АВТОТРАНСПОРТНЫЕ СРЕДСТВА

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DISK MATCHING DEVICES FOR METHODS OF EXTERIOR LEVELLING OF CAR BODY PANELS

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Abstract. *The basic equipment of the given methods consists of the power source, the levelling tool and the matching device for exterior levelling methods of car body panels is presented in the paper. Using the obtained analytical expressions, the numerical estimations of the basic characteristics of the considered matching device have been plotted. The schematic solution as to technical realization of the disc matching device is proposed. The experimental approbation of the elaborated tool of the exterior magnetic and pulse levelling has been carried out.*

Key words: *straightening, removing dents, body repair, matching device.*

УЗГОДЖУВАЛЬНІ ПРИСТРОЇ ДИСКОВОГО ТИПУ ДЛЯ МЕТОДІВ ЗОВНІШНЬОГО РИХТУВАННЯ КУЗОВНИХ ПАНЕЛЕЙ АВТОМОБІЛІВ

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Анотація. *Проведено аналіз електромагнітних процесів і чисельні оцінки характеристик узгоджувального пристрою дискового типу. Побудовано графічні залежності радіального розподілу індукованих струмів узгоджувального пристрою, запропоновано схемне рішення для його технічної реалізації і проведено його експериментальну апробацію.*

Ключові слова: *рихтування, видалення вм'ятин, кузовний ремонт, узгоджувальний пристрій.*

СОГЛАСУЮЩИЕ УСТРОЙСТВА ДИСКОВОГО ТИПА ДЛЯ МЕТОДОВ ВНЕШНЕЙ РИХТОВКИ КУЗОВНЫХ ПАНЕЛЕЙ АВТОМОБИЛЕЙ

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Аннотация. *Проведены анализ электромагнитных процессов и численные оценки характеристик согласующего устройства дискового типа. Построены графические зависимости радиального распределения индуцированных токов согласующего устройства, предложено схемное решение для его технической реализации и проведена его экспериментальная апробация.*

Ключевые слова: *рихтовка, удаление вмятин, кузовной ремонт, согласующее устройство.*

Introduction

At present of special interest are methods of reconditioning and repair of car body panels which make it possible to perform so-called the exterior levelling without dismantling of body elements and disturbance of the existing protective paint coating [1, 2].

Analysis of publications

The greatest promise of them are magnetic and pulse methods based on energy application of pulse magnetic fields [3–7]. The basic equipment of the given methods consists of magnetic and pulse plant (MPP) – the power source, the inductor system (IS) – the levelling tool and the pulse step-up current transformer – the matching device (MD). The last-mentioned matches the MPP with the tool by inductive load which allows levelling operation to be performed effectively [3, 4]. Fundamentally, the MD is the step-up current transformer which makes it possible to change the current amplitude in the IS and vary values of the operating frequency of working fields [8].

Developments of powerful tools for magnetic and pulse attraction of sheet metals were initiated by increase in demand to production operations by body coating levelling of cars and aeroplane frames [3-7]. Levelling process efficiency depends on value of current and its parameters (amplitude value, frequency, discharge pulse form) in the tool – the inductor system. Consequently, problems, connected with the attainment of necessary parameters of the discharge current pulse in the inductor system are rather urgent and one of ways of their solution is to bring into the equipment exterior magnetic and pulse levelling methods of different hardware components – the MD [9].

Purpose and problem statement

Analysis of electromagnetic processes in the disk matching device for methods of exterior levelling of car body panels. The development and suggestion of schematic designs as to technical realization of the disk matching device as a tool of exterior magnetic and pulse levelling. The experimental approbation of the development tool of exterior magnetic and pulse levelling.

Design model of the disc matching device

One of a variation of a possible practical MD construction is a structure which consist of the massive metal disk with the radial sectional view (the secondary winding), on one the side of which the multiturn coil (the primary winding) is located. The primary winding is connected up to the MPP lead. The inductor system is connected up to the secondary winding in the field of the radial section. Schematically, the MD with the connected IS is shown on the block diagram of the magnetic and pulse levelling complex (fig. 1) [3, 9].

For an analysis of electromagnetic processes in the disk MD and calculation of its basic characteristics, we set a design physical and mathematical model in the cylinder coordinate system shown on fig. 2 [8, 10–12].

We perform calculation by the use of integration equation methods of mathematical physics-classical methods of boundary-value problem solution of electrodynamics [8, 12, 13].

Without dwelling on the deduction of calculation relationships the final expression for the induced current density in metal of the secondary winding may be written as

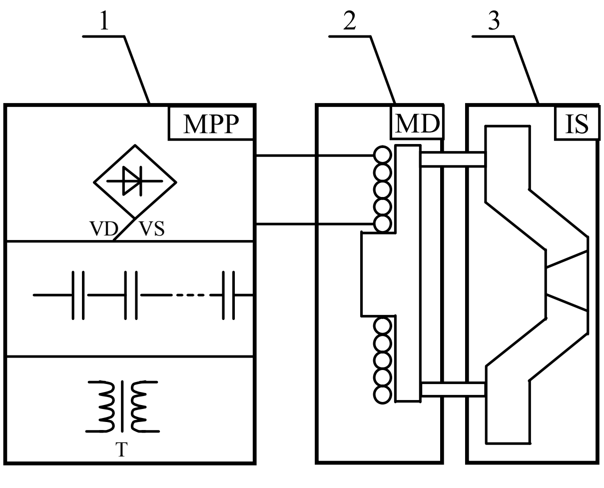
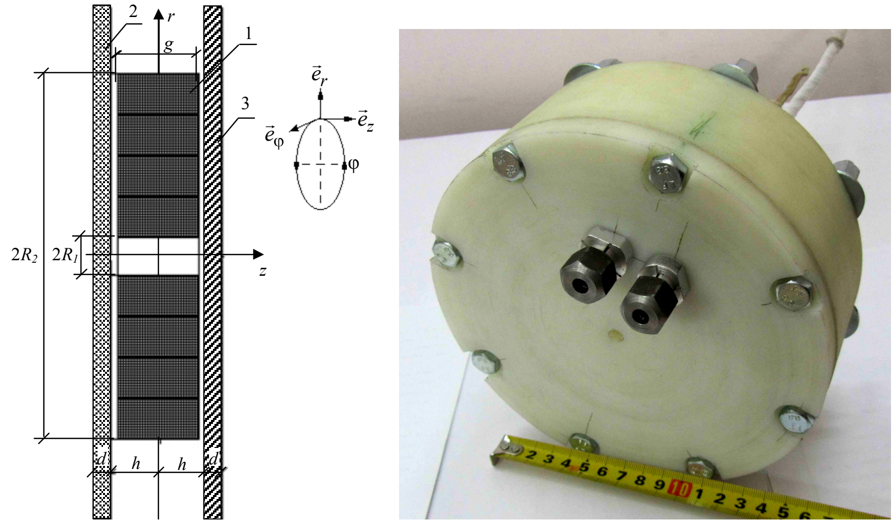


Fig. 1. Block diagram example: 1 – magnetic and pulse plant; 2 – matching device; 3 – inductor system



a b

Fig. 2. Plane disk matching device: a – design model; b – physical model; 1 – primary winding, plane multiturn solenoid; 2, 3 – secondary winding, conducting disks; $\vec{e}_r, \vec{e}_\varphi, \vec{e}_z$ – guide unit vectors of the cylinder coordinate system

$$j_\varphi(z,r,\varphi)=\frac{2I_m}{d}\int_0^\infty f(x)e^{-x\frac{h}{d}}xJ_1\left(x\frac{r}{d}\right)\times \left(\sum_{k=0}^{\infty}\frac{\beta_k F_{1k}((\mu_r\cdot x),\zeta)}{\Phi_k(\mu_r\cdot x)}f_{1k}(x,\varphi)\right)dx, \quad (1)$$

where $f(x)=\frac{1}{x^2}\cdot\int_{(x\cdot R_1/d)}^{(x\cdot R_2/d)} y\cdot J_1(y)\cdot dy$;

$F_{1k}\left((\mu_r\cdot x),\zeta\right)=(\mu_r x)\cdot\sin\left(\beta_k(1-\zeta)\right)+ +\beta_k\cdot\cos\left(\beta_k(1-\zeta)\right)$;

$\Phi_k(\mu_r\cdot x)=\cos(\beta_k)\left[(\mu_r\cdot x)^2+2(\mu_r\cdot x)-\beta_k^2\right]- -2\beta_k\sin(\beta_k)\left[1+(\mu_r\cdot x)\right]$;

β_k – roots of an equation: $\mathrm{tg}(\beta_k)=-2\left(\frac{\beta_k}{\mu_r\cdot x}-\frac{\mu_r\cdot x}{\beta_k}\right)^{-1}$; I_m – current amplitude; δ_0 – relative damping factor; $\varphi=\omega\cdot t$ – running phase; $\tau=\mu_0\gamma d^2$ – characteristic time of field diffusion in a metal blank; $x=(\lambda\cdot d)$ – integration variable; λ – integral Fourier-Bessel transform parameter; μ_r – magnetic metal permeability;

$$f_{1k}(x,\varphi)=e^{-\delta_0\cdot\varphi}\sin\varphi-\frac{\left(\beta_k^2+x^2/\omega\tau\right)}{1+\left[\frac{\beta_k^2+x^2}{\omega\tau}-\delta_0\right]^2}\times \left[e^{-\delta_0\varphi}\left\{\left[\frac{\beta_k^2+x^2}{\omega\tau}-\delta_0\right]\sin\varphi-\cos\varphi\right\}+e^{-\frac{\beta_k^2+x^2}{\omega\tau}\varphi}\right].$$

We integrate expression (1), by sheet metal thickness $\zeta\in[0,1]$. We obtain dependence for radial distribution of linear density of the induced current

$$j_\varphi(r,\varphi)=2\cdot J_m\cdot\int_0^\infty f(x)\cdot e^{-x\cdot\frac{h}{d}}x\times \times J_1\left(x\cdot\frac{r}{d}\right)\sum_{k=0}^{\infty}\frac{F_{2k}(\mu_r\cdot x)}{\Phi_k(\mu_r\cdot x)}\cdot f_{1k}(x,\varphi)dx;, \quad (2)$$

where $F_{2k}\left(\mu_r,x\right)=\left(\mu_r x\right)\left(1-\cos\left(\beta_k\right)\right)+ +\beta_k\sin\left(\beta_k\right)$

Obtained results are illustrated by numerical estimations for situations which are real in magnetic and pulse levelling of car body panels [8, 9, 12].

Structural parameters of the MD:
a) the primary winding: $w=20$, $h\approx 0{,}0025$ m, $R_1=0{,}015$ m, $R_2=0{,}075$ m;
b) the secondary winding: non-magnetic metal of disks – aluminium $\gamma\approx 3{,}75\cdot 10^7\frac{1}{\mathrm{Ohm}\cdot\mathrm{m}}$,

electrical-sheet steel; $\gamma \approx 0{,}2 \cdot 10^{7} \dfrac{1}{\text{Ohm} \cdot \text{m}}$ external radius of disks – $R = R_2$.

The operating frequency of the current pulse in the MD – $f = 2$ kHz, relative damping factor – $\delta = 0{,}25$ (it is defined by structural parameters of the MD).

Results of induced current calculations are shown on plots below, fig. 3 and fig. 4.

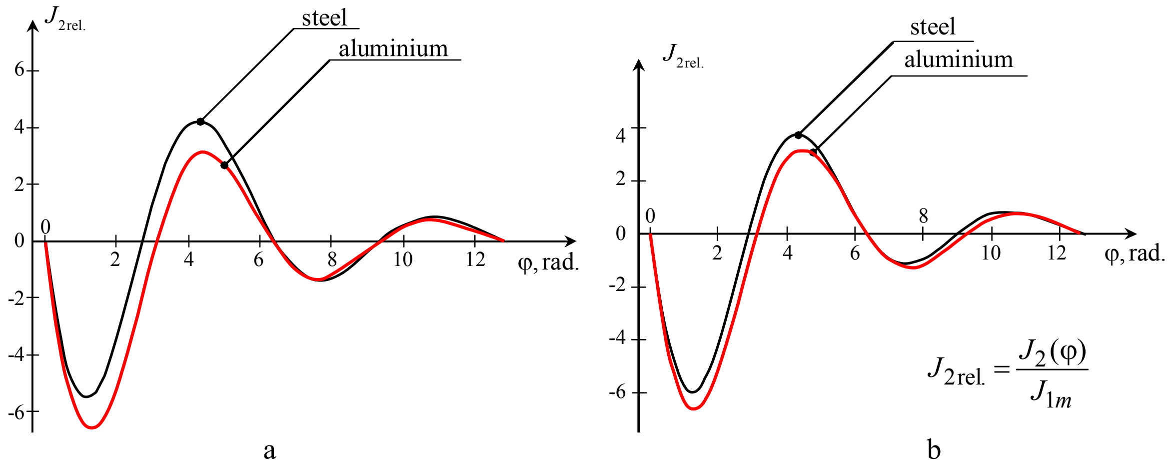


Fig. 3. Current density induced in one disk of the second winding: a – thickness of disks is the same d=0,005 m; b – thickness of the aluminium disk is d=0,005 m, thickness of the steel disk is d=0,008 m

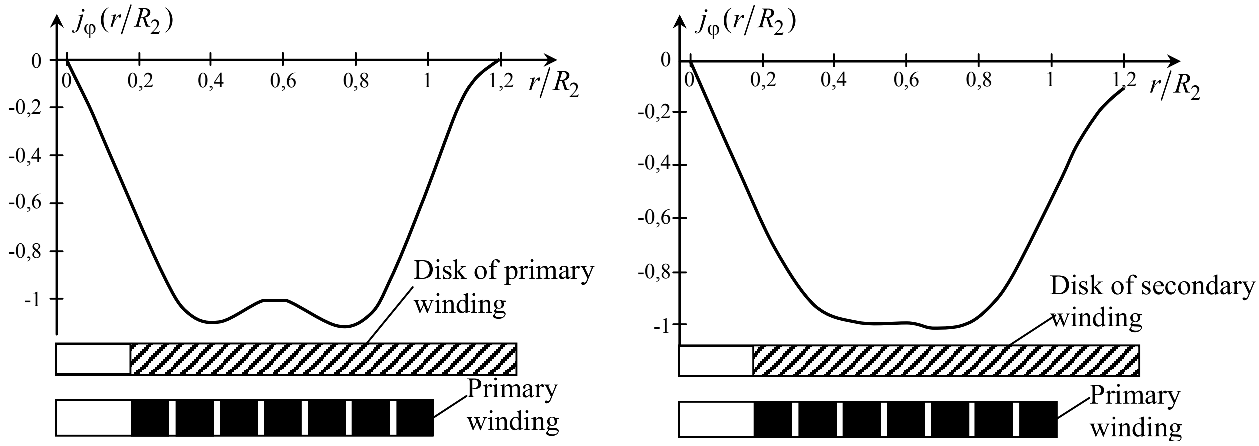


Fig. 4. Current radial distribution induced in disk metal – the secondary winding in relative units: a – aluminium disk; b – steel disk

From performed calculations it should be emphasized that:

1. Time and amplitude characteristics of the induced current are determined by the electrical conduction and metal thickness of the secondary winding.

2. The circle through the center of the primary winding of the matching device ($r/R \approx 0{,}6$) is a place of the most powerful current pick-off a signal with the secondary winding.

3. Metal thickness of the secondary winding of the MD and its electrical conduction determine time and amplitude parameters of the induced current:

a) with decreasing conduction and thickness of disks the transformation ratio value is lowered and, in comparison, with the primary winding current it's time dependence is distorted;

b) with increasing conductivity the transformation ratio value increases, for example, steel – aluminium increase is 20 %.

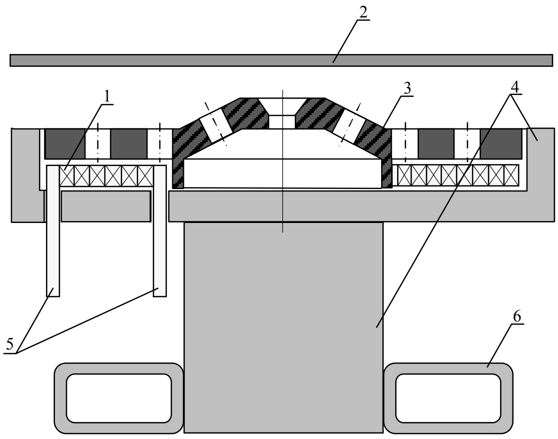
Construction and the principle of tool operation of exterior levelling on the basis of the disk compatible MD

The made analysis of electromagnetic processes in the MD and performed numerical estimations make it possible to develop and propose one of possible technical implementations of the tool of exterior magnetic and pulse levelling on the basis of the disk MD (fig. 5). The given MD has been developed in the KhNAHU laboratory of electromagnetic technologies and it is protected by the patent.

In the outlined technical implementation of the tool (fig. 5) the second winding of the disk MD is combined with the inductor which has an internal hole in the form of the truncated cone. The given tool is rather a powerful one in working of thin-walled ferromagnets in the low frequency mode of operating fields. The tool for exterior magnetic and pulse levelling of frame and body elements of transport facilities [9] is an example of one of the ways of its practical application.

The principle of the tool operation

Electrical leads 5 of the primary winding 1 of the combined disk MD which is applied in the form of spiral on the dielectric frame are connected to the power source – the MPP [14, 15]. In current flowing along the spiral primary winding 1 the magnetic field is formed around it, which excites electric current in the inductor-tool with the internal hole in the form of the truncated cone 3 (the secondary winding of the MD).



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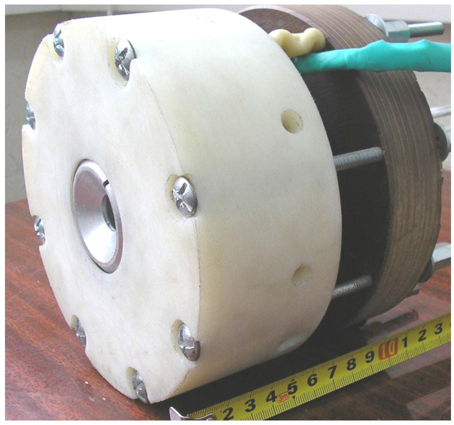


b

Fig. 5. The tool of the exterior magnetic and pulse levelling: a – the design sketch; b – the experimental variant1 – turns of the flat spiral of the primary winding of the pulse transformer; 2 – the thin-walled blank; 3 – the inductor-tool with the internal hole in the form of the truncated cone; 4 – dielectric frame; 5 – electric leads of the primary winding of the pulse transformer; 6 – tool handles

In induced current flowing along the inductor the powerful magnetic field is induced which excites in the thin-walled metal blank 2 intensive normal and tangential components of the magnetic field strength. The interaction of the inductor magnetic field with excited vector components of the magnetic field strength in the thin-walled metal blank under conditions of low frequencies of operating fields and the availability of magnetic properties of the blank results in the emergence of the magnetic force which directs to the geometrical inductor centre and creates bending mechanical moment and in the equivalent it gives attraction effect. The operator clamps the tool over a dint in the thin-walled metal (car body panel) holding it for handles 6.

Experiments by magnetic and pulse leveling

Experimental investigations by the serviceability checking of the developed tool of the exterior magnetic and pulse levelling have been carried out by the magnetic and pulse plant MIUS-2. The given plant has been designed in the KhNAHU laboratory of electromagnetic technologies and it is a source of power for the exterior magnetic and pulse levelling complex of car body panels [3, 9].

The specifications of magnetic-pulse installation MIUS-2 (fig. 6): stored power W = 2 kJ; mains voltage ~ 380/220 V; capacity of condensers C = 1200 μF; self-frequency f_0 = 7 kHz; selfinductance L = 440÷500 nH; charge voltage of capacitive storages U_c =100÷2100 V; repetition rate of discharge pulses f_i =1÷10 Hz.

Fig. 6. The laboratory equipment for EMF attraction processes with maximum charging voltage of 2kV and accumulated energy of 2kJ: 1 – straightening tools - combined disk matching device; 2 – cable connection; 3 – magnetic-pulse installation (pulse generator)

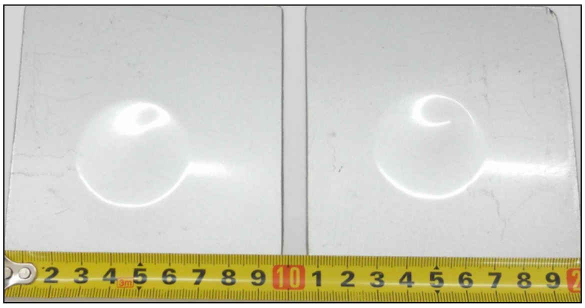
Conditions of experimental researches.
With cable tool connection to MIUS-2:
- the number of discharge pulses series is 3;
- the number of discharge pulses in one series is 20;
- the pulse repetition frequency is 9 Hz;
- charging voltage of capacity accumulators MIUS-2, U_c =2100 V.

Without cable connection of the tool to MIUS-2 (the tool is connected to MIUS-2 directly):
- the number of discharge pulses serious is 3;
- the number of discharge pulses in one series is 10;
- the pulse repetition frequency is 9 Hz;
- charging voltage of capacity accumulators MIUS-2 U_c =2000 V.

Citroen car models of the body panel used in the experiment are shown on fig. 7.

In the first part of experimental investigations using the developed tool deformations on body panel elements of Citroen car have been created, fig. 7, a. In the second part of experimental investigation obtained deformations were removed, fig. 7, b (body panel elements were turned by the opposite side to the tool and the formed deformation was made coincident with the tool operating zone then crater retraction to the plain metal surface of the body panel was carried out).

It should be noted that during experimental investigations the protective paint coating was unchanged.



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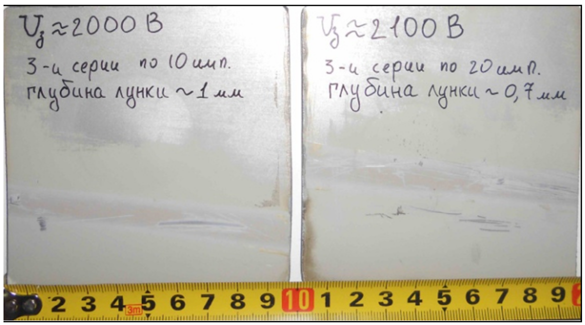

b

Fig. 7. Citroen car body panel elements at the left – without cable tool connections at the right – with cable tool connection: a – dint creation;b – dint removal

In tool connection through the cable joint a small energy loss is observed and it has a detrimental effect on the tool operation and necessitates upgrading of the energy stored level in MIUS. Without the cable joint capacity accumulators of the plant were charged up to the voltage of 2000 V and for dint removal it was necessary to the form three series by 10 force pulses. With the cable joint of the tool capacity accumulators of the plant were charged up to the voltage of 2100 V and for dint removal it was necessary to perform three series by 30 force pulses.

Performed experimental investigations showed that the developed tool of magnetic and pulse levelling on the basis of the combined disk MIUS a powerful one and it can be used both for creation of necessary deformations and for removal of dints on the car body panel bringing formed craters to the level of the surface.

Conclusions

Performed investigations make it possible to formulate the following conclusions.

1. The analysis of electromagnetic processes in the disc matching device for exterior levelling methods of car body panels has been performed.

2. It was determined that time and amplitude characteristics of the induced current are defined by the electrical conduction and metal thickness of the secondary winding of the matching device.

3. It has been found that the circle through the centre of the primary winding of the matching device ($r/R \approx 0{,}6$) is the place of the most powerful signal current pick off with the secondary winding.

4. The schematic handling on the technical implementation of the disc matching device, as the exterior magnetic and pulse levelling tool has been developed and proposed.

5. The experimental approbation of the developed tool of the exterior magnetic and pulse levelling has been carried out. Results of the conduced investigations showed that the developed tool is a powerful one and it can be used both for creation of necessary deformation and for dint removal from car body panel elements.

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