Robot assisted fluid jet polishing of advanced materials

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Abstract

Aalen University has developed a high pressure fluid jet polishing and lapping system, which is able to remove material in the range of several 10 microns as well as to remove material in the nanometre range and to smooth surfaces. Existing available fluid jet systems (see e.g. [1], [2], [3]) are designed for shape correction of optical surfaces within the nanometre range. In addition to the shape correction the Aalen system is designed to offer a broad range of removal rates, from nanometre polishing to micrometre lapping. In this paper the results of the robot assisted fluid jet polishing to machine hardened steels, ceramics and glass are described. Attempts to improve the positioning of the movement system with the use of image processing methods and machine vision are presented and discussed.

1 Introduction

The increasing number of advanced materials generates manifold challenges in their processing. Robot assisted fluid jet polishing is a promising way of machining those new materials. Aalen University is investigating the possibilities of this new processing method within the context of the FRAM project, a joint research project on free formed surfaces made of advanced materials together with Furtwangen University, Deggendorf University as well as several industrial partners. The aim is to develop a process with a large variety of removal rates for advanced materials which generates in parallel low roughness surfaces by smoothing the surface on different materials and surface geometries.

2 Setup at Aalen University

The setup at Aalen University consists of a robot as a movement system and a high-pressure pump with tubes and a nozzle for generating the fluid jet (cf. fig. 1). A machine vision system with camera and image processing tools is used for calibration of the positioning.

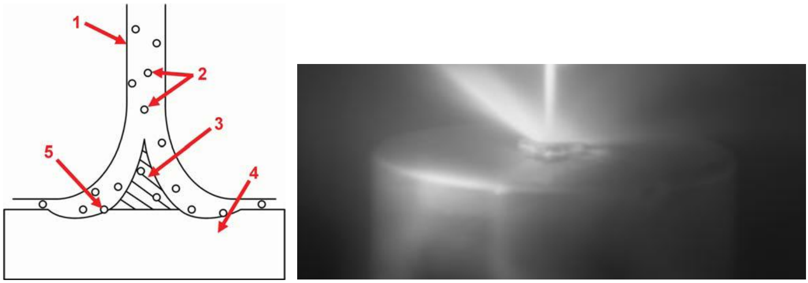

Figure 1: Principle (left) and picture (right) of the fluid jet polishing and lapping; 1 - jet, 2 - abrasives, 3 – low fluid flow, 4 – workpiece, 5 – abrasives generating removal

2.1 Movement system

The movement system used in this process is a standard type six axis industrial robot. This kind of robot is often used for processes like e.g. welding or spray painting. The movement system positions the nozzle in respect of the workpiece and moves it over the workpiece surface on a predefined path with variable, also predefined speed.

2.2 Fluid jet polishing system

The fluid jet system consists of an industry standard high pressure pump driven by a frequency converter and equipped with a pressure control. The pump can be controlled via the robot CNC code; therefore a very good repeatability can be achieved. The robot-mounted nozzle is connected via flexible tubes. The nozzle itself is also a standard industrial product. We used powder based solutions for the following experiments but the fluid jet system is also capable of handling other polishing agents as well. To achieve good results it is necessary to adapt pressure and dwell time profiles for the machining of different materials.

2.3 Machine vision system

For improving the positioning of the movement system and therefore the positioning of the fluid jet on the workpiece surface a machine vision system was used. A camera is taking pictures of the fluid jet under different angles of incidence. Proprietary software is calculating correction values out of those pictures. The values are then fed back into the CNC code generation for the movement of the robot. The positioning of the nozzle in respect of the workpiece is a crucial factor. The first tests already show good results and are further investigated.

2.4 CNC code generation

The key element for a successful processing is the CNC code generation with suitable software algorithms. The CNC code for the movement of the robot and for the process parameters of the fluid jet system is generated offline using proprietary software "Zaphod" [4]. The path of the nozzle over the workpiece surface is calculated using all geometric parameters from robot and workpiece as well as the determined correction values of the machine vision system. The removal for the fluid jet polishing is dwell-time controlled. This means the longer you stay at a specific point of the workpiece surface, the more material is removed. Therefore the velocities have to be adapted to the workpiece material and the desired type and amount of removal.

3 Experiments

As a first test, areas of 100mm^2 are removed with different feed rates from several types of material. As an example the removal on a BK7 glass is shown in figure 2 and 3. With a typical, classical polishing, the removal would be a factor of 100 less.

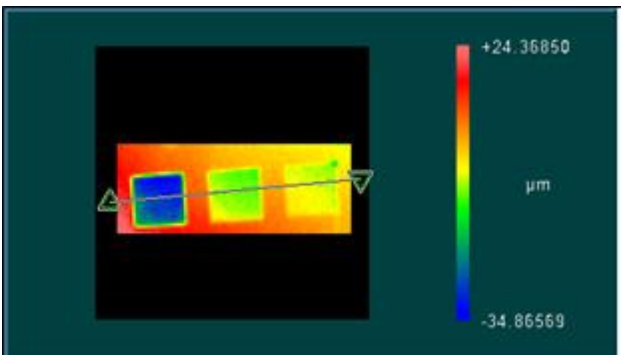

Figure 2: Removal of fluid jet lapping on BK7 glass with 3 different feed rates (false colour plot, top view)

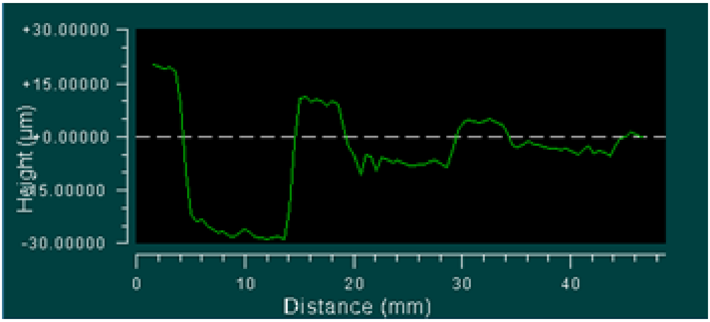

Figure 3: Removal of fluid jet lapping on BK7 glass with 3 different feed rates (axial cut/side view), the maximum removal is 45µm and the removal is proportional to the feed rate

4 Acknowledgments

The authors like to thank the German Federal Ministry of Education and Research BMBF for funding the work under the "Fram Project" (FKN 17098B10).

References:

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