ULTRASONIC WELDING. VIBRATION MODES AND WORKING PARAMETERS OPTIMISATION

Gheorghe AMZA Dan Florin NITOI Catalin AMZA
University Politehnica of Bucharest, Materials Technology and Welding Dept.
E-mail: amza@amza.camis.pub.ro

Abstract: The paper proposes a new position and implementing method of parking sensor for automotive industry. The method is represented by the ultrasonic welding for which the authors proposed a method to optimize the working process using the finite element method. The ANSYS modal analyze offers good information about the ultrasonic system vibration modes and frequency that are used forward to optimize the welding process.

1. INTRODUCTION

One of the used methods in the plastic material welding is the ultrasonic welding. The method main advantages are: local temperature increasing in the welding spot that avoids the whole plastic material heating, like in other methods, long distance welding possibility, welding possibility on critical zones (hard to get), material welding with not cleaned surfaces enough and others. Comparing with high frequency current welding, the ultrasonic method has the advantage of material selecting independent with dielectric looseness and in different medium welding (water, oil, shampoo…).

The basics of ultrasonic welding are presented in the fig.1.

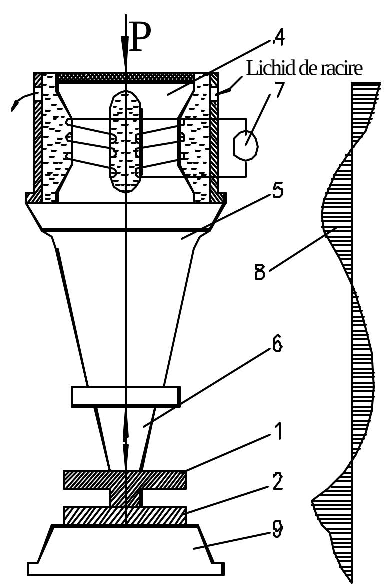

Fig.1 Ultrasonic welding scheme
1,2 – welded plastic materials; 3 – acoustic support; 4 – transductor; 5 – concentrator; 6 – sonotrode; 7 - ultrasonic generator; 8 - vibration amplitude diagram

On the other hand, the ultrasonic welding permit ultrasonic welding of metal with plastic materials, a continuous welded zone of synthetic textile materials or cave shape pieces welding. The welded materials 1 and 2 are laid on support 3. The ultrasonic vibrations produced by the transductor 4 are conduced, concentrated and focused on welding zone using the ultrasonic energy concentrator 5 and sonotrode 6. To get the welding conditions, a force P is applied on the acoustic block that presses the materials to weld. The force and ultrasonic vibration direction are the same.

The welding process is divided in two stages. In the first, the ultrasonic vibrations produce a temperature increasing on the materials contact surface because of the high frequency materials displacements one faced to the other. The produced heat corresponds to the friction process between the surfaces in contact and has the result in the thermoplastic materials welding in a very short time (about 1 minute). The temperature in the contact zone has to be smaller the minimum temperature that in normal condition produces the material melting, but greater than temperature when a strong link occurs. In the second steep, between the surfaces in contact, heated up to plastic stage for a high resistanc e spot welding strong links appears.

2. ULTRASONIC WELDING WORKING PARAMETERS FOR THE PLASTIC MATERIALS

The welded zone quality depends on the process main parameters that directly influences the quality of transmitted and absorbed energy in the welding zone and on the auxiliary parameters. The main parameters group consists in:

- tool active part vibrations amplitude
- pressing time
- ultrasonic oscillations frequency
- static pressure in the welding zone
- ultrasonic energy intensity

The group of auxiliary parameters consists in:

- tool active part and support dimensions, shape and material
- tool and concentrator shape factor
- absorption and reflexing support quality

The optimal welding working condition that depends on the welded materials, thickness and materials shape, contact surface condition are experimental determined and corresponds to each purpose. Different author’s experiments established optimal values for the ultrasonic oscillations frequency between 10…40 KHz, depending on piece material and welded zone shape.

One of the most important parameters of the welding process is the oscillation amplitude. Considering this, the welding strength increase when then the vibration amplitude increase also and the maximal value limitation depends on the material deformation in the welding zone. The oscillation amplitude influences the radiation energy level transmitted to welding zone and also the welding zone, the local heating and the surfaces cleaning.

To reduce the welding time and for a high quality product, an initial manufacturing of the pieces surfaces is required. This operation depends on welding type (fig.2) and requires an “acoustic energy concentrator”. Their role is to concentrate and direction the acoustic energy in the welding zone.

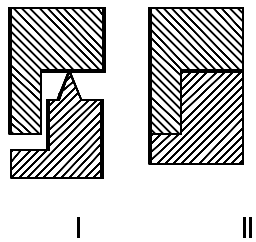

Fig.2 Plastic material welding fixing type

One of this paper purposes is to propose a new method of parking sensor implementing in the rear automotive lamp. Because of the sensor higher position the damage possibility risk in a back side impact is decreasing. The schematic of sensor welding on the rear lamp back face plastic face in presented in the fig. 3.

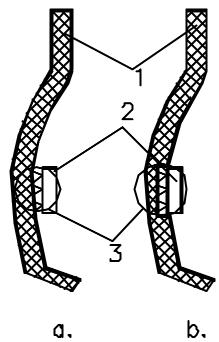

Fig.3 Schematic of sensor welding on the rear lamp back face plastic
1 – rear lamp plastic material; 2 – parking sensor; 3 – ultrasonic concentrators zone

The proposed method is available in the case when the plastic face is not provided with a special hole for the senor position (fig. 3.a) and also when the plastic has a corresponding hole to place the sensor (fig.3.b). Because of the sensor small dimension comparing with the actual rear automotive lamp dimensions, this technology is available for the most rear lamp shape.

The paper second purpose is to optimize the working conditions of the Mecasonic Omega MCS welding machine. Because of the acoustical system possibility, the oscillations frequency setup is in the range 18…….45 kHz. The human operator can adjust the working frequency, as a function of the local conditions, but not each imposed frequency is optimal because the oscillating system has its own natural vibration mode. Considering this, when the imposed frequency is very near or the same with the natural frequency vibration mode, the resonance phenomenon occurs. In this case the machine has lower energy consumption.

To define the natural vibration mode of the ultrasonic system the authors used the ANSYS software for the vibration simulation. In the fig. 4 it is presented the vibration mode at frequency f = 14659 Hz. Using this image and the software animation the active part tool vibration mode performs a rotation around longitudinal axis and a small displacement along this axis. In the same time this tool part increases its radial dimension in the working zone. Because all this vibrations appears in the lower end of the tool, and the rest of the system remains fix, it is considering that at this frequency the welding process performs in very good conditions.

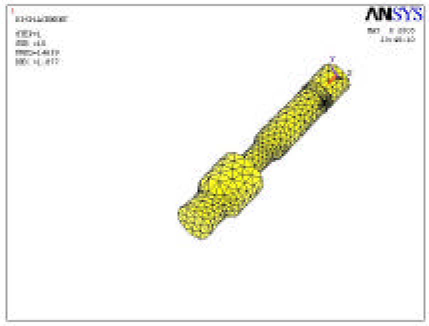

Fig. 4 Tool vibration mode at frequency f= 14659 Hz.

The second vibration mode in this frequency range is at f = 24009 Hz. From this image study it can be observed that the end part vibration type remains the same like at frequency f = 14659, but another undesired vibration type appears at the middle tool part that may be not desired. In this condition, at this frequency the welding can be done but the vibration mode is much complicated with energy losses and undesired deformations.

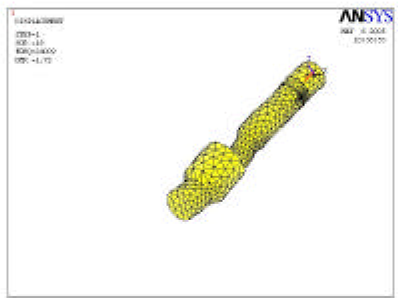

Fig. 5 Tool vibration mode at frequency f= 24009 Hz.

The third vibration mode in this range occurs at frequency f = 24958 Hz. Different from the others vibration modes are the displacements of the tool free end, displacements of the half of this zone. The contact tool zone with the piece is divided in two parts, each of them having displacements side by side. These tool displacements provide pieces displacements that provide good conditions for the welding process. In the same time, the tool has rotations in the middle part and supplementary the upper tool zone has an also a rotary oscillation. In conclusion, this modal vibration can create good condition for the plastic welding because of the free end tool complex movement. Also, the frequency f = 24958 Hz can be very easy achieved by the ultrasonic machine system.

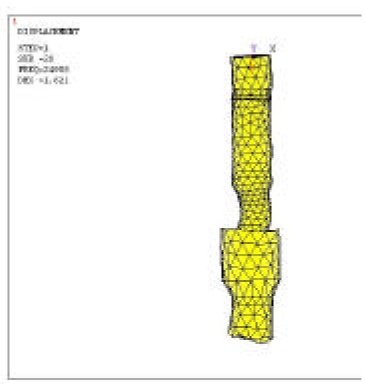

Fig. 6 Tool vibration mode at frequency f= 24958 Hz.

The following vibration mode corresponds to frequency f = 25156 Hz. As it can be seen, in this case the important vibrations are on the upper ultrasonic system that has no importance in the welding process. The active tool part has no vibrations (or very small amplitude vibrations), not fitted for the plastic material ultrasonic welding.

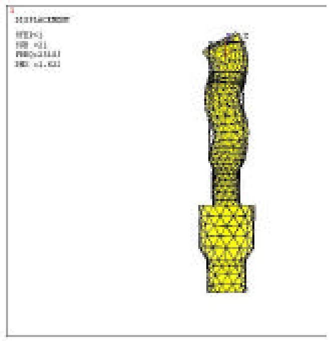

Fig. 7 Tool vibration mode at frequency f= 25156 Hz.

The fifth vibration mode corresponds to frequency f = 25750 Hz. In this case, the system performs longitudinal and rotary vibrations. The middle tool part rotates around the longitudinal axis that has no influence in the welding process especially because their amplitude is very low. The two ends of the tool perform a relative longitudinal vibration that is proper to the desired process. The lower tool part, splitted in two parts performs, one by one, also a combined (transversal and longitudinal) movement that has good influences to ultrasonic welding. This case is recommendable and also the frequency is easy to get.

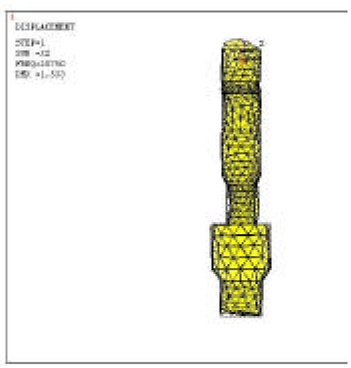

Fig. 8 Tool vibration mode at frequency f= 25750.

The following vibration mode corresponds to frequency f = 26296 Hz (fig.9).

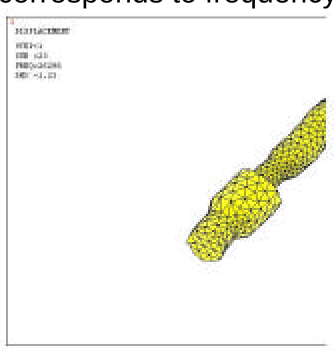

Fig. 9 Tool vibration mode at frequency f= 26296 Hz.

From the study it results a very similar behavior to the frequency f = 25750 that has goof practical results. In consequence this frequency can be used also for plastic material ultrasonic welding.

For the frequency f = 48917 Hz, the ultrasonic system performs a very useful vibration mode characterized by vibrations on the contact tool zone. These vibrations are complex and provide longitudinal and transversal displacement (see the picture) of the tool end. The rest tool part has very small vibrations and the whole system offers good conditions for the welding.

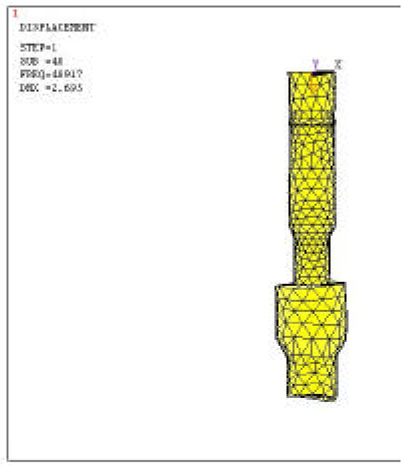

Fig. 10 Tool vibration mode at frequency f= 48917 Hz.

Comparing all the presented vibration mode the final one fits the best to the plastic material ultrasonic welding.

3. CONCLUSIONS

The paper proposed a new position and implementing method of parking sensor for the automotive industry. The new sensor position on the rear lamp presents some advantages comparing with the rear bumper position. The method offers a very easy fixing system using the ultrasonic welding. Even this sensor type has a metal case the method is also good to be applied.

For the Mecasonic Omega MCS machine ultrasonic system (piezoceramic plates – concentrator – active tool), the authors proposed a very useful method to optimize the working process that means the vibration mode and frequency. The ANSYS modal analyse offers good informations about all the vibrations frequency and vibration modes used on this machine type.

4. Bibliography

1. Amza Gheorghe, Danila Barb; Florica Constantinescu, Sisteme Ultraacustice, Editura Tehnica, Bucuresti 1988.

2. Fabien Josse, Zach Shana, David Radtke, Analysis of Piezoelectric Bulk – Acoustic – Wave Resonators as Detectors in Viscous Conductive Liquids, IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Controls, 1990.

3. Jan Soderkvist, Electric Equivalent Circuit for Flexural Vibrations in Piezoelectric Materials; IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Controls, 1990.

4. Loriann Ries, Stephen Smith, Finite Element Analysis of a deformable Array Transducer, IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Controls, 1999.