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APPLICATION OF THE ELECTROMAGNETIC IMPULSES FOR JOINING OF DETAILS AND COMPACTING OF POWDERS

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ABSTRACT

The basic physics and technological aspects of application of the electromagnetic impulses for the obtaining of permanent connections from pipes, for compacting of powders and for shaping of details from metallic and nonmetallic materials are analyzed. The recommendations on choice of parameters of the equipment (pulsed electromagnetic fields generator) and of the tool (magnetic coil) for the annular and flat machining are offered. The optimal working conditions (maximal pressure plus durability) for each type of magnetic coils are revealed. Thus, the presence of the electromagnetic enhancers promotes the increasing of the impulse pressure on the specified area of the detail and, hence, increases the tool zone.

Examples of practical application of the proposed technology for joining of details from heterogeneous materials (copper-aluminum, copper-steel and others) are offered. Compacting of powders using the electromagnetic impulses allows to increase the density and to improve the physical mechanical properties of the powder production. Besides the absence of the mechanical contact in this method open up possibilities to produce the new modifications of the sintered metal powder details.

Keywords: pulsed electromagnetic field, pressure**,** compacting of powders

1. INTRODUCTION

The main principles and effects of pulsed electromagnetic field force effort on conducting environment are known since middle of 60s years of 20 century [1, 2].

The method of magneto-impulse metal machining (MIOM) appears in mechanical engineering. This method depends on interaction of quick-change strong pulsed electromagnetic field and eddy currents in nearly situated conductor (metal billet). High technological elasticity, simplicity of technological equipment and availability of high specific pressures open up wide possibilities of MIOM application in different fields: punching and assembling [3], compacting of powders [4] and welding [5].

However in concrete application of MIOM it is necessary to bear in mind the restrictions of geometry of details, properties of material of machining billet, tool life, equipment reliability and etc.

In recent years the new fields of MIOM application were revealed: pulsed displacement of materials in electromagnetic field [6], jarring of loose materials bins [7], forming of powder coatings [8] and others. Original solutions appear in combination of traditional machining with additional using of pulsed electromagnetic fields [9].

2. THEORETICAL BACKGROUND

The concentration of force that influences on conductor in changing electromagnetic field with intensity *H,* is determined by following equation:

$$f_v = \mu\left[\bar{j} \cdot \overline{H}\right), \tag{1}$$

where $\bar{j}$ and $\overline{H}$ are the vectors of current density in conductor and electromagnetic intensity; μ is the magnetic inductivity. Here the vector of current density is inversely proportional to specific electrical resistance of conductor.

Pulsed electromagnetic field with fast attenuation is often use for technological purposes [11]. In this case the law of current variation in working coil is accepted as damped sinusoid:

$$i = Ime^{-\alpha t} \sin \omega t, \tag{2}$$

where I_m is the current amplitude; ω is the circular frequency of discharge current pulse; t is the time of current influence. The electromagnetic field intensity on surface of conductor respectively is determined as:

$$H_1 = H_m e^{\alpha t} \sin \omega t, \tag{3}$$

where H_m is the maximal value of intensity ; α is the attenuation coefficient. The pressure of electromagnetic forces on the surface of billet with high electric conductivity can be calculated as:

$$p = \frac{1}{2} \mu H_1^2. \tag{4}$$

At some critical value of the electromagnetic field intensity the pressure of electromagnetic forces on the surface of billet can exceed the yield strength or ultimate strength of material that leads to plastic deformation or destruction of billet. Critical value of the electromagnetic field intensity is within from 10 to 100 MA/m and substantially depends on density and electric conductivity of material.

If billet is the thin-walled tube or thin plate the pressure on billet will reduce according to appearance of reflected from internal surface electromagnetic waves. In this case in the pressure equation it is necessary to insert the coefficient K_{os} of release of pressure:

$$p = \frac{\mu_0}{2} H_1 (1 - K_{os}). \tag{5}$$

It could notice that the K_{os} is the complicated function, dependent on parameters of the electromagnetic field generator and coil (where billet is situated) as well as on parameters of billet and environment properties.

3. PULSED ELECTROMAGNETIC FIELDS GENERATORS AND THOSE PARAMETERS

The principal scheme of pulsed electromagnetic field generator (IEG) is shown on Figure 1. IEG for technological purposes manufacture in USA, Russia, Germany and others countries [4,5,8]. Widest application has IEG for assembling and punching [3, 4, 9].

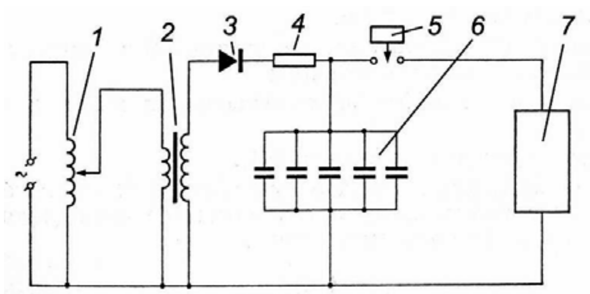

Fig. 1. Principal scheme of IEG equipment: 1 – autotransformer; 2 – step-up transformer;3 – rectifier; 4 – charging resistance; 5 – storage of condenser type; 6 – discharge device; 7 – coil.

One of the main parameters of MIOM are the energy of capacitive storage W, discharge frequency f, discharge current A, voltage U and number of impulses at minute n (Fig. 2). Regulation of W is possible by changing of discharge voltage U and capacity of storage C. Moreover, it is more preferable to change the voltage. Since exist following dependence.

It is necessary to take into account that increase of working voltage can cause the problems related with decreasing of equipment reliability. Significant increasing of capacity increase the time of influence and decrease the value of electromagnetic field impulse pressure.

Inductor is the one of the main element of IEG equipment. Inductor has to provide high coefficient of energy transformation, optimal frequency of discharge current, required distribution or concentration of electromagnetic field on the given area of billet and tolerance to electrical overvoltages. The simplest solution is the application of multiturn inductor. The wired inductors are mounted in metal water-cooled case for increasing of tolerance.

By changing the ratio of internal radius and length of inductor it is possible to concentrate the effort on required area (length) of billet. Water-cooled inductors with field concentrator were elaborated during investigation. By changing the working zone length it is possible to obtain the amplification of magnetic induction (Fig. 3).

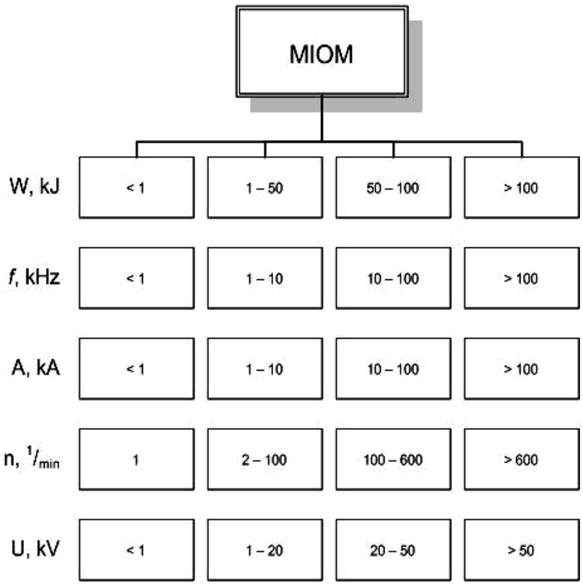

Fig. 2. Main parameters range of IEG equipment

4. MIOM APPLICATION IN POWDER METALLURGY

Intensive impulse loads allow to achieve the high density powder material during compacting. In [7] is revealed, that during single-pass compacting the density of powder was 7.2 gr/cm^3. Working voltage increases to 36 kV and energy to 50 kJ. There are some methods in powder metallurgy, that allow to solve similar tasks with less consumption of energy. For example, forming by magnetic field of billets from previously compacted and sintered metal powders.

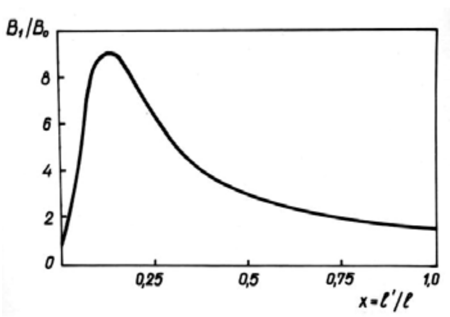

Fig. 3. Changing of magnetic induction on the internal surface of concentrator depending on length of billet and concentration zone

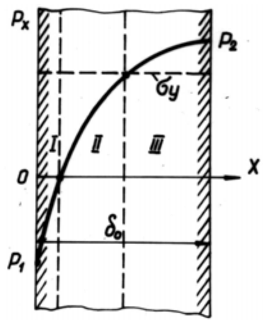

Fig. 4. Changing of electromagnetic pressure on thickness of the detail from bronze powder

The pressure of electromagnetic forces on the surface of billet is practically identical to zero (Figure 4) and the maximum value achieve in the depth δ – so-called length of skin layer [3, 4]. New method allows to built-up the details from powder on the basis of iron, copper and other materials with good electrical conductivity.

5. MIOM APPLICATION IN PRODUCTION OF COMPOSITE MATERIALS

MIOM approach is effective in production of monodirectional composite materials too. For reasons of geometry at compacting in container the maximum permissible shrinkage dependent on initial structure of composition and velocity of loading during compacting exists.

MIOM method in current-conducting covering allows producing details from fiber composite materials with minimal porosity (Fig. 5, 6).

Fig. 5. Part with unidirectional steel fibers in copper holder (d = 0.7 mm)

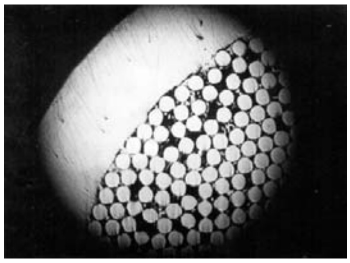

Fig. 6. Macrostructure of fibers built-up onto the copper holder (D = 0.7 mm, d = 15 mm)

By MIOM method it is possible to built-up the details on fragile goods from glass, ceramics. Since short-term influence of the electromagnetic impulse the fragile detail is not destroyed. The simultaneous assembling of few details is possible (Fig. 7). Permanent connections as multilayer pipes from heterogeneous materials were produced on the MIOM equipment, for example, from copper with titanium or steel (Figure 8).

Fig. 7. Assembling of bronze filters in copper case

Fig. 8. Welds of the pipes (copper-steel, copper-titanium)

At certain technological parameters welding is possible too. The main parameters are: velocity of impingement and angle in the contact zone of welded surfaces. Excessive high velocity causes the breaking of surface and decreasing of weld strength. Optimal velocity for welding aluminium alloys is v = 300-450 m/sec. Angle of impingement could be 6°-8°.

6. CONCLUSION

1. Application of electromagnetic impulses in plastic working and powder metallurgy gives new possibilities in producing of mechanical engieering and instrument-making details.
2. MIOM method is more effective in assembling of details from heterogenous materials.
3. The optimal parameters must be determined in each MIOM process.

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