Machining of rotationally symmetric parts with abrasive waterjet

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Abstract. Recently, water jet cutting is widespread, because almost any material can be machined by this machining method. The technique and technology of cutting has also improved a lot. Further utilising of waterjet cutting advantages could Application of waterjet cutting for machining surfaces with different geometries (rotationally symmetric parts) beyond simple cutting tasks, could be a further utilisation of this method. This paper demonstrates a solution for machining cylindrical surfaces by abrasive waterjet. For this examination of kinematics at machining of cylindrical parts could be the starting point. Appropriate movement conditions can be created by considering the machine as a basic machine and complementing it with a water jet cutting head or a device which can be installed on the water-jet cutting machine. We have developed an equipment for this latter solution. Design aspects and the device are presented in the paper.

1. Introduction

The main advantage of waterjet cutting is that it is possible to cut so complicated planar curve which with other technology is not workable. During the application of abrasive waterjet cutting technology, heat effect does not affect the material so its’ structure does not suffer during the machining. The great advantage of the waterjet cutting in contrast with other technologies, that this is a cold cutting process [1]. This technology does not cause fracturing in the material, and suited for cut different materials, therefore the application field is wide.

This technology is applied on cutting in the food and automotive industry, in manufacturing of medical appliances. In addition it is applied on work of arts and mosaics. Almost all materials can be machined: non-metallic materials (simple and fiber reinforced plastics, rubber, leather, paper, textiles), brittle materials (glassware, ceramics, rocks, and concrete, building materials), tough materials (non-ferrous metals, iron and nonferrous metals, in any heat treatment condition), soft, flammable materials, plastic foams.

In general terms, abrasive waterjet cutting machining offers a set of unique capabilities: cuts any materials regardless of their mechanical, wear-resistant properties which makes the process attractive for part generation in difficult to cut materials, generates negligible heat during the material removal process which is an advantage when machining heat sensitive alloys [2].

Aim of this work is to create a device that allows the machining of rotational symmetrical parts from the above mentioned materials with help of waterjet machining. This machining from external point of view is very similar to turning operation that is why this method is called waterjet turning.
2. Essence and characteristics of waterjet turning
Because of the good characteristics of abrasive waterjet cutting there are a lot of researches oriented on investigation of application waterjet in other machining methods. Most often, the kinematic relationships of the chip removal processes are applied for the machining with abrasive waterjet. From this point of view, we can say about waterjet milling, drilling or turning. In the following sections the abrasive waterjet turning will be discussed.

2.1. Kinetics of waterjet turning
Waterjet turning from external point of view is very similar to the normal turning process accomplished with a single point tool. Workpiece has a rotational motion while the tool has a linear motion, usually parallel with the axis of the workpiece. The depth of cut determined by the relative displacement of the waterjet and the workpiece [3]. Some elements of the waterjet turning can be seen on Fig. 1. [4] Forces effecting on the workpiece are neglectable.

![Figure 1. Elements of waterjet turning](image)

The depth of cut is a result of more process parameters and defined by the machinability of the material, the displacement of the waterjet and the real speed of the grains, which defined among others by the water pressure and the abrasive mass flow rate. [4]

According to the kinematics of the turning the main cutting speed is the speed of the jet, ie. the speed of the abrasive grains in the jet. There are two auxiliary motions here, a linear feedrate of the jet along the contour of the workpiece and a circular feedrate of the workpiece (rotation).

2.2. Technological parameters of abrasive waterjet turning
There are a lot of parameters affecting on the geometry of the workpiece at waterjet cutting. The depth of cut determined not only by the displacement of the jet, but the efficiency of the jet and the machinability of the workpiece as well. The diameter of the jet is a technological characteristic too. The formed geometry of the workpiece depends on the cutting speed ($v_c$), linear feedrate ($v_l$), circular feedrate ($v_{cin}$), the displacement and direction of the jet and the energy of the waterjet.

The efficiency of the jet is determined by the water pressure (p), the abrasive mass flow rate (m), and the geometry of the primary (water) and secondary (abrasive) nozzle of the cutting head, the extent,
and the material of the abrasive grains. From these parameters usually, the pressure and the abrasive mass flow rate are easy to change.

Depending on the energy of the jet, the actual machining diameter can be formed in two ways. The jet either completely cuts the material or just at a certain depth. (Fig. 2) When machining rotationally symmetric parts, extent of the removed material depend on the energy of the jet [5][6]. When planning the machined diameter of the workpiece results of kerfing tests (not cut through tests) can be a very good base information to define technological parameters (abrasive mass flow rate, pressure, and feedrate).

![Figure 2. Formation of the workpiece diameter depending on the energy of the jet](image)

Formation of the machined diameter of the workpiece is shown on Fig. 2. Extent of the final diameter depends on the energy of the jet, and the displacement of the jet according to the workpiece axis.

3. **Characteristics of the planned device for waterjet turning**

For turning with abrasive waterjet, a special device should be planned. This device should be meet the following requirements:

- the waterjet machine tool assures the waterjet and the linear feedrate, the device assures the circular feedrate
- the device should be stable fixed on the machine tool
- workpiece should be fixed in the device
- electrical and corrosive parts of the device are protected from the water

During the design, the workpiece rotating device was divided into three main units: a power unit, one waterproofing structure and one supporting structure.

The power unit is an infinitely variable drive ensuring the fixing and rotation of the workpiece. This task is solved by a three-jaw chuck and pulleys. For the infinitely adjustment of the number of revolutions a toroid-type transformer with speed meter was applied. The device is able to change of the direction of the rotation motion. The speed meter is shown in Fig. 3.
For protect the device from the coming back water a special waterproofing structure was planned. All these parts should be place on a special supporting structure with help of which the device can be fixed on the waterjet machine-tool. This part should ensure the parallelism of the axis of the workpiece end the linear motion of the cutting head. Considering the supporting structure, the dimensions of the machine-tool and the range of motions, the place of the waterproofing element can be defined.

After planning and manufacturing of the parts, the waterjet turning device was assembled (Fig. 4). First, dry motion tests have been accomplished for today. The power of the motor, the stability of the rotation parallelism of the motions were tested. During these preliminary tests all the appeared mistakes were eliminated.

For the waterproofing the device has a special protective cover made of polymer, soft PVC. Fig. 5 shows the waterproofing structure of the waterjet turning device. The test part are under pre-machining from steel and aluminium-alloy material.[7] Different fixing mandrels and other fixing elements are available for the tests as well. For today the device can work for real cutting tests.
Figure 5. Waterproofing structure of the waterjet turning device

For planning and implementation of cutting experiments technological parameter should be determined. These main parameters are as follows: cutting speed \((v_c)\), which is defined by the pressure of the water, the abrasive mass flow rate and the geometry of the nozzles; feedrate speed of the cutting head \((v_f)\) and the circular feedrate speed \((v_{circ})\) of the workpiece defined by the rotation of the workpiece.

On base of previously accomplished cutting tests oriented to the determination of depth of kerf on different these turning parameters can be estimated. In the first waterjet turning test we will estimate the needed cutting parameters by this way, with help of previously made kerfing nomograms.[8]

4. Summary
Planning of a special waterjet device was shown I this paper. For today the device has been produced. With help of this device waterjet turning can be accomplished on a two-dimensional waterjet machine tool. This gives the possibility to machine cylindrical part (or rotationally symmetric parts) from special materials difficult to cut by chip removal. Future tasks of the research work to investigate the connection between the very high numbers of technological parameters and the geometry of the machined parts, the analysis of the efficiency and accuracy of the cut.

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