ANNOTATION

The preparation of the theoretical model enabling creation of the master program for a liquid jet technology automation is the topic of this doctor thesis. The problem is tackled by virtue of the theoretical analysis of the physical phenomena of the process. Transformation of the static energy of the liquid in the pump into the kinetic energy of the liquid jet is described by the own semiempirical relationship. This relationship makes possible to determine the shape of the velocity profile as a continuous function of the Reynolds number value. The evolution of the velocity profile shape along the jet in medium between the nozzle outlet and the target material surface is derived from the continuity and the exponential attenuation of force on the plane perpendicular to the jet axis. The theory describing the cumulative charge is used for derivation of the coefficient of attenuation. The interaction of jet with target material is described by the conservation laws of mass and energy. The material parameter is specified applying momentum conservation law. This law together with law of inertia are used for analysis of the jet - abrasive material interaction in the mixing chamber based on the ejector principle and dedicated for generation of abrasive liquid jet. Physical relationships describing these processes form the base model for determination of quantitative jet effects on the worked up material.

Outputs of relationships derived for description of the origin and evolution of the liquid jet velocity profile as well as outputs of relationships for determination of the energy attenuation in the medium between the nozzle outlet and the target material surface are compared with results of special experiments focused on measurement of the liquid jet force. The methodology is developed enabling determination of values of the liquid jet velocity profile from the jet force data and the jet cross section close to the impact plate of the force sensor. Comparison of the values calculated from the theoretical relationships and data obtained from measurement of jet forces verifies the applied theoretical model. Relationships for quantitative determination of disintegration of either abrasive or target material are verified by comparison of results with the large package of experimental data. Some coefficients and parameters are implemented or specified according to this comparison. The resulting model is compared with data obtained from liquid jet technology use in practice. This comparison also proves very good correlation of the outputs from theoretical model and experimental results.

The computer program based on the proved theoretical model is carried out. It is utilizable for analysis and prediction of liquid jet technology efficiency. Program can be upgraded to the master program for particular application. It is proved by comparison of results obtained from the program and the ones acquired in practice that the outlined task is fulfilled and the model applicable for processing of the master programs for the liquid jet technology automation is prepared. Theoretical and experimental know-how is used for proposition of the master program structure. The program is dedicated for automated control of machining of elements, especially non-rotary ones, made of glass and rock materials by abrasive water jet.

CONCLUSIONS

In this work focused at the creation of the model for liquid jet parameters control there are firstly summarised physical conditions and presumptions for this task. Control of the jet parameters is directly dependent not only on the variable parameters (e.g. pressure before nozzle) but also on the large amount of fixed parameters resulting from the technological and other requirements (e.g. material of the water nozzle, shape of the water nozzle outlet). Therefore the attention is also paid to the description of the physical processes proceeding upon generation of the liquid jet and its evolution in the medium filling the space between liquid nozzle and target material. The most important criterion of the work is the highest possible simplicity of the physical relationships and equations because too complex and sophisticated relationships with complicated computing may complicate the required on-line control.

The description of the liquid jet generation and evolution is followed up by description of its interaction with material in solid state. It may be the abrasive particle the liquid jet is impinging on in the mixing chamber and mixing tube during generation of the injection abrasive liquid jet or the material to be processed by liquid jet. The physical description of the pure liquid jet and abrasive liquid jet interaction with material is presented simultaneously. The laws of conservation of energy, momentum and mass are used for derivation of the physical description of interaction between liquid jet and solid state matter. Several necessary parameters are determined from experimental data.

Physical relationships describing generation and evolution of liquid jets and their interaction with material are used for linking the software for prediction of cutting speeds. This software can be easily modified into the master program for on-line control. The values determined by calculation play the role of master quantities and the triggers from sensors provide information about the state of the controlled quantities. The part calculating from these data the regulation offsets is to be add to the contemporary software. The regulation offsets should determine the output triggers that together with perturbances should create the action quantities for corresponding actuators handling the technology system in the manner to change respective regulated quantities. Nevertheless, these parts of software are preferably to be created for particular technology equipment therefore there are not a part of contemporary software.

The possibilities of application of the presented model in practice are discussed in the final chapter, respectively for machining by liquid jet. The critical changes in material are described and the decisive parameters of regulation are chosen by virtue of the analyses of incident mechanisms of material disintegration occurring in the process of solid state materials machining by liquid jet. This know-how is used for proposition of structure of the master program for machining of glass and rock material elements, especially the non-rotary ones. The accuracy of the central computing part of the program is proved by comparison of the results obtained from the model and the ones acquired in practice.

The essential notes of the theoretical physical model of generation, evolution and interaction of the liquid jet can be summarised into the following conclusions:

- theoretical description of liquid outflow from the nozzle and the jet evolution in the medium between nozzle and target material is proved by experimental results;
- energy of jet in the distance from the nozzle outlet is determined from the energy of jet in the nozzle mouth and the aerodynamic attenuation of liquid flow velocity;

- presented theoretical description of jet and its behaviour in the medium between nozzle and target material enables quick and sufficiently exact calculation of the velocity profile;
- the model of interaction very well describes quantitatively the depth of disintegration made by both the pure and the abrasive liquid jets;
- the model of jet interaction with material in solid state makes possible to analyse the tools with multiple motion of nozzles (rotating, vibrating, swinging);
- physical model enables to determine parameters of liquid jet efficiency;
- presented theoretical model quantifying results of liquid jet - solid state material interaction has a satisfactory accuracy for use in control of the automated systems for material processing by liquid jets;
- presented model proved its enforcement in solution of the problems from practice;
- the values calculated for the amount of material disintegration using the software based on the presented theoretical physical model correspond very well to the results obtained in practice for various types of material.

Based on the results of my doctor thesis I suggest the following further steps to realisation of the automated liquid jet technology complex:

- process the contactless methods for surface quality measurement to the forms usable for determination of this parameter during technological process of liquid jet processing of material;
- build up the experimental technology centre with sufficient technology equipment (high pressure pump with electronically regulated operating pressure set-up, equipment for inlet water filtration, high pressure tubing, robot and device for measurement of material surface);
- to implement the automation of this technology complex through the master program based on my model, to prove the functionality of this control and subsequently use this workstation both for scientific and education purposes and for special applications;
- study, theoretically and experimentally, the chaotic oscillations rising during liquid jet generation and actions of the kinetic mechanisms for nozzle or material movement as sources of instabilities for both the qualitative and the quantitative jet operation on the processed material - the aim is to minimise the disadvantageous influence of these oscillations on the quality of machining or to find the positive utilisation of them for special purposes (pulsed jets generation).