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# Computational Fluid Dynamics Analysis of Nozzle 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. The general nature of flow through the machining, results in rapid wear of the nozzle which decrease the cutting performance. It is well known that the inlet pressure of the abrasive water suspension has main effect on the erosion characteristics of the inner surface of the nozzle. The objective of the project is to analyze the effect of inlet pressure on wall shear and exit kinetic energy. The analysis would be carried out by varying the inlet pressure 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. The availability of minimized process parameters such as of abrasive water jet machining (AWJM) is limited to water and experimental test can be cost prohibitive.

## 1. Introduction

AWJM is a well-established nontraditional machining process. It is a machining process where material is removed in 1980 and 1983 the first commercial system with abrasive involvement in the jet becomes available. The added abrasives increased the range of materials, which can be cut with a Watergate drastically. It is widely used, because of its main advantages. Materials which are cut by AWJM are Polymers, Honey comb, Metal matrix Composites, Ceramic Matrix Composites, Concrete, stone, Granites.

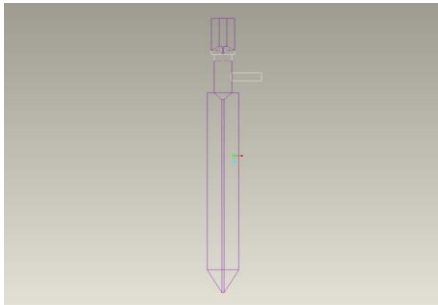
## 2. Theoretical Formulation

### 2.1 Numerical Model and Assumptions

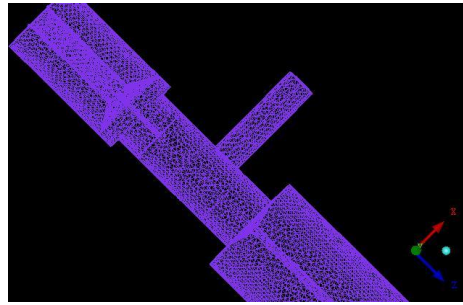
The abrasive water suspension mixture [1] is let into the nozzle at inlet and carried through converging cone to focus tube and exits at nozzle, in which the focus tube is used for guiding the flow. The numerical model adopted closely follows the work at Hu et al [2] which liquid-solid two-phase flow 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, but mixed with the liquid phase. Two phase flow is steady and possesses turbulent flow characteristics [3]. The nozzle head of AWJM [4] is modeled by using pro/E software and it is saved. We modeled the nozzle head of varying inlet



pressure of nozzle, 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 by impact erosion of high pressure high velocity of water and entrained high velocity of grit abrasives on a work piece. The invention of the abrasive water jet by impact erosion of high pressure high velocity of water and entrained high velocity of grit abrasives on a workpiece



**Figure 1** Pro/E model of nozzle head



**Figure 2** Meshed Model of Nozzle head

## 2.2 Material Domain Input

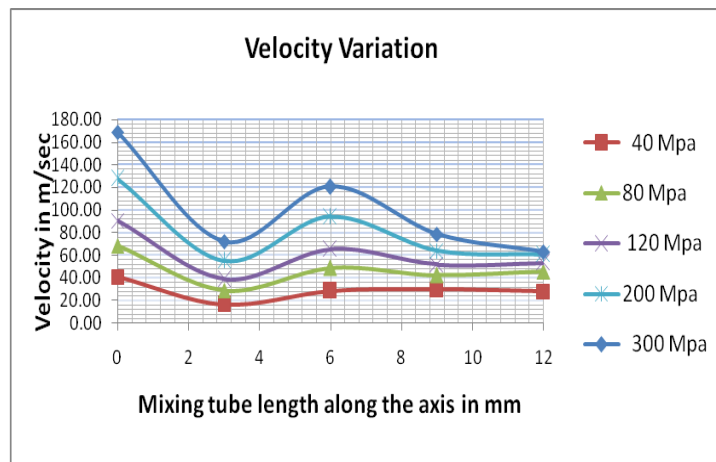
For the meshed model computational domain input should be given in the first. You have to create a water inlet, abrasive inlet and mixture outlet to the meshed model. In CFX preprocessor, you have to give the thermodynamic properties of water and abrasive. The water is taken as continuous liquid, and 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 models is imported and post process the results.

## 3 Results and Discussions

### 3.1 Validation of the numerical model (Effect of nozzle inlet pressure)

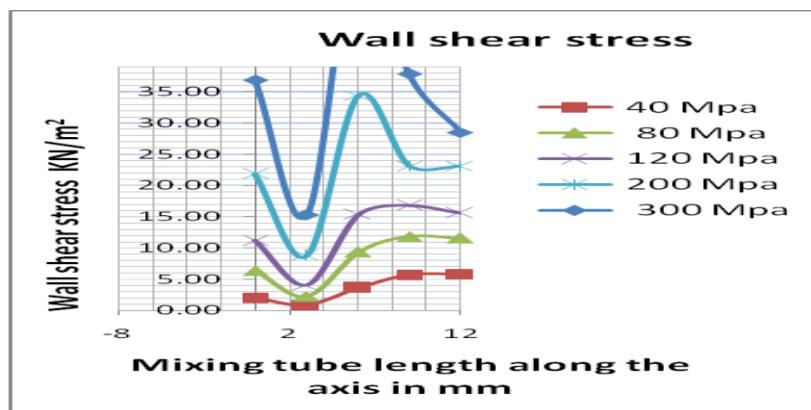
#### Velocity Variation

In the case of mixing tube the velocity reduces gradually and it reaches maximum in the mixing region and then gradually decreases when it reaches at the end of tube. The magnitude of velocity is high at higher water inlet pressure. In the case of focus tube length, the gain in velocity is observed when the flow past the nozzle. The velocity gain is more for 300 MPa pressure. 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 do collide with the focusing tube wall.



**Figure 3** shows the velocity variation along the mixing chamber.

### 3.2 Wall shear stress distribution

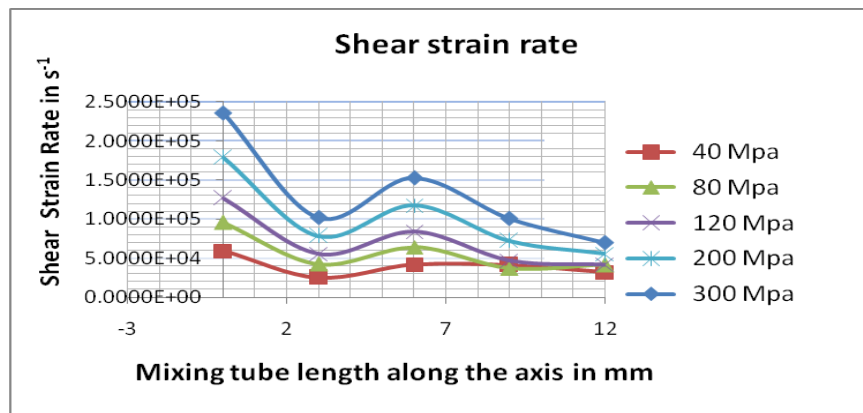


**Figure 4** shows the wall shear stress distribution along the mixing chamber

The above diagram shows that increased wall shear for at higher water inlet pressure. Wall shear increases maximum at the mixing region and it decreases along its flow. It has been observed from the graph that when the water pressure increases the magnitude of wall shear increases sharply in the mixing region. The wall shear is relatively low in the case of 40 MPa water pressure.

### 3.3 Shear Strain Rate Variation

The above diagram shows that strain rate is high at entry of mixing tube for both cases and it decreases gradually along its flow and it increases in the mixing region.



**Figure 5** shows the shear strain rate distribution along the mixing chamber

#### 4. Conclusion

The effect of pressure of the abrasive fluid suspension has significant effect on the erosion characteristics of the inner surface in the nozzle. The general nature of flow through the abrasive fluid jet machining, results in rapid wear of the nozzle which affects the cutting performance. High pressure of water and abrasive particles may cause severe wall shear stress due to wear. Various flow parameters are considered wall shear stress, velocity, shear strain rate. While taking parameters, the outlet velocity should be high and wall shear stress due to wall shear, and shear strain rate should be low. These phases of flow through nozzle head of abrasive fluid jet Machining has been carried out and analysed by using Computational fluid dynamic [CFD] software CFX. The water inlet pressure increases, its velocity increases, wall shear stress also increases and all parameters increases. Without affecting wall shear stress, we take inlet pressure. So, it is optimum to take velocity and with out affecting wall shear stress, energy dissipation of flow, rate of energy dissipation of flow, shear strain rate. Here we obtain the optimal inlet pressure as 120 Mpa and 200 Mpa of nozzle head of abrasive fluid jet machining.

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