The 4th International Conference
″Advanced Composite Materials Engineering ″
COMAT 2012
18- 20 October 2012, Brasov, Romania

CONTRIBUTIONS TO ULTRASONIC WELDING OF INTELLIGENT COMPOSITE MATERIALS USED IN VEHICLE MANUFACTURING

Z. Apostolescu[1], G. Amza[1], M. Dragomir Groza[1], S.L. Paise[1]
Polytechnic University of Bucharest, Romania, amza@camis.pub.ro , zoia@camis.pub.ro.

Abstract: *The paper presents main methods of permanent joining of smart composite pulling into obvious advantages of using ultrasonic energy. Experimental results are presented ultrasonic welding used in the construction of intelligent composite automotive bumper protection and some intelligent auto stops.*
Key words: *smart, composite, welding, method.*

1.INTRODUCTION

Making smart composite parts through assembly welding technology is very complex because it must take into account a number of factors related to the intelligent processing of composite materials and technological parameters, mechanical and acoustic influencing a greater or lesser extent small welding process. The main elements to be taken into account, related to smart composite materials processing are: the nature of the components that make smart composites, matrix smart composites, reinforcing elements, sensors or sensor system used, the geometric configuration of the surfaces to be joined, overall dimensions the surfaces to be joined, the properties of each component of smart composite materials and overall system properties, how to obtain composite materials smart grid sensors, productivity required.

2. WELDING PROCESS PARAMETERS OF SMART COMPOSITES

Ultrasonic welding smart composites depends on three categories of parameters: acoustic and mechanical. The main technological parameters of welding process are: the nature of matrix smart composites, the reinforcing nature of the item, condition of combined surface, thickness combined materials, the requirements of the functional role; welding method, the number of acoustic energy concentrators etc. Acoustic parameters are related ultrasound system used for ultrasonic welding system, they are: type ultrasonic oscillations excited in the system, oscillation amplitude, oscillation frequency, intensity ultrasonic energy, energy density ultrasound, size, shape and material sonotrode and anvil acoustic form factor of ultrasonic energy concentrator, reflection and absorption qualities of the support, pre-heating temperature, etc. sonotrode. Mechanical parameters with significant influence on the welding process are: pressed static force, local contact pressure surfaces combined, ultrasound etc during activation. Synthesis welding process parameters shown in figure 1. /1/,/2/.
To optimize the ultrasonic welding of a smart composite material is to find an objective function that includes all factors shown in figure 1 and determine the minimum cost and maximum productivity of the process in terms of a outstanding quality of the welded joint.
In most cases, investigating the influence of various parameters on the quality of welded joints ultrasound is done by determining the breaking strength and tensile shear tests at an angle of 45 ° and 90 ° to the plane of the joint. Reproducibility is made by combining quality variation coefficient kv, given by:

$$k_v = \frac{\sigma_m}{N_m} \cdot 100 \qquad (1)$$

where: σm is the standard deviation of effort shear or tension, Nm - arithmetic mean value of shear or tension, which is determined by the relationship:

$$N_m = \frac{1}{n} \cdot \sum_{i=1}^{n} N_i \qquad (2)$$

where n is the number of individual measurements, Ni - the value of individual measurements. deviation σm is determined by the relationship:

$$\sigma_m = \frac{\sum_{i=1}^{n} \left(N_m - N_i\right)^2}{n-1} \qquad (3)$$

and its value is particularly significant because the determination error is ± 1.5%..

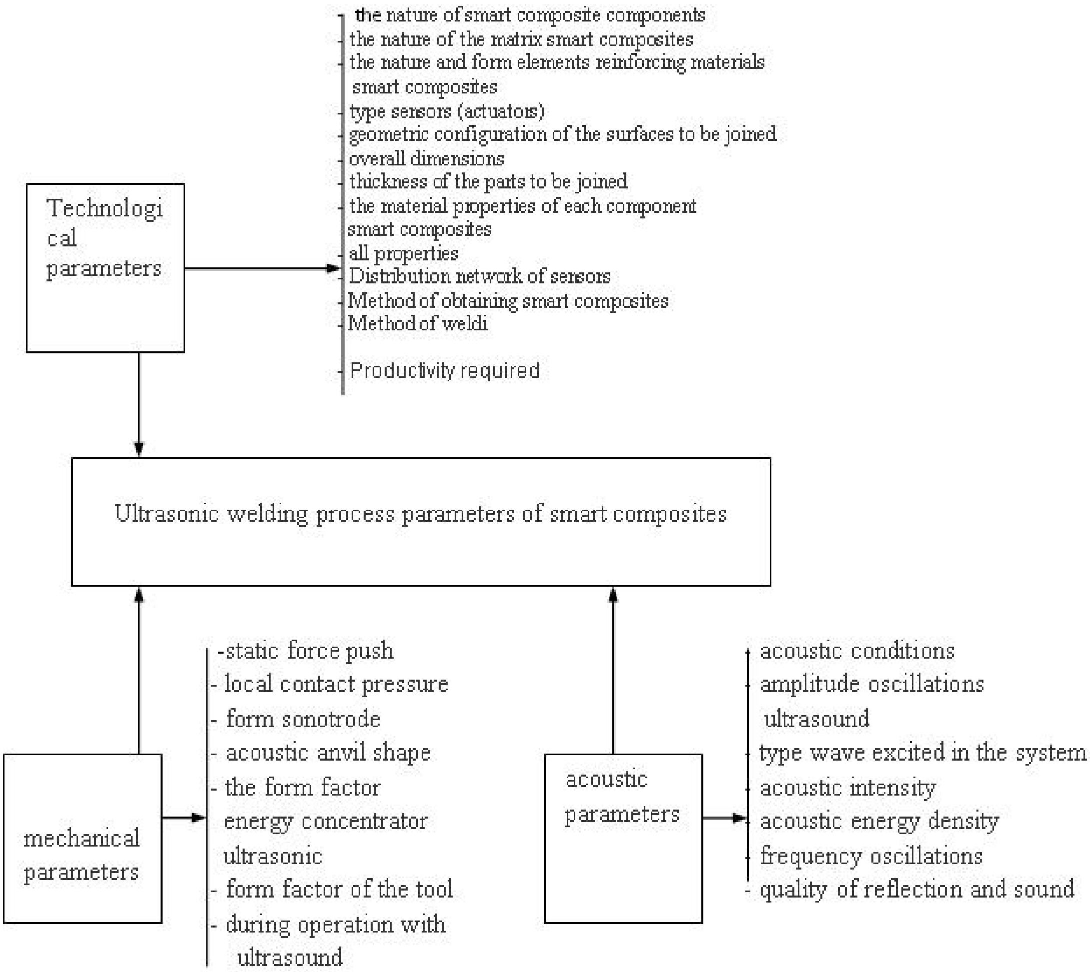

Figure 1: Ultrasonic welding process parameters of smart composites

This work aims to establish the influence of acoustic parameters of the welding process on the quality of welded joints. /1/,/2/,/3/.

Types of sensors and their distribution network have direct influence on the actual welding parameters nor the quality of welded joints obtained. But bear in mind that the sensor network must be designed so as to not interrupt or welded joints are not affected sensors during welding, thus indicating smart composite material and property of intelligence. It is important when designing the track to consider how to place sensor network (actuators) and sensors, so that the functional role of the part to be observed and the continuity of the network is not affected. Research undertaken using optical fiber sensors and piezoceramic plates showed that if they are included in the joint, there is a deterioration of the fiber surface protection and a depolarization of plates with piezoceramic sensors loss properties. /4/, /5/, /6/, /8/.

3. CONTRIBUTIONS ACOUSTIC PARAMETERS INFLUENCE THE QUALITY OF WELDED JOINTS ULTRASONIC SMART COMPOSITES

One of the phenomena that cause seam quality is the emergence and development of plastic deformation in the material layers combine, on which a particular influence have joint training acoustic conditions. Different acoustic conditions can be produced by the action of the elements that combine different types of oscillation: longitudinal, shear, bending, torsion and combinations whose excitement in the joint is achieved through design, construction and systems specific ultrasound used for initiation and propagation of ultrasonic oscillations. /1/, /2/ .
Experimental research conducted has shown that the excitation of longitudinal waves in sonotrode, ie ultrasound system for calculating the resonant frequency of longitudinal waves, combining resistance and coefficient of variation kv depend on the length of the sonotrode properly and where the force is applied static push.
Quality of welded joints obtained with systems that excite and propagate bending oscillations is lower than joints made with longitudinal waves, this explaining the large variation in the input impedance of the autoregulation system frequency
The experimental results obtained with some smart composite materials with polymeric matrix showed that the most effective systems are those in which ultrasound excites and propagates oscillations or oscillations longitudinal-transverse shear as it provides the best destruction and removal of oxide layers surfaces to be joined, fail better to limit oxygen penetration in the contact area, producing a complex movement of the material in the contact area and creates favorable conditions for achieving the highest quality joints./1/, /2/, /3/, /4/, /5/.

3.1. Influence of ultrasonic oscillation amplitude on the quality of welded joints

The formation of the welded joint using ultrasonic oscillations depends to a large extent I sonotrode amplitude oscillations and static power pressing Ps. 1 is transmitted oscillations sonotrode material combined 2 and 3 (Fig. 2) and acoustic anvil 4, each vibrating with corresponding amplitudes fulfilling the condition: /1/, /2/.

$$As > Aps > Api > An \quad (4)$$

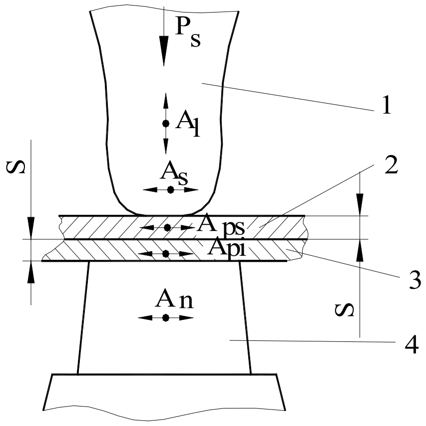

Figure 2: Scheme when welding ultrasonic vibration of composite materials with polymeric matrix

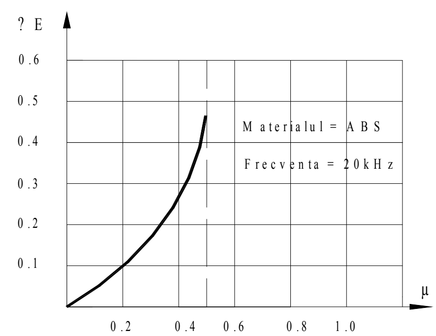

Figure 3: Energy loss ΔE, based on dry friction coefficient μ, the frequency of 20kHz

Between sonotrode and top part 2 triggers a force Fs, of the form:

Fs = I sin ωt (5)

and between parts 2 and 3 in contact and friction acting Ff, of the form:

Ff = I sin ωt (6)

pressure and static power Ps.

Relationship exists between these forces:

Ff ≤ μPs (7)

Ff ≤ μPs as long as the two materials overlap oscillates without it appearing only when Ff> Ps and the energy loss ΔE is the largest (Fig. 3). Experimentally determined optimum value for static pressure Ps force eight form:

Ps eight = Sc • σc ° (8)

where: Sc is the contact surface sonotrode - top piece, σc ° - yield limit of the material at the reference temperature of 20 ° C.

Knowing the pressure amplitude of the sonotrode can determine the best optimal, considering that the optimum tangential force Pt eight that appears is:

P t opt = k • μ • Psopt (9)

and leads to the appearance of the weld voltage shift τf, of the form:

τf = τx • sin ωt (10)

The link between τx, Aps and Api is:

$$A_{ps} - A_{pi} = 10\frac{\tau_x}{G}h + k \tag{11}$$

where: h is the height of the zone of plastic deformation, G - shear modulus, τx - yield shear in the joint and is expressed as:

$$\tau_x = \tau_s \cdot \sqrt{1 - \left(\frac{mP_s}{3\pi a^2 \tau_s}\right)^2} \tag{12}$$

where: m is a coefficient depending on the construction sonotrode (m = 0, 1, 2, 3); τs-shear yield strength of the material it is made sonotrode, a - coefficient depending on the thickness of the welding parts (a = 1 ... 3s) s - thickness welding parts. /1/, /2/, /3/.

For example, smart composite materials with polymeric matrix (ABS) to find optimal link next relationship:

$$A_s = 3{,}3\left(10\frac{\tau_x}{G}h + k\right) \tag{13}$$

Breakthrough influence the amplitude of the ultrasonic welded joint shown in figure 4.6. It is noted that if the amplitude of the ultrasonic vibration is reduced and Fr joint resistance is also reduced, and the amplitude values lower than a minimum value I min, the combination does not occur.

The front of the sonotrode amplitude of the oscillations depends on dosage acoustic energy in the joint, which should be higher in the first stage to achieve intimate contact between the surfaces to be joined. After creating physical contact foci formation stage of interaction between the surfaces to be joined and increase their contact surfaces is necessary to reduce the amplitude of oscillations up to 50% of its initial value to prevent broken links that were formed.

At this stage all acoustic energy is spent on speeding up the process of plasticization and melting the material in the joint.

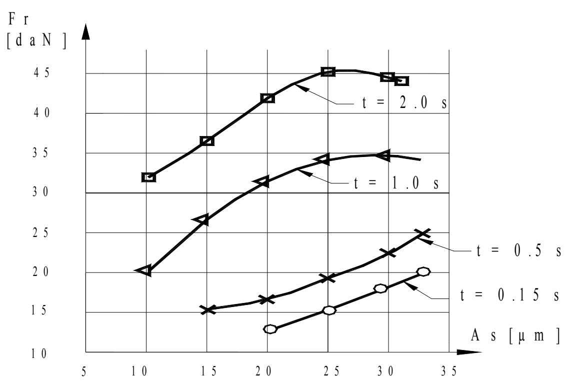

Figure 4: Influence of sonotrode amplitude of Breakthrough As Fr, at different times of welding.

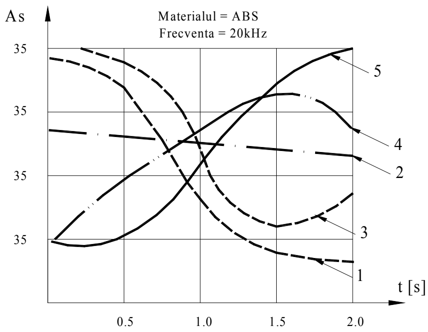

Figure 5: I sonotrode amplitude variation, while for different types of oscillations:
1 - longitudinal, 2 - shear 3 - bending, 4 - longitudinal, torsional, 5 – torsional

Temperature increase in the contact area increases heat atoms which favors the transfer of material in micropores existing damage diffusion process. Therefore, the amplitude variation in the two stages of the process of formation of the joint must be of the form shown in figure 5, depending on the type oscillation excited and propagated in sonotrode./1/, /2/, /3/.

3.3. Acoustic intensity influence the quality of welded joints

Determination of optimal acoustic intensity is a rather complex because it depends not only on output power and amplitude ultrasound the system but also the nature of the sonotrode tip oscillation that propagates into the ultrasound, welded shape, size and nature of the surfaces in contact combined materials.

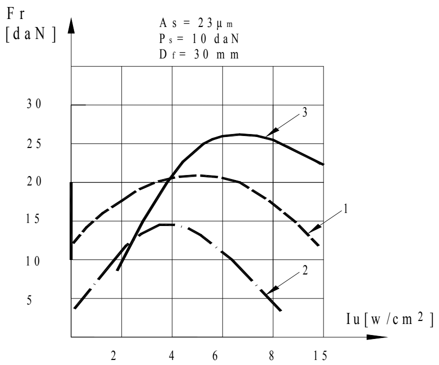

Figure 6: Variation of tensile strength of welded Fr Is acoustic energy density,for different plastics

Experimentally it is found that as the acoustic energy density increases during joint training lowers and increases the tensile strength of the joint (Fig. 6) but there is an optimum, which is understandable because if it exceeds a certain acoustic energy density, greatly increases heat in the contact area and the material begins to destroy. How noise affects energy density is very different depending on the material to be joined and the dimensions of the joint. It is noted that there is always an optimal acoustic energy density depending on the nature of the material, the amplitude and static force pressing the sonotrode in the combined./1/, /2/.

4. CONCLUSIONS

The experimental results obtained in welding smart car stops and some intelligent auto bumpers allow the following conclusions:

- The quality of welded joints is expressed primarily by tensile strength determined by testing shear and tension at an angle of 450 and 900 to the plane of the joint;
- Optimize welding process involves finding a smart composite objective functions encompassing technological parameters, acoustic and mechanical and determination of minimum cost and maximum productivity in terms of a outstanding quality of the weld;
- The formation of welded joints with ultrasound depends to a large extent and amplitude of the oscillations sonotrode contact surfaces of micro irregularities surfaces to be joined.

REFERENCES

[1] Amza Gheorghe, Ultrasound of high energy - Ed. Academiei, Bucureşti, 1984.
[2] Amza Gheorghe, Systems ultraacustice – Ed. Tehnică, Bucureşti, 1989.
[3]. Amza, Gh. Borda C. , Marinescu M., Arsene D., Design of Ring – Type Ultrasonic Motor – Scientific Session of the University "Petru Maior" - Targu Mures, 27-28 oct. 2001, vol.6, pa.7-14, Petru Maior University Press - Targu Mures , 2001, ISBN 973-8084-10-5, vol.6ISBN 973-8084-19-0.
[4] Berlin, A.A., et al. – Principles of Polymer Composite, Ed. Springer – Verlag, New York 1986 (Polymer – Properties and Aplications, vol. 10).
[5] Dry M. Carolyn, Sottos, R. Nancy, Passive smart self-repair inpolamer matrix composite materials- Smart Structures abd Materials 1993, Albuquerque, N.M. USA- Proceedings of SPIE – The International Society for Optical Engineering v 1916 1993, Publ by Society of Photo Optical Instrumentation Engineers, Belligham, WA USA, p- 438-444.
[6] Gandhi M.V. and Thompson B.S. , A New Genertaion of Revolutionary Ultra Advanced Compostes Materials Faturing Electro-Reological Fluide, U.S Army Research Office Workshop on Smart Materials Structures and Mathematical Issues, 1988.
[7] Kim, J., Varadan V.V., Varadan V.K. and Bao X.Q., Finite elemente modelling of a smart cantilever plate and comparison with experiments, Smart Materials and Structures, vol. 5, 1996, pag. 165-170
[8] Lawrence C.M., Nelson D.V., Spingarn J.R. , Measurement of process-induced strain in composite materials using embedded fiber-optic sensors, SPIE Vol. 2718, San Diego, 1996, pag.60-68.