AUTOMATED SYSTEM FOR PREDICTION OF TECHNOLOGICAL PARAMETERS OF ABRASIVE WATER JET CUTTING MECHANISM

AUTOMATIZOVANÝ SYSTÉM PRO NÁVRH TECHNOLOGICKÝCH PARAMETRŮ HYDRO-ABRAZIVNÍHO DĚLENÍ MATERIÁLU

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Abstract

The abrasive waterjet technology is used today mainly for cutting metal materials. However, it is possible to use this technology also for cutting non-metal materials like marble or other materials whose surface must comply with specific parameters. Cutting non-metal materials using the abrasive waterjet technology is quite rare at present and we can find it mainly in laboratories. The main reason can be complicated settings of technological parameters. Technicians working with these mechanisms can predict these parameters based on their previous experience. Without such experience or when using new materials they have to make a lot of experiments to find the right technological parameters. The main task of this paper is to show how to use modern small computers to apply the automated system for the prediction of necessary parameters for the abrasive water jet cutting system which is developed at our university. This automated system can be helpful especially for the technicians who works with the abrasive waterjet technology or it may be part of robotized workplaces in future.

Abstrakt

V dnešní době je technologie hydro-abrazivního paprsku (AWJ) užívána zejména pro dělení kovových materiálů. Avšak tuto technologii je možné také využít pro dělení nekovových materiálů např. mramor nebo jiných materiálů, u kterých je důležité získat povrch s určitými parametry. Využití této technologie pro dělení nekovových materiálů je v dnešní době zatím ojedinělé, protože nastavení technologických parametrů je velice komplikované. Technici, kteří pracují s tímto zařízením, obvykle nastavují technologické parametry podle předchozích zkušeností. Pokud však nemají předchozí zkušenosti nebo pracují s novým materiálem, musí provést mnoho testů, tak aby byli schopni nalézt odpovídající technologické parametry. Článek je zaměřen na seznámení s automatizovaným systémem pro návrh technologických parametrů technologie AWJ a využití malých počítačových systémů. Tento automatizovaný systém je použitelný zejména pro techniky pracující s technologii AWJ a nebo v budoucnu může být součástí robotizovaných pracovišť v dolech.

Key words: Abrasive Water Jet, Prediction, Robots, Marble Mine

1 INTRODUCTION

The modern waterjet cutting technology was initiated by Norman Franz in 1968 [BURNHAM, C. D., KIM, T. J.]. However, this technology was not widely accepted in industry, till the ultrahigh pressure pumps became commercially available in the mid 1980's. Today, as one of the most recently developed non-traditional cutting processes, the Abrasive Water Jet (AWJ) technology, has been found to have extensive applications in manufacturing industries for machining a wide range of metals and non-metals by using a fine jet of ultrahigh pressure water-abrasive slurry. It has been particularly used in cutting 'difficult-to-cut' materials such as ceramics and marbles, and layered composites [BITTER, J].

A conventional AWJ cutting system normally includes four major modules (Fig. 1): an intensifier pump, providing high-pressure water; an abrasive delivery system and a cutting head producing the abrasive waterjet; a computer controlled manipulator, which effectuates the desired motion of the cutting head; and a catcher, which dissipates the remaining jet energy after cutting [BUMBÁLEK, B., OBVODY, V., OŠŤÁDAL, B. and BURNHAM, C. D., KIM, T. J.].

This technology is mainly used in two ways:

a) for disintegration (cutting) of material

b) *for cleaning cutting surfaces*, where the material was disintegrated by a different technology.

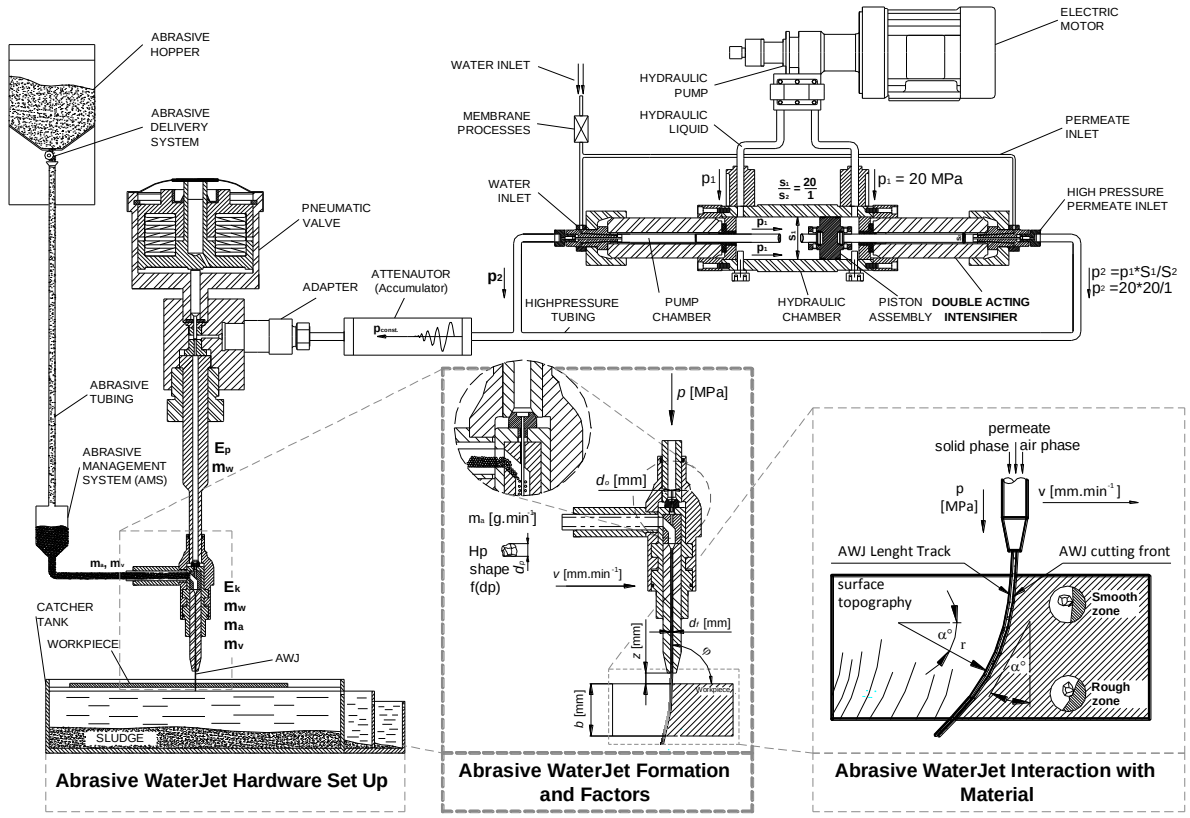

Fig. 1 Overview of Abrasive Water Jet Hardware [VALÍČEK, J., HLOCH, S., KOZAK, D.]

2 ABRASIVE WATERJET DISINTEGRATION PROCESS AS A SYSTEM

To be able to control this disintegration process automatically it is necessary to describe this process as a system. To do this we have to choose output parameters from this process and define input parameters. A graphical description of this system is presented in Fig. 2.

These output parameters are divided into two categories. The first category is defined by the customers who want to disintegrate some materials. The customers usually need to disintegrate materials with a specific depth and quality. The other category of parameters is defined by the owner of the abrasive waterjet technology. The owners usually need maximum productivity with minimal operating costs. This category represents two parameters – cutting speed and power consumption.

In this process a lot of input parameters exists affecting output parameters. It is a reason why we didn't show here all these parameters. We described here only some categories with few parameters in Tab. 1. In these days most people working with the abrasive waterjet technology must set all the input parameters for the disintegration process to acquire a specified depth and quality of cutting surface. It is a serious problem, because a large number of input parameters exists with a quite huge range of each. Usually these parameters are set by the user of the abrasive waterjet technology who has some experience with the disintegration of specific materials. However, if there is a new material then many experiments must be realized with this new material. And it takets money, time, material and energy.

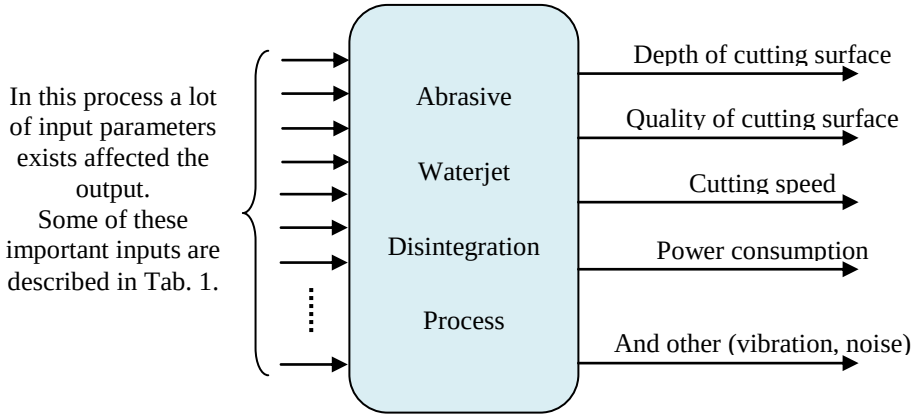

Fig. 2 Abrasive Waterjet Cutting Process as a System

Tab. 1 Examples of input parameters classified into categories

Categories of input parameters	**Technology**	**Hydraulics**	**Abrasive**	**Mixing**
Some examples of input parameters	*Stand off* z [mm]	*Pressure* p [MPa]	*Abrasive material*	*Length of focusing tube* l_F [mm]
	Traverse rate v [$m.s^{-1}$]	*Orifice diameter* d_o [mm]	*Abrasive feed rate* m_a [$kg.min^{-1}$]	*Diameter of focusing tube* d_F [mm]
	Traverse direction s [°]	*Material of orifice*	*Particle diameter* d_p [mm]	*Material of focusing tube*
	Impact angle φ [°]		*Shape of abrasive material*	*Abrasive feeding direction* f_d [°]

3 SYSTEM FOR PREDICTION OF INPUT PARAMETERS

At our university we try to develop a control system for the abrasive waterjet technology. To use the control system with a real time feedback is quite complicated for this process. It is a reason why we started to develop the control system without feedback. A model of this control system is presented in Fig. 3.

The main aim of this control system is to predict the output parameters which are used as input parameters into abrasive waterjet disintegration process. By this control system it is possible to set up the optimum input parameters of abrasive waterjet cutting process much more effectively. With respect to the size of abrasive waterjet system our team develops a remote control system which can be used in online or offline modes.

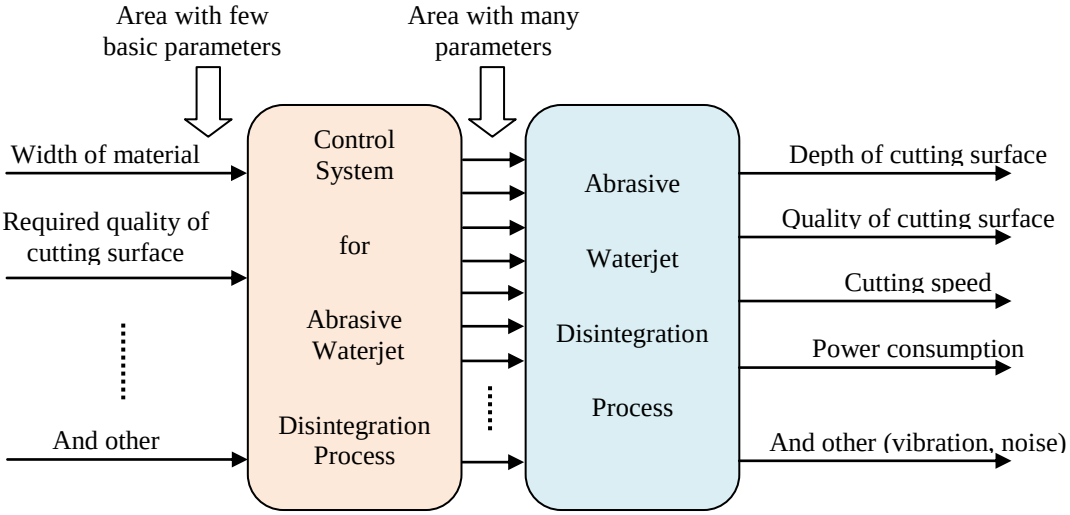

Fig. 3 Control system for Abrasive Waterjet Cutting Process

The online mode means that the predicted parameters can be directly uploaded into abrasive waterjet system and the user can control the start/stop operations of the cutting process. The offline mode means that the user can use this control system for example to calculate preliminary cutting costs of a specific material. It can be useful also for managers and not only for technicians. The offline mode can be used also to determine specific material cutting plan. For example, the customers need to cut some shapes in different materials, then it is important to choose the correct order of materials beibg cut. If we choose the right order of materials, then we need to change a few parameters on the abrasive water jet machine before starting to cut a next different material. This correct order increases the productivity.

For the control system implementation we focuse on small computers like PDA (Personal Data Assistants) or smart phones, because at present these computers are used by more and more people and are comfortable.

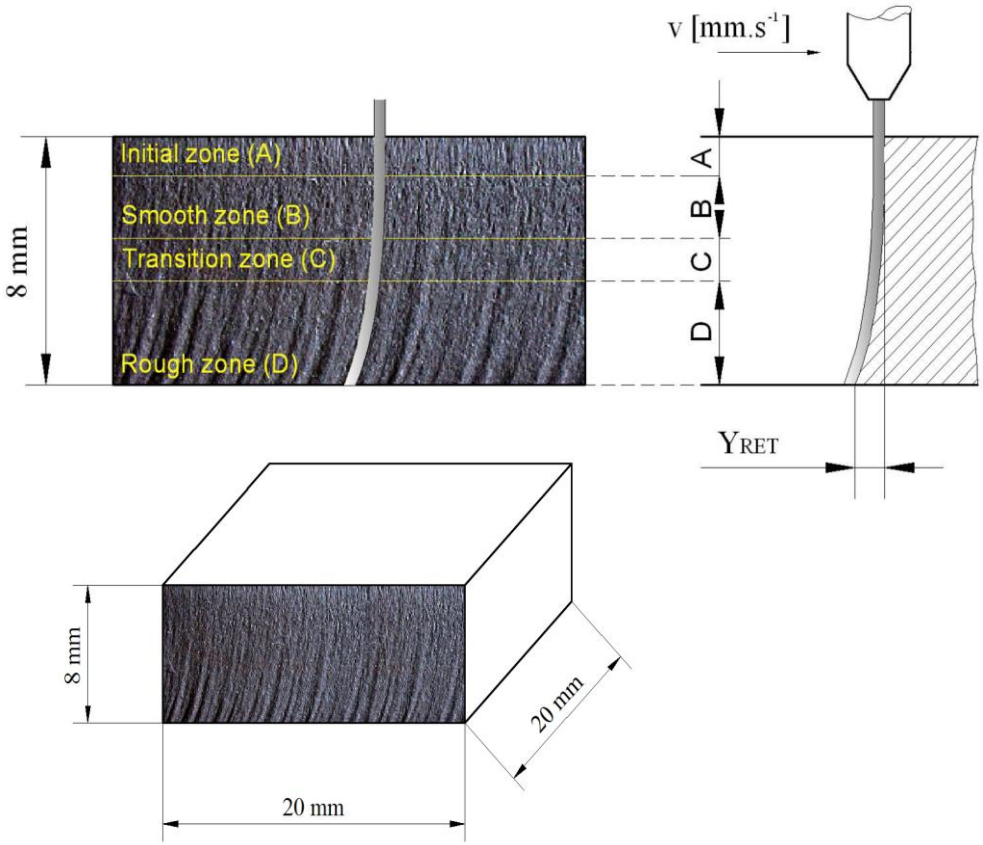

Fig. 4 Topography example of surface created under AWJ factor conditions, traverse speed v = 200 mm/min, material AISI 309 [VALÍČEK, J., HLOCH, S., KOZAK, D.]

4 CONLUSIONS

At present we realize this control system for PDAs and smart phones with the operating system Windows Mobile 5.0 and higher. This system can be used in the offline mode only,. but we work also on the online mode system. We prepare as well the application of optimization methods for calculating most parameters.

We expect the utilization of this control system also in future, because we suppose that in future more autonomous robotic workplaces will exist . These autonomous robots will need to use a similar control system like we mentioned in this paper. However, this control system will be only a small subsystem in a more complex system.

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RESUMÉ

Technologie hydro-abrazivního paprsku je v dnešní době doménou specializovaných pracovišť. Jedním z důvodů je fakt, že pro dosažení požadovaného výsledku je nutné vhodně nastavit mnoho technologických parametrů. Některé z těchto parametrů jsou uvedeny v Tab.1. Avšak ono vhodné nastavení parametrů obvykle vyžaduje velké zkušenosti s danou technologií a s konkrétním typem materiálu. Tzn., pokud tyto zkušenosti chybí, je obvykle nemožné dosáhnout specifických vlastnosti děleného materiálu. Doposud se tato situace řeší prováděním experimentálních vzorků, na kterých lze zjistit, který technologický parametr je třeba upravit. Tento způsob nalezení vhodných hodnot technologických parametrů je sice funkční, ale v praxi často velice nákladný. Zejména na čas, energii a materiál (v případě drahých materiálů, např. titan apod.). Z tohoto důvodu na VŠB TU Ostrava probíhá vývoj automatizovaného řídicího systému, který by mohl řešit zmíněné nevýhody doposud používaného způsobu nastavování technologických parametrů.