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Research Article

Fe Modelling of Shock Waves

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Abstract:

Among the well-known methods in medicine is the application of mechanical waves, as well as ultrasound and shock wave methods. It is known that the characteristics of mechanical waves are determined by amplitude and frequency. If the frequency of the wave is above 20000Hz, then it cannot be heard by the human ear. These waves are called ultrasounds. The basic principle of ultrasound application in medicine is that different tissues or foreign bodies (e.g. stones) reflect ultrasound waves differently. In ultrasonography, reflected ultrasound waves are recorded by transducers and translated into a recorded image. On the other hand, if the mechanical wave propagates through a medium with a speed greater than the speed of sound propagated through that medium, then we have the shock wave. In this case, the waves produce an instantaneous increase in pressure or energy for very short intervals of time. These energetic impulses are usually applied in medicine to break kidney stones or urinary channels stones. The basic principle of the application is to focus the energy impulse of the wave on the places where the stones are found and hit them. During shock, the stones are broken and these can come out through the urinary channels. Such a method is called lithotripsy, while the device is called a lithotripter. In this contribution, we modelled the shock waves according to the FE method, while the simulation was done in the ANSYS application.

1. Introduction

A shock wave is a type of wave that propagates faster than the local speed of sound in the medium [1]. During the spread, shockwaves produce an abrupt spike in pressure over a very short time period, figure 1 [2,3]. As can be seen from figure 1, shock waves are characterized by a single, mostly positive pressure pulse followed by a comparatively small tensile wave component (negative pressure pulse).Thanks to the impulsive and high pressure, shock waves have found application in medicine [3-7]. Originally, shock waves were used only to break stones in the kidneys and urinary tract, while recently they are used in orthopedic therapy or to treat patients with Alzheimer's disease. For example, for the first time in 1981 in the USA, shock wave pressure was used in medicine to break

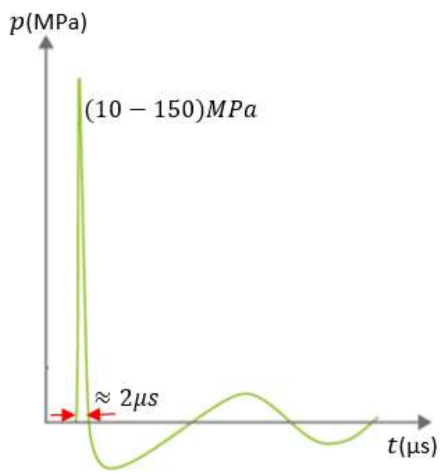

Figure 1. *Depend p of t by shock wave.*

stones in the urinary tract [8]. The device where the shock waves are produced and enables their focusing is called a lithotripter. This device consists of electromagnetic coil, an elastic membrane, and acoustic lens, figure 2 [9].

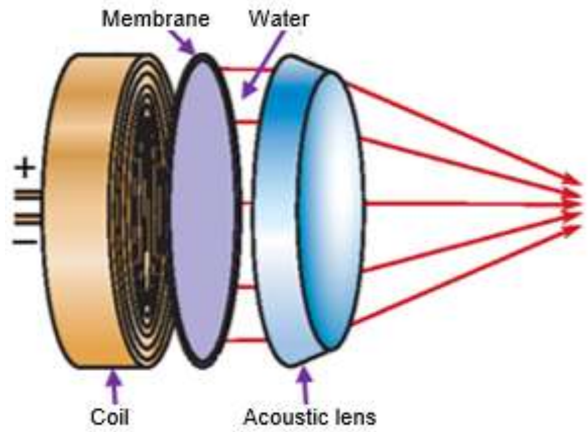

Figure 2. *Scheme of Lithotripter* [5].

If the coil is excited by a short pulse of alternating current, then the metal plate will resist this excitement and thus it starts to oscillate. In fact, the plate generates the shock wave. Since the metal plate is flat, the resulting shock wave is a plane wave which is then focused by an acoustic lens. Water is placed between the lens and the membrane, which enables the best propagation of the waves.

2. Modelling of shockwave pressure

The pressure of the shock wave can be calculated with the expression [10],

$$p = p_0 \cdot sin\left(\frac{2\pi}{2T} \cdot t\right) \cdot e^{-\frac{t}{2T}}$$

From the membrane, the shock wave propagates through the water to the acoustic lens. Therefore, it is important to know the dependence of pressure from time in this area, which we have calculated by Finite Element Method, while the support was the ANSYS application [11-13]. At first we have obtained a circular integration area, which corresponds to the shape of the coil. Then in the space above the coil (where there is water and the acoustic lens) in order to make calculations as easy as possible, we obtained an area with a regular geometry in the shape of a quadrilateral, figure 3. For the meshing of the integration area, for the basic element we took Fluid29, figure 4. The freedom degrees for this element are U_x and U_y, which represent the pressure at nodes I, J, K and L.

The meshed area looks like in Figure 5.

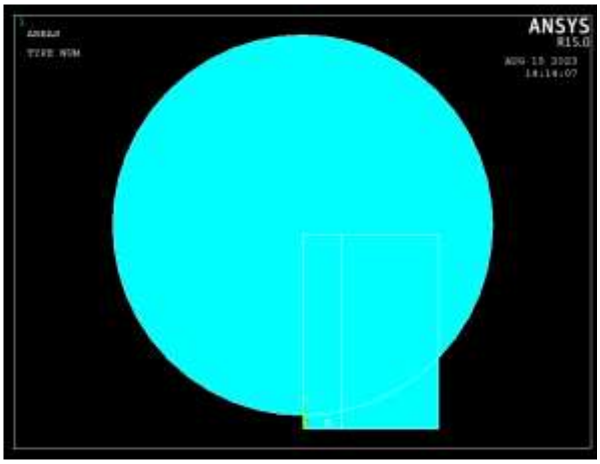

Figure 3. *Integration area in the ANSYS working window.*

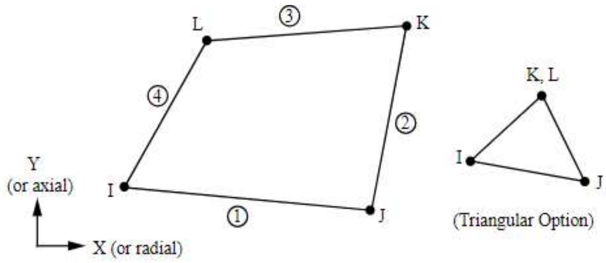

Figure 4.*Element Fluid 29.*

In the integration area above the coil there we have water and an acoustic lens. The physical quantities for water that affect wave propagation are density, $\rho_w = 1000\frac{kg}{m^3}$and sound propagation speed $c_w = 1500\frac{m}{s}$.

Recently, acoustic lenses are made of acrylic plastic material PMMA [14]. The density, respectively the sound propagation speed of PMMA is

$\rho_l = 1150\frac{kg}{m^3}andc_l = 2750\frac{m}{s}$.

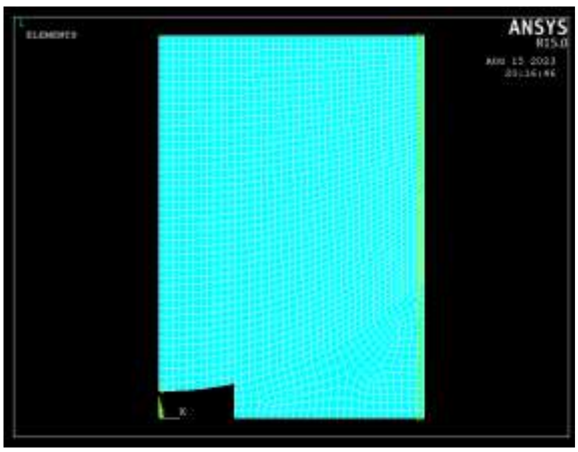

Figure 5.*The meshed area.*

3. Results

The solution algorithm was built in the APDL language of ANSYSI and it was of the transient type. While the solution is the distribution map of the pressure intensity at the nodes of the integration area for a moment in time, figure 6. From figure 6, pressure depending from time can be found, namely its dynamic form. For example, figure 7 shows the pressure intensity as afunction of time for node 136 with coordinates x=0.0425997486459m and y= 0.016743207540m.

From figure 7 we see that the pressure amplitude is 0.4MPa, the pulse period is 16μs, the shock pulse duration interval is approximately 8μs, and the shock wave propagation duration is 60μs. Also, from the figure, it can be seen that the main pulse is accompanied by a small tensile pulse. In figure 8, we have presented together the dependence of pressure on time for three nodes with different coordinates. From figures 7 and 8 it is clearly observed that the pressure profile is similar to that of figure 1, respectively the theoretical one. This proves the accuracy of the model built according to the Finite Element Method.

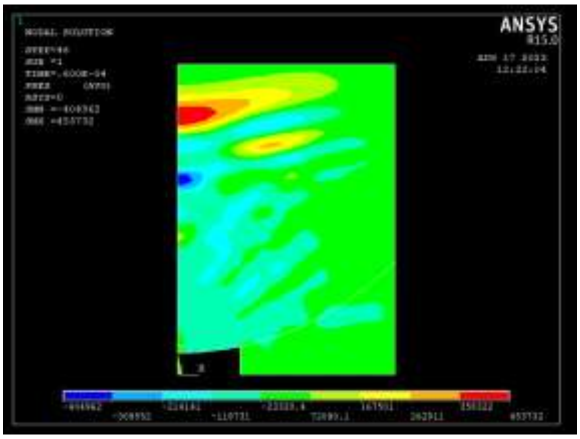

Figure 6.*Distribution of pressure intensities at the nodes of the integration area.*

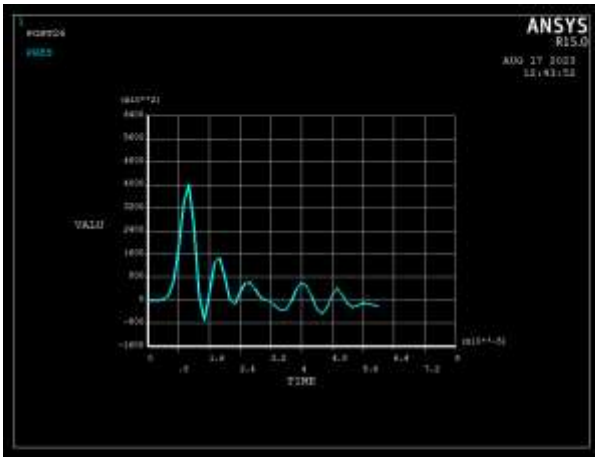

Figure 7.*The dependence of p on t for node 136.*

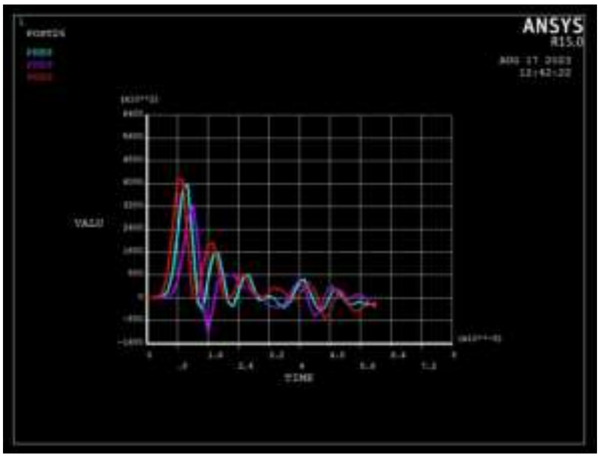

Figure 8.*The dependence of p on t for three different nodes.*

4. Conclusions

- The pressure profile of the shock wave can be modeled.
- The profile of more than one node can be modeled simultaneously.
- The time interval for which p is maximal can be read directly from the graph.
- For different nodes, the maximum of p is reached at different times.
- The experimental and modeled profile according to the FE Method are of the same shape.
- The dynamic model of the profile$p(t)$ can be simulated in the ANSYS application.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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