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Development of Frequencies from Hertz to Gigahertz in Ultrasonic Technique

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Abstract: A series of effects of the interaction of the ultrasound with matter has been observed which, until now, can not be explained satisfactorily. Some of this effects are the so called hot spots where could be generated temperatures of the order of 5000°C, pressures of about 50 MPa and temperature gradients higher than 600°C. This research presents the results obtained from spectral analyses performed on two ultrasonic pulses. These results showed frequencies of 23 GHz generated by an ultrasonic pulse of 5 MHz. Other effects observed were the volatilization of micro-particles (74 μ) of hematite and galena minerals, an intense fading of the color in a methylene blue solution and the generation of an electric current in de-ionized water.

Key words: Ultrasound intensity, resonance, spectral, analysis

INTRODUCTION

Power ultrasound has many industrial applications. However, the growth of industrial uses of power ultrasound has been unpredictable and asymmetrical. These uses include cleaning, disinfection, welding, soldering, machining, generation of dispersion and production and processing of metals, foods and pharmaceuticals; at present, it is used also as a scientific tool.

The petroleum industry in México has been favoured for the ultrasonic technique for cleaning the Maya crude by means of the elimination of asphaltenes. Also it has been demonstrated the chemical effects of ultrasound on aqueous and non aqueous solutions. That is known as the acoustic cavitations, consisting in growth and violent collapse of vapour filled micro-bubbles in a liquid^[1].

Ultrasound is a form of mechanical energy and its interaction with matter could result in permanent physical changes. For a given power the length of ultrasonic exposure determines the total energy transferred to the material. Most macroscopic effects do not present unless the ultrasonic intensity has reached a threshold level. The acoustic intensity is an

important factor due that the energy transmitted by an ultrasonic wave is proportional to the square of the amplitude of the wave^[2].

In other hand, the free vibration frequency of a body depends both on its size and on its physical properties^[2]. Oscillations take place not at a single frequency but at frequencies extending over a continuous range. Finally, the resonance behavior is a function of the static magnetic field. At present, there is not a satisfactory explanation of the interaction of the ultrasound with matter.

The Fourier transform, decomposes or separates a wave function into several sinusoidal functions of different frequency which sum restores the original waveform. It identifies the different frequency sinusoids and their corresponding amplitudes^[3].

MATERIALS AND METHODS

Experimental study was conducted in two directions: One in on the spectral analysis of the ultrasonic pulse in order to determine the development of the fundamental ultrasonic pulse. The other consisted in the ultrasonic excitation of matter to observe the interaction of ultrasound with matter.

Ultrasonic sources used were an ultrasonic device Kraut Kramer Branson, model USL-48 coupled to a 5 MHz transducer, a Sonogen bath, model D-100 coupled to 17.920 kHz transducer and a simple Branson bath model B220 operating at approximately 17 kHz.

Spectral analyzes were performed before and after the piezoelectric element using a Spectrum Analyzer, Agilent Technology, model 4407B, of 26.5 GHz and a Spectrum Analyzer Hewlett Packard model 35665B of 100 kHz, respectively. A Picoamperimeter Keithley Instruments, model 619C was used to measure the electric currents produced.

In order to observe the effects of the ultrasonic power on hematite and galena, these minerals were crushed and powdered selecting powder with grain size of 74 μm . This powder was placed into the ultrasonic cube and excited with a fundamental ultrasonic pulse of 17 kHz.

At the first stage, an ultrasonic pulse of 17.920 kHz from an ultrasonic cube Sonogen model D-100 was analyzed using a Spectrum Analyzer Hewlett Packard model 35665B of 100 kHz. The second stage consisted in analyzing the fundamental ultrasonic pulse of 5 MHz from an ultrasonic device Kraut Kramer Branson model USL-48 operating at approximately 5 MHz.

The spectral analyzer used was an Agilent Technology, model 4407B, of 26.5 GHz and, calibrating the signal with another analyzer Agilent model 849B of 16 GHz. In order to observe the effect of the ultrasonic power on methylene blue, a solution of methylene blue were submitted to ultrasonic excitation with a fundamental pulse of 17.920 kHz during one hour using the Sonogen bath as an ultrasonic source.

In the ultrasonic bath Branson model B220, containing 250 cm^3 on a glass, of de-ionized water were inserted depth two electrodes, one of copper and another of zinc, in order to measure the electric current generated between them when the water is excited by a fundamental ultrasonic pulse of 17.920 kHz.

RESULTS

Figure 1 shows the spectrum obtained for the fundamental ultrasonic pulse of 17.920 kHz, as measured after the piezoelectric element. In this spectrum it can observed five harmonics at 88.832 kHz.

In Fig. 2 it can be observed a frequency of 23 GHz from the spectral analysis of a fundamental pulse of 5 MHz analyzed before the piezoelectric element.

After the ultrasonic excitation of hematite and galena powders, with a fundamental frequency of 17 kHz, during 10 min, powder having grain sizes of approximately 20 μm was obtained.

Fading of the color of methylene blue was observed at sight when the solution was excited with an ultrasonic fundamental pulse of 17.920 kHz for 1 h. It was also observed that the process is reversible due that when the ultrasonic excitation was stopped, the methylene blue solution returned to its original color.

Table 1 presents the electric current measured between the electrodes when the water contained in the ultrasonic bath is excited by a fundamental ultrasonic pulse of 17.920 kHz as a function of the excitation time.

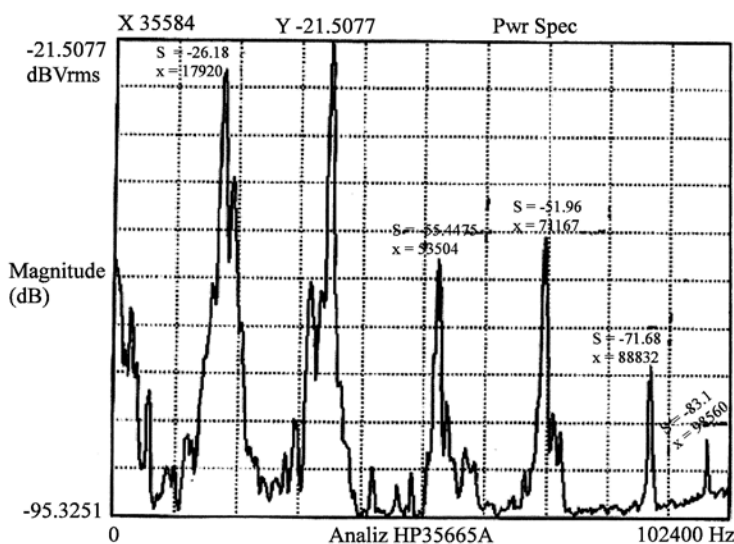


Fig. 1: Spectrum obtained for a fundamental ultrasonic pulse of 17.920 kHz, as measured after the piezoelectric element

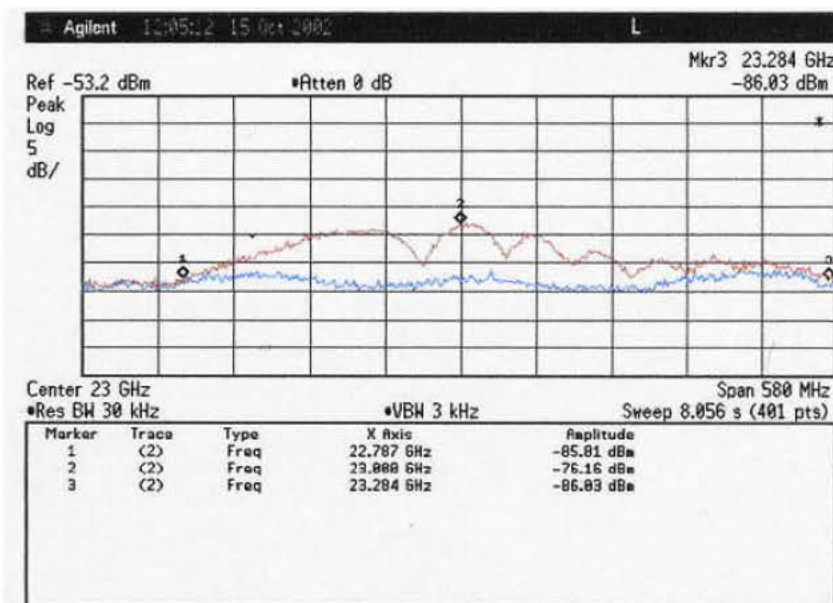


Fig. 2: Spectral analysis of a fundamental pulse of 5 MHz analyzed before the piezoelectric element

Table 1: Electric current produced by a fundamental ultrasonic pulse of 17.920 kHz as a function of the excitation time

| Excitation time (h) | Electric current produced (mA) |
|---------------------|--------------------------------|
| 10.50 | 0 |
| 10.60 | 0 |
| 10.65 | 0.30 |
| 10.70 | 0.15 |
| 10.75 | 0.10 |
| 10.80 | 0.05 |
| 10.85 | 0 |
| 11.00 | 0 |

CONCLUSIONS

Theoretically it is possible to demonstrate, using Fourier transformations, that a fundamental pulse can be developed into several harmonics of higher frequency which could confirm the experimental results obtained in this study.

From the observed pulverization of hematite and galena it could be supposed that the particles were fragmented by the effect of the high frequency harmonics developed.

It is noticeable that the fading in the color of methylene blue has been observed previously when a solution of methylene blue is submitted to gamma irradiation which is an ionizing radiation^[4-6]. This effect could be due to the color centers probably produced by high frequency harmonics in resonance with the atoms of the methylene blue solution.

The production of an electric current could be attributed the dissociation of water similarly to the radiolysis provoked by ionizing radiation^[7,8].

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