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ANALYSIS ELECTRODYNAMIC PROCESSES IN INDUCTION INDUCTOR SYSTEM WITH NONFERROMAGNETIC SCREEN WITH USE OF MAGNETIC PULSE TECHNOLOGY

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Abstract. *The theoretical study of cylindrical induction inductor system and the analysis of the radial density distribution of the induced currents, the Lorentz force, Ampere force and the force due to the magnetic properties of the workpiece in the system studied are presented.*

Keywords: *induction inductor system, magnetic pulsed technology.*

АНАЛИЗ ЭЛЕКТРОДИНАМИЧЕСКИХ ПРОЦЕССОВ В ИНДУКЦИОННОЙ ИНДУКТОРНОЙ СИСТЕМЕ С НЕФЕРРОМАГНИТНЫМ ЭКРАНОМ ПРИ ИСПОЛЬЗОВАНИИ МАГНИТНО-ИМПУЛЬСНЫХ ТЕХНОЛОГИЙ

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Аннотация. *Представлено теоретическое исследование цилиндрической индукционной индукторной системы и анализ радиального распределения плотности индуцированных токов, силы Лоренца, силы Ампера и силы, обусловленной магнитными свойствами заготовки в исследуемой системе.*

Ключевые слова: *индукционная индукторная система, магнитно-импульсные технологии.*

АНАЛІЗ ЕЛЕКТРОДИНАМІЧНИХ ПРОЦЕСІВ В ІНДУКЦІЙНІЙ ІНДУКТОРНІЙ СИСТЕМІ З НЕФЕРОМАГНІТНИМ ЕКРАНОМ ПРИ ВИКОРИСТАННІ МАГНІТНО-ІМПУЛЬСНИХ ТЕХНОЛОГІЙ

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Анотація. *Представлено теоретичне дослідження циліндричної індукційної індукторної системи та аналіз радіального розподілу щільності індукованих струмів, сили Лоренца, сили Ампера і сили, зумовленої магнітними властивостями заготовки в досліджуваній системі.*

Ключові слова: *індукційна індукторна система, магнітно-імпульсні технології.*

Introduction

Electromagnetic forming is an impulse or high speed forming technology, which uses pulsed magnetic fields to apply forces to tubular or sheet metal workpieces, made of a material of high electrical conductivity. The force application is contact free and no working medium is required. The principle is based on physical effects described by Maxwell (1873). Maxwell explained that a temporarily varying magnetic field induces electrical currents in nearby conductors and additionally exerts forces (the so-called Lorentz forces) to these conductors. Northrup (1907) reported accordingly that “in passing a relatively large alternating current through an non-electrolytic, liquid conductor contained on a trough, that the liquid contracted in cross section and flowed up hill lengthwise of the trough, climbing up upon the electrodes" was observed. With increasing current a contraction of the cross section and a depression in the liquid was found.

The first one who generated magnetic field strengths which were sufficient to deform solid conductors was Kapitza (1924). Thus, he Corresponding author provided the foundation for the electromagnetic forming process. However, the earliest work on technologically exploiting this principle for a target oriented forming of metals began in the 1950s with the patent of Harvey and Brower (1958). A more detailed description including examples of applications is given in Brower (1969).

In theory and practice of the magnetic-pulse treatment of metals (MPTM), one of the most important issues is to the study tools of pulsed magnetic effects – various inductor systems. A special place is occupied by the so-called induction inductor systems [1, 2]. Studies of an induction inductor system with a massive support screen which is located in parallel with a thin walled non-ferromagnetic sheet work-piece in the low-frequency mode of magnetic fields were performed in [1].

The purpose of a massive conducting screen, is to create conditions for the manifestation of Ampere law, i.e. to create conditions for the work-piece parts to gravitate towards the body in its working area.

The aim of this paper is the theoretical study of a cylindrical inductive inductor system and the analysis of the radial density distribution of induced currents, Lorentz force, Ampere force and power due to the magnetic properties of the work piece in the system studied.

We consider the induction system with a single-turn inductor cylindrical solenoid, a massive non-ferromagnetic conductive screen and a thin walled ferromagnetic sheet work-piece in the low frequency mode of the live magnetic fields.

In previous studies the ratio to calculate the basic characteristics of the processes occurring in the system, was received.

The source of power is magnetic pulse installation MIU-15(МИУ-15) has performance as follows: storage capacity *C=1000mkF*, operating frequency *f=1kHz*, the relative decrement δ_0=0,2(amplitude of current in the inductor is *19.61 kA* when capacitor stored energy is *12,5 kJ*).

The field source is a flat single-turn cylindrical coil a massive auxiliary screen and storage are made of electrical steel with the conductivity of $0{,}2\cdot10^7$ *1/Om·m*, workpiece has flat metallic sheet thickness *d=0,001m*. The distance between the working surfaces of the screen and the workpieces is *h=0,002 m*.

The graphical dependences of the radial density distribution of the induced current were built on the data obtained. After having analysed the results, we can do the next conclusion:
• distribution of the induced current on the radius is almost independent of the magnetic permeability of a metal sheet;
• the heterogeneity of distribution on the thickness of the sheet increases with increasing magnetic permeability;
• physical, growth of the heterogeneity distribution of the induced current over the thickness can be attributed to the normal component of the magnetic field in a metal work-piece;
• the amplitude of induced current increases with increasing magnetic permeability.

The force, whose nature is conditioned by the interaction of the induced current and magnetic field is known as Lorentz force [2]. In addition to the tangential component and the normal component of the magnetic field vector appears takes the significance. In a metal sheet workpiece the force vector with a normal and tangential component is excited.

Normal component corresponds to the strength of the magnetic pressure which ensures the success of the actual magnetic-pulse treatment of metals in the regime of an abrupt surface effect, the tangential one is acting in the radial direction. In this case, the tangential forces which are multiplied by the shoulder of the normal strain should initiate rotating mechanical moments.

The forces of gravity in this induction inductor system is the force of gravity sheet workpiece due to the action of the auxiliary screen (the mutual attraction of the conductors with the same direction induced currents - Ampere law), and the force of gravity due to the magnetic properties of the metal workpiece per ce. The analytical data are used to build the radial dependence forces.

Thus the influence of the magnetic properties of a workpiece is manifested in the of forces of magnetic gravitation. This fact suggests that the influence of the magnetic properties of the workpiece is unimportant, but the magnetic pulse treatment of metal with magnetic properties will be more effective than non-ferromagnetic. The more is metal magnetic permeability, the more effective is its treatment.

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