production time of welding the root of the welds before the implementation of mechanization and changes in the technological procedure, according to equation (1) and (2):

$$t_{zk} = \frac{l_z}{v_z} = \frac{2.(235{,}5 + 728)}{150} = 13\ minutes \tag{5}$$

2) Calculation of the production time of welding filler beads weld before the implementation of mechanization and changes in the technological procedure, according to equation (3) and (4):

$$t_{zv} = \frac{l_{zh}}{v_z} = \frac{2.(5.267 + 2.728)}{200} = 28\ minutes \tag{6}$$

From the aforementioned calculation, it is possible to conclude that the production time for the root weld was 13 minutes and the production time for welding the filler beads weld was 28 minutes. The total production time of the weld was 41 minutes. The time required for preparation, auxiliary work and handling of the part have to be also added to the calculated time. The total time needed to produce one weld was 210 minutes on average. The lengthening was caused, for example, by the necessity which was based on the control of the connection of the bead weld as well as the use of two special welding methods.

5.2 Calculation of the production time of the investigated part after the implementation of mechanization and changes in the technological procedure

After the implementation of mechanization, the production time of welding was recalculated. The equation for calculating the welding time of filler beads weld was only used [7]:

$$t_{zvh} = \frac{l_{zvh}}{v_z} = \frac{2.(4.267 + 728)}{250} = 14\ minutes \tag{7}$$

Where:
l_{zvh}…The total length of the weld (mm),
v_z…Welding speed (mm.min^{-1}).

By mutual comparison of the production time before and after the change, it can be concluded that there was a significant time saving of 27 minutes compared with the production time before implementation. The total time required for the formation of the weld was from 100 to 110 minutes per product on average before the changes. Eliminating the TIG method for root welding from the process resulted in a savings of 13 minutes of the production time. The implemented mechanization provided the possibility to weld the front part with the tube with one bead weld. To weld the face and shaft, it was necessary to create 4 bead welds. The saving of production time was also reflected in welding speed which was significantly higher, reaching up to 250 mm.min^{-1}.

6 Results and discussion

Relating to the implementation of mechanization into the technological procedure as well as the impact of the proposed changes in the technological procedure, the calculation and comparison of the research results proved that there were significant savings in the production time of part welding, leading to shortening total production time. Since saving the production time of a part means saving costs as well as the fact that it is possible to produce more parts and thus increase the profit, it will also reflected in the financial savings and profit. On the basis of the savings in production time and the operating rates of the given workplace, the annual financial savings were determined (U_f) for a given welding workplace. The given calculation is based on [7]:

$$U_f = R_{hz}.n_y.t_s = 25.400.1{,}5 = 15\ 000\ EUR \tag{8}$$

Where:
R_{hz}…Welding workplace rate per hour (EUR),
n_y…Annual production volume (pcs),
t_s…Time saving for one weld (hour).

When calculating the savings in financial units, it is also necessary to take into account the costs of a new welding source and positioner at a price of EUR 8,500. Then the financial savings for a volume of 400 parts produced was EUR 6,500 due to the reduction in production time. Subsequently, the costs of welding per year before and after the technology change were compared. Costs N_{zzry} with an annual volume of 400 manufactured pieces after the proposed change were [7]:

$$N_{zzvy} = n_y . N_z . t_{vz} = 400.25.1{,}5 = 15\,000\ EUR \quad (9)$$

Welding costs N_{pzvy} with an annual volume of 400 pieces, before the change there were:

$$N_{pzvy} = n_y . N_z . t_{vz} = 400.25.3 = 30\,000\ EUR \quad (10)$$

Where:
n_y…Annual production volume (piece),
N_z…Welding costs (EUR),
t_{vz}…Production time for one weld (hour).

The return on the investment in mechanization and the subsequent necessary change in the technological procedure can be expected within 7 months from the implementation of all recommended measures. In addition to the economic aspect of changing the technological proposal of welding, there was a significant technical benefit in the form of an increase in the quality of welded joints and workplace safety. This paper illustrated the impact of the implementation of a higher level of mechanization into the production process on the quality of the structural part used in the food line. With the gradual implementation of mechanization, the whole process was simplified and individual parts of the production process were made more efficient. The implementation of the positioner and changes in the welding procedure had a significant impact on the quality of the part as well as on the safety of the production workplace with the significant reduction of the risk of occupational accidents. The quality of the butt and bead weld under investigation was verified by macroscopic observation, and subsequently the hardness tests of both welds were performed and it can be used as proof of the increase in the overall accuracy and reliability of the tested welds. The measurements proved that the measured values in the heat-affected areas of the welded metal decreased for both investigated welds after implementing the mechanization procedure. From the experimental assessment, in addition to the mentioned positive changes, other advantages of a technical as well as an economic nature for the production workplace emerged. By combining two separate welding methods into one, production time was shortened. By removing the unwanted but necessary interruption of the welding process from the technological procedure, work productivity and the quality of the welded joint increased significantly. Mechanization was also reflected in lower energy consumption for increased control, possible repairs of defects and costs of employee incapacity due to possible work accidents. Savings were also calculated in relation to the costs of purchasing cutting tools, which had a significantly reduced service life due to sufficient organization at the workplace and metal spatter during pulsed transmission. This described change also significantly affected the profitability of the company. From the above, it follows that, in addition to technical advantages, the change in the technological process and the implementation of mechanization has a positive effect on the economic situation of the company, and the saved funds can be used to investment into new, progressive technologies. Every change in technological progress will be reflected in financial terms. When proposing further investments, it is recommended to develop a plan and recalculate the expected return.

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