Researches of High Frequency Welding Process Validation for Same Polymers

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The paper presents a methodology devoted to statistical analysis of welding characteristic process parameters in high frequency for Polyvinyl Chloride. The experimental values for technological parameters assure a high stability during the control processes in production as well as a high quality of joint welding.

Key words: high frequency, welding, polymers, process

Quality is a very complex notion, the basic of quality are conferred by technical, economical and social functions.

The original equipment manufacturer has as focus obtaining of desired quality in time according to higher expectation of final customers who want to buy and use high quality products.

A big step forward was done when it was introduced in each production step the self control, this means checking and measurements of process parameters for raw materials, subassemblies and final products [1].

As a result, the manufacturing processes have to be controlled with statistical methods, so that the requested characteristics (specification) to be more accurate.

Today, the statistics is part of success in obtaining of requested specifications of products.

For a product which is in production, the quality assurance depends by how the process is known, that means all influences (operators, machines, tools, gauges, method) which are in process [8-10].

The process have to be conducted in order to be statistically controlled, which means detection and elimination of process variation and moving the characteristics in established limits of tolerance (process validation).

Supervision and measurement of process parameters in automotive industry is mandatory according to ISO TS 16494 (Quality Management Handbook referenced to SR EN ISO 9001:2001) [7].

Concepts and definitions

For defining of constancy level for a specific quality characteristic which belongs to a process we need the following information [4]:

- customer specification required;
- measurement of center (target value);
- measurement of constant distribution in the process during a period of time;
- measurements of natural or inherent variation which should appear in the process (“reproducibility level” of process);
- reevaluation of causes for discrepancy between center nd entire constant distribution in process, during a defined period of time and a cost estimation needed for elimination of causes.

The ke elements which are evaluated during capability study are presented in table 1.

The variation of characteristc under process fluctuation gives us *the dispersion field* (capability) [5].

The limits where the characteristic variation is accepted represent the limits of tolerances, which are defined through specifications (lower limit and upper limit).

The machine adjustment represents the position of distribution field of characteristic value, express through center of distribution group.

The machine precision is given by distribution field size. This is suitable when the distribution center size is between tolerances field.

The process is stable as adjustment when the center (Xbar, Xmed, Xmax, Xmin) is stabile in time.

The process is stable as precision when the distribution (σ, R, R-bar)is stable in time.

Typical situation of distribution for stable processes = position and distribution of dispersion field are stable in time (table 2).

Centre	$\overline{\overline{X}}$	$\overline{\overline{X}} = \frac{\sum_{j=1}^{k} \overline{X}_j}{k}, \overline{X} = \frac{\sum_{i=1}^{n} x_i}{n}$
Distribution	6σ	$6\frac{\overline{R}}{d_2}$, $6\frac{\overline{s}}{c_4}$, 6σ
Capability	C_p și C_{pk}, P_p și P_{pk}	$\sigma_c = \frac{6\overline{R}}{d_2}$, $\sigma_p = s$ (all sample)
Stability	L_{XIC}, L_{XSC} L_{RIC}, L_{RSC}	The process is not stabile if more than 0 from 25 or 1 from 35 points are outside of limits.

Table 1
KEY CAPABILITY ELEMENTS

Table 2
DISTRIBUTION SIZE FOR STABLE PROCESSES

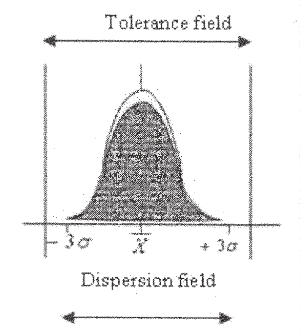
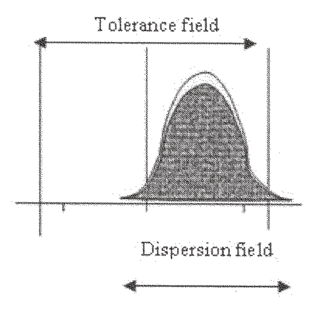
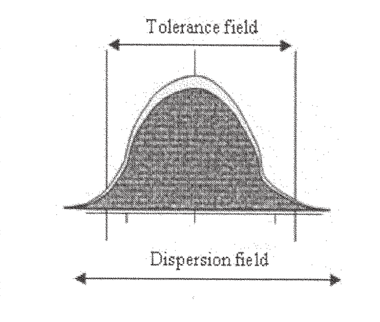
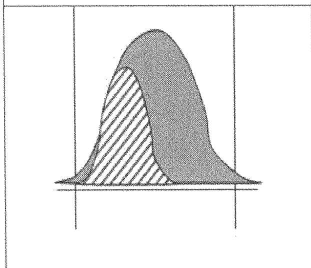
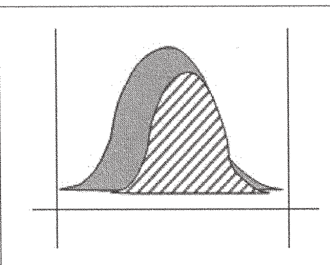
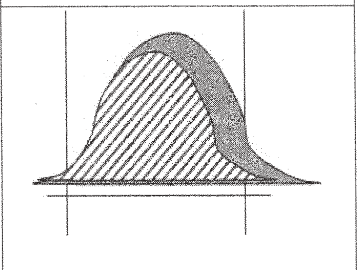
Center OK, Capability OK	Center not OK, Capability OK	Center OK, Capability not OK
		
Not actions in place.	Improve the center obtain with modified process target.	Modified the process or revised the specification.

Table 3
DISTRIBUTION SIZE INSTABLE PROCESSES

Dispersion out of specified limits, capability is good.	Dispersion in specified limits, capability is very good.	Dispersion out of specified limits, capability is not OK.
		
Find the root cause for instability and eliminate the causes if is convenient from cost point of view.	Not action needed.	Change the process or revised the specification or find the root cause for instability and eliminate the causes if is convenient from cost point of view.

Typical situation for distribution for instable processes = position and distribution of dispersion field are variable in time and showed in table 3.

Validation of high frequency (HF) welding process of polymers type Polyvinyl Chloride (PVC) using statistical analyses

During validation of HF welding process of polymers type Polyvinyl Chloride (PVC) using statistical analyses must be respected the rules [11]:

-the materials must have constant characteristics (same batch);

-the process parameters must remain constant (no adjustment);

-same operators, same quality inspector etc;

-same welding machine;

-same welding tool;

-same control method.

HF welding process input description [3]:

• Equipment:

- HF welding machine Herfurt Trumpf 15 000 with sliding welding table (fig. 1);

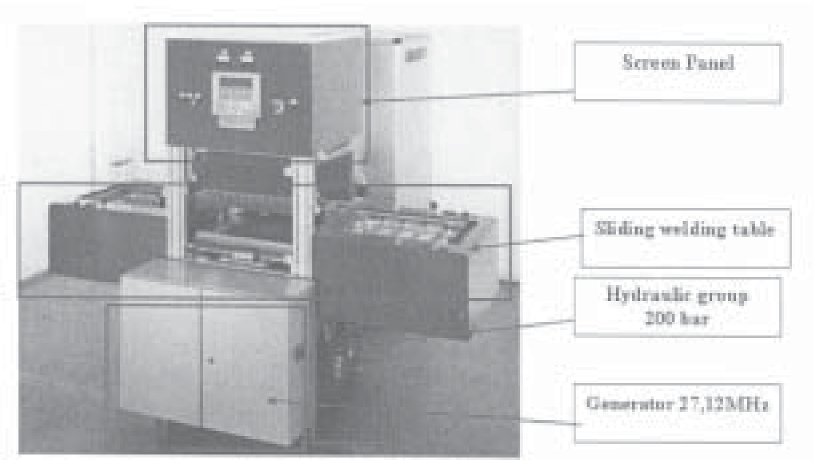


Fig. 1. HF welding machine used during experiment

- Symmetrical HF welding tool (fig. 2);

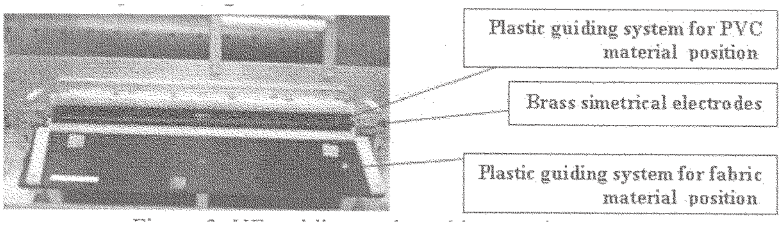


Fig. 2. HF welding tool used in experiment

· Materials [2] (fig. 3):

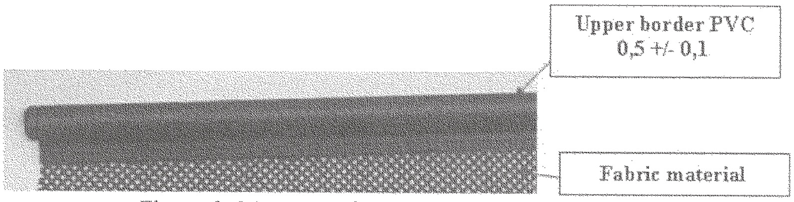


Fig. 3. Macroscopic appearance of welded part

• Method:

The testing method used is PEUGEOT S.A. test method D41 1033, which imposes the minim break force 35N/50 mm, according to figure 4.

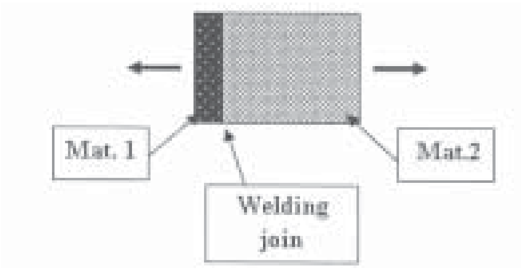


Fig.4. Testing method sketch

Measurement device (fig. 5) was build up so that to respect the method requirements. This has a fix part where the sample is fixed with a pin and a sliding part which is moving through a screw- nut technique.

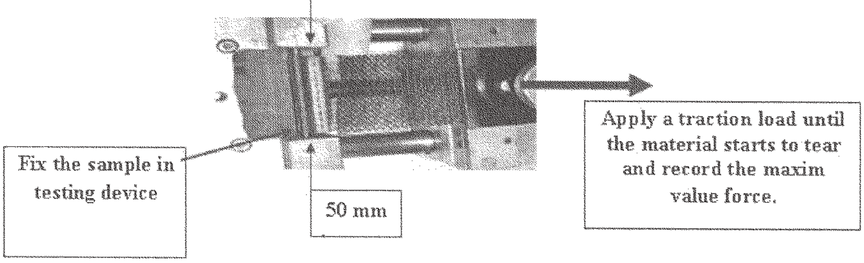


Fig. 5. Testing device

Main welding requests imposed (fig. 6) are:
a.Macroscopic appearance:
- Welding steps have to be visible and uniforms (1);
- Overlapping of PVC has to be max. 1mm (2);

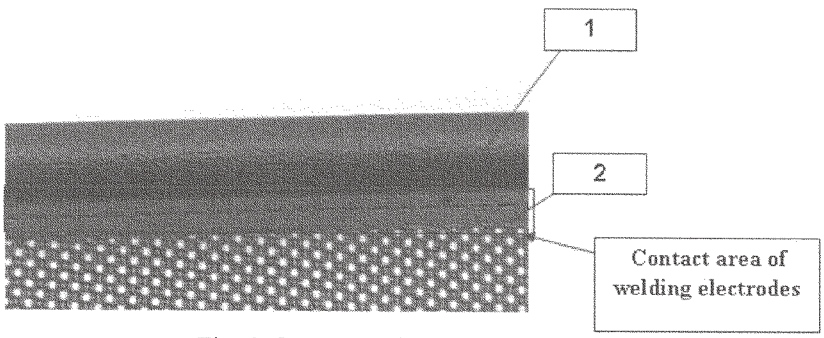


Fig. 6. Geometry of welded structure

b.Minimum brake force have to be 35 N / 50 mm according to PEUGEOT S.A. test method D41 1033.

c.PVC material has to bewell melted on entire surface (fig. 7).

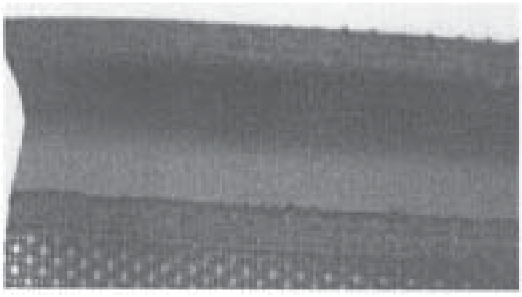


Fig.. 7. Distribution of melt material

Experimental results, statistical interpretation

With successive trials and checking of welding according to customer requirements it was establish a welding parameters condition which fit with customer specification, presented in table 4.

Table 4
OPTIMAL VALUES OF WELDING PARAMETERS

Parameter type	Parameter Value
Power Is [A]	5,0
Weld Time [s]	2,2
Weld Pressure [bar]	5,0
Cooling time [s]	2,0
Cooling pressure [bar]	5,0

For validation and statistical analyses were welded 25 consecutive products and were drawn 3 samples with 50mm width from each part (from left and right 25mm away from edges of welded join and from middle), recording the break force according to described test method.

The samples have to be careful identified with number of part, position, date (figs. 8, 9).

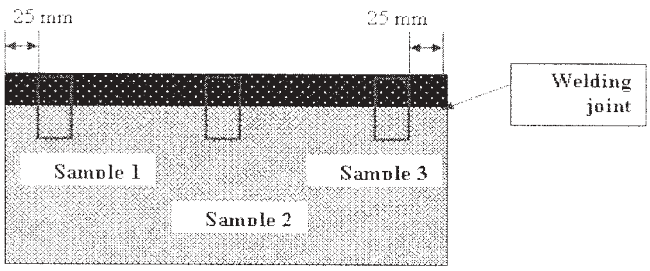


Fig. 8. Cutting location of samples

The resulted values were recorded in table 5 for statistical processing being kept a constant process input.

We can visually observe that the breaking area is in fabric material, so we can say that the welding joint as mechanical strength higher than the basic material mechanical strength.

According to statistical processing of measured values defined during process we have the following observations:

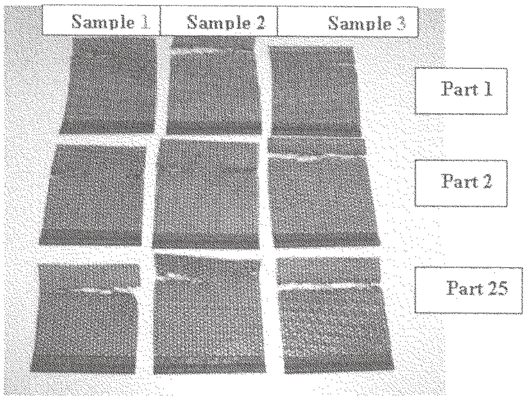


Fig. 9. Source of tested samples

-from process center diagram (Xbar, Xmed) we can see that the HF welding process is stable from adjustment point of view, so we can say that with the establish parameters we reach the imposed requirements;

-the process is stable from precision point of view according to the process stability diagram (R, R bar);

-the capacity indicators are in target according to 6σ limits (Cp>1.67;Cpk>1.33)

$$Cp = 4.07$$
$$Cpk = 2.366.$$

Starting from normal distribution curve of frequencies, represented in figure 10, we can observe that:

- 99.73 % from measurement points are into the normal curve in central range = 6σ;
- 99.73 % are included into the range = 8σ.

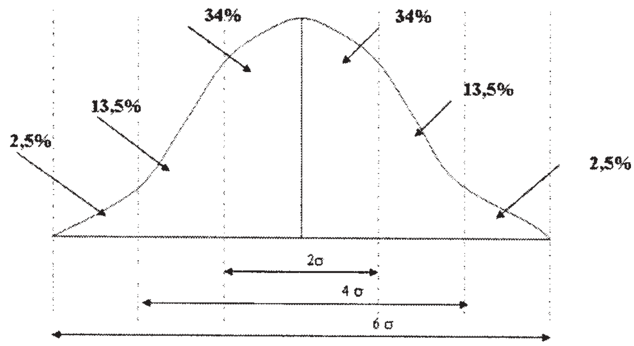


Fig.10. Normal distribution curve of frequencies

For our process analyses we used 6σ limits and we are between, so we can say that we have 99.73% process confidence.

In our situation we decided to control and monitor the welding process at each 2 h according to method use during validation PEUGEOT S.A. test method D41 1033 and to record the values.

If the break force is outside the asked range (>35N), the operator has to stop the production and to inform the process engineer.

For a more confidence in the process we defined a warning limit for break force at 45 N and in this case the operators should continue the production, but they must inform the process engineer to analyze the elimination of the process variation.

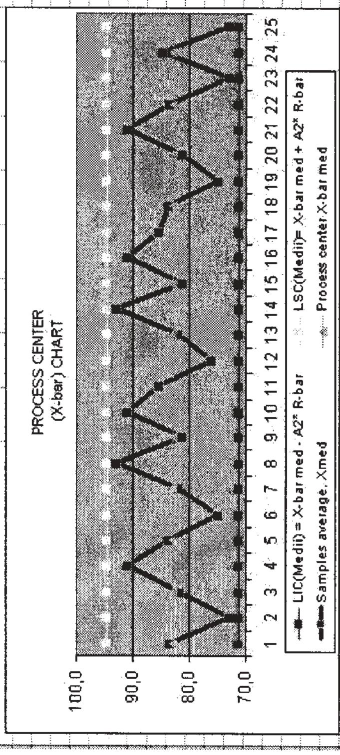
For appearance request, during the validation have to be used the sample approved by customer.

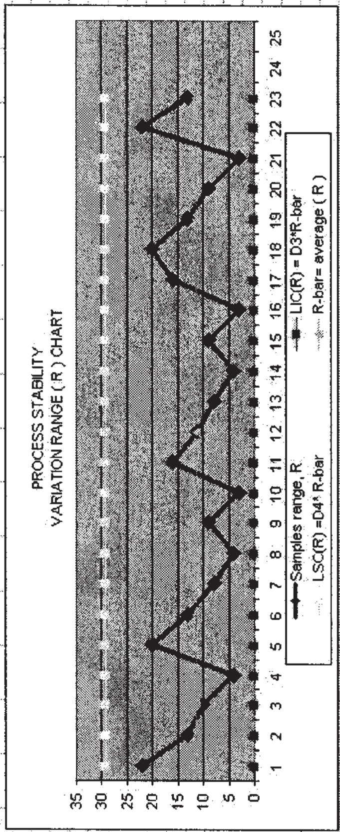
During welding process the process engineer and quality engineer have to define boundary samples, OK samples,

Table 5

MEASUREMENT VALUES AND STATISTICAL ANALYSES

Product	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Caracteristic	Measured Breake Force [N]																								
Sample 1 (left)	70	68	79	91	71	70	80	93	78	90	75	73	80	93	78	90	75	71	70	78	90	70	68	72	69
Sample 2 (midle)	92	70	88	89	91	72	87	91	87	90	91	72	87	91	87	90	91	91	72	87	90	92	70	93	69
Sample 3 (right)	88	81	78	93	89	83	79	95	79	93	90	83	79	95	79	93	90	89	83	79	93	88	81	89	81
Samples sum	250	219	245	273	251	225	246	279	244	273	256	228	246	279	244	273	256	251	225	244	273	250	219	254	219
Samples average, Xmed	83	73	82	91	84	75	82	93	81	91	85	76	82	93	81	91	85	84	75	81	91	83	73	85	73
Samples range, R	22	13	10	4	20	13	8	4	9	3	16	11	8	4	9	3	16	20	13	9	3	22	13	21	12
R-bar= average (R)	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
X-bar med = average(Xmed)	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83
LIC(Medii) = X-bar med - A2* R-bar	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3	71,3
LSC(Medii)= X-bar med + A2* R-bar	94,6	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63	94,63
LIC(R) = D3*R-bar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LSC(R) =D4* R-bar	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4	29,4





Break force > 35 N/ 50mm	F	UM
Upper Tolerance (Ts)	200	N
Lower tolerance (Ti)	35	N
Process capability:		
Target Cp>1,67		
Cp = (Ts- Ti)/6σ	4,07	
Target Cpk>1,33		
Cpk = min((Ts-Xmed)/3σ, (Xmed-Ti)/ 3σ)	2,366	
Cpkl	5,774	
Cpki	2,366	
6σ= 6* Rbar/ d2	40,54	
3σ= 3* Rbar/ d2	20,27	
Estimated value of square root average deviation of process (σ)		

NOK samples, which have to be used by operators during production.

Conclusions

From economical point of view, it is very important to avoid in the same time the cost for implementing an excessive control in production in order to gain "an over quality" as well as to reduce and control of scrap rate and of all other loses conducting to a "low level quality".

The capability analyses of process discover if is feasible to have a higher uniformity of products starting from process capability estimation, based on history and help in cost analyze improvement, so that the process should run at maximum possible capacity.

The technological parameters established during validation of HF welding process for Polyvinyl Chloride proved that this it is stabile from adjustment and precision points of view according to quality requirements imposed by customer for join welding.

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