6th International DAAAM Baltic Conference
INDUSTRIAL ENGINEERING
24-26 April 2008, Tallinn, Estonia

EQUIPMENT FOR MAGNETO-ABRASIVE FINISHING OF ROLLER BEARING BALLS

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Abstract. *The processing of surfaces by magneto-abrasive erosion is achieved by working media with both magnetic and abrasive properties, the binder of the grains forming the working medium being the magnetic field. The paper presents a device for magneto-abrasive finishing of roller bearing balls adaptable on a universal milling machine.*
Keywords: magneto-abrasive finishing, roller bearing balls.

1. INTRODUCTION

Abrasive erosion holds an important weight amongst surface machining processes, this being a technological method of dimensional machining by means of cutting – scratching – plastic deformation of the part surface carried out by the abrasive grains held in a solid, liquid, gas or magnetic support. This procedure is based on the destruction of the integrity and subsequent removal of the tooling allowance at the surface of a part, by means of the dynamic action of the erosive agents, materialized by solid particles (abrasive grains). The use of abrasive grains as cutting tools aims mainly at rendering special quality surfaces of high precision in regard of dimensions, form and position. Achieving these objectives however requires small values of the tooling allowance, often even under one micron [1].

Considering these requirements, Japanese researcher Norio Taniguchi has introduced the concept of „*nanotechnology*”, placing abrasive erosion within this category of cutting procedures [2].

Abrasive erosion can be achieved with the grains fixed in a solid body (procedures known as grinding, honing, etc.), with semi-free grains held by a magnetic field or a viscous liquid medium (known as *magneto-abrasive finishing*, lapping, ultrasound dimensional machining, etc.), or with free grains set into motion by a small viscosity liquid or gas (abrasive jet cutting).

Magneto-abrasive finishing falls into the category of machining by abrasive erosion, the principles of which are presented in the following.

2. MAGNETO-ABRASIVE FINISHING

The first mention of a magneto-abrasive machining procedure is connected to the name of the Russian scientist Karol, who in 1938 proposed the use of an alternating magnetic field for finishing the interior surfaces of pipes, by means of magneto-abrasive powders. Further major contributions acknowledged in literature are *inter alia* those of M. Baron, E.G. Konovalov, L.M. Kozuro in Russia, Al. Makedonski in Bulgaria, and K. Kato, Nakagawa, Taakeo Shinmura, Koya Takazawa, Eiji Hatano in Japan [3].

Machining with magneto-abrasive grains is based on the effects generated by the relative motion and the pressure generated between the part surfaces to be machined and the abrasive particles acting as tools and sustained in the machined area by means of a magnetic field.

Magneto-abrasive machining implies firstly the contact between the part surface and an abrasive grain. Maintaining the contact with the machined surface, even for a mobile grain and/or part requires the existence of a sufficiently strong magnetic field on one hand, and ferromagnetic properties of the grain, on the other.

The existence of relative motion between the "hairs of the abrasive brush" and the part surface determines a micro-cutting process if the edges of the grain are sufficiently sharp, or a process of superficial deformation for less sharp grain edges. Due to the existence of a relative motion, as well as due to the friction forces, a deformation of the hairs composing the "magneto-abrasive brush" can be recorded (fig. 1) [4]:

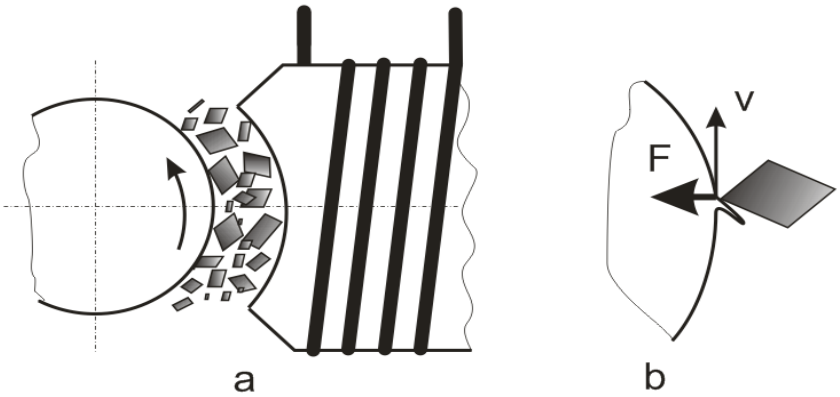

Fig. 1. Deformation of the „ magneto-abrasive brush"

In order to achieve micro-cutting or micro-deformation the grains need to be sufficiently hard and must have cutting edges. Secondly, the grains need to be maintained in the machining area by the electromagnetic field. This last requirement is achieved when the structure of the grains contains at least one ferromagnetic component. The simultaneous materialization of these requirements was possible either by using particles made of sufficiently hard ferromagnetic materials, or by using complex grains consisting of an abrasive component and a ferromagnetic one. The action mode of a grain can be observed in figure 1 –b.

The main characteristics which define magneto-abrasive erosion are:

(a) the energy brought to the working area generates continuous, progressive and cumulative elementary processes;

(b) the 3D form of the transfer object can be copied onto the machined object;

(c) low mechanical strain on the components of the machining equipment.

The machining of parts by magneto-abrasive erosion is based on its numerous advantages:

(a) the presence of the permanent "self-sharpening" of the "magneto-abrasive brush", as the worn edges of the grains are continuously oriented;

(b) the absence of the "clogging" phenomenon characteristic for abrasive bodies (grinding stones, etc.);

(c) the hardness of the "magneto-abrasive brush" can be easily adjusted between certain limits, depending on the nature of the processed material;

(d) due to the forces generated during machining, the remaining tensions are low.

This type of processing has also a few disadvantages, which however do not affect the efficiency and applicability of the procedure:

(a) a remnant magnetic field is generated following to machining;

(b) the cost of obtaining powders with simultaneously abrasive and magnetic characteristics;

(c) the procedure cannot be applied to too large parts, due to the complexity of the equipment required in such cases.

Due to its performance related to surface quality, dimensional and geometrical precision, magneto-abrasive machining falls into the category of super-finishing procedures. The obtained performances are close or even superior to those achieved by lapping or vibratory smoothing.
Further on a variant of magneto-abrasive finishing equipment for roller bearing balls will be presented, designed and manufactured at the Transylvania University of Brasov, Romania.

3. MAGNETO-ABRASIVE FINISHING EQUIPMENT FOR ROLLER BEARING BALLS

The presented equipment belongs to the category of magneto-abrasive finishing equipment for complex surfaces, that is for spherical surfaces. The device allows finishing roller bearing balls of diameters between 8 and 18 mm (fig. 2). It is mounted on the table of the FUS 22 universal milling machine by means of six screws for T grooves.

Fig. 2. Roller bearing balls

The finishing procedure consists in rolling the balls by “magneto-abrasive brushes” achieved by electromagnets and magneto-abrasive powders.
The kinematics of the equipment consists in driving the two disks in opposed senses of rotation, the balls to be finished being located between these. While the inferior disk will be driven by an electric motor by means of a belt transmission, the superior disk will be driven by the main shaft of the milling machine.

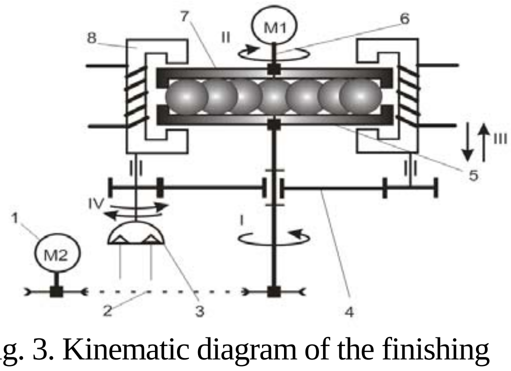

Fig. 3. Kinematic diagram of the finishing equipment

The milling machine also carried out the positioning of the device in relation to the superior disk, by vertically moving the machine table.
In order to remove the superior disk for a new charge of balls, the magnetic yokes are rotated by means of a straight cylindrical gear driven by an oscillating pneumatic motor. The cinematic diagram of the equipment is presented in figure 3.

The components of the cinematic diagram are:
1 – Electric motor;
2 – Belt transmission;
3 – Oscillating pneumatic motor;

4 – Gear – pinions mechanism;
5 – Inferior disk;
6 – Main shaft of the milling machine;
7 – Superior disk;
8 – Electromagnet.

The magneto-abrasive particles in the working space become magnetic dipoles from the moment they are subjected to the action of an exterior magnetic field. Generally the direction of the vector of the magnetic moment of a dipole does not coincide with either the exterior induction vector or the geometrical axes of the particle. For this reason the magneto-abrasive particle will carry out three motions in the working space between the two disks (figure 4):

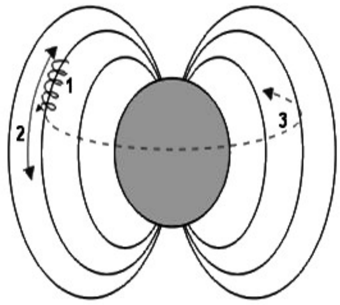

Fig. 4. Magneto-abrasive grain – magnetic dipole analogy

1. Larmor rotation;
2. Motion along the force lines with reflection in the polar zones;
3. Drift transversal to the force-lines by effect of the centrifugal force generated from motion 2.

The following figures present sections and views of the developed equipment:

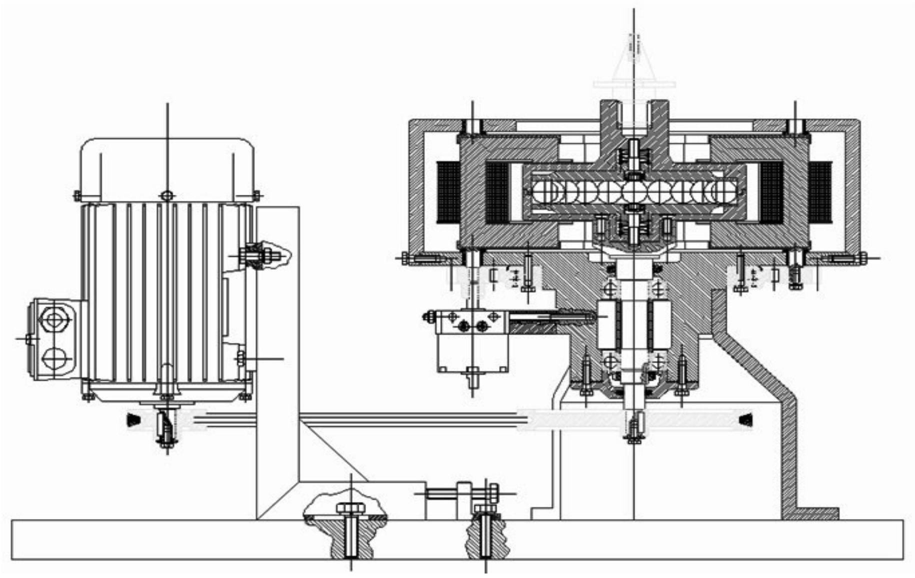

Fig. 5. Section through the roller bearing balls finishing equipment

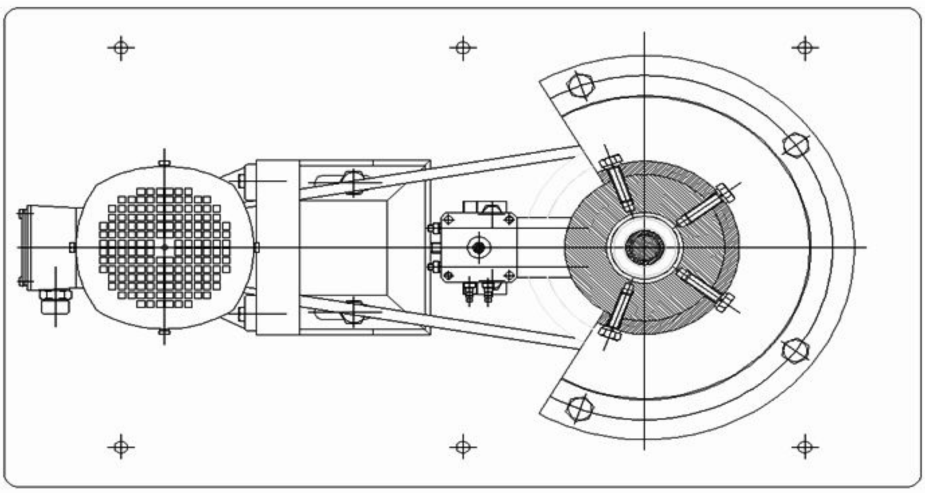

Fig. 6: View of the finishing equipment

The magneto-abrasive finishing of roller bearing balls by means of the device presented above allowed also the improvement of the geometrical form of the machined parts. Figure 7 shows the results obtained by finishing 12 mm diameter balls, where the initial deviation from sphericity of about 70 μm was reduced by machining to only 0.15...0.20 μm.

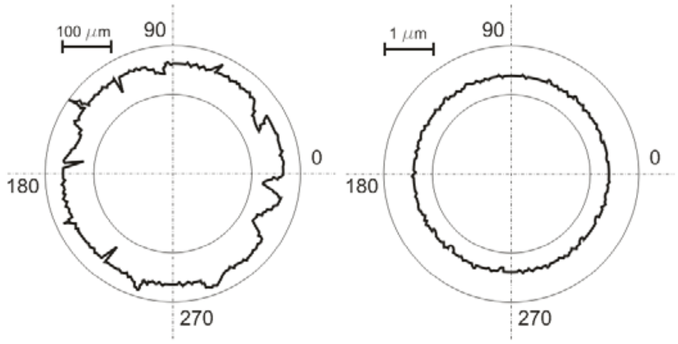

Fig. 7. Deviations from sphericity corrected by magneto-abrasive finishing

The materials recommended as working media can be divided into several categories:

(a) *ferro-magnetic grains*, obtained from materials with both abrasive and magnetic properties. The most frequently used materials of this type are ferro-boron, ferro-tungsten and hard cast iron.

(b) *composite grains*, made from a matrix with ferro-magnetic properties and holding a multitude of abrasive particles.

While the dimensions of the composite grains are of the order D = 100...200 μm, those of the abrasive grains are: d = 5...30 μm (figure 8). The main materials included by the ferro-magnetic matrix of a composite grain are: Al_2O_3 (10...20 %), TiC (15 %), WC (20 %), Cr_3C_2 (20...30 %), ZrC (10...20 %), diamond. [5].

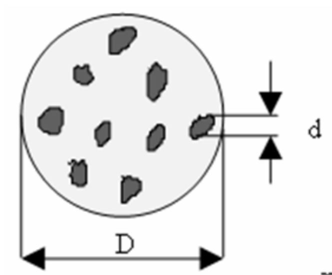

Fig. 8 Composite grain

The graining of the magneto-abrasive material is one of the performance determining factors of the procedure, indicated by roughness Ra and productivity Pr. It was observed that for obtaining the best surface roughness and the highest productivity, when using 15%TiC+ 85%Fe magneto-abrasive material, a graining of d=125/160 μm is recommended (figure 9):

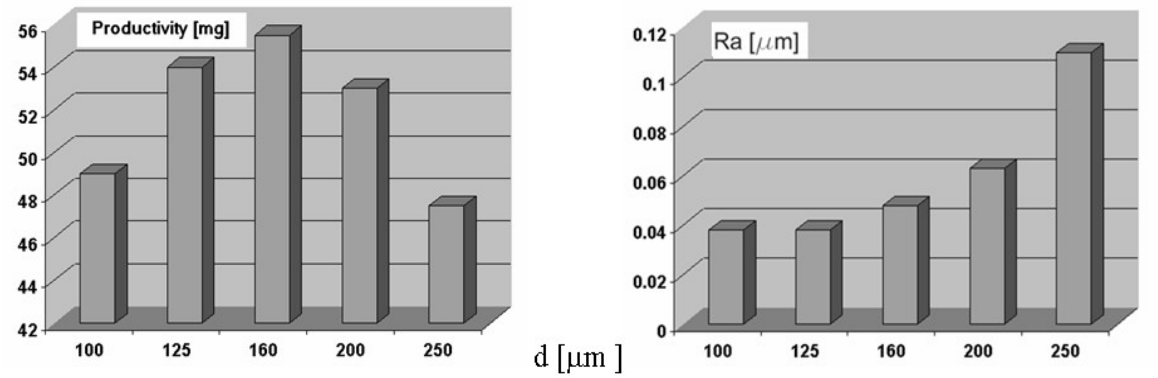

Fig. 9. Pr = f(d) and Ra = f(d)

The particle shape is determined by surface finish and profile requirements and the type of contaminant to be removed. The shape of an abrasive when new is not always the same as when in the operating mix. Whereas steel shot remains round throughout its life and iron grit remain angular, steel grits may loose angularity depending upon their initial hardness. The grains preferred for magneto-abrasive finishing should have initially positive rake angles. The attached figure shows chilled iron grits, their shape being adequate for this type of machining.

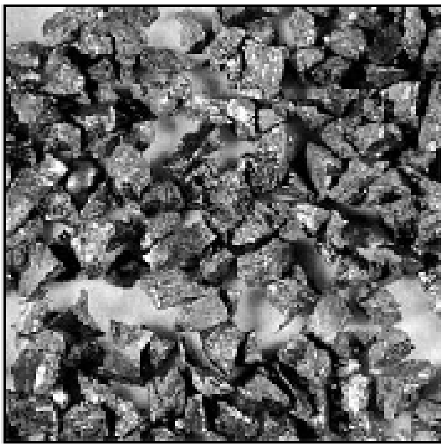

Fig. 10. Chilled iron grits

The performance of magneto-abrasive machining is influenced by some technological parameters, the most important ones being cutting speed, magnetic induction, dimension and shape of the machining gap, the characteristics of the magneto-abrasive material, the degree of filling of the area, etc.

On the device presented above, the thickness of the removed material layer depending on the cutting speed was:

- v =10 m/min, h=1.27 μm,
- v =15 m/min, h=2.68 μm,
- v =50 m/min, h=4.11 μm,
- v =150 m/min, h=4.48 μm.

4. CONCLUSION

The main characteristics of the magneto-abrasive finishing device described in the paper are constructive simplicity and high performance. Its launching into series manufacturing and addition to the accessories kit of universal milling machines is bound to significantly enlarge the range of machining procedures achievable on such machines.

5. REFERENCES

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