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SOME ASPECTS REGARDING THE RADIO FREQUENCY WELDING OF TEXTILE COMPOSITES

BY

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Abstract. The paper presents the results of some researches regarding the behaviour of welded textile composites; the textile composites had been produced by polyurethane coating. Another aim of the paper is the identification of some specific characteristics used for the evaluation of the seam sealing quality. The interdependences between the characteristics of the textile composites and the technological parameters of the welding process are analysed in the paper.

Key words: waterproof, welding, seam sealing, thermoplastic coating.

1. Introduction

Technical textiles represent a huge field with many different domains for applications that require the increased functionality of the textile materials/products. These functional textiles are characterised by specific mechanical behaviour; the study of their mechanical properties is complicated by the fact that textiles are atypical, elastic and hyperelastic materials (Ciobanu & Filipescu, 2012). The use of textiles as reinforcement for composite materials is currently well developed. There are different types of rigid and flexible textile

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reinforced composites and one of the processes used to assemble composite products is welding.

Generally, textile welding is the process of joining pieces of fabrics using heat and pressure. Thermoplastic coatings, such as polyvinylchloride (PVC), polyurethane (PU), polyethylene fabric (PE) and polypropylene (PP) are used for heat sealing (Davies, 1998).

Textile welding is not used for the usual daily clothing or other traditional textile products. Fabric welding is used only when the product destination requires its functionalization. Such requirements include certain mechanical properties - high resistance to water and pressure, as well as abrasion resistance at the seam.

A basic requirement for the waterproof protective garments is for the seam sealing to correspond to EN 343 (Loghin, 2003). This type of products implies:

− the use of waterproof materials as raw material, mainly textile composites;

− the use welding technologies as methods for seam sealing.

Basically, waterproof composites are made of a textile layer and a coating polymer placed on the face or the back side of the material. The way in which the coating polymer is placed represents a criterion for the selection of the adequate welding method for seam sealing (Loghin, 2003; Loghin, 1998).

The most used welding methods as established by previous researches (Loghin, 1998) and industrial practice are:

− *Welding with hot air jet* for seam sealing for coated composites, with the polymer placed inside the garment;

− *Welding with radio frequency* (RF) or *dielectric welding* for seams sealing for coated composites, with the polymer placed outside the garment.

According to the welding characteristics and the stresses produced in the seams during wearing, the dielectric welding is considered appropriate for the following technological variants (Loghin, 2003):

− Welding for joining purpose,

− Welding for seam sealing, after sewing.

2. Materials and Methods

The aim of the experimental research is to study the behaviour during welding process of a group of textile composites, with polyurethane coating (PUR). Two types of textile fabrics were used for support – woven fabrics and knitted fabrics. The coated materials were produced by indirect layering method, on the face of the material (Loghin, 1998). The research variants are presented in Table 1.

Table 1
Research Variants

Variant code	Textile support characteristics	
	Composition, [%]	Type / Structure
B.1	PA 100%	Warp knitted / Locknit (charmeuse)
B.4	67% PES + 33% cotton	Woven / Cloth structure
B.5	PA 100%	Warp knitted / Locknit (charmeuse)

The assemblies were made on the RF welding machine UZP 1600, in the following technological conditions (Loghin, 1998; Jones & Stylios, 2013; UZP technical manual):

− Seam type SSa, with fabrics placed face to face;

− Seam allowance – 10 mm;

− Linear superior electrode, unshaped, l = 3 mm width and L = 100 mm long, made of OL40;

− Technological parameters:

1. power (P), adjustable between 400 – 1200 W, 5 steps;
2. welding time (t), adjustable between 0 – 5 s, 10 steps;
3. pressure force (Fp), adjustable at 10 preset levels, between 9 – 200 daN.

In order to evaluate the seam sealing and to analyse the correlation with the technological parameters of the RF welding process, following indicators are considered as relevant (Davies, 1998):

− the seam tensile strength depending on the direction of the tensile load (longitudinal or transverse, see Fig. 1);

− the seam waterproofness.

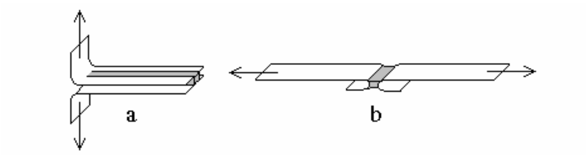
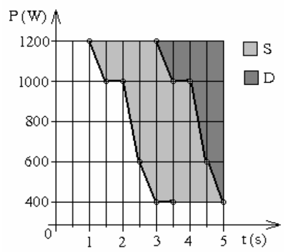
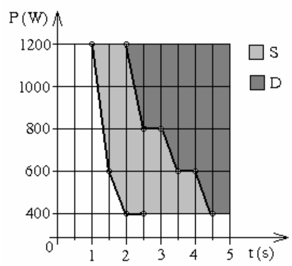
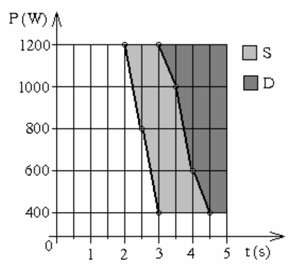


Fig. 1 − Tensile strength, testing direction:
a – successive loading of the welding line (longitudinal); *b* – simultaneous loading of the welding line (transversal).

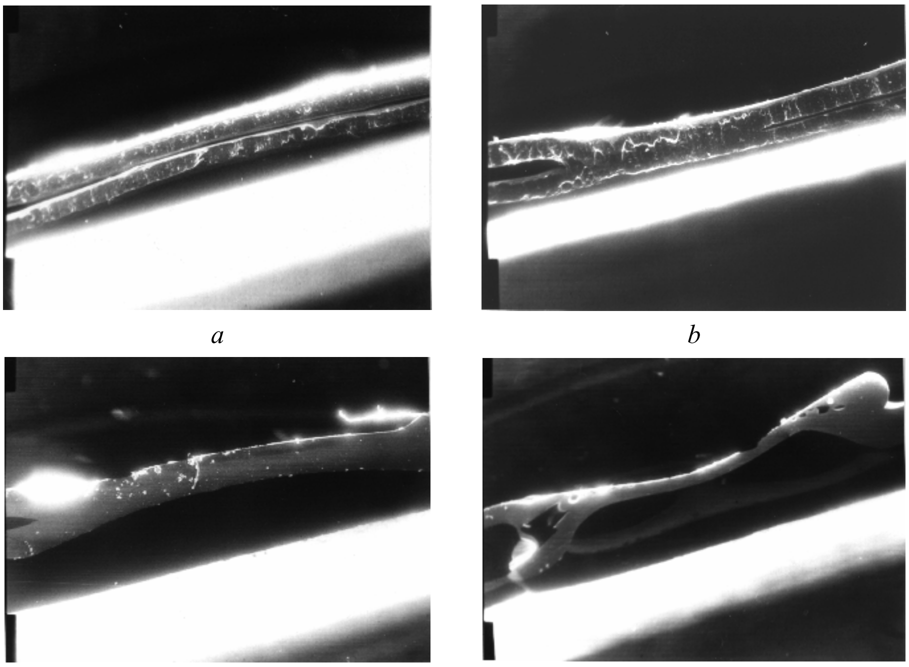
The tensile strength was determined on the strength testing machine with constant deformation gradient MESDAN TENSOLAB. The waterproof was appreciated using the hydrostatic pressure method, on the FF-19/A METRIMPEX testing device, according to standard SR 9051/5-94.

A series of empirical manual experiments for the strength of the welding seams was necessary in order to define the technological practical range. Table 2 presents the area of weldability for all three variants. The criterion for the weldability area was to have at least the adherence of the coating polymer, considering that subsequently, by adjusting the pressing force, there are conditions for obtaining a suitable seam. The Table records the different types of welded composites obtained for different power values. The aspect of their cross section is defined using SEM (x50), as presented in Fig. 2.

Table 2
Welding Behaviour

Variant	t [s]	P, [W]					Welding area
		400	600	800	1000	1200	
B.1	1	–	–	AS	AS	A	
	1.5	–	AS	AS	A	A	
	2	–	AS	AS	A	S	
	2.5	AS	A	A	A	S	
	3	A	A	S	S	S	
	3.5	A	S	S	EM	D	
	4	S	S	S	EM	D	
	4.5	S	EM	EM	D	D	
	5	D	–	–	–	–	
B.4	0.5	–	–	–	–	AS	
	1	–	AS	AS	AS	A	
	1.5	A	S	S	S	S	
	2	S	S	S	S	S	
	2.5	S	S	S	D	D	
	3	S	S	EM	EM	D	
	3.5	S	EM	EM	D	D	
	4	S	EM	EM	D	-	
	4.5	EM	D	D	–	–	
	5	D	–	–	–	–	
B.5	0.5	–	–	–	–	–	
	1	–	–	–	–	–	
	1.5	–	–	–	–	AS	
	2	–	–	AS	AS	AS	
	2.5	AS	A	A	S	S	
	3	A	S	S	S	S	
	3.5	A	S	S	EM	D	
	4	S	S	EM	EM	D	
	4.5	S	EM	EM	D	D	
	5	D	–	–	–	–	

AS – low adherence (Fig. 2 *a*); A – adherence before welding (Fig. 2 *b*); S – welding (Fig. 2 *c*); EM – edge effect (Fig. 2 *d*); D – destruction (tearing of the up layer or appearance of the electrical penetration phenomenon).



a *b*

c *d*

Fig. 2 – SEM images (x50) of the welded samples in cross section: AS – low adherence (*a*); A − adherence before welding (*b*); S − welding (*c*); EM – edge effect (*d*).

The influence of the process parameters on the major characteristics of the seams was analysed using regression analysis by passive experiment (un-linear, with an independent variable). The mathematical models obtained are useful for illustrating the variation trend of the analysed characteristics.

The experimental program was designed to observe the influence of the followings:

− *Variant F1 – influence of the processing power*, P. For certain values of the processing time within the weldability area, the level of power is gradually modified. The variants selected have at least good layer adherence (A) and the strongest edge effect (EM). The pressure force is maintained at the same level for all the variants (F_p = 28 daN).

− *Variant F2 – influence of the processing time*, t. For certain values of the power within the weldability area, the processing time is gradually modified, in the same conditions as for variant F1.

−*Variant F3 – influence of the pressure force,* F_p. For the variants from the weldability area with good adherence (A) or welding (S), the processing time and power are maintained constant and the pressure force is modified at precise levels.

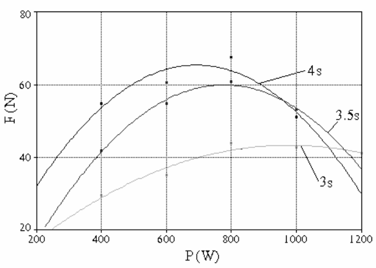
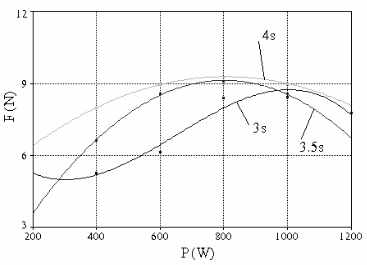
The experimental data were processed using the JANDEL SCIENTIFIC – TableCurves program that generates all the models for the multiple regression equations depending on an independent variable. The models with high values for the coefficient of determination r^2 were selected ($r^2 > 0.8$).

3. Results and Discussions

3.1. The Influence of the Power on the Seam Strength, F1

The mathematical models for the breaking strength (transversal stress ST and longitudinal stress SL) and the corresponding graphics are presented in Table 3. Because the analysed fabrics have a similar behaviour, the paper discusses only the results for variant B1.

Table 3
Mathematical Models for Variant B1, Experiment F1

Test direction	Graphics	Mathematical models
ST		$y_{1(3)} = 1.64+0.08P-4.3\ 10^{5}P^{2}$ $y_{1(3.5)} = -18.3+0.2P-12.9\ 10^{5}P^{2}$ $y_{1(4)} = -0.7+0.19P-13\ 10^{5}P^{2}$
SL		$y_{2(3)} = 7.66-0.02P+4.3\ 10^{5}P^{2}-$ $-2.17\ 10^{-8}P^{3}$ $y_{2(3.5)} = -0.73+0.024P-1.5\ 10^{5}P^{2}$ $y_{2(4)} = 4.17+0.01P-7.8\ 10^{-6}P^{2}$

As a result of $y_{1,2(t=cst)} = f(P)$ graphics analysis, the general conclusion is that for an increased power over the limit of 1000 W, the breaking strength decreases significantly, more so at higher processing time. This a logical conclusion if we consider the existence of the degradation process of the welding line, due to the edge effect and increased polymer rigidity near the joining zone.

It can be observed that the composites present a well defined optimum interval for the breaking strength (power 800…1000 W). This interval can be explained by the high values for the processing time that restrict the interval in which the power varies. Generally, higher power determines shorter processing time, with the same technological effect.

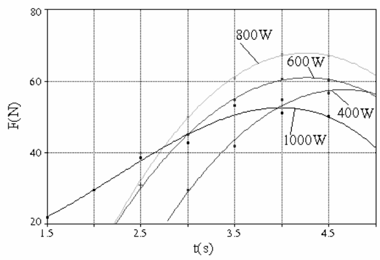
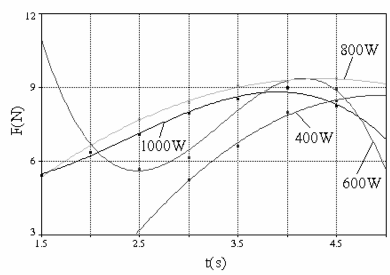
3.2. The Influence of the Processing Time on the Seam Strength, F2

The mathematical models for the breaking strength (transversal stress ST and longitudinal stress SL) and the corresponding graphics are presented in Table 4. The models that describe the correlation between strength and processing time, for different values of power, confirm the previous conclusions.

Two trends are identified:

1. *The increase of strength* with time *t* for the lower power range (400…600 W), within the fabric welding area;
2. *The decrease of strength* with time *t* for the higher power range (1000…1200 W).

Table 4
Mathematical Models for Variant B1, Experiment F2

Test direction	Graphics	Mathematical models
ST		$y_{1(400)} = -168+97.1t-10.4t^2$ $y_{1(600)} = -118.3+83.8t-9.8t^2$ $y_{1(800)} = -139+97.5t-1.4t^2$ $y_{1(1000)} = 15.7-9.5t+ +11.6t^2-$ $-1.74t^3$
SL		$y_{2(400)} = -13.6+9.01t-0.9t^2$ $y_{2(600)} = 54.3-49t+15.7t^2-1.5t^3$ $y_{2(800)} = -0.005+4.29t-0.49t^2$ $y_{2(1000)} = 6.4-3.06t+2.04t^2-$ $-0.28t^3$

A critical value for power, P = 800 W, can be defined for which the processing time has a low influence on the breaking strength. Between 2 and 4 s, the force increases regardless of the power value. Maximum values are reached for P = 800 W and t = 4 s. In the case of the longitudinal stress (SL) the force is similar for the 600 and 800 W power values.

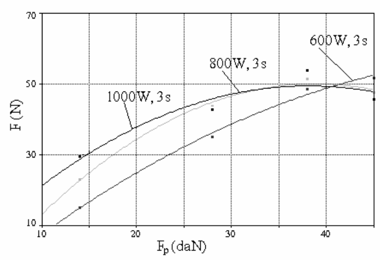
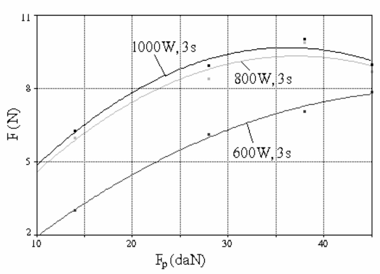
From the technological point of view, the following values for the process parameters are recommended: P = 600 W/t = 4.5 s or P = 800 W/t = 4 s that ensure good seam strength.

3.3. The Influence of the Pressure Force on the on the Seam Strength, F3

The mathematical models for the breaking strength (transversal stress ST and longitudinal stress SL) and the corresponding graphics are presented in Table 5.

Table 5

Mathematical Models for Variant B1, Experiment F3

Stress type	Graphic	Mathematical models
ST		$y_{1(600,3)} = -13.49+2.27F_p-0.02F_p^2$ $y_{1(800,3)} = -16.8+3.43F_p-0.04F_p^2$ $y_{1(1000,3)} = -2.56+2.72F_p-0.03F_p^2$
SL		$y_{2(600,3)} = -1.28+0.35F_p-0.003F_p^2$ $y_{2(800,3)} = 0.42+0.47F_p-0.0064F_p^2$ $y_{2(1000,3)} = 0.44+0.5F_p-0.007F_p^2$

The experimental results show two behaviour trends at the pressure force, as following:

1. *The breaking force increases* with the pressure force for the entire variation range; this conclusion is valid for a low value of the power (P = 600 W), the variant is presenting a good adhesion for the weldability area defined in Table 1.

2. *The breaking force grows significantly* for the first two pressure levels (14 and 28 daN), then for the following two levels (28 and 38 daN) the breaking force increases less, while for last two pressure levels (38 and 45 daN) the tensile force decreases.

All the mathematical models are second degree equations, the graphics are parabolic with a maximum point. The result is that with the increasing of the pressure force the tensile force will be significant reduced so that there is no point in continuing the experiment.

4. Conclusions

The experimental study carried out on the seam strength of welded fabrics hallows for the following conclusions:

1. For the RF welding method of a great importance is the definition of the weldability area, made based on welding tests and subjective evaluation of the seam. The experimental studies have shown that any generalisation is difficult, the composite materials presenting variable behaviour, any difference (fabric thickness, nature of the covering polymer, additives, dye, etc.) affecting the weldability area.

2. In order to diminishing the detaching of the coating polymer from the supporting base, as a result of the strength, the combined assembles sewing-welding are recommended. In this case the welding process is used to tighten the seam, the resistance of the assembly being mostly assured by sewing.

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ASPECTE LEGATE DE SUDAREA MATERIALELOR
TEXTILE COMPOZITE

(Rezumat)

Lucrarea prezintă rezultatele unor cercetări privind comportarea materialelor textile compozite sudate; materialele compozite au fost obținute prin peliculizarea cu poliuretan. Un alt scop al lucrării este identificarea unor caracteristici specific utilizabile în evaluarea calității cusăturii. Sunt analizate interdependențele dintre caracteristicile materialelor textile compozite şi parametrii tehnologici ai procesului de sudare.