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CONTRIBUTIONS ON THE PHYSICAL MODELING OF THE MAGNETO – ABRASIVE FINISHING PROCESS WITH FERROFLUIDS. MACHINES AND EQUIPMENTS

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Abstract: *In this work are presented some contributions concerning the physic modeling of the magneto-abrasive process with ferrofluids which contain abrasives granules and some requests on the installation and subassemblies using the magneto-abrasive method.*

Key words: *magneto-abrasive finishing, ferrofluids, machines; equipments.*

1. INTRODUCTION

The physical model of the technological processes, is generally an idealized approximation, fundamental in facts and represents the admission of simplified assumptions, of some approximations as a logical system on which to be able to study all the phenomena that accompany these processes.

It is, in fact, a process of abstraction and must meet two basic conditions:

- to be simple;
- to represent the true essence of the problem or the solution studied;

Physical model of magneto-abrasive finishing is conditional on the chosen finishing variant, but especially for the working environment used, which may be composed of: fine granules of tough iron, ferro-boron or ferro-wolfram cermets type granules and last, but not least, ferrofluids in which are immersed abrasive granules.

2. PHYSICAL MODEL OF MAGNETO ABRASIVE FINISHING WHEN USING FERROFLUIDES

On the basis of magneto-abrasive finishing using as the working environment ferrofluids mixed with abrasive granules (silicon carbide, artificial corundum, diamond granules), it lies the property of levitation of the non-ferromagnetic substances that are dipped into ferrofluid [1, 5] levitation that arises because of the force with which the ferrofluid, placed in a magnetic field gradient, acts on these substances opposing the gradient.

The relation of electromagnetic levitation force is depending on the abrasive granular form (spherical, oblong oval rotation, cube, conical, double conical, regular tetragon etc.) and depending on its orientation towards magnetic induction (the gradient) or to the axis coordinates.

Determining the correct levitation force, operating on a given granule is quite complicated as a result of the loose micro-chips, and the ferrofluids' properties.

The complexity of determination could be influenced by possible phenomena which may appear during the finishing, i.e.: electrochemical phenomena, the phenomena due to magnetic field heterogeneity and due to the affinity between the abrasives and ferrofluids.

The accurate evaluation of the levitation force propounds the complete system of equations of the magneto-hydrodynamic and the distortions that appear in the set of strengths when introducing the granules.

This system would consist of the Maxwell equations, the Ohm's law, the Navier-Stokes equation and the equation of continuity and it would be like:

$$\begin{gathered}\nabla x\overline{B}=\mu_0\cdot\bar{j};\ \nabla x\overline{E}=\frac{\partial\overline{B}}{\partial t};\ \nabla\overline{B}\cdot\nabla\overline{E}=\frac{\rho_1}{\varepsilon_0},\\ \bar{j}=\sigma\cdot\left[\overline{E}+\overline{V}xB-\beta\left(\bar{j}xB\right)\right],\\ \left(\nabla\bar{v}\right)\cdot\overline{V}=-\left(\frac{1}{\rho}\right)\nabla p+\bar{g}+\frac{1}{\rho}\left(\bar{j}xB\right)+\frac{\eta}{\rho}\cdot\nabla^2\overline{V},\\ \nabla\overline{V}=0.\end{gathered}\tag{1}$$

Solving this system is very difficult without subjecting some simplifying assumptions.

The inductive effect, $\frac{\partial\overline{B}}{\partial t}$ the free load excessive density, the current due to Hall effect from the generalized Ohm's law etc., can be neglected.

For a quick determination of the levitation force, the starting point was the principle of the ferrofluids separators [2, 3, 5] and the fact that the literature [4, 7] doesn't offer enough elements regarding the physics simulation of magneto-abrasive finishing when using ferrofluides.

The buoyancy (Archimedes' force) and any possible centrifugal forces were not taken in consideration (Fig. 1).

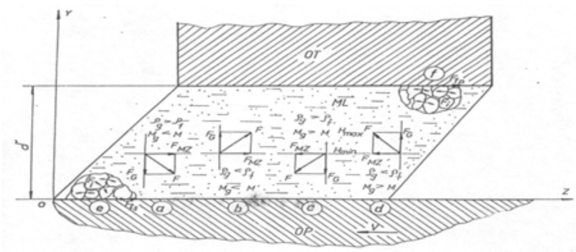

Fig. 1. The action of gravity force.

Under the action of a magnetic field gradient, the magnetic force per unit volume will be:

$$F_{Mv} = \mu_0 \cdot M\nabla\overline{H}\,, \tag{2}$$

which is equal in modulus and in opposite direction of the levitation force that acts on the non – magnetic granules which expression is:

$$F_k = \frac{\mu_0}{V_g}\int M \cdot \frac{\mathrm{d}H}{\mathrm{d}z}\cdot \overline{k}\,. \tag{3}$$

The resultant magnetic force acting on unit volume of granules immersed in the ferrofluid will be:

$$F_k = \mu_0\left(M - M_g\right)\cdot \frac{\mathrm{d}H}{\mathrm{d}z}\cdot \overline{k}\,. \tag{4}$$

The gravitational force is:

$$\overline{F_G} = \left(\rho_g - \rho_f\right)\cdot g \cdot \overline{j}\,. \tag{5}$$

In these relations were made the following notations:

- v – the volume of dipped granules
- M – the ferrofluids magnetization
- $\frac{\mathrm{d}H}{\mathrm{d}z}$ – vacuum field gradient;
- H_0 – vacuum magnetic permeability;
- M_g – the magnetization of immersed granules;
- $p_g > p_f$ $\rho_g > \rho_g$ – the density of granules / ferrofluid

The relation of dependency between these components is:

$$F \cdot \overline{k} + \left(\rho_g - \rho_f\right)\cdot g \cdot \overline{j} + \mu_0\left(M - M_g\right)\cdot \frac{\mathrm{d}H}{\mathrm{d}z}\cdot \overline{k} = 0 \tag{6}$$

3. MAGNETO-ABRASIVE FINISHING MACHINES AND EQUIPMENTS

In processing with magneto-abrasive finishing act following main factors:

- the speed of mechanical movements;
- the physical characteristics and magnetic properties of the pieces to be finished;
- abrasive and magnetic properties of the working environments;
- the intensity of the magnetic field;
- the granulation of the used abrasives;
- the material of the cores or magnetic poles,
- the shape and orientation of the polar pieces;
- the size of the working electrical gap;

The devices, equipment, stands for research and magneto-abrasive finishing machines should ensure the modifying of the parameters above in a range of adjustment higher or lower. The change of all parameters requests complexity and difficulties in achieving the magneto-abrasive finishing equipment.

Due to the fact that the process is not applied in industry, there aren't machine tools designed to work with this process. For this reason, it has been appealed to design simple machines by attaching on available universal machine-tools devices consisting of several subassemblies and systems using the modular design of the equipments.

The basic idea of the conception is overlapped on that of the magneto-abrasive finishing technology as a system.

As a starting point in designing the magneto-abrasive finishing machines was the decomposition of the technological system in a certain number of subsystems, each corresponding to a certain function.

Each subsystem is a module, a part of itself, able to function and perform in a wide variety of outdoor conditions. The whole system can be considered as an arrangement of modules.

The modules present a series of additional features:

- self-state, meaning that it can operate independently and can be tested independently,
- the ability to work and act in a variety of external conditions, the ability to be interconnected with other modules.

Magneto-abrasive finishing equipment should comprises the following components and systems:

- the subassembly for turning (rotational) movement of the working piece or of the magnetic inductor;
- the subassembly for small amplitude swinging movement;
- the subassembly of the magnetic system;
- the feeding and the dosing system with magnetic powder or with ferrofluid; the supply system and electric control;
- the feeding and the guiding system of the lubricant to the working area, the system of powder separation and demagnetization of the finished pieces;
- the recovery and regeneration of the ferrofluids, when used.

In literature [8, 9, 16] there are many variants of devices, equipments or magneto-abrasive finishing machineries, variants that contain whole or in part the subassemblies and the systems listed.

The magneto-abrasive finishing equipments, regardless of the used working environment, must be accomplished with high accuracy and must be stable in terms of static and dynamic.

In Fig. 2 it is shown a block diagram of magneto-abrasive finishing equipment for the flat surfaces.

There are relieved the necessary movements, as the shape of the poles (polar parts) that have considerable influence on the magnetic field intensity.

In Fig. 3 it is shown the detail of the magneto-abrasive finishing equipment for flat surfaces with the evident basic modules. The inductor can be mounted on a vertical milling or drilling machine. The annotations have the following meaning: 1 – the pole; 2 – inductor body, on which the winding is wrapped; 3 – the brushes system for supplying the coil from the main source.

The positioning and fixing module for part 4, has a separate drive, the movement being sent from the motor through the eccentric shaft 6, to the supporting table through the guides 5. The working environment, which may be magneto-abrasive powder or mixed with abrasive ferrofluid granules, is noted with 8.

The equipment is an invention of the authors [14] and is characterized by simplicity and the possibility of mounting on universal machine tools.

In Fig. 4 it is shown the block diagram of a magneto-abrasive finishing machine for exterior revolution surfaces, and in Figs. 5 and 6 it is relieved the position of the poles, respectively their constructive shape.

Both the position and the constructive shape of the poles are influencing the magnetic field gradient on the working place.

Figure 7 accentuates the block diagram of magneto-abrasive finishing equipment for interior revolution surfaces that includes two modules: the positioning – fixing and carrying away module and the magnetic one.

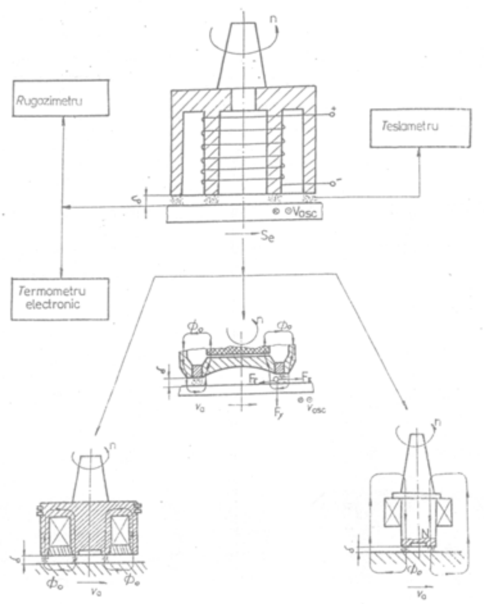

Fig. 2. A block diagram of magneto-abrasive finishing equipment for the flat surfaces.

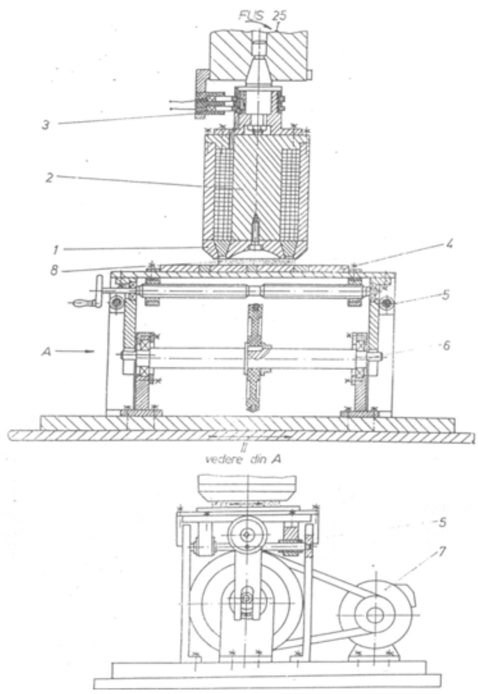

Fig. 3. Detail of the magneto-abrasive finishing equipment for flat surfaces with the evident basic modules.

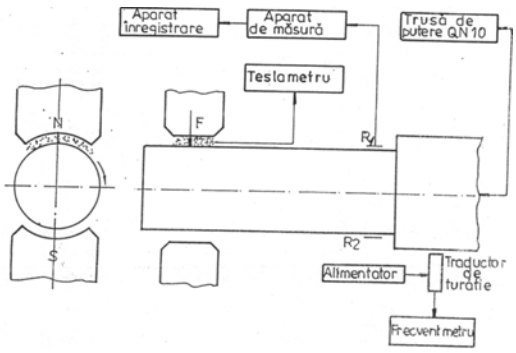

Fig. 4. The block diagram of a magneto-abrasive finishing machine for exterior revolution surfaces.

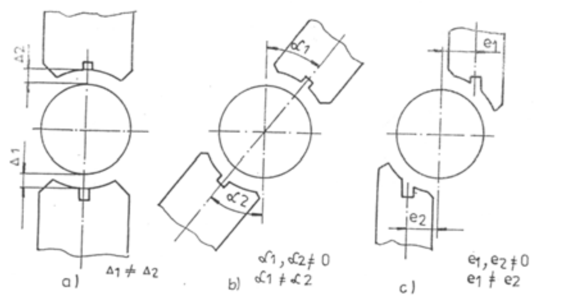

Fig. 5. The position of the poles.

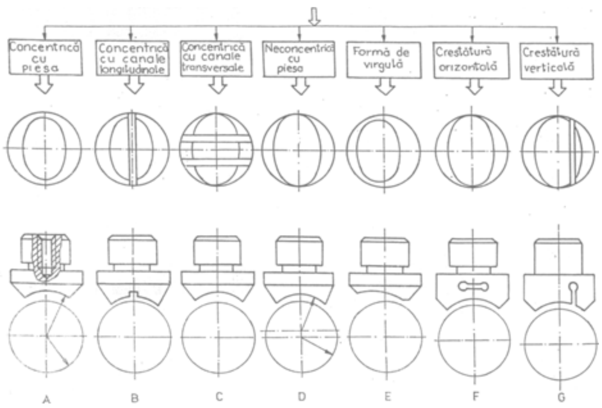

Fig. 6. The constructive shape of the poles.

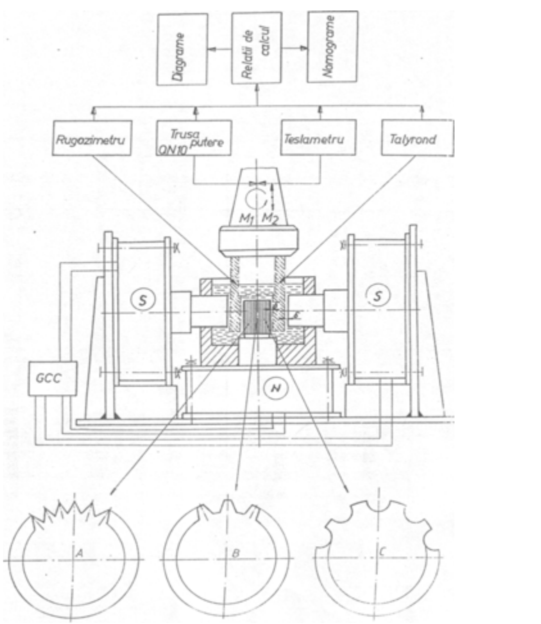

Fig. 7. The block diagram of magneto-abrasive finishing equipment for interior revolution surfaces.

4. CONCLUSIONS

Depending on the direction of action of levitation forces, the magneto-gravimetric force will act upon the granules from ferrofluid , fetching them up or down (Fig. 1e, f), which is why it will change the corresponding parts or even polar installations finish.

Depending on the ratio p_g / p_f, the orientation of the gravity force will be according to Fig. 1a, b, c, d.

In case of ferrous chips due to micro cutting, it will be considered the second hand levitation.

To enhance magneto-abrasive finishing with ferrofluids, some authors [12, 15] propose using a "float" between the poles and the parts subject to finishing.

You can also use variations of magneto-abrasive finishing, using sharp poles or very strong magnetic fields, with the aim of improving the quality of the processed surface and to increase the amount of sampled material.

Using the ferrofluids, mixed with abrasive granules can be, for processing, a smart tool holder, as a result on how it is formed in this case the "magneto-abrasive brush".

All devices and installations presented are the invention of the authors [11, 12, 13, 14]. There are other variants of special designed equipments and machines (for flat surfaces, for interior revolution surfaces with great length and small diameter, for balls) that can be made available to interested companies.

Also, it has been designed universal finishing equipments for this process (the magneto-abrasive finishing one), relatively new [15], and it believes that the industrial applications can successfully replace, in some cases, classical finishing and super finishing methods.

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