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TECHNOLOGIES AND EQUIPMENTS FOR COMPLEX SURFACES NANOFINISHING BY ABRASIVE FLOWING WITH REOPECTIC WORK MEDIUMS

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Abstract: This paper is based on the development of a AFM (**A**brasive **F**low **M**achining) nanoprocessing integrator concept, especially nanofinishing, by mediums which use nanomaterials, and also on the achievement of a nanofinishing technology and equipment for complex surfaces, using reopectic work mediums, which assure a better productivity than the one obtained by the nowadays technological applications, and which is a perfect ecological technology comparing with the similar technologies at the world level. It was achieved a structural analysis of the chassis, by using the finite element, trying to achieve an accurate image of the main forces which actuate to the chasses and also its behave while the processing process.

1. INTRODUCTION

Processing processes based on abrasive flow machining (AFM) were conceived in order to eliminate the deficiencies which appear at common mechanical processing, which were previously used.

This paper is based on the development of a nanoprocessing integrator concept, specially nanofinishing by mediums which use nanomaterials, on the achievement of a technology and equipment in order to nanofinish complex surfaces, by using reopectic work mediums and the goals are to assure a productivity superior to the one which is obtained by applying nowadays technology and to achieve a technology which is perfectly ecological comparing with similar technologies at international level.

2. NANOFINISHING BY ABRASIVE FLOW MACHINING AND REOPECTIC WORK MEDIUMS

The Abrasive Flow Machining (AFM) process use a reopectic work medium, which, according to its name, has as a main fundamental property the viscosity increasing at the compression forces' actuation [1].

By the AFM method can be finished surfaces and edges by extruding an abrasive medium, with variable viscosity, depending on the pressure that it is constrained, and by focusing this medium on the areas which must be finished. Abrasion occurs only there, where the flow of the medium is restricted; other areas remain unaffected.

In order to nanofinish with a reopectic work medium, which has a certain consistence, there is necessary that the medium be focussed by a nozzle, on the part surface, which has to be finished. Function of the part's material properties, of the reopectic medium characteristics and of the quality that must be achieved by this process, it will be determined the suitable cycles number.

The work medium used in order to achieve the processing is a reopectic medium and consists of a polymer which carry a certain concentration of abrasive particles [3]. The work medium is related with the process characteristics and it has as the main parameters the size of the particle, the particle material and the base medium.

- **The particle size.** In the AFM process, the cutting tool is formed by the abrasive particles, and they have the biggest influence on the surfaces quality. If the particles sizes are smaller, then, the removed material quantity will be smaller but the quality of the finished surfaces will be increased. The particle sizes are between 0.005 mm and 1.5 mm. In the same medium they can be used two or three different sizes for the particles.
- **The particle material.** The material of the abrasive particles commonly is silicon carbide but also it can be used boron carbide or aluminium oxide and diamond. The abrasive material choosing depends mainly on two factors. First it depends on the material which will be finished taking into account its density and its physical properties. Secondly, the requirements regarding the final surface's roughness must be considered.
- **The base medium.** The medium temperature can be modified or constantly kept during all processing process. The temperature control during the process is very difficult because the medium is extruded under pressure in the part cavity. The main reason for which the temperature must be considered is that its variation involves the medium viscosity variation. If the temperature increases, the viscosity decreases, and sometimes this might put in danger the abrasive particles suspension in the work medium.

3. MODELATION AND SIMULATION OF THE NANOFINISHING PROCESS

The simulation of the nanofinishing process, using reopectic mediums has as a purpose to supervise the evolution of the main parameters of the work medium, which influences the processing. These parameters are: extruding pressure, flowing speed, temperature and medium viscosity.

For a better correlation with the experimental results, the theoretical model was represented as a 3D model of the experimental system, and the theoretical results are compared with the experimental ones.

The model of the AFM device is presented in the figure 1. The work principle of the device consists in moving the fluid by the part nozzle, by two cylinders which are pneumatic actuated. Function of the pressure and the air supply from the two cylinders, the reopectic medium will pass through nozzle with a certain pressure and a certain speed. The fluid pressure involves the compression of the nanoparticles on the processed surface, and the speed will determinate the finishing level.

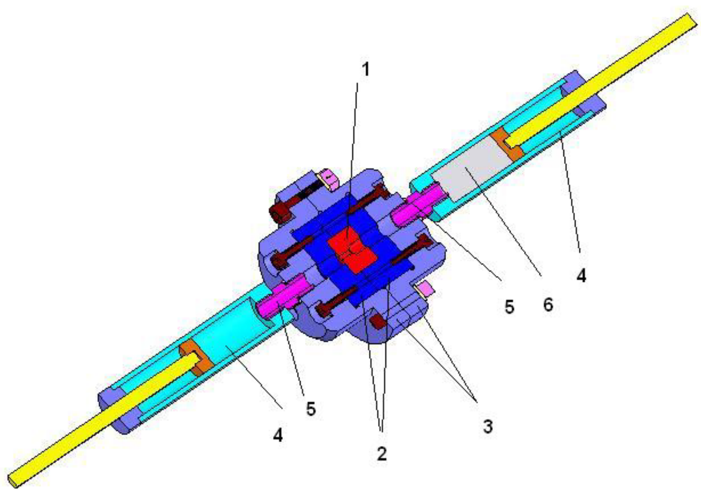

Fig. 1 Device model for AEM nanofinishing. Components

1 – The processing piece;
2 – The box for fixing the piece, which is made for two pieces;
3 – Device body with two flanges;
4 – Pneumatic cylinders (simplification representation);
5 – Bond nipple of the pneumatic cylinders with the device body;
6 – Reopectic fluid.

The nanofinishing system analyse it was achieved using the analyse system ANSYS CAD. After the finite elements method analyses was accomplished, there were determined the pressure variations, the speed variations and the turbulences which appear in any point of the analyzed area. By results interpretation, it can be notice that the process is made right and by input parameters changing, it can be seen the way they influence the process.

It was achieved a process simulation, taking 6 bars for the work air pressure, in the pushing cylinder and 1.5 bars for the other cylinder.

In the figure 2, it can be noticed that in the area of the surface which is to be processed, turbulences appear and they modify the pressure, so there is the possibility of an nonuniform processing for various sides of the nozzle.

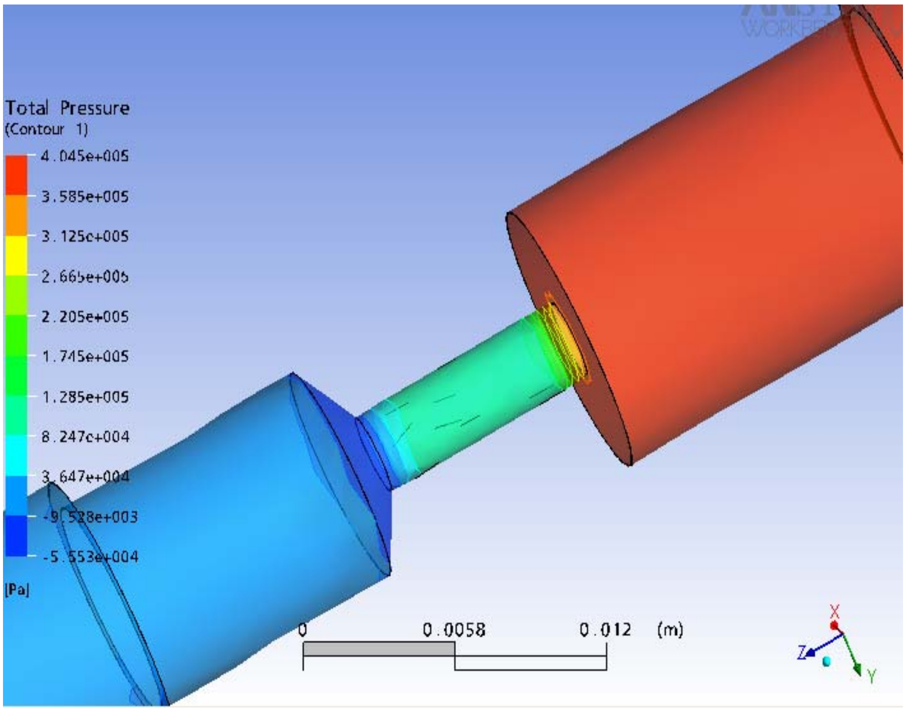

Fig. 2 Turbulences can determine the pressure variation

The fluid speed variation is represented in figure 3. It can be noticed that in the corner areas, the surfaces are not completely covered by the fluid, and the abrasive particles don't work efficiently in those areas. In the processed area it can be observed a non-laminar flowing, with a central crowdedness and rareness on the exterior diameter, and this might bring to some nonregularities on the part surface.

The situation can be improved by increasing the pressure from the cylinder displaced down the part.

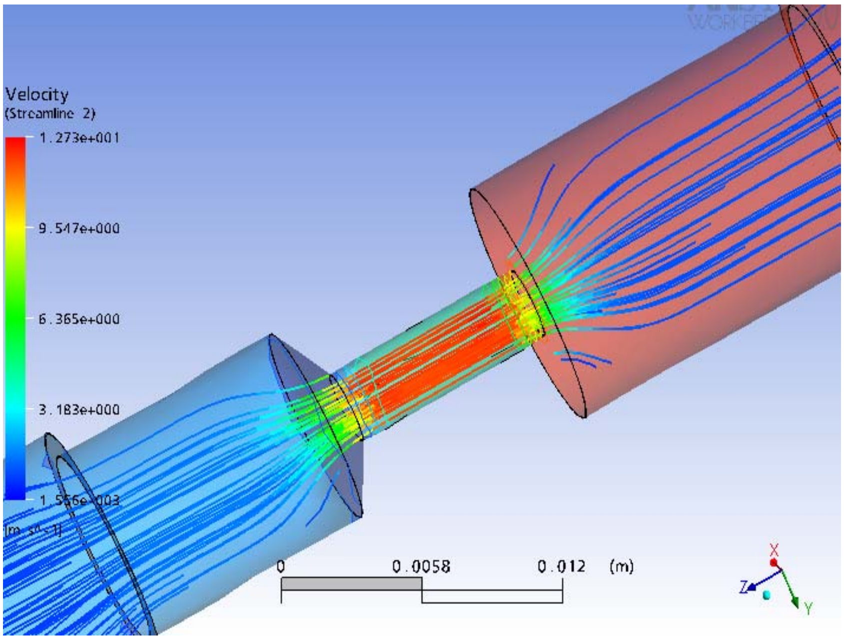

Fig. 3 Fluid speed variation

The fluid passing through the part nozzles brings at the heating of the work medium and also at the heating of mechanical parts which are in contact with the work medium. In the figure 4, it can be noticed that in this case, the temperature variation is maximum 20° C, and this don’t influence too much the materials which are contained by the device’s elements, but it is influencing the abrasive medium viscosity. It can be noticed that the temperature is growing after the entrance in the part nozzle, and especially in the area of exit from this nozzle.

This allows a better processing at the entrance of the reopectic liquid, and a lower one at the exit.

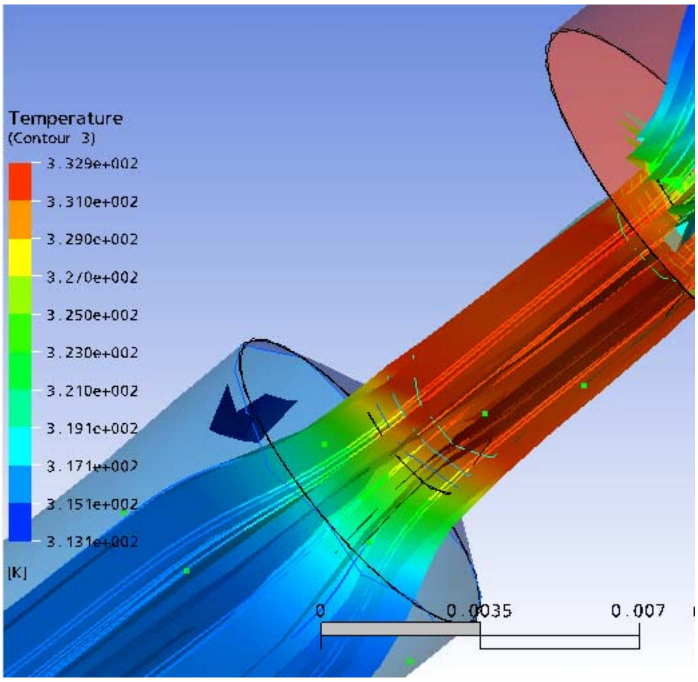

Fig. 4 The temperature variation in AFM process

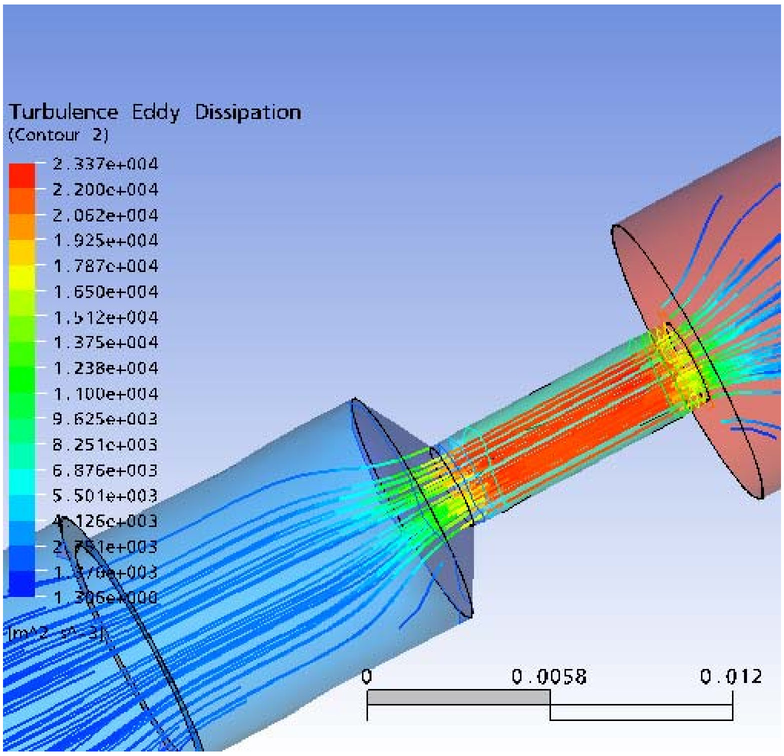

Fig. 5 Turbulences variation in AFM prcess

The temperature increasing involves a viscosity reduction, but also an important changing of the turbulences which appear, as it can be seen in figure 5.

As a conclusion, the process parameters variation expose a nonomogenity of the work medium, which brings to nonuniform processing in various areas of the part which is to be processed.

The situation can be improved if the flowing sense of the abrasive liquid is alternatively changed, and on this principle it is based the equipment designed by ICTCM.

4. EQUIPMENT FOR FINISHING BY ABRASIVE FLOW

The equipment for nanofinoshing, by abrasive flow, which is designed by ICTCM is an universal tool machine, which is made for finishing the patrs which are resulted by cutting and electro-erosion.

The blank is fixed in a work device, which is specific to a part type or to parts aggregate. The surfaces processing is made by AFM process with two opposite cylinders and with the fixed part.

4.1. The component and the technical characteristics of the equipment

The equipment which is designed at ICTCM, is presented in figure 5 and it is made by the following units:

The frame is a welded construction with a ribbed structure. The electrical and pneumatic installations are put here.

The inferior work cylinder is put on the frame. It is made by two cylinders with a diameter of 200 mm and the stroke of 125 mm, which are fixed on a support with columns and its bars are communed with an intermediary part.

The lower cylinder is pneumatic and the higher cylinder is actuated by the lower cylinder. In the higher cylinder there is the reopectic medium.

The work blade assures the displacement space of the device and the real work space.

It is made by a tub and it has at the base the inferior table of the machine and the lower cylinder is fixed on it.

The work superior cylinder has a diameter of 200 mm and the stroke is of 125 mm, and inside of it there is the reopectic medium. It is put under the superior work table and it is actuated by a pneumatic cylinder, by an intermediary part.

The vertical beam assures the equipment frame and it is a welded construction with a ribbed structure.

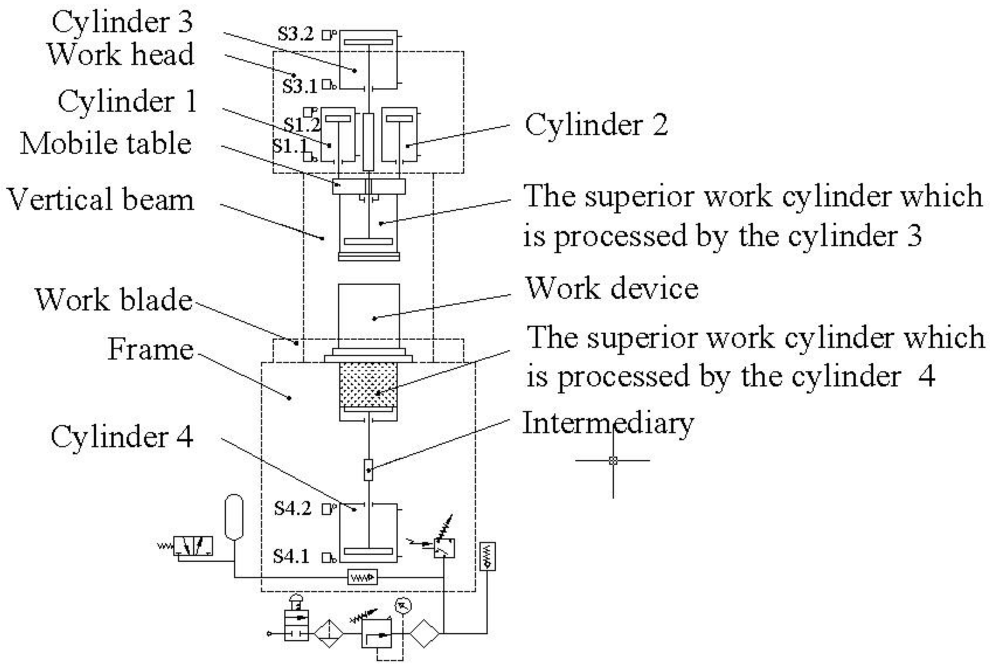

Fig. 6 Equipment for finishing by abrasive flow

The work head is rested on the superior face of the vertical beam. Inside it, there are the two actuating cylinders of the superior work table and the diameter of these cylinders is of 125 mm and the stroke is of 125 mm. The superior work table is guided at descending and ascending, by two columns which are common with it, which coulisses by bushings with recirculary balls, and in this way it is assured the closing and opening of the work device after the die principle. On the two columns there are put some adjustable cams which actuate the micro switches in order to show the open and the close positions of the work device.

Also, inside of the work head is put the pneumatic cylinder which has the diameter of 200 mm and the stroke of 125 mm for actuating the superior work cylinder.

The work device is put inside of the work blade, on the inferior table of the machine. Its role is for positioning, orienting and fixing the piece and also for conducting the abrasive fluid to the areas which have to be processed, and in this way it is assured the work interstice in the processed areas, so the other surfaces of the part are unprocessed.

The main technological and functional characteristics of the equipment for processing by abrasive flow, which is designed by ICTCM are:

- The work pressure for pneumatic cylinders: minimum 5 bar
- The cylinder diameter work head: 125 mm
- Cylinders diameter for processing: 200 mm
- The work cylinders diameter: 200 mm
- The stroke of all cylinders: 125 mm
- The capacity of the work cylinders: 5 liter
- The reopectic work average output: 60 l/min
- The viscosity of work medium: 10-12 Poise (Ns/m^2)
- The size of the abrasive particles: 0,005-1,5 mm
- The used abrasive material: SiC, Al_2O_3, diamond
- The adjustment coverage of the work medium temperature: 30-40°C
- The high size of the procesed parts (ϕxH): 200x120 mm
- The cycles number of the work cylindres: 20-40 cycles/minute
- The productivity: 10-150 pieces/hour
- The final roughness of the procesed pieces: minimum 0,002 mm
- The overall dimension of the device (LxlxH): 1020x840x2930 mm
- The net mass of the device: 1430 kg

4.2. The work thechnological cycle presentation

At the beginning, the superior work table is raised in order to insert the piece in the device. The pneumatic cylinders – 1 and 2 – which actuate the work table, have their bars retired in order to act the micro switch S1.2. The pneumatic cylinder 3 which actuates the superior work cylinder, has also its bar retired in order to actuate the micro switch S3.2. The inferior work cylinder, which is displaced under the fixed inferior table, where there is the work device, has its bar retired. The bar of the pneumatic cylinder 4 is also retired, and this fact is determinate by the micro switch S4.1.

After the part was introduced in the device, this will be closed by lowering the superior work table. For this, there will be actuated the pneumatic cylinders – 1 and 2 – and theirs bars are let down till the micro switch S1.1 is actuated. In the same time, the bar of the cylinder 3 is let down for actuating the micro switch S3.1. In this way the piston of the superior work cylinder is standing down but also it is letting down with the table in the same time.

After the device was closed, the processing cycles can start.

In order that the reopectic fluid ascends from the inferior work cylinder into the superior cylinder throw the processed part, the bar of the cylinder 4 ascends till the micro switch S4.2 is actuated, in the same time with the bar of the cylinder 3 ascending, till the micro switch S3.2 is actuated.

The reverse circulation of the work fluid is made by descending the bar of the cylinder 3 till the micro switch S3.1 is actuated, in the same time with the descending of the cylinder 4's bar, till the micro switch S4.1 is actuated.

After the work cycles' number is finished, the reopectic fluid should be inside of the inferior work cylinder; in this moment it can open the work device by ascending the superior work table. For this fact, there is ordered the ascending of the 1 and 2 cylinders bars from the work head till the micro switch S1.2 is actuated.

In the same time, the 3 cylinder bar ascends till the micro switch S3.2 is actuated.

5. CONCLUSIONS

By applying the finishing technology with reopectic mediums, they can be processed simple or complex surfaces of the parts, which are made from materials with high hardness, in the conditions of time and processing costs reduction.

Also, the nanofinishing by abrsive flow machining with reopectic work mediums involves: the surfaces' quality growing by reducing the roughness, the diminution of the deviation from the shape and also the relative position of the surfaces and the improvement of the loadings state in the superficial layer.

Between the most important applications of the AFM process, there are the following: the finishing and the trimming of the critics components of the hydraulic systems, the trimming of the distributors, used in the craft area [2], the edges filleting and polishing in only one operation for the bearings pockets, the trimming and the polishing of the bodies for Diesel engines injectors, the finishing of the parts made for the surgical implants, the hard layer of fragile materials removing, the polishing of the active sides of the dies, the polishing of the turbines for aircrafts' engines, etc [4].

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