A

MAJOR PROJECT REPORT

On

DESIGN, FABRICATION AND ANALYSIS

OF

ABRASIVE JET MACHINE

Thesis Submitted in partial fulfilment of the requirement for the award of
The Degree of

Bachelor of Technology

In

Mechanical Engineering

Submitted by

S.RAGHUVEER (14N81A0362)

Under the Guidance of

Mr.B .SHREENIVAS   Assistant Professor

SPHOORTHY ENGINEERING COLLEGE

(Approved by AICTE, Affiliated to JNTU, Hyderabad
NAAC Accredited / ISO 9001:2008 Certified)

Nadergul Village, Near Vanasthalipuram, Sagar Road, Saroornagar Mandal-501510
Hyderabad, Telangana

2014-2018

SPHOORTHY ENGINEERING COLLEGE

Nadergul(V), Saroornagar (M), Ranga Reddy Dist-501 510.
(Permanently Affiliated to JNTUH, Approved by AICTE, New Delhi; NAAC Accredited, Recognized by UGC u/s 2(f) & 12 (B); ISO 9001: 2008 Certified)

CERTIFICATE

Date :

This is to certify that the major project entitled "Design, Fabrication and Analysis of Abrasive Jet Machine" for the award of degree of Bachelor of technology in Mechanical engineering,Jawaharlal Technological University,Hyderabad, is a record confide project work carried out under our supervision and they fulfil the requirements of the regulations laid down by the university. The result of the project work either partially or fully has not been submitted to any other university or institute for the award of any degree.

Presented by

S.RAGHUVEER (14N81A0362)

INTERNALGUIDES

Mr.B.SHREENIVAS
Assistant professor

HEAD OF DEPATMENT

Mrs.R.N.S.DIVYA
Dept. Of Mechanical engineering

PROJECT COORDINATOR

Mr.NATRAJ
Assistant professor

EXTERNAL EXAMINER

DECLARATION

I here by declare that the whole work is done in completing this project with my own effort and I have not copied it from anywhere.During my project, my guide Mr.B.SHREENIVAS guided us to complete my project taking his valuable time.I am thankful to Sphoorthy engineering college for giving me this opportunity to do my project in the institute.

Presented by

S.RAGHUVEER (14N81A0362)

ACKNOWLEGMENT

I would like to express my sincere gratitude to **DEPARTMNET OF MECHANICAL ENGINEERING SPHN** for the enormous opportunity they presented me. The depth of knowledge and experience they put at my disposal is the most sincerely appreciated. I have gained such valuable knowledge and experience while working there.

I thank our beloved Principal, **Dr.K.S.SHAJI** for giving me permission to do the project in our campus

Having natured the project with our hard labour for the period of one month it is indeed a great pleasure and matter of immense satisfaction for me to express my deep sense of gratitude and indebtedness towards the lecturers of Mechanical Department and **R.N.S DIVYA** Head of Department of Mechanical engineering, **SPHOORTHY ENGINEERING COLLEGE** for permitting me to carry out my project work in college premises and allowing me to use college laboratories, infrastructure and facilities.

I would like thank my guide **Mr. SHREENIVAS** for his expert guidance and continuous encouragement, which led to the successful completion of my project.

I am grateful to **Mr. VARUN BHATT (**Asst professor), and other staff members of **DEPARTMENT OF MECHANICAL ENGINEERING SPHN** for their valuable inputs on design, fabrications and analysis of abrasive jet machine.

In my association with all the above persons, I experienced not only their expert guidance and continuous encouragement which led to the successful completion of the project.

I am also grateful to the entire **ENGINEERING WORKSHOP FACULTY, EXPERTS** for their cooperation throughout our project.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Abrasive Jet Machining is a non-conventional subtraction-type machining process in which brittle-fracture mechanism is used to remove the material from work-piece. The small but hard abrasive particles hit the work-piece material with very high velocity (which is imparted by the pressurised air) & the ensuing collision results in minute fractures on the work-piece. This explains why this process can be used only for brittle materials. If the work-piece is ductile, the abrasive particles simply embed in or bounce off the work-piece surface and there is no material removal.

The real beauty of this machining process is that it can be used to drill holes & make cuts in extremely thin & brittle materials like silicon wafers & egg-shells.

Key words : Non conventional machining , Nozzle , Abrasive,Brittle materials

CHAPTER 1

INTRODUCTION

We all know that the term machinability refers to the case with which a material can be machined to an acceptable surface finish. In ordinary machining we use harder tool to work on work piece, this limitation is overcome by unconventional machining, and unconventional machining is directly using some sort of indirect energy for machining.

Conventional machining involves the direct contact of tool and work piece, whereas unconventional machining does not require the direct contact of tool and work piece. Conventional machining has many disadvantages like tool wear which are not present in non-conventional machining.

1.1Definition of Unconventional Machining Processes.

An unconventional machining process (or non-traditional machining process) is a special type of machining process in which there is no direct contact between the tool and the work piece. In unconventional machining, a form of energy is used to remove unwanted material from a given work piece.

1.2 Importance of Unconventional Machining Processes.

The answer is simple. In several industries, hard and brittle materials like tungsten carbide, high speed steels, stainless steels, ceramics etc., find a variety of applications.
For example, tungsten carbide is used for making cutting tools while high speed steel is used for making gear cutters, drills, taps, milling cutters etc. If such materials are machined with the help of conventional machining processes, either the tool undergoes extreme wear (while machining hard work piece) or the work piece material is damaged (while machining brittle work piece).This is because, in conventional machining, there is a direct contact between the tool and the work piece. Large cutting forces are involved and material is removed in the form of chips. A huge amount of heat is produced in the work piece. This induces residual stresses, which degrades the life and quality of the

work piece material. Hence, conventional machining produces poor quality work piece with poor surface finish (if the work piece is made of hard and brittle material).To overcome all these drawbacks, we use unconventional machining processes to machine hard and brittle materials. We also use unconventional machining processes to machine soft materials, in order to get better dimensional accuracy.

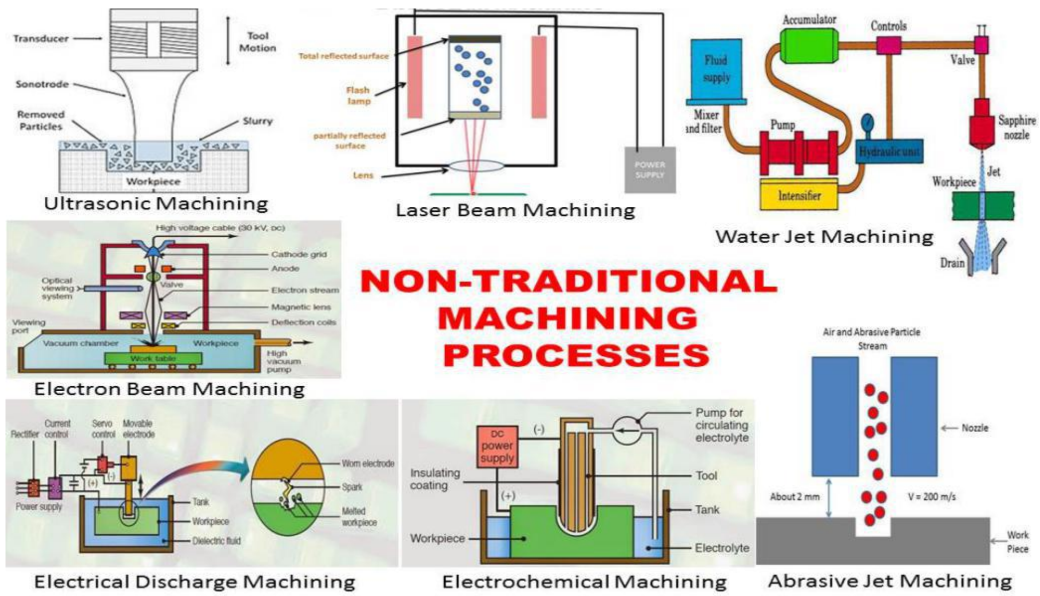


Fig 1.1: Unconventional machining processes

Nontraditional machining processes are widely used to manufacture geometrically complex and precision parts for aerospace, electronics and automotive industries.

1.3 Classification

Classification of unconventional machining processes was mainly on the basis of the nature of energy employed in machining process. They are:

1. Chemical Processes

1. Chemical Machining (CM)
2. Photochemical Machining (PCM)

2. Electrochemical Processes

1. Electro-Chemical Machining (ECM)
2. Electro Chemical Grinding (ECG)

3. Electro-Thermal Processes

1. Electrical Discharge Machining (EDM)
2. Electron Beam machining (EBM)
3. Plasma Arc Machining (PAM)
4. Laser Beam Machining (LBM)

4. Mechanical Processes

1. Ultrasonic Machining (USM)
2. Abrasive Jet Machining (AJM)
3. Water Jet Machining (WJM)
4. Abrasive Water jet Machining (AWJM)

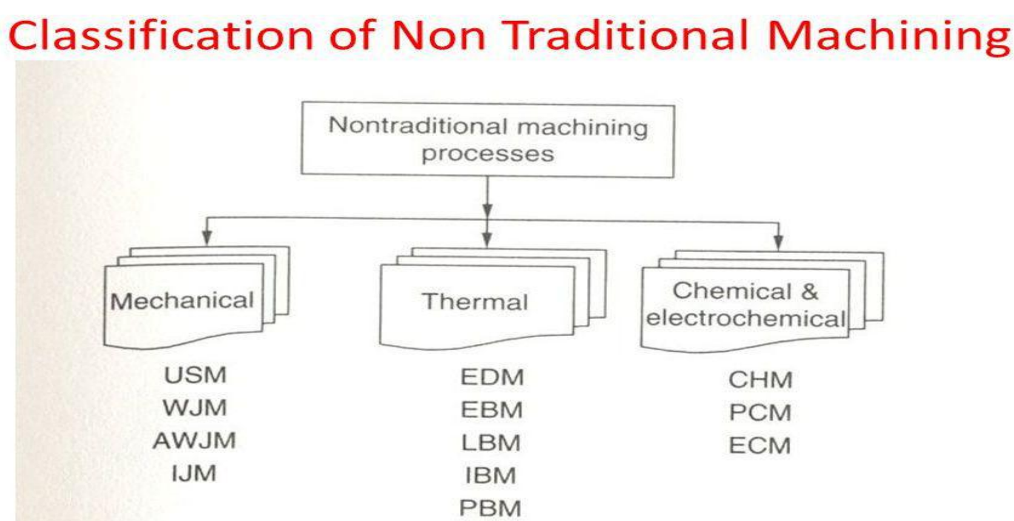


Fig 1.2: Classification of Non Traditional machining

1.4 General Characteristics of Advanced Machining Processes

Table 1.1: General Characteristics of Advanced Machining Processes

Sno.	Process	Characteristics	Process Parameters and MRR or cutting speed.
1	**Chemical machining (CM)**	Shallow removal on large flat or curved surfaces; blanking of thin sheets; low tooling and equipment cost; suitable for low-production runs.	0.0025-0.1 mm/min.
2	**Electrochemical machining (ECM)**	Complex shapes with deep cavities; highest rate of material removal among other nontraditional processes; expensive tooling and equipment; high power consumption; medium-to-high production quantity.	V: 5-25 DC; A: 1.5-8 A/mm^2; 2.5-12 mm/min, depending on current density.
3	**Electrochemical grinding (ECG)**	Cutting off and sharpening hard materials, such as tungsten-carbide tools; also used as honing process; higher removal rate than grinding.	A: 1-3 A/mm^2; typically 25 mm^3/s per 1000A.
4	**Electrical-discharge machining (EDM)**	Shaping and cutting complex parts made of hard materials; some surface damage may result; also used as a grinding and cutting process; expensive tooling and equipment.	V: 50-380; A: 0.1-500; typically 300 mm^3/min.
5	**Wire electric discharge machining**	Contour cutting of flat or curved surfaces; expensive equipment.	Varies with material and thickness.

6	**Laser-beam machining (LBM)**	Cutting and hole making on thin materials; very small holes and slots; heat-affected zone; requires a vacuum; expensive equipment.	0.50-7.5 mm/min.
7	**Electro-beam machining (EBM)**	Cutting and hole making on thin materials; very small holes and slots; heat-affected zone; requires a vacuum; expensive equipment.	1-2 mm^3/min.
8	**Water-jet machining (WJM)**	Cutting all types of nonmetallic materials; suitable for contour cutting of flexible materials; no thermal damage; noisy.	Varies considerably with material.
9	**Abrasive water-jet machining (AWJM)**	Single-layer or multi-layer cutting of metallic and nonmetallic materials.	Up to 7.5 m/min.
10	**Abrasive-jet machining (AJM)**	Cutting, slotting, deburring, etching and cleaning of metallic and nonmetallic materials; tends to round off sharp edges; can be hazardous.	Varies considerably with material.

CHAPTER 2

LITERATURE REVIEW

The literature study of Abrasive Jet Machine reveals that the Machining process was started a few decades ago. Till date there has been a through and detailed experiment and theoretical study on the process. Most of the studies argue over the hydrodynamic characteristics of abrasive jets, hence ascertaining the influence of all operational variables on the process effectiveness including abrasive type, size and concentration, impact speed and angle of impingement. Other papers found new problems concerning carrier gas typologies, nozzle shape, size and wear, jet velocity and pressure, stand-off-distance (SOD), or nozzle-tip-distance (NTD). These papers express the overall process performance in terms of material removal rate, geometrical tolerances and surface finishing of work pieces, as well as in terms of nozzle wear rate. Finally, there are several significant and important papers which focus on either leading process mechanisms in machining of both ductile and brittle materials, or on the development of systematic experimental-statistical approaches and artificial neural networks to predict the relationship between the settings of operational variables and the machining rate and accuracy in surface finishing.

[1]Umberto Prisca; Maria Carmina D'Onofrio: "Three-Dimensional CFD Simulation of Two-Phase Flow Inside the Abrasive Water Jet Cutting Head"

Computational fluid dynamics (CFD) simulation of the formation and discharge process of an air-water flow in an abrasive water jet (AWJ) head is presented by Umberto Prisco & Maria Carmina D'Onofrio. Numerical simulations have been conducted using the commercial code Fluent. 6.3 by Ansys. Dynamic characteristics of the flow inside the AW] head and downstream from the nozzle has been simulated under steady state, turbulent, two-phase flow conditions. The final aim is to gain fundamental knowledge of the ultrahigh velocity flow dynamic features that could affect the quality of the jet, such as the velocity and pressure distributions in different parts of the AWJ head and at the outlet.

[2]KhanI Ahsan Ali; AwangI Mohd Efendee Bin; AnnuarI Ahmad Azwari Bin: "Surface Roughness of Carbides Produced by Abrasive Water Jet Machining"

Experiments have been performed on effect of jet pressure, abrasive flow rate and work feed rate on smoothness of the surface produced by abrasive water jet machining of carbide of grade P25. Carbide of grade P25 is very hard and cannot be machined by conventional techniques. The abrasive used in investigations was garnet of mesh size 80. It was tried to cut carbide with low and medium level of abrasive flow rate, but the jet failed to cut carbide since it is too hard and very high level of energy is required. Minimum rate of abrasive flow that made it possible to cut carbide efficiently was 135 g/ min with increase in jet pressure the surface becomes smoother due to higher kinetic energy of the abrasives. But the surface near the jet entrance is smoother and the surface gradually becomes rougher downwards and is the roughest near the jet exit. Increase in abrasive flow rate also makes the surface smoother which is due to the availability of higher number of cutting edges per unit area per unit time. Feed rate didn't show significant influence on the machined surface, but it was found that the surface roughness increases drastically near the jet entrance.

The study of the results of machining under various conditions approves that a commercial AJM machine was used, with nozzles of diameter ranging from 0.45 to 0.65 mm, the nozzle materials being either tungsten carbide or sapphire, both of which have high tool lives. Silicon carbide and aluminium oxide were the two abrasives used. Other parameters studied were nozzle tip distances (5-10 mm), spray angles (60" and 90°) and pressures (5 and 7 bars) for materials like glass, ceramics, and electro-discharge machined (EDM) die steel. The holes drilled by AJM may not be circular and cylindrical but almost elliptical and bell mouthed. High material removal rate conditions do not necessarily yield small narrow clean-cut machined areas.

[3]Ghobeity, A.; Spelt, J. K.; Papini: "Abrasive jet micro-machining of planar areas and transitional slopes"

Studies reveal that MM is an attractive micro-machining method for ceramic materials. The machinability during the NM process can be compared to that given by the established models of solid particle erosion, in which the material removal is assumed to originate in the ideal crack formation system. However, it was clarified that the erosion models are not necessarily applicable to the NM test results, because the relative hardness of the abrasive against the target material, which is not taken into account in the models, is critical in the micro-machining process. No strength degradation took place for the AJM ceramic surfaces. This is attributed to the fact that radial cracks did not propagate downwards by particle impacts during the machining process.

[4]D.A.Axinte, J.P.Stepanian, M.C.Kong, J.McGourlay: "Abrasive water jet turning-An efficient method to profile and dress grinding wheels"

Abrasive Water Jet (AWJ) turning is a technology that still tries to find its niche field of application where it can be economically viable. But a particular application of AW] turning has proved its technological and economical capability, i.e. profiling and dressing of grinding wheels. Starting from the theoretical considerations, the key operating parameters of AWJ turning are identified and included in a methodology to generate various profiles of grinding wheels by means of tangential movement of the jet plume. Roughing in single pass to concave/convex geometries (experimented depth of cuts < 30 mm), generation of thin walls/slots (thickness < 2 mm, depth > 430 mm) and intricate profile (e.g. succession of tight radii) on a variety of grinding wheels show the capability of AWJ turning to fulfill the requirements of this nice application.

The machining process produces no heat and hence changes in microstructure or strength of the surface is unlikely. The air acts as a coolant and hence AJM process has a high potential as damage free micromachining method. The fracture toughness and hardness of the target materials are critical parameters affecting the material removal rate in AJM. However, their influence on the machinability varied greatly with the employed abrasives.

In recent years abrasive jet machining has been gaining increasing acceptability for deburring applications. The influence of abrasive jet deburring process parameters is not known clearly. AJM deburring has the advantage over manual deburring method that generates edge radius automatically. This increases the quality of the deburred components. The process of removal of burr and the generation of a convex edge were found to vary as a function of the parameters jet height and impingement angle, with a fixed SOD. The influence of other parameters, viz. nozzle pressure, mixing ratio and abrasive size are insignificant. The SOD was found to be the most influential factor on the size of the radius generated at the edges. The size of the edge radius generated was found to be limited to the burr root thickness.

[5]Li.C.H, Ding Y.C, Lu B.H: "Modelling and simulation for material removal in abrasive jet precision finishing with wheel as restraint"

Abrasive jet finishing combined with grinding gives rise to a precision finishing process called the integration manufacturing technology, in which slurry of abrasive and liquid solvent is injected to grinding zone between grinding wheel and work surface under no radial feed condition. The abrasive particles are driven and energized by the rotating grinding wheel and liquid hydrodynamic pressure and increased slurry speed between grinding wheel and work surface achieves micro removal finishing.

Abrasive water jet machines are becoming more widely used in mechanical machining. These machines offer great advantages in machining complex geometrical parts in almost any material. This ability to machine hard-to-machine materials, combined with advancements in both the hardware and software used in water jet machining has caused the technology to spread and become more widely used in industry. New developments in high pressure pumps provide more hydraulic power at the cutting head, significantly increasing the cutting performance of the machine. Analysis of the economic and technical has been done by researchers. Those technology advancements in applying higher power machining and intelligent software control have proven to significantly improve the overall performance of the abrasive water jet machining operation, thus widening the scope of possible applications of this innovative and promising technology.

[6]TaiudinI Harnisah Bt, KhanI Ahsan Ali; MunaiatI Noraziaty Bt: "A Study on Abrasive Water Jet Machining of Aluminium with Garnet Abrasives"

Quality of the surface produced during abrasive water jet machining of aluminium has been investigated in recent years. The type of abrasive used was garnet of mesh size 80. The cutting variables were stand-off distance of the nozzle from the work surface; work feed rate and jet pressure. The evaluating criteria of the surface produced were width of cut, taper of the cut slot and work surface roughness. It was found that in order to minimize the width of cut; the nozzle should be placed close to the work surface.

Increase in jet pressure results in widening of the cut slot both at the top and at exit of the jet from the work. However, the width of cut at the bottom (exit) was always found to be larger than that at the top (at a stand-off distance of 3 mm and the work feed rate of 15 mm min-1). It was found that the taper of cut gradually reduces with increase in stand-off distance and was close to zero at the stand-off distance of 4 mm (at a jet pressure of 30 ksi and a work feed rate of 15 mm min-1). The feed rate of the work should be kept within 40 mm min-1 (at the jet pressure of 30 ksi and the stand-off distance of 3 mm), because a feed rate beyond 40 mm min-1 results in sharp increase in taper angle. The jet pressure does not show significant influence on the taper angle within the range of work feed and the standoff distance considered. Both stand-off distance and the work feed rate show strong influence on the roughness of the machined surface. Hence stand-off distance should be kept within 3 mm (at a jet pressure of 30 ksi and a work feed rate of 15 mm min-1) and the work feed rate should be kept within 30 mm min-1 (at a jet pressure of 30 ksi and a standoff distance of 3 mm) in order to have a good surface finish, since beyond those values of the parameters the roughness of the machined surface rises sharply. Increase in jet pressure shows positive effect in terms of smoothness of the machined surface. With increase in jet pressure, the surface roughness decreases (at a stand-off distance of 3mm and work feed of 15 mm min-1). This is due to fragmentation of the abrasive particles into smaller sizes at a higher pressure and due to the fact that smaller particles produce smoother surface. So within the jet pressure considered, the work surface is smoother near the top surface and gradually it becomes rougher at higher depths.

2.1 Abrasive materials

An abrasive is a material, often a mineral, that is used to shape or finish a workpiece through rubbing which leads to part of the workpiece being worn away by friction. While finishing a material often means polishing it to gain a smooth, reflective surface, the process can also involve roughening as in satin, matte or beaded finishes. In short, the ceramics which are used to cut, grind and polish other softer materials are known as abrasives.

The most common abrasive materials used for Abrasive jet machining are aluminum oxide, silicon carbide. Sodium bicarbonates, glass beads of small grain size and dolomite are used for cleaning and polishing purpose. The selection of abrasive material depends on the work material, machining operation and required material removal rate.

The size of the material is also important. The material removal rate (MRR) depends on the grain size. The coarse grains give high MRR, and they are recommended for cutting. The finer grains are useful in finishing operation. However, the finer grain tends to stick together and cause a clog in the nozzle. The grain must be sharp edged, but fine enough to remain suspended in the carrier gas, and it should have good flow characteristic. The favorable grain size is between 10 to 50μ.

Abrasive material and their specific application are given below

Table 2.1: Abrasive material and their specific applications

Abrasives	Grain Sizes	Application
Aluminium oxide (Al2O3)	12, 20, 50 microns	Cleaning, cutting, grooving and deburring
Silicon carbide (SiC)	25, 40 micron	Cutting, grooving and deburring of hard material
Glass beads	0.635 to 1.27mm	Light polishing and deburring, matte finish
Dolomite (Calcium magnesium carbonate)	200 mesh	Etching and polishing Machining of soft material, light cleaning
Sodium bicarbonate	27 micros	Cleaning, deburring and cutting of soft material. Light finishing below 50°C

2.2 Aluminium oxide (Al2O3)

Aluminium oxide (British English) or aluminum oxide (American English) is a chemical compound of aluminium and oxygen with the chemical formula Al_2O_3.

It is the most commonly occurring of several aluminium oxides, and specifically identified as aluminium(III) oxide.

It is commonly called alumina, and may also be called aloxide, aloxite, or alundum depending on particular forms or applications. It occurs naturally in its crystalline polymorphic phase α-Al_2O_3 as the mineral corundum, varieties of which form the precious gemstones ruby and sapphire.

Al_2O_3 is significant in its use to produce aluminium metal, as an abrasive owing to its hardness, and as a refractory material owing to its high melting point.

Fig 2.1: Aluminum oxide

2.3 Silicon carbide

Silicon carbide (SiC) is a semiconductor containing silicon and carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral moissanite. Synthetic silicon carbide powder has been mass-produced since 1893 for use as an abrasive. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. Electronic applications of silicon carbide such as light-emitting diodes (LEDs) and detectors in early radios were first demonstrated around 1907. SiC is used in semiconductor electronics devices that operate at high temperatures or high voltages, or both. Large single crystals of silicon carbide can be grown by the Lely method; they can be cut into gems known as synthetic moissanite. Silicon carbide with high surface area can be produced from SiO_2 contained in plant material. Silicon carbide (SiC) is also known as carborundum.

Fig 2.2: Silicon Carbide

2.4 Glass beads

Glass Beads will clean metal parts without etching the surface. Glass Beads are commonly used for automotive restoration, polishing of castings, stainless steel fabrication, and light deburring of precision parts.

Glass Beads are most commonly used in abrasive blast cabinets. Its round shape gently cleans metal parts, leaving a smooth, polished or matte finish.

Glass Beads are typically blasted at 60–90 PSI to achieve the most productive results. This lower PSI, along with glass bead's durability, produces lower dust levels than most mineral or slag abrasives. Low dust levels improve the operator's visibility of the work surface, increasing production rates. Lower dust levels also reduce cleanup costs on the work site.

Glass Beads are an environmentally-friendly and clean abrasive that is aggressive enough to clean and deburr parts, yet will not damage them.

Glass beads can be recycled up to eight times or more. Abrasive blast cabinets provide the best recyclability rate.

Glass Beads can easily perform a wide variety of abrasive blasting jobs. Larger sizes can be used for the cleaning of automotive parts, castings, and deburring rough edges from castings and gears.

Medium sizes are suited for blending surface defects and working with aluminum and stainless steel parts, providing a satin to matte finish. Fine sizes work best for light duty work and allow for fine detail work

Fig 2.3: Glass beads

2.5 Dolomite (Calcium magnesium carbonate)

Dolomite is an anhydrous carbonate mineral composed of calcium magnesium carbonate, ideally $CaMg(CO_3)_2$.

The term is also used for a sedimentary carbonate rock composed mostly of the mineral dolomite. An alternative name sometimes used for the dolomitic rock type is dolostone.

Fig 2.4: Dolomite

2.6 Sodium bicarbonate

Sodium bicarbonate (IUPAC name: sodium hydrogen carbonate), commonly known as baking soda, is a chemical compound with the formula $NaHCO_3$. It is a salt composed of sodium ions and bicarbonate ions. Sodium bicarbonate is a white solid that is crystallinebut often appears as a fine powder. It has a slightly salty, alkaline taste resembling that of washing soda (sodium carbonate). The natural mineral form is nahcolite. It is a component of the mineral natron and is found dissolved in many mineral springs.

Fig 2.5: Sodium Bicarbonate

2.7 Grit = Micron = Mesh Conversion Chart

We have used 160 grit=120 mesh=125 micron **Aluminium oxide (Al2O3)** as abrasive.

Table2.2: Conversion chart

Grit	Mesh	Micron
100,000	0- 0.5	1/4
60,000	0-1	1/2
14,000	0-2	1
13,000	1-2	1.5
9,000	2-3	2.5
8,000	2-4	3
5,000	2-6	4
4,500	4-6	5
2,800	5-10	7
1,800	6-12	9
1,400	8-20	14
1,200	10-20	15
1,050	12-25	18
800	20-30	25
600	20-40	30
500	30-40	35
325	40-50	45
285	50-60	55
240	60-80	70
225	80-100	90
160	100-120	110
100	120-160	150

2.8 Uses/functions of Al_2O_3

- Used as abrasive in sandpaper, sanding and cutting tools, and toothpaste. Large crystals with metal ion impurities often of gemstone quality. Inert support for chromatography. In fibrous forms, woven into heat-resistant fabrics; also used to strengthen ceramics and metals.
- Is widely used as a refractory and as a support for catalysts.

- This material is extraordinarily hard, a property that leads to its use as the abrasive in grinding wheels, "sandpaper," and toothpaste.
- Aluminium oxide is also widely used as an abrasive. An abrasive is a very hard material used to grind, polish, sand, scour, and scrub, smooth or polish some other material. Among the products that include aluminium oxide as an abrasive are emery boards, sandpaper, grinding and polishing wheels and belts, lens grinding devices, and gem polishing wheels.
- The high melting point of aluminium oxide also makes it a good refractory product. A refractory product is one that does not melt easily, making it suitable for lining the inside of furnaces or the manufacture of glass and ceramic materials that will not melt when exposed to very high temperatures.
- As adsorbent, desiccant, abrasive as filler for paints and varnishes; in manufacture of alloys, ceramic materials, electrical insulators, and resistors, dental cements, glass, steel, artificial gems in coatings for metals, etc. as catalyst for organic reactions.

2.9 Properties of Alumina/Aluminium Oxide (Al_2O_3)

- Moderate to extremely high mechanical strength (300 to 630 MPa)
- Very high compressive strength (2,000 to 4,000 MPa)
- High hardness (15 to 19)
- Moderate thermal conductivity (20 to 30 W/mK)
- High corrosion and wear resistance
- Good gliding properties
- Low density (3.75 to 3.95 g/cm^3)
- Operating temperature without mechanical load 1,000 to 1,500°C.

2.10 Physical properties of Aluminium Oxide (Al_2O_3)

- **Melting Point:** 2053°C = 2326.15 K = 3727.4°F
- **Boiling Point:** 3000°C = 3273.15 K = 5432°F
- **Density (g/cm3):**3.97 at room temperature/1 atm pressure

CHAPTER 3

WORKING PRINCIPLE OF ABRASIVE JET MACHINING

- In abrasive jet machining (AJM), the material removal takes place due to impingement of the fine abrasive particles.
- The abrasive particles are typically of 0.025mm diameter and the air discharges at a pressure of several atmosphere.

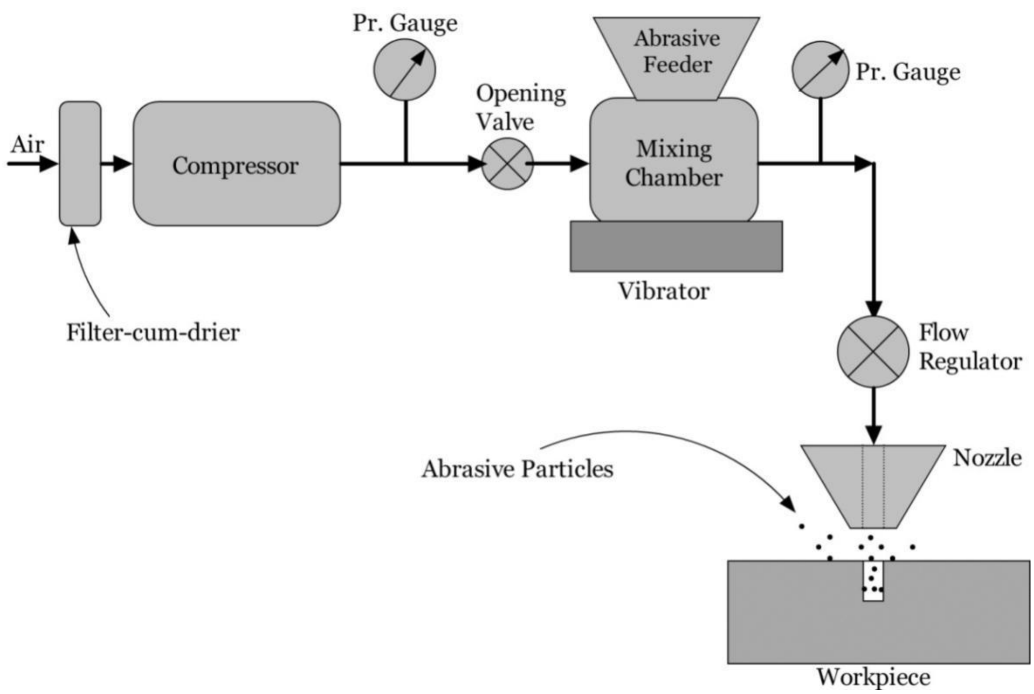


Fig 3.1: Layout of AJM

The operating principle of process is very simple. High pressure air from the compressor passes through filters and control valves into mixing chamber. The abrasive particles and carrier gas are thoroughly mixed in the mixing chamber and a stream of abrasive mixed gas passes through a nozzle on the work piece. It causes indentation on the work piece. The indentation ultimately results in Capture of particles from the work surface.

3.1 Components of abrasive jet machine

The major components of abrasive jet machine are:

- Air compressor with tank
- Nozzle
- Abrasive
- Pressure regular
- Hopper
- Mixing chamber
- Blast cabinet
- Abrasive collector
- Table
- Hose pipe
- XY motion module

3.2 Air compressor with tank

An air compressor is a device that converts power into potential energy stored in pressurized air (i.e., compressed air).

Fig 3.2: Air compressor with tank.

Table 3.1: Air compressor specification

Sno.	Parameters	Specifications
1	Power	2HP
2	Voltage	220V
3	Displacement	100L/min
4	Pressure	115Psi
5	Tank capacity	30L
6	Speed	2850 rpm
7	Weight	23 kg

3.3 Nozzle

A nozzle is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipe.

Fig 3.3: Nozzle

3.4 Abrasive

A substance or material capable of polishing or cleaning a hard surface by rubbing or grinding.

Fig 3.4: Abrasive

3.5 Pressure regulator

A pressure regulator is a control valve that reduces the input pressure of a fluid to a desired value at its output. Regulators are used for gases and liquids, and can be an integral device with an output pressure setting, a restrictor and a sensor all in the one body, or consist of a separate pressure sensor, controller and flow valve.

Fig 3.5 Pressure regulator

3.6 Hopper

A container for a loose bulk material such as grain, rock, or rubbish, typically one that tapers downward and is able to discharge its contents at the bottom.

Fig 3.6: Hopper

3.7 Mixing chamber

A volume or space within which a mingling of substances may occur. Abrasive particles are dropped into mixing chamber where high speed air mixes with abrasive particles and impinge on work piece passing through nozzle.

Fig 3.7: Mixing chamber

3.8 Blast cabinet

A blast cabinet is essentially a closed loop system that allows the operator to blast the part and recycle the abrasive

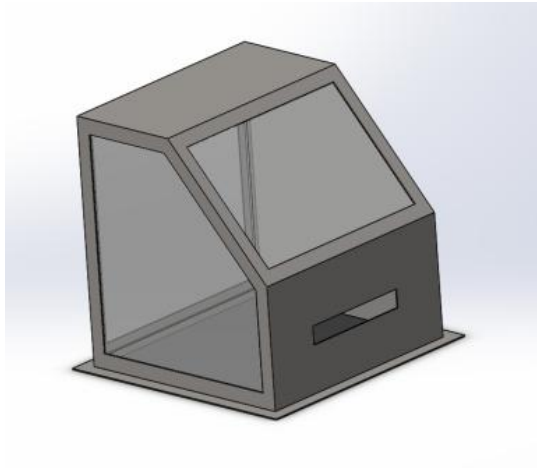


Fig 3.8: Cabinet

3.9 Abrasive collector

A collector guides used up abrasive combined with removed material into a container from where it can be either reused or disposed off.

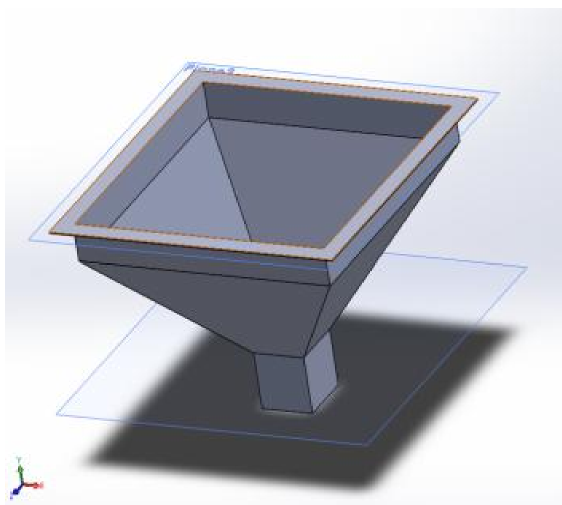


Fig 3.9: Abrasive collector

3.10 Table

All the components are to be assembled and given support and this support is provided by a table. On these table components are placed according to requirement.

Fig 3.10: Table

3.11 Hose pipe

A hose is a flexible hollow tube designed to carry fluids from one location to another. Hoses are also sometimes called pipes (the word pipe usually refers to a rigid tube, whereas a hose is usually a flexible one), or more generally tubing. The shape of a hose is usually cylindrical (having a circular cross section).

Fig 3.11: Hose pipe

3.12 XY motion module

X-Ytables help provide horizontal motion for automated machinery. XY motion module allows the nozzle to move along X axis, Y axis. We used dresser drawer slides to achieve moment in X axis, Y axis.

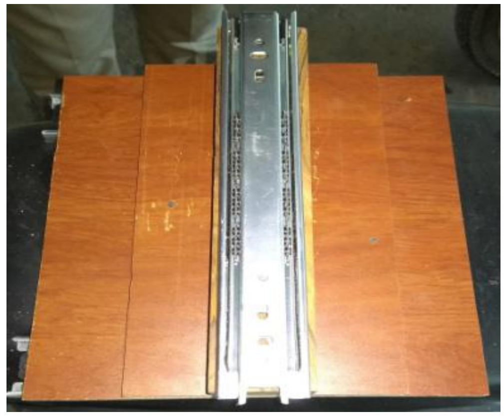


Fig 3.12: XY motion module

3.13 Mechanics of AJM

Abrasive particle impinges on the work surface at a high velocity and this impact causes a tiny brittle fracture and the following air or gas carries away the dislodged small work piece particle.

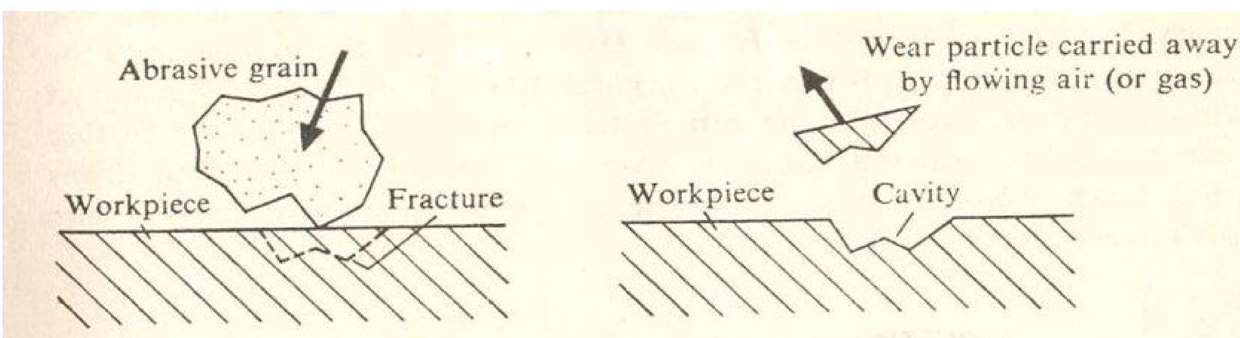


Fig 3.13 (a): Fracture of work surface Fig 3.13 (b): Formation of cavity

3.14 Process

Material is removed by fine abrasive particles, usually about 0.001 in (0.025 mm) in diameter, driven by a high velocity fluid stream; common gases are air or inert gases.

Pressures for the gas range from 25 to 130 psig (170–900 kPa or 4 bars) and speeds can be as high as 300 m/s (1,000 km/h).

3.15 Process parameters

The process characteristics can be evaluated by judging

- The MRR,
- The geometry of the cut.
- The roughness of the surface produced, and
- The rate of the nozzle wear.

The major parameters which control these quantities are:

- The abrasive (composition, strength, size and mass flow rate).
- The gas (composition, pressure and velocity).
- The nozzle (geometry, material, distance from and inclination to the work surface).

3.16 Abrasive

- Mainly 2 types of abrasives are used (1) aluminum oxide (2) silicon carbide. (grains with a diameter 10-50 microns are readily available)

Fig 3.14: Abrasives

- For good wear action on the surfaces, the abrasive grains should have sharp edges.
- A reuse of the abrasive powder is normally not recommended because of the decrease of cutting capacity and clogging of the nozzle orifices due to contamination.
- The mass flow rate of the abrasive particles depends on the pressure and the flow rate of the gas.

- There is an optimum mixing ratio (mass fraction of the abrasive in the jet) for which the material removal rate is the highest.
- When the mass flow rate of the abrasive increases the material removal rate also increases.

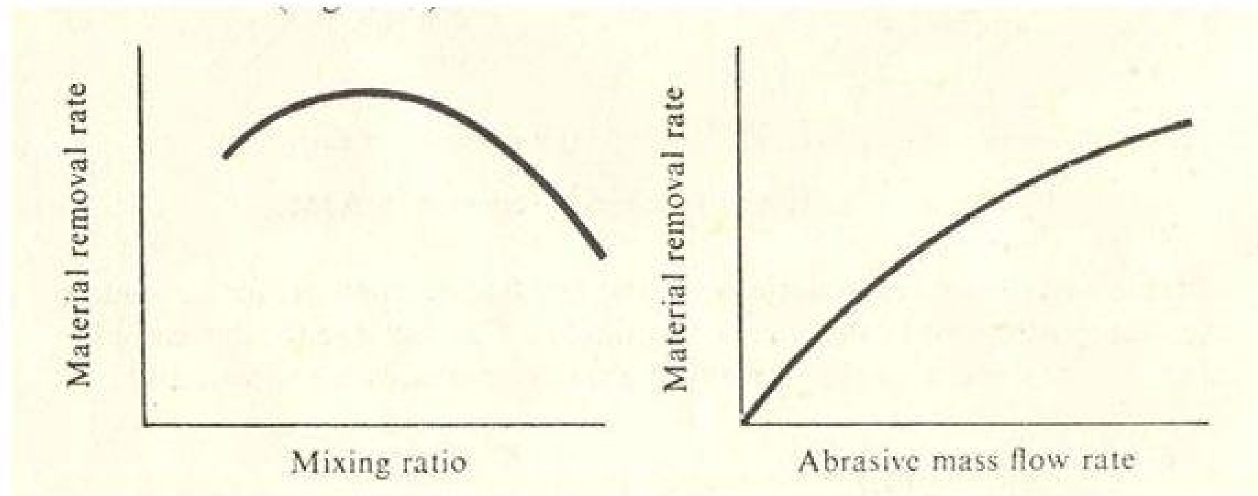


Fig 3.15(a): Relation between mixing ratio & MRR   Fig 3.15(b): Mass flow rate & MRR

3.17 Gas

- The AJM unit normally operates at a pressure of 0.2-1.0 N/mm2.
- The composition of the gas and high velocity has a significant impact on the MRR even if the mixing ratio is not changed.

3.18 Nozzle

- The nozzle is one of the most vital elements controlling the process characteristics.
- The nozzle material should be hard to avoid any significant wear due to the flowing abrasive.
- For the normal operation the cross-sectional area of the orifice can be either circular or rectangular and between 0.05-0.2 mm2.

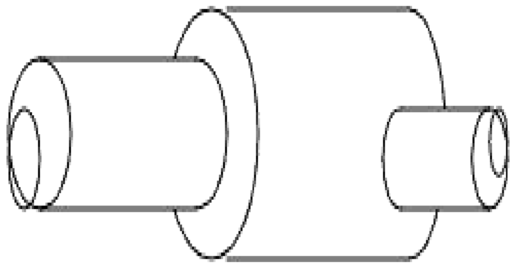


Fig 3.16(a): Right angled head

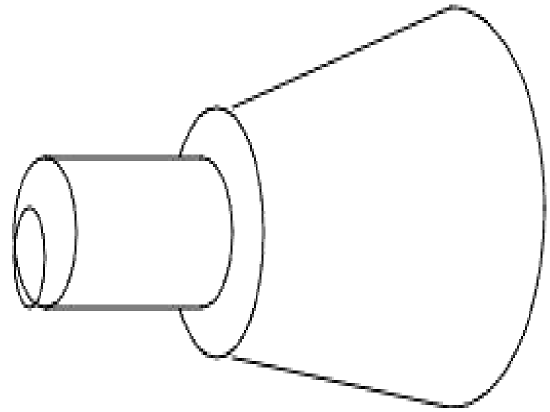


Fig 3.16(b): Straight head

3.19 Nozzle to tip distance (Standoff distance)

- The nozzle tip distance (NTD) or the standoff distance is a critical parameter in AJM.
- The NTD not only affects the MRR from the work surface but also the shape and size of the cavity produced.
- When the NTD increases, the velocity of the abrasive particles impinging on the work surface increases due to their acceleration after they leave the nozzle. This increases the MRR.
- With a further increase in the NTD, the velocity reduces due to the drag of the atmosphere which initially checks the increase in MRR and then decreases it.

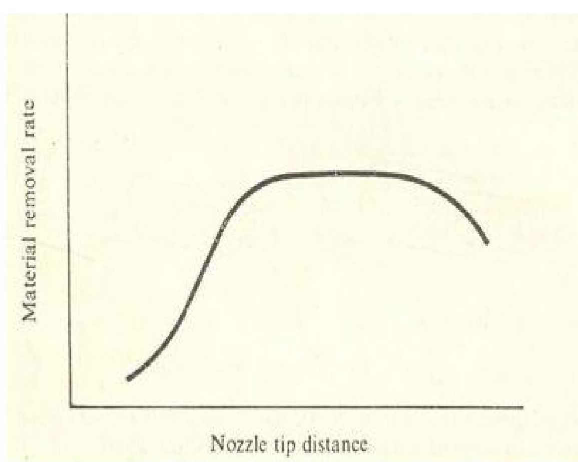


Fig 3.17: Graph between NTD & MRR

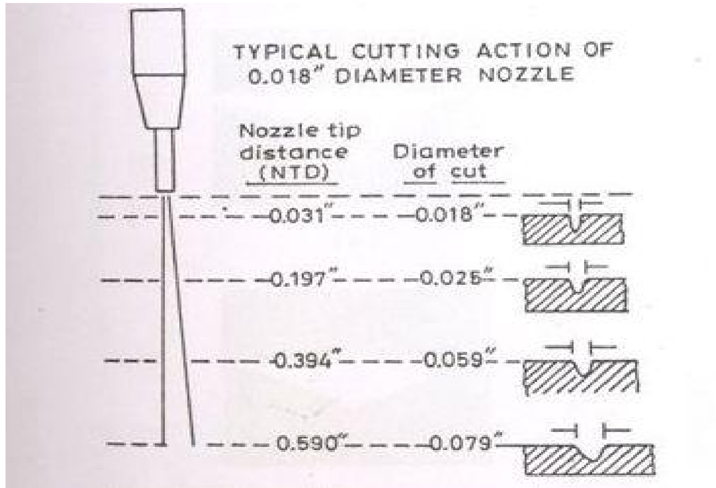


Fig 3.18: Standoff Distance

CHAPTER 4

DESIGNING OF COMPONENTS

4.1 Designing of nozzle

We started our project by designing nozzle, as nozzle is the key component of AJM. Various researchers used different nozzle materials for various applications and process. Tungsten carbide, sapphire, HCHCr steel, aluminium nozzles for mixing stage, brass and steel nozzles at the exit stage, Stainless steel, Tool Steel , deep reactive ion etching (DRIE), Alloy steel (EN38) heat treated of hardness 50 HRC was used for nozzles are used as nozzle materials for research purpose.

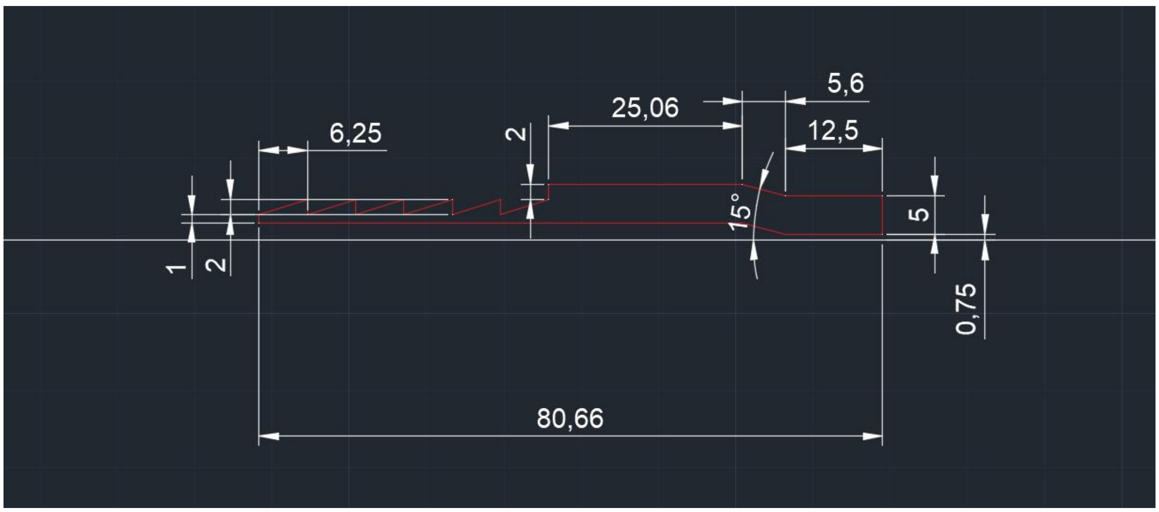


Fig 4.1: Nozzle dimensions

The above figure shows the dimensions of the nozzle, we have considered a nozzle with 1.5mm diameter.

The abrasive particles are directed into the work surface at high velocity through nozzles. Therefore, the material of the nozzle is subjected to great degree of abrasion wear and hence these are made of hard materials such as tungsten carbide or synthetic sapphire. Nozzles are made with an external taper to minimize secondary effects due to ricocheting of abrasive particles. Nozzles made of tungsten carbide have an average life of 12 to 30 hours while nozzles of sapphire last for about 300 hour of operation.

Due to lack of availability of materials like tungsten carbide and synthetic sapphire, we considered stainless steel as nozzle material.

4.2 Solid works

Dassault Systems SOLIDWORKS Corp. offers complete 3D software tools that let you create, simulate, publish, and manage your data. SOLIDWORKS products are easy to learn and use, and work together to help you design products better, faster, and more cost-effectively.The SOLIDWORKS focus on ease-of-use allows more engineers, designers and other technology professionals than ever before to take advantage of 3D in bringing their designs to life.

SolidWorks is a solid modeler, and utilizes a parametric feature-based approach which was initially developed by PTC (Creo/Pro-Engineer) to create models and assemblies. The software is written on Parasolid-kernel.Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allows them to capture design intent.

Design intent is how the creator of the part wants it to respond to changes and updates. For example, you would want the hole at the top of a beverage can to stay at the top surface, regardless of the height or size of the can. SolidWorks allows the user to specify that the hole is a feature on the top surface, and will then honor their design intent no matter what height they later assign to the can.Features refer to the building blocks of the part. They are the shapes and operations that construct the part. Shape-based features typically begin with a 2D or 3D sketch of shapes such as bosses, holes, slots, etc. This shape is then extruded or cut to add or remove material from the part. Operation-based features are not sketch-based, and include features such as fillets, chamfers, shells, applying draft to the faces of a part, etc.

Building a model in SolidWorks usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of SolidWorks means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch.In an assembly, the analog to sketch relations are mates. Just as sketch relations define conditions such as tangency, parallelism, and concentricity with respect to sketch geometry, assembly mates define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies. SolidWorks also includes additional advanced mating features such as gear and cam follower mates, which allow modeled gear assemblies to accurately reproduce the rotational movement of an actual gear train.

Finally, drawings can be created either from parts or assemblies. Views are automatically generated from the solid model, and notes, dimensions and tolerances can then be easily added to the drawing as needed. The drawing module includes most paper sizes and standards

Developer(s)	Dassault Systèmes
Initial release	November 1, 1995; 22 years ago[1]
Stable release	SolidWorks 2018 SP1 / January 10, 2018
Operating system	Microsoft Windows
Available in	English
Type	CAD and CAE
Website	www.solidworks.com

4.3 Analysis of nozzle (simulation)

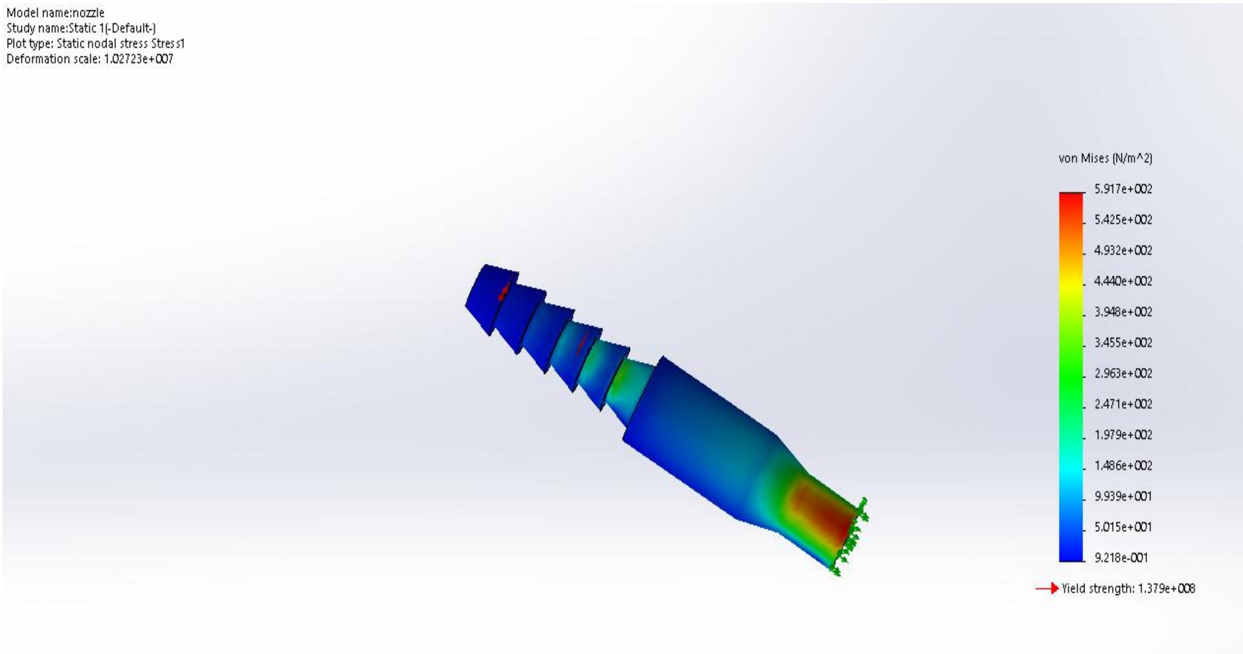


Fig 4.2: Nozzle Simulation in Solid works

The steps needed to perform an analysis depend on the study type. You complete a study by performing the following steps:

- Create a study defining its analysis type and options.
- If needed, define parameters of your study. A parameter can be a model dimension, material property, force value, or any other input.
- Define material properties. This step is not required if material properties were defined in the CAD system. Fatigue and optimization studies use referenced studies for material definitions.
- Specify restraints and loads. Fatigue and optimization studies use referenced studies for restraints and loads. Drop test studies do not allow you to define restraints and loads other than what is specified in the setup.
- The program automatically creates a shell mesh for surfaces and sheet metals with uniform thicknesses. For sheet metals, right-click on shell icon and select

Treat as Solid to mesh with solid elements. For drop test studies sheet metals mesh with solid elements.

- The program automatically meshes structural members with beam elements.
- The program automatically creates a mixed mesh when different geometries (solid, shell, structural members etc.) exist in the model.
- Define component contact and contact sets.
- Mesh the model to divide the model into many small pieces called elements. Fatigue and optimization studies use the meshes in referenced studies.
- Run the study.View results.

4.4 Designing of cabinet

Abrasive jet machining should be performed in containment since AJM deals with the use of abrasive like aluminum oxide and silicon carbide which are harmful for human operator. So we designed a cabinet in which we can perform various machining experiments and observe each stage of machining process from outside and making it safe since abrasive materials are not in contact with the operator.

The figures below show the design of the cabinet

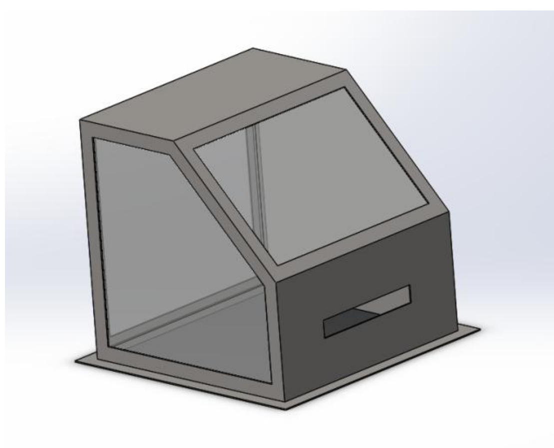


Fig 4.3: Cabinet design

4.5 Designing of collector

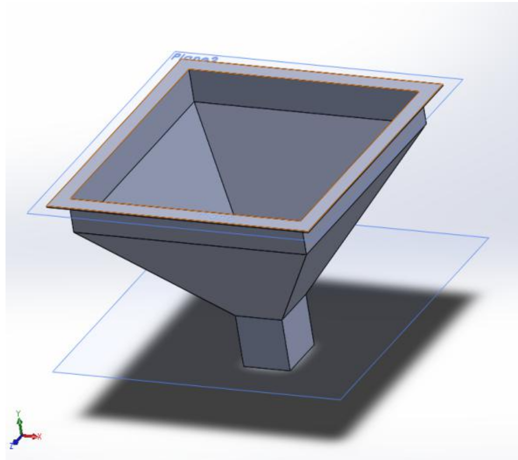


Fig 4.4: Collector design

Collector is placed under the cabinet; it is helpful in collecting the used up abrasive and the removed material from work pieces. A collector guides used up abrasive combined with removed material into a container from where it can be either reused or disposed off

4.6 Designing of table

Fig 4.5: Table design

All the components are to be assembled and given support and this support is provided by a table. On these table components are placed according to requirement

4.7 Expected output

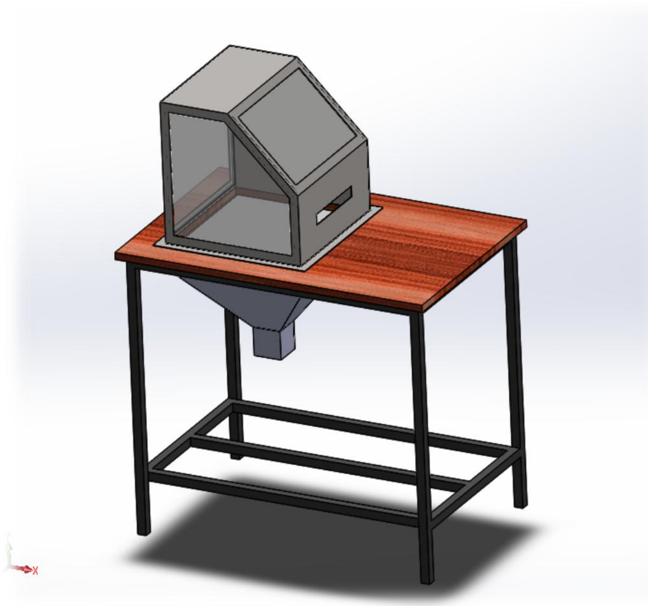


Fig 4.6: Expected output

CHAPTER 5

FABRICATION AND ASSEMBLE OF COMPONENTS

5.1 Materials used for fabrication of abrasive jet machine

Table 5.1: Materials used for fabrication

Sno:	Part name	Material
1	Nozzle	A304 stainless steel
2	Cabinet	Mild steel
3	Collector	Aluminum sheet
4	Hopper	Stainless steel
5	Mixing chamber	Stainless steel
6	Hose pipe	Reinforced rubber
7	XY motion module	Wood
8	Table	1inch iron rods & wood

5.2 Fabrication of nozzle

A nozzle is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipe.

A304 stainless steel hub of length 100mm, 22mm diameter was purchased and fixed on lathe machine to perform cutting, drilling, chamfering, grooving.

Fig 5.1: Lathe operations

Fig 5.2: Nozzle after lathe operations

5.3 Fabrication of cabinet

A blast cabinet is essentially a closed loop system that allows the operator to blast the part and recycle the abrasive

According to the design of the cabinet, required dimensions were marked on the MS sheet. After performing cutting on MS sheet as per the dimensions all the pieces of cabinet were attached together using gas welding.

Fig 5.3: Marking dimensions on MS sheet

Fig 5.4: Cutting MS sheet as per dimension.

Fig 5.5: Gas welding

Fig 5.6: Painting job on cabinet

5.4 Fabrication of collector

Aluminium sheet was cut as per the dimension mentioned in the design of the collector. Rivets were used to attach all pieces of collector.

Fig 5.7: Abrasive collector

5.5 Fabrication of table

Wood of length 1800mm, width 1200mm and thickness 25mm was mounted on 1inch iron rods using screws. Cutting of wood was done as per the expected output. 40*40cm2 of wood was cut on the one half of the table to assemble cabinet, mesh and collector at bottom and above of the table respectively.

Fig 5.8: Fabrication of table

5.6 Fabrication of XY motion module

XY motion module allows the nozzle to move along X axis, Y axis. We used dresser drawer slides to achieve moment in X axis, Y axis. Wood was attached to dresser drawer slides using screws.

Fig 5.9: Wood cutting Fig 5.10: Drawer slides Fig 5.11: XY motion module

5.7 Fabrication of hopper and mixing chamber

Hopper is a container for a loose bulk material such as grain, rock, or rubbish, typically one that tapers downward and is able to discharge its contents at the bottom. Mixing chamber is a volume or space within which a mingling of substances may occur.

Hopper carries abrasive particles. Hopper and mixing chamber are connected through a valve mechanism, when valve is open abrasive particles are dropped into mixing chamber where high speed air mixes with abrasive particles and impinge on work piece passing through nozzle.

We used stainless steel cans to fabricate hopper and mixing chamber, brass hose fitting connectors were welded on the hopper and mixing chamber to attach hose pipe.

Fig 5.12: Brass hose fitting connector Fig 5.13: Hopper

Fig 5.14: Hopper and mixing chamber connected using valve mechanism

5.8 Air compressor with tank specifications.

We have an air compressor with tank of following specification:

Table 5.2: Air compressor specification

Sno.	Parameters	Specifications
1	Power	2HP
2	Voltage	220V
3	Displacement	100L/min
4	Pressure	115Psi
5	Tank capacity	30L
6	Speed	2850 rpm
7	Weight	23 kg

5.9 Assembling of components

After fabricating all the components of abrasive jet machine, components were assembled on the table using nuts, bolts, washers and screws.

Fig 5.15: Assembling cabinet, collector

Fig 5.16: Assembling hopper, mixing chamber

Fig 5.17: Final output (connecting air compressor, hose pipe, nozzle and XY motion module

CHAPTER 6

RESULTS

We performed drilling, cutting, depth of cut machining operations on glass samples to check the efficient working of the abrasive jet machine.

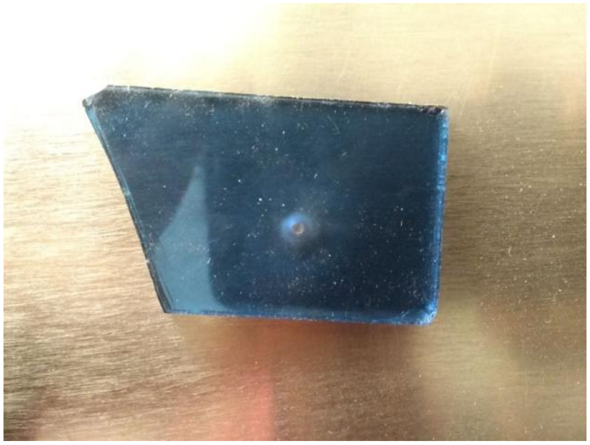


Fig 6.1: Glass specimen after drilling

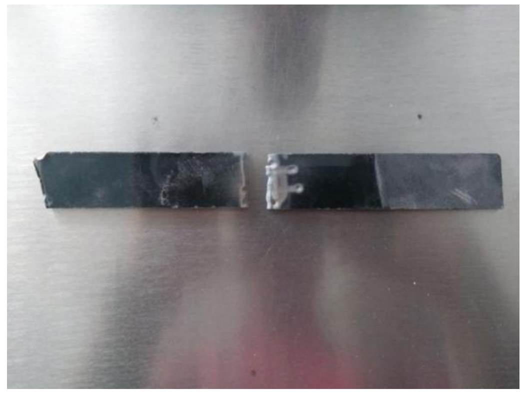


Fig 6.2: Specimen after cutting

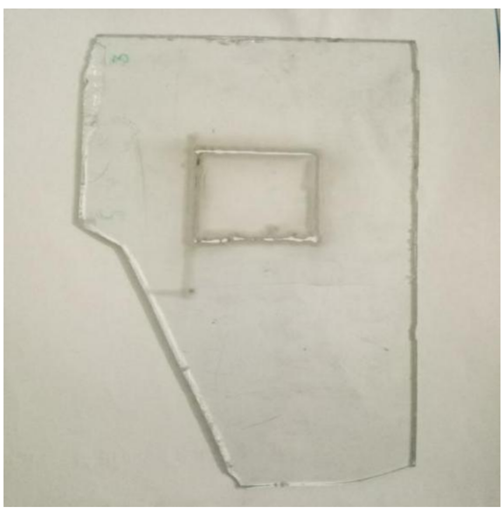


Fig 6.3: Specimen after shape cutting

Fig 6.4: Specimen after depth of cut

Table 6.1: Experimental results

Sno:	**Machining operation**	**Operating pressure**	**Glass thickness in mm**	**Time taken in minutes**	**MRR in mm3/min**
1	Drilling	4.2bar	3.34	0.5	11
2	Cutting	4.4bar	3.33	1.08333	14
3	Shape cutting	4.5bar	3.36	4.33333	15
4	Depth of cut	5bar	11	2.25	17

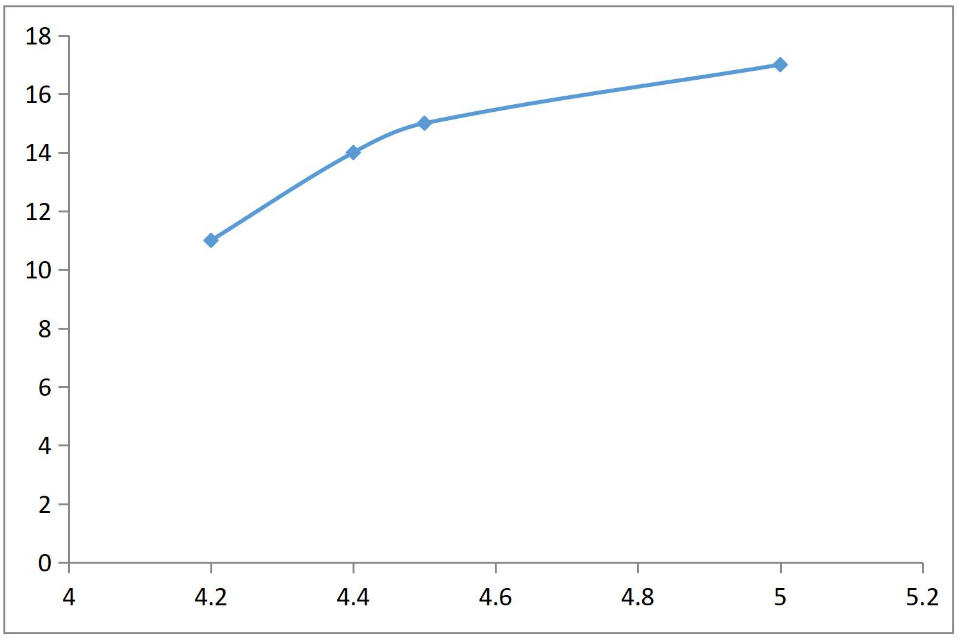


Fig 6.5: Graph showing relation between MRR & Pressure

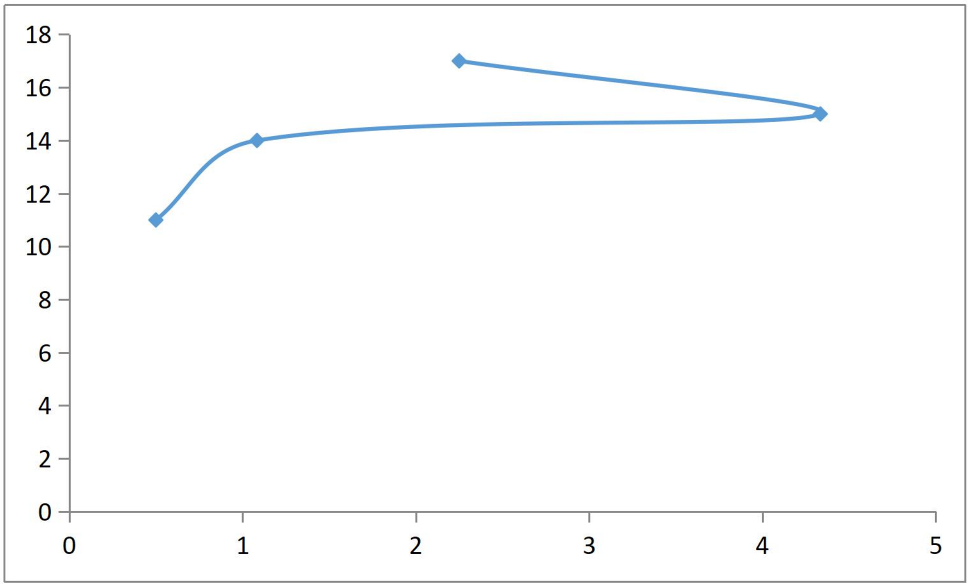


Fig 6.6: Relation between MRR & Time

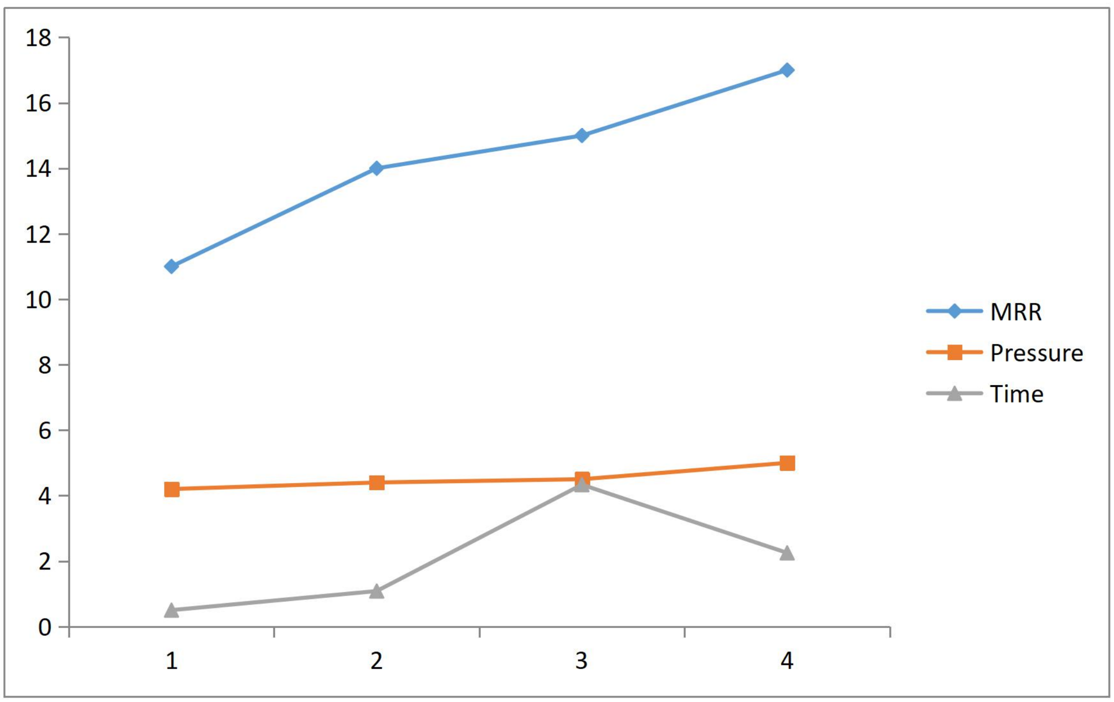


Fig 6.7: Relation between MRR, Pressure and Time

CHAPTER 7

ADVANTAGES, DISADVANTAGES AND APPLICATIONS

7.1 Advantages

- This process is quite suitable for machining brittle, heat resistant and fragile materials like, glass, ceramic, germanium, mica etc.
- It can be utilized for cutting, drilling, polishing, deburring, cleaning etc. of the materials.
- The depth of damage to the surface is very little.
- Holes of intricate shapes could be produced efficiently.
- The surface machined can have good finish (by controlling the grain size mainly).
- The process is free from chatter and vibration as there is no contact between the tool (nozzle) and work material.
- Do not cause hardening of work piece material.
- Very little or no heat generation during the cutting process, so it is suited for machining of heat sensitive material.
- High surface finish can be obtained by choosing a suitable abrasive material with a size that is suitable for the requirement.
- In case of damage, the depth of damage is very small (less than 3 microns).
- Thin sections of brittle and hard material like ceramic, glass, and germanium can be machined.
- It can be used for drill holes of intricate shape. It is used for machining cavities which are inaccessible by other methods.
- Low capital cost and ease of operation

7.2 Disadvantages

- The materials removal rate is low. For example, for glass, it is 0.0164 cm3/min.
- The tapering of hole especially, when the depth of the hole is more, becomes almost inevitable.
- A dust collecting chamber is a basic requirement to prevent atmospheric pollution to cause health hazards.
- The abrasive particles may remain embedded in the work surface.
- Abrasive particles cannot be reused.
- The material removal rate is low.
- The process tends to environmental pollution. A dust collection system must be provided to avoid air pollution and health hazards. This can be eliminated by using abrasive water jet machining.
- The abrasive powder cannot be reused because its cutting ability decrease and it may clog on orifice of the nozzle.
- Higher chance of stray cutting. Tapering may occur during drilling.
- AJM not suited for machining of soft material because the abrasive may get embedded in the work material.
- Nozzle life is low (300hr), and short standoff distance causes frequent damages on the nozzle.
- The air used for abrasive jet must be moister and oil free.

7.3 Applications

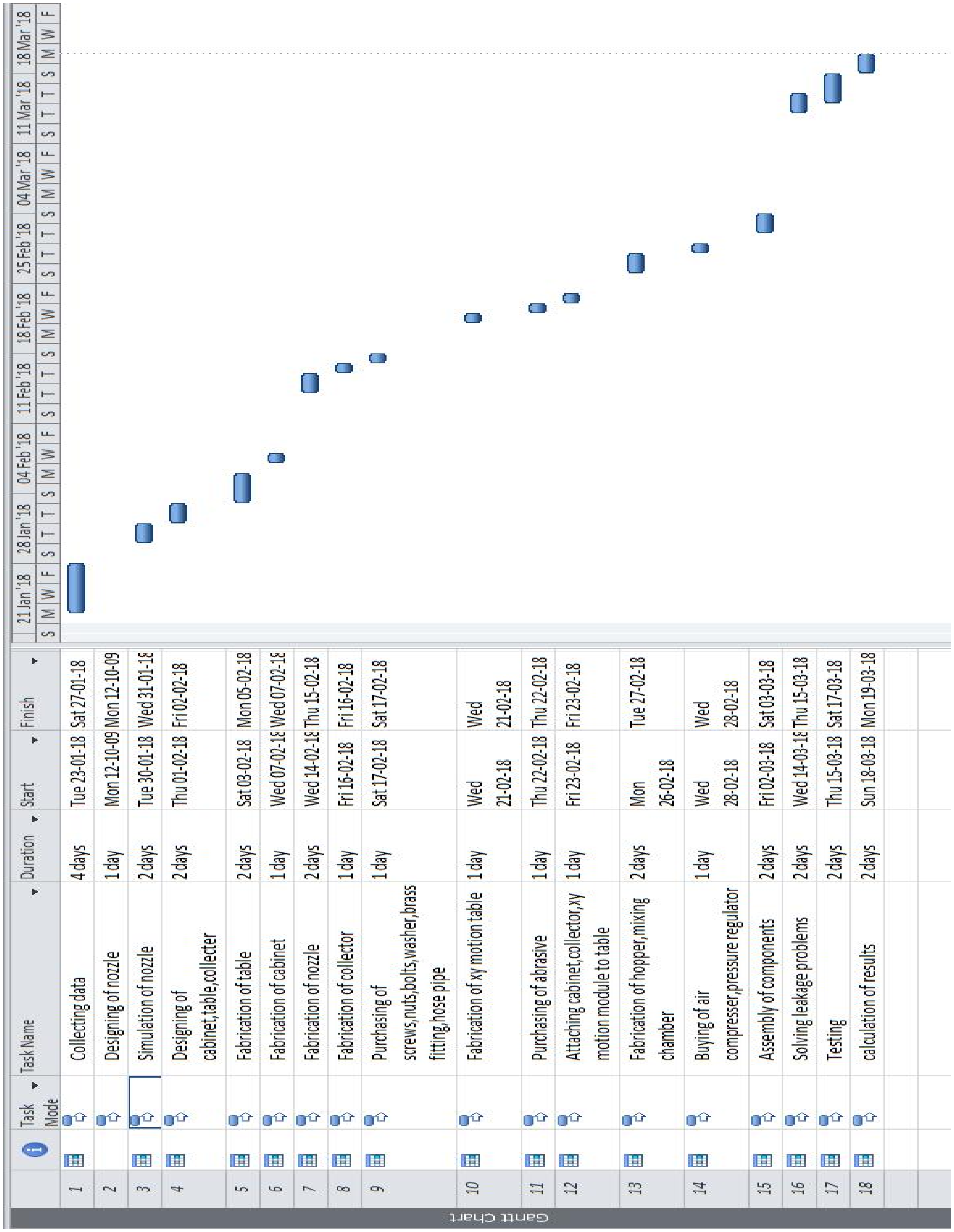
- AJM is suitable for machining heat sensitive material like silicon, gallium because the heat generation during the machining is very low.
- AJM can be used for cleaning purposes. Removal of oxides on metal smears on ceramics, and other resistive coating on work material (e.g., insulator stripping and cleaning of wire).
- For removal of parting lines from injection moulded parts.
- AJM is useful in deburring of plastic, cutting of metallic foils, machining of super alloys and refractory materials.
- Frosting (roughened matte finish) of shiny material
- They are used for machining of thin, brittle, fragile materials like germanium because of low overall force.
- To engraving permanent mark on the material.
- Deburring of small precision parts that required a burr free finish such as medical appliances, hydraulic valves, aircraft fuel system.
- Micro grit blasting, Trimming and bevelling.
- It is the best method for deburring small milled slots in hard metallic components, small hole like in hypodermic needles and cavities inaccessible by other means.
- Polishing of nylon and Teflon components.

EXPENDITURE

Table E.1:Expenditure

S.No	Part name	Quantity	Expenditure
1	Air compressor with tank	1	10000/-
2	Nozzle	2	3500/-
3	Abrasive	3kg	900/-
4	Pressure regulator	1	1100/-
5	Hopper	1	1100/-
6	Mixing chamber	1	600/-
7	Cabinet	1	2200/-
8	Collector	1	1000/-
9	Table	1	2500/-
10	Hose pipe	5meters	300/-
11	XY motion module	1	500/-
12	Nuts, bolts, washers, screws, brass hose fittings, rivets, clamps etc	As per requirement	500/-
13	Travelling expenses	-	1500/-

GANTT CHART



	Task Mode	Task Name	Duration	Start	Finish
1		Collecting data	4 days	Tue 23-01-18	Sat 27-01-18
2		Designing of nozzle	1 day	Mon 12-10-09	Mon 12-10-09
3		Simulation of nozzle	2 days	Tue 30-01-18	Wed 31-01-18
4		Designing of cabinet,table,collecter	2 days	Thu 01-02-18	Fri 02-02-18
5		Fabrication of table	2 days	Sat 03-02-18	Mon 05-02-18
6		Fabrication of cabinet	1 day	Wed 07-02-18	Wed 07-02-18
7		Fabrication of nozzle	2 days	Wed 14-02-18	Thu 15-02-18
8		Fabrication of collector	1 day	Fri 16-02-18	Fri 16-02-18
9		Purchasing of screws,nuts,bolts,washer,brass fitting,hose pipe	1 day	Sat 17-02-18	Sat 17-02-18
10		Fabrication of xy motion table	1 day	Wed 21-02-18	Wed 21-02-18
11		Purchasing of abrasive	1 day	Thu 22-02-18	Thu 22-02-18
12		Attaching cabinet,collector,xy motion module to table	1 day	Fri 23-02-18	Fri 23-02-18
13		Fabrication of hopper,mixing chamber	2 days	Mon 26-02-18	Tue 27-02-18
14		Buying of air compresser,pressure regulator	1 day	Wed 28-02-18	Wed 28-02-18
15		Assembly of components	2 days	Fri 02-03-18	Sat 03-03-18
16		Solving leakage problems	2 days	Wed 14-03-18	Thu 15-03-18
17		Testing	2 days	Thu 15-03-18	Sat 17-03-18
18		calculation of results	2 days	Sun 18-03-18	Mon 19-03-18

Fig G.1: Gantt chart

CONCLUSION

This project is a prototype of abrasive jet machine. Complete design, analysis and fabrication are provided in the report. The designing and assembling of components was a tremendous task and was completed on time. The project can go beyond its current position and capabilities by employing automation into it.

Using SOLIDWORKS designing of nozzle, cabinet, collector and table was done. Simulation of nozzle was also done using SOLIDWORKS. Fabrication of the components was done under the supervision of guides and equipment such as air compressor with tank, pressure regulator and hose pipe etc were assembled.

We have used 160 grit=120 mesh=125 micron Aluminium oxide (Al_2O_3)as abrasive for testing. The speed of abrasive impinging on the work piece (glass) is around 240-280m/s. Drilling, cutting, shape cutting, depth of cut machining operations were performed on the glass specimen and we found material removal rate (MRR) for each machining operation.

AJM process mainly deals with brittle materials and heat sensitive materials. It is also used in cutting slot, thin sections, countering, drilling, for producing integrate shapes in hard and brittle materials. Delicate cleaning, such as removal of smudges from antique documents, is also possible with AJM. Our abrasive jet machine (AJM) is capable of drilling and cutting on brittle materials

REFERENCES

- [4]D.A.Axinte,J.P.Stepanian,M.C.Kong,J.McGourlay : “Abrasive water jet turning-An efficient method to profile and dress grinding wheels” International Journal of Machine Tools and Manufacture, Volume 49, Issues 3-4, March 2009.
- [5]Li.C.H, Ding Y.C, Lu B.H: “Modelling and simulation for material removal in abrasive jet precision finishing with wheel as restraint” Proceedings of the IEEE International Conference on Automation and Logistics, ICAL 2008, Article number 4636666, 2008.
- [3]Ghobeity, A.; Spelt, J. K.; Papini : “Abrasive jet micro-machining of planar areas and transitional slopes” Journal of Micromechanics and Micro engineering, Volume 18, Issue 5, pp. 055014,May 2008.
- [1]Umberto Prisca; Maria Carmina D'Onofrio : “Three-Dimensional CFD Simulation of Two-Phase Flow Inside the Abrasive Water Jet Cutting Head” international Journal of Computational Methods in Engineering Science and Mechanics 9 (5), pp. 300-319, September 2008
- [2]KhanI Ahsan Ali; AwangI Mohd Efendee Bin; AnnuarI Ahmad Azwari Bin : “Surface Roughness of Carbides Produced by Abrasive Water Jet Machining“ Journal of Applied Science, vol. 5, Issue 10,June 2005.
- [6]TaiudinI Harnisah Bt, KhanI Ahsan Ali; MunaiatI Noraziaty Bt: “A Study on Abrasive Water Jet Machining of Aluminium with Garnet Abrasives” Journal of Applied Science, vol. 5, Issue 9, Jan 2005.