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Fabrication of Pneumatic Abrasive Jet Machine

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Abstract: Abrasive Jet Machining (AJM) is the process of material removal from a work piece by application of a high-speed stream of abrasive particles carried in gas or air medium from a nozzle. The material removal process is mainly by abrasive erosion. The AJM will chiefly be used to cut shapes in hard and brittle materials like glass, ceramics etc. The machine will be automated to have axes travels. 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., taking into consideration of commercially available components. Care has been taken to use less fabricated components rather than directly procuring them because the lack of accuracy is fabricated components would lead to a diminished performance of the machine.

Keywords: Abrasive Jet, Mixing Chamber, Air filter, Abrasives and Nozzle.

I. Introduction

Abrasive Jet Machining (AJM) is the removal of material for a workplace by the application a high-speed stream of abrasive particle carried in gas medium from a nozzle. The AJM process prefers from conventional sand blasting in that the abrasive is much finer and the process parameter and cutting action are carefully controlled. In Abrasive jet machining abrasive particles are made to impinge on work material at high velocity. Jet of abrasive particles is carried by carrier gas or air. The high velocity stream of abrasives is generated by converting pressure energy of carrier gas or air to its Kinetic energy and hence high velocity jet. A nozzle directs abrasive jet in a controlled manner onto work material. The high velocity abrasive particles remove the material by micro-cutting action as well as brittle fracture of the work material. The process is used chiefly to cut intricate shapes in hard and brittle materials which are sensitive in heat and have a tendency to chip easily.

The process is also used for deburring and cleaning operations. AJM is inherently free from charter and vibration problems. The cutting action is cool because the carrier gas serves as a coolant. The process parameters are used like variables which effect metal removal. They are carrier gas, abrasive, and velocity of abrasive, work material, and nozzle tip distance (NTD). Abrasive jet cutting is used in the cutting of materials like: Titanium, Brass, Aluminum, Stone, Any Steel, Glass, Composites, Plastics, Ceramics, Tungsten carbide etc. Abrasive Jet machining is non-traditional manufacturing process that can make complex shapes on the surface of the hard and brittle material. It is a process of material removal through the action of a focused stream of fluid with abrasive particles. It is especially used for machining super alloys, ceramics, glass and refractory materials. Here, the material removals are mainly due to the impingement of the fine abrasive particles on the work surface. The metal cutting occurs due to erosion caused by the abrasive particles impacting the work surface at a high speed. As a result of repeated impact, small bits of material get loosened and separated from the workpiece surface, exposing a fresh surface to the jet. The AJM is different from conventional sand blasting as the latter is a surface cleaning process and AJM is a metal cutting process. The process is used mainly to cut complex shapes in hard and brittle materials which are heat sensitive and have a tendency to chip easily. AJM is also used for removing burrs and cleaning operations. AJM is free from and vibration and chatter problems. As the carrier gas itself serves as a coolant, the cutting action is cool.

II. Literature Survey

Ingulli C. N. [1], was the first to explain the effect of abrasive flow rate on material removal rate in AJM. Along with Sarkar and Pandey (1976) concluded that the standoff distance increases the MRR and penetration rate increase and on reaching an optimum value it starts decreasing. J. Wolak (1977) and K. N. Murthy (1987) investigated that after a threshold pressure, the MRR and penetration rate increase with nozzle pressure.

Dr. A. K. Paul & P. K. Roy [2], carried out the effect of the carrier fluid (air) pressure on the MRR, AFR, and the material removal factor (MRF) have been investigated experimentally on an indigenous AJM set-up developed in the laboratory, conducted experimentation on the cutting of Porcelain with Sic abrasive particles at various Air pressures. There observed that MRR has increased with increase in grain size and increase in nozzle diameter.

Ghobeity et al. [3], have experimented on process repeatability in abrasive jet machining. They mentioned that many applications have several problems inherent with traditional abrasive jet equipment. Poor repeatability in pressure feed AJM system was traced to uncontrolled variation in abrasive particle mass flux caused by particle packing and local cavity formation in reservoir. Use of mixing chamber improved the process repeatability. For finding out process repeatability they measured depth of machined channel.

El-Domiaty et al. [4], did the drilling of glass with different thicknesses have been carried out by Abrasive Jet Machining process (AJM) in order to determine its machinability under different controlling parameters of the AJM process. The large diameter of the nozzle lead to the more abrasive flow and which lead to more material removal rate and lower size of abrasive particle lead to the low material removal rate. They have introduced an experimental and theoretical analysis to calculate the material removal rate.

Shanmugam and Masood [5], presented an investigation on the kerfs taper angle generated by Abrasive Water Jet (AWJ) technique to machine two types of composites: epoxy pre-impregnated graphite woven fabric and glass epoxy. Comprehensive factorial design of experiments was carried out in varying the traverse speed, abrasive flow rate, standoff distance and water pressure.

Stephen Wan et al. [6], present simple deterministic process models for the prediction of the evolution of the cross-sectional profile of the glass channels generated by erosive wear in micro air abrasive jet machining using a round nozzle. Experiments were carried out on soda lime and borosilicate glass to verify the process models. Predicted model results show fairly good agreement with experimental results.

III. Objectives and Methodology

3.1 Objectives

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 major field of application of AJM process is in the machining of essentially brittle materials and heat sensitive materials like glass, quartz, sapphire, semiconductor materials, mica and ceramics. It is also used in cutting slot, thin sections, countering, drilling, deburring, for producing integrate shapes in hard and brittle materials. The main objectives of the pneumatic abrasive jet machine are listed below.

- Ability to cut intricate holes shape in materials of any hardness and brittleness.
- Ability to cut fragile and heat sensitive material without damage.
- No change in microstructure as no heat is generated in the process.
- Low capital cost.

3.2 Methodology

Abrasive Jet Machining (AJM) is the removal of material from a workpiece by the application of a high-speed stream of abrasive particles carried in gas medium from a nozzle. The AJM process differs from conventional sand blasting in that the abrasive is much finer and the process parameters and cutting action are carefully controlled. The process is used chiefly to cut intricate shapes in hard and brittle materials which are sensitive to heat and have a tendency to chip easily. The process is also used for deburring and cleaning operations. AJM is inherently free from chatter and vibration problems. The cutting action is cool because the carrier gas serves as a coolant.

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. Below figure shows schematic diagram of jet machine. The major variables that influence the rate of metal removal and accuracy of machining in this process are as follows:

- Composition and density of carrier gas
- Types of abrasive
- Size of abrasive grain

- Velocity of abrasive jet
- Flow rate of abrasive jet
- Work piece material
- Geometry, composition and material of nozzle
- Nozzle tip distance (stand-off distance)
- Shape of cut and operation type
- Mixing ratio
- Impingement angle

IV. Working Principle

The fundamental principle of Abrasive jet machining involves the use of a high-speed stream passed through filter first shown in Fig. 1 where abrasive particles carried by a high-pressure gas and pressure of the gas is measured by pressure gauge shown in Fig. 2 and fed on the work surface through a nozzle. The metal is removed due to erosion caused by the abrasive particles impacting the work surface at high speed. With repeated impacts, small bits of material get loosened and a fresh surface is exposed to the jet. 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 which is shown in Fig. 3 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.

This process is mainly employed for such machining works which are otherwise difficult, such as thin sections of hard metals and alloys, cutting of material which is sensitive of heat damage, producing intricate holes, deburring, etching, polishing etc. The abrasive particles are held in a suitable holding device, like a tank and fed into the mixing chamber**.** A regulator is incorporated in the line to control the flow of abrasive particles compressed air or high-pressure gas is supplied to the mixing chamber through a pipeline. The completed project is shown in Fig. 4. The main parts or components used in this project are listed below.

1. Air Compressor
2. FRL Unit (Dehumidifier)
3. Pressure Gauge
4. The Vibrating Unit
5. Nozzle
6. Arrangement to Hold the workpiece
7. Pressure Gauge
8. The Vibrating Unit
9. Nozzle
10. Arrangement to Hold the workpiece

V. FIGURES

Fig. 1 Air Filter Fig. 2 Pressure Gauge Fig. 3 Mixing Chamber

Fig. 4 Completed Project Model

VI. CONCLUSION AND FUTURE SCOPE OF WORK

6.1 Conclusion

In AJM, a focused jet or stream of abrasive particles carried by high-pressure gas (carrier) is made to impinge on the work surface through a nozzle. The metal cutting occurs due to erosion caused by the abrasive particles impacting the work surface at high speed. As a result of the impact, small bits of materials get loosened and separated from the workpiece surface, exposing a fresh surface to the jet. This process is capable of cutting intricate holes and shapes in materials of any hardness and brittleness. Some of the remarks on the present work:

- Each part is modelled in CATIA software.
- Each part is fabricated in the workshop.
- Each part is assembled to make a complete AJM setup.
- Can be used to drill the materials like ceramics, fibres, plastics.
- Very small holes can be drilled by changing the nozzle starting from 5mm.
- Since it is not hydraulic the cost is less.

6.2 Future Scope of Work

After conducting the operations using this abrasive jet machine, following things can be upgraded in the future.

- Manual nut assembly has been used to vary the nozzle tip distance. This process can be done automatically.
- For shaking of the mixing chamber, we have used handle manually. This can be done automatically by using a motor.
- The required shape or the place to be cut is adjusted manually, this can be done automatically by using motors or programming method.

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