FUNCTIONAL REQUIREMENTS FOR AN ABRASIVE EROSION TEST EQUIPMENT

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Abrasive erosion is one of the forms of manifestation of erosion processes capable of affecting the operation of certain parts. When such parts include polymeric materials, it is important to have information on the materials' behavior to abrasive erosion.

In pursuing the identification of equipment usable for abrasive erosion testing, the requirements that must be met by the various subsystems were analyzed. The analysis carried out allowed the gradual contouring of an equipment solution based on pressing the test sample with a force of known magnitude on a cylindrical abrasive surface when there is a relative movement between the two components.

Keywords: abrasive erosion, process analysis, testing equipment, functional requirement.

1. Introduction

In the field of machine manufacturing, erosion is considered to be a mechanical process by which material is gradually removed from a solid body, as a result of the action of various factors. Erosion processes can be generated, for example, by the action of thermal factors, such as laser beam, electron beam, or thermal plasma, or by chemical factors, in the case of chemical or electrochemical erosion. When these factors are abrasive grains in motion relative to the surface of the solid body, it is a process of *abrasive erosion*. Abrasive erosion effects are used in manufacturing technologies to remove surplus material constituted by so-called machining allowances. From the point of view of manufacturing technologies, it is

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of interest to know some aspects related to the intensity of the abrasive erosion process, to the extent that abrasive erosion can reach a certain level of the asperities generated on the surface of the workpiece or to certain changes in the superficial layer of the workpiece material, etc.

Plastic material is a non-metallic material, usually with an amorphous structure, obtained by melting together different constituents, such as resins, plasticizers, dyes, lubricants, constituent or filler materials, auxiliary materials, etc. In general, plastic materials have the property of being able to be shaped with relative ease in the temperature range of 140-180 ° C, a range in which these materials are characterized by high plasticity. There are known uses of plastic materials for making various objects. In some cases, they are also used for the manufacture of parts intended for equipment that will work in abrasive environments. In such situations, plastics should have a high resistance to abrasive erosion, but not all plastics are characterized by a high resistance to abrasion. For such reasons, it has been reached, among others, the use of composite materials, i.e., materials made up, in this case, of a non-metallic mass, called *matrix* and, respectively, *reinforcing elements*, intended to contribute to improving the behavior of parts made of composite materials to certain categories of mechanical stress. As reinforcing elements, fibers of different lengths, fabrics, felt, particles of different sizes and materials, etc., can be used. A way to improve the abrasive erosion behavior of some parts made of materials with matrices of plastic materials is the inclusion in the materials of the respective parts of some granules of harder materials. Thus, some composite materials are used.

Over the years, different solutions have been identified to obtain plastic materials capable of providing increased resistance to abrasive erosion.

Mahapatra and Chaturvedi investigated the abrasive wear behavior of some composite materials using the Taguchi approach [1]. The tested material was a composite material with a matrix made of polyester resin and with reinforcing elements in the form of short lignocellulosic fibers.

A review of the abrasive erosion resistance of some polymeric nanocomposite materials was elaborated by Malucelli and Marino [2]. They believed that by studying how to remove material through abrasive erosion, more efficient designs for nanocomposite materials could be developed.

A scientific investigation regarding the abrasion resistance of some commercially available polymeric materials was undertaken by Pejakovic et al. [3]. They sought to highlight the influence exerted by polymer hardness and abrasive particle embedment on the wear behavior generated by the presence of silicon dioxide particles.

Ashrafizadeh et al. investigated the possibilities of increasing the service life of some equipment in the land gas industry by covering it with a protective layer of polyurethane elastomers [4]. Some surfaces of such equipment are affected by material loss as a result of the impact and sliding of a particle stream. It was appreciated that the good behavior of the polyurethane elastomers from the point of view of resistance to abrasive erosion is due to high resilience and the ability to absorb the impact energy of the eroding particles.

Hrițuc et al. presented results of experimental tests on determining the abrasive erosion behavior of plastic parts manufactured by 3D printing [5, 6]. By processing the experimental results, they determined empirical mathematical models capable of highlighting the intensity of the influence exerted by certain factors on the abrasive erosion resistance in the case of using the pin-on-disk method.

In the present work, some aspects of the processes that develop at the microscopic level and that determine the development of abrasion processes will first be analyzed. Intending to design and materialize a device or equipment that allows abrasive erosion testing of some samples made of composite materials with a polymer matrix, some requirements that such a device or equipment must meet will be formulated. Later, by taking into account such requirements, it will be used to design the base scheme of equipment or devices adaptable to some of the machine tools existing in a mechanical workshop.

2. Abrasive erosion process

An abrasive erosion process occurs when free or embedded abrasive particles in an abrasive body are forced to move relative to the surface of the solid body that will be subjected to an abrasion effect. If the abrasive particles have sufficient energy, if they have appropriate geometries and positions, if they are made of materials having a hardness higher than the hardness of the workpiece material, and if the particles move along a certain trajectory, they will contribute to the development of micro-chipping processes. These processes will end with the detachment of small amounts of the workpiece material affected by the abrasive process, usually as very small chips (Fig. 1, a). A simultaneous or consecutive action of several abrasive particles will determine the development of an abrasive process.

Abrasive particles can move in contact with the surface of the workpiece, for example, as a result of their inclusion in a more or less flexible abrasive tool. They can also exert an abrasive effect as a result of the movement of free abrasive particles by a liquid, a gas, or a material that has good flow properties.

If the abrasive tools are preferentially used for materializing processes of grinding, and polishing, including with cloths or abrasive papers, there are, on the other hand, possibilities for cutting with an abrasive fluid jet, in which case the abrasive particles are transported with the help of a gas jet or liquid (e.g., using a water jet). A more special application is the vibration of a liquid containing abrasive

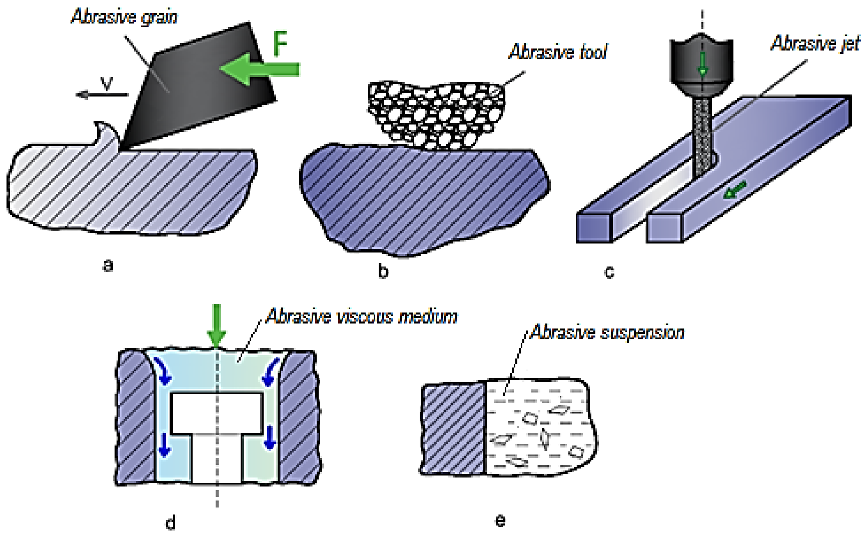

Fig. 1. The generation of a microchip by an abrasive particle (a) and, respectively, the use of abrasive erosion processes in grinding (b), in abrasive jet cutting (c), in machining with abrasive grains carried by a viscous medium (d), and in abrasive-cavitation machining

particles in suspension. Such a solution is used, for example, in the ultrasonic processes of abrasive-cavitation machining.

If in the case of processing with abrasive grains, there is an interest in the abrasive grains developing abrasion processes, in the case of some machine parts that will work in abrasive environments, the question arises of evaluating the ability of the materials from which these machine parts are made to withstand better to abrasion erosion.

Such an evaluation takes place by using samples whose surfaces are subjected to abrasive erosion processes. The evaluation of resistance to abrasive erosion usually takes place by measuring the amount of material removed by abrasion in a certain time interval or by measuring the change in some dimensions of the test samples after time intervals during which the test samples have been subjected to abrasive erosion processes.

3. Requirements for a device for experimental research of the abrasive erosion process and solutions for their fulfillment

It was considered to carry out some experimental research that would highlight the influence exerted by different factors on the resistance to abrasive erosion of some samples made of polymer composite materials. For this purpose, it is necessary to design a device or equipment that allows the determination of some values characteristic of the abrasive erosion process and, at the same time, ensures conditions for changing the magnitudes of some factors entering the process.

Next, the main functional requirements that such equipment must fulfill will be briefly analyzed.

Composite material test sample shape and dimensions. Too small test sample sizes will not allow longer experimental tests to be performed, while larger test sample sizes could excessively increase the dimensions of the device. It was decided to use cylindrical samples with a diameter of 8 mm and a length of 25 mm.

Selection of test scheme. It is appreciated that the abrasive erosion testing will be based on the relative displacement of the test sample on the abrasive surface of a solid body, the respective surface having abrasive grains. For the time being, a test scheme based on the use of loose abrasive grains will not be considered. The names of abrasive erosion test schemes are currently used that take into account how the test sample is pressed against the surface of the abrasive body. Pin-on-disk, pin-on-cylinder, and pin-on-belt test schemes are thus known (Fig. 2). Establishing the test scheme also involves defining the mode of relative movement between the test sample and the work surface belonging to the abrasive body. The existence in the space where the experimental tests are to be carried out of some machine tools in which the main shaft performs a rotational movement has led to the consideration of a pin-on-cylinder type test scheme. Such a scheme can be materialized on a universal lathe, which will provide conditions for turning a mandrel that will have a cylindrical surface with abrasive properties.

Establishing the subsystem for locating and clamping the test sample. As such subsystems, small vices, chucks, and bushings to insert the test samples and to be provided with screws for clamping the test samples could be used. Among the different subsystems for locating and clamping the test sample, it was chosen to use chucks that allow a safe and fast clamping of the test sample.

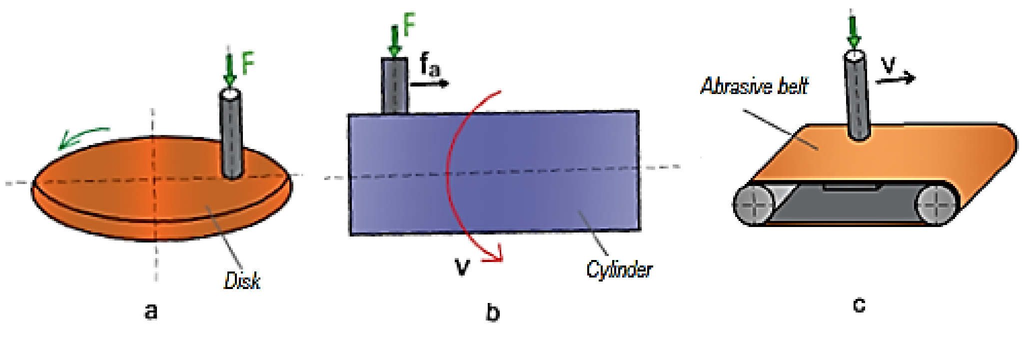

Fig. 2. Working schemes usable for abrasive erosion testing: a – pin-on-disk; b – pin-on-cylinder; c – pin-on-belt in movement

Identification of a solution for pressing the test sample on the abrasive surface. Spring subsystems, using weights, generating or hydraulically transmitting pressure of known value, could be considered to meet such a functional requirement.

Ensuring the movement training of the body that has an abrasive surface. Solutions involving the use of a dedicated motor could be considered, or, in the case of a device adaptable to a machine tool, the necessary movement could be performed by the machine tool's spindle.

Ensuring additional movement of the test sample on the surface of the abrasive body also implies the existence of less-worn areas of this body. To meet such a requirement, additional motors could be used for the movement of the test sample on the abrasive surface. In the case of an adaptable device on a universal machine tool, the possibilities of using a feed motion commonly existing on such a machine tool could be identified.

Providing possibilities for quantitative assessment of resistance to abrasive erosion. Such a requirement could be met by periodically measuring a dimension of the test sample affected by the erosive process or by tracking the change in mass of the test sample as a result of material loss through abrasive erosion.

Apart from the main functional requirements mentioned before, it is of course also possible to formulate some requirements related to other aspects of the constructive solution pursued. For example, identifying a way to locate and clamp the device on a machine tool or the components capable of supporting the other subsystems, in the case of a stand-alone test rig, could be under consideration.

3. Proposed solution for an abrasive erosion test equipment

Considering the previously mentioned functional requirements and some constructive solutions identified in the accessed specialized literature, a variant of the abrasive erosion testing device adaptable to a universal lathe was gradually outlined (Fig. 3).

As can be seen in Fig. 3, such a device could use a mandrel on the outer cylindrical surface, which can be placed in abrasive papers characterized by different values of abrasive grain sizes.

To exert a pressure force by the test sample on the cylindrical abrasive surface, it was decided to use a subsystem equipped with a plate on which different weights of known sizes can be placed. Assuming that a weight G is placed on the plate and that the gravitational force corresponding to this weight will be transmitted entirely to the subsystem of locating and clamping the test sample of diameter D, the pressure p exerted by the test sample will be:

$$p = \frac{4G}{\pi D^2}. \quad (1)$$

The components for supporting and pressing the test sample could be located on a Z-shaped part, which could be located and clamped in one of the four slots of the universal lathe tool holder.

To avoid keeping the sample on the same area of the abrasive surface, which would mean reducing the intensity of the abrasive erosion process by using an area of the abrasive paper that will register a certain amount of wear, it will be considered to drive the carriage in a straight feed movement, together with the tool holder in which the subsystem for locating and clamping the test sample is placed and, respectively, the subsystem for generating the force of pressing the test sample on the abrasive surface of the paper mounted on the mandrel.

The use of a chuck to locate and clamp cylindrical test samples having diameters of 8 mm and lengths of 25 mm was considered.

Quantitative evaluation of mass loss by the test sample will require periodic disassembly of the test sample from its locating and clamping subsystem and weighing of the test sample using an analytical balance. After removing the test sample, a measurement of the length of the test sample becomes possible, which should decrease as a result of the abrasive erosion process.

4. Conclusions

The need to increase the resistance to abrasive erosion of the materials of some parts that work in abrasive environments has led, among other things, to the use of composite polymer materials, whose resistance to abrasive erosion has been increased by including some particles of harder materials. Distinct test schemes can

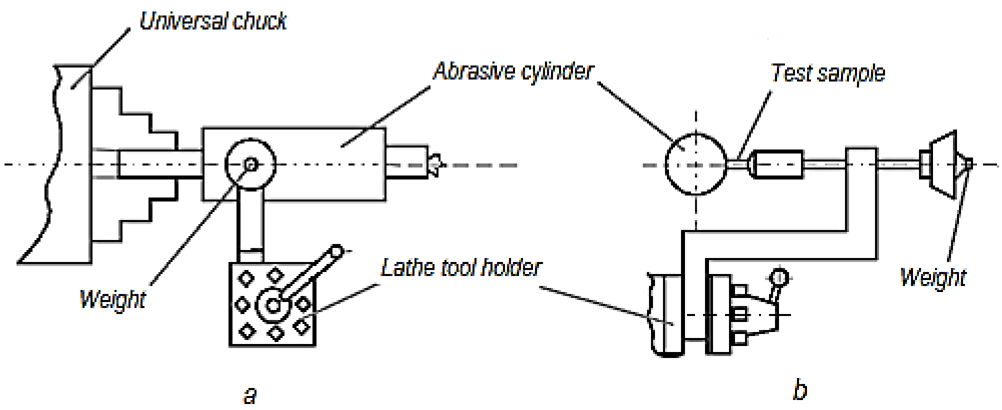

Fig. 3. Abrasive erosion test device adaptable to a universal lathe

be used for testing resistance to abrasive erosion, which has led to the promotion of distinct equipment and devices for testing resistance to such stress. To develop some experimental research to evaluate the resistance to abrasive erosion of some composite polymer materials, the problem of designing equipment or a device that can be adapted to other machine tools and that can be used for the quantitative evaluation of material loss to the test samples by abrasive erosion was analyzed. For this purpose, the main functional requirements that the equipment or device must meet were formulated, and different ways of meeting those requirements were analyzed. The analysis allowed the step-by-step design of a solution for an abrasive erosion test device adaptable to a universal lathe. Such a device would allow the use of some facilities that the universal lathe has in terms of making different movements and, respectively, some possibilities of easy modification of the sizes of some input factors in the abrasive erosion process. In the future, it is planned to materialize the device and use it to evaluate the wear resistance of some test samples made of composite polymer materials.

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