

Computational Fluid Dynamic Simulation of Flow in Abrasive Water Jet Machining

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Abstract. Abrasive water jet cutting is one of the most recently developed non-traditional manufacturing technologies. In this machining, the abrasives are mixed with suspended liquid to form semi liquid mixture. The general nature of flow through the machining, results in fleeting wear of the nozzle which decrease the cutting performance. The inlet pressure of the abrasive water suspension has main effect on the major destruction characteristics of the inner surface of the nozzle. The aim of the project is to analyze the effect of inlet pressure on wall shear and exit kinetic energy. The analysis could be carried out by changing the taper angle of the nozzle, so as to obtain optimized process parameters for minimum nozzle wear. The two phase flow analysis would be carried by using computational fluid dynamics tool CFX. It is also used to analyze the flow characteristics of abrasive water jet machining on the inner surface of the nozzle. The availability of optimized process parameters of abrasive water jet machining (AWJM) is limited to water and experimental test can be cost prohibitive. In this case, Computational fluid dynamics analysis would provide better results.

1. Introduction

AWJM is a well-known non-traditional machining process. It is a machining process where material is removed by smack erosion of high pressure high velocity of water and entrained high velocity of grit abrasives on a work piece [1]. The added abrasives [2] increased the materials range, which can be cut with a Watergate desperately. It is widely used, because of its main advantages Materials which are cut by AWJM are

Polymers, Honey comb, Metal matrix Composites [3].

Ceramic Matrix Composites, stone, Granites,

Wood, Reinforced Plastics, Metal Polymer Laminates and Glass Fibre metal Laminates.

Page layout (headers, footers, page numbers and margins)



2. Theoretical Formulation

2.1 Numerical Model and Assumptions

The abrasive water suspension mixture[4] is let into the nozzle at inlet and carried through converging cone to focus tube and exits at nozzle, in which the focus tube is used for guiding the flow. The numerical model adopted closely follows the work at Hu et al which liquid-solid two-phase flow is considered.

- Water is a continuous medium and incompressible.
- Flow is considered as two phase flow mixture in which water is liquid phase and abrasives is solid phase.
- Two phase flow is steady and possesses turbulent flow characteristics.

The nozzle head of AWJM is modeled by using pro/E software and it is saved. We modeled the nozzle head of varying taper angles. Then it is imported in ICEM meshing software for meshing the model. Tetrahedron is used for fine meshing. Then it is imported in CFX Pre for giving input parameters and properties of water and abrasive.

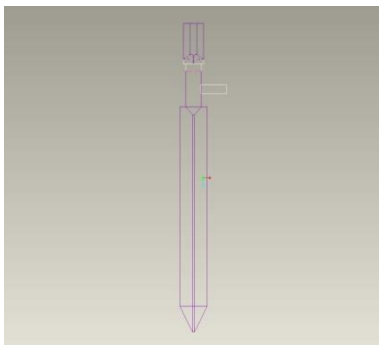


Figure.1 Pro/E model of nozzle head

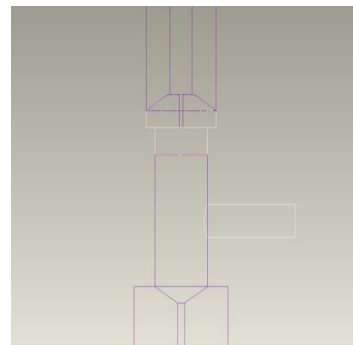


Figure 2.15 deg. Taper Angle

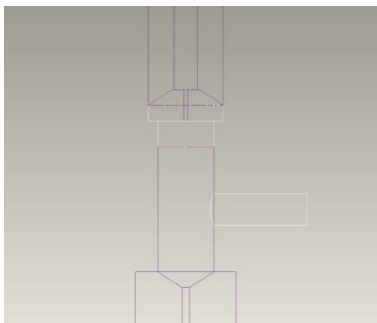


Figure.3 30 deg. Taper Angle

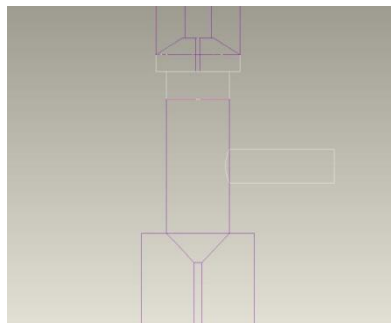


Figure 4. 45 deg. Taper Angle

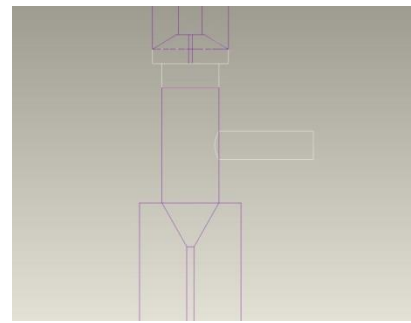


Figure 5. 60 deg. Taper Angle

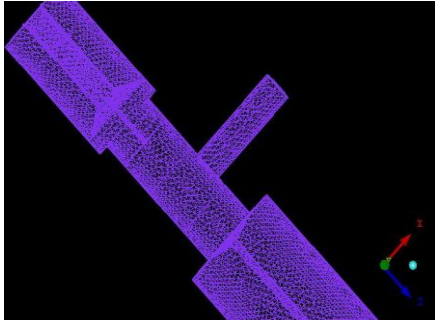


Figure 6. 15 deg. Taper Angle

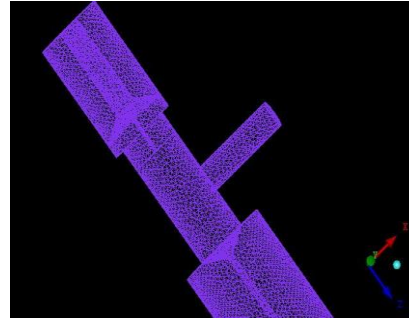


Figure 7. 30 deg. Taper Angle

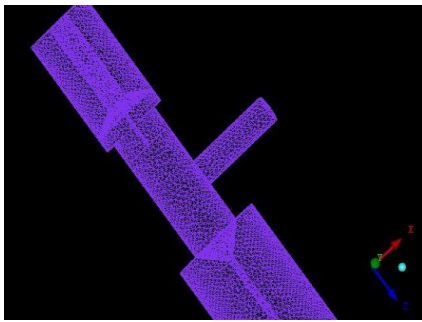


Figure 8. 45 deg. Taper Angle

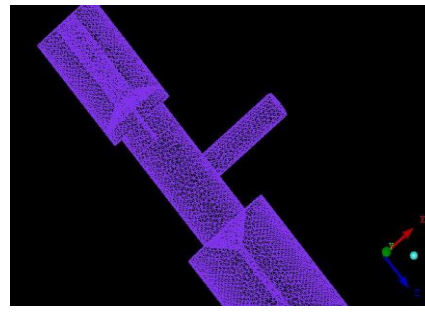


Figure 9. 60 deg. Taper Angle

2.2 Computational Domain Input

For the meshed model computational domain input should be given in the first. You have to create a water inlet, abrasive inlet and mixture outlet to the meshed model. In CFX preprocessor, you have to give the thermodynamic properties of water and abrasive. The water is taken as continuous liquid, and dispersed solid abrasive size is 1mm. In boundary condition you have to give domain type, name of nozzle head and mixing chamber. You have to name the liquid domain and solid domain of nozzle head and mixing chamber. Then you have to tell at water inlet, water enters and at abrasive inlet abrasive enters and also give the boundary details. Then you have to give domain interface between solid and liquid domain. The outlet will be the velocity. In CFX Solver, the model is imported and no of equations is performed and you have to give no of iterations and run solver and monitor. In CFX post, the model is imported and post processes the results.

2.3 The general specifications of our model

Focus tube (Mixing tube) Diameter : 0.76 mm

Focus tube length : 76 mm

Taper angle of nozzle : 45 deg

Mixing chamber diameter: 6 mm

Mixing chamber length: 12 mm

Orifice diameter : 0.2 mm

Water inlet diameter : 2.5 mm

Abrasive inlet diameter : 3 mm

The pressure of water is taken as 400 bar and Density of water $\rho_w = 1000 \text{ kg/m}^3$

The velocity and mass flow rate of water and abrasive will be calculated by using the standard dimensions. This will be used for domain input. The properties of water and abrasive will be given.

3. Results and discussions

3.1 Validation of the numerical model (Effect of nozzle angle)

3.1.1 Velocity Variation

Fig 10 shows the velocity variation along the mixing chamber and focus tube length. In the case of Mixing Chamber the velocity reduces gradually and increases when it reaches near the end of tube. In the case of focus tube, the gain in velocity is observed when the flow past the nozzle. Further kinetic energy lost is observed when the flow is along the focus tube for all the cases. This may be due to some of the abrasive particles collide with the wall of the focusing tube. Hence, there is some overall velocity reduction as the jet exits the focusing tube. The kinetic energy lost is high in the cases of taper angle 30° and 60° and it is significantly less in the case of 45° taper angle

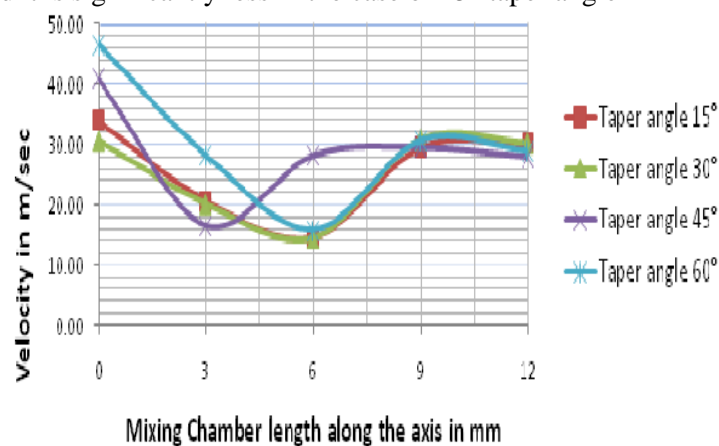


Figure10.(a) Mixing Chamber

3.2 Wall Shear Stress Distribution

Figure 11 shows the wall shear stress distribution along the mixing and focus tube length. Figure 11(a) shows that increased wall shear at the entry of Mixing Chamber for 60° taper angle. The magnitude decreases till the mixing region after that it increases sharply along its flow.

Figure 11(b) shows that the wall shear increases when the taper angle increases. Increased magnitude of wall shear has been observed for 60° taper angle.

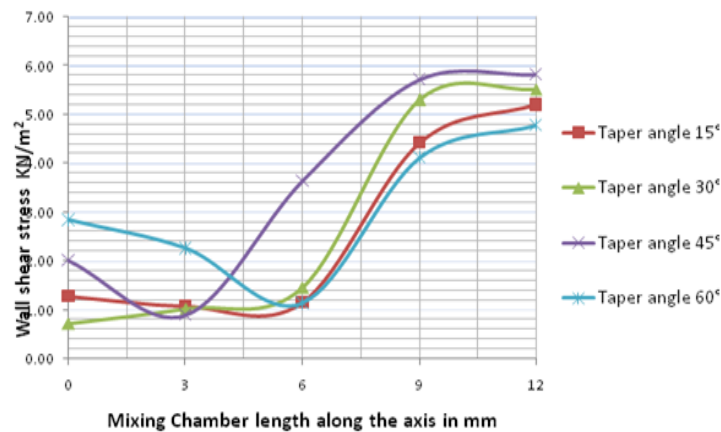


Figure 11(a). Mixing Chamber

3.3 Rate of Energy Dissipation

Figure 12 shows the rate of energy dissipation due to wall shear along the mixing and focus tube length. Figure 12(a) shows rate of energy dissipation that is high at inlet of the Mixing Chamber for the taper angle 30°. Its magnitude decreases sharply along the flow and it increases gradually beyond the mixing region. It is observed from the Figure 12(b) the rate of energy dissipation is high for

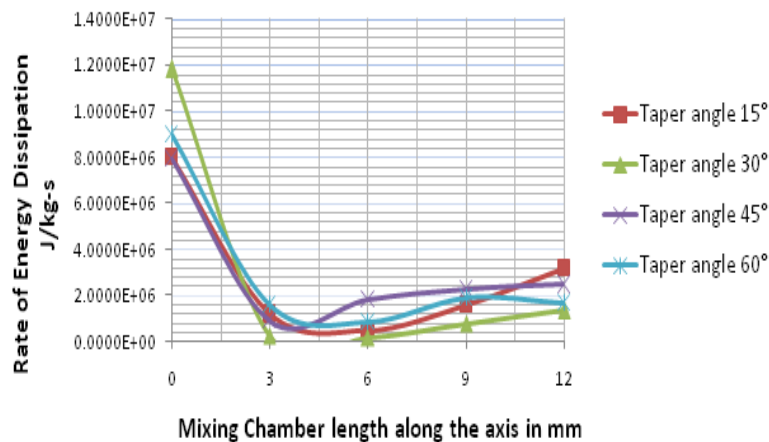


Figure 12(a). Mixing Chamber

4. Conclusions

Therefore, Computational fluid dynamic [CFD] simulation of flow through nozzle head of abrasive water jet Machining has been carried out and the following conclusion has been drawn.

4.1 Effect of nozzle angle

- Loss in kinetic energy has been observed when the flow is along the focus tube. This may be due to some of the abrasive particles do collide with the focusing tube wall. The kinetic energy loss is relatively less for 45° taper angle.
- The magnitude of wall shear stress increases when the taper angle increases. The wall shear in the mixing chamber increases sharply after the mixing region.
- The energy dissipation due to wall shear is relatively low for 30° taper angle.

5. References

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