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# A METHOD WHICH MAY BE UTILIZED IN CASE OF ACOUSTIC RESONATORS USED FOR ULTRASONIC WELDING TECHNIQUE

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**Rezumat.** *Vibraţiile ultrasonice, în gama* (20-40) kHz*, având energie mare, în gama* (1-2) kW *sunt utilizate pentru suduri neconvenţionale. În acest mod se pot suda metale ca aluminiu-aluminiu. În lucrare se porneşte de la forma generală a ecuaţiei de propagare a undelor plane longitudinale prin bare care au diferite secţiuni şi grosimi. Este găsită forma matematică pentru formele de variaţie ale tensiunii mecanice şi pentru amplitudinea de vibraţie în funcţie de forma barei şi materialul din care este făcută. Curbele care se pot trasa ajută pentru proiectarea transformatoarelor de impedanţă, componente care sunt plasate între generatorul de vibraţii ultrasonore (format de elementele piezoelectrice) şi capul de sudură. Ecuaţiile găsite sunt verificate în cazul maşinii de sudat de tip TELSONIC-MPS-2. Articolul propune realizarea unui program pentru a calcula şi pentru a fi experimental verificat în cazul unui lanţ acustic menit a înlocui lanţul acustic defect, care există pe maşina de sudat TELSONIC-MPS-2. Lucrarea prezintă principiul de calcul, modul de calcul şi rezultatele experimentale comparative obţinute cu câteva modele selectate în acest scop.*

**Cuvinte cheie:** Ultrasunete, Vibraţii, Sudură, Propagare unde

**Abstract.** *The ultrasonic vibrations, of high energy in the range of 1-2 kW and frequencies in the range of (20-40) kHz are utilized to no conventional welding. Such waves can weld metals like aluminum to aluminum. In this paper, we start from general form of the propagation equation of plane longitudinal waves through bars, which have different sections and thickness. We have found the mathematical expression for the variation form of mechanical tensions and for vibration amplitude as a function of the bar shape and material from which it is made. The obtained diagrams will help the design of the impedance transformers, of the components which are placed between the ultrasound vibration generator (formed by piezoelectric elements) and of welding head. The found equations are experimentally verified for the case of a TELSONIC-MPS-2 welding machine. The paper describes our program used to calculate mechanical tensions and vibration amplitudes, which are then experimentally verified in the case of a new acoustic chain intended to replace the less optimized acoustic chain, of the present welding machine TELSONIC-MPS-2. The paper presents the principle for calculus, the calculus mode and experimental results obtained comparative with a few models selected for this scope.*

**Key words:** Ultrasonic, Vibrations, Welding, Propagation waves

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## 1. Introduction

In order to optimize the behavior of the acoustic chain of the existing machine welding, it is necessary to develop a model-based design able to increase the efficiency and performances of the new acoustic chain with respect to the original acoustic chain.

Also, the new design should provide flexible working regimes for the next generation of TELSONIC-MPS-2 welding machine. For this purpose, we start from propagation equation of waves in solid environment, as it is presented in the paper [1].

That paper showed a calculus program for getting the mechanical tensions and vibration amplitudes in the case of sundry shapes for acoustic chain. Later, in paper [2], we have shown the influence of geometrical and material parameters on ensemble acoustic chain of a welding machine.

Our present paper describes an optimum acoustic chain resulted from our calculus, and which is well matching the work in the requisite regime. The acoustic chain was experimentally realized and our model was thus verified by a good functionary of welding machine.

## 2. Methods

The operating principle consists in the generation of ultrasonic vibrations in piezoelectric transducers, and their transfer to an acoustic chain. The ultrasonic vibrations [3] are produced by piezoelectric pastille when sinusoidal voltage of high amplitude, of about 2000V is applied on that piezoelectric material

The acoustic chain must transmit these vibrations and must perform: the vibration amplification, the impedance adaptation between piezoelectric transducer and acoustic charge and the realization of strong mechanical catch for good operating of solder head.

During the soldering operation, the welding head must execute the following phases: to dispose the welding head on welding place, to press on welding place, to apply the necessary ultrasonic vibrations for performing the welding, to cool the solder and to elevate the welding head from welding place.

The ultrasonic vibrations propagate through acoustic chain by stationary waves [4]. The acoustic chain provides the necessary vibration amplitude on the contact place between welding head and material for soldering.

The propagation of plane longitudinal waves through the bar is described in [1]

$$\frac{\partial}{\partial x}\left[A(x)\cdot\frac{\partial\zeta}{\partial x}\right]=\frac{A(x)}{c^2}\cdot\frac{\partial^2\zeta}{\partial t^2} \qquad (1)$$

with the following boundary condition: $\left(\frac{\partial\zeta}{\partial x}\right)_{x=0}=\left(\frac{\partial\zeta}{\partial x}\right)_{x=l}$.

There vibrations should have maximum amplitudes at ends of bar (for $x = 0$, where the piezoelectric transducer that generates vibrations is located, and for $x =$ l, where the solder head which transmits vibrations to work medium is located). The calculus method for (1) equation was presented earlier in [7].

In the above relation, we have the following notations:

- $\zeta(x, t)$ - represents the vibration amplitude in $Ox$ direction;
- $A(x)$ - represents the transversal section area at $x$ distance;
- $c=\frac{E}{\rho}$ - represents the propagation velocity of signal through bar;
- $E$ - represents elasticity module of bar material;
- $\rho$ - represents the density of the bar;
- $l$ - represents the length of the bar.

**3. Results**

Using the equations presented in [7], one can calculate:

**1.** The vibration amplitude in $Ox$ direction, which represented by : $\zeta^1(x, t) = X^1(x)\cdot\cos\omega_1 t$, where vibration amplitude at moment $t = 0$ will be $\zeta^1(x,0) = X^1(x)$

**2.** The amplification through bar which is given by the ratio from vibration amplitude at the end of bar ($x = 1$) and vibration amplitude at begin of bar ($x = 0$). So we can write: $G=\frac{\zeta^1(l,0)}{\zeta^1(0,0)}$

**3.** The areas ratio, which in the case of a bar having different sections, it is given by the relation: $\frac{A(0)}{A(l)}$, where A(x) represents the equation which defines the transversal section area at x distance for the bar having different sections along $Ox$ axis.

**4.** If it is noted that $X_0 = q$, then the distance at which the vibration amplitude $\zeta(x,t)$ is null will have: $\zeta^1(q,0) = 0 \Rightarrow X_0$

**5.** One can trace the curve of mechanical tensions along bar - $T_m$ - starting from relation: $T_m(x) = \rho\cdot c\cdot v_m(x)$,

where:

$\rho$ - represents the density of bar material;

$c$ - represents the propagation velocity of signal along the bar;

$\upsilon_m(x)$ - represents the propagation velocity of vibration particles through the bar;

The propagation velocity of vibration particles through the bar - $\upsilon_m(x)$ - is direct proportional with the first derivative of vibration amplitude $\zeta^1(x,0)$. So, one can write: $T_m(x) \sim \upsilon_m(x) \sim \frac{d}{dx}\left[\zeta^1(x,0)\right]$

With the help of this program that uses the relations and methodology presented above, one can trace the curves that define the acoustic chain by point of vibration amplitude and mechanical tensions along its length, as seen in Fig.1.

In Fig. 2 is presented the case where there is no diameter rise in front of interface connector.

So the transmitted chain-T2 does not exist and transmitted chain T1 has a bigger length, in concordance with the working frequency utilized here. One can be observed that this diameter increase has the following advantages:

- It assures an easy catch in the zone when vibration has small amplitude;

- It takes away or diminishes the maximum of mechanical tension into termination catch of welding head in order to minimize the mechanical solicitations at linkage zone from those two cylinders which forms the acoustic chain.

From the presented program, a resonance frequency of acoustic chain of 36,5 kHz was obtained, which is very close to the necessary frequency for a good operation of original welding machine.

The acoustic chain, as obtained from our method, and which will replace the original acoustic chain is presented in Fig. 3. It consists of :

- a reflector-R, having ∅=41mm, made of steel;
- a pair of piezoelectric rings, of SL-4040W-W type;
- a director-D, made of aluminum alloy, having ∅=41mm;
- a transmitted chain-T1, made of aluminum alloy, having ∅=49mm;
- a transmitted chain-T2, connected to welding case, made of aluminum alloy and having ∅= 55mm; this part has an important contribution to the cooling of the solder head;
- a solder head-S, having a variable section, made of titan.

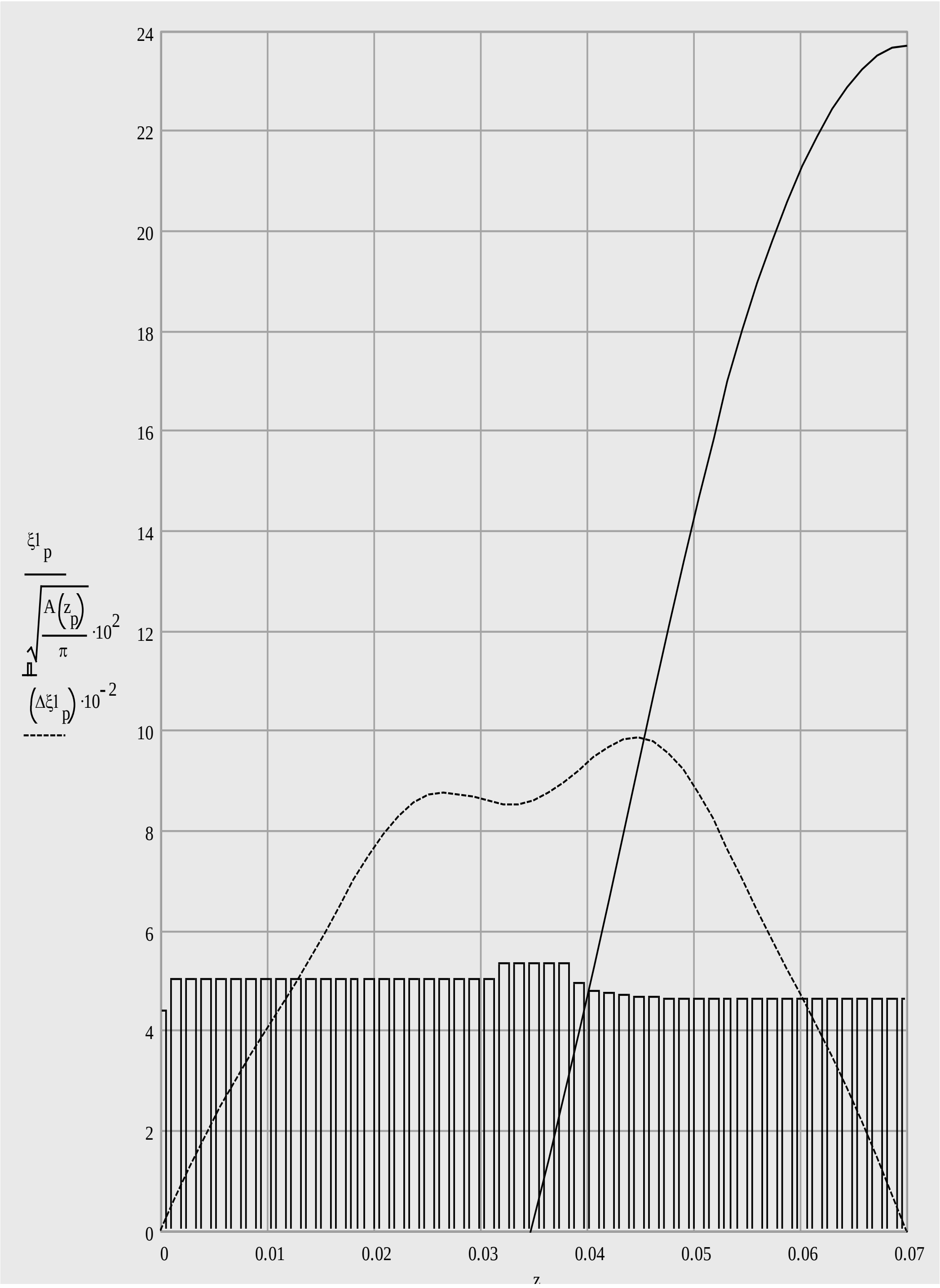

**Fig.1** The evolution of vibration amplitude and mechanical tensions along the acoustic chain in case of increasing the diameter before interface connector salt.

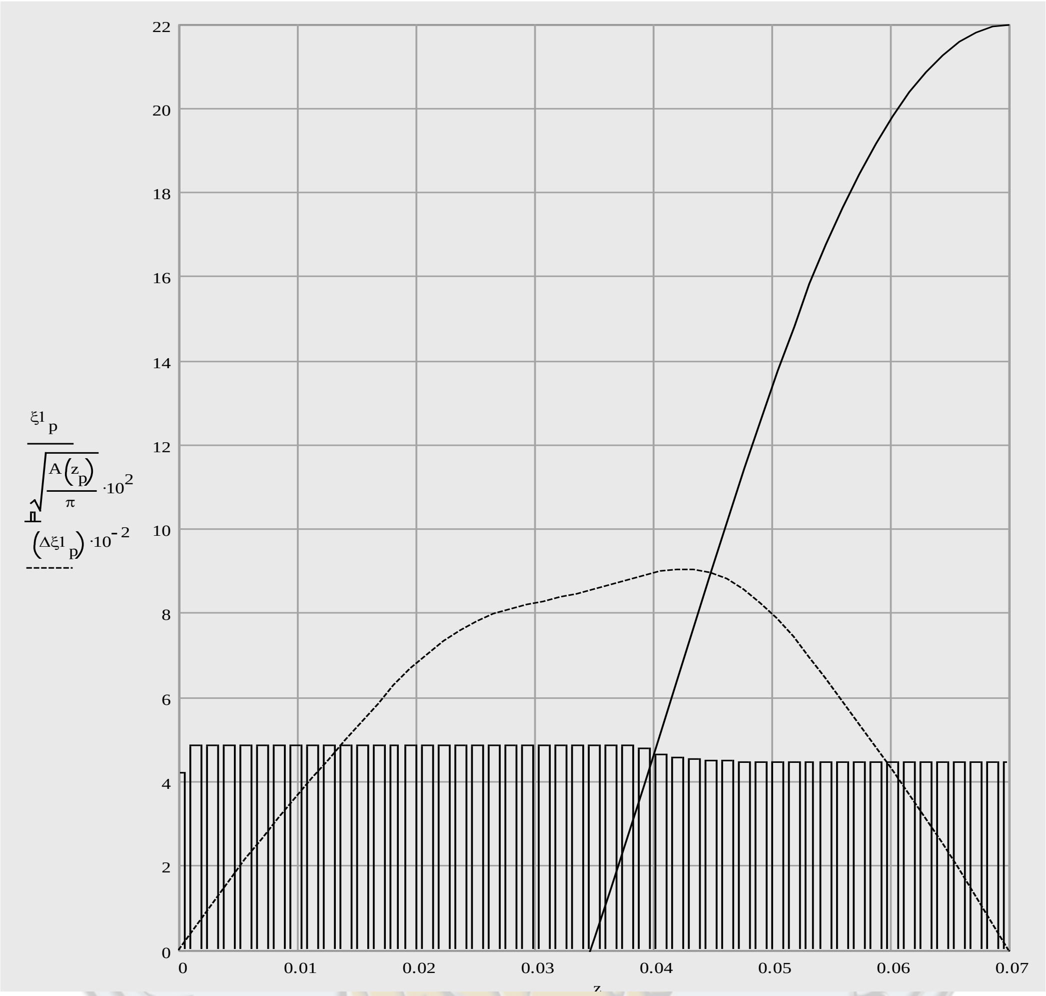

**Fig.2** The evolution of vibration amplitude and mechanical tension along the acoustic chain in case of a constant diameter before interface connector salt.

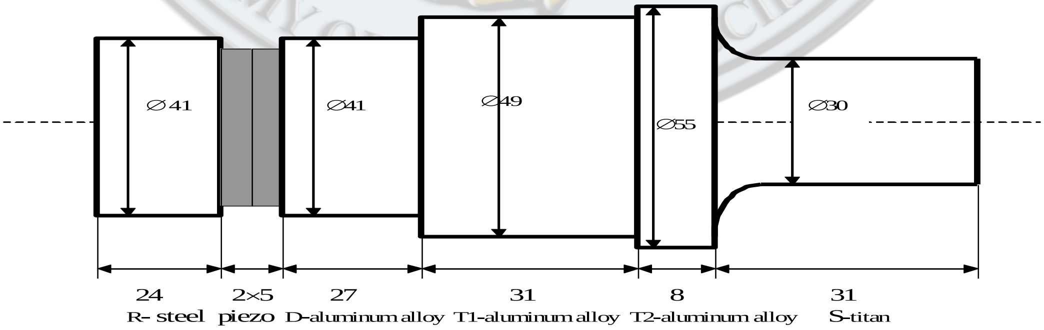

**Fig.3** The acoustic chain realized by us for equipping the welding machine.

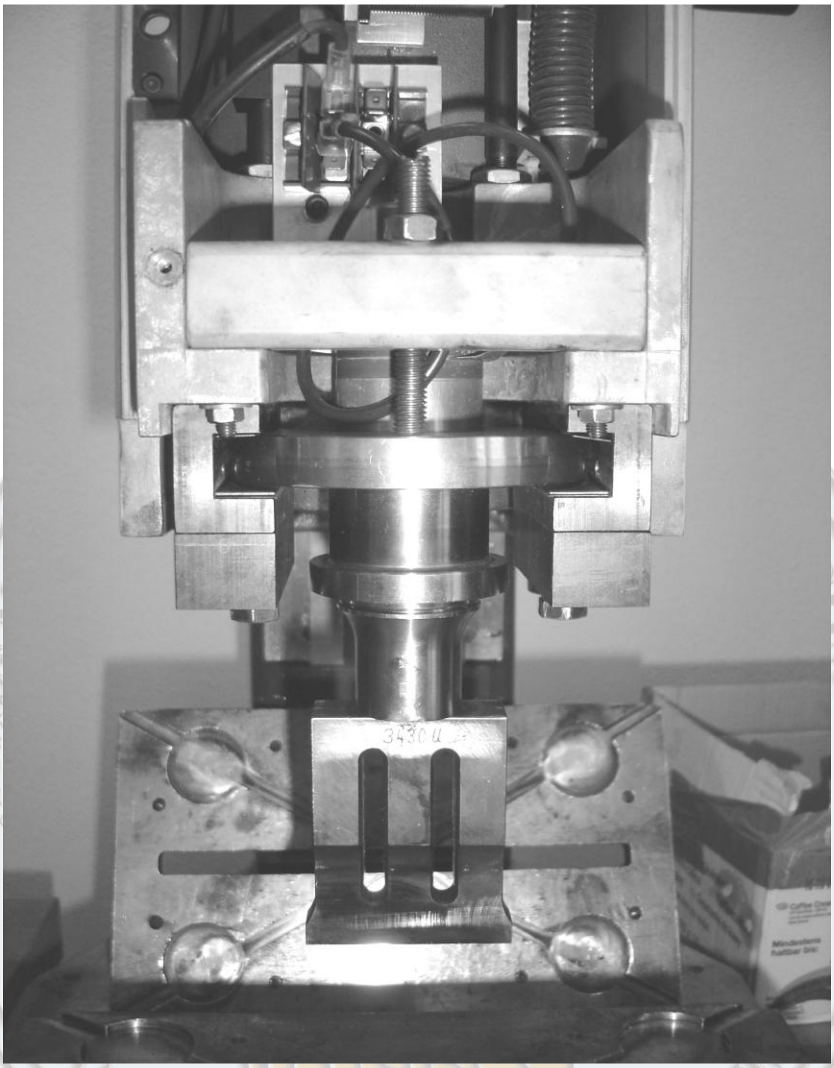

**Fig. 4** The acoustic chain realized and mounted on welding machine.

## Conclusions

Within this paper we have shown that the propagation theory described in [7] can be applied for longitudinal plane waves through bars having variable section. This theory was applied for the optimization of the acoustic chain used on welding machine TELSONIC - MPS - 2. As a result of this theoretical work, we have obtained:

- An optimum acoustic chain from the point of view of shape, component materials and energy transfer;
- The mathematical model which defines this acoustic chain, and which was introduced in the presented calculus program;

- Excellent agreement between the model and the experimental results based on the above method;
- Excellent theoretical tool for the study the influence of different parameters on final result, all aiming the increased efficiency of ultrasound power transmission;
- An optimum acoustic chain, with help of this analysis;
- A prototype of next generation of welding machine containing a new and optimized acoustic chain with increased efficiency.

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