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Process Monitoring of Abrasive Waterjet Formation

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Abstract

Difficult to machine materials require innovative processing solutions for a stable and high quality contouring process of complex forms. Abrasive waterjet cutting gains in importance due to the continuous development of novel high performance materials and multi-material components.
A reliable process monitoring during the machining operation becomes essential to avoid waste production. However, the measurement of the process conditions during abrasive waterjet cutting is difficult based on the rough environment inside the machining zone. In this paper appropriate methods for in-process monitoring of the jet conditions, in particular the critical nozzle wear as well as other process output parameters are being tested, discussed and classified.

Keywords: Waterjet machining; In-process measurement; Monitoring

1. Introduction

In the context of developing novel high-performance materials new challenges become apparent during their manufacturing, especially in machining. In particular, multi-material components are difficult to handle due to the fact that different types of materials usually require different tool geometries for the best machining result possible. Abrasive waterjet machining is a process that overcomes this barrier with an almost unlimited processing variety of diverse materials [1].

Raising the process stability at a simultaneous increase of the operating time of the nozzles, which results in a reduction of the downtime, necessitates new methods for the in-process monitoring of abrasive waterjet machining. However, due to the demanding contamination with reflecting splash water, water fog or abrasive particles, a measurement recording of the waterjet quality after the outlet of the cutting head is not useful during contouring or surface structuring [2].

2. Process Disturbances and their Influence on the Machining Result

During abrasive waterjet cutting based on the injection principle, first of all the pressure of pure water is increased above 3,000 bar by using a high pressure pump. The water runs through a so-called water nozzle, thus changing the hydraulic energy into kinetic energy. Here, water can achieve a speed of 800 m/s and more [3]. Inside the mixing chamber an underpressure, which intakes the applied abrasive particles, arises due to the high velocity of the waterjet. In the focusing tube the abrasive material is being accelerated and aligned in its flow direction [4]. In this context the water inside the abrasive waterjet only serves as an acceleration fluid. The abrasive particles are responsible for the cutting action [5]. Hashish et al. [6] describe the different influences on the waterjet inside the cutting head, impairing the machining result. One of these factors is the condition of the water nozzle.

As a result of furring, blockages due to dirt and disruptions

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at the water nozzle, the kinetic energy of the pure waterjet is already being influenced [7]. In this connection turbulences occur as well as a consequential nonpoint fanning out of the waterjet inside the mixing chamber. So, the process typical recess of the focusing tube caused by continuous contact between the abrasive particles and the inner surface of the nozzle is intensified. As expected, besides a change of the acoustics, there is a transformation of the kinetic energy of the waterjet to thermal energy as a consequence of the friction between focusing tube and the abrasive waterjet. This factor is connected with an intense speed reduction of the cutting jet. Thus, the acceleration of the abrasive material is insufficient for chipping as well.

Interruptions and accordingly blockages of the abrasive supply can be related to water contamination of the abrasive inlet or bad suction performance inside the cutting head. In this case, no more abrasive material is added into the cutting jet anymore. Inevitably, a process interruption occurs.

Based on the knowledge of these facts and the difficult circumstances inside the workspace, it proves to be useful to interpret the process conditions inside the cutting head without monitoring the waterjet pattern itself.

3. Experimental Equipment and Setup

The investigations were executed using a test stand of Technische Universität Chemnitz for 5-axis simultaneous machining via abrasive water fine jet based on the injection principle (cf. Fig. 1).

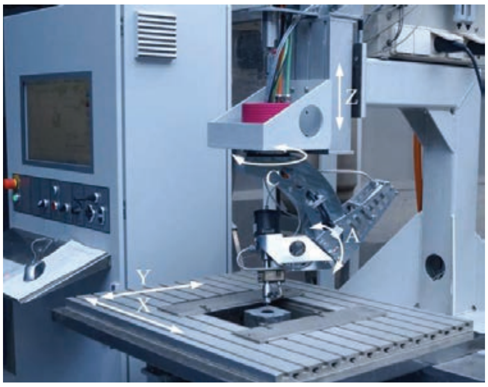

Fig. 1. Experimental rig abrasive waterjet cutting.

A waterjet with a diameter of 0.8 up to 1.0 mm is used for conventional machining tasks [8]. However, the diameter of the examined abrasive water fine jet being used for precise machining is 0.3 mm. According to [9, 10, 11] the diameter ratio between the water nozzle and the focus nozzle is 1:3 for ideal flow conditions. Appropriate nozzle diameters were utilized accordingly. The length of the focusing tube was set to be 24 mm.

Due to the adverse conditions inside the working space of a 5-axis abrasive waterjet machine, first of all measurement systems have to be preselected regarding their usability. The utilized sensors and their positioning at the cutting head are illustrated in Figure 2. Under the presupposition that disturbances inside the cutting head cause changes in its thermal conditions, a thermocouple was positioned in direct contact with the water nozzle carrier. As a result of a changing friction rate, for example due to damages at the sapphire nozzle, changes of the temperature in this area can be detected without influencing the possibility to replace the nozzle. In order to validate the results as well as to collect the temperature changes due to changed flow conditions, a resistance thermometer was attached at the outside casing of the cutting head near the mixing chamber.

Furthermore, a monitoring microphone capsule was positioned in a borehole inside the cutting head carrier, directed towards the mixing chamber. Thus, surrounding noises shall be faded out and changes of the flow conditions shall be detected to the greatest extent possible.

By conducting structure-borne sound measurements it is possible to detect vibrations of the cutting head. The vibrations can be a result of the start of oscillations, which occur, for example, due to changing flow conditions inside the mixing chamber and the focusing tube. The monitoring principle was executed by the application of a single-axis accelerometer directly attached to the cutting head. The accelerometer was positioned in a way to record radial amplifications of the head. Reference values were delivered by a second tri-axial accelerometer attached to the machine frame near the cutting head.

The observation of the air volume flow inside the abrasive particle supply offers valuable clues concerning the wear status of the water nozzle. Ideally it is possible to detect blockages of the abrasive particle supply as well. The measurement took place by using a single-pipe flow measuring system that had been attached inside the abrasive supply hose.

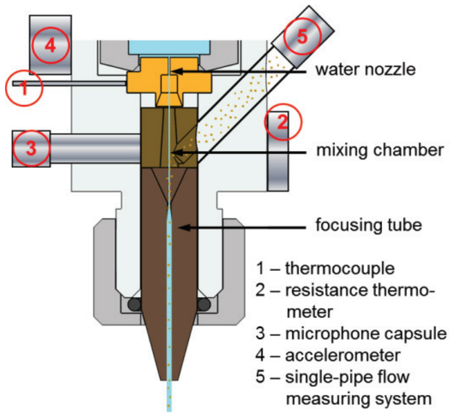

Fig. 2. Cutting head and position of the measurement equipment.

4. Experimental Procedure and Results

The investigations were carried out using the parameter combinations listed in Table 1. During data acquisition, the abrasive waterjet was switched on as usual for a machining operation. After that, constant process conditions without feed motion were recorded in a time range of 15 seconds. Finally, the turning off of the jet was recorded, as well.

The experiments took place under different water nozzle conditions. Figure 3 shows the wear states of the two utilized water nozzles and its effects.