

## 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 law of 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. It has a good correlation with practice and hence the further advancement of the physical studies has to be started as it is apparent from the last author's works.

## CONCLUSIONS

This work is aimed at recapitulation of up-to-date evolution of physical cognition in the scope of liquid jet research with potential further advance in this sphere. The present state is summarized up and the directions and steps of presumptive expansion in subsequent period are outlined. Three stages of the up-to-date advancement in studying of the liquid jets are distinguished and described. This worldwide trend is reflected in the author's works.

The transformation of static energy of liquid into its kinetic one during the outflow of liquid through the nozzle is one of the basic problems solved in past period. The energy of the jet (the liquid motion after its outflow) 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 was paid both 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. Problems of jet structure determination and simulation of the flow were solved as well as the problems of energy losses and phenomena attending the interaction of liquid jet with abrasive particles during abrasive water jet generation using Venturi tube principle. The most important criterion of the work was the highest possible simplicity of the physical relationships and equations because too complex and sophisticated relationships with complicated computing may complicate the on-line control thus being less handy for applications in practice.

The description of the liquid jet generation and evolution is followed up by physical analysis of jet interaction with various types of material in solid state within the next part of the work. The problems of jet interaction with solids are namely considered to be the second pivotal ones. It is analysed and discussed the interaction of jet with materials regarding their elastic-plastic behaviour. The material structure influence on disintegration process during liquid jet impact is also considered. Processes of disintegration are studied also considering various types of liquid jets regarding intermixtures in liquid. There are liquid without additives and intermixtures (pure one), liquid with additives influencing viscosity and skin tension and liquid with solid particles (abrasive materials). Phenomenological description of physical differences typical for interaction of these liquid jet types with materials enable to select the most important phenomena and parameters for description and modelling of jet-material interaction and material disintegration.

The final part of the work presents the most important analytical models of the author. They enable to calculate evolution and structure of jet and jet-material interaction. The laws of conservation of energy, momentum and mass were used for their derivation. Several necessary parameters were determined from experimental data. Physical relationships describing generation and evolution of liquid jets and their interaction with material are used for preparation of a complex model of abrasive liquid jet. Models were linked to the software usable for prediction of cutting speeds, cutting costs and cutting output analyses. Nevertheless, this software can be easily modified into the master program serving thus for on-line control of equipment used for liquid jet machining, i.e. x-y tables, x-y-z tables, manipulators and robots.

The most essential features of the theoretical physical description of generation, evolution and interaction of the liquid jet with material 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 was proved by experimental results;
- ◆ energy of jet in the distance from the nozzle outlet is determined from the kinetic 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 quantitative results yield by models describing the depth of disintegration made by both the pure and the abrasive liquid jets are in a good matching with results accomplished both in laboratory and practice;
- ◆ physical model of interaction enables to determine parameters of liquid jet efficiency;
- ◆ results of software based on the presented theoretical physical model correspond very well to the results obtained in practice for various types of material.

The following specialities that distinguish the presented model from the analogical models used in practice, were processed and implemented into the software for calculation of abrasive liquid jet efficiency:

- ◆ disintegration of abrasive particles by jet impact in the mixing chamber;
- ◆ dependence of abrasive particle disintegration in mixing process on liquid pressure, properties of abrasive material and mass flow rate of both abrasive material and liquid;
- ◆ strong dependence of the abrasive jet efficiency on both the liquid nozzle and the mixing tube diameters;
- ◆ sharp maximum of abrasive jet efficiency regarding the average grain size of the input abrasive material corresponding to change of the mixing mechanism for certain grain size provided that ratio between the liquid nozzle and the mixing tube diameters is constant;
- ◆ saturation of the system if the abrasive material flow rate is increased and the input average grain size of abrasive material, the liquid nozzle diameter and the mixing tube diameter stay constant.

For the sake of very shortened experimental possibilities some of the presented theoretical conclusions could not be fully proved yet. The author supposes, however, that wide verification of the theoretical models should be possible to carry out in the upcoming three years.