GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

ANALYSIS AND OPTIMIZATION OF SAPPHIRE NOZZLE WEAR IN ABRASIVE WATERJET CUTTING FOR VARIOUS ABRASIVES BY ANSYS FLUENT

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ABSTRACT

This paper predicts the computational wear rate of sapphire nozzle for various abrasive materials by having constant inlet parameters in Abrasive waterjet machining. The software used for this analysis is Fluent 2.0. The inlet parameters considered are water inlet pressure, water density, air inlet velocity and pressure and mass flow rate of the abrasive. The various abrasives analyzed in this paper are Silicon Carbide, Boron Carbide, Corundum, Emery, Aluminium oxide, Topaz and Tungsten carbide. Discrete Phase model was used to predict the wear rate of the nozzle. The wear rate should be optimum for the nozzle life and also for efficient cutting. Based on analysis, the wear rates of those materials are in the range of 0.0002 to 0.02 kg/m^2-s. The erosion rate contours of the abrasives for optimization are discussed in this paper. The results seems to be satisfactory for those materials and can be extended for experimentation.

Key words: *Abrasive waterjet machining, fluent, abrasives, optimization*

I. INTRODUCTION

Abrasive Waterjet cutting is the appealing technology for cutting thick materials ranging upto 150 mm. the working principle is that the pressure head of water is converted into velocity head by allowing high pressure water into small orifice diameter. As the high velocity issues from the orifice into mixing chamber, low pressure (vacuum) is created within the mixing chamber. The abrasive particles are introduced into mixing chamber through the port. Due to high velocity and shear stress developed on the focusing tube wall, erosion occurs. The abrasive jet is made up of two continuous phase and a solid phase which makes them much more complex than plain water jet. Sapphire is one among the promising materials used for nozzle. The erosion rate influences the life of the Sapphire nozzle very much. In order to reduce the wear that occurs at the wall surfaces of the nozzle, the slurry parameters have to be optimized. For average material removal rate, sapphire nozzle have a useful life up to 150 hours. If the wear rate is reduced by optimizing the slurry parameters, the nozzle life can be augmented.

II. DESIGN OF NOZZLE

The sapphire nozzle is designed by using NX-CAD software. The design considered for analysis is shown below in the figure 1

ISSN 2348 – 8034
Impact Factor- 3.155

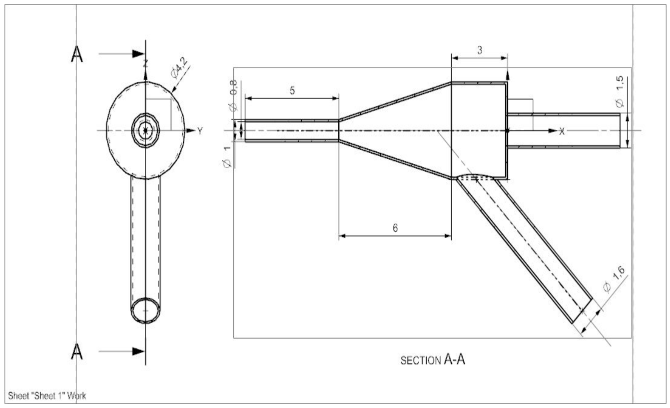

Fig 1: Nozzle design

III. ANALYSIS

The analysis is done by using CFD techniques. Analysis by CFD involves three steps. They are pre-processing, solver set-up and post processing.

Pre-processing:

Pre-processing involves defining the geometry of the region of interest, grid generation for various domains into smaller non-overlapping subdomains and selecting the phenomena that needs to be modelled. The meshing criteria considered for the analysis is given in table 1. The maximum equiangular skewness for surface mesh is kept as0.6 and 0.9 for volume mesh elements .The Surface mesh of the sapphire nozzle is generated in Automatic Net generation for Structural Analysis (ANSA).

Table 1

Mesh	Count	Quality
Surface mesh	17318	0.6
Volume mesh	89630	0.89

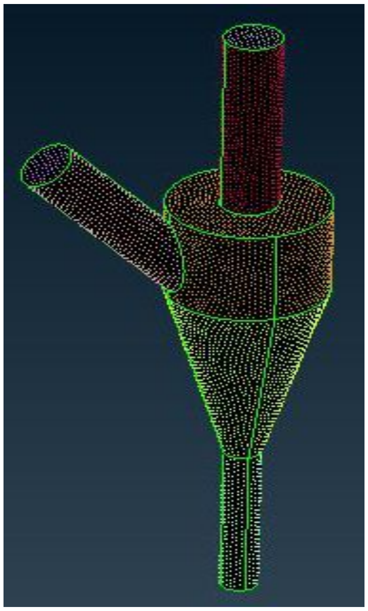

Fig 2: Surface mesh

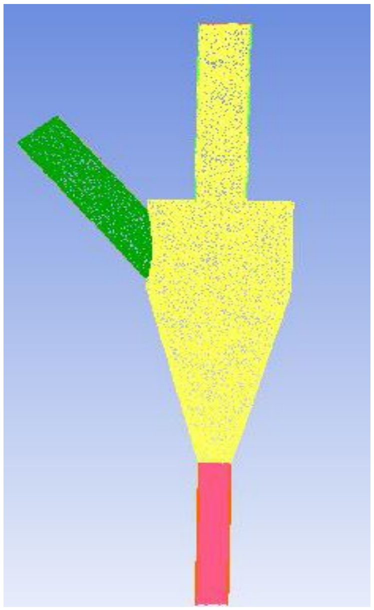

Fig 3: Volume mesh

Solver set-up:

The solver set-up involves integration of the governing equations of fluid flow over all the finite control volumes of the domain, discretization of resulting integral equations into a system of algebraic equation followed by solving the equation by iterative method. The iteration is governed by gauss seidel iterative techniques. The table below gives the parameters for solving.

Table 2

Parameter	**Value**
Mass flow rate	5 kg/s
Water inlet pressure	460 MPa
Water density	1136 kg/m^3
Air inlet velocity	5 m/s
Air inlet Pressure	100 MPa

Post processing:

This analysis, at the post processing step, gives the domain geometry, grid display and line and shaded contour plots. This facilities may also include animation for dynamic result display and in addition to graphics all codes produce output and have export data facilities for further manipulation. A huge amount of development work has been done in post processing field to get accurate results.

IV. RESULTS AND DISCUSSIONS

Below are the wear rate results obtained for the various abrasives in the sapphire nozzle.

CONTOURS AND GRAPHICAL RESULTS FOR VARIOUS ABRASIVES:
Aluminium Oxide abrasive:

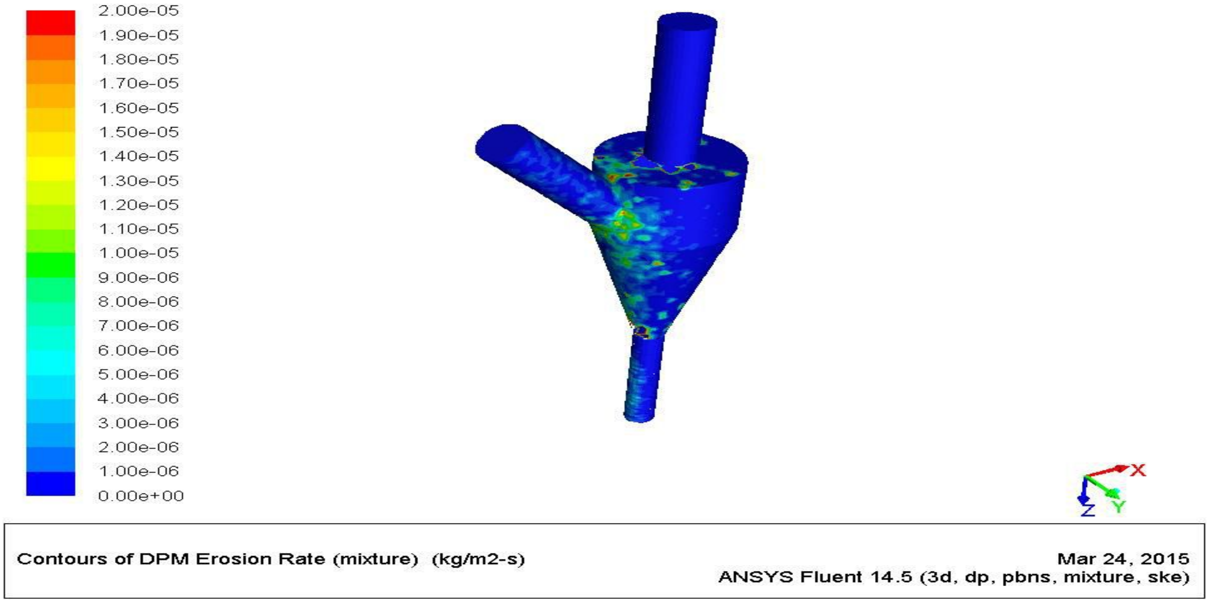

Fig 4: contour of erosion rate for Aluminium oxide

From this figure, we can observe that the erosion occurs mainly in the corners and edges of abrasive inlet section. The maximum erosion rate is identified as 0.0135 Kg/sq.m-s.

Boron Carbide abrasive:

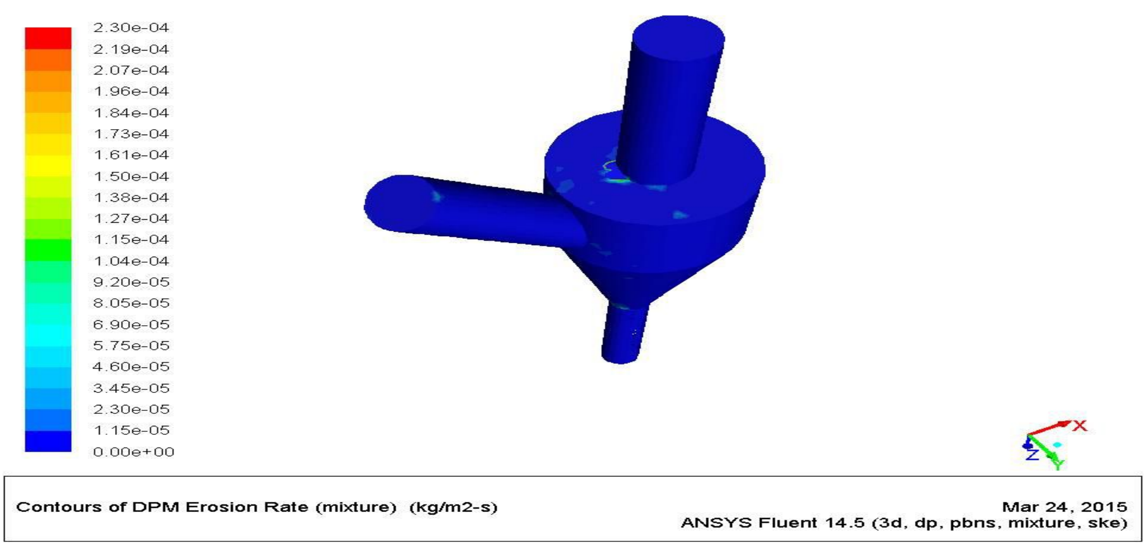

Fig 5: contour of erosion rate for Boron Carbide

In this abrasive model, very low erosion rate was observed. The maximum rate of erosion is in the order of 0.00023 Kg/sq.m-s.

Corundum abrasive:

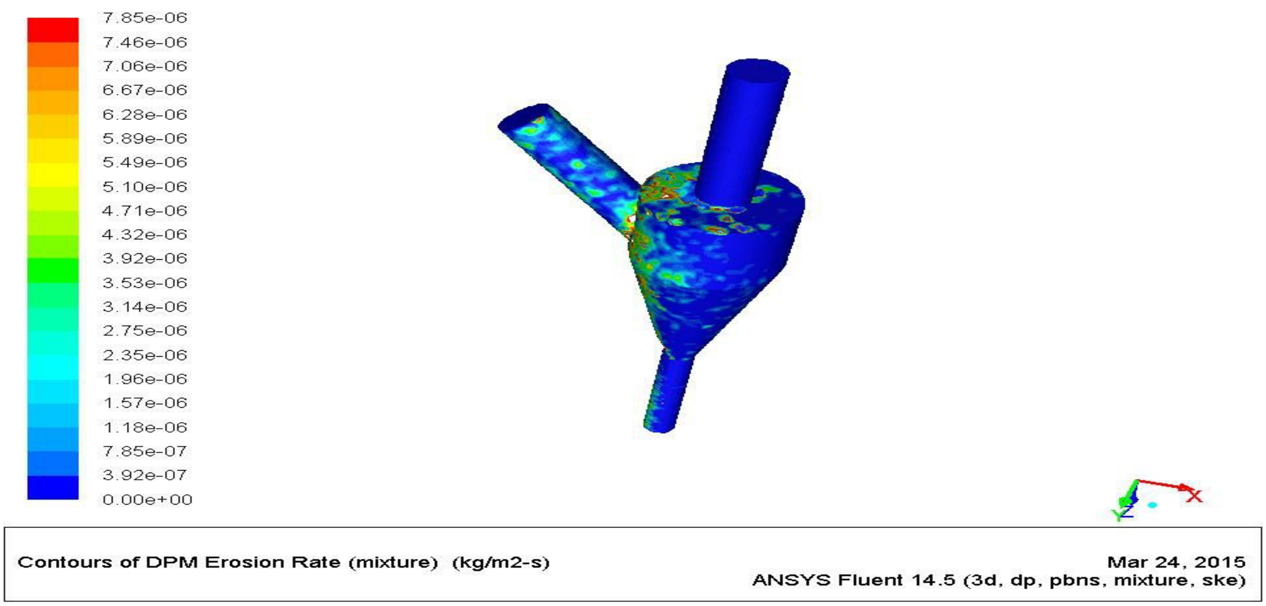

Fig 6: Contour of erosion rate for Corundum

This figure shows the maximum erosion rate of sapphire nozzle and it was found to be 0.01945 Kg/sq.m-s.

Emery abrasive:

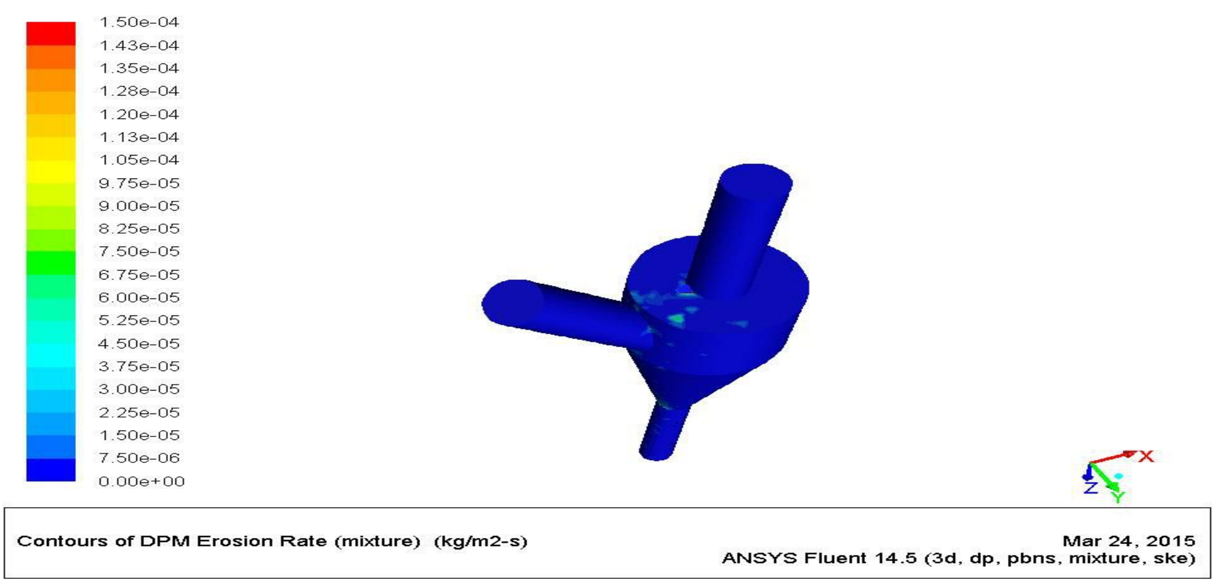

Fig 7: Contour of erosion rate for Emery

This figure shows the minimum erosion rate of sapphire nozzle and it was found to be 0.00015 Kg/sq.m-s.

Silicon Carbide abrasive:

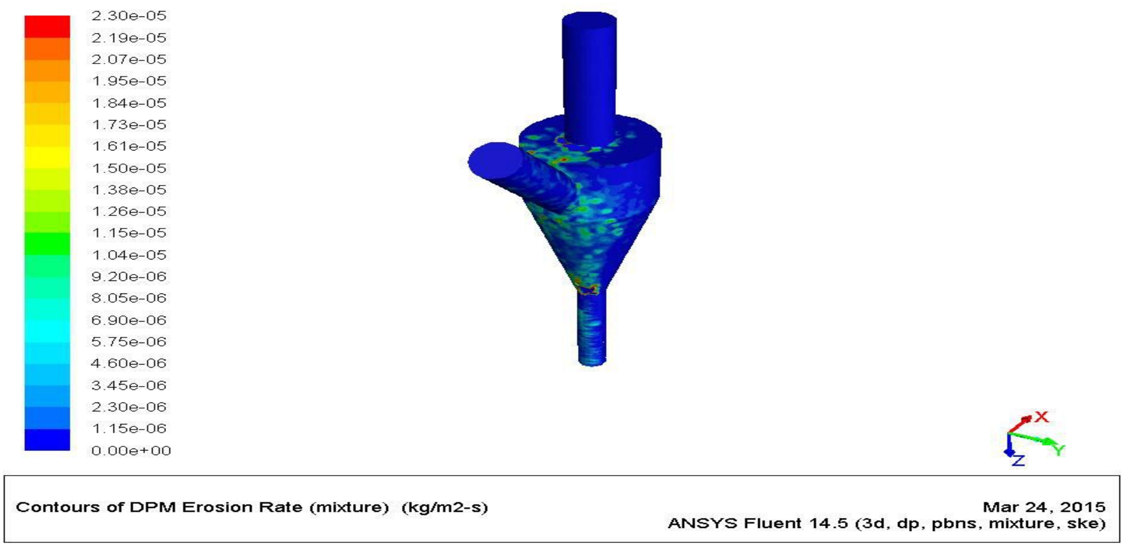

Fig 8: Contour of erosion rate for Silicon Carbide

This figure shows the erosion rate of sapphire nozzle with silicon carbide abrasive and it was found to be 0.01549 Kg/sq.m-s.

Topaz abrasive:

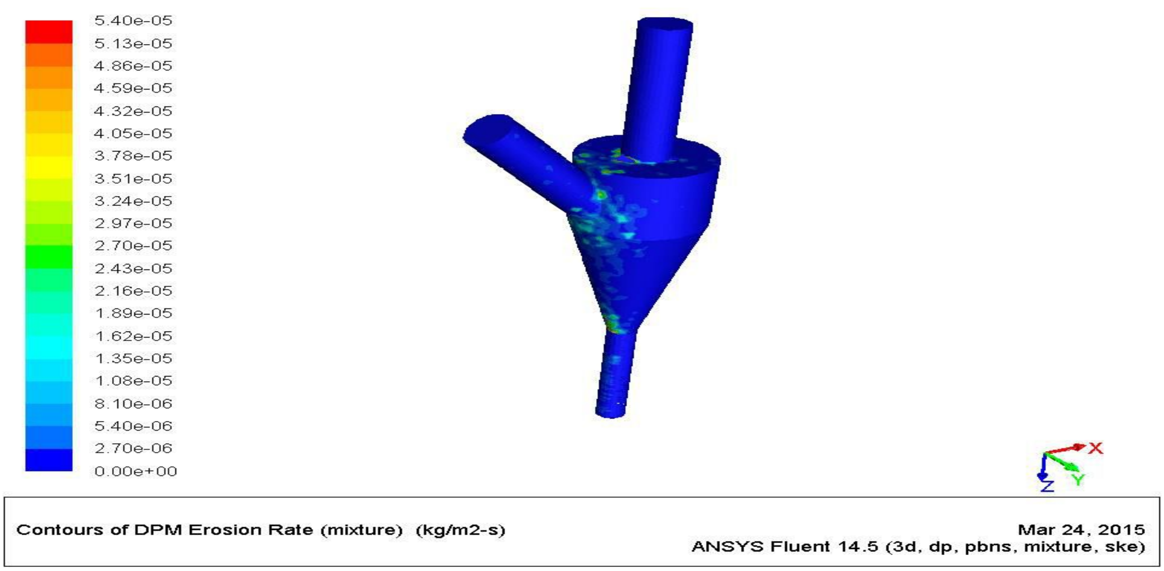

Fig 9: Contour of erosion rate for topaz

This figure shows the erosion rate of sapphire nozzle and it was found to be 0.0364 Kg/sq.m-s.

ISSN 2348 – 8034
Impact Factor- 3.155

Tungsten carbide abrasive:

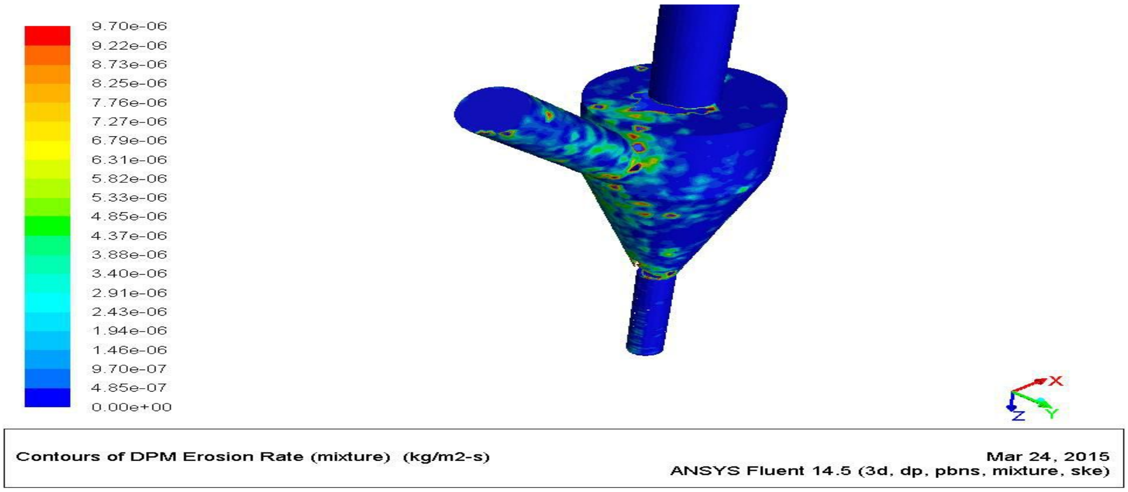

Fig 10: Contour of erosion rate for tungsten carbide

This figure shows the maximum erosion rate of sapphire nozzle and it was found to be 0.0240 Kg/sq.m-s.

V. CONCLUSION

In this erosion rate analysis of sapphire nozzle, the possible combinations of abrasives were used and tested using CFD software. The maximum erosion rate (in Kg/sq.m-s) of sapphire nozzle in each combination were obtained and shown. The decreasing order of abrasives having erosion rate are Topaz, Tungsten Carbide, Corundum, Silicon Carbide, Aluminium Oxide, Boron Carbide and Emery. The maximum erosion rate will be for Topaz abrasive and minimum for Emery abrasive combination. From the above results, we can select a best combination that could increase the nozzle life and to get optimum performance.

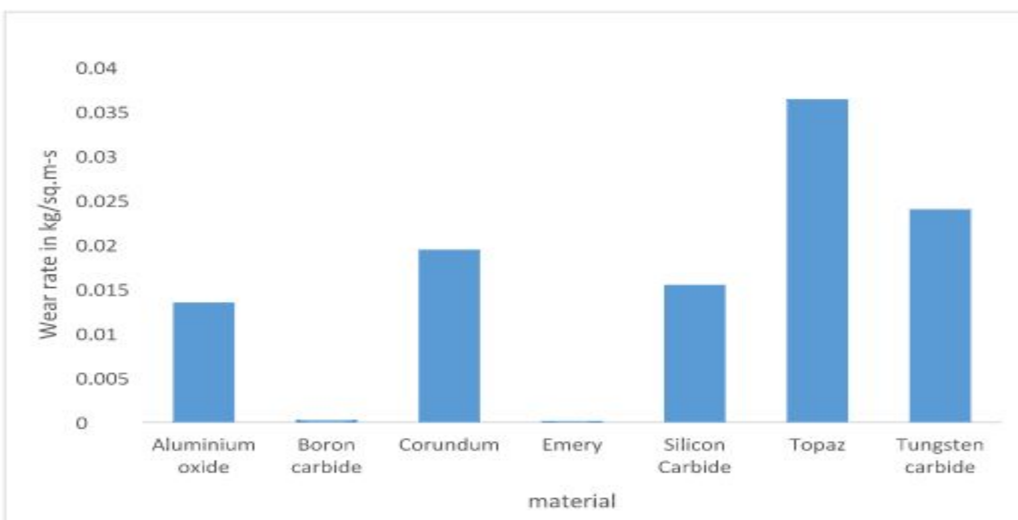

Fig 11: Comparison of wear rates for various abrasives

Finally, the optimum combination of Silicon Carbide or Aluminium Oxide could be used for abrasive Water jet machining.

VI. ACKNOWLEDGEMENT

The authors express their profess gratitude to the Principal and management of Coimbatore Institute of Technology, Coimbatore for their encouragement and suggestions.

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