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MAGNETIC PULSED PROCESSING OF METALS FOR ADVANCED TECHNOLOGIES OF MODERNITY – A BRIEF REVIEW

The aim of the article is dedicated to the brief review of the main achievements of the advanced technologies with usage of the energy of the pulsed magnetic fields. Originality. The new suggestions are represented. They are based on the results of development of the new scientific direction in area of the magnetic pulsed processing of thin-walled sheet metals when a penetration of the acting fields is quite significant. The known traditional approaches based on the skin-effect in electro-dynamics and were successfully implemented. Methodology of the analysis consist of careful theoretical and practical experiments review and its future development. Results of the research based on the existing experimental approbation were presented visually with the description followed The known approaches to solution actual production problems based on the skin-effect in electro-dynamics are described. Practical value. The first of practical propositions is related to stamping of the drawing the printed circuit boards on the cooper foil with thickness about ~50 mkm. This operation is realizing by the forces of magnetic pressure directly without any supplements introduction. The second consists in usage the magnetic pulsed attraction for external removing the dents in the car body. This operation does not demand disassembling of elemental base and allows preserving the paint of coverings. Both of these technologies could to minimize the working time, to decries the volume of the waste products and to make the manufacturing existed much cheaper. References 10, figures 3.

Key words: magnetic pulsed processing, metal forming, printed circuit boards stamping, external flattening.

Работа посвящена краткому обзору основных достижений передовых технологий с использованием энергии импульсных магнитных полей. Описаны известные традиционные подходы, основанные на скин-эффекта в электродинамике и были успешно реализованы. Представлены новые предложения, основанные на результатах развития нового научного направления в области магнитно-импульсной обработке тонкостенных листовых металлов, когда проникновение действующих полей весьма существенно. Первое из этих предложений связано с оттиском рисунка печатных плат на медной фольге толщиной около ~ 50 мкм. Эта операция реализуется силами магнитного давления непосредственно. Второе предложение заключается в использовании магнитного импульсного притяжения для внешнего удаления вмятин в кузове автомобиля. Эта операция не требует демонтажа элементной базы и позволяет сохранить краску покрытий. Библ. 10, рис. 3.

Ключевые слова: магнитно-импульсная обработка, обработка металлов, оттиск печатных плат, внешняя рихтовка.

Introduction and publications analysis.

The ecology, economy of resources and energy are the most sharp problems among the main problems of modernity. Discussion of what is the first one, what is the second one, and what is the third one has no sense. The different viewpoints may consider these problems, as they want. The main thing is in answers for questions: where energy and material resources can be taken, and how to preserve our environment for the next generations?

Solving these problems will define the future of the all Humanity.

The practical usage of energy of the pulsed electromagnetic fields (in the other terminology this is the «Electromagnetic Metal Forming» – «EMF») opens exclusive perspectives for creation of advanced technologies for processing of the materials of any physical nature. They have the doubtless advantages, among which there are ecological purity, low energy consumption, economic expenditure of the material resources, at last, high speed of the manufacture process.

A scientific technical information about the magnetic pulsed metal working (EMF) appeared beginning in the fifties year's end of the last century. First magnetic pulsed equipment for processing the tubular objects was demonstrated by «General Dynamics Corp» in Geneva at the Nuclear Energy Peaceful Usage Exhibition in 1958.

The intensive development of the magnetic pulsed technologies was continued till beginning of eighties approximately. The next fifteen - twenty years may be characterized by decreasing of the interest to the processing field methods. There were many different technical and

social obstacles. They are not interesting and should not be announced. But at the beginning of 2000th the magnetic pulsed processing technologies are again attracting attention of the industrial manufacture. The quantity of the science-practical publications essentially increases. They are devoted to elaboration and practical usage of the magnetic pulsed technologies in different branches of industrial manufacture in USA, Germany, France, Sweden etc. There are many reasons of the increasing interest to the magnetic pulsed methods. The new alloys appeared. They had some unique properties which may be displayed in the pulsed action only. For example, hyper-plasticity property was among them, when the relative deformations may reach ~200 %.

For the time being worsening of the natural conditions for the Humanity is one of reason of the high interest to the magnetic pulsed technologies. The world public is worried by exhausting of the natural resources, by pollution and poisoning of the Planet Earth. The Humanity owns by the known high productive technologies in the different areas of activity. But increasing of the work productivity becomes not a main problem of the Science Technical Progress. The ECOLOGY, RESOURCES and ENERGY SAVING are becoming by the main problems.

There are many European and American publications of the different authors devoted to the description of magnetic pulsed working metals, for example [1]. But the most of them are not acquainted with achievements of the former soviet schools (in the main question is about the Russian language scientific literature!) which was one of

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the first in this area of the SCIENTIFIC TECHNICAL PROGRESS [2]. That is why the main attention of this article will be concentrated on the publications of the scientists from former Soviet Union.

Purpose of the article is to make a brief review of the main achievements of the advanced technologies with usage of the energy of the pulsed magnetic fields.

Main equipment for the magnetic pulsed metal processing. The distinguishing particularity of the methods of the field action is an absence of any immediate contacts with processed object. The practical sense of this particularity becomes obvious, for example, in comparison the mechanical processing and electromagnetic stamping. The electromagnetic stamping is being realized without any puncheon (striking element!). The pressure forces are appearing during interaction of the field with metal of the conducting work-piece. Nevertheless, as it is in mechanics for the technological operation realization the two main components are necessary. These are a source of energy and the tool. The energy source is a system of the high voltage. In the special technical literature it was named «THE MAGNETIC PULSED INSTALLATION». The tool is a complex consisting of the generator of the field which is named «INDUCTOR» and a processed work-piece. In the whole, the present complex is the INDUCTOR SYSTEM.

Should mark if the energy source (the Magnetic Pulsed Installation!) is an universal element of equipment in different production operations, but the tool of the method has to be created for implementation of a particular manufacturing operation only. Thus, the MAGNETIC PULSED INSTALLATION plus the INDUCTOR SYSTEM are the necessary components of the technical equipment for the metal working with help of the energy of the pulsed magnetic fields [3](see Fig. 1).

Some implemented and new advanced technologies. First of all a brief information about the traditional implemented magnetic pulsed technologies should be given [1-3].

In the special literature there is some general adopted classification of the technological operations. It defines belonging to three of the possible scheme of their practical realization.

The first group unites the manufacturing processes, which are being fulfilled according to scheme what was named as «COMPRESSION». The magnetic pressure forces are directed to a system axis. They are working for compression.

The second group includes the production operations which were named «EXPANSION» according to the type of deformation of the work-pieces. In this case the INDUCTOR (tool!) was placed in inner cavity of the work-piece. The magnetic pressure forces are directed from the system axis. They are working for expansion.

The third group of operations is realized according to scheme what was named as «FLAT SHEET STAMPING». In this case the inductor and work-piece are the parallel flat objects divided by insulating inserts. The magnetic pressure forces are directed from inductor to work-piece. They are working for repelling. The last remark demands more precision. The last experiments showed that under decreasing of frequencies of the acting

magnetic fields the pressure forces are changing their direction. They are working for attraction the sheet work-piece to inductor. For the first time this phenomenon was displayed and described by scientists of the National Technical University «Kharkiv Polytechnic Institute» Professors Yu.V. Batygin, V.I. Lavinsky and L.T. Khimenko for a flat variant of the INDUCTOR SYSTEM. It may be suggested this phenomenon would appear and in a case of the known cylindrical constructions of the tools under some fixed conditions too. But should mark that it is hypothesis only. A final conclusion demands its experimental confirmation.

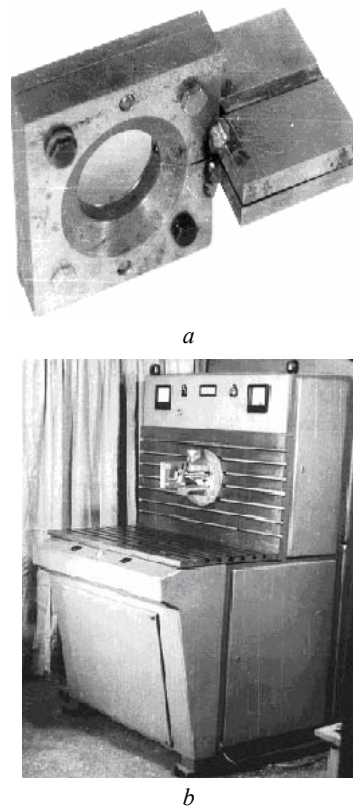


Fig. 1. The technical equipment created in the National Technical University «Kharkiv Polytechnic Institute» (Ukraine) for processing of the tubular work-pieces: a) it is the massive single turn INDUCTOR; b) it is the MAGNETIC PULSED INSTALLATION MIU-24 (the stored energy is ~ 24 kJ)

The given classification is general one. In its turn each of the distinguished schemes may be divided by sub-groups with more detailed any separate properties. All magnetic pulsed schemes which were pointed out above allow fulfilling not only different assemblage and separation in the production operations. The cold welding, all necessary and possible combinations of the schemes which were distinguished have to be mentioned too.

For example, the known compression of the cable tips is a clear illustration of the effective assemblage. A wire is being put into a cavity tip of the body. Then the body is being compressed by the magnetic pressure. Identically, not only cable tips for electrical engineering elements but also the tips onto flexible hoses, ropes etc. can be compressed by this way too. A quality of this connection is very high. Its strength till destruction, is not lower than analogical index for the material of the cable, rope, wire, as a rule.

The schemes of «compression» or «expansion» allow realizing the strength connections of the metal details with elements of glass, ceramics and other non-metal materials. Connection of metal with a non-metal by the magnetic pulsed action provides a high density and reliability of the connection, increasing the working exploitation characteristics in many cases.

All above enumerated the magnetic pulsed schemes of force action allow realizing the cold welding of not only the identical metals but also different ones (aluminum-cooper, aluminum-steel, cooper-steel etc.). For qualitative welded connection of the work-pieces their speeds of the movement in the opposite directions must have maximum values. In this case a mixed boundary layer of the metals is appearing during their clash at the expense of the inertial effects.

Some production operations for quite big areas on the flat metal sheets have to be distinguished particularly. Usually they are being fulfilled in accordance with scheme of the «flat sheet stamping». The most successful among them are forming of membranes, stamping of the automobile and airplane components, the pictures and inscriptions minting. These operations characterize possibilities of the magnetic pulsed action for processing of the quite large-scale articles of the ordered shape. In dependence on the energy-capacity of equipment a dimension of the processed area may be increased to $\sim 0.2 \text{ m}^2$.

Finishing description of the typical and successful magnetic pulsed technologies, should point out that all adduced examples had been implemented practically for the metals with high value of the specific electrical conductivity. The processing is being fulfilled under condition of the skin-effect regime when the field penetration processes through the work-piece are not essential and they do not decrease the magnetic pressure forces.

The scheme of the traditional magnetic pulsed processing demands some supplements to design of the tool when the question is about deformation of the bad conductors or enough thin metal objects.

The most effective supplement in the inductor systems turned out usage of the «sputniks» together with elastic transmitting inserts. This solution suggests placement (for any scheme of the magnetic pulsed action!) by layers: the inductor - the good conductor (it is the «sputnik»!) - the elastic insert which is transmitting the force action on the object of processing. The magnetic pressure is acting on the well conducting «sputnik». This pressure is being transmitted on the work-piece through elastic insert. Usually, the «sputnik» is made from a cooper. Some special sorts of rubber are being used as transmitting inserts. As well, some liquids may be used for this goal.

The usage of «sputniks» at the radio manufacture allows successful to fulfill some production operations for stamping small flat details and to print quite complicated picture on the cooper foil for fixing of different components of radio apparatus.

In spite of successful usage «sputniks» for solving many production problems this technical solution essentially decreases effectiveness of the process deforming and excludes the non-contact force action on the work-

piece what is the main advantage of the magnetic pulsed metal processing.

Unlike the known methods of processing massive conductors in the skin-effect regime the qualitatively new direction in the magnetic pulsed working of metals provides the intensive non-contact force action on thin-walled metal objects (practically, the «transparent» for magnetic fields!) was founded and was formulated in the works of scientists of the National Technical University «Kharkiv Polytechnic Institute» at beginning of the last century. Its physical essence consists in creation of the demanded spatio-temporal distribution of the acting magnetic field in the metal work-piece [3, 4].

The investigations of processes of the force interaction between the pulse magnetic fields and thin-walled («transparent» for acting fields!) conductors led to the patented technical solutions for designs of the inductor system which permit the practical realizing the most important production operations in the modern industrial manufacture.

The new progressive technology of the magnetic pulsed stamping the printed circuit boards for the electrical engineering devices was suggested for the first time. This operation for stamping of the conducting drawing in the charging-rectifying device of the micro-calculators «Electronics» was tested experimentally. The positive results were got. The experimental specimens are represented on Fig. 2.

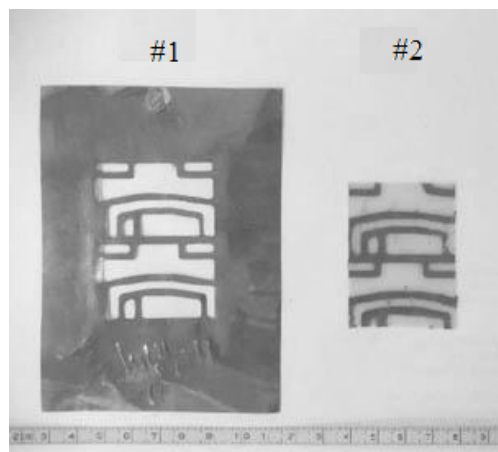


Fig. 2. The experimental specimens of the printed circuit boards conducting elements which were stamped in the cooper foil with thickness $\sim 50 \text{ mkm}$ by the magnetic pulsed pressure:

- #1 – it is the drawing in the cooper foil;
- #2 – it is the ready-made printed circuit board

The principle action of the inductor system was based on the phenomenon in the electrodynamics. Its essence consists in what the packet of the flat electromagnetic waves does not penetrate practically through thin-walled conductive screens into the free space. Technically, this phenomenon is being realized with help of the inductor system where a drawing in a foil sheet has to be stamped with help of a dielectric die.

Should mark what the practical usage of the suggested inductor systems is not limited by stamping of printed circuit boards from the cooper foil only. The accepted principle action permits realizing the effective magnetic pressure on the thin-walled objects from the

wide class of metals with different electrophysical and mechanical characteristics.

Continuing discussion of processing the thin-walled metals should particularly distinguish a clear example of new usage of the electromagnetic energy under low frequencies of the acting fields. A question is about a practical realization of the magnetic pulsed attraction of the sheet work-pieces under excitation of the electrodynamic forces.

For the first time at 2004 the scientists from the National Technical University «Kharkiv Polytechnic Institute» (Professors Yu.V. Batygin, V.I. Lavinsky, L.T. Khimenko) had watched an interesting phenomenon. The question is about the force action of the pulsed magnetic fields with enough low working frequencies on the steel specimens. As it followed from experiments, decreasing of the frequency till a definite limit was leading to the work-piece attraction in direction to the working surface of the single turn inductor-tool. The question is about the deforming and pulling out of a part of the sheet metal [5].

A practical application of the displayed effect may be an operation for the dent removing on the body car without any mechanical contacts with it and without possible damages of their outer painted coats. Should mark the more deep sense of this direction of the magnetic pulsed working metals. It consists in essential widening of possibilities of the force action with help of the energy of the electromagnetic fields. A combination of the magnetic pulsed repelling and the magnetic pulsed attracting can give absolutely new solutions for creating absolutely new flexible progressive technologies of the future.

Let us stop on the attraction for the dent removing. For the time being some positive results have a place here already. Some experimental results could be illuminated more in detail [6, 7].

Many technical solutions for the outer magnetic pulsed flattening of the airplane are known long ago. The most practical and interesting suggestions in this area are belonged to the American engineers from the «Boeing», «ElectroImpact» and «Fluxtronic». As it follows from their publications the attraction could be realized with help of a single turn inductor with two pulsed currents of the different frequencies [8, 9].

Should mark the suggestion of the magnetic pulsed attraction with help of superposition of «slow» and «quick» magnetic fields had been discussed in the works of the former soviet scientists too [3].

The physical essence of these both suggestions is identical. Eventually they are based on superposition of the magnetic fields with low and high frequencies which are excited in the inductor system.

The technical level of these ideas for practical realization is approximately identical too. According to these suggestions the real devices for the magnetic pulsed attraction of the sheet metals must have two synchronized power sources, the high-voltage and high-current electronics for the complicated controlling systems, etc. All these factors are the reasons of a high cost and of low reliability what decreases essentially a practical significance of these elaborations.

The practical usage of the displayed effect of the steel sheets attraction by the forces of the low-frequency

magnetic fields opens new possibilities for creating enough simple, reliable and relatively cheap devices for the magnetic pulsed flattening the sheet metals.

These devices must have the evident advantages.

Among them the following positions may be distinguished particularly.

- Any mechanical contacts with a processed surface are absent, the magnetic pulsed forces are acting.
- The list of the processed metals (steel and its different alloys which are being used in the auto branch of the manufacture) is quite wide.
- Flattening is being realized from the outer side of the body car without any disassembling what is sure necessary in the traditional technologies.
- The possible preserving of the outer coating (without any damages!) on the surface being worked.
- There is possibility of the damaged element restoration till the initial state with preserving the existing coating.

The experimental model of the inductor system allowing to excite the magnetic pulsed attracting forces was elaborated, made and tested in the real conditions for different specimens of the sheet steels.

The single turn inductor was connected to output of the magnetic pulsed installation (power source) with energy stored ~4.5 kJ.

Creating and removing the dents in the different parts of the metal sheet were fulfilled. One of them will be removed but other dent will stay for comparison.

The first operation was dedicated to creating the dents with help of the attraction forces. Two dents with half-sphere shape with diameter about ~ 0.03 m and depth about ~ 0.002 m were pulled from the steel sheets after eight repetitions of the force action.

The next experiment was dedicated to removing of one of the before created dents on the sheet surface with help of the attraction forces too. This specimen was placed on the flat insulated surface of the inductor so that the interior of existing dent turned out opposite the inner hole of the inductor. Removing the dent was produced by the same way as it was created by the magnetic pulsed attraction.

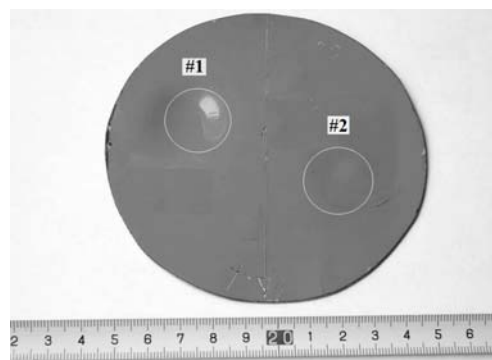


Fig. 3. The experimental specimen from the sheet steel of the body car «Mitsubishi» with the painted covering: #1 – is the dent got by the magnetic pulsed attraction from the assigned part of the experimental sheet specimen, #2 – is the part of the experimental sheet specimen with removed dent

After five repetitions the dent had been practically removed. The surface of the sheet, where it was, had

become quite smooth. The subsequent magnetic pulsed attraction would lead to appearance of a new dent with opposite curvature in relation to the initial.

The experimental specimen with initial and removed dents is shown on Fig. 3.

The main results of the conducted experiments are the following.

- The energy of the force action what is necessary for the dent removing is essentially smaller what is necessary for the dents creating on the smooth surface.
- In fulfilling production operations of the magnetic pulsed attraction the repetition stability of the got results was marked. This fact testifies about reliability of the tested method for the practical application. For example, it could be external flattening of a damaged body car.

Ending a description of the conducted experiments should mark that the magnetic pulsed attraction with help of the presented equipment may be realized for the ferromagnetic steels only.

Besides should point out that the practical achievement not only for steels but and suggestions for non-magnetic metals are represented on Web Site of Laboratory of the Electromagnetic Technologies (Kharkiv National Automobile & Highway University, Ukraine) [10].

Conclusions.

The conducted review is briefly illuminating the main achievements of the advanced technologies with usage of the energy of the pulsed magnetic fields.

1. The known approaches to solution actual production problems based on the skin-effect in electrodynamics are described. They were demonstrated their effectiveness in many cases of the practical approbation and were implemented in different branches of the industrial manufacture.

2. The new suggestions of the magnetic pulsed force action are represented.

They are based on the results of development of the new scientific direction in area of the magnetic pulsed processing thin-walled sheet metals when a penetration of the acting fields is quite significant. The first of these suggestions is related to stamping of the drawing the printed circuit boards on the cooper foil with thickness about 50mkm. The second suggestion consists in usage the magnetic pulsed attraction for external removing the dents in the car body. The operation does not demand disassembling of elemental base. As well the paint of coverings may be preserved.

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