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Literature Review on Abrasive Jet Machining - Past and Present

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Abstract

Abrasive jet machining is very simple and low cost technique in which different materials (hard, brittle, etc.) will be machined. This is low budget and very effective conventional machining process. It has many advantages like high machining versatility, less stress on specimen, high machining process flexibility, no heat distortion during the process and low cutting forces on edges as compared to the other non-conventional technologies. This review paper give insight of AJM from beginning to current status as well as latest development in abrasive jet machining process.

Index Terms: Versatility, flexibility, nontraditional

1. INTRODUCTION

Abrasive jet machining (AJM) deals with cutting, edging, debarring and drilling. This process use air like nitrogen or carbon dioxide along with abrasive grain in powder form, which size depends on operation type and material to be used. The most common abrasive use for this process are silicon dioxide, silica etc. [1-5]. In AJM air and abrasive material mix together and hit on surface to be machined and the potential energy changes into kinetic energy. The result obtained will be in shape of erosion. This technique is best for metal because of its nonconventional method and hence useful in procedures where conventional machining is failed. It is of advantageous as no heat and vibration involve in this process and the results obtained are in simple traditional process [6-12]. AJM has the application on various processing techniques of different materials like, Brass, Steel, Glass, Composites, Aluminium, Ceramics, Tungsten, and carbide Titanium etc. This non-conventional technique is cheap comparatively to other non-Conventional processes. As the globe advances technologically in the fields of space exploration, missiles, and nuclear power, these businesses demand extremely intricate and accurate components that meet specific specifications and AJM will prove helpful to them. [13-18].

2. HISTORY OF ABRASIVE JET MACHINING (AJM)

Franz developed this groundbreaking technology in 1968 by cutting laminated paper tubes, and it was first commercialized in 1983. [19-21]. The abrasive jet was created in the nineteen century when garnet abrasive and water stream was mixed. Dr. John Olsen, the inventor of the water jet, began to investigate abrasive jet cutting as a viable solution to traditional machining in the early 1990s. His ultimate objective was to create an abrasive jet that could control noise, dust, and skill that was required at the time. A lot of work has been done in this field in the past two decades. [22-24]

3. WORKING PRINCIPAL AND PARAMETERS

The AJM is very simple technique that works on same basic principles as regular sandblasting. In this process high-speed airflow forced abrasive particles to remove material from work piece when it hit its surface. Each impact can only remove a little amount of material at a time. Both abrasive particles and fragments of work piece material are carried away by the airflow. [25].In figure 2 schematic diagram of AJM is presented. AJM machine have many parts. Air is compressed by air compressor at 5 bar for this purpose, electric air compressor is used or pressure cylinder and the air used most of time is carbon dioxide or cold nitrogen [26].Air purifier is used to purify air from dust, Pressure gauge is used to control pressure. After that gasses reaches into a chamber that is called mixing chamber, or close chamber. The air is mixed with abrasive in this chamber through hoper that is mounted on mixing chamber through a metallic sieve. An electromagnetic force shaker vibrates the sieve on a regular basis. The frequency and amplitude of the sieve's vibration determine the mass flow rate of abrasive (.016 Kg/minute) [27]. The carrier gas then transports the abrasive particles to next step of mixing into a close container. Close container is very important for keeping machined particles and abrasives contained in a safe and environmentally responsible manner. Process is done at a high speed (210-310 meter/sec), with abrasion materials being ejected from AJM machine.

Table 1. Show Parameter of Abrasive Jet Machine.

Requirements for polish	Requirements for abrasion	Pneumatic Requirements
Material characteristics	abrasive dimension	Nozzle thickness
Angle of impact	Flow rate	Abrasive pressure
SOD	Abrasion used	Jet speed
Traverse speed		

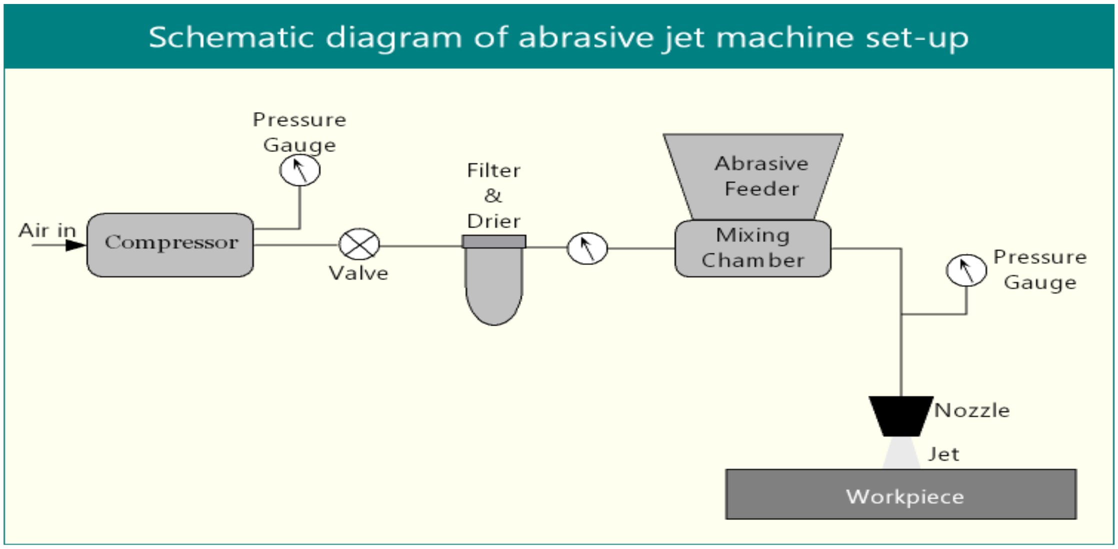

Figure 1. Working of AJM.

4. LITERATURE REVIEW

Abrasive jet machining process first introduce commercially in 80s. At that time technology is not mature but today abrasive jet machining process is much advancer. Although many articles and research paper have been published on AJM but only newest papers have been discussed in this review paper.

Y. Yamauchi article on ceramic materials removal by AJM process

This article shows the effect of work piece characteristics on machinability of ceramic materials. The experiment was conducted using following types of typical abrasives: Aluminum Oxide, Silicon Carbide, and synthetic diamond. Four types of ceramics were used as target materials: ZrO2, Si3N4, Al2O3, and Sic. The volume reduced by abrasive jet machining was measured using a laser scanning microscope. In AJM process machinability was equated to erosion models of hard particle, in the ideal crack formation system. The material elimination was believed to begin when the radial fissures did not prolong down by the AJM technique as shown in figure 2 [28].

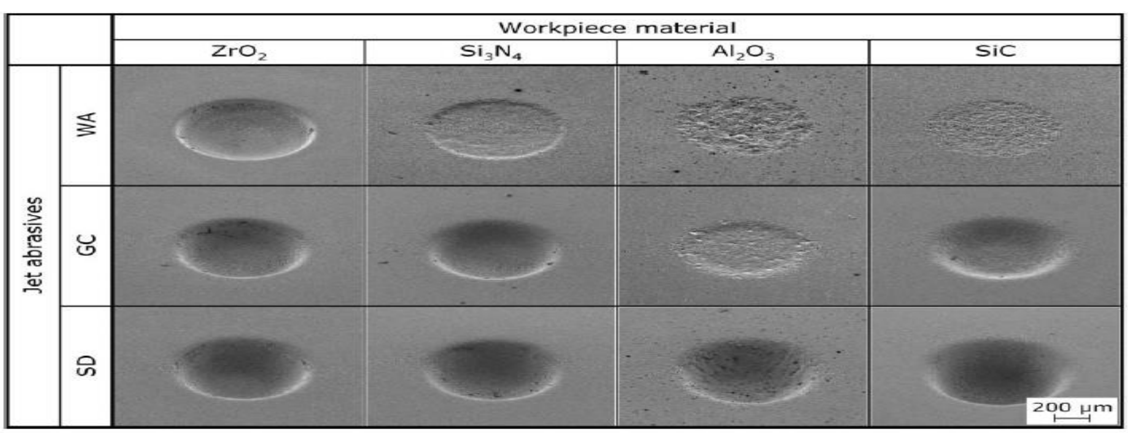

Figure 2 show the abrasive jet effect on materials

Table 2 Abrasive Material Properties.

Materials	Hardness	Erosion rate min	Erosion rate max
Al2o3	2100	0.01	1
si3n4	7000	0.01	0.8
sic	2480	0.01	1.2
zro2	1300	1	1.5

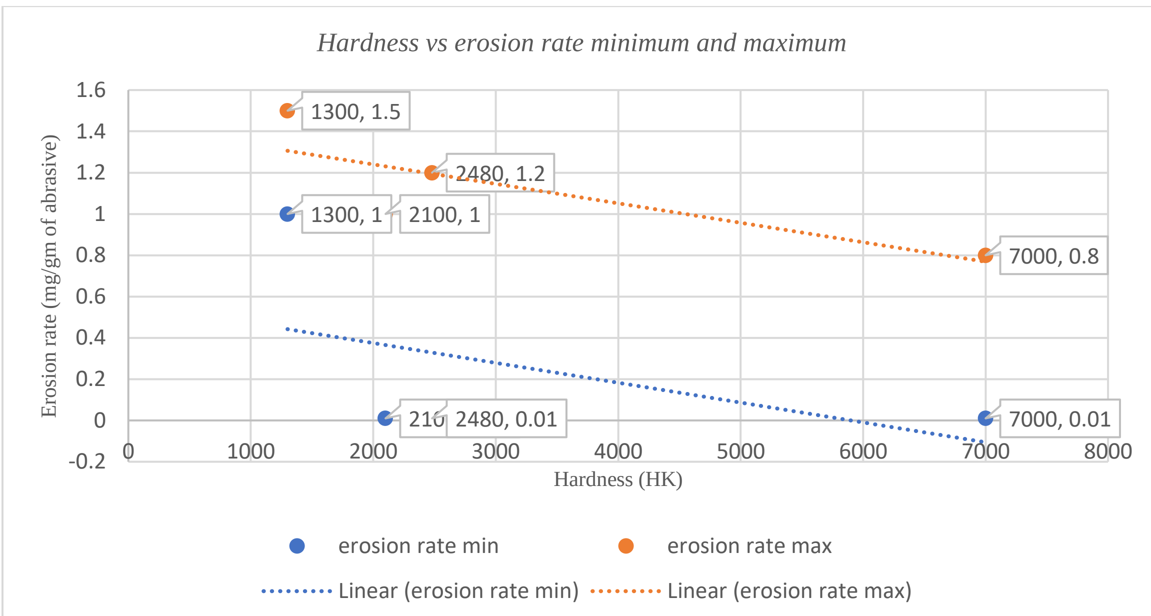

Figure 3 show hardness vs. erosion rate of different abrasive materials

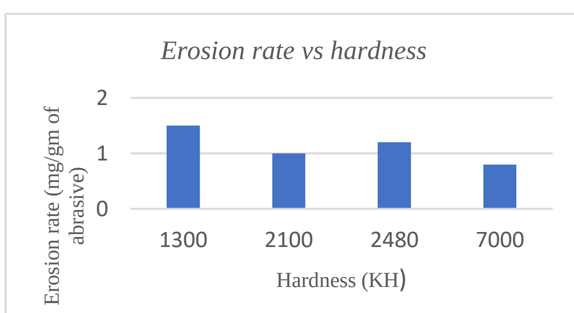

Figure 4 show the hardness vs. erosion rate

Ally Model substrate surface removal

AJM of metallic substrates was predicted using surface evolved models. The inclination angle of the abrasive jet for abrasion rate was calculated. Titanium alloy, Aluminum, and SS were used. Angle of inclination calculated by throwing to 50 micrometers of Al_2O_3 abrasive powder with speed of 6600m/min. For the systems, 210 to 360 meters above the surface were determined to have the highest rates of erosion. Volumetric erosion rate in descending order was Aluminum, Titanium alloy and stainless steel. Stainless steel had even lower volumetric erosion rate as compared to brittle materials like glass and plastics [27].

Pawar Research on Ocean Sand used as abrasive metal in AJM Process

This study was very beneficial. The abrasive substance sea sand was examined. In the abrasive jet tiny machining procedure, a tungsten metal carbide nozzle was used. For the experiment, 100-150 metric linear units of sand were employed. A four-millimeter thick glass was used as the work piece. Material removal rate and flow rate were the two performances metrics that were assessed. The impact of the nozzle on the fabric of the work piece was found to induce considerable erosion. The result of erosion was undeniably dependent on the material's velocity, its direction and also the brittleness of the material. [28-30].

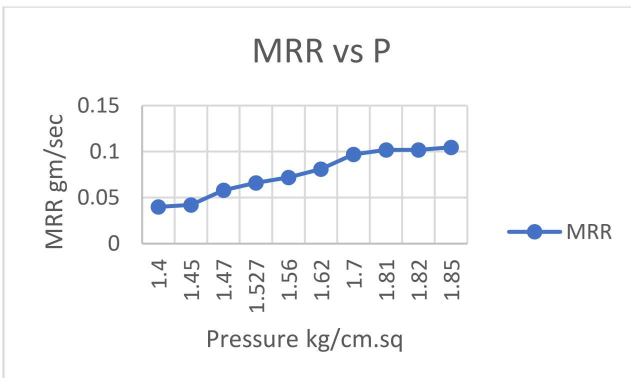

Figure 05 Curve Fitting of MRR v/s PFR

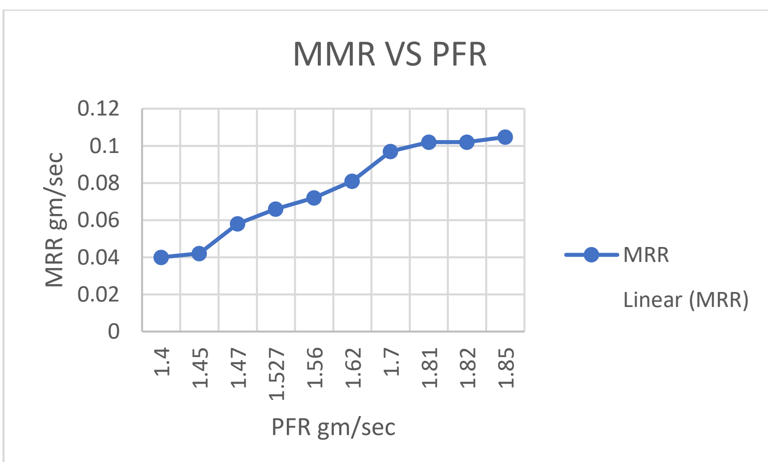

Figure 06 Graph showing MRR v/s PFR

Table 03 SOD & Pressure in Variables

Pressure P Kg/c m²	*Stand of distance SOD mm*	*Material removal rate MRR W/T = gm/sec)*	*PFR Wa/T = gm/sec*	*Diameter D Mm*
5.1	5.1	0.05	1.42	4.6
5.55	6.1	0.04	1.47	4.8
6.55	7.2	0.057	1.48	5.1
7.1	8.1	0.067	1.52	5.2
7.6	9.1	0.07	1.57	4.5
8.1	9.6	0.080	1.61	5.3
8.6	10.1	0.098	1.71	5.5
9.1	11.1	0.103	1.82	5.7
9.6	12.1	0.104	1.84	5.5
10.1	12.2	0.1045	1.87	5.7

Table 04 SOD & Pressure constant.

Pressure Kg/cm²	*Standoff distance mm*	*Material removal rate W/T = gm/sec)/ 10⁻³*	*PFR Wa/T = gm/sec*	*Diameter mm*
6.3	8.5	6.8	0.52	5.5
6.3	8.5	8.2	0.65	5.6
6.3	8.5	5.95	0.62	6.2
6.3	8.5	1.65	0.38	6.2
6.3	8.5	1.53	0.32	6.2

Dong-Sam Park Improve Micro-Machining

Micromachining ceramics, semiconductors, electronic devices, and LCDs has improved after this study. This study tested the performance of micro-scale level AJM for glass micro grooving. The process parameters for micro AJM determined were velocity, duration, Pressure as well as stand-off distance, characteristics of the material, and the number of scanning times of the nozzle. Masking, Withdrawal of mask and cleaning were also part of the micro grooving process. Al2O3 was the principal element of white Alundum, which was used for machining. The results showed that the masking results were significant when the heat quantity was 160mJ and the temperature was 1050°C, but were unsatisfactory otherwise [31].

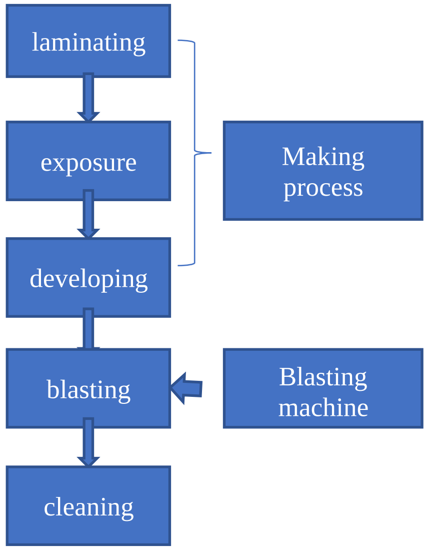

Figure 07 Process Flow chart of Grooving

Manabu Wakuda on Ceramic

This study examined the reaction of alumina ceramics and impact of abrasion material. For the impact on alumina ceramics, abrasive grains used were: Silicon Carbide, Aluminum Oxide and Synthetic Diamond. The Micro-Blaster (MB2-ML-001, Sintobrator, Japan) capable of firing fine abrasives was used. The blaster used with AJM equipment had N_2 gas through a micro type nozzle. This study concluded that abrasive Al_2O_3 caused roughness of the alumina surface without marks and increasing in temperature as well. [32].

Gamage. J. R. & Desilva. A. K. M Work on of Non-Traditional Manufacturing Processes

The objective of this study was to find the existing techniques in terms of calculating the sustainability of unconventional machining processes of AJM. The data was then coded and analyzed by using (NVivo), a software for qualitative data analysis [33].Understanding the interrelationships, the latest researches, and the generate data in respect to the sustainability of machining processes, especially in term of AJM, utilizing NVivo content analysis [34-35].

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Table 05 Process vs. Power

process name	process Rate cm3/s	Power Required kW
	3.76E+00	10.76
	9.77E+00	26.1
	5.05E+01	71.4
Injection Molding	1.40E+01	35.76
	2.70E+01	47.46
	4.51E+01	65.34
	7.66E+00	12.73

	1.09E+01	13.17
	4.25E+01	51.41
	2.00E+01	194.8
	4.70E+00	194.8
	5.00E+00	10.65
Machining	1.20E+00	10.65
	1.50E+00	2.8
	3.50E-01	2.8
	4.01E-01	75.16
Finish Machining	2.05E-03	9.59
	6.54E-05	16
CVD	3.24E-03	15
	9.63E-04	14.78
	1.65E-03	25
	1.05E-05	6.75
Sputtering	3.25E-04	19.5
	6.70E-04	5.04
Grinding	2.85E-02	7.5
	1.66E-02	10
	1.04E-02	16
Waterjet	8.01E-02	16
	1.14E-02	8.16
	5.15E-03	8.16
Wire EDM	2.23E-03	14.25
	2.71E-03	6.6
Drill EDM	1.70E-07	2.63
Laser DMD	1.28E-03	80
Oxidation	8.18E-07	21
	4.36E-07	48

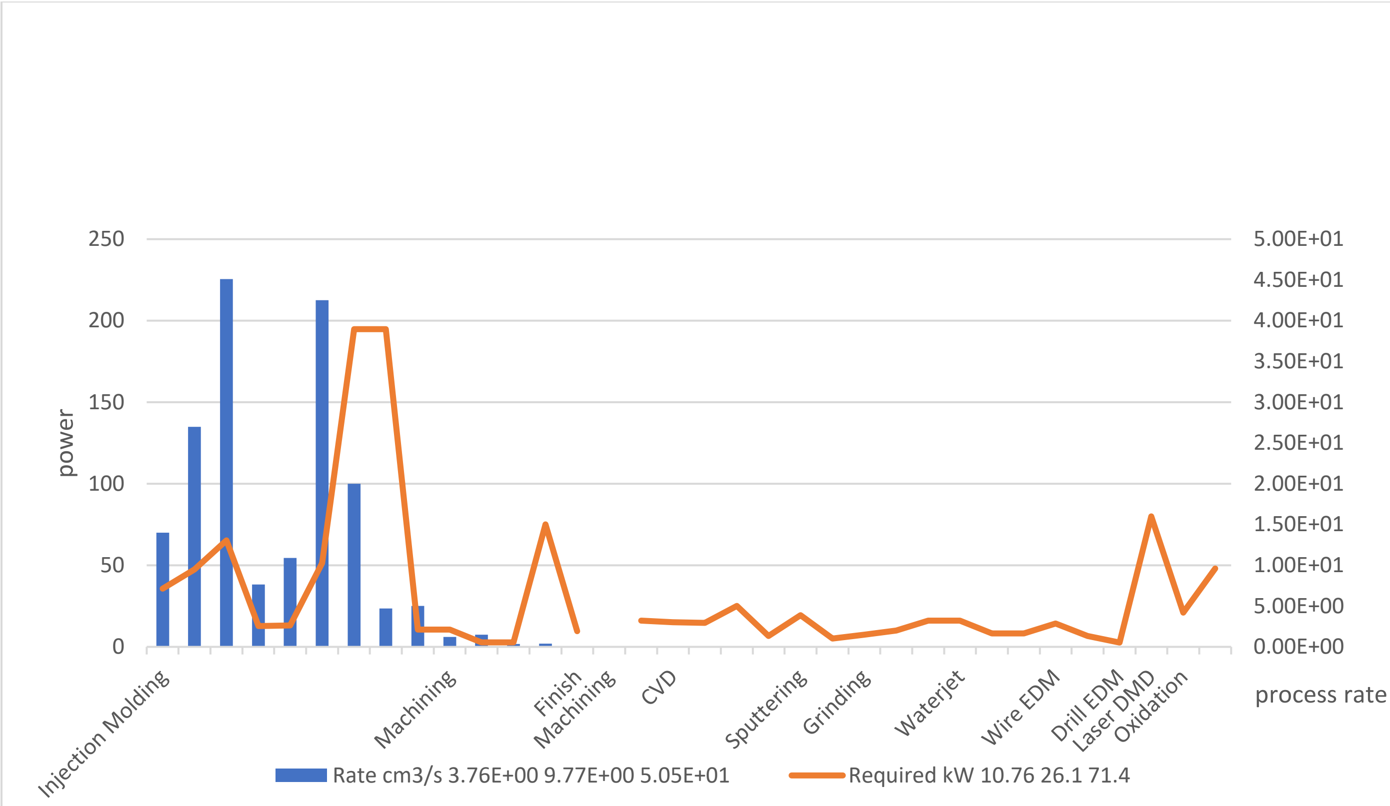

Figure 08 power requirement for various Manufacturing Process

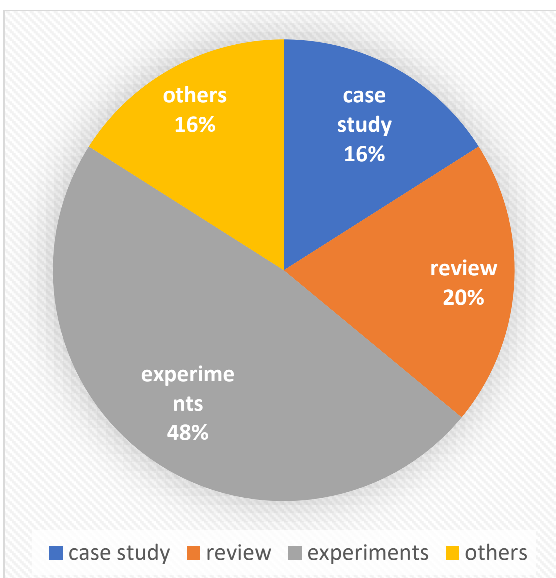

Figure 09 Methodology used in Previous Researches.

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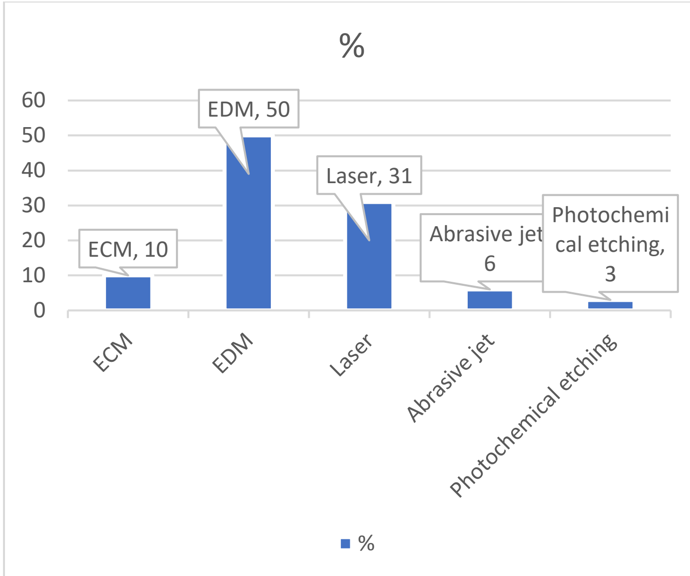

Figure 10 Current studies for sustainability

5. CONCLUSION AND FUTURE WORK

A total of 25 papers in the field of Abrasive Jet machining process were reviewed for this paper. Ninety percent of them were published after the year 2012, accounting for about 40% of the total. Within the last three years, there have been a number of publications. This indicates that there is a positive and growing trend in terms of Abrasive Jet Machining researches. Only 25 papers deal with it directly or indirectly about Concerns of AJM processes. Abrasive jet machining is very simple, low cost technique and effective nonconventional machining process. It has many advantages such as machining versatility, minimization of stress, high machining process flexibility, no heat generation, and low cutting forces on edges and so on. A new trend is set in AJM research focus area. More measurable and comprehensive investigation on AJM practices with long-term viability is needed. In future we need more modernization in AJM process for auto space industry.

6. FUNDING

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7. CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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