International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 04, April-2019

Recent Developments in Electro Chemical Machining- A Review

Ashish Kumar[1], P.S. Rao[2]

[1]ME Student, Department of Mechanical Engineering, NITTTR Chandigarh,
[2]Assistant Professor, Department of Mechanical Engineering, NITTTR Chandigarh

Abstract- Electrochemical machining (ECM) is a technique of removing metal by an electrochemical method. It is typically used for mass production and is used for working enormously hard materials or materials that are difficult to machine by conventional techniques. ECM give an enhanced alternative in producing precise 3-D complex shaped and components which are difficult-to-machined by conventional methods.
The aim of this paper is to study some electrochemical processes for material removal. The parameters such as tool feed rate and the applied voltage also plays a vital role in increasing the material removal rate. Higher surface quality, low tool wear, higher in material removal rate have been studied by using modern unconventional machining process like electrochemical machining operations.

Keywords- Electrochemical machining, Electro chemical honing, Electrochemical Micro Machining, Electro Chemical Drilling, Electro Chemical jet machining

I. Introduction

1.1 Principle of ECM

Electrochemical machining is a technique of removing metal by an electrochemical process. It uses an electrolyte and electrical current to ionize and remove metal atoms. ECM is a reverse process of electrochemical coating. The important process parameters in electrochemical machining are tool feed rate, material removal rate, electrolyte flow rate, surface roughness and applied voltage. In electrochemical machining, there is a reaction occurring at the electrode or workpiece and at the cathode or tool along within the electrolyte. As the potential difference is applied between the tool (cathode) and the workpiece (anode), the negative ions move towards the workpiece and positive ions move towards the tool as shown in figure 1.
The main focus on electrochemical machining is to find out the optimum process parameter with various electrolyte material, varying the electrode gap and applied voltage.

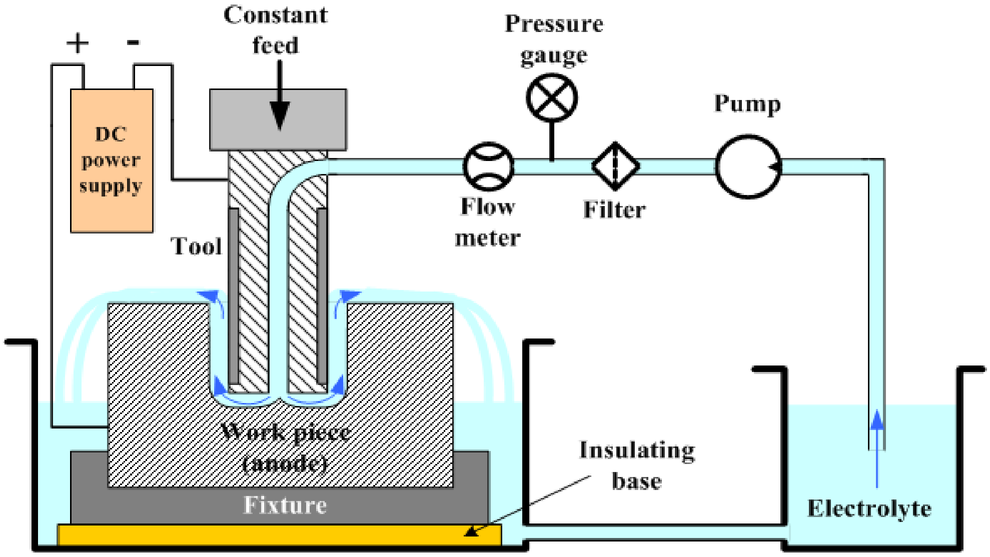

Figure 1: Schematic diagram of ECM

1.2 Literature review

The improvement in the material removal rate of electrochemical machining experimentally was investigated. The Material Removal Rate (MRR) calculated for different electrolytes condition on aluminium and stainless steel. The experimental results shows that the theoretical and actual material removal rates by using sea water as an electrolyte in electrochemical machining on aluminum alloy and steel alloy gives better MRR [1].

The metal removal rate(MMR), overcut and surface roughness (Ra) of mild steel work piece of diameter 50 mm as by using copper electrode and brine solution as electrolyte by using Taguchi L9 orthogonal array approach was determined. Then optimized the best setting of process variables for higher MRR, lower surface roughness and overcut. Three parameters selected as process variables are tool, feed rate, voltage, and electrolyte concentration. Investigation has been done on Mild steel of 50mm diameter by electrochemical machining. Three factors were considered that are voltage, tool rate and electrolyte concentration. These experiments were conducted to obtain high MRR, low overcut and low surface roughness. Feed rate is typically affected process parameter in metal removal rate (MRR), then comes voltage and at last electrolyte concentration.. For surface roughness, feed rate effects it most then concentration and at last voltage. Tool feed rate effects most to overcut at second rank is voltage and at third rank is concentration which affects most to overcut [2].
Electro chemical machining of Special stainless steel $Cr_{12}Ni_9MO_4Cu_2$, which has multiple composition and inhomogeneous tissues; short circuiting frequently occurred during machining when using conventional electrolyte processing was described. They analyzed the reason of machining is difficult from the material composition and structure. They used the $NaNO_3$ and $NaClO_3$ electrolyte composite to select the appropriate concentration, and then by using the orthogonal experiment and gray relational analysis method. Under optimum conditions of 20 V, an electrolyte composite concentration of 41 gram per litre $NaClO_3$ and 178 gram per litre $NaNO_3$, a feed rate of 0.7 mm/min, and an electrolyte pressure of 0.8 MPa, a material removal rate of 100.8 mm^3 /min, a surface roughness of Ra 0.8, and a side gap of 0.16mm were produced. At the same voltage, with an increasing cathode feed rate, the metal removal rate was shown to decrease in side gap while increase the surface roughness. Under the same cathode feed rate, the metal removal rate decreased, while the side gap and the surface roughness increase as the electrochemical machining application voltage increases. Their studies proves that using a certain concentration of electrolyte composite is a simple, low-cost, and feasible approach in improving efficiency and quality [3].
The Electro Chemical Machining for machining of LM25 al/10% SiCp composites during electrolysis with sodium chloride as electrolyte and copper as tool was investigated. The process parameters such as applied voltage, MRR, electrolyte concentration, tool feed rate and electrolyte flow rate were determined by performing experiments on METATECH ECM equipment. The mathematical models were developed based on response surface methodology and were tested by ANOVA and the parameters were optimized by NGSA-2 approach. The results showed optimized Metal removal rate and surface roughness. Optimization will increase production rate considerably by reducing machining time [4].
The Electro Chemical machining of stainless steel EN series 58 A (AISI 302 B) was described. They investigated the effect of voltage variation on metal removal rate. Inter electrode gap (IEG) was maintained constant during the experimentation. They found that the MRR improved significantly by increasing the voltage [5].
The material removal rate by controlled anodic dissolution at atomic level of the work-piece with a hollow cylindrical copper electrode electrically conductive, stainless steel electrode and aluminium electrode, Mild Steel as work piece was investigated. The investigation carried out to find the influence of machining parameters such as Electrolyte concentrations, current density and electrodes. From the experiment, they determined that by the use of different electrolyte concentrations there is a change in MRR. It increases as electrolyte concentration increases. Also by using various types of tools like stainless steel, aluminium and copper it affects the material removal rate. Out of which copper tool material showed good results as compared to the aluminium and stainless steel. By increasing in current density, the material removal rate is also increases. At 10 amp metal removal rate is greater than at 5 amp for given tool material and electrolyte concentration [6].
The Electro Chemical Machining of SS AISI 30 4 work piece Taguchi approach of experimentation showed the best performance in terms of MRR, and surface roughness can be obtained by variation in current, feed rate and electrolyte concentration. It was observed that metal removal rate increased with increase in current. while, high MRR is achieved by increasing the speed of chemical reaction [7].

1.3 Electro chemical honing

Electrochemical honing is a process in which the metal removal capabilities of electrochemical machining are combined with the precision capabilities of honing. This process involves a rotating and reciprocating tool inside a cylindrical component. The material is removed through anodic dissolution and mechanical abrasion 7.5% or more, of the material removal, occurs through electrolytic action. As with conventional electrochemical machining, the workpiece is the anode and a stainless steel tool is a cathode.

Electrochemical honing can offer a unique range of benefits to the machined surface which cannot be obtained by either of the processes when applied independently [7]. The main benefits of ECH process are the complex geometry can be finished with a single setting, high rate of finishing which is virtually independent of removal material without heat and material hardness because the material is removed at an atomic level [8]. Electrochemical honing was used first time in 1979 for making helical gear using specially designed helical gear as cathode and $NaNO_3$ as electrode [9]. A model was established for metal removal rate using pulsed current, this system was successfully used for making micro-holes and for profile refinement. They compared successfully experimental data to theoretical data within 9.99% [10]. A very minor amount of material was removed from the workpiece by an electrochemical honing process and remaining by electrolyte [11]. In 1963-65, the idea of micro material removal from the workpiece by anodic dissolution was developed. This idea was used to improve the productivity and performance of manufacturing parts which was not possible with the existing conventional honing process [12-15]. Electrochemical honing is a highly productive alternating finishing process for the bevel gears [16]. The theoretical model was developed for material removal rate and surface roughness of the bevel gear by an electrochemical honing and for fine finishing of all the teeth of a bevel gear eliminating need to provide the reciprocating motion to the gear workpiece [17-18]. The input process parameters like electrolyte composition, electrolyte temperature, processing time and electrolyte concentration were studied and they found a significant role in minimization of roughness [19].

1.4 Electro Chemical Micro Machining

Electro Chemical Micro Machining (ECMM) is used to increase the production of complex micro structures such as semi-conductors, ultra-precision machinery. A suitable manufacturing process for mass production of these micro scale component needs to be established. The principle of electro Chemical Micro Machining has been investigated the influence of ultrashort voltage pulse and the wire electrode amount on the machining process. In recent years, micro-machining has increased the importance in mass production of micro complex components because manual drilling and milling machines are unsuitable for many micromachining application due to the stress reported on the workpiece.

1.5 Electro Chemical Drilling (ECD)

Electrochemical drilling is a useful process to produce small holes with a large aspect ratio on hard-to-machine materials. Recently, more research has focused on neutral salt electrolytes because they are less harmful to the environment. Whereas, more problems have been caused to the removal of waste products, especially in deep-hole drilling. Usually, an electrolyte flow with constant pressure control is adopted in Electro Chemical Drilling, which might result in the poor removal of waste products at depth because of pressure loss. An electro chemical drilling method with a constant electrolyte flow is obtain a consistent ability to remove insoluble waste products from machining gap. Experiments of Electro Chemical Drilling with both constant flow electrolyte pressure are conducted on workpieces. The results shows that when a constant electrolyte flow rate is applied, the machining currents are much smoother and the profile of machined holes is also uniform. In addition, the pressure variation in the constant flow method increases linearly with machining depth, electro Chemical Drilling with a constant flow also has an increased feed rate [20].

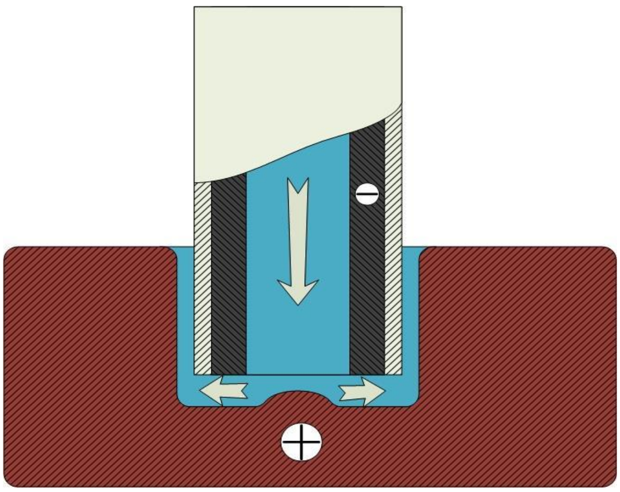

Figure 2: Processing principle of Electro Chemical Drilling [20]

Electrochemical drilling (ECD) uses metal tubes as cathodes, which allows electrolyte pumped through the pipe and into the machining area. When the power is on, workpiece would start to dissolve. Then with the feeding of cathode, the dissolve continues, and eventually, hole 3 with a shape similar to the cathode would be produced (Fig.1). As an important branch of electrochemical machining, ECD was established for drilling holes with a large aspect ratio on hard-to-machine metals. Though it would be difficult to fabricate holes with diameters smaller than 0.8mm, ECD produces a good machined surface and has relatively high stock removal rates [21]. Due to its advantages, ECD has various applications ranging from the aerospace and automotive industries to the die mould industry [22].

1.6 Electro Chemical jet machining

Electro-Chemical jet machining (ECJM) employs a jet of electrolyte for anodic dissolution of workpiece material but there is a lost machining effect which leads to diminishing the effectiveness of machining. The primary method of material removal occurs when an electrical potential is applied between the nozzle and workpiece resulting in anodic dissolution. ECJM is very effective to manufacture complex shapes with the help of multi-dimension mechanical motion, which can meet the complex design requirement [23]. Electro-Chemical jet machining is widely used for drilling small cooling holes in aircraft turbine blade and for producing microelectronic parts. In Electrochemical Jet Machining (EJM) material removal is limited to the exposed substrate directly below the electrolyte jet therefore not requiring additional masking. This is due to the confinement of the current density field in the working gap [24].

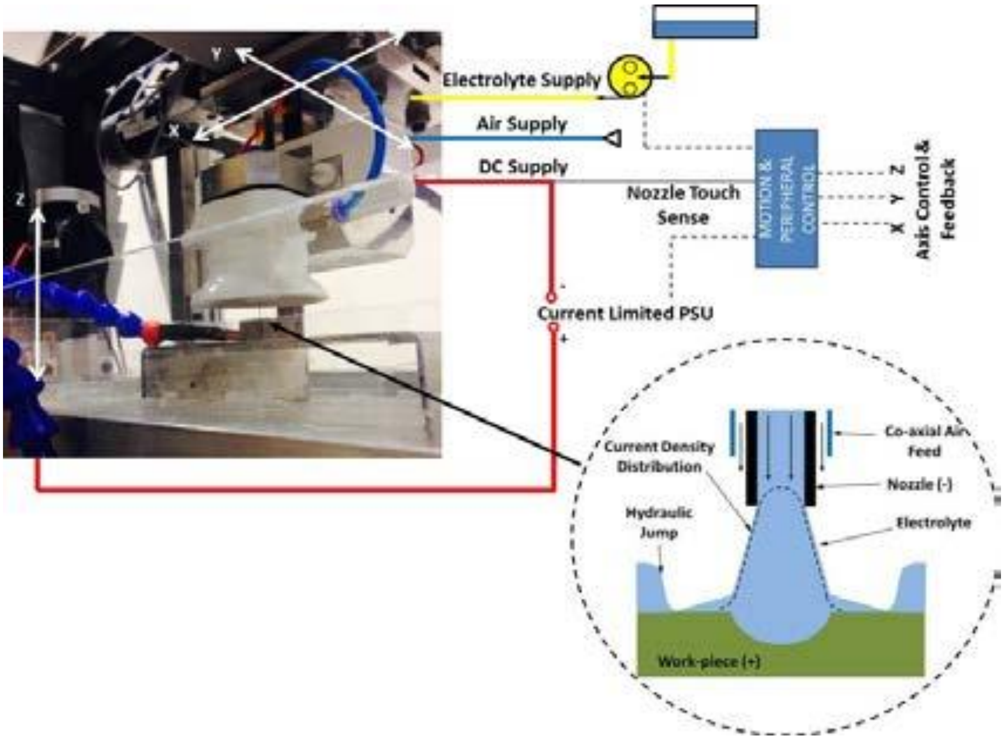

Figure 3: Schematic of Electrochemical Jet Machining apparatus and process [25]

1.7 Electro Chemical Discharge Machining

A study of all machining processes indicates that any scheme for removing material in the form of small particles in a controlled fashion can be used for the shaping of objects. To circumvent material and shape problems, quite often the approach adopted for machining is to cause the melting of a small portion of the workpiece by means of intense localized heat generation. By controlling the location of the heat source in a proper way, the required shape of the workpiece can be achieved.

One phenomenon used to produce intense localized heat generation without using any sophisticated technology like electron beam or laser beam is the electrochemical discharge. Figure 4 shows an electrochemical cell where one electrode is very small and the other is relatively much larger. When these electrodes are connected to a voltage source (either AC or DC) an electrical discharge can be seen at the tip of the smaller electrode if the supply voltage exceeds a critical value. This is known as electrochemical discharge which takes place between the tip of the smaller electrode and the electrolyte in its immediate neighbourhood [26].

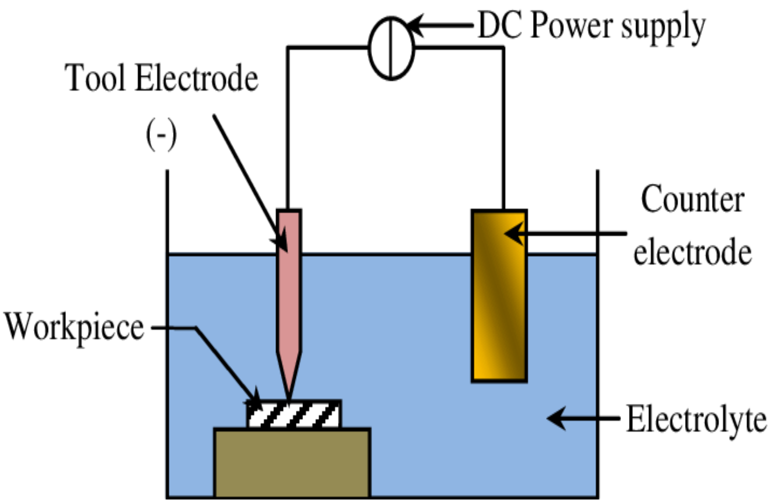

Figure 4: Electrochemical discharge machining [27]

1.8 Electro Chemical Grinding

Electrochemical grinding (ECG) is a relatively new process which has a combination of electrochemical machining and mechanical grinding processes. Nowadays, ECG is more important due to its industrial applications as material removal is independent of the strength and prior treatment of workpiece materials. The electrochemical grinding process is relevant for shaping or grinding an electrically conductive material.

The process of ECG is very similar to ECM except that the cathode is a specially constructed grinding wheel instead of a cathodic shaped tool. Diamond and aluminium oxide are used as an insulating abrasive material for grinding wheel and this grinding wheel is rotated tool with abrasive particles on its periphery as shown in fig.5. The abrasive wheel is attached to a spindle, when the voltage is applied the rotary wheel is fed perpendicular to the workpiece surface as shown in fig.5.The current density and applied voltage are used in the range of 45-350 amp and 5 to 45 V respectively.

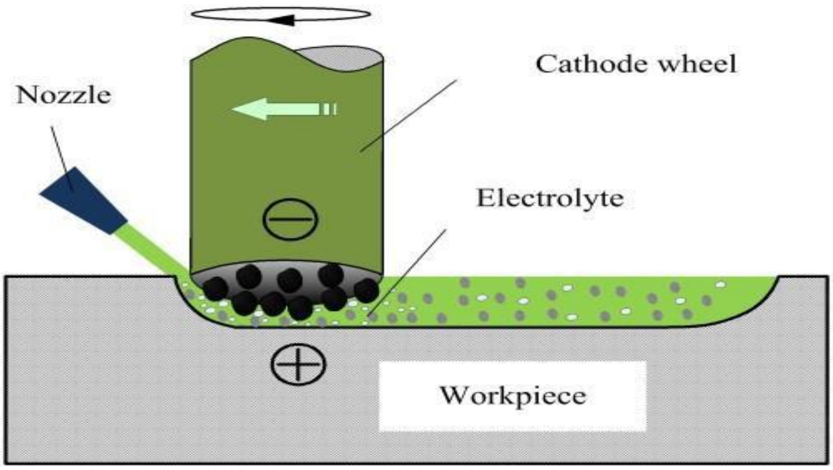

Figure 5: Schematic diagram of electrochemical grinding [28]

II. CONCLUSION

The electrolyte concentration influenced the material removal rate were found by the researchers, hence, by obtaining the favorable concentration of the electrolyte one can easily achieve the higher Material removal rate. The parameters such as tool feed rate and the applied voltage also plays a vital role in increasing the material removal rate. Higher surface quality, low tool wear, higher in material removal rate have been studied by using modern unconventional machining process like electrochemical machining operation, Electro Chemical Drilling, Electro Chemical jet machining, Electro Chemical Discharge Machining, Electro Chemical Grinding etc.

REFERENCES

[1] Pradeep Kumar P, “Investigation of Material Removal Rate in Electrochemical Process” International Journal of Applied Engineering and Technology ISSN: 2277-212X (Online) 2014 Vol. 4 (1) January- March, pp.68-71/ Pradeep.

[2] Deepanshu Shrivastava, “Experimental Investigation of Machining Parameter in Electrochemical Machining” International Research Journal of Engineering and Technology (IRJET) Volume: 02 Issue: 03 June-2015.

[3] L. Tang, “Experimental investigation on the electrochemical machining of $Cr_{12}Ni_9Mo_4Cu_2$ material and multi-objective parameters optimization” International Journal of Advanved Manufacturing and Technology, 2013 67:2909–2916 DOI 10.1007/s00170-012-4703-1.

[4] Chinnamuthu Senthilkumar, “Optimization of ECM Process Parameters Using NSGA-II” Journal of Minerals and Materials Characterization and Engineering, 2012, 11, 931-937.

[5] S. S. Uttarwar, “Effect Of Voltage Variation On MRR For Stainless Steel EN Series 58A (AISI 302B) In Electrochemical Machining: A Practical Approach” Proceedings of the World Congress on Engineering 2009 Vol II.

[6] Charan Shivesh, “Effect of Various Process Parameters on Material Removal Rate on Mild Steel in Electrochemical Machining” International Journal of Engineering Sciences & research Technology [shivesh*, 5(2): february, 2016]

[7] G.F. Benedict,Nontraditional manufacturing processes, Marcel Dekker, New York, 1987.

[8] Electrochemical Machining,J. A. McGeough, in “Kirk-Othmer Encyclopedia of Chemical Technology” (5th edition), Vol. 9, pp. 590-606, J. I. Kroschwitz (editor), Wiley-Interscience, NY 2005.

[9] Capello, G. and Bertoglio, S. (1979) ‘A new approach by electrochemical finishing of hardened cylindrical gear tooth face’, Annals of CIRP, Vol. 28, No. 1, pp.103–107.

[10] Pankaj Agrawal, Hemant Jain, Richa ThakurValue Engineering of Micro-Manufacturing Using ECM and its Applications, MIT International Journal of Mechanical Engineering Vol. 2, No. 2, Aug. 2012, pp. 109-113.
[11] J. Bannard,On the electrochemical machining of some titanium alloys in bromide electrolytes, J. of Applied Electrochemistry, 6 (1976) 477-483.
[12] Eshelman, R. H. (1963) Electrochemical honing reports ready for production jobs. Iron Age, Pp. 124.
[13] Singh, H., and Jain, P. K., (2014) Remanufacturing with ECH- a concept, International Journal of Procedia Engineering, Vol. 69, Pp.1100-1104.
[14] Ann. Tooling for electrochemical honing. Tool Mfg Engrs, 1965, 68.
[15] Given, N. Electrochemical honing: four times faster. Machinery, 1965, 72, 119.
[16] J.P. Misra, P.K. Jain, D.K. Dwivedi, N.K. Mehta, Study of Electrochemical mechanical finishing of bevel gears, Int. J. of Manufacturing Technology and Management, 27(4-6)(2013) 154-169.
[17] Shaikh, J.H. and Jain, N.K. (2014) 'Modeling of material removal rate and surface roughness in finishing of straight bevel gears by electrochemical honing process', Journal of Materials Processing Technology, Vol. 214, No. 2, pp.200–209.
[18] Shaikh, J.H., Jain, N.K. and Venkatesh, V.C. (2013) 'Precision finishing of bevel gears by electrochemical honing', Materials and Manufacturing Processes, Vol. 28, No. 10, pp.1117–1123.
[19] P.S. Rao, P.K Jain, D.K Dwivedi, Electrochemical honing of external cylindrical surfaces- An innovative Step, DAAAM International Scientific Book, Chapter-9, pp. 97-116, 2015.
[20] Xindi Wang, Ningsong Qu, Xiaolong Fang, Hansong L, Electrochemical drilling with constant electrolyte flow, Journal of Materials Processing Technology, Volume 238, December 2016, Pages 1-7.
[21] McGeough, J.A., Pajak, P.T., De Silva, A.K.M., Harrison, D.K., 2003. Recent research and developments in electrochemical machining. Int. J. Electric Machining .8, 1–14.
[22] Amalnik, M.S., McGeough, J.A., 1996. Intelligent concurrent manufacturability evaluation of design for electrochemical machining. J. Materials Processing Technol. 61, 130–139.
[23] Schudert A, Hackert-Oschatzchen M, Martin A, Winkler S, Kuhn D, Meichsner G, Zeidler H, Edelmann J (2016) Research on generation of three-dimensional surface with micro-electrolyte jet machining. Procedia CIRP 42:384–389
[24] Hackert M, Meichsner G, Schubert A. Generating Micro Geometries with Air assisted Electrochemical Machining. In EUSPEN 10th 1st International Conference. 2008. Zurich.
[25] Mitchell-Smith, J, Clare, A.T, Electrochemical Jet Machining of Titanium: Overcoming Passivation Layers with Ultrasonic Assistance, Procedia CIRP, 42, 2016, 379-383.
[26] Amitabha Ghosh, Electrochemical discharge machining: Principle and possibilities, Sddhana, Vol. 22, Part 3, June 1997, 435-447.
[27] Sree Prasanna Rajagopal, Vishnu Ganesh, Amol V. Lanjewar, M. Ravi Sankar, Past and Current Status of Hybrid Electric Discharge Machining (H-EDM) Processes, Advanced Materials Manufacturing & Characterization Vol 3 Issue 1 (2013).
[28] Qu N.S, Zhang Q.L, Fang X.L, Experimental Investigation on Electrochemical Grinding of Inconel 718, 15th Machining Innovations Conference for Aerospace Industry, Procedia CIRP 35 (2015), 16-19.