Fabrication of abrasive jet machining

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ABSTRACT: Abrasive Jet Machining (AJM) is a non-traditional machining process that utilizes a high-velocity stream of air or gas mixed with abrasive particles to remove material from a workpiece. This method is highly effective for delicate and intricate machining of brittle materials like glass. The key benefits of AJM are its precision, minimal thermal damage, and ability to operate without direct contact with the workpiece. The fabrication of an Abrasive Jet Machine (AJM) specifically designed for glass processing involves careful consideration of various factors, including material selection, design features, nozzle construction, air pressure, and abrasive flow regulation. These abstract highlights the fabrication process of an abrasive jet machine and its application in glass cutting, engraving, etching, and surface preparation.

i. INTRODUCTION

Abrasive Jet Machining (AJM) is a non-conventional machining process that uses a high-velocity stream of abrasive particles carried by a compressed gas to remove material from a workpiece through erosion. It is especially effective for machining hard, brittle, and heat-sensitive materials like glass, ceramics, and composites, where traditional machining techniques may not achieve the desired precision or cause thermal damage. The fabrication of an AJM system involves designing and assembling critical components, such as a compressor, abrasive feeder, mixing chamber, nozzle, and control mechanisms, to ensure efficient and precise material removal. The compressor provides a continuous supply of pressurized gas, typically air or inert gases, to propel the abrasive particles. These particles, which may include materials like aluminum oxide, silicon carbide, or glass beads, are carefully chosen based on the material to be machined and the desired surface finish. The abrasive feeder regulates the flow of abrasive particles into the mixing chamber, where they blend uniformly with the gas stream. The nozzle, often made of wear-resistant materials like tungsten carbide or sapphire, focuses the high-velocity jet onto the workpiece, allowing for controlled erosion and material removal. During fabrication, key parameters such as gas pressure, abrasive flow rate, and nozzle geometry are optimized to achieve the best results for specific applications. A well-fabricated AJM system is characterized by its precision, versatility, and ability to machine intricate shapes, fine details, and delicate surfaces without significant heat-affected zones or mechanical stress. The process is widely used in industries such as aerospace, electronics, and medical device manufacturing, where high accuracy and surface quality are paramount. However, the fabrication of AJM systems presents challenges, including nozzle wear, abrasive waste management, and ensuring uniform abrasive flow, which require careful consideration during design and assembly. Advances in material science, manufacturing techniques, and automation have significantly enhanced the performance and reliability of AJM systems, enabling their use in more complex and demanding applications. Overall, the fabrication of an AJM system is a critical step in leveraging this innovative machining technique to meet the growing demands of modern manufacturing, where precision, efficiency, and adaptability are essential.

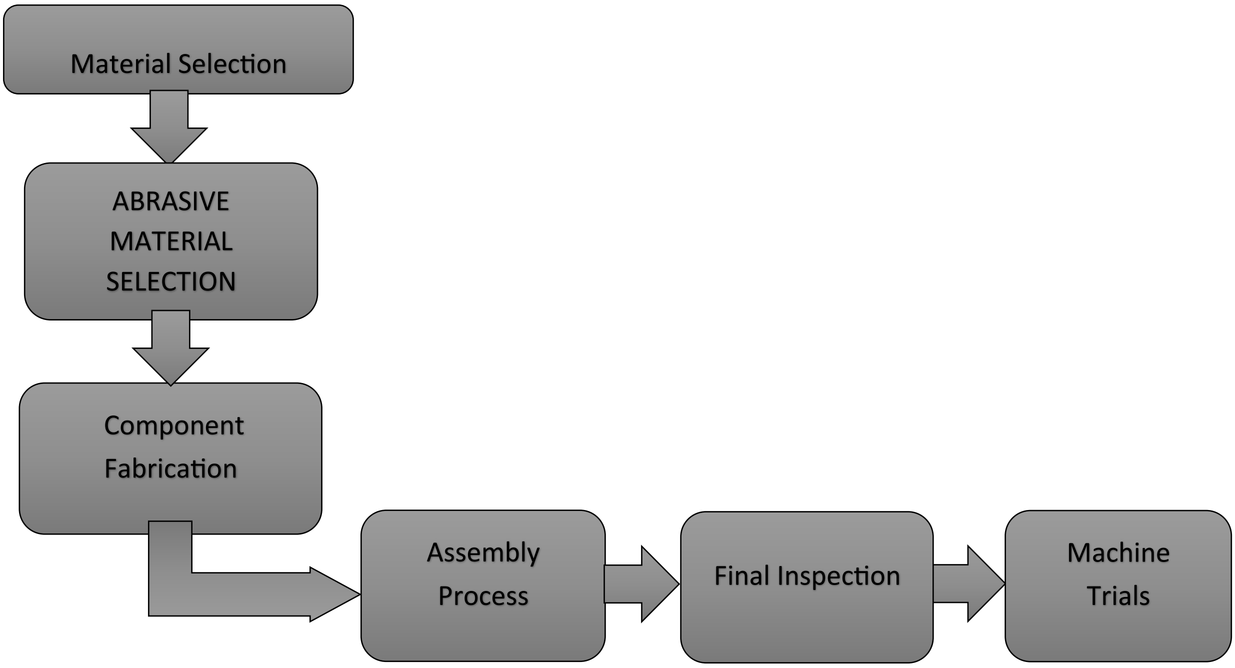
ii.LITERATURE SURVEY

DR. Lakshmi Kumari Dr. Yadavalli Basavaraj (1) "Fabrication of abrasive jet machining". This paper focuses on in the present project, Abrasive Jet Machining (AJM) is a non-traditional machining process that utilizes a high-velocity stream of air or gas mixed with abrasive particles to remove material from a workpiece. This method is highly effective for delicate and intricate machining of brittle materials like glass. The key benefits of AJM are its precision, minimal thermal damage, and ability to operate without direct contact with the workpiece.

Vasa Ramu. et.al Abrasive Jet Machining (AJM) is the process of material removal from a work piece by the application of a high-speed stream of abrasive particles carried in a gas medium from a nozzle. The AJM will chiefly be used to cut shapes in hard and brittle materials like glass, ceramics etc. It has various distinct advantage over the other non-traditional cutting technologies, such as, high machining versatility, minimum stresses on the work piece, high flexibility no thermal distortion, and small cutting forces. It also known as micro-abrasive blasting. It is a mechanical energy based unconventional machining process used to remove unwanted material from a given work piece.

Md Abdul Junaid.et.al The machine will be automated to have 1 axes travel. The different components of AJM are Compressor, Vibrator, dehumidifier, Pressure Regulator, and Dust filter, Nozzle, Pressure gauge etc. The different components are selected after appropriate design calculations. In this project, a model of the Abrasive Jet Machine is designed using available hardware and software etc.

iii. Methodology



1. Material Selection

- **Frame Material**: High-strength materials like stainless steel or carbon steel for the machine structure to handle pressure and vibrations.
- **Abrasive Material**: Common abrasives include silicon carbide, aluminium oxide, or garnet, chosen based on the type of material being machined and the required surface finish.
- **Nozzle Material**: Wear-resistant materials such as tungsten carbide or hardened steel for the nozzle, as they are exposed to high-velocity abrasive particles.
- **Compressor Materials**: Materials suitable for high-pressure environments (e.g., aluminium or stainless steel) for the air or gas supply system.

2. Component Fabrication

- **Abrasive Delivery System**: Fabricate the hopper, feeder system, and pipes to ensure proper and consistent abrasive flow.
- **Pressure Chamber**: Manufacture the chamber to withstand high air pressure; it should be sealed and leak-proof.
- **Nozzle Design**: Precision machining of the nozzle to ensure the correct diameter and shape for effective abrasive particle acceleration.

- **Control System**: Fabricate valves, regulators, and gauges for controlling air/gas pressure, flow rates, and abrasive delivery.
- **Dust Collection System**: Design and fabricate a dust collection unit (e.g., cyclone separator, filter) to capture airborne abrasive particles.

3. Assembly Process

- **Frame Assembly**: Assemble the machine's frame, ensuring structural integrity to withstand the forces during operation.
- **Component Integration**: Install the abrasive delivery system, pressure chamber, nozzle, air supply, and control systems into the machine frame.
- **Nozzle and Feeder Placement**: Mount the nozzle and abrasive feeder in a manner that allows for precise positioning during operation.
- **Electrical Wiring**: Integrate wiring for the control systems, including sensors and safety devices, for monitoring pressure, abrasive flow, and machine status.
- **Dust Collection Setup**: Position the dust collector in alignment with the work area to efficiently collect abrasive particles.

4. Testing

- **Pressure Testing**: Test the pressure chamber and air system to verify they can handle the required operational pressures without leaks.
- **Flow Testing**: Ensure consistent and controlled flow of abrasives from the feeder to the nozzle.
- **Nozzle Performance**: Test the nozzle to ensure it directs the abrasive stream accurately and at the desired velocity.
- **Safety Features**: Test safety systems (e.g., pressure relief valves, emergency stop functions) to ensure proper function.

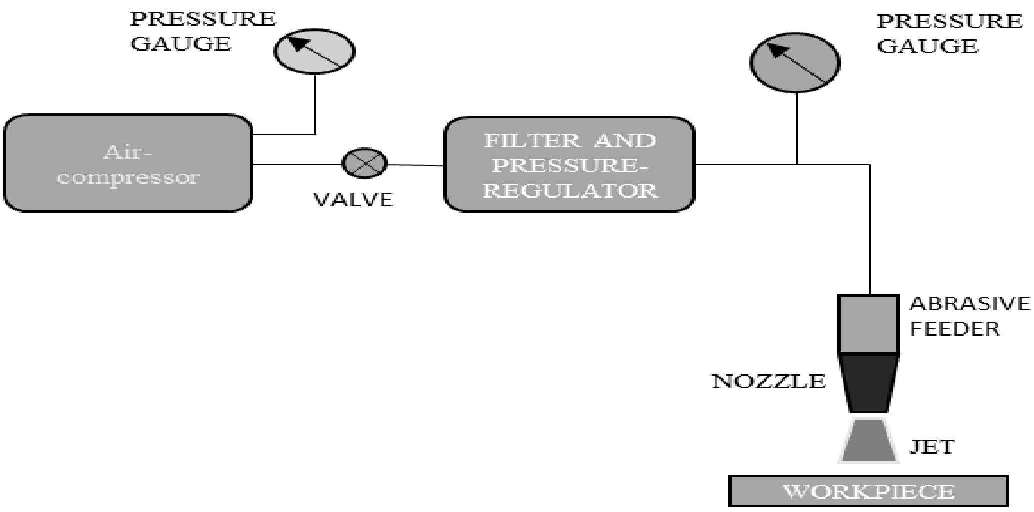
5. Final Inspection

- **Component Inspection**: Inspect all components for material defects, correct dimensions, and proper fit.
- **System Integrity Check**: Confirm all mechanical and electrical connections are secure and the system is operating without issues.
- **Safety Compliance**: Ensure the machine complies with relevant safety standards, including noise levels, dust containment, and protective enclosures.
- **Functional Testing**: Verify that all operational aspects, including abrasive flow, nozzle function, and air pressure, are within specified ranges

6. Machine Trials

- **Test on Workpiece**: Perform initial abrasive jet machining on a test workpiece to evaluate performance, such as cutting rate and surface finish.
- **Parameter Optimization**: Fine-tune operating parameters (abrasive flow, air pressure, nozzle distance, etc.) to achieve desired machining results.
- **Long-term Testing**: Run extended trials to evaluate machine durability, abrasive wear, and system stability over time.
- **Final Adjustments**: Make necessary adjustments based on trial feedback to optimize machine efficiency and reliability before full-scale operation.

iv. Block diagram of Abrasive jet machine



The working principle of Abrasive Jet Machining (AJM) can be explained with reference to the provided schematic diagram:

1. **Compressed Gas Supply**: An air compressor generates high-pressure gas, typically air or an inert gas, which acts as the carrier medium for the abrasive particles.
2. **Filter and Pressure Regulator**: The compressed gas passes through a filter to remove impurities and contaminants. A pressure regulator adjusts the gas pressure to the required level, ensuring consistent performance and controlling the velocity of the abrasive jet.

3. **Abrasive Feeder**: Abrasive particles such as silicon carbide or aluminium oxide are stored in the abrasive feeder. These particles are fed into the gas stream in controlled quantities to maintain a uniform mixture.
4. **Nozzle**: The mixture of gas and abrasive particles is expelled through a nozzle at high velocity. The nozzle focuses the abrasive jet onto the workpiece with precision. The nozzle material, typically tungsten carbide or sapphire, is wear-resistant to withstand erosion by abrasive particles.
5. **Workpiece Material Removal**: When the high-velocity abrasive jet strikes the workpiece, it erodes material through a combination of micro-cutting and brittle fracture mechanisms. This makes AJM highly effective for machining hard and brittle materials like glass, ceramics, and composites.
6. **Exhaust and Collection**: The spent abrasive particles and eroded material are collected or exhausted to maintain a clean working environment.

The process operates on the principle of material removal by high-energy abrasive particles impacting the work surface. By adjusting parameters such as gas pressure, abrasive flow rate, and nozzle design, the machining process can be tailored for specific applications, offering precision and versatility for intricate machining tasks.

V. CALCULATIONS

Volume of 2 mm Glass

$L \times W \times H = 20.3 \times 22.7 \times 2$

V= 921.62m³

Volume of 4 mm Glass

$L \times B \times T = 20.3 \times 22.7 \times 4$

V =1843.24m³

Area of 2mm Glass

$L \times W = 20.3 \times 22.7$

=460.81 m²

Area of 4mm Glass

$L \times W = 20.3 \times 22.7$

=460.81 m²

Assume E= 10-15J/m³ for 2mm Glass

P= (10× 0.208× 2)/ (0.85×0.125× 8)

P =4.89≈5 bar

1.Air Flow Rate through Nozzle

Using Bernoulli's principle, calculate the air velocity (v) and volumetric flow rate (Q):A*V

$v=\sqrt{2*P/\rho}$

Where:

P=5bar=500,000 Pa(pressure)

ρ=1.225 kg/m3 (density of air)

$v=\sqrt{2\times500{,}000/1.225}$

=903.50 m/s

Now calculate the nozzle cross-sectional area (A):

$A=\pi\times d^2/4$

Where:

d=0.004 m

$A=\pi*(0.004)^2/4$

=1.2566×10^-5 m²

Volumetric flow rate (Q):

Q=A*v= (1.2566×10^−5)903.50

=0.0113 m³/s

Q=0.0113×60=**0.678 m³/min**

2. Abrasive Flow Rate

The abrasive feed rate (ma) is determined as:

ma = ρ a× Q a

Assume the abrasive volumetric flow rate (Qa) is 0.5% of the air flow rate:

Qa = 0.005

Q = 0.005×0.0113

=0.0000565 m³/s

The abrasive density (ρa) for silica sand is typically around 2600 kg/m³.

Now calculate the abrasive mass flow rate:

ma =2600×0.0000565

=0.1469 kg/s

= 146.9 g/s.

3. Material Removal Rate (MRR)

The MRR depends on empirical constants and machining conditions:

MRR=K× P n× d× ma

Where:

K=0.5(constant for glass)

P=5 bar=5×10^5 Pa

n=1.5(empirical pressure exponent)

d=4 mm=0.004 m

ma= 0.1469 kg/s

MRR=0.5× (5×10^5) ^1.5×0.004× 0.1469

First, calculate P^1.5

P^1.5= (5×10^5) ^1.5=1.64×10^8

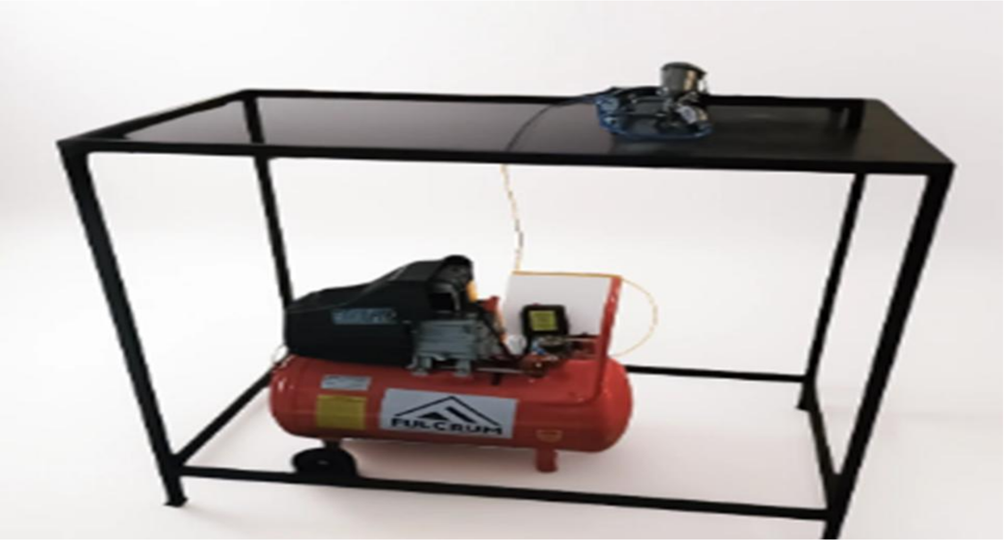
Now calculate the MRR:

MRR=0.5×1.64×10^8×0.004× 0.1469

=48183 .2mg/s=0.0481 g/s

This means the machine can remove **0.0481 g/s** of glass material.

vi. MODEL



vii. V. CONCLUSION

The better performance, and the applications represented above statements confirm that abrasive jet machine is continue to expand.

Abrasive jet machining can be used for polishing, deburring and other finishing operation where the rate of material removal is important, while in operation such as micro drilling cutting it is the erosion depth which is more relevant

Abrasive jet machining provides process control flexibility. Machining spot, material removal rate, and surface roughness are easily changeable through numerous options of pneumatic, abrasive or machining process parameters.

Abrasive jet machining is capable of fulfilling recent and oncoming industrial demands. Concerning the influence of process parameters, it should be noted that there is no universal algorithm for process parameter selection. The results of distinct independent factors may vary significantly or even change to the opposite. However, the dominant effects of key factors were established by various researches by conducting experimentations.

viii. VI. REFRENCES

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