International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 05 | May 2020 www.irjet.net p-ISSN: 2395-0072

3D MODELLING AND FABRICATION OF ABRASIVE JET MACHINE

Abdullah Mohd Hashir[1], Md Muzafar Ullah Khan[2], Mohammed Abdul Shukoor[3], Mohammed Fazal Uddin Junaidi[4], Mohd Abdul Moyeed[5]

[1,2,3,4]UG, Students, Dept. of Mechanical Engineering, Nawab Shah Alam Khan College of Engineering and Technology, Hyderabad, Telangana, India.
[5]Associate professor, Dept. of Mechanical engineering, Nawab Shah Alam Khan College of Engineering and Technology, Hyderabad, Telangana, India.

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Abstract - *Abrasive jet machining is employed for cutting any intricate shapes on brittle materials like glass. We cut any difficult shapes and make holes in glass and brittle material using compressed gas and abrasive particles. Here sand is employed as an abrasive. A compressor is employed which is connected through PU pipe to flow control valve. Control valve operates the air abrasive flow through the plumbing system to the nozzle. The pressure gauge indicates the varying measure of pressure. Pressure valve has an additional filter which is attached between an effect valve and nozzle which cleans the air and passes it to the mixing chamber. The function of the mixing chamber is to combine clean air with the sand or abrasive particle with high velocity. The abrasive particle will be poured from the upper inlet of mixture chamber. Discharge of this mixing chamber is attached to a nozzle. Nozzle increases the rate of this high pressurized discharged air mixed with abrasive particles. This discharge of air impacts the glass or any brittle material held by the bench-vice. Thus, the specified holes will be achieved. We have employed Solidworks to model the AJM, the key aspect in modelling was to produce a machine with high accuracy.*

Key words: AJM, Unconventional machining, Material Removal Rate, Solidworks, Air compressor.

1.INTRODUCTION

Abrasive Jet machining is a micro machining process which was considered to be an unconventional method but since there was a lot of research and development in the last few decades the method is pragmatically employed in the modern manufacturing industry and plays a key role in production facilities across the globe. AJM is used to make holes and also has a capacity to machine desired geometry depending upon the construction and component employed; with the help of erosive action different processes such as cutting, deburring, etching and polishing is achieved. AJM is free from heat generation because the carrier gas acts as a coolant, the cutting action itself is cool. Abrasive Jet Machining (AJM) is the operation that employs a sharp collision between a high speed flow of abrasive-gas mixture from nozzle and the workpiece as a result of which glass crystals are removed from the work surface, the glass particle removal is caused by erosion. It helps in machining complex shapes into brittle materials due to its high withstanding capacity. The various components of AJM are compressor, mixing chamber, pressure regulator, filter regulator unit, nozzle, pressure gauge, flow control valve etc the various components are opted after optimal modelling.

In this project, we modelled and fabricated Abrasive Jet Machine with available physical components and software etc. taking into account the economically available components. A key focus has been made over the use of more fabricated components instead of directly purchasing them from the market, because higher accuracy in fabricated components can increase performance of the machine significantly.

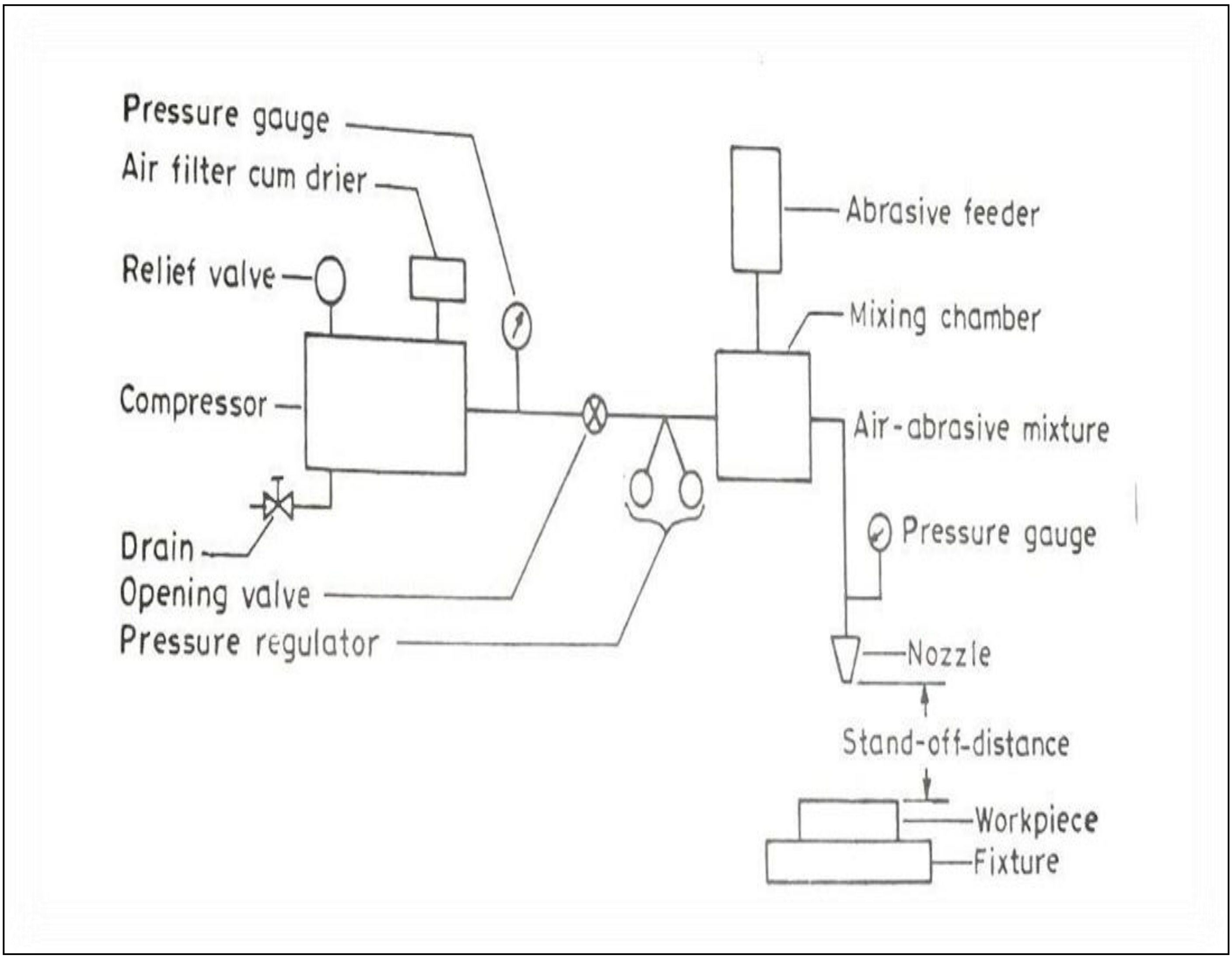

Fig. 1.1 A schematic representation

1.1 Principle of Abrasive Jet Machine

Material is eroded from the brittle workpiece with the impingement of fine abrasive particles hitting it at a high-velocity.

A jet of inert gas having very fine abrasive particles hits the glass workpiece, finally leading to chipping/erosion of workpiece material.

1.2 Process Description

A schematic representation of Abrasive Jet Machine is depicted in Fig. 1.1. In AJM air is compressed at a high pressure using an air compressor.

The major components are:

- Air Compressor.
- Filter Regulator unit
- Pressure Gauge.
- Control Valve.
- Mixing chamber(Abrasive–Air)
- Nozzle.

1.3 Material Removal Rate (MRR)

The removal of material comes into picture from the application of high velocity abrasive jet particle hitting the work piece, by the kinetic energy possessed by the particle which is the reason behind the erosion of work piece. The material removal rate varies depending upon certain parameters such as abrasive flow rate, mixing ratio, gas pressure, stand-off distance etc. Material removal rate (MRR) increases with increase in stand-off distance then it remains constant for a certain period of time and then successively it decreases with increase in stand-off distance.

1.4 Application

- Suitable for removal of oxide from metal and resistive coating of metal.
- Interior surface of glasses can be frosted.
- For the removal of flash and parting lines in injection moulding casting.

1.5 Advantages

- Low tolerance (-0.12 to +0.12).
- Easier in operation.
- Heat generation is negligible or none.
- Low tool wear rate.
- Depending upon abrasives used desired surface finish can be obtained.

1.6 Disadvantages

- Restricted to less application due to limited material removal rate.
- Environment is polluted by the abrasive wastes.
- Abrasives once used cannot be reused in many cases.

2. LITERATURE REVIEW

On carrying out the literature survey of Abrasive Jet Machine we found that it was initiated a few decades ago. The experimental and theoretical studies on Abrasive Jet Machining process continues till date. A major part of this study is based on experiment and only a minor part is based on modelling and analysis.

A novel hybrid method known as Flexible Magnetic Abrasive Jet Machining was designed by Ke et.al. This method allows us to investigate the machining characteristics of a self-made magnetic abrasive in AJM. Using Taguchi method we were able to draw a conclusion that the MRR (Material Removal Rate) and surface roughness of a flexible magnetic abrasive particle is better than that of a traditional abrasive.

A theoretical analysis associated with mathematical models was represented by J.M. Fan and Yu-Fei Wang. It is used to calculate the velocity of abrasive particles in abrasive jet machining. On considering the parameters such as particle mean diameter, nozzle length, air density and velocity of air flow, the velocity of particle at the exit of nozzle can be determined. It also incorporates the modelling related to the distribution of particle velocities along the jet center line downstream from the nozzle and also the particle velocity profile at jet cross-section by considering surrounding air entrainment and air-particle interaction. On comparing the experimental result with theoretical calculation, they concluded that less than 4% error occurred.

A cryogenic abrasive jet machining apparatus was used by Gradeena et.al for the erosion of solid particle polydimethylsiloxane (PDMS) using aluminum oxide as an abrasive at a temperature range between -178^0C to 17^0C. He deduced that the optimum machining of PDMS occurred approximately at -178^0C and the attacking angle was in between 30^0

to 60^0. They were also successful in finding out that a machining operation can be performed at a temperature above its glass transition temperature.

Ally et.al found that the optimum erosion rate when machining Aluminum 6061-T6, 316L stainless steel and Ti 6Al–4V alloy occurred at impact angles lying between 20^0and30^0on using the 50 µm AL_2O_3 abrasive powder. On demonstrating the surface evolution model, a model that was originally developed for ductile polymer; during the machining process of metal, it was found that AJM etch rate in case of metals was minimum in comparison with glass and polymer.

Tyagi worked hard and hence was able to present a theoretical study that was carried out with the help of mathematical model and computational technique of abrasive jet machining. It is primarily based on the principal of velocity and shear instability, generated by thermionic process. On the basis of plasma factor the rate of erosion from metallic surface can be controlled by varying the input parameter such as electric field, magnetic field and shear scale length.

Lin et.al was able to design a hybrid model on the basis of combined mechanism of Abrasive Jet Machining (AJM) and Electrical Discharge Machining (EDM). Moreover the hybrid process not only increases the material removal rate but also has the ability to generate fine surface finish.

3. MODELLING OF AJM IN SOLIDWORKS

The entire 3D modeling of all the component was concluded in solidworks. There are five different components of AJM, they are:-

3.1 Mixing chamber

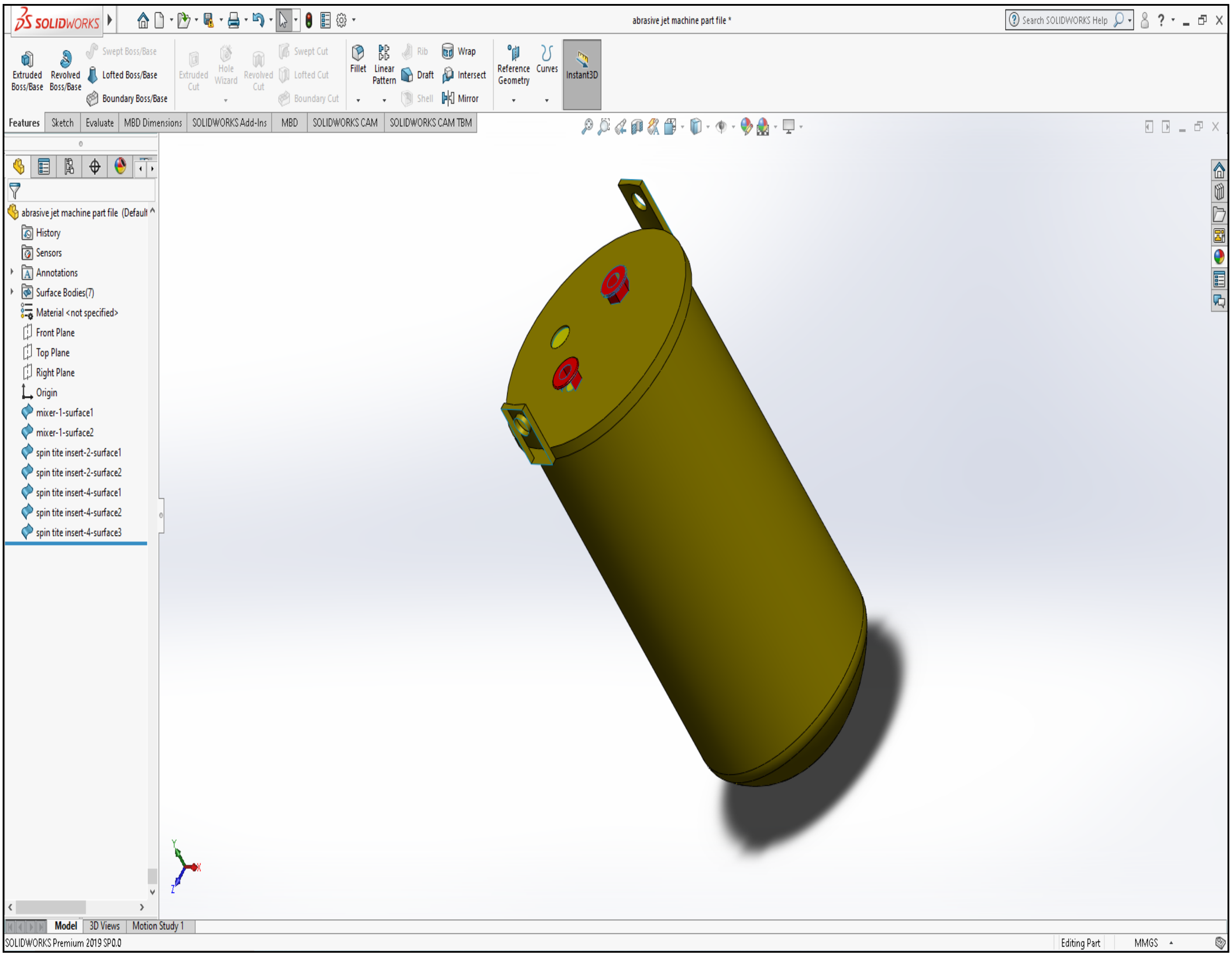

Fig. 3.1 Mixing chamber

Mixing chamber is designed in such a way keeping in mind the cylindrical geometry. Mixing chamber consists of two pneumatic connections i.e., inlet and outlet. The inlet of mixing chamber is connected to FRL unit and the outlet is connected to the nozzle. The modelled view of mixing chamber is shown in the Fig. 3.1.

3.2 Nozzle and its holding instrumentation

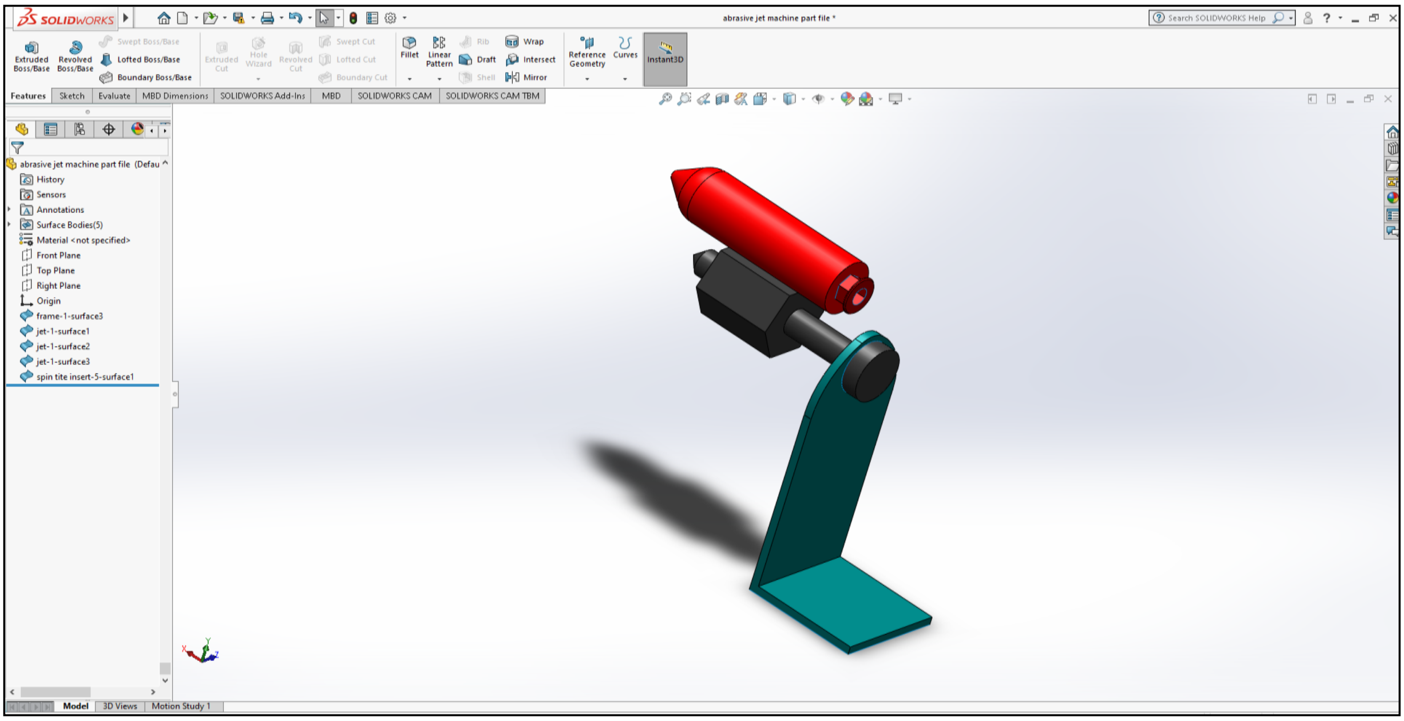

Fig. 3.2 Nozzle

Nozzle is designed with due consideration to obtain high precision while machining the workpiece. Tungsten carbide is used for the fabrication, produced at workshop. Nozzle holding arrangement (Fig.3.2) was designed and fabricated in the workshop. The nozzle holder was attached to acrylic sheet, whose thickness is10 mm, having two 10mm diameter holes in the center to accommodate nozzle and two 4mm holes on the two sides for tightening the arrangement by nut-bolt assembly with the MS frame of machine.

3.3 Piping circuit

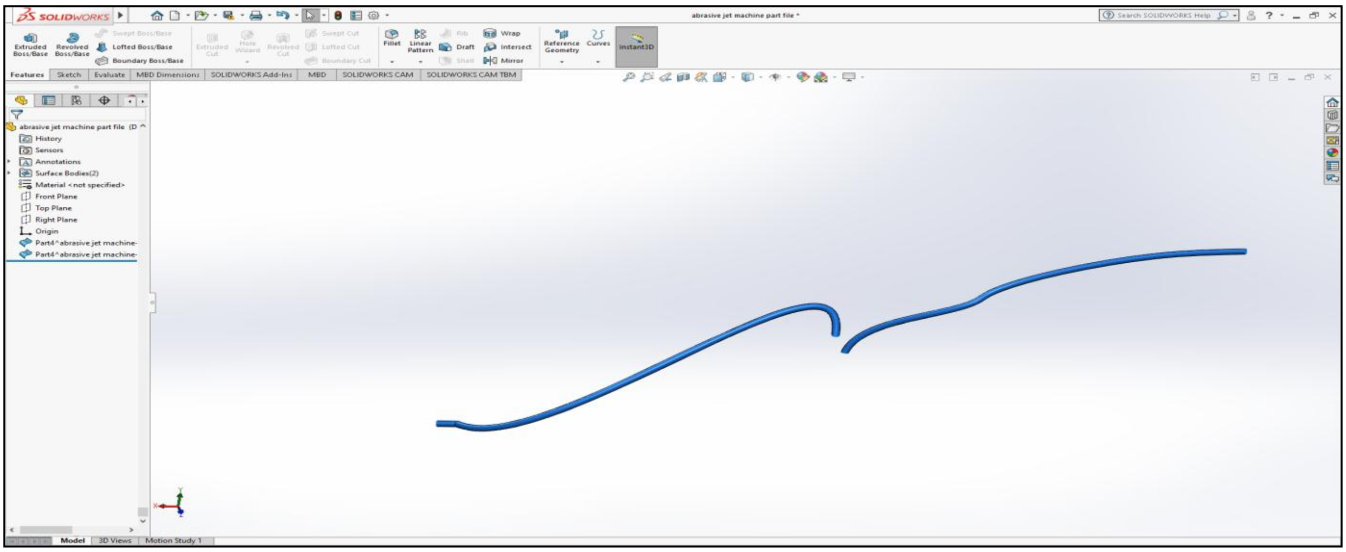

Fig. 3.3 Piping circuit

Piping circuit is used for smooth flow of mixture of abrasive particles and compressed air. Polyurethane pipe (Fig. 3.3) of 12 mm diameter is used as pipe material, which has been bought straight from market.

The piping systems are required for carrying the compressed air from the compressor to the mixing chamber and from the mixing chamber to the nozzle orifice via the FRL unit. It is utilized for its long life, tough, easily accessible and alongside offers little head loss when the pipe gets bent unlikely.

3.4 MS Frame

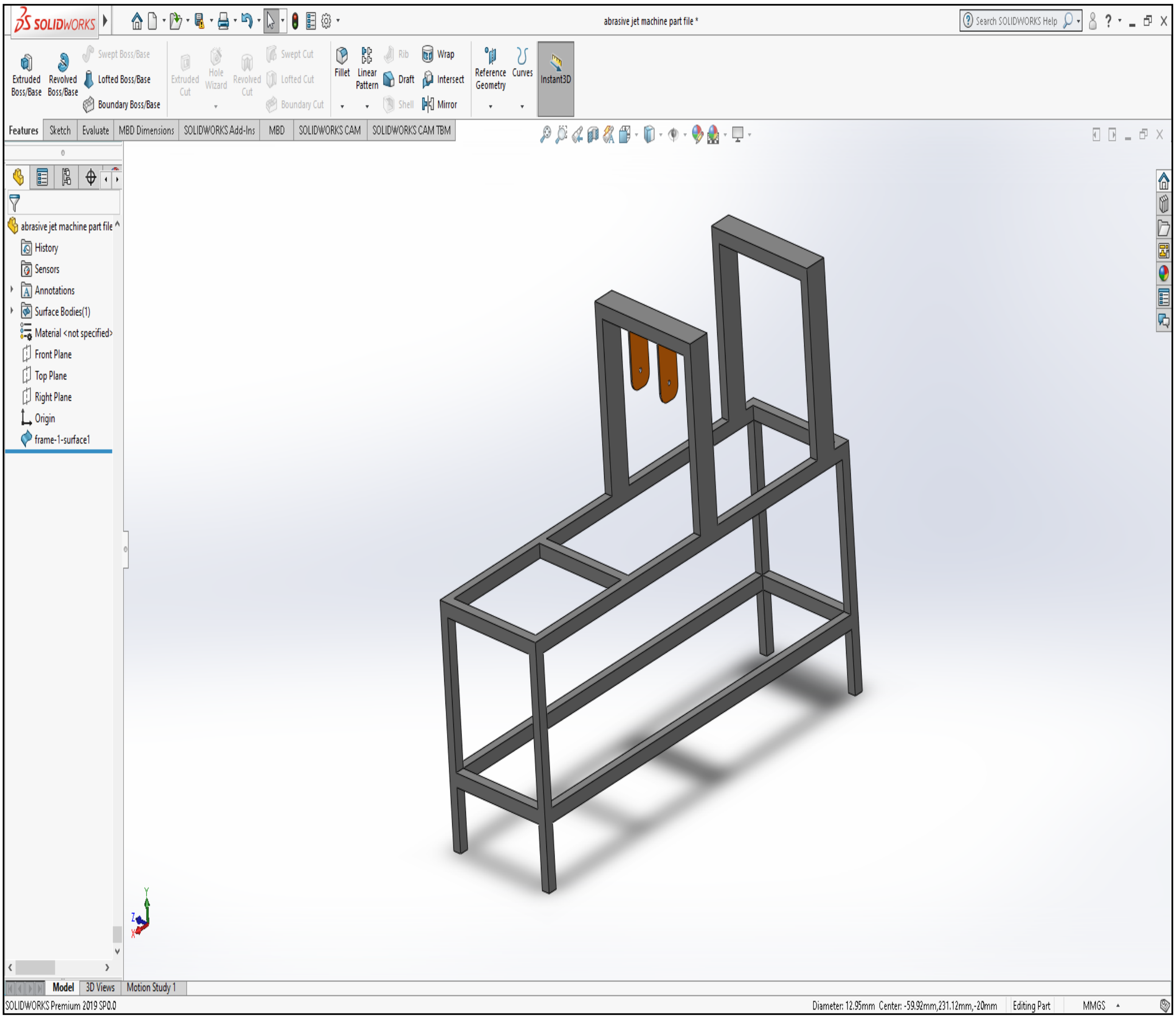

Fig. 3.4 - Mild steel frame

Mild steel frame is a structural system which is used to support other components of a physical assembly and therefore acts as the foundation for the assembly.

3.5 Bench Vice

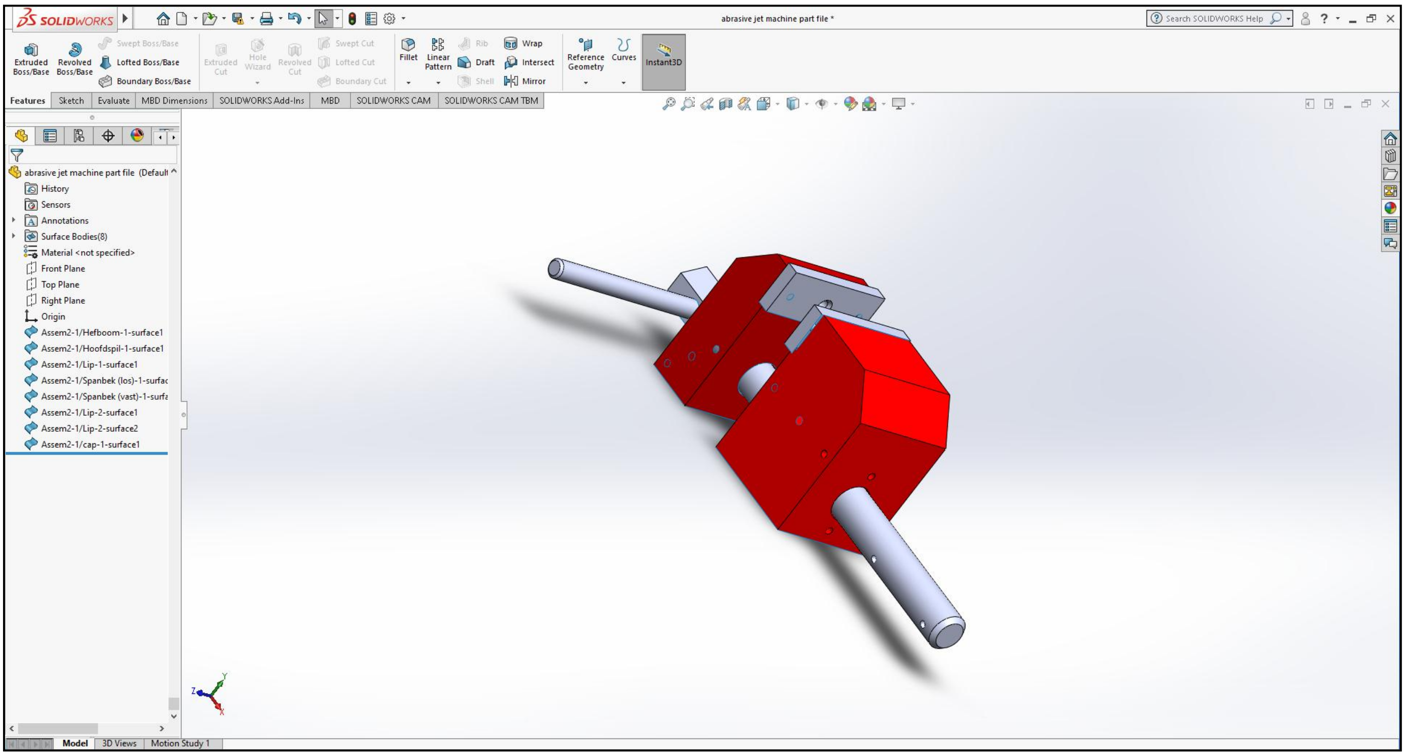

Fig. 3.5 Bench vice

A Bench Vice is a work piece holding tool which is used to hold the specimen or the workpiece in between the jaws. It consists of two jaws; where one jaw is movable while the other one is fixed.

3.6 Assembly

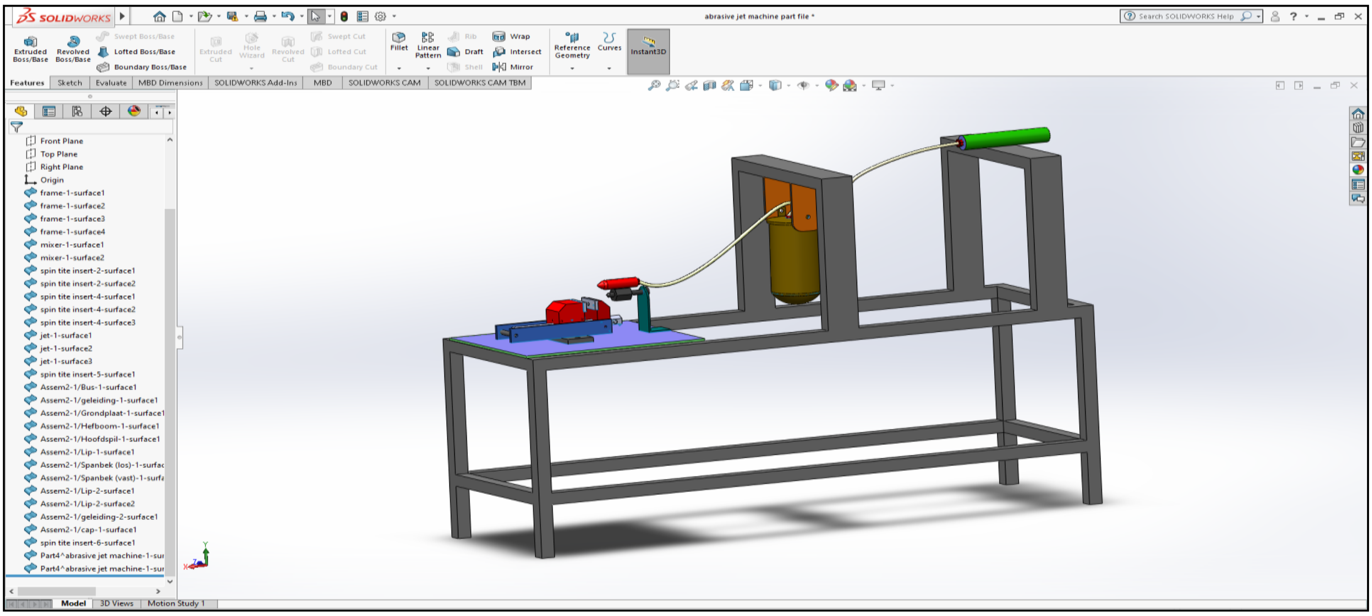

Fig. 3.6 Complete assembly

A complete 3-d assembly of AJM is shown in (Fig.3.6).

4. FABRICATED MODEL

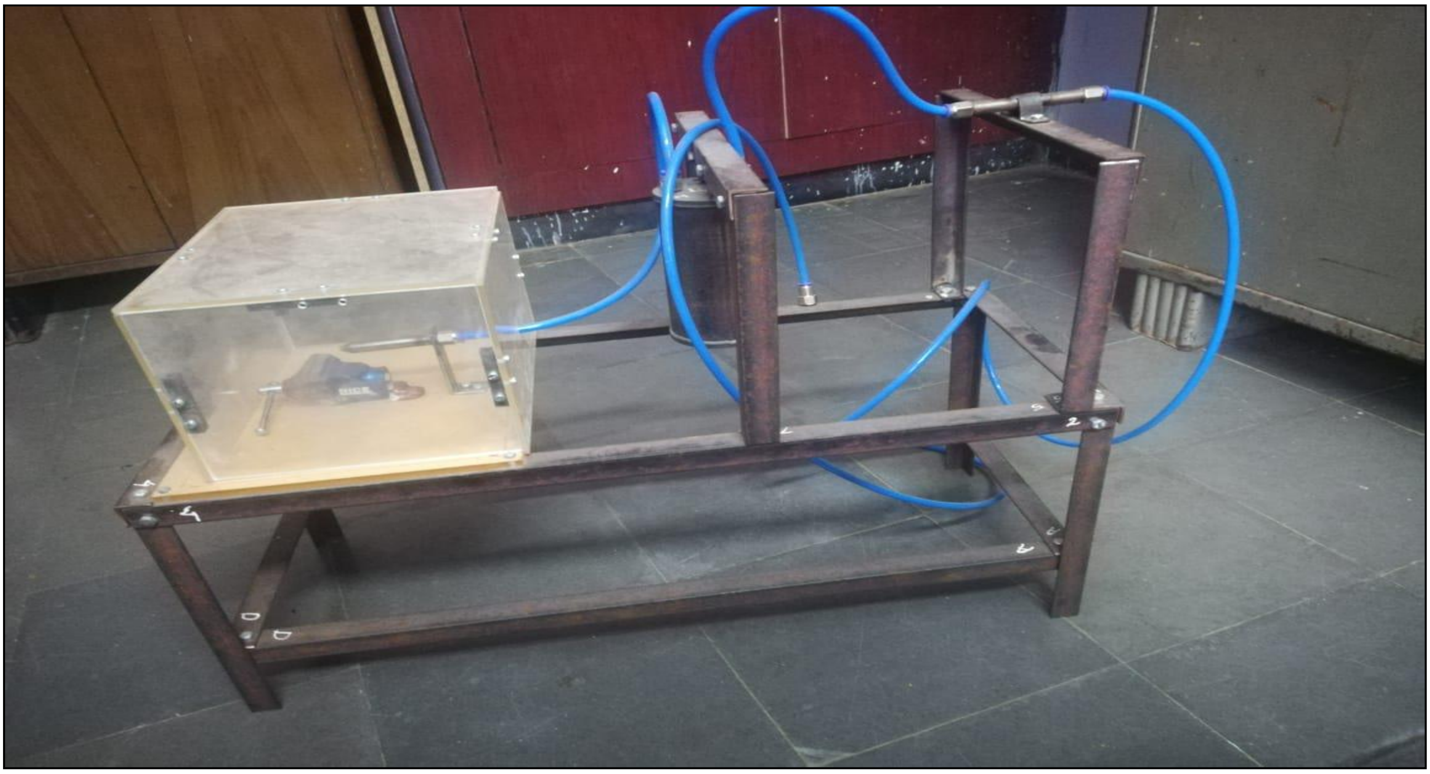

Fig. 4.1 Actual fabricated AJM

The pragmatic implementation of solidworks was done in this project, the various component modeled in solidworks was manufactured. We prepared cylindrical mixing chamber from 16 gauge M.S. sheet. A nozzle is attached at the top of the acrylic sheet with the necessary provisions. Housing for working chamber was made by the use of acrylic sheet in order to prevent the environment from getting polluted. The pneumatic connectors ie; PU pipes were used as a source of connection between working component and piping circuit to restrict any leakage whatsoever.

5. CONCLUSIONS

The complete modelling was done in Solidworks and fabrication of abrasive jet machine is done with mild steel, aluminium alloy and tungsten carbide, depending on the requirement of the component with a key objective to maintain high precision of all working components. The wear of nozzle was found to be negligible when the stand-off distance was constant. The current project can be further improved by the use of solenoid valve by which automation can be increased significantly. The idea to employ Solidworks in 3D modeling was colossal advantageous and had offered an accurate assistance in fabrication. Hence from the above mentioned context we understand and also practically observe that AJM machining process is one on which manufacturers can rely a great deal especially for machining those areas/portions which are inaccessible with good accuracies by means piping circuit as discussed above that has the ability to transport the abrasive-gas mixture to the desired part of the workpiece.

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BIOGRAPHY

Abdullah Mohd Hashir[1] is an undergraduate student in mechanical engineering at NSAKCET.

Md Muzafar Ullah Khan[2] is an undergraduate student in mechanical engineering at NSAKCET.

Mohammed Abdul Shukoor[3] is an undergraduate student in mechanical engineering at NSAKCET.

Mohammed Fazal Uddin Junaidi[4] is an undergraduate student in mechanical engineering at NSAKCET.

Mohd Abdul Moyeed[5] is working as assistant professor of mechanical engineering department in Nawab Shah Alam Khan College of Engineering and Technology for 7 years. He had completed his M-Tech in CAD/CAM and B-Tech in mechanical engineering. He has around 3 Publications and have 10 years of total experience in industry and Academy