THE FLUID FLOW SIMULATION THROUGH TO A CONVERGENT NOZZLE

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Abstract: In this work it was performed a fluid flow study of lubricant and cooling systems in machining process. In machine tools industry is very important to reduce the costs when are using the lubricant and coolant fluids to increase the productivity. It was been performed a simulation of the fluid flow through a nozzle, that nozzle type is commonly used for pressure cooling of the machined area. In these types of nozzles can be made a mixture of two types of fluids, such as air and water, to increase machined productivity and decrease the quantity of lubricant used for cooling systems.

Keywords: fluid, pressure, velocity, jet, nozzle

1. INTRODUCTION

Coolants used in machine building are polluting, excessively using of coolants are improper from point of view of its costs. According to the researches carried out in that field, costs of acquisition and maintenance of cooling fluids occupies 7.5 % and 17 % of the total production, respectively where the cost of tools is only 4 % [1].

Coolants generally may not be easily recycled due to chemical reactions that occur during processing at the contact between liquid and the surface to be cooled. Furthermore flow of coolant leads several particles, dust, metal powder which is very harmful to the environment. Another problem of cooling liquids may be the volatile substances can be released to machined process these can be inhaled by the operator could be unwholesome [2].

A generally accepted trend is to reduce the amount of fluid used for machining process by finding of appropriate geometries of the dispersion nozzles. The choosing of these cooling liquids is been made from several points of view: by achieving of cooling in the processed area, by the lubrication and its impact on the environment.

Complete renunciation of using cooling fluids may not be always possible; knowing that the cooling fluid removes most of the heat generated in machining process also decreased and the residual stresses which may occur in the worked piece, the resulting most improved quality of the machined surface [3].

In the cutting process to reduce costs of coolants and increase productivity may be used mixed fluids blended in a nozzle specifically designed for this purpose and it shall be released into the cutting zone by air-liquid mixture (aerosols). By this technique is also achieved savings of working fluids, being able to achieve their optimization in order to use a minimal amount of the coolant [4].

This paper aims at an analysis the way in which a fluid flows through a small dimensions convergent nozzle. That nozzle combines two working fluids, one gas (air) and another liquid (water). Nozzle type chosen is a common type with a high degree of processing and low price cost. That fluid flow study is needed to understand

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the occurring phenomena and ways to improve cooling by accurately directing of the fluid flow by using a minimal quantity of lubricant to achieve cooling of the processed area.

2. EXPERIMENTAL PROCEDURE

To achieve simulations was made a three-dimensional model of the nozzle by means of which is performed mixing of working fluids and then distributing to be cooled that area. Geometric model was developed as shown in Figure 1. Penetration angle of the second fluid is 30° and respectively 45° degrees, entry dimensions of cooling fluids being D_1 = 16 mm and respectively D_2 = 6 mm. The total length of the nozzle L = 60 mm, in which the convergent nozzle having a length of l = 16 mm, and outlet diameter cooling fluid is 3 mm.

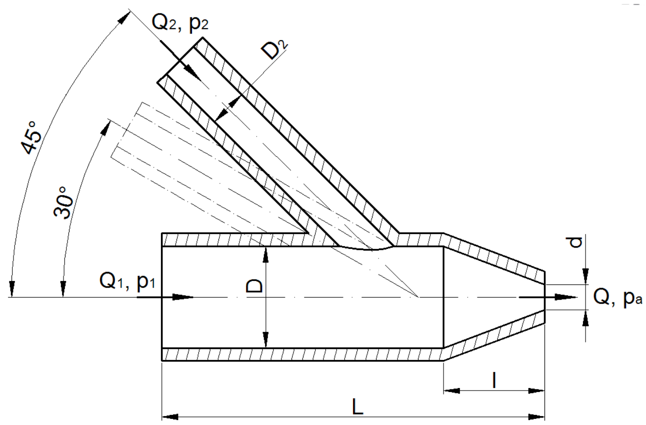


Fig. 1. Geometrical dimensions of the nozzle.

Mathematical modeling of the volume of fluid specific phenomena is delimited by the tube current, begins from impulse theorem described as follows [5]:

$$\rho \cdot Q(\overline{v}_2 - \overline{v}_1) = \sum \overline{F}_e \qquad (1)$$

Forces of surface are exercised on the input portion, on the output surface and to the lateral surface of the nozzle. Impulse theorem may be rewritten as:

$$\rho \cdot Q(\overline{v}_2 - \overline{v}_1) = \overline{F}_{p_1} + \overline{F}_{p_2} + \overline{F}_l + \overline{F}_g \qquad (2)$$

Given the consideration the angular momentum theorem which can be written as:

$$\rho \cdot Q(\overline{r} \times \overline{v}_2 - \overline{r} \times \overline{v}_1) = \overline{r}_1 \times \overline{F}_{p_1} + \overline{r}_2 \times \overline{F}_{p_2} + \overline{r}_l \times \overline{F}_l + \overline{r}_G \times \overline{F}_g \qquad (3)$$

Magnitudes of pressure forces $\overline{F}_{p_1}$ şi $\overline{F}_{p_2}$ can be calculated using the formulas:

$$F_{p_1} = p_1 S_1 \text{ şi } F_{p_2} = p_2 S_2 \qquad (4)$$

Where: p_1 şi p_2 are average speeds corresponding to the average pressures v_1 and v_2. These can be calculated using the surface integrals:

$$F_{p_1} = \int_{S_1} p\overline{n}_1 \, \mathrm{d}S_1 \text{ şi } F_{p_2} = \int_{S_2} p\overline{n}_2 \, \mathrm{d}S_2 \qquad (5)$$

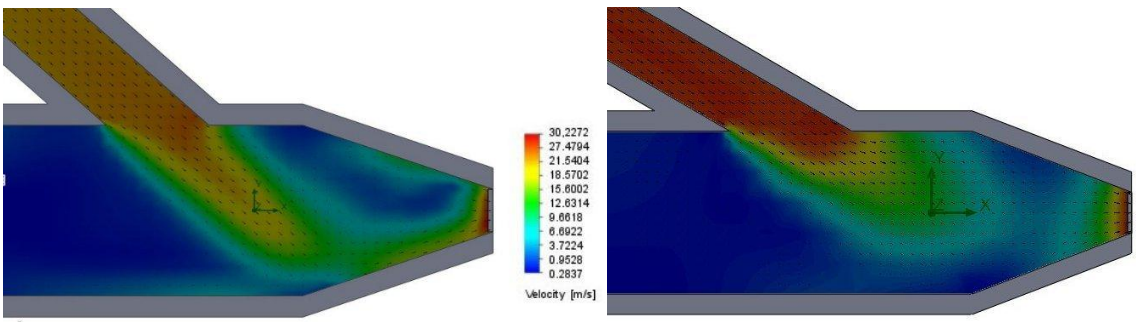
This could be determined by the pressures distributed on the surfaces S_1 and S_2, using Bernoulli's relationship for the light fluids in gravitational field [6]:

$$\frac{V_0^2}{2} + \frac{p_0}{\rho} + gz_0 = ct. \tag{6}$$

The fluid’s pressures in the inlet of nozzle are 2 bars for the water and 3 bars for air being the same for both cases of incidence angles studied.

3. FLOW SIMULATION PROCEDURE

The fluids flow simulations through the convergent nozzle were performed using SolidWorks software. Figure 2 presents the distribution of fluid velocities through the nozzle for both angles of incidence studied.



a. b.

Fig. 2. Velocity distribution in convergent nozzle:
a. angle of incidence 45°; b. angle of incidence 30°.

By analyzing of the velocity distribution inside of the nozzle can be observe that, if the angle of incidence is 30° the fluid mixture is achieved closer to the nozzle axis of symmetry helping their uniform distribution. For the use of angles of incidence larger there is a risk that fluid introduced into the nozzle to hit its walls thus realizing a loss of its energy. Also according to how to choose these two working fluids this think can be beneficial since it creates the most turbulent motion of joint area thereby facilitating the mixing two fluid media (Figure 3).

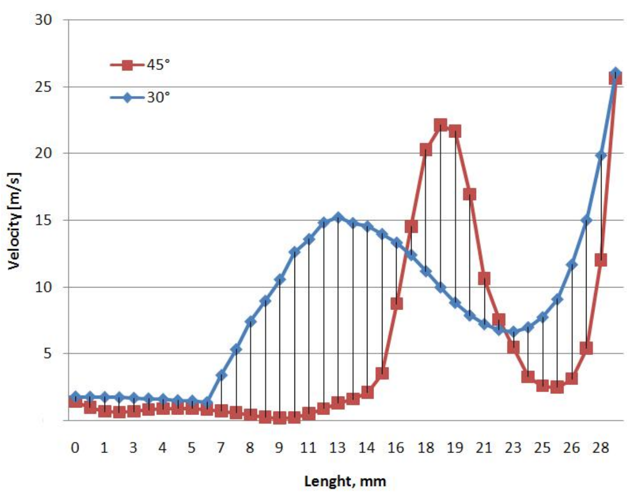


Fig. 3. Velocity distribution through the convergent nozzle.

If we consider as a reference the horizontal axis of convergent nozzle, basically the main axis of fluid flow and is analyzed the chart of the velocity distribution in length of the nozzle, we can observe that speeds records a maximum at the junction of the two fluids. Variation curve where the secondary fluid enters at a lower angle, near the flow axis is better distributed.

Average speed on the cylindrical nozzle area is approximately 10 m/s, which increases in the course of the convergent nozzle area to the fluid outlet where the speed is approximately 27 m/s.

For case when the incidence angle of the secondary fluid increases to 45°, in the mixing zone speed increases suddenly followed by a relaxation just as sudden. Like in the previous case fluid velocity at the exit recording the same maximum but are increased suddenly in the second case.

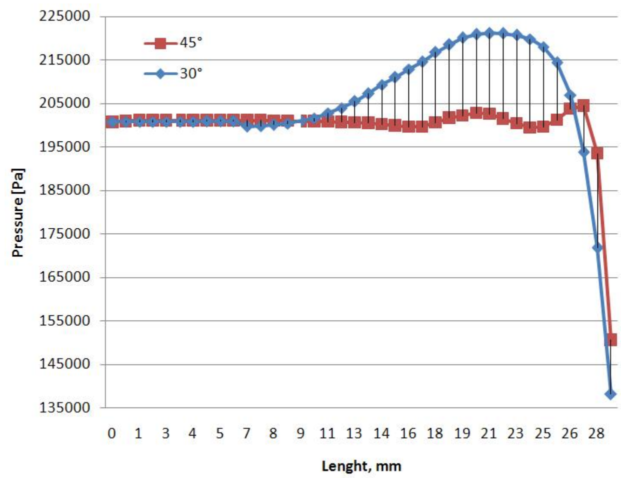


Fig. 4. Pressure distribution through the convergent nozzle.

From the analysis of chart pressures measured in the axis of nozzle at equal distances by 1 mm throughout its length we can observe that it have a variation approximately linear for the 45° angle (Figure 4), followed by a sudden decrease with increasing of the velocity in the convergent nozzle.

Where the secondary fluid enters into the nozzle at smaller angles the pressure gradually increase at the mixture of working fluid, finally registering the same decreasing like as in the previous case, due to convergence of the nozzle and pressure-speed ratio.

4. CONCLUSIONS

The simulations performed in this work showed that fluid flow is better when the angles of incidence are smaller. Angle of incidence of working fluids is limited by geometric conditions by achieving of the convergent nozzle.

The analysis performed in this work leads to a better understanding of the phenomena from cooling of cutting process domain, by optimizing the amount of fluid, use of fluids with improved cooling properties, their quality must be suitable to be less polluting for the environment. For this optimum correlation of the working parameters like: viscosity, pressure, speed, temperature, etc., being particularly important.

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