

EXPERIMENTAL STUDY OF ALUMINIUM SURFACES CREATED BY WATERJET WITH PRESSURE 0,9 GPa

ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ АЛЮМИНИЕВОЙ ПОВЕРХНОСТИ, СОЗДАННЫЕ ГИДРОАБРАЗИВНАЯ ПРИ ДАВЛЕНИИ 0,9 ГПА

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Abstract: The paper deals with the experimental study of aluminium surfaces created by waterjet with pressure 0,9 GPa. The experimentally prepared surfaces from aluminium have been evaluated by means of grid projection method. The grid projection method was used for measurement of samples from the aluminium.

KEYWORDS: ABRASIVE WATERJET, SURFACE TOPOGRAPHY, ROUGHNESS

1. Introduction

Along with the development of technology, the scientists and the technologists in the field of manufacturing are facing more and more challenging problems. The demand for the highest accuracy and surface finish, the challenge to produce critical surfaces and complex shapes has necessitated for the use of non-traditional machining techniques. The use of such non-traditional machining techniques is found to be the best option for manufacturing complex dies and aerospace components with the required high precision and accuracy. Competition and scientific progress requires introduction of technologies that perform challenging claims of modern production in automation field, from economy, environmental and energy efficiency point of view. Abrasive waterjet cutting represents all of these claims. Knowledge of the topography of surfaces and their classification is very important for machining techniques. In the report optical methods will be used for the investigation of the surface structure cutting of areas [1], [4], [5]. Optical methods are based on illuminating by defocused laser beam and white light beams [16], [17], [18], [19]. Measurement of surfaces generated by water jets and abrasive water jets is quite difficult. It is caused by specific surface structure. In contrast to classical methods, the surface created by water jet is rather diffuse [9], [11]. Both visualization and analysis of the relationship between surface relief structures and the characteristics of the machining tool, machining process and machined material is the object of the paper. This work is at the interface of many fields such as solid state physics, physics of liquids and optics with their technical application for the metrology of surfaces created by water jet machining.

2. Geometrical specification of surface structure

In Fig.1 we can see the specific characteristics of the surface profile of samples cut by WJ. Further parameters for the quantification of surface quality are defined in the engineering literature [2], [3] and standards [10].

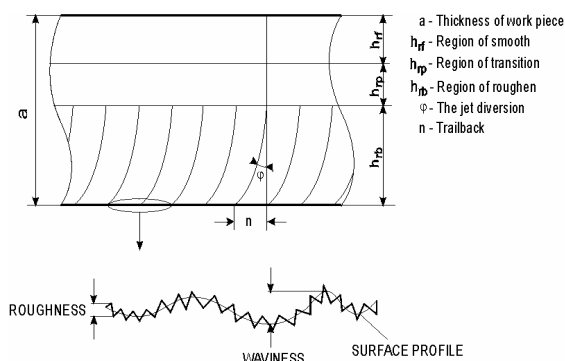


Fig. 1 Drawing of the most typical patterns on the walls inside the slot cut by water jet

Nevertheless, many of standards are derived especially for the measurement of surface quality of workpieces by a contact profilometer. Most of them can be evaluated by optical measurement of surface quality. In the case of measurement by contact profilometers we use direct measurement and the indirect measurement is used for optical methods.

The shape of the cutted walls depends on the front spreading of WJ from the upper to the lower side (Fig.1). This is an image of the changes in the mechanism of disintegration. All the authors were concerned about the physical-mechanical aspects of the interaction of disintegration energy accumulated by the water jet with the mechanical structure of the material [7], [20]. They divide these cutting walls into an upside qualitative smooth cut and the part of the cut deformation beginning from the critical depth. Unevenness of the upper part of the cut is considered as microscopic, mostly unevenness at the roughness level. Unevenness in the lower part of the cut is already macroscopic with the presence of grooves and slots on the surface, mostly at the waviness level [7], [8]. By using a term of critical depth h_c which means the depth when the mechanism of disintegration changes quickly, mostly from shear disintegration to pressure destruction of the samples. Experimentally discovered equations for the calculation and prediction of this depth, for example, reveal its functional dependence on many technical parameters, such as abrasive mass flow rate, traverse rate, average of WJ, effective amount of particles in the cut etc. So the angle of fall α of abrasive particles in the AWJ cut is changing. The critical angle α_c is the angle corresponding to the critical depth h_c . Authors [6], [7], [9] have the opinion that the shear cutting characteristics of the stream change to pressure destruction at critical angle α_c .

3. Experimental study

The experiments have been provided at the Institute for Werstoffkunde in Hannover. The samples from 15 mm thick aluminium have been prepared under following conditions; traverse rate $v = 10 \text{ mm} \cdot \text{min}^{-1}$, pressure $p = 0,9 \text{ GPa}$, diameter of the nozzle $d = 0,1 \text{ mm}$ and with standoff distance 2 mm.

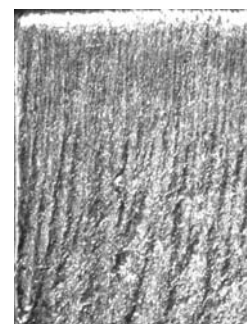


Fig. 2 The character of the surface made by waterjet with pressure 0,9 GPa (material – aluminium $b = 15 \text{ mm}$)

Surface has been scanned by optical signal by grid projection method throughout the zones situated around the lines perpendicular to the sample height at the distances 2, 4 and 6 mm from the top, according to the direction of the abrasive water jet flow.

4. Results and Discussions

We can see more or less illuminated places on the illuminated surface. From the illuminated surface the transformation to 2D is obtained and then it is possible to perform single cuts on the 2D. Information about the structure of the surface is obtained from signals of the surface profile from zones A, B, C for WJ technology. We can see that the first part of the 2D photo is much more illuminated. This more illuminated part belongs to the initial zone that means to the area which is more illuminated. We can also see that there are some places in other parts which are only slightly illuminated. The following problems exist:

- with more or less illuminated parts on the surface – that depends on achieving homogeneous illumination. There is no way to change the illumination angle in the case of measurement with the commercial device, so that satisfactory uniform illumination cannot be achieved.
- on the structure it is possible to see very small mirror spots which induce false signals in the measured signals. These false signals have the effect of garbling the information and they thus contribute to the noise part,
- the measured length is very small, about 3 mm. From a statistical point of view it is necessary to take into account a number of such sizes.

The trend is the same during the whole cut except the width, which changes continuously from the upper to the bottom part. The spectra in Fig. 6, Fig. 7 and Fig. 8 are obtained from the WJ signals in Fig. 3, Fig. 4 and Fig. 5.

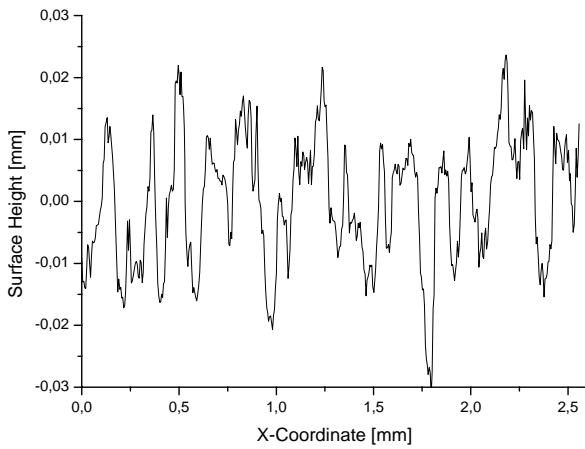


Fig. 3 The signal of zone A surface profile

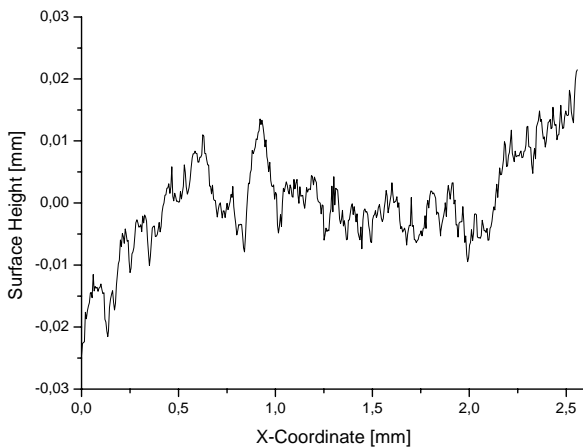


Fig. 4 The signal of zone B surface profile

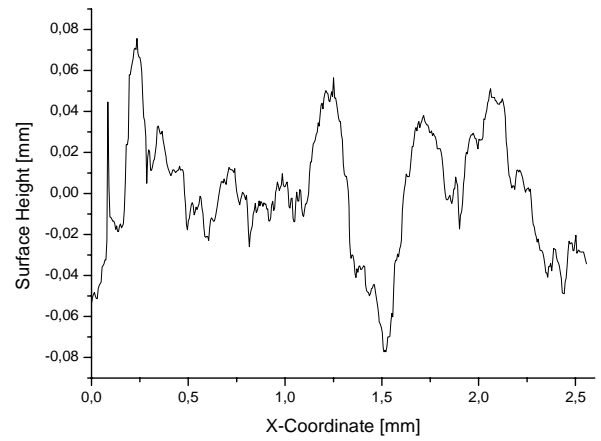


Fig. 5 The signal of zone C surface profile

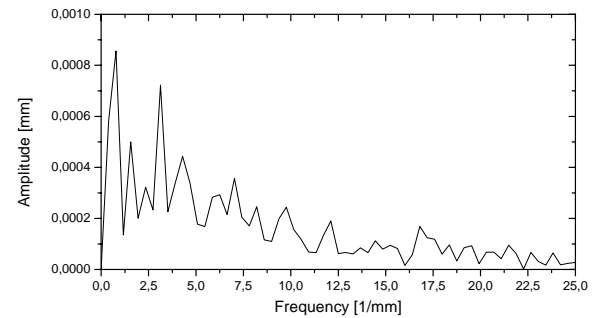


Fig. 6 Frequency spectrum of the signal - zone A

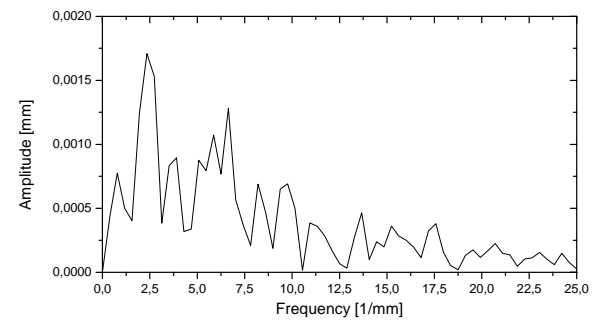


Fig. 7 Frequency spectrum of the signal - zone B

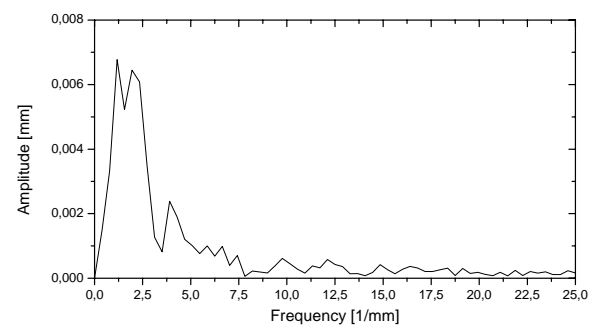


Fig. 7 Frequency spectrum of the signal - zone C

The experimental results obtained show that the surface correlation length increases along a trace of the water jet. The correlation length represents the horizontal property of a surface profile. The stochastic component in the upper part of the cut is much bigger than in the lower part.

The spectra obtained give information about the quasi-periodical as well as the random part; moreover, we can distinguish the amount of waviness and roughness. From the practical point of view the spatial frequency range can be divided into a spectrum composed of three parts, namely: (0 – 2.5) mm⁻¹ – the waviness, (2.5 – 20) mm⁻¹ – grooving and slotting, which is hard to distinguish from the

roughness (20 – 100)mm⁻¹ because they depend on the vibration of water equipment.

It is believed that:

- the waviness – is due to the instability of the water-jet, owing to outflow (discharge, flowing out) and consequently to fluctuation in the pressure pump;
- in the spectrum other components (defects) are superimposed, namely from lateral vibration and longitudinal vibration of the jet's mechanical equipment. By stopping the water jet, a dimple is created in the wall and thus the groove is extended;
- roughness – is due to random influences such as for example the cavitation effect, rising turbulence etc.

From these 3 areas it was created a classification table with general validity. But of course we need further measurements to confirm this table. For the creation of the classification table it has been used 100 spectra obtained in the "Wasserstrahl Labor" laboratory in Hannover and 500 spectra obtained using the shadow method. It has been made 1 table which is valid for both technologies (the same scale was used [19]).

5. Conclusion

The lack of full understanding of the cutting process is still a frequent problem. There are still different opinions on the physical process of machining in the literature. It is very complicated and interesting problem because of occurrence of combinations of several affects for example the cavitation effect, turbulence etc. Of course by measurement of vibrations, acoustic emission and other measurement methods could be traced some dependencies, which demonstrative on the surface topography related to the process of machining, so physical action of machining can be far better described. We think, that differences between WJ and AWJ may be following:

- non-coherent jet which is composed of water + air + cavitation vapour bubbles,
- the deformation removal is far more destructive,
- the cavitation effect is far more destructive (micro-explosion),
- the kinetic energy changes into potential energy and a deformation created by work
- (the jet strikes an effective area and the jet affects the pressure and begins to affect
- destructively), the water is reflected by the material (inhomogeneous, anisotropic) and
- affecting traction-it is destroyed by pressure, the cavitation vapour bubble on
- the material bursts and is dragged up by traction from the cutting wall of particles
- before being destroyed by the pressure,
- the obtained spectra give information about the quasi-periodical as well as the random
- part, moreover, we can distinguish the quantity among of waviness and roughness,
- the roughness/waviness surface height vs. frequency are given for different surface
- zones along the water jet stream.

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