USE OF A SYSTEM DESIGN ULTRAACUSTIC WELDING

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Abstract – *This article presents elements of a computer modeling system and ultraacustic using analyzing finite element method used in its design. With the experimental results obtained for a system used for welding ultraacustic determine variation curve aplitudinii particle velocity along the system.*

Keywords: ultraacustic, ultrasonic, resonance.

1.Introduction

Ultraacustic system is the most important part of an equipment or ultrasonic activation as ultrasonic energy transfer and increase in focus on the processing and activation. Ultraacustic system consists of an active element - transducer - one that converts electrical oscillations in ultrasonic and passive elements - Ultrasonic energy concentrator - who lead concentrate and focus ultrasonic energy on the focus of processing. ..
Ultraacustic system is calculated and designs so that to work in the resonance regime. [11],[12],[13].

2. Problem formulation

The main elements of calculation are:

1) The condition of mechanical resonance resulting from the equality:

$$\rho' v' A' tg(\omega_0 I'/v') = \rho v^E A\, ctg[\omega_0 l/(2v)^E] \quad (1)$$

$$ctg(\omega_0 l'/v') ctg[\omega_0 l/(2v^E)] = q \quad (2)$$

where $\rho' v' A'$ and $\rho v^E A$ are impedanceses characteristic acoustic and passive elements that are characteristic of active element; $l'$and l - their length, the report impedanceses characteristic;

2) Electromechanical resonance condition resulting from the equality:

$$\rho' v' A' tg(\omega_0' l'/v') = \rho v^D A\, ctg[\omega_0' l/(2v^D)] \quad (3)$$

3)Sound power, the resonance is issued:

$$P_a^0 = \frac{4n^2 U^2 \cos^2(\omega_0 l'/v') \eta_{am}^2}{\alpha_0 \rho_m v_m A'} \quad (4)$$

where n is the coefficient of electromechanical transformation;

4) Sound power at low frequency is calculated by the relationship:

$$P_{aj}^0 = \frac{\alpha_n^2 U^2 \rho_m v_m A' \omega^2}{4(v')^2 (\rho v^E A)^2} \quad (5.)$$

5) Characteristic frequency noise power near the resonance is given by:

$$P_a = \frac{\alpha \rho_m v_m A' n^2 U^2}{|Z|^2 \cos^2(\omega_0 l'/v')} \quad (6)$$

where:

$$|Z| = \tau^2 + \chi^2 \quad (7)$$

$$\tau = \tau_0[1 + (\alpha/\alpha_0 - 1)\eta_{am}] \quad (8)$$

and

$$\tau_0 = \frac{\alpha_0 \rho_m v_m A'}{4\eta_{am} \cos^2(\omega_0 l'/v')} \tag{9}$$

Coefficient X the impedance expression is given by:

$$\chi = 0{,}5\left[\rho' v' A' tg(\omega l'/v') - \rho v^E A\, ctg\left[\omega l/\left(2v^E\right)\right]\right] \tag{10}$$

Approximate formula of frequency dependence of power near the resonance is given by:

$$\frac{P_a}{P_a^0} = \frac{1}{1 + Q_m^2 (f/f_0 - f_0/f)^2} \tag{11}$$

where Q_m is the mechanical quality factor, which is obtained from the relationship:

$$Q_m = \frac{4\pi f_0 \eta_{am} m' \left[1 + (m/2m')\right]\left[\cos^2(\omega l'/v') + q^2 \sin^2(\omega l'/v')\right]}{\alpha \rho_m v_m A'} \tag{12}$$

In relation (12) *m* - is the mass of the active element*; m'*- the element mass passive; q- characteristic impedances report.

6) Characteristic impedance Z, the transducer near resonance is obtained from the known relationship

$$Z = \frac{1}{\frac{1}{R_p} + \frac{1}{R_m + jX_m} + j\omega C} \tag{13}$$

where *Rp*- is electrical resistance losses; R_m, X_m - resistance, reactance that mechanical data relationships:

$$R_p = \frac{1}{\omega Ctg\delta} \quad , R_m \frac{\tau}{n^2}, X_m = \frac{\chi}{n^2} \tag{14}$$

Coefficients τ and *x* are obtained from relations (12) and (14), and the resonant frequency $X_m = 0$.

7) Return of the electroacoustic of transducer. η_{ea} electroacoustic yield is the product:

$$\eta_{ea} = \eta_{am}\eta_{em} \tag{15}$$

Return acustomecanic η_{em} have constant value (0.6 0.8) and electromechanical η_{am} efficiency is obtained from the relationship:

$$\eta_{em} = \frac{1}{1 + \frac{\alpha_0 \rho_m v_m A \omega_0 Ctg\delta}{4n^2 \eta_{am}}} \tag{16}$$

8) Under the receiving transducer sensitivity to electro-mechanical f_0' resonance is obtained from the relationship:

$$\nu_0' = \frac{2n\eta_{am} \cos(\omega_0 l'/v')}{\alpha_0 \rho_m v_m \omega_0' C} \tag{17}$$

For active element transducer with cut has the formula:

$$\nu_{0C}' = \frac{\nu_0}{k} \tag{18}$$

where k is the number of sections.

9) Receiver sensitivity at low frequency is obtained from $\nu_j (f \langle\langle f_0')$ the relationship:

$$\nu_j = \frac{dA'w}{2qa} = \frac{dY^E w}{2\varepsilon Y^D A} \tag{19}$$

where w is the distance between the electrodes.

To cut active transducer element, sensitivity to low frequencies is:

$$\nu'_{jc} = \frac{\nu_j}{k} \tag{20}$$

10) Characteristic frequency transducer sensitivity in the receiving system is obtained from the relationship

$$\frac{\nu}{\nu'_0} = \frac{(f'_0/f)}{2\alpha_\omega \cos(\omega l'/v')\cos(\omega'_0 l'/v')} \times \left\{ \left[1 - \frac{v^D/V^E}{\sin(\omega l/v^D)[qtg(\omega l'/v') + F]} \left(1 - \frac{1}{q} tg \frac{\omega l'}{v'}\right)\left(qtg\frac{\omega l'}{v'} + 2F\right) \right]^2 + \right.$$

$$\left. + \left(\frac{\rho' v' \eta_{am}}{\rho_m v_m \, \alpha'_0 \alpha_\omega} \right)^2 \left[\frac{1}{q}\left(qtg\frac{\omega l'}{v'} + F \right) - \frac{2v^D / v^E}{sin(\omega l / v^D)} \right]^2 \right\}^{-1/2} \tag{21}$$

where:

$$F = \frac{v^D}{v^E} tg \frac{\omega l}{2v^D} \tag{22}$$

the transverse piezoelectric effect and

$$F = tg \frac{\omega l}{2v^D} \tag{23}$$

the longitudinal piezoelectric effect and α_ω is obtained from the relationship:

$$\alpha_\omega = 1 + (\alpha - 1)\eta_{am} \tag{24}$$

11) Specific sensitivity of reception ν'_{os} is obtained from the relationship:

$$\nu'_{os} = \frac{\nu_0}{\sqrt{|Z|}} = \frac{2nw\eta_{am} \, cos(\omega'_0 l' / v')}{\alpha'_0 \rho_m v_m \sqrt{\varepsilon \omega'_0 \varphi A}} \tag{25}$$

3. Finite element modeling of system ultraacustic Examining the various modeling concluded that modeling by finite element method using ANSYS package is the most recommended.

3.1. Finite element modeling of piezoelements

Active elements of the system are ultraacustic pills PZT4 Piezoceramic components of geometric dimensions shown in Figure 1.

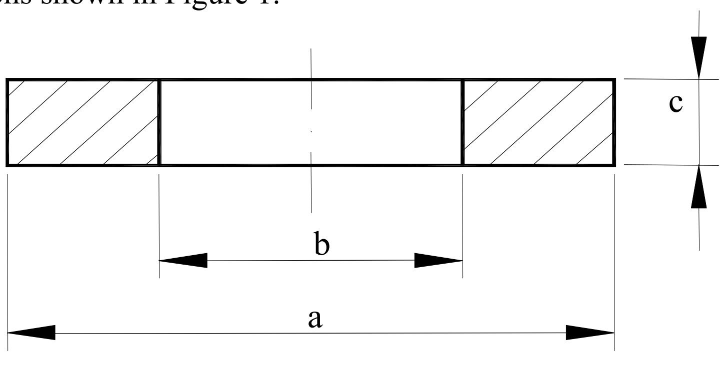
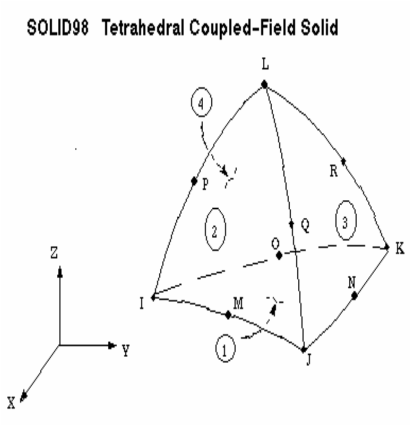


Fig. 1. Geometric dimensions of piezoceramic

Material properties of ANSYS piezoelementelor are understood as three arrays: dielectric, piezoelectric and elastic.[4],[5],[6],[7].

Turn the main menu preprocessor that generates geometry volumes. From the main menu to choose the type of structural analysis and magnetic hub which makes dialing and libraries with mesh elements.

Meshing SOLID98 item is made with (3-D tetrahedron solid 10 knots) shown in Figure 2.



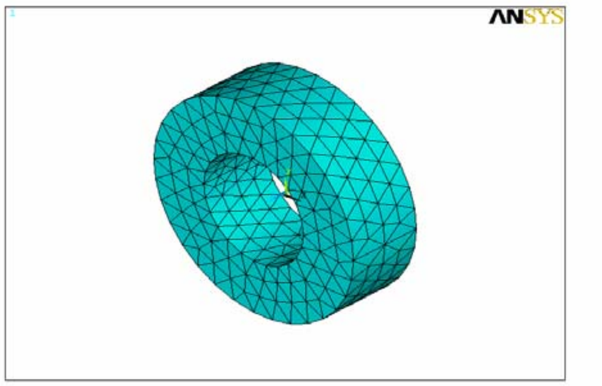


Fig. 2. SOLID98 element Fig.3

Mesh is shown in Figure 3 pills with previously selected element mesh.

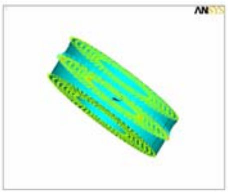


Fig.4

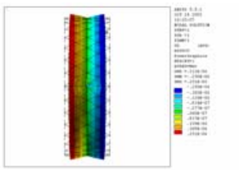


Fig.5

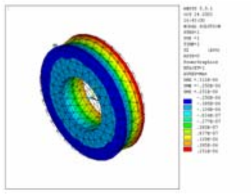


Fig.6

Fig. 4. Application type voltage loads.
Fig. 5. Representing the deformation front / nedeformatei for positive charges.
Fig. 6. Isometric representation of the strain / nedeformatei for positive charges.

Power source (ultrasonic signal generator) without the normal place elecrozii direction of polarization of electric charges in the frequency of pills Piezoceramic components required entry into a scheme of the combination resonance Piezoceramic components. In Figure 4 are represented the symbols corresponding electrical charges applied to nodes in areas that are (0 ÷ 2000 V).

After enabling the processor "Solution" to choose the type of static analysis.
The results of calculations made by calling GENERAL POSTPROCESSOR see it. Of interest is the distorted states and non-deformable structures studied. These can be represented by graphical user interface settings in various positions and in animation. Each representation of states obtained is accompanied by a caption containing sandy strain values.

Figure 5 is represented all deformed and non-deformable two pills Piezoceramic components in frontal position and in Figure 5 for the same in isometric external electrodes where the tasks appear positive and focal plane, negative.
By performing harmonic analysis for the desired resonant frequency of the combination Piezoceramic components (20 kHz), ie the nodal displacements are obtained oscillation amplitude ultrasonic concentrator that attack.[4],[5],[6],[7].

The results of this analysis (0 ÷ 2000 V). is given in Table 1. a sweep of blood supplied by generator power.

Table 1 depending on the voltage dependence of oscillation amplitude attack aplicată pills piezoceramic components

Table 1

Tensiune atac pastile piezoceramice [V]	Amplitudinea oscilației[μm]
0	0
100	0.94
200	1.877
300	2.82
400	3.75
500	4.72
600	5.63
700	6.57
800	7.50
900	8.44
1000	9.38
1200	11.26
1400	13.14
1600	15.01
1800	16.89
2000	18.692

Graphical representation of these pairs of values (Fig. 7) shows linear response of the voltage amplitude size pellets attack piezoceramic components

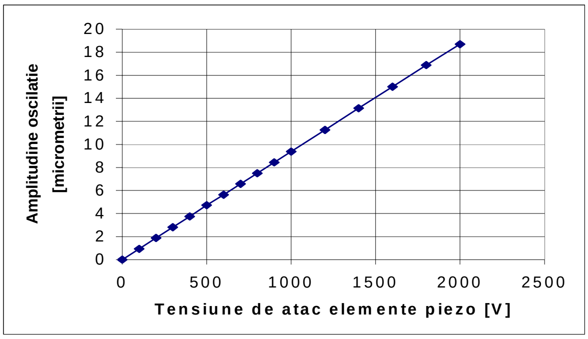


Fig. 7. Linear response function of voltage oscillation amplitude attack pill.

3.2. Finite elements modeling of all piezoceramic components

In all Piezoceramic components (Fig.8), 2 pills piezoceramic components are between asmblate with a reflector element 3 and one speaker or removed. [1],[2],[4].

Modeling by finite element method provides a prediction of all piezoceramic components of its behavior both in the size of deformations (amplitude) and the state of tension.

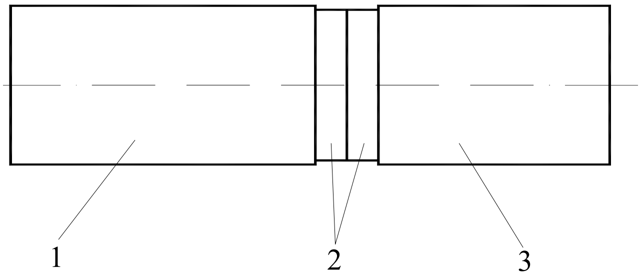


Fig. 8. Overall Piezoceramic components components:
1 - radial; 2 - pills piezoceramic components,
3 – Reflector.

Was chosen type harmonic analysis giving the possibility to predict the dynamic behavior of structures maintained, to check whether the model reaches the resonance, fatigue and other effects of harmonic vibration forces. [3],[4],[7].

Harmonic analysis can be achieved and a prestressed structure. The analysis was performed for frequency of 20 kHz which corresponds to the resonant frequency of piezoceramic components and assembly of the whole ultrasonic system considered.

Figure 9 is represented deformed state / non-deformable in isometric and verticală of all piezoceramic components for resonant frequency of 20 kHz and represented in figure 10 is deformed state / non-deformable in the vertical assembly Piezoceramic components for resonant frequency of 20 kHz.

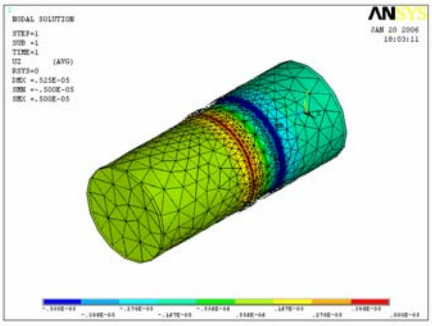


Fig. 9. Isometric representation of the strain of all piezoceramic components.

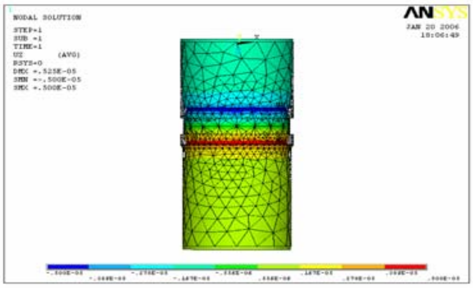


Fig. 10. Vertical representation of strain / nedeformation of all piezoceramic components.

Results of analysis regarding the state of deformation of the assembly piezoceramic components are given in table 2.

It contains pairs of nodes aplitudine coordinate values elements located generators and radiant reflector blocks and elements Piezoceramic components, the origin of the coordinate system being out of plane reflector.[4],[7].

Table 2. Amplitude values across all size piezoceramic components.

Coordinate **Z** **[mm]**	**Amplitude [μm]**	**Coordinate** Z **[mm]**	**Amplitude [μm]**
0	-17.68	50	0
8.08	-17.52	53	6.88
10.17	-17.08	56	16
16.01	-16.24	56	15.68
21.86	-15.04	61.64	14.6
26.11	-14.08	67.09	16.04
30.36	-13.08	73.54	21.24
33.19	-12.52	79.98	26.08
36.02	-12.12	86.8	30.68
37.91	-12.04	93.62	34.32
39.8	-12.32	98.68	36.44
41.06	-12.92	103.75	37.96
42.32	-13.84	107.12	38.64
43.16	-14.68	110.5	39.08

Graphical representation of the variation in amplitude across all piezoceramic components is given in figure 11.

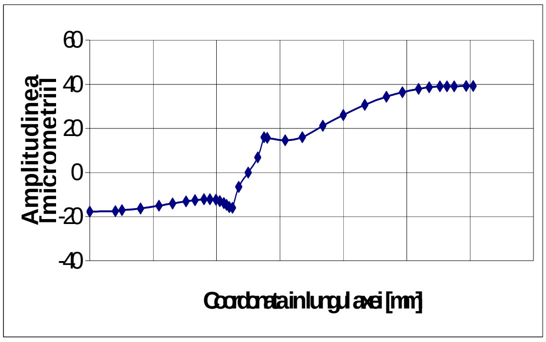


Fig. 11. Amplitude variation along all piezoceramic components.

3.3. Finite elements modeling of ultrasonic energy concentrator

Figure 12 presents the geometry is all concentrated - active element used in certain types of processing .

Ultrasonic energy concentrator meshing is done using the Solid 92 element mesh. Meshing with Solid element 92, this volume generates 9542 of elements with 15467 nodes as shown in Figure 13.

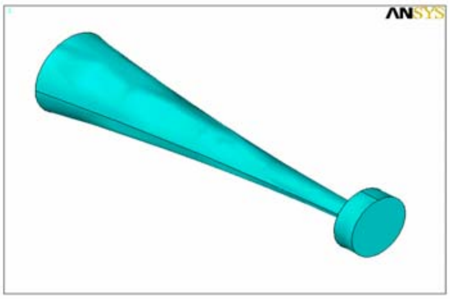


Figure12 Generation of assembly geometry concentrator element - cutting tools used for meshing the internal grinding

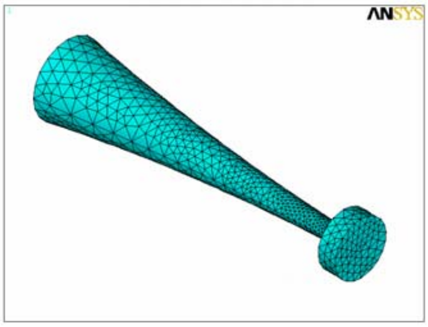


Figure 13 Meshing the volume meshing SOLID 92

Respecting the physical reality, concentrator of ultrasonic energy is applied as a result of type load displacement input section (area than the head), obtained from analysis of all piezoceramic components (Fig. 14).

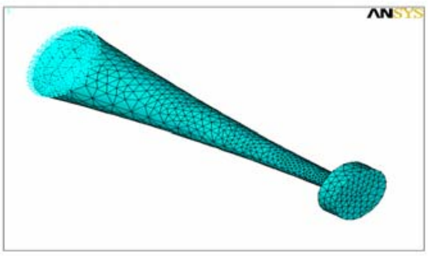


Fig. 14. Application type load displacement

In table 3 is presented the set of selected frequencies of ultrasound field 7 vibration mode (20,600 kHz) proves to be the closest resonance system ultraacustic frequency (20 kHz).

Table 3 Set the frequency obtained by calling postprocesing general

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	17900	1	1	1
3	18800	1	2	2
5	19700	1	3	3
7	20600	1	4	4
9	21500	1	5	5
11	22400	1	6	6
13	23300	1	7	7
15	24200	1	8	8
17	25100	1	9	9
19	26000	1	10	10

Deformed and non-deformable states corresponding to this mode of vibration, to move in the direction Z, represented by the graphical interface settings in isometric and front are given in figure 15 and figure 16. Figure 17 is shown deformed and non-deformable in the effort to isometric and figure 18 is shown deformed and non-deformable in the horizontal effort.

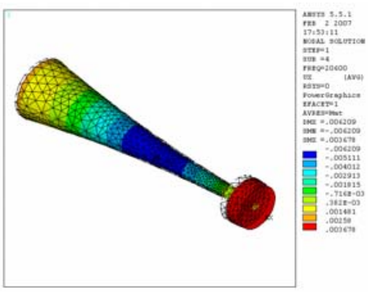


Fig. 15. Deformed and non-deformable the isometric for travel

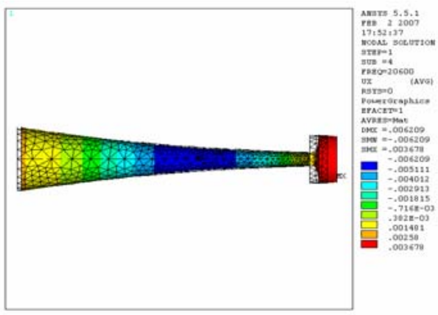


Fig. 16. Deformed and non-deformable in the isometric for horizontal travel

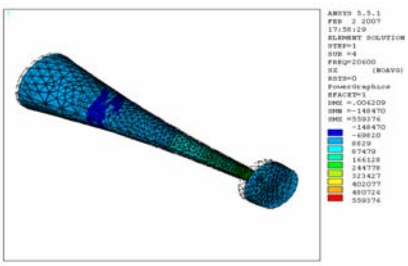


Fig. 17. Deformed and non-deformable in the isometric for effort

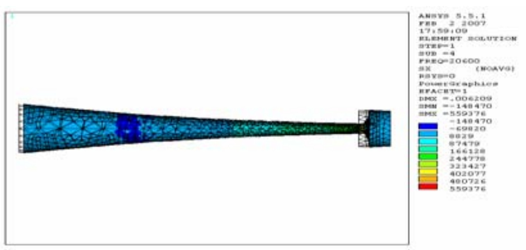


Fig. 18. Deformed and non-deformable in the horizontal for effort

Table 4. Size variation amplitude oscillation

No. Crt.	No. node	Length concentrator [mm]	Size oscillation amplitude [mm]
1	8	0	0.01302893
2	116	3.59918	0.01299083
3	117	7.20852	0.01297254
4	118	13.59154	0.01287704
5	6	19.99996	0.01280363
6	91	23.28418	0.01268273
7	92	26.57094	0.01249121
8	93	29.6545	0.01241831
9	94	32.7406	0.01203554
10	95	36.36772	0.01172032
11	3	39.99992	0.01147801
12	51	43.8023	0.01084199
13	52	47.60468	0.0107917
14	53	51.11242	0.01038149
15	54	54.62524	0.01018184
16	55	57.31256	0.00999998
17	4	59.99988	0.00949147
18	200	62.69228	0.00872261
19	201	65.38214	0.00786714
20	202	67.71894	0.00703224
21	203	70.05828	0.00613359
22	204	72.50938	0.00513029
23	205	74.96048	0.00406324
24	206	77.48016	0.00290779
25	15	79.99984	0.00169034
26	228	82.52206	0.00038232
27	229	85.04428	-0.00099705
28	230	87.99322	-0.00271475
29	231	90.94216	-0.0044991
30	232	93.39072	-0.00601751
31	233	95.83928	-0.00759714
32	234	97.91954	-0.00894334
33	18	99.9998	-0.0103185
34	258	102.0826	-0.01174267
35	259	104.1654	-0.01318844
36	260	106.393	-0.01479499
37	261	108.6206	-0.01641069
38	262	110.7415	-0.01799082
39	263	112.8624	-0.0195928
40	264	114.8842	-0.02112442
41	265	116.9035	-0.02266823
42	266	118.4529	-0.02381428
43	21	119.9998	-0.02496007
44	292	121.5492	-0.0260985

45	293	123.0986	-0.02722626
46	294	125.1102	-0.02874772
47	295	127.1219	-0.03028442
48	296	130.617	-0.03286252
49	297	134.1095	-0.03536442
50	298	135.7782	-0.03652266
51	299	137.4445	-0.03764534

The figure 19 is shown along the oscillation amplitude changes size of ultrasonic energy concentrator.

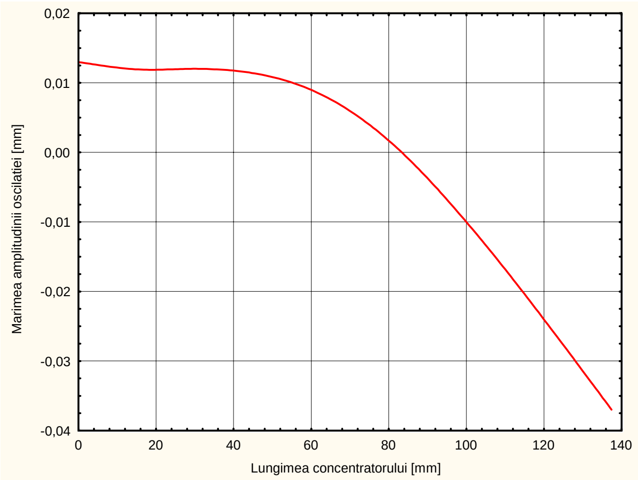


Fig. 19. Variation in size oscillation amplitude along concentrator

4. Conclusions

The work included research for the following conclusions:

- Ultrasonic transducer is one of the most important ultraacustic system, the way it is calculated and designed depending on the efficiency and performance of equipment manufactured or activated with ultrasound;
- Knowledge of the state of stresses and strains as well as amplitude variation along ultraacustic system is absolutely necessary to design an efficient system, which operate in a mode of resonance;
- Knowledge of how each section of the vibrating system can be ultraacustic using finite element analysis, after which the diagram plot particle velocity variation along ultraacustic system.

References

[1] Amza Gh - *Ultraacustic Systems* - Technical Publishing House, Bucharest, 1989.

[2] Amza, Gh - *Ultrasound* - active applications, Ed ASTRA, Bucharest, 2007.

[3]. Bailey M and Hubbard F. - *Control of vibrations composite structure using distributed piezoelectric sensors and actuators* - Proceedings of the SPIE 1985 2779: 118-23.

[4]. Cheng, M. *Finite Elements Analysis of Finite Axisymmetric Cylindres*, MS Thesis Tennnessee Tech., Univ. Cookeville, in 1998.

[5] Lerch R - *Simulation of piezoelectric devices by 2-dimensional and 3-dimensional finite elements*, IEEE Trans. Ultrasonic. Ferroelec. Freq. Control 37 (3) (1990) 3-247.

[6] Amza, Gh et all – *Damage Detection of Composite Materials with LAMB Wave Method* – Revue Plastic Materials, 45, No2, 2008

[7]. Amza, Gh et all – *Theoretical and Experimental Contributions Regarding the Influence of Technological and Mechanical Parameters over the Quality of Ultrasonic Welds of Various Material Combinations,* Revue Plastic Materials, 45, No3, 2008