RESEARCH REGARDING THE PROJECTION WELDING OF CYLINDRICAL FILTERS MADE OF STAINLESS STEEL NET

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ABSTRACT: This paper presents a case study about the manufacturing of stainless steel net filters, which are to be used into thermoplastic materials injection machines. The manufacturing process and the welding devices are presented, and then the metallographic analysis of the welds is shown. The experimental research was carried out by means of the ZGB-80 welding equipment in the resistance welding laboratory of the “Politehnica” University of Timișoara, along with other research devices, such as Myachi recorder. Several kinds of INOX steel nets were used, with different wire diameters and mesh/inch^2. The quality, strength and aspect of welding were tested after completion.
KEYWORDS: filter, projection welding, resistance spot welding, resistance seam welding, metallographic analysis.

1. PRODUCT DESCRIPTION

The cylindrical filter is made of stainless steel net, belongs to the filtering system of the plastic mass injection devices, and its general view is shown in figure 1. The product is composed of two concentrical overlapped filters, made of two kinds of net, with different wire diameter, mesh dimensions and mesh density per square inch. This is determined by the constructive and functional role of each component, as follows.

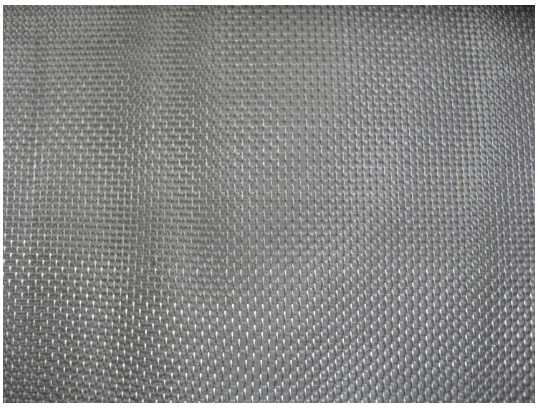
Figure 1. General view of the cylindrical filter.

The inner filter is made of net with 0.4 mm wire diameter and 46 mesh/inch^2 (figure 2a), and it ensures the mechanical strength, the dimensional stability and the shape of the entire cylindrical filter.

The outer filter is made of finer net, with 0.1 mm wire diameter and 76 mesh/inch^2 (figure 2b), and its main role is to filter out the impurities of the molten plastic, so that the injection nozzles stay clear and the quality of the injected product is not harmed.

The cylindrical filter has the following main dimensions:

- filter (cylinder) length: L = 140 mm;
- outer diameter: De = 63 mm;
- inner diameter (informative): Di = 62 mm;
- wire diameter of inner filter: di = 0,4 mm;
- inner net meshing : Ni = 46 mesh/inch^2;
- wire diameter of outer filter: de = 0,1 mm;
- outer net meshing: Ne = 76 mesh/inch^2.



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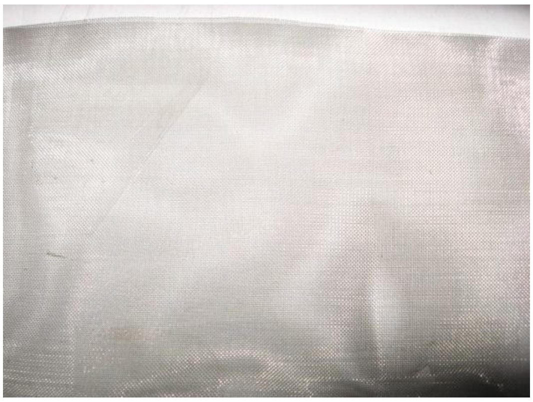

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Figure 2. Filter details.

The filter is assembled by means of two kinds of welding (figure 3).

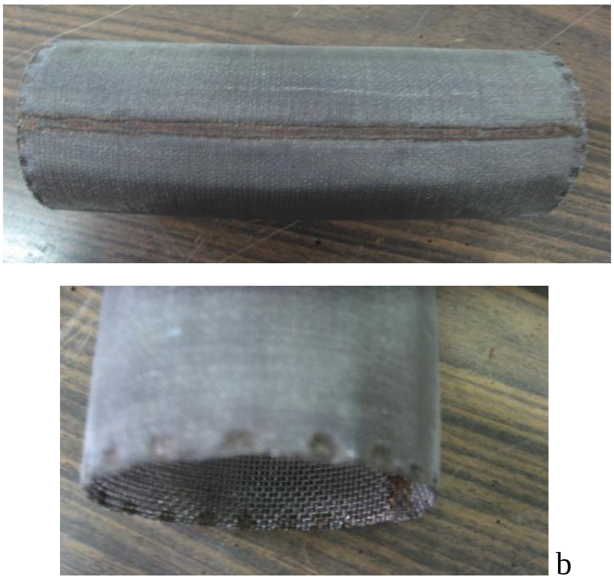
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Figure 3. Aspect of welds.

- one seam weld on the cylinder generator, in order to attain the geometry of the cylindrical filter (figura 3a); the weld must be tight in order to ensure the filtering the impurities out of the molten plastic material; the tightness is attained by overlapping the edges of the net and continuous welding; the welding length is Ls = 140 mm and its width is b ≈ 4mm; the weld width is determined by the overlapping of the net edges, and the weld must be done in such manner that all wires ends must be included (the weld must not feature so-called “whiskers” made of loose ends of the welded wires);
- spot welding on equidistant points of the circumferences of both ends of the cylindrical filter (figura 3b); the weldes spots are approximately 20, with de 3-4 mm diameter, at aproximately 20º each; the weld is not supposed to be tight, and it should only keep the nets from shredding at their edges, but also they must ensure the very close contact between the inner and outer filter, and to maintain the rigidity and geometry at the extremities; the tightness of the filter extremities is achieved by mounting the filter in the two fastening rings of the injection machine; the spot welds must locally melt the ends of the nets wires, previously cut by scissors.

2. CHOICE OF THE WELDING PROCEDURE

The analysis of the geometry of the two welds, of their functional roles and of the nets dimensions (thickness of the nets and and diameters of the wires) results that two electric pressure welding procedures must be used:

- resistance lap seam and projection welding for the seam welding of the filter generator, which ensures weld tightness;
- resistance lap spot and projection welding for the circumference welding, which ensures the shape and rigidity of the filter ends.

Also, the analysis if the welds results that two welding equipments must be used, which are expressly designed to make cylindrical filters in large series, such as a resistance lap seam and projection welding machine for the welding of the generator of the filter, which allows the access of the interior roller and lower arm of the machine inside the filter, and a specialized spot welding machine which allows the access of the inferior electrode inside the filter.

In the case of small-series production, standard welding equipment will be used, on which the above-mentiones procedures can be implemented with small or no supplemental investment in order to reduce the welding costs for the filters.

Starting from these aspects and particularities, the resistance seam welding and projection welding was chosen, with ZGB-80 welding machine from the resistance welding laboratory of the “Politehnica” University of Timișoara.

The resistance seam welding and projection welding procedure (SPR) derives from the resistance spot welding and projection welding procedure (SPP).

At SPP welding, the current passing surface and the pressure ar e determined by the shape and dimensions of the tips of the contact electrodes (figure 4a). At SPR welding, the current passing and pressure are localised into a point which already exists on the surface of the components to be welded (figure 4b). Also, the contact electrodes are replaced with flat electrodes. The welded joint is similar to SPP welding (figure 4c), [1].

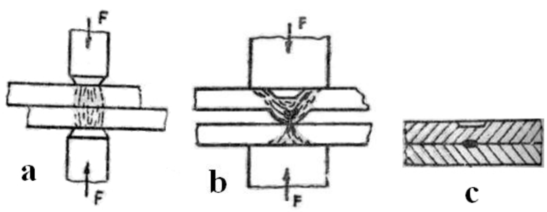

Figure 4. Current passing at SPP and SPR welding.

The prominence defines perfectly the passing surface of the welding current, and it increases the concentration of the produced heat, which is an advantage. It is emphasized that the welding current passes from o component to the other only by means of the prominence.

At the beginning of the welding operation, the heat is much localized and very intense at the contact point, due to the small contact surface which determines a large contact resistance and an elevated current density. As the contact zone heats up, the passing surface increases as the prominence and asperities flatten down. Then, when the entire material that forms the prominence becomes plastic, it flattens and it determines the closing of the components and the appearance of the molten nucleus, and the welded joint is formed under the action of the pressing force of the flat electrodes.

The main advantages of the SPR welding are, [2]:

- elevated productivity due to the possibility to weld more spots simultaneously;
- stronger concentration and localization of the heat by means of the prominence;
- smaller wear of the electrodes, due to their shape and low current density.

Basically, the prominences can be classified as artificial prominences and natural ones.

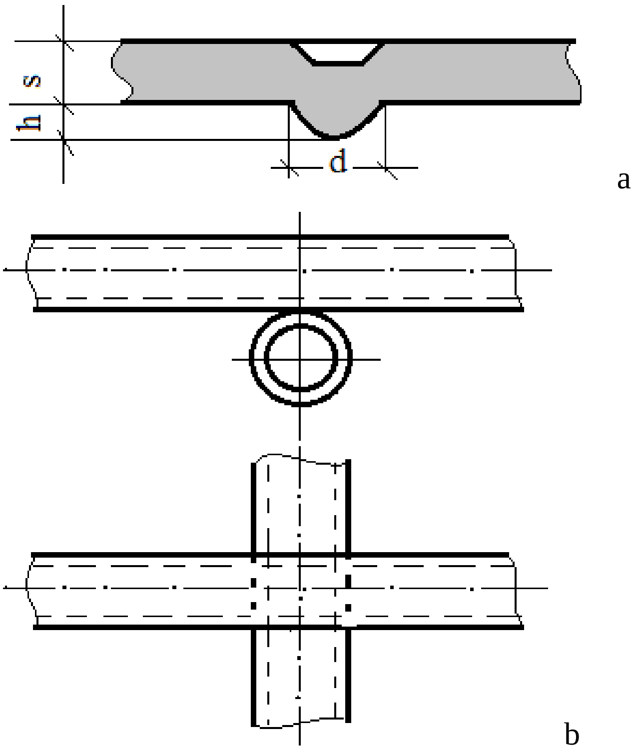

Figure 5. Shapes of prominences: a) spherical artificial; b) natural.

The artificial prominences are made by plastic deformation or mechanical working. They can be spherical, oblong or annular. The spherical prominences are the most usual, easy to make and not expensive. The shape and dimensions of the spherical prominences are chosen according to the thickness of the components, the nature of the material and their respective positions. The shape and dimensions of the spherical prominences are standardised and are characterised by their height "h" and diameter "d" (figure 5a).

The natural prominences are obtained by adequately placement of the components to be welded, in such manner that the passing of the welding current can be localized into a certain contact zone, where the welded joint is to be made. The contact zone can be made on a single point or on a line.

The most typical SPR welding with natural prominences is the case of right-angle welding of two bars, pipes, wires or other round components. By placing these components as a cross, the intersection of their generators yields a very small contact zone. This first pointlike contact will grow progressively according to the welding current and time, and will eventually turn into a larger welded spot. The initial contact determines the occurrence of an elevated current density in the contact zone, which creates fast and concentrated heating in the welding spot.

Natural prominences are attained by overlapping the edges of the nets, on the intersections of their wires (figure 6).

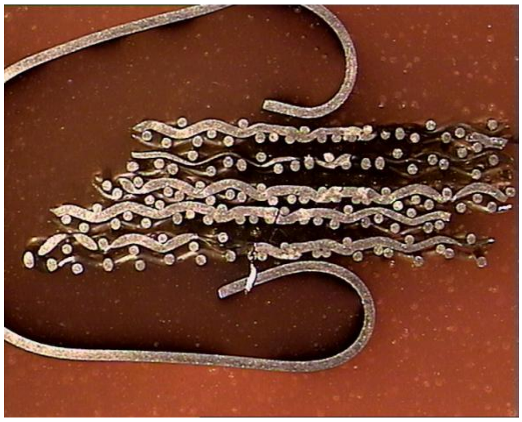

Figure 6. Natural prominences by wire overlapping.

Figure 6 shows a combination of two prominence types, such as *an infinity of spot prominences where wires cross*, and *a certain number of linear prominences where wires overlap on their length.*

3. PRESENTATION OF THE BASE METAL – BEHAVIOUR AT PRSSURE WELDING

The base material of the filter nets is austenitic INOX steel series 304 AISI (1.4301 DIN). Its chemical composition is shown in table 1.

Basically, the austenitic INOX steels are allied with (16-26%) Cr and (6-26%) Ni.

The A INOX steels feature great corrosion resistance, high tenacity at low temperatures, high oxidation resistance at elevated temperatures (the refractory austenitic INOX steels allied with Al or Si), high plasticity (30-50)%, non-magnetic, cannot be annealed (won't produce structural changes, irrespective of the cooling speed). As a disadvantage, they cannot be used in sulphur environments because of the danger of Ni_3S_2 forming (eutectic with low melting temperature 650ºC), which determines the corrosion danger.

Table 1. Chemical composition.

Chemical composition (%)							
C	Cr	Ni	Mn	Si	S	P	Fe
max. 0,08	18-20	8,0-10,5	max. 2,0	max. 1,0	max. 0,03	max. 0,045	66-74

The thermo-physical properties of these steels are different from the ones of the carbon steels, [4]:

- the linear expansion coefficient α is approximately 50% bigger;
- the thermal conductivity coefficient λ is 2,5 times lower;
- the electrical rezistivity ρ is approximately 5 times bigger;
- the melting temperature is lower 1400 - 1450ºC (compared to 1500ºC).

All these lead to some welding particularities:

- bigger welding deformations for the same thickness and linear energy;
- heat concentration into the welding zone;
- powerful heating due to Joule-Lenz effect.

The INOX steels feature higher electrical resistivity and lower thermal conductivity compared to non-allied steels. Thus, the heat accumulation for the welding is favorised. From this point of view the austenitic steels are very suitable for pressure welding. One disadvantage consists of their larger thermal expansion, which enables the occurrence of thermal welding deformations.

When welding austenitic steels, plastic deformation is maintained into the welding zone. Due to this, basically there is no fracture danger because the internal stresses decrease by material flowing. Spot welding, seam welding and pressure welding maintain the delta ferrite content due to the fast cooling. However, due to the fact that cooling occurs fast and under pressure at pressure welding, the fracture tendances are lower at austenitic steels than for melting welding. The shorter heating time is favourable for sigma phase forming and intercrystalline corrosion sensitivity.

When performing pressure welding with austenitic steels, due to their higher electrical resistivity, the mechanical pressure of the electrode must be two-three times bigger that for non-allied steels. The pressure must be maintained throughout welding procedure. Due to the higher electrical resistivity of austenitic Cr-Ni steels, lower welding currents may be used in comparison to the non-allied steels, [3].

4. EXPERIMENTAL RESEARCH

The experimental research aim to establish a feasible pressure welding procedure for manufacturing the filter in small-series production, as an alternative to seam pressure welding which requires specialised welding equipment and suits better large-series production.

The setting of the welding procedure is based on the assembly and welding of the filter and the order of the welding operations is established accordingly. First the outer filter is preliminary spot welded by overlapping the wires, and then the two filters are temporarily assembled. Thus, a 0.8 mm + 0.2 mm joint is formed by assembling the outer and inner filter on their generator, and a 0.4 mm + 0.1 mm joint is formed by assembling the outer and inner filter on their circumference.

An efficient method to increase the productivity and the aspect & quality of the welded filters is to use projection welding. This requires a high power projection welding machine, because of the extended area of the welded surface, such as l x b = 140 mm x 4 mm = 560 mm^2, where an infinity of prominences to be welded are placed, formed by the intersection of the wires of the nets.

Figure 7 shows a general view of the ZGB-80 welding equipment, used for research. The machine features great rigidity and electrodes shaped as copper plates.

Figure 7. ZGB-80 projection welding machine.

In order to weld the filters, due to their cylindrical shape, it is necessary to adapt the machine by reshaping the welding electrodes. Figure 8 shows the inferior electrode, which is prismatic with rectangulat active surface, calibrated to the weld dimensions.

Figure 8. Shape of the inferior eletrode.

For the welding operation, the electrode is placed on two rectangular copper prisms (figure 9).

Figure 9. Positioning of the filter for welding.

It is easy to see that the filter is suspended on the inferior electrode. Previously it has been temporarily spot welded on five points on the generator, by the BOSVA spot welding machine.

Taking into account the lack of information in the literature about the projection welding of nets, the first tests were made by welding two plane nets superimposed (figure 10).

The checking of the resistance and quality is performed by plucking test (figure 11).

Figure 10. Positioning for welding.

If the welding power and heating are insufficient, then the welding is inadequate, equivalent to solid state pressure welding which tears easily apart (figure 11a). The increase of the welding current leads to greater welding power and yields resistant welds which tear apart by plucking the upper net (figura 11b).

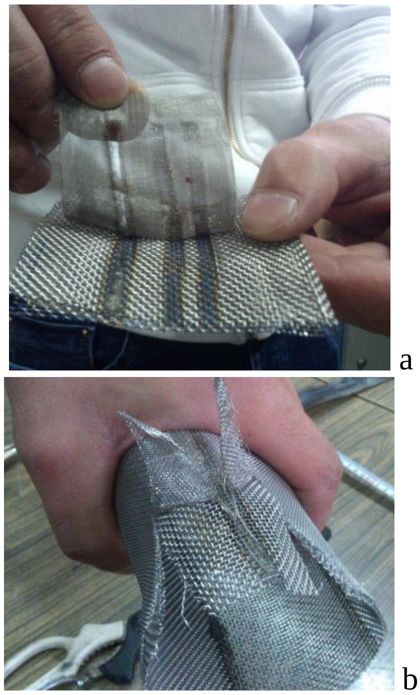

Figure 11. Plucking test.

The adequate technology, which ensures resistance and optimal welding quality, was resulted according to the welding tests (figura 12).

The measurements and the recording of the tehnological parameters were made by means of Myachi recorder (figure 13).

The positioning of the filter for welding is shown in figure 14.

Figure 12. Aspect of pressure welds (down - detail).

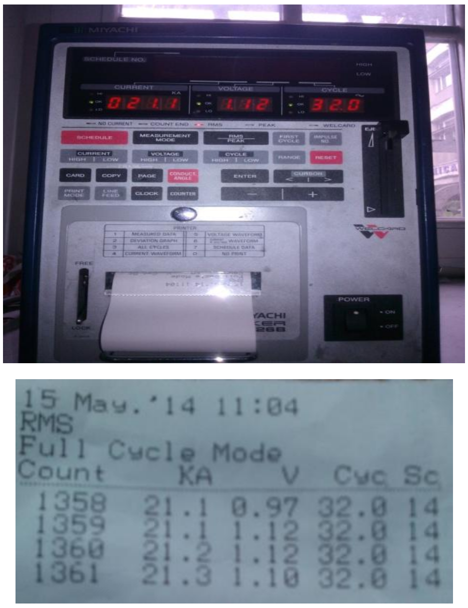

Figure 13. Recording of welding parameters.

Figure 14. Positioning for welding.

The aspect of the projection welding on the generator of the filter is shown in figure 15.

The welding technological parameters, considered as optimal, are shown below:

- welding current: Is= 21 kA;
- welding time: ts= 32 p (1p = 0,02s);
- pressing force: 400 daN;
- welding voltage: Us=1,12 V.

Figure 15. Aspect of the projection welded joint.

The welding has constant width, is aesthetical, with constant heating on all length. If the pressure of the electrodes is not uniform, then the welding is not uniformly heated, with overheated and colder areas. This may lead to the conclusion that the weld features fluctuations of the mechanical strength, even with unwelded spots, only jointed in solid state. The cause of this uneven heating of the weld consists of the uneven pressure of the upper electrode upon the length of filter, because of lack of parallelism of the lower support, caused by its deformation under the bending stress that may occur during welding. The welded surface is delimited by the blackened zone which occurs by oxidation caused by air cooling of the material, specific to inoxidable steels. If the corrosion danger may occur during use, then the welded surface must be passivated by removing the oxides surface and recreating the protective Cr layer.

5. QUALITY CONTROL OF THE WELDED FILTERS

The quality control consisted in checking of the visual aspect of the welded joints and in checking of the dimensions of the filter (figure 16). The visual control tests for flaws of the welded joint, such as lack of tightness, material burnout, molten wires etc.
The dimensional control followed the dimensions of the filters and their tolerances. This check is mandatory inorder to guarantee the possibility to mount the filter in the injection machine with adequate tightness. Callipers and templates were used for the dimensional control (figure 16).
The metallographic analysis (figure 17) shows the occurrence of two kinds of welding between the wires of the nets, according to the local conditions in the contact zone, such as typical projection weldings resulted from partial melting and solidification of the molten metal (figure 17a), and weldings in solid state as a result of insufficient heating of the wires in the contact zone (figure 17c). Also, there are superimposed wires that were not welded because there was no contact between them (figure 17a). However, the projection weldings that ensure the strength of the welded joint are predominant. Any structure alterations in the welded joint are not present, which is normal for this base metal.

Figure 16. Dimensional control with templates.

The hardness measurements confirm the absence of any structural alterations in the welded joint, the thermally influenced zone and base metal (table 2). The measurements were carried out for three welded spots, by means of Vickers HV5 method.

Table 2. Hardness measurements of the welded joints.

Spot	MB	ZITM left	Welding	ZITM right
1	175	178	172	168
2	164	185	180	175
3	164	185	177	175

According to the tests, we can conclude that the projection welding technology complies to the requirements of the filters normal use.

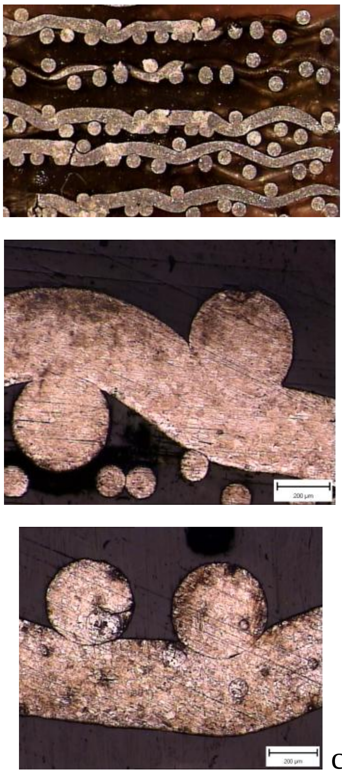

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Figure 17. Metallographic analysis ot the welded joints.

6. FINAL CONCLUSIONS

The experimental research yielded the following conclusions:

- the projection welding procedure is very suitable for the generator welding of the filters, as an alternative to the seam pressure welding if there is no specialised welding machine;
- the welding features an aesthetical aspect and uniform width on all its length;
- however, it is necessary to design special eldctrodes for this particular welding process, which increases the costs in comparison with spot pressure welding;
- the quality of the welded joint is affected by the irregularity of the pressure on the length of the weld, which is hard to cope with because of its relatively great length, and this leads to fluctuations of the quality in some spots; this aspect complicates the device, in order to avoid any deformations caused by bending stresses;
- it is rather difficult to place the filter on the inferior electrode because of insufficient viibility;
- for the welding, standard welding of adequate power can be used, such as the ZGB-80 projection welding equipment (80 kVA);
- the equipment must be fitted with rigid arms in order to avoid deformations.

By applying the projection welding procedure for the welding of the above-mentioned filters, the highest productivity is achieved, in comparison with the seam welding or spot welding.

7. REFERENCES

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