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CONTROLLING THE THICKNESS OF THE PLASTIC LAYER APPLIED USING 3D PRINTING BY ELECTROMAGNETIC ACOUSTIC METHOD

Background: Currently, the EMA method is not used to control the thickness of the layer of plastic applied to a metal platform using 3D printing, which significantly limits the scope of its use. However, EMA flaw detectors are widely used to control the quality of the metal platform itself. The solution of the problem of radiation research will allow carrying out complex control of the thickness of the layer of plastic applied by 3D printing, which will increase the efficiency of ultrasonic flaw detection in the reliability and speed of work.

Objective: This article considers the possibility of determining the thickness of the layer applied by 3D printing using electromagnetic-acoustic (EMA) method.

Methods: The analysis of the relationship between the thicknesses of the layer of plastic applied by 3D printing on the acoustic pressure created in it during the control using EMA transducers. The influence of the thickness of the plastic layer applied to the metal platform by means of 3D printing on the acoustic parameters of the EMA transducer was investigated with the help of mathematical modeling. Experimentally obtained dependences showing the influence of the thickness of the layer applied by 3D printing on the generated acoustic pressure.

Results. The effect of the thickness of the plastic layer applied to a metal platform using 3D printing on the acoustic parameters of the EMA transducer is studied using mathematical modelling.
Dependences showing the effect of the thickness of the plastic layer applied to the metal platform using 3D printing on the created acoustic pressure are obtained experimentally. The maximum acoustic pressure is created when there is no thickness of the plastic layer applied to the metal platform using 3D printing. The pressure drops sharply, as the layer thickness increases.

Conclusions: Good convergence of the outcome of theoretical and experimental studies is demonstrated, with the approximation error of experimentally obtained data generally not exceeding 5%.
The study is based on a widely proven approach to analyzing the process of acoustic wave formation by an EMA transducer. The reliability of the results obtained is confirmed by the correct use of the mathematical tools and good convergence of the outcome of theoretical and experimental studies.

Keywords: EMA, converter, 3d, Printing, layer, plastic, thickness, acoustic pressure, non-destructive testing.

Introduction

Among the studies related to the development of non-destructive testing equipment, the search for non-contact methods for excitation and recording ultrasound in solids is the most important one [1]. Progress in this area has been achieved through the use of the electromagnetic acoustic (EMA) method of excitation and reception of ultrasonic vibrations.

Nowadays, the EMA method is not used to control the thickness of the plastic layer applied to a metal platform using 3D printing, which significantly limits the scope of its application. Nevertheless, EMA flaw detectors are widely used to control the metal platform's quality. The problem of controlling the thickness of the plastic layer applied by 3D printing using EMA transducer can be addressed only in joint study of radiation, magnetic field [2, 3] and probe pulses formation [4]. The solution of the radiation study's problem is to allow for comprehensive control of the thickness of the plastic layer applied using 3D printing, which will increase the efficiency of ultrasonic flaw detection in terms of reliability and speed of work.

Problem statement

The problem is to analyze the relationship between the thickness of the plastic layer applied using 3D printing and the acoustic pressure created therein during controlling with the use of EMA transducers.

Analysis of the dependence of acoustic wave parameters on the thickness of the plastic layer applied to a metal platform using 3D printing

Based on the studies of a number of authors [5,6,11], in our case, a wire with simple harmonic current is mounted on the surface of a layer of plastic applied using 3D printing on a metal platform [5,11]:

$$I = I_0 \cdot \cos(\omega \cdot t) = I_0 \cdot \cos(2 \cdot \pi \cdot f \cdot t)$$

Where I_0 − is current amplitude value, ω − is angular frequency, f − is frequency of current in the wire.

As a rule, external magnetic fields are used to improve the quality of EMA transduction. There is an explanation in the ferromagnetism theory, according to which eddy currents that occur due to domain displacement have the greatest impact on the attenuation of ultrasonic waves in the object. The external magnetic field reduces ultrasound attenuation by or-

dering the domain structure. Consequently, the total magnetic field can be expressed as follows[6,11,12]:

$$B_\Sigma = B_\approx + B_=$$

Thus, we can put down the equation of acoustic pressure's distribution on the surface [6,11]:

$$p = -\mu_0 \cdot \mu \cdot \frac{I_0 \cdot h^2}{4 \cdot \pi \cdot (h^2 + y^2)^2} \bullet (1 + \cos(4 \cdot \pi \cdot f \cdot t) - \\ - \frac{I_0 \cdot h \cdot B_=}{\pi \cdot (h^2 \cdot y^2)} \bullet \cos(2 \cdot \pi \cdot f \cdot t)$$

Where $B_=$ − is induction of the external constant magnetic field, h − is thickness of the plastic layer applied using 3D printing, − is distance from the wire projection along the surface of the object under test, $\mu_0 = 4 \cdot \pi \cdot 10^{-7} Gn/m$ − is magnetic constant, μ − is magnetic permeability of the controlled material.

Above equation demonstrates that there is an inverse relationship between the thickness of the plastic layer applied using 3D printing h and acoustic pressure. That is when increasing h the acoustic pressure will decrease.

As a result of modelling, the relationship between the thickness of the layer applied using 3D printing and the acoustic pressure was established, which is shown in the following diagram, Fig.1:
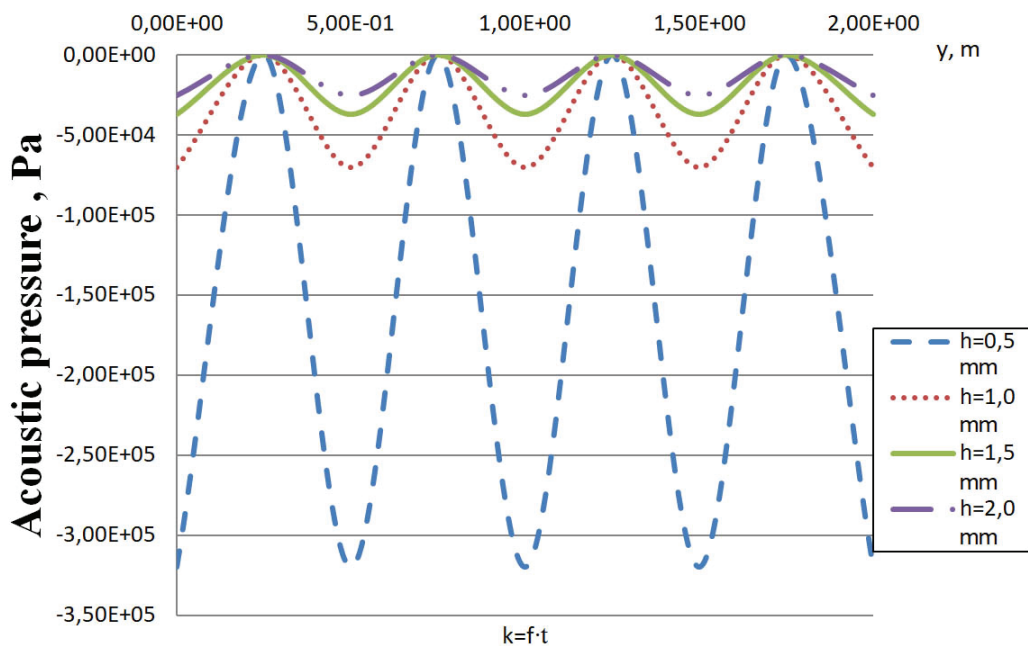

Fig.1. Diagram of the acoustic pressure dependence on the thickness of the plastic layer applied to a metal platform using 3D printing when generating a signal with a single emitter.
$AtB_= = 0.3Tl, I_0 = 2A, f_i = 0.5 MHz$

Fig.1 shows a diagram demonstrating the dependences of acoustic wave formation by a single emitter. There is a sharp decrease in acoustic pressure, with an increase in the value of the layer thickness h.

Analysis of the acoustic vibrations' formation by a common-mode emitter system.

The process of forming acoustic vibrations in the body of the object under test was studied in detail by a number of authors [7, 8, 9, 10, 11, 12]. Based on which, to study the process of forming common-mode wires/emitters of acoustic vibrations by the grid, the effect of the thickness of the layer applied to a metal platform using 3D printing is modelled, with its uniform thickness over the entire

surface of the metal base it is applied on, on the total acoustic pressure created (Fig.2).

Fig.2 shows a diagram demonstrating the formation of an acoustic wave by the grid consisting of emitter wires. Similarly with the diagram shown in Fig.1, there is a sharp decrease in acoustic pressure, with an increase in the value of the layer thickness h.

A study of the effect of the formation of common-mode wires/emitters of acoustic vibrations by the grid was also carried out. The effect of an uneven distribution of the thickness of a layer of plastic applied to a metal platform using 3D printing on the total acoustic pressure created was modelled

If the layer is applied unevenly using 3D printing, the form of the pressure distribution changes dramatically (fig. 3,4)
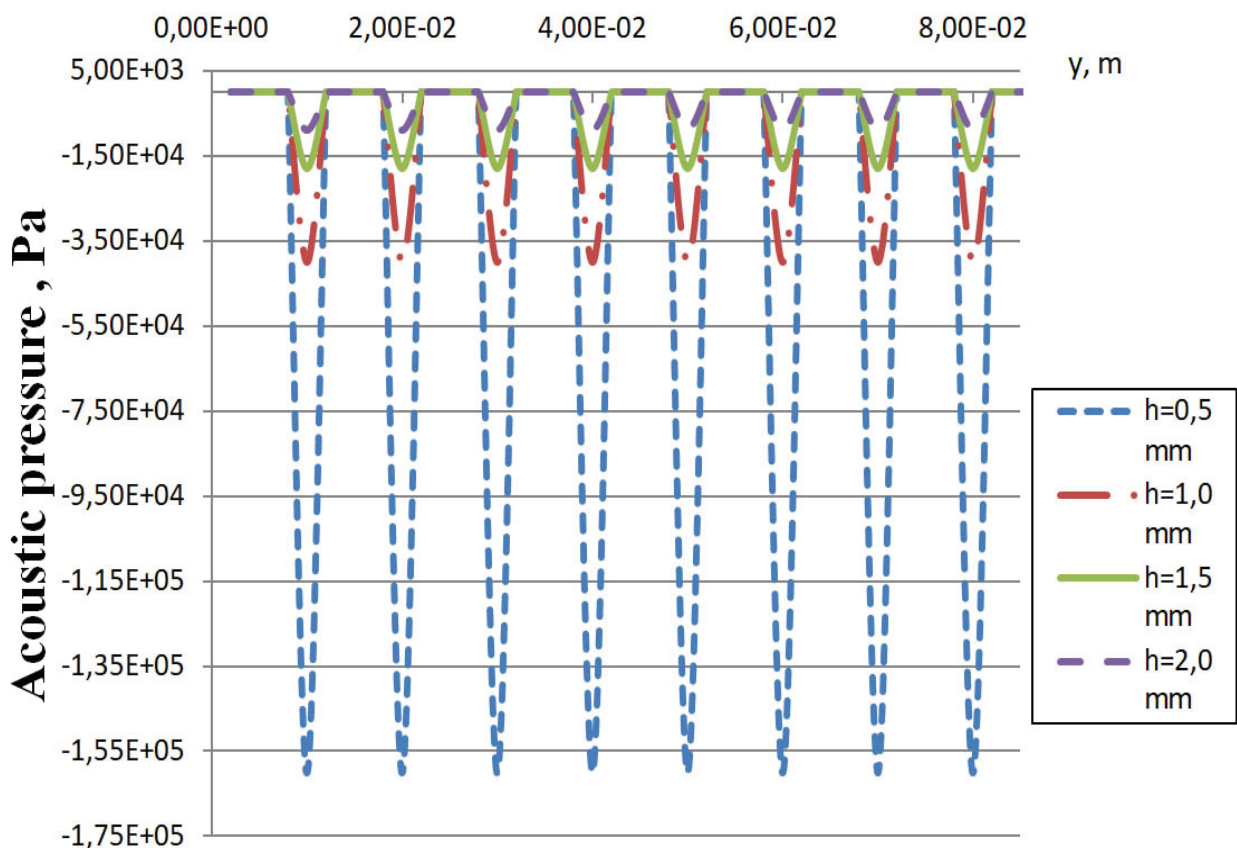

Fig.2. Diagram of the dependence of the total acoustic pressure on the thickness of the plastic layer applied to a metal platform using 3D printing when generating a signal by a family of emitters.
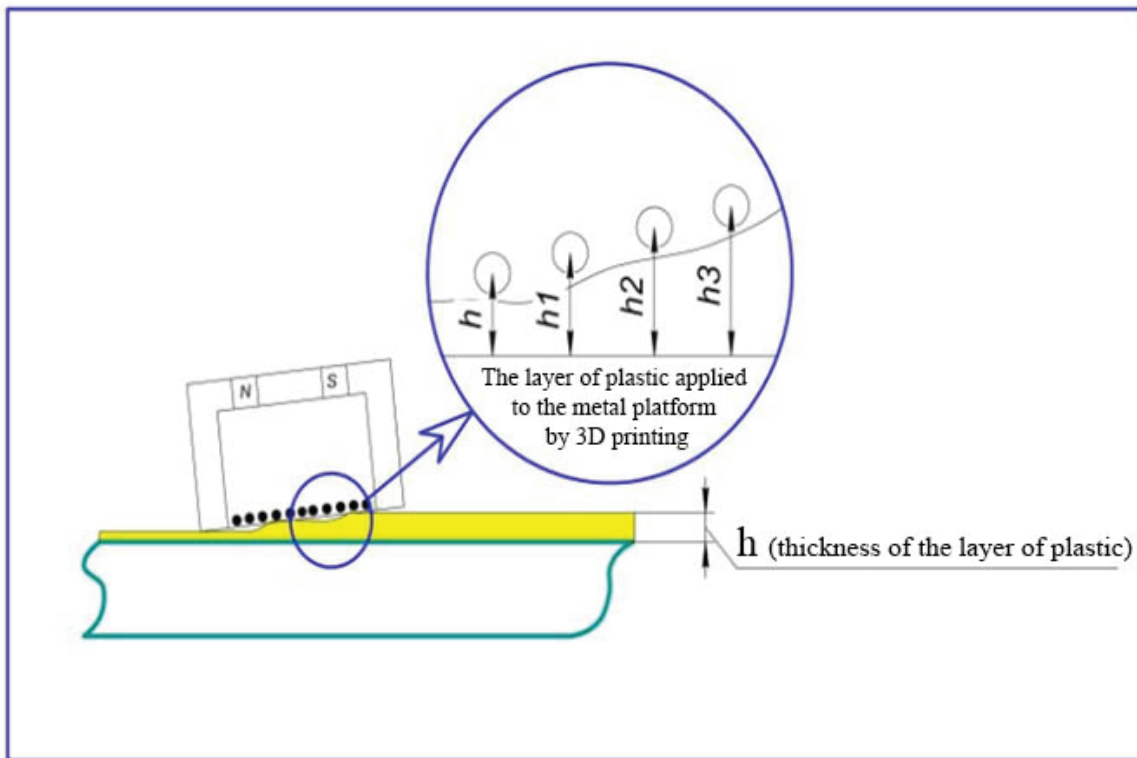$At\, B_= = 0.3\,Tl,\, I_0 = 2\,A,\, f_i = 0.5\,MHz$

Fig. 3. The EMA method is used to control the thickness of the layer of plastic applied to a metal platform using 3D printing.
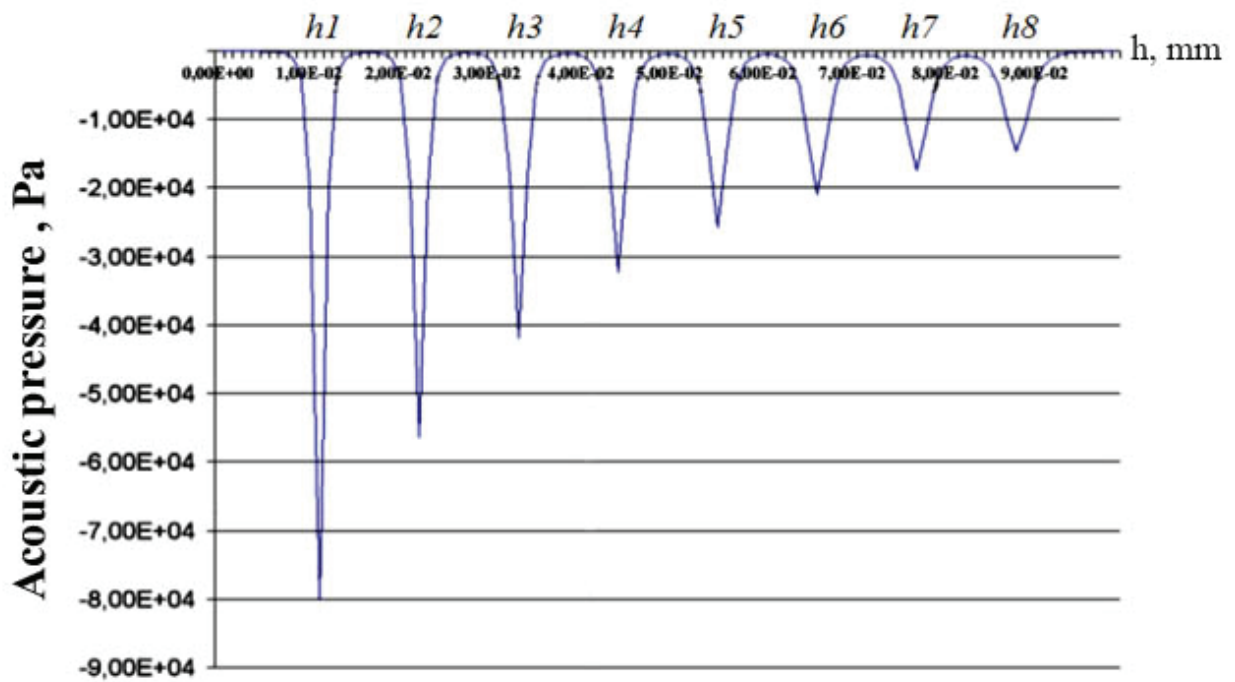

Fig. 4. Dependence of total acoustic pressure at different thickness of plastic layer applied to a metal platform using 3D printing. $At B_= = 0.3 Tl, I_0 = 2A, f_i = 0.5\ MHz$

Experimental studies

To confirm the theoretical studies, a number of experiments have been conducted. Universal flaw detector UD4-T and an EMA transducer E411-5-K12 were used during the experiment. The dependence of the acoustic pressure and thickness of the layer applied to the metal platform was analyzed using 3D printing, by applying layers and further measuring the acoustic signal in the area of its application.

As an imitation layer, there were sheets of paper used (with density 80 g/m², thickness 104 microns, or 0.0104 mm), which possesses approximate dielec-

tric and magnetic characteristics with plastic used in 3D printing.

The layer's thickness was regulated by the number of layers of paper, not exceeding 1.3 mm. With further increase in thickness, the received signal is disrupted. Two standard 59 and 29 mm thick bars were used as a metal base.

The outcome of the experimental studies is demonstrated in the diagrams of Fig.5 and Fig.6:

The discrepancy between theoretical and practical data does not exceed 5%, which shows good convergence of the outcome of theoretical and experimental studies.
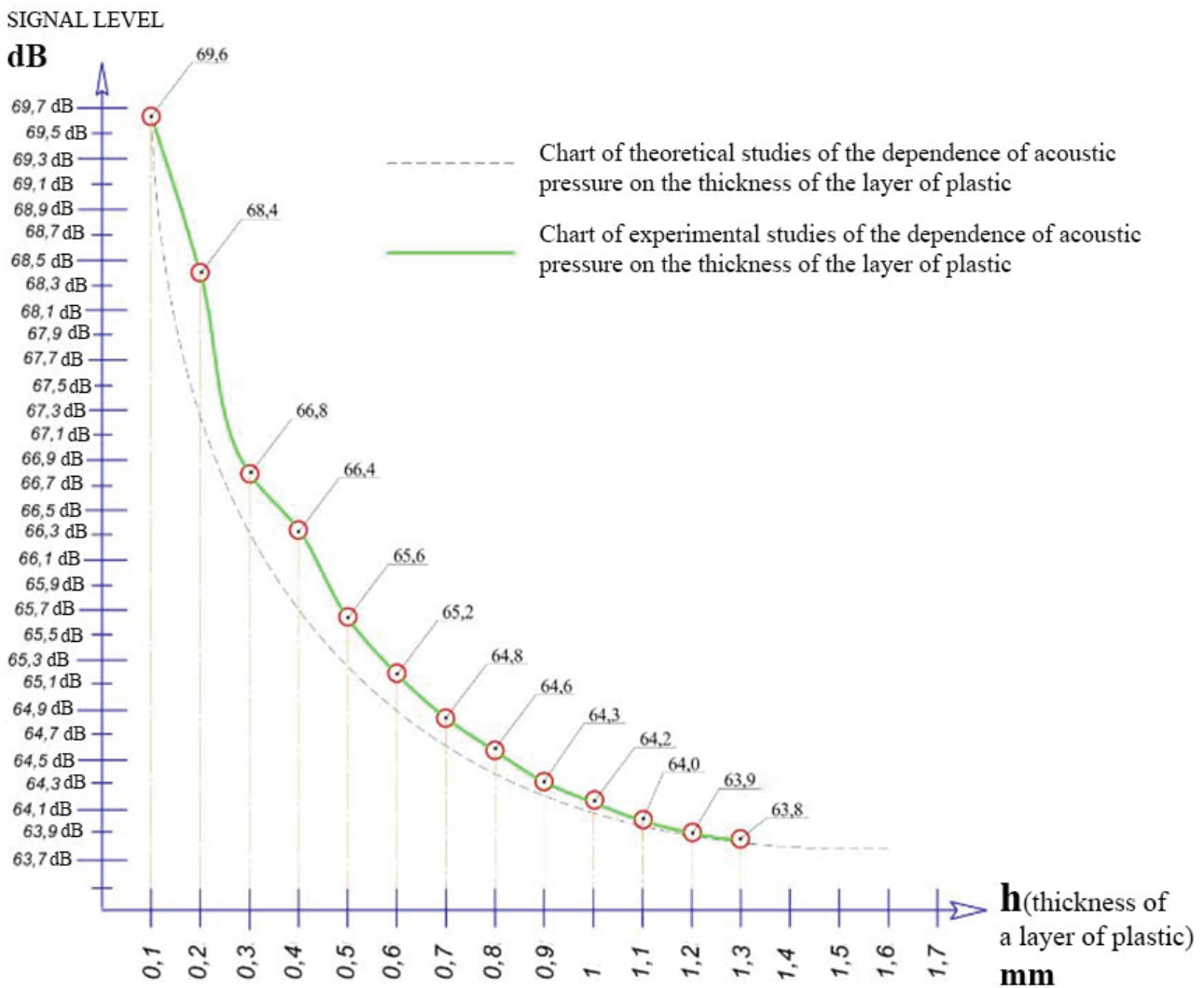

Fig. 5. Diagram of experimental studies of the acoustic pressure's dependence on the thickness of the plastic layer applied to a metal platform using 3D printing, with the 59 mm thick metal base it is applied on.
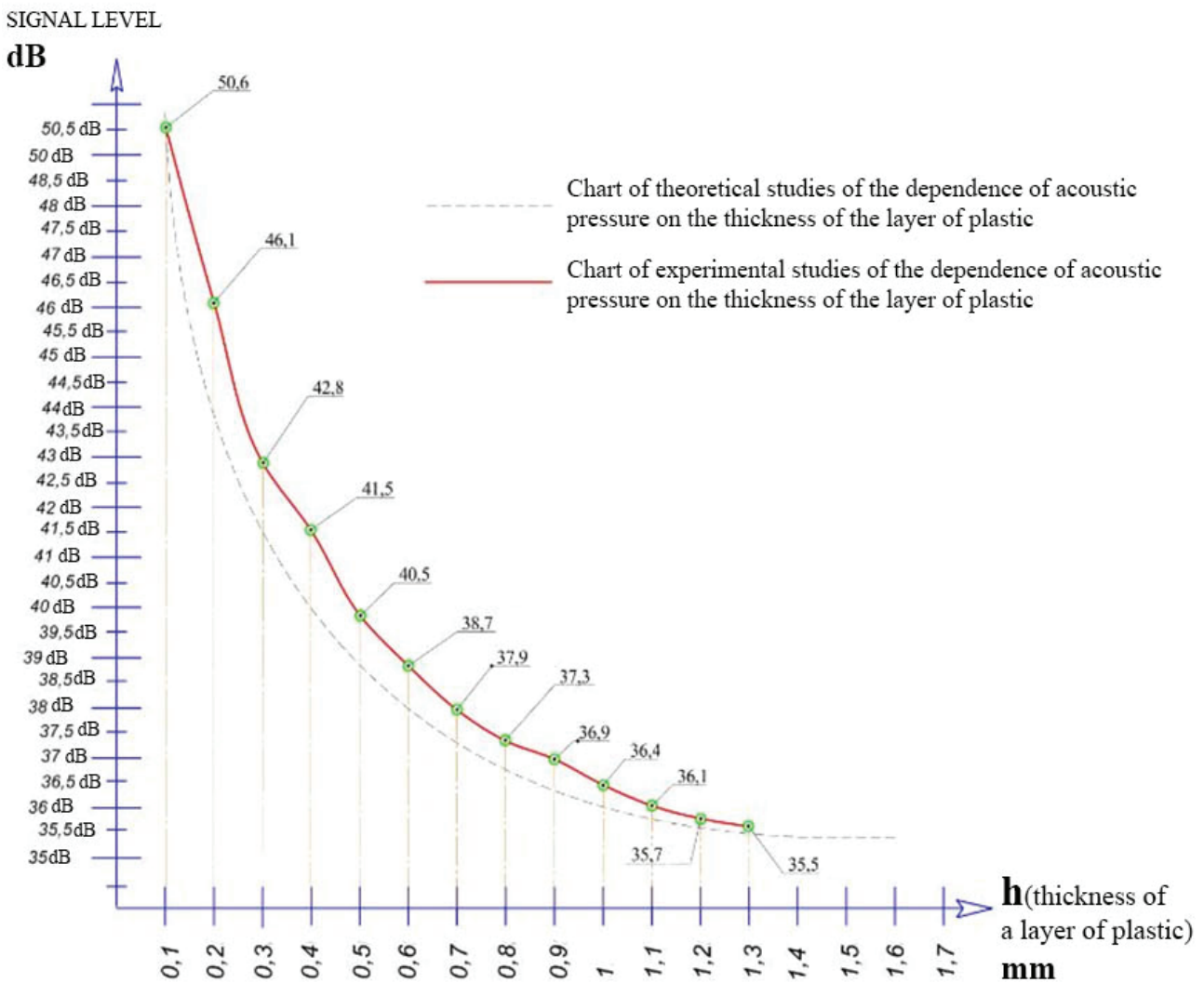
Fig. 6. Diagram of experimental studies of the acoustic pressure's dependence on the thickness of the plastic layer applied to a metal platform using 3D printing, with the 29 mm thick metal base it is applied on.

Summary

The effect of the thickness of the plastic layer applied to a metal platform using 3D printing on the acoustic parameters of the EMA transducer is studied using mathematical modelling.

Dependences showing the effect of the thickness of the plastic layer applied to the metal platform using 3D printing on the created acoustic pressure are obtained experimentally. The maximum acoustic pressure is created when there is no thickness of the plastic layer applied to the metal platform using 3D printing. The pressure drops sharply, as the layer thickness increases.

Good convergence of the outcome of theoretical and experimental studies is demonstrated, with the approximation error of experimentally obtained data generally not exceeding 5%.

The study is based on a widely proven approach to analyzing the process of acoustic wave formation by an EMA transducer. The reliability of the results obtained is confirmed by the correct use of the mathematical tools and good convergence of the outcome of theoretical and experimental studies.

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КОНТРОЛЬ ТОВЩИНИ ШАРУ ПЛАСТИКУ НАНЕСЕНОГО ЗА ДОПОМОГОЮ 3Д ДРУКУ ЕЛЕКТРОМАГНІТНО-АКУСТИЧНИМ МЕТОДОМ

Проблематика: В даний час ЕМА метод не застосовується для контролю товщини шару пластику нанесеного на металеву платформу за допомогою 3Д друку, що істотно обмежує області його використання. Разом з тим, широко використовуються ЕМА дефектоскопи, для контролю якості самої металевої платформи. Рішення поставленої задачі дослідження випромінювання дозволить проводити комплексний контроль товщини шару пластику нанесеного за допомогою 3Д друку, що підвищити ефективність ультразвукової дефектоскопії по достовірності і швидкості проведення робіт.

Мета дослідження: У даній статті розглядається можливість визначення товщини шару нанесеного за допомогою 3Д друку використовуючи електромагнітно-акустичний (ЕМА) метод.

Методика реалізації : Проведено аналіз залежності між товщиною шару пластику нанесеного за допомогою 3Д друку на акустичним тиском створюваний в ньому під час контролю з використанням ЕМА перетворювачів. За допомогою математичного моделювання досліджено вплив товщини шару пластику нанесеного на металеву платформу за допомогою 3Д друку на акустичні параметри ЕМА перетворювача. Експериментально отримані залежності, що показують вплив товщини шару нанесеного за допомогою 3Д друку на створюваний акустичний тиск.

Результати дослідження. За допомогою математичного моделювання досліджено вплив товщині шару пластику нанесеного на металеву платформу за допомогою 3Д друку на акустичні параметри ЕМА перетворювача.

Експериментально отримані залежності, що показують вплив товщині шару пластику нанесеного на металеву платформу за допомогою 3Д друку на створюваний акустичний тиск. Максимальний акустичний тиск створюється при відсутності товщині шару пластику нанесеного на металеву платформу за допомогою 3Д друку. Зі збільшенням товщини шару тиск різко падає.

Висновки: Показана хороша збіжність результатів теоретичних і експериментальних досліджень, похибка апроксимації експериментально отриманих даних в основному не перевищує 5%.

В основу досліджень покладений широко апробований підхід до аналізу процесу формування акустичної хвилі ЕМА перетворювачем. Вірогідність отриманих результатів підтверджується коректним використанням математичного апарата й гарною збіжністю результатів теоретичних і експериментальних досліджень.

Подальші дослідження планується проводити в напрямку дослідження впливу акустичних параметрів елктромагнітно-акустичного перетворювача на якість шару пластику нанесеного на металеву платформу за допомогою 3Д друку.

Ключові слова: ЕМА, перетворювач, 3д, друг, шар, пластик, товщина, акустичний тиск, неруйнівний контроль.