Failure Analysis of High Frequency Welding Fixed Joints of Thermoplastic Polymers

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The increasing of the field usage of high frequency (HF) welding joints technique of thermoplastic polymers gives advantages regarding productivity, quality of welded joints and high reproducibility of results. Base of experiments, this debate analyzes the main types of failure, the causes of the failure and the prevention method for HF welding of polyvinyl chloride PVC foils.

Keywords: HF welding, polymers, failures

The automotive industry development corroborate with high quality and low price requirements, lead to the development of materials with improved performances which can be joined with HF welding.

For industrial implementation of this technology with high productivity, it is mandatory a quality certification of materials manufacturability keeping the material properties after HF welding, due to risk of defects and requirements imposed by automotive industry.

The quality management evolution consists in the transition from missing of failures in the products to avoiding of failure through preventive actions along entire production, starting from design to final assembly.

An important step was done when the control was included in succession of production steps, which means checking and measurement of process parameters, components, subassemblies and finished products [1, 2].

For each product which is in manufacture flow, the quality assurance depends on the processes stability; this means all the facts which influence the processes for finished product: manpower, equipment, materials, methods, environmental.

The monitoring and measurement of process parameters in automotive industry is required by ISO TS 16494 [3].

The technological process and energy adjustment at HF welding are done considering the HF welding machine- Generator and Press like Transmitter and Receptor.

When a new material or new electrode is used, the power of generator is successively defined, meaning application of Generator - Press- Welding Die.

The wrong choice of HF machine components- generator, press, welding die- can lead to an unsatisfied welding process, uncontrolled or even to impossible energy transition into the material which need to be welded, so the welding joining cannot be made.

To understand the HF welding process we will make an analogy with radio transmitter and receptor. When the radio receptor and radio channels are set up to the same frequency, the music transmited from transmitter, will be very clearly broadcasted to the environment.

If the transmitter- receptor are not set up to the same frequency, the music will have a bad quality, with noises and jamming; and if there are set up for different frequencies the music is not be transmited.

Using the analogy, if HF generators are the transmitter and the welding die is the receptor, it is very logic that both units must have the same frequency to run up. Additional from radio application, in HF welding we have a generator and a press- welding die application which havenot a potentiometer for volume adjustment.

The adjustment of welding joint characteristics is done through generator frequency adjustment, so if the frequency is reduced, the welding joint quality is lower.

To avoid this effect, the welding machine contains an adjustable electrical condenser (capacitor) which reduces the energy variation from HF generator to welding die [9].

In HF welding, the conditions to have a good joint are:

- the materials which will be welded must to be heated up to melting into the contact area to obtain the joint of materials to molecular level;
- the welding joint is obtained through a specified pressure in a specified time;
- after materials melted during welding time, they have to be cooled under specified pressure and cooling time.

The result is a welding joint with the same mechanical resistance like the basic material.

The polymers which are HF welded are bipolar materials which are heated up through molecules friction, caused by polarities changes (27 millions times/ second) and applying of HF energy.

Because the polymers have low electrical conductibility and a high dielectric constant, they act like an dielectric between electrodes of welding die, they are heated up and under electrodes pressure, after cooling time, it is obtained the welding joint [4-6].

The quality criteria of HF welding joint

Mechanical characteristics

As tested method, for establishing of HF welding aptitude of PVC foils with different dimensions used in automotive industry, it is considered PEUGEOT S.A. test method D41 1033 which has as impose requirement minimum breaking force under 35N/50 mm, according to sketch- figure 1 [4, 7, 8].

The minimum breaking force must to be 35 N/50 mm in welding joint areas A, B and C, and the melt materials repartition to be constant (fig.2) [4, 9- 11].

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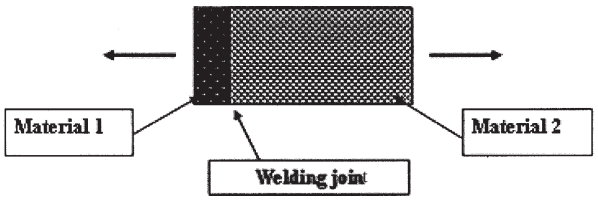


Fig. 1. Testing method sketch

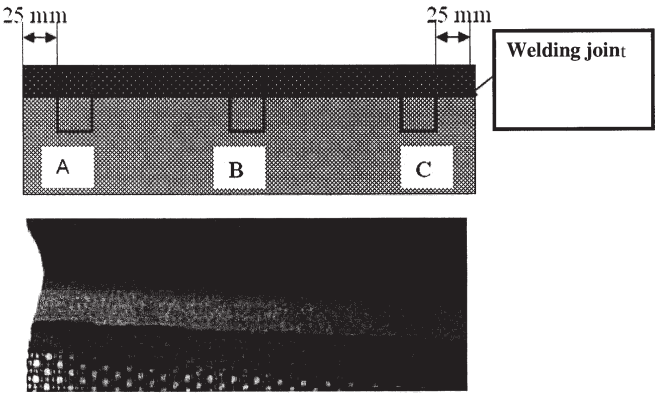


Fig. 2. Repartition of melt material into the welding joint

Geometrical characteristics (visual aspect of welding joint and constant welding width according to specification, overlap deviation of PVC materials must to be maximum 1mm)

After HF welding, the steps have to be visible on front side of product and welding width must to be constant and overlap deviation of PVC materials must to be maximum 1mm (fig.3).

Possible failures and solving methods

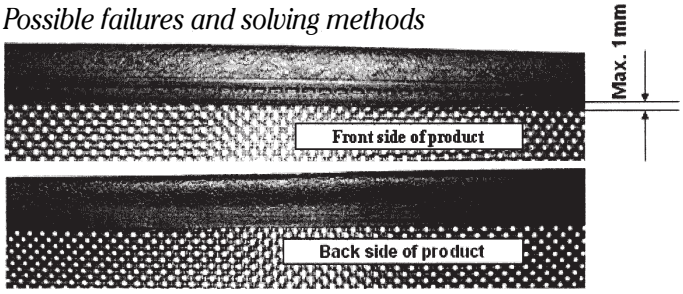


Fig.3. Macroscopic appearance of welded parts

The possible failures and solving methods are detailed as follows.

a) Description of failure/ problems, the overlapping of PVC materials is according to specification in the handle area (max. 1 mm) and is presented in figure 4.

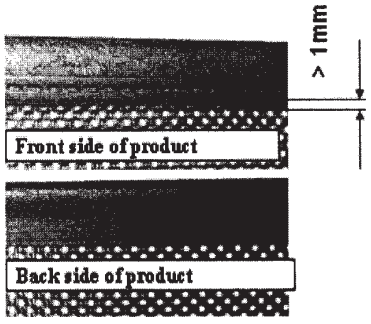


Fig.4.Overlapping of PVC materials

Root cause: because of distance between handle and guiding piece, we have a movement of assembly-wire, handle-which move the PVC material during closing HF welding die.

Corrective action: Adjust plastic guiding so that to reduce the movement of handle into the guiding (fig. 5).

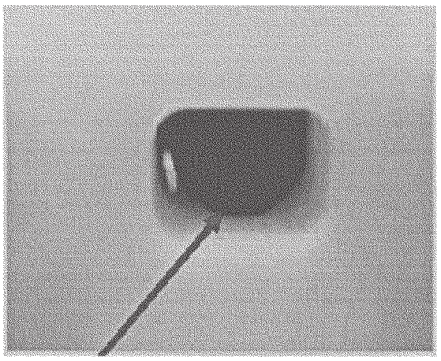


Fig. 5

b) Another failure is materials breaking in welding area.

Failure correction is done with revalidation of the lower and upper limit of process parameters:

- power [KW] =0.2 – 1,2
- welding time [sec] = 0.5 – 3

Table 1

No test	Power [KW]	Time welding [sec]	Picture with the welded piece
1	0.5	1.5	
2	1.0	1.5	
3	1.5	1.5	
4	1.8	1.5	
5	1.5	3.0	
6	*2.0*	*3.0*	
7	*2.2*	*3.0*	

Note: On the welding machine the welding pressure cannot be modified. Using the lower and upper validated process parameters, we can see that the braking of materials is not possible.

Corrective actions:

1. Increase of welding pressure
2. Decrease the hight pressure of plastic guiding.
3. Increase the electrodes hight, using brass plates between electrodes and basic plate of welding die.

c)Another defect is endurance test Not OK at 100°C for PVC material welded with textile fiber parallel with welding joint.

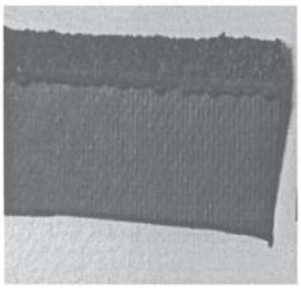
It was analyzed using testing method PEUGEOT S.A. test method D41 1033 the HF welding behaviour of PVC material with textile insertion:

- textile fiber perpendicular at welding joints (6a).
- textile fiber parallel at welding joint (6b).

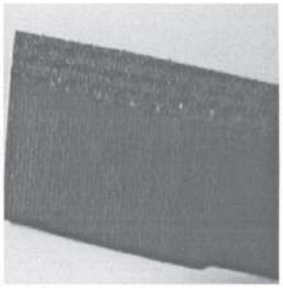
The analyses give us the next conclusion:

For the textile fiber perpendicular on welding joins the melt material distribution is constant, but with burrs (red on graph);

- for textile fiber parallel at welding joint the melt material distribution is constant, without burrs (continuous line on the graph).



a



b

Fig.6. Position of fiber in correlation with welding joints

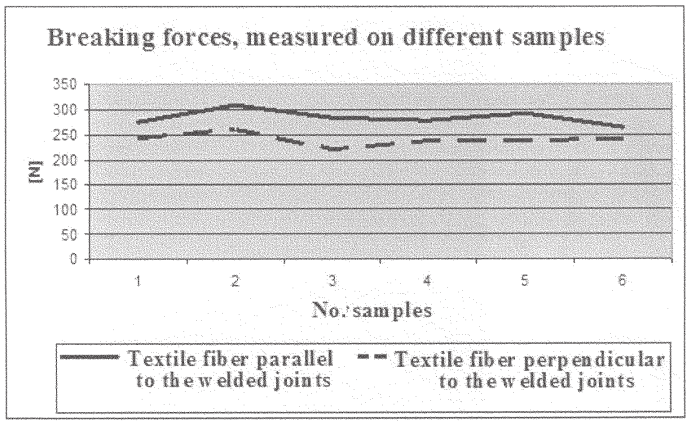


Fig.7. Breaking force of welding joints

After analyzing of breaking force of welding joint it is recommended the use of PVC materials with fiber direction parallel at welding joint (continuous line on the graph).

d) One defect which cannot be controlled is Electrical shortage in welding die between electrodes and aluminum profile (marked area, fig. 8).

This defect cannot be controlled.

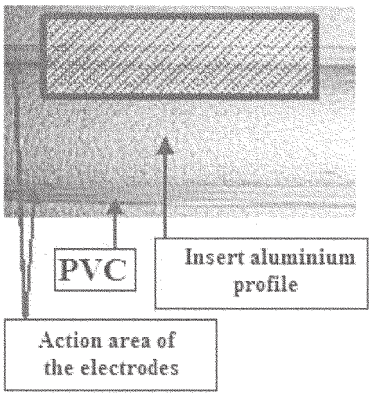


Fig.8. Failure generated by electrical shortage

The PVC material, black color, contains carbon in composition, which is a good electrical conductor.

Due to carbon agglomerate on material thickness there is the risk of electrical shortage in pattern area where we have the aluminum profile.

e) Defects are considered also the shine area or bubbles near HF welding joint (fig. 9).

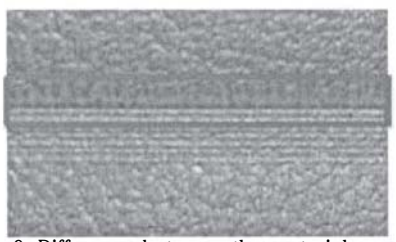


Fig.9. Difference between the materials near the joint welding and base material

The biggest energy acting on materials, changes the macroscopic structure of materials and the material appearance is different from the base material.

After analyzing we concluded that the distance between aluminum insertion and electrode influences the superficial surface of PVC material. So, if the distance is lower the PVC material has more Shine area and/ or bubbles on it.

f)Missing metallic insertion for product rigidity- failure presented in figure 10.

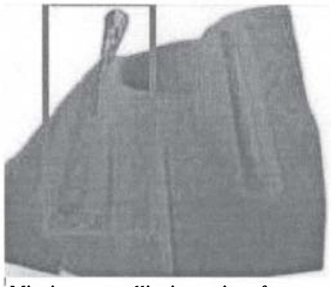


Fig.10. Missing metallic insertion for product rigidity

Corrective action:

- Retrain the operator.
- Install anti-proofing devices (Poka-Yoke) with inductive sensors for metallic insertion detection

g)Electrical shortage or/and mechanical damage caused by metallic insertion position, figure 11.

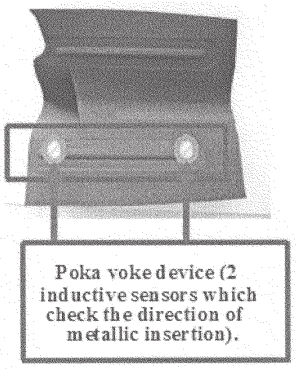


Fig.11

After the analyze it was established that due to flexible metallic wire there is a big risk to damage the electrodes.

Corrective action**:**

• Implement Poka-Yoke device (2 inductive sensors which check the direction of metallic insertion presented in figure 11).

h)Joint welding too weak or too strong are a failure which appear due to:

- welding parameters incorrect set up if the welding joint is not correct on entire contact area with electrodes.
- welding die not correct adjust if the welding joint is not correct on few parts of contact area with electrodes.

i)Some defects are generated by visual failures on electrodes surface (dots, visible marks (steps) which are not uniform, etc) and are presented in figure 12.

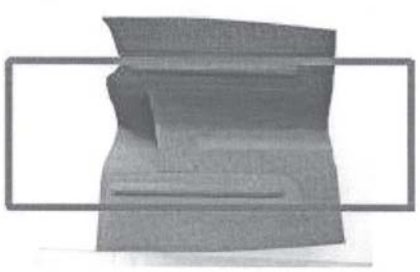


Fig.12. Visual failures

After analyzing we can say that these failures appear due to:

- foreign material on the electrodes;
- electrodes surface damaged;
- foreign material on the foil.

a) A defect which can be corrected is burr on welding joint edges (fig. 13).

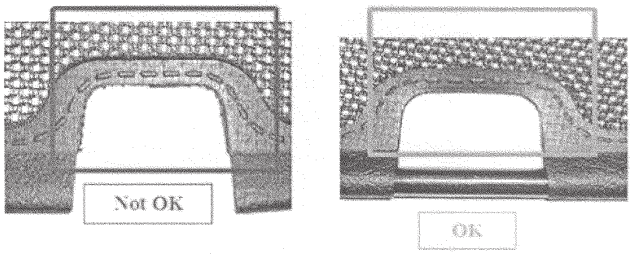


Fig.13. Burr acceptable/ not acceptable on welding joints edges

After analyzing it was defined the root cause for this: space between electrode and guiding which permit flowing of melt material during welding process (fig. 14).

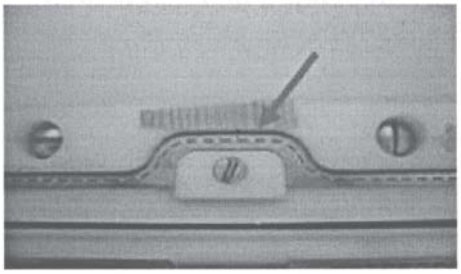


Fig.14

Also, there have been seen marks on the surface welding die which conduct to the conclusion that the pressure is not uniform (fig. 15).

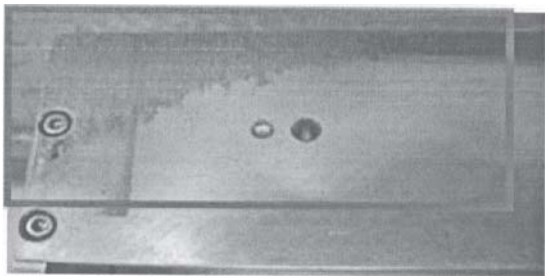


Fig.15

Actions:

-Correct the welding die.

Put 4 plastic identical blocks inside of welding machine in the corners to compensate and uniform the pressure on the welding die.

k)Overlapping of PVC materials is not according to specification in handle area (max. 1 mm) showed in figure 4.

After analyzing there were measured and put in table 2 the values and marked with grey the deviation of dimension of PVC material (fig.16).

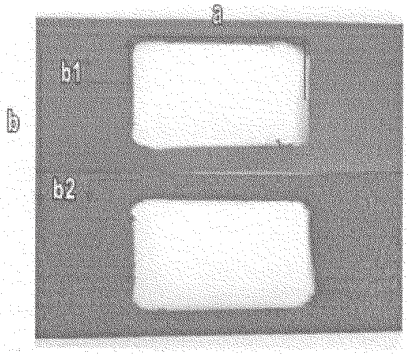


Fig.16

Corrective action: The PVC material is sorted and the supplier is informed by an official letter.

Conclusion

Using the Ishikawa analyses diagram (5M= Machine, Manpower, Method, Material, Medium/ Environmental) there were obtained the following results (fig. 17).

From this graph it results that the main failures appear from HF welding dies design, materials quality and operators influence, and the lowest influence is work method.

As conclusion, the validation of HF welding process at process implementation is mandatory, welding die and work method [4,5].

A very important point of process validation is the establishment of boundary samples and failure catalogue for components and welded pieces.

The HF welding process optimization must contain the raw materials reception according to the specifications, for minimum variations.

For the elimination of manpower influence it is the recommended to implement mistake-proofing devices (Poka-Yoke).

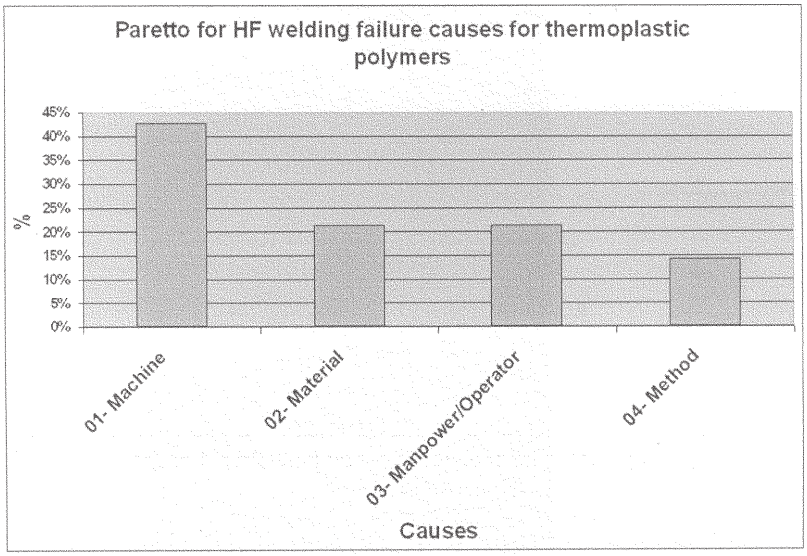


Fig.17. Pareto diagram for HF welding failure causes

For stability and improvement of processes it is important to extend the experience from best practice (Lesson& Learn).

References

1.BARON T., ISAC-MANIU AL., Calitate si Fiabilitate, Ed. Tehnică Bucureşti, 1988, p.90, 336
2.VERMESAN H., PUP M., AHMADI M., OLARIU L., VERMESAN D., PREJBEANU R., Rev. Chim. (Bucuresti), **59**, no. 8, 2008, p. 891
3. *** SR ISO/TS 16949:2002, Editia 1, ASRO Bucuresti, p.40
4.MITELEA, I., VĂRZARU, N., POPOVICI, D., POPESCU, M., BORDEASU, I., Mat. Plast., **45**, no. 3, 2008, p. 289
5. MITELEA, I., VARZARU, N., BORDEASU, I., POPESCU, M., Mat. Plast., **46**, no. 1, 2009, p. 101
6. COCARD, M., GROZAV, I., IACOB, M., CANEPARU, A., Mat. Plast., **46**, no. 4, 2009, p.452
7.JACSCH E., CHETARITI D., Materiale plastice poliamidice, Ed. Tehnică Bucureşti, 1988, p.14
8.LORENSCHEIT K., Hoch Frequenz Technik, Verlag, Mainz 1997/1998
9.BARON T., Metode statistice pentru analiza si controlul calităţii producţiei, Ed. Tehnică Bucureşti, 1988, p. 270
10.MITELEA, I., TILLMANN W.., Ştiinţa materialelor II, Editura Politehnica Timişoara, 2007, p.269
11.**** Normalisation Renault Automobiles - Renault V.I. Service 60201 Section Normes et Cahiers des Charges: Norma 1033- Shearing Stengh of HF Welds Textiles- Plastic Sheets, Plastic- Coated Textiles, Revision February 1987, p.2

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