IMPACT PHENOMENA AT THE ABRASIVE JET MACHINING

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Abstract: The abrasive jet machining is based on the material removal due to the hard particles motion in contact with the workpiece surface. Certain physical and mechanical conditions must be fulfilled to generate a process of micro-cutting or micro-cracking, these being the main phenomena able to ensure the material removal from the workpiece. The analysis of the abrasive jet machining may highlights the main input factors which exert influence on the parameters of technological interest. The paper presents some authors considerations concerning the developing of the material removal process at the abrasive jet machining. These considerations will be used to develop adequate equipment for the study of the processes specific to the abrasive jet machining.

Keywords: Abrasive jet machining, Impact phenomena, Surface profile

1. INTRODUCTION

The abrasive jet machining method is based on the effects exerted on the workpiece surface by the abrasive grains placed in a high velocity gas stream [2, 3, 5]. Essentially, the equipment for abrasive jet machining has to include (fig. 1) a compressed air source, a recipient to store the abrasive grains, a nozzle in which the abrasive grains are absorbed in the air stream, a subsystem for positioning the nozzle, a subsystem for positioning and clamping the workpiece, a subsystem for recuperation of the abrasive gains, a recipient where the machining process develops, filters subsystem for the air evacuation etc. There are different techniques which uses the abrasive grains transported by a moving gas to perform a machining process; the most known such process is sanding, but when the pressure of the gas which transports the abrasive grains is higher enough, cutting or drilling processes could be applied.

As above mentioned, nowadays, the most applied abrasive machining jet process is the sanding; even this machining method is well known for some decades, the researchers tried to extend its technological possibilities or to find the optimal work conditions. Of course, other abrasive machining processes were also objectives of the research activities.

Thus, Achtsnick et al. developed [1] a dimensional flow model to calculate the particle velocity of each individual grain in the airflow, by taking into consideration two types of nozzles.

A. -G. Pawlowski included the results of his research about the microblasting with a high resolution [3] in a doctoral thesis presented in 2006.

2. ANALYSIS OF THE IMPACT PROCESS

The abrasive jet machining uses preferentially the effect of the impact of the abrasive grains with the surface layer of the workpiece to which the abrasive jet is directed. Usually, the abrasive jet direction is perpendicular on the workpiece surface, but interesting effects could be also obtained by directing the abrasive jet in an inclined direction to the workpiece surface. To be transported by the moving gas, the abrasive grains must be acted by a force which depends on the compressed air pressure p and on the equivalent area A_e of the grain exposed to the gas stream action:

$$F = pA_e . \qquad (1)$$

As result of its motion with a speed v, the abrasive grain having a mass m_g will have the kinetic energy W_k:

$$W_k = \frac{m_g v^2}{2} \quad (2)$$

The so-called superficial speed of the abrasive grains at the nozzle exit depends on the volume flow Q_g of the abrasive particles and the cross sectional area A_n of the nozzle orifice:

$$v = \frac{Q_g}{A_n} \quad (3)$$

The fraction of the cross sectional area of the hole existing in the nozzle which is available for the flow of the gas can be considered similar to the volume fraction occupied by the transport gas; it is called *void fraction* ε. This means [4] that the fraction of the nozzle orifice area for the flow of the abrasive grain is (1- ε).

Thus, the actual grain velocity can be defined by:

$$v = \frac{Q_g}{A_n((1-\varepsilon)} \ . \quad (4)$$

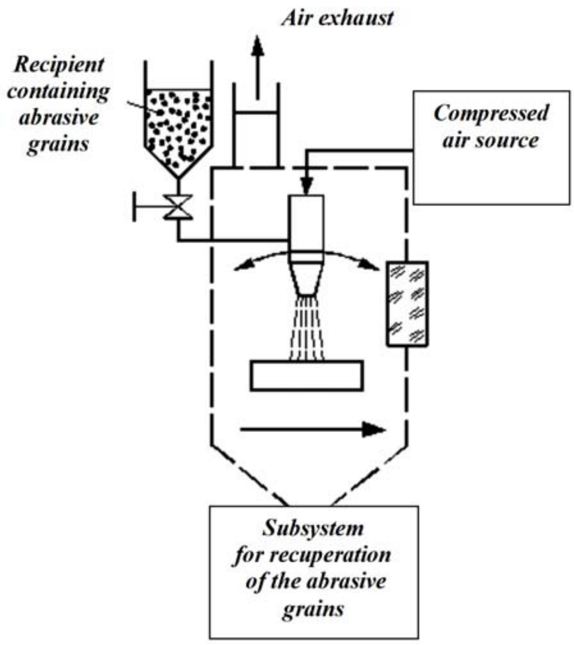


Fig. 1. Structure of the equipment for abrasive jet machining

By taking into consideration the relations (2) and (4), the following relation for the kinetic energy can be written:

$$W_k = \frac{m_g {Q_g}^2}{2{A_n}^2(1-\varepsilon)^2} \quad (5)$$

3. SYSTEMIC ANALYSIS OF THE IMPACT PROCESS

The abrasive jet machining process can be considered as a system characterized by input and output factors (fig. 2). The main *input factors* are:

a) Certain geometrical characteristics of the abrasive grains (dimensions, sharp edges, angles between the active surfaces etc.);

b) Characteristics of the abrasive materials (hardness, shock resistance, ultimate tensile strength etc.);

c) Properties of the workpiece material (hardness, shock resistance, ultimate tensile strength etc; obviously, the hardness of the workpiece material must be smaller with some HRC unities than the hardness of the abrasive grains material and it may be characterized by a certain fragility);

d) Parameters which characterize the gas circulation (pressure, speed);

e) Parameters defining the distance between the nozzle and the workpiece surface, the angle between the abrasive jet axis and the tangent plane to the workpiece surface in the point where the jet axis contacts the workpiece surface;

f) Relative speed between the nozzle and the workpiece etc.

As *output factors*, one may take into consideration:

a) Material removal rate, evaluated usually as the ratio between the volume of material removed from the workpiece in a time unit;

b) Microgeometry of the machined surface (the depth of the cavities, the presence of sharp edges, angles between the surfaces that define the asperities etc);

c) Thickness of the layer affected by the machining process; it is expected that the grains of the workpiece base material are plastically deformed on a certain thickness;

d) Thickness of the layer removed from the workpiece at a single pass of the abrasive jet on the workpiece surface etc.

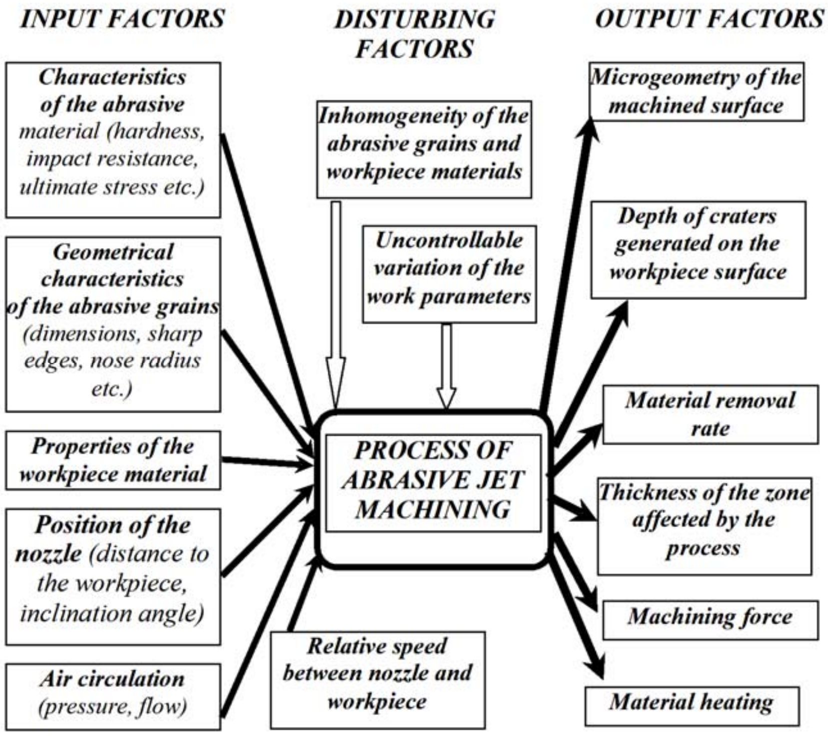


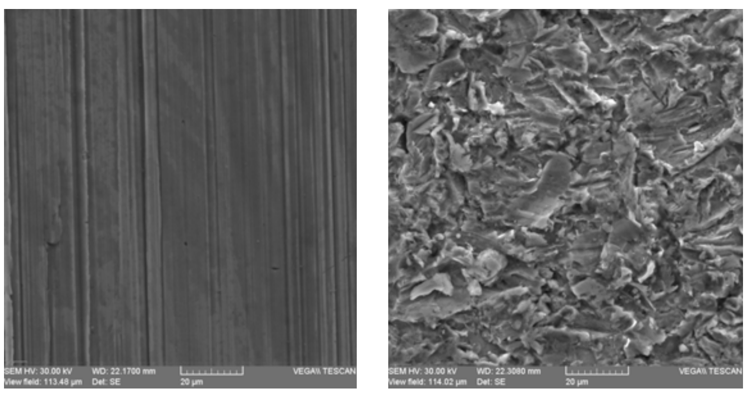
Fig. 2. Abrasive jet machining considered as a system

Of course, some factors could be considered as *disturbing factors:*

a) Inhomogeneity of the workpiece material properties, along the zone where the machining process occurs;

b) Instability of the work parameters etc.

If the direction of the abrasive jet is perpendicular on the workpiece surface, it is expected that as consequence of its impact with the workpiece surface, a part of the kinetic energy to be used to generate microcracks on the workpiece surface; by joining of such microcracks or even by the displacement of the workpiece zones among different microcracks, small quantities of the workpiece material are separated from the workpiece material and afterwards removed from the work zone, also as consequence of the air jet reflected by the workpiece surface.



a b

Fig. 3. Workpiece surface before and after the applying of the sanding (images obtained by means of the scaning electronic microscope, 2500 x magnification).

4. SURFACE PROFILE

To emphasize the aspect of the surface obtained by abrasive jet blasting, the profile of this surface was studied by means of a scaning electronic microscope (fig. 3) and a surface roughnessmeter type Mitutoyo (fig. 4). The initial surface (test piece made of low carbon steel) was prepared by grinding, being characterized by a surface roughness

R_a=0.89 µm. The test piece was affected by a blasting process (average dimensions of the abrasive grains – 0.13 mm, gas pressure 0.25 MPa).

One may remark that after the blasting, the surface roughness increased (R_a=1.32 µm). The image obtained by means of the scaning electronic microscope highlights the aspect of the machined surface, including a concatenation of small groves generated by the action of the abrasive grains.

The image proves also the existence of the zones affected by the plastic deformation of the metallic material.

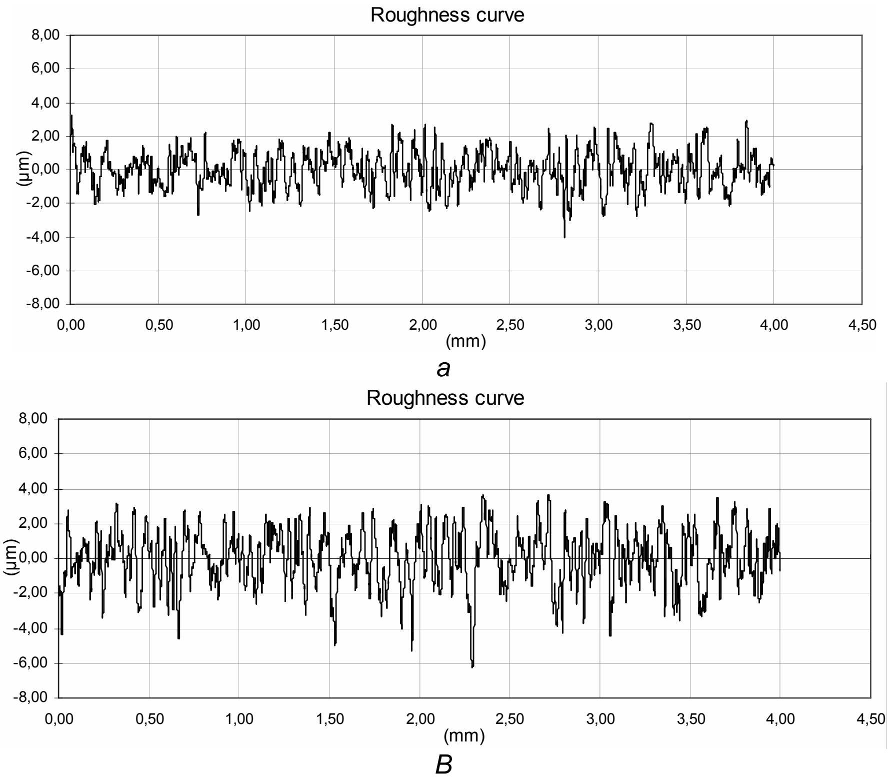


Fig. 4. Roughness curve before (a) and after (b) applying of the sanding (images obtained by means of the scaning electronic microscope, 2500 x magnification

5. CONCLUSIONS

One of the abrasive jet machining techniques is the abrasive jet blasting. Some considerations concerning the speed of the abrasive grains were elaborated. The experimental research proved the change of the surface profile as consequence of the applying the abrasive jet blasting. The systemic analysis allowed to highlight the main factors able to influence the results of the abrasive jet blasting; such factors will be considered in design of an equipment for study the abrasive machining process.

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