MODELING OF AN ULTRASONIC ENGINE WITH TWO DEGREES OF FREEDOM

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Abstract. *In the paper is presented the design an ultrasonic engine with two degrees of freedom, a translation and a rotation along with the construction elements belong to type of this kind of motor and the modal analyses ways of vibration inhere in piezoceramics active elements of disk and bar type.*

Keywords: modeling of a piezoceramics; degrees of freedom

1. Theoretical considerations

For the modelling of a piezoceramics engine with two degrees of freedom that achieves a motion of translation around of an axis OZ and a motion of rotation around same axis is necessary to define the ways of vibration for the two piezo-ceramics active elements which are forming the motor elements of the system.[1]

On the basis of results obtained thereby modeling can be established the constructive shape of ultrasonic engine which must be represent an optimum performances of it as much from the angle of size displacement of activated element and as from the part of the force realized by motor.[2]

2. Description of engine operating

The basic diagram of an engine with two variances is presented in Figure 1

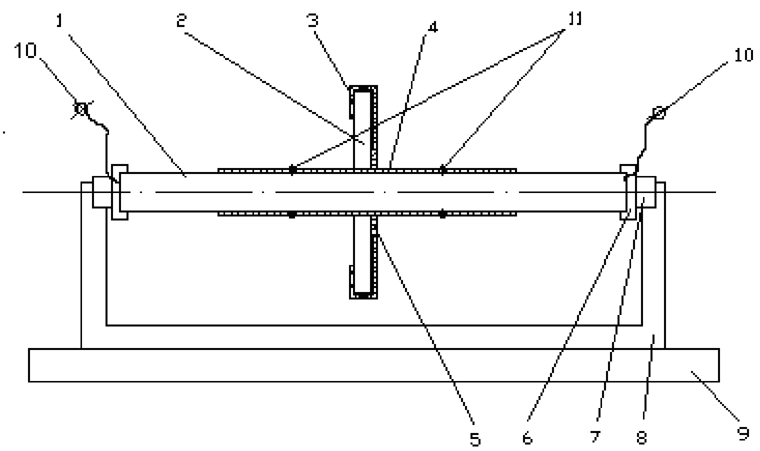

Fig.1. *Basic diagram of an engine with two degrees of freedom:*
1 – active element piezo-ceramic of type bar ; 2 – active element piezo-ceramic of type ring;
3 – activated element that executes the rotation motion; 4 – auxiliary element (activated) that executes the translation motion; 5 – bushed bear of adjusting and orientation of the activated element; 6 – contact element ; 7 – fixed camps; 8 – frame support the engine; 9 – base plate;
10 – voltage source of ultrasonic frequency; 11 – flexible rings for tightening.

According as is can noticed from the study constructive diagram with two degrees of freedom this executes a motion of translation on direction axis OX and a motion of rotation around same axis.

The first piezoceramic element is noted with 1 and achieves through oscillations of traveling type the movement of the activated element 2, which is a bushed bear from raylon easy embossed on hereof surface.

For achieving a force of optimum pre-tightening between bushed bear and piezo-ceramic cylinder, the bushed bear is driven on length and has foreseed two channels on which are introduced respectively two rings from rubber or belong to flexible elements. These rings achieve the force of pre-tightening that is materialized in friction force which is necessary for the transformations of traveling oscillations type of active element in linear movements, incrementally to bushed bear.[3]

The bushed bear length of raylon is calculated so that on his length to contains the minimum three maxims of vibration which are consisted in all yield points of contact between active and activated element. As four maxims of oscillation experimentally consisted represent a good value for the conduction of motion. In conclusion the translation motion is obtained using the piezoceramic element of bar type where the active element is displaced on his surface which is a bushed bear.[4]

The second degree of freedom of ultrasonic engine consist in the realization of rotation motion of one activated element that consist in a embossed bushed bear 3 on the surface of the active element of ring type marked with 2.

The bushed bear 3 is designed to enter in contact with the lateral surface of piezoceramic ring because on this surface are produced oscillations of traveling type. For the orientation and realization of pre-tightening of the bushed bear 3 (the activated element of rotation) on the surface of piezoceramic element it is necessary that this to be coupled on a conical surface with bushed bear 5 which is pressed easily on the surface of activated element 4, bushed bear which executes the translation motion .In this way a material point from the surface of bushed bear 3 can execute a motion of rotation and one of translation simultaneous or concomitant depending on the way which are excited the piezoceramic active elements 1 and 2 .For the realization of translation motion is activated the piezo-ceramic element through the excitation with voltage that has an ultrasonic frequency to the heads of this through the feeder system 10.For the excitation of piezo-ceramic disk is used a voltage source of ultrasonic frequency phase-shifted to 90^0, each phase being applied on the sector of 90^0 bounded by plane surface of piezoceramic disk. This will be divided in 4 sectors according of in Figure 2.

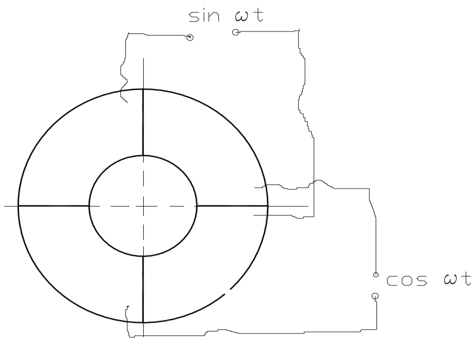

Fig.2. *90^0 the phase –shifted excitation of active element type piezoceramic-disk.*

Through this alternative act sine α, cosine α, a material point place to the surface of piezoceramic active element will have the followings coordinates:

$$x = x_0 \sin(\varpi t) \quad (1)$$

$$y = y_0 \cos(\varpi t + \varphi) \quad (2)$$

These two equations can be written also under the following shape:

$$\frac{x^2}{x_0^2} + \frac{y^2}{y_0^2} = 1 \quad (3)$$

This equation represents an ellipsis what means as a material point studies , placed to the surface of piezo-ceramic element describes an elliptical trajectory. This trajectory explains step by step the motion of activated element.With all as the motion is step by step , this thing is happening to a level which isbelow microne, what does that the motion of activated element to the level of our perceptions to be a continuous motion.

3. Modal analyse

For the determination ways of vibration to the piezo-ceramic active elements and understanding which phenomenas are in progress to undermikronical scale, in the next place a modal proper analysis of these will be realized.

In this way is not necessary the adjusment of whole ultrasonic usual domain for noticed the frecquencies whereat the piezo-ceramic cylinder respectively the active element of ultrasonic engine begins to vibrates and will be tried especially the frecquencies in which the shape obtained through the value of finite method element is optimum to the process.[5]

3.1. Modal analyse of piezo-ceramic active elements- cylinder type

For procurance a translation motion of activated element belongs to ultrasonic engine with two degrees of freedom it has been studied the ways of vibration pertaining to one piezo-ceramic active element of bar type manufactured from piezo-ceramic material with diameter d=12 mm and length l=120mm. For the determination the ways of vibration of piezo-ceramic cylinder that can drive to a realization of a translation motion for an mobil element which is linking along this will be achieved a modal analysis using the software ANYSYS.

In Figure 3 is presented the geometry of cylinder whose structure is defined in Solid type elements ,and on the heads of this is applied a difference of potential U=300V.In the same time the cylinder’s heads are embeded to allow the fixation in his space.

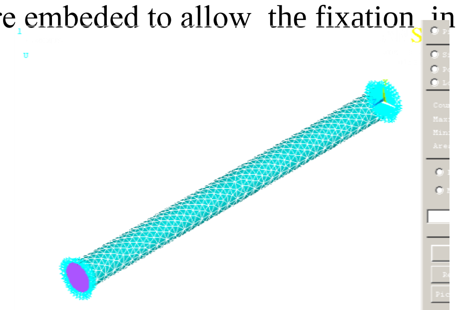

Fig.3. *Geometric definiteness of piezoceramic cylinder ,*
the adhibition of electric tasks and his embedment at the heads

For the realization of one modal analyses, the ways of own vibrations belong to piezoceramic active elements will be defined and presented in the next figures. It is necessary to take in consideration that the program causes not only the vibrations from ultrasonic domain but also the others from zone with inferior frequency. In Figure 4 is presented the way of proper vibration frequencies f=23860Hz which supposes only a kink of piezoceramic bar.

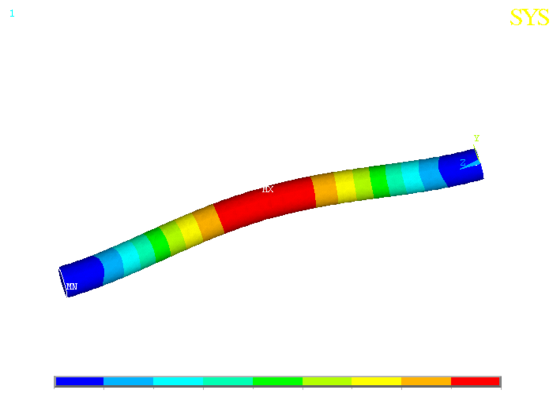

Fig. 4. *Mode of vibration to a frequency f = 23860 Hz*

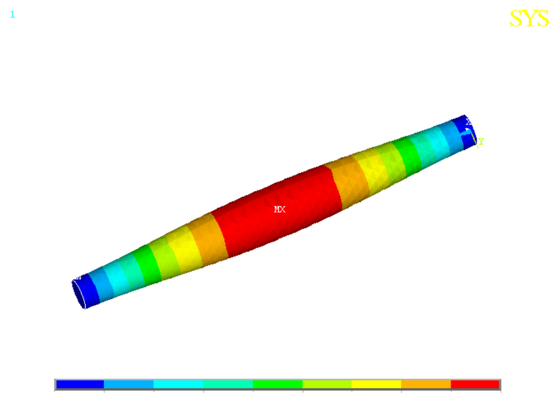

Fig.5. *Mode of vibration to a frequency f = 11715 Hz*

At frequency f=11715 Hz presents a twisting moment around longitudinal axis but also an enlargement of the diameter in the central area, which can't produce the movement of the mobile activated element, Figure 5.

Opening with the frequency f=19460 Hz, frequency which is approached to the ultrasonic domain of the piezoceramic active element begins to vibrate in ''traveling'' mode having four maxims of vibration that constitute a sufficient number of tacpoints for an empty cylinder type which wraps up the piezoceramic bar, Figure 6.

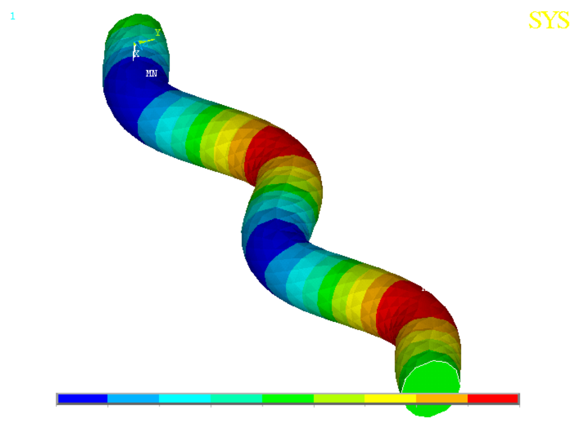

Fig.6*. Mode of vibration to a frequency f = 19640 Hz*

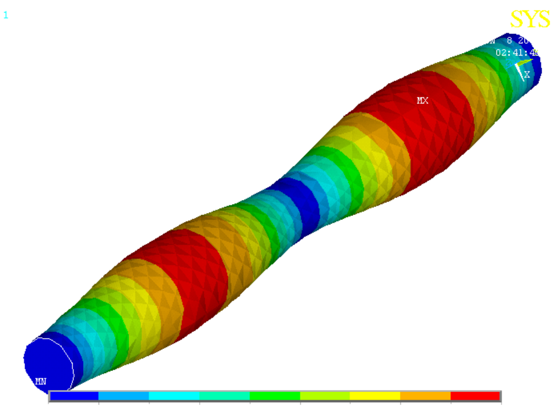

Fig.7*. Mode of vibration to a frequency f = 23877 Hz*

To frequency f=23877 Hz in the ultrasonic zone, the mode of vibration isn't ''traveling'' type, activated element presenting an enlargement of the diameter in two zones of his ((Figure 7) along with a torsional motion in these areas.
An way of favorable oscillation for procurement a translational motion of one activated element from cylindrical type which is linking on the bar is presented in the Figure 8, where at frequency f=38687 Hz are obtained vibrations of traveling type with six zones of maxim amplitude.

In this situation the length of friction contact between the active element and the one activated can be more lower and to corresponds to the three maxims of vibration along the bar.

3.2. Modal analyse of piezo-ceramic active elements- disk type

Within the work are presented also a second modal analyse which is adverted to a piezo-ceramic disk used in the construction of engines with two variances having an inside diameter d=6mm ,an outside diameter D=32mm and a tickness h=2.5mm. In Figure 9 for frequency f=59193 Hz , the first way of vibration appears in which the disk does an inflexion motion on a halfs of this ,motion that is not able to produce in noway the movement of active element.

To frequency f=105531 Hz the piezoceramic cylinder again begins to vibrate with oscillations of traveling type only that for this time the number points of minimum and maximum has increased to six. In this way the number of friction points with activated element is growing therefore the possibility of obtain the motion is high.

The force of friction being more bigger the torsional moment developed by ultrasonic engine is also growing what means that is willable.

In the Figure 10 is presented this kind of vibration.

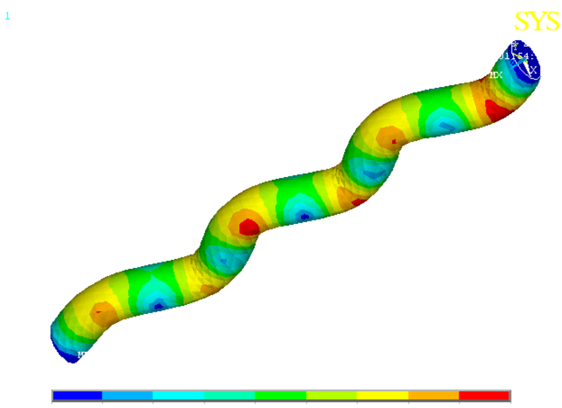

Fig. 8. *Mode of vibration to a frequency f = 38687Hz*

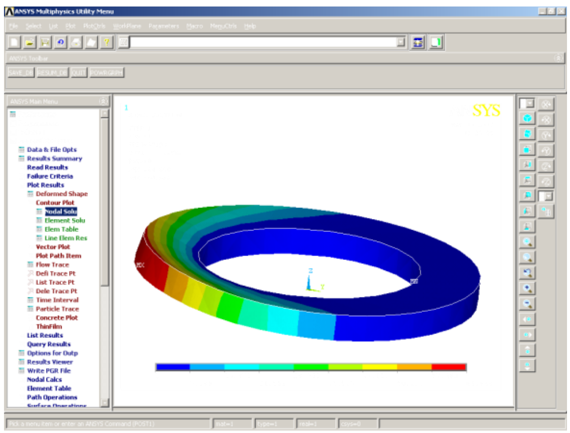

Fig.9. *Mode of vibration to a frequency f = 59193Hz*

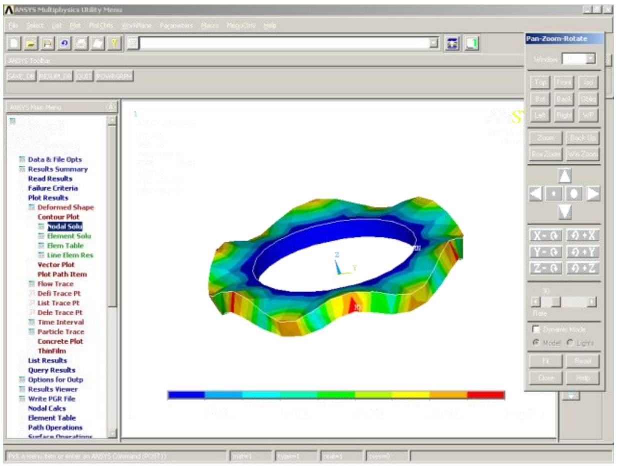

Fig.10. *Mode of vibration to a frequency f = 105531Hz*

4. Conclusions

Can be spoken of advantages's study using the theory of finite element which are:

Comprehension and the study of which phenomenas are in progress in the contact zone,designing the shape of active element in order to obtain a maximum answer of activated element, prediction of the form and amplitude vibrations ,substantial reducing for experimentation time through the research only for domains with adequate frequency of analyses,the optimum designation of relative position among active element and the activated one through the utilization of those zones in which the amplitude vibrations is maximum and where are very good presented by the used software.In the same time can be achieved too, a very important piezoceramic materials saving through the designing and the selection only for those forms which are useful by desirable aim.Therefore through the analysing of vibration modes for many more tipo-dimensions of plates will be selected those desirables vibration modes belong to those material shapes that carried out an certain preestablished conditions.

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