ID: 2016-ISFT-220

A Review on Impacts of EDM on Environment, Health and Safety

M. K. Satyarthi [1], Pushpendra S. Bharti[2]

[1,2]U.S.I.C.T., Guru Gobind Singh Indraprastha University, New Delhi [INDIA]
[1]mksssrewa@gmail.com

Abstract: *The unconventional machining process like electric discharge machining (EDM) has shown remarkable benefits over other conventional manufacturing processes, like higher material removal rate, better surface finish and improved topographic features. Therefore, the present work is an attempt to understand the impact of EDM on environment, health and safety of the operator. The recent attempts of various researchers in this field have been studied in detail to find viability of EDM process. The various methods of EDM have also been studied and their findings are compared. It was concluded that the green processing would be a better option for manufacturing by EDM process.*

Keywords: *EDM, Green Processing*

1. INTRODUCTION

Electric discharge machining (EDM) process is one of the most widely practiced un-conventional material removal process that enjoys remarkably huge market share which is approximately greater than 7% of the total machine tools sell worldwide [1]. In EDM process, the material removal is governed by high frequency electric sparks that causes ionisation of the dielectric media resulting in the thermo-electric decomposition of the workpiece material. The intense temperature of the order of 8000 to 12000K is generated eventually which is sufficient to melt and vaporize the work material [2]. Uniqueness of the process lies in the fact that material is removed accurately and precisely at extremely high temperature [2]. Controlled material erosion makes it possible to generate dimensionally and geometrically accurate 2D and 3D profiles on difficult to cut materials [3]. EDM is also used for the manufacturing operations like preparing moulds, dies, surface texturing, surface alloying, production of aero engine components, components for electronic, surgical instruments and prosthesis [4]. EDM also finds increasing applications in the field of medical, optical, jewellery, automotive and aeronautic industries [4]. Due to developments of various variants of EDM like Die sinking EDM, Wire-cut EDM, Micro EDM, electric discharge milling (EDM), electric discharge grinding (EDG), electric discharge honing (EDH), electro discharge coating and texturing (EDCT) etc., its applications are likely to increase exponentially here on [5]. The dielectric fluid plays an extremely important function regarding productivity, costs and quality of the machined parts [6]. Functions performed by dielectric fluids in EDM process [6], are grouped into primary and secondary functions as listed below.

1.1 PRIMARY FUNCTIONS:

- To insulate the sparking gap between electrode and work piece up to breakdown voltage and then breaks down by ionization for plasma channel generation.
- To flush away the eroded particles (debris) produced in the sparking gap during machining.
- Restriction of the spark energy in to narrow region for higher energy density to re-establish the insulation condition in the sparking gap between the electrode and the work-piece by deionization when energy level goes below the breakdown voltage.
- To cool the electrode and work piece materials heated by the electric discharge machining.

1.2 SECONDARY FUNCTIONS:

- To capture the emissions generated because of decomposition of the dielectric fluid and vaporized matters of tool and work materials.
- To serve as a liquid adsorbing filter for gas and liquid phases when expelled from the gap.
- To minimize the electromagnetic radiation effect by immersion of the plasma channel.
- To assist molten metal globules to detach from the work piece surface
- To generate an environment for the subsequent discharges to take place uniformly across the sparking gap.

The type of dielectric fluid and its supply mode are significant to have stable, efficient and operator friendly material removal process. Due to the rapid rise and fall of the intense temperature and pressure due to short spark cycles, plasma surrounding dielectric media undergo partial ionisation which in turn results in emission of solid metallic particles, finely mixed tiny droplets of liquid dielectric and emitted gases in the form of aerosols, toxic gases, waste dielectric etc [7]. These by-products are hazardous to the operator and the environment.

The mechanism of ionization and deionization depends on various properties of dielectric like breakdown strength, dielectric constant, viscosity, thermal conductivity, specific heat capacity etc., which differs for types of dielectric fluids and its supply form. Rate of ionization and deionization, intensity of pressure & temperature generated and decomposition products generated & emitted significantly depends on type of dielectric and its supply form. Each mode of dielectric supply is suitable and favourable for specific machining requirements. It also has adverse impacts on environment, personnel health and operational safety due to various types and forms of toxic and hazardous emission products released to atmosphere. These emission products have adverse impacts on operator's health and safety while the post operation sludge and waste dielectrics pollutes environmental. Due to extreme business competitions, short term survival strategies lead to deliberate ignorance towards adverse impacts on environment, personnel health and operational safety of a manufacturing practices at the same time for long term survival and growth of the business, industries are compelled to adapt ISO 14000 series environmental management standards to ensure minimum environmental impact by the production processes, products, by-products and post production operations.

This review work mainly aims to highlight the research carried out related to the environmental impact, Personnel health and operational safety of EDM process which eventually will help to develop and implement sustainable manufacturing practices to improve sustainability of EDM process.

2. LITERATURE REVIEW

Since introduction of EDM as one of the advanced manufacturing process, kerosene is unarguably considered as the preferred dielectric fluid. Properties of dielectric fluid deteriorates with continuous usage, which in turns reduces the efficiency of EDM process, its volatility substances and emission products pollutes the air and high discharge temperature of the process decomposes the kerosene, causing carbon elements to adhere on the electrode surface. The adhered carbon elements affect normal discharge. Therefore a brief literature review has been attempted to understand the ill effects of the dielectric fluid on environment, health and safety of the operator.

Tonshoff et al. [8] have evaluated the potential hazards during EDM process as shown in (figure-1). Researches carried out in various areas of EDM process pinpoints that in order to suit specific machining requirements, various modes of dielectric supply and form of dielectric fluid have been experimented like wet EDM using liquid dielectrics, Dry EDM using gases or compressed air and Near Dry EDM using a mixture of liquids and gases in specific proportions.

The author had also investigated that hydrocarbon based dielectrics releases hazardous substances like aliphatic hydrocarbons, aerosols, non-specific aliphatic hydrocarbons, benzene and fine dust. In addition, mineral oil vapours and aerosols, decomposition products of oil and additives are likely to be emitted.

Yeo et al. [9] investigated that at the end of the EDM operation, the sludge (materials removed from both the work piece and tool), dielectric waste and deionising resin need to be disposed of appropriately otherwise, there is a risk of land and water pollution. High temperature and pressure in the discharge channel of the EDM process can lead to the generation of reactive products of the hydrocarbon oil based dielectrics. Consequently, operators as well as the broader environment are exposed to these toxic aerosols and gaseous emissions emitted from the dielectric surface.

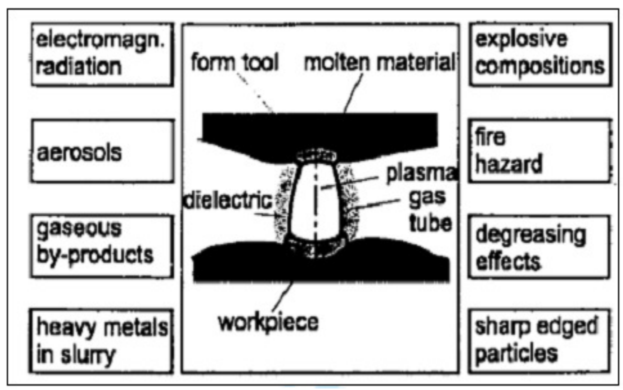

Fig. 1. Hazard potentials during EDM machining [8]

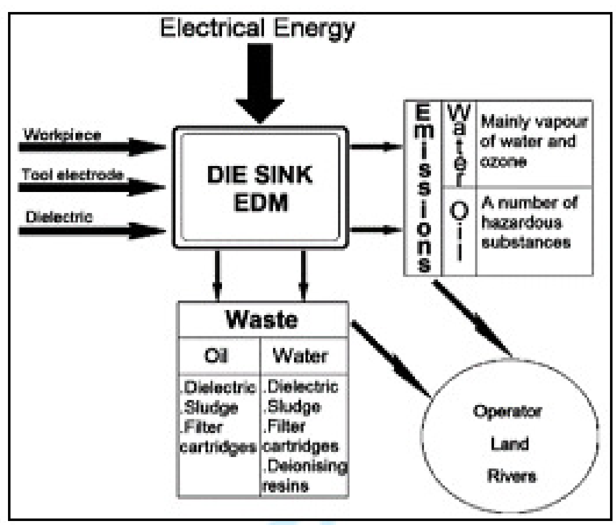

Fig. 2. Environmental impact of die-sinking EDM [9]

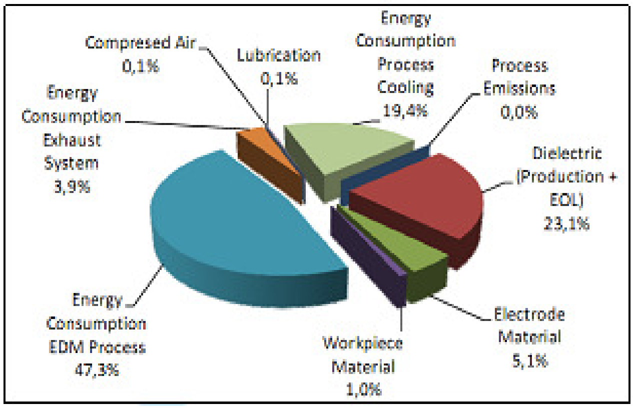

Fig. 3. Environmental impact during EDM processing [9]

Boyko et al. [10], reported that for hydrocarbon oil based dielectric fluids, fumes and vapours contains polycyclic aromatic hydrocarbons (PAH), Benzene, vapour of mineral oils, mineral aerosols, various by-products generated due to dissociation of oils and its additives. Synthetic dielectric fluids generate various forms of vapours and aerosol products. Due to extremely high temperature and pressure in the sparking gap, composition of dielectric fluid and its viscosity have a significant influence on generation of fumes and vapours.

Kellens et al. [11] has carried out life cycle analysis, for EDM process and reported that there is a potential risk for EDM operators due to higher than the permitted concentration of aerosols and gaseous emissions near breathing zone and nearby surroundings. This influence of process parameters on the breathing zone concentration of the aerosol generated from the electrical discharge machining process using Taguchi methodology. Near operator breathing zone, major portion of aerosol (about 69%) constitutes metallic particulates of spherical shape with an average sizes ranging from 20 to 29nm. The analysis of the aerosol samples indicated the presence of about 20 different hydrocarbons which are potential threats to the operators.

Muthuramalingam et al. [12] and Sivapirakasam et al. [13-17], has analysed that gaseous hydrocarbons present in the work atmosphere were a complicated mixture including straight chain, branched chain aromatic, alicyclic, and heterocyclic compounds. So, there is an uncertainty of the risk associated with exposure to gas phase emissions generated from the EDM process. Water based dielectric fluids The EDM process with deionized water and commercial water based dielectrics also generates toxic gases and fumes due to the thermal decomposition. The emissions from de-ionized water and commercially available water-based fluids, produces the lowest number of substances (by-products), which are much less hazardous to the operator and environment. Some of those substances, e.g., benzene, benzo-pyrene, are classified into norms and are submitted to severe prescriptions in matter of toxicology and limit values of concentration. Benzo-pyrene and benzene are considered as carcinogenic. water based solvents releases carbon monoxide nitrous oxide, ozone, and harmful aerosols. Antisepticise action must be taken into consideration when water-based working fluid was used.

3. DISCUSSION

Personnel health in the context of manufacturing activities is related to impact of emissions from manufacturing operations on directly exposed labour due to chronic exposure, high level of breathing zone concentrates and compliance of regulatory requirements for the maximum permissible emissions values. In the manufacturing industry, exposure to hazardous gases, toxic aerosols, and metallic particles for a long time was considered to be a serious occupational health hazard to the operator.

During EDM operation, harmful products such as aromatic hydrocarbons, pitch and sulphur disintegrates in to sulphur dioxide and monoxide, which are injurious to operator's health, and may cause benign and malign tumours. Boyko [10], highlighted that dielectric based on mineral oils generates detrimental products such as polycyclic aromats in solid and liquid states, oily fog, metal particles and disintegrated parts of oils and additives. Metallic particles can cause allergic reactions, asthma and lung diseases.

Hydrocarbon exposure causes health problems like headache, dizziness, confusion, irritation of the skin, eyes and nose, memory difficulties and stomach discomfort. Generally, carcinogenic hydrocarbons like benzene and polycyclic aromatic hydrocarbons (PAHs) are expected while using hydrocarbon-based dielectric fluids. It contains high concentrations of paraffinic and naphthenic petroleum solvents and small amounts of aromatic compounds. Hydrocarbon solvent in the dielectric fluid causes irritation by exerting its solvent effect primarily on the upper epidermal cells. Yeo [9, 18, 19], has found that during EDM operation, the operator, can easily inhale the vaporized dielectric which may cause an adverse effect on health.

4. CONCLUSIONS

Although, hydro-carbon based dielectric fluids are cheaper and readily available but are not free from demerits and detrimental effects on environment as well as operator's health. The present study reveals that the green processing would be a better option for manufacturing by EDM process as it generates least by-products which are less hazardous for the operator's health as well as environment.

REFERENCES

[1] Cao, F.; Zhang, Q. Neural network modelling and parameters optimization of increased explosive electrical discharge grinding (IEEDG) process for large area polycrystalline diamond. Journal of Materials Processing Technology, 2004, 149, 106-111.

[2] Satyarthi, M.K.; Pandey. P.M. Processing of conductive ceramic composite by EDG and powder mixed EDG: A comparative study. 4th International and 25th All India Manufacturing Technology, Design and Research Conference (AIMTDR-2012), 2012.

[3] Dev, A. et al. Machining characteristics and optimisation of process parameters in micro-EDM of SiCp–Al composites. International Journal of Manufacturing Research, 2009, 4, 458-480.

[4] Satyarthi, M.K.; Pandey, P.M. Comparison of EDG, Diamond Grinding, and EDM Processing of Conductive Alumina Ceramic Composite. Materials and Manufacturing Processes, 2013, 28, 369-374.

[5] Patel, K.M.; Pandey, P.M.; Rao, P.V. Surface integrity and material removal mechanisms associated with the EDM of Al2O3 ceramic composite. International Journal of Refractory Metals and Hard Materials, 2009, 27, 892-899.

[6] DiBitonto, D.D., et al., Theoretical models of the electrical discharge machining process. I. A simple cathode erosion model. Journal of Applied Physics, 1989, 66, 4095-4103.

[7] Eubank, P.T. et al. Theoretical models of the electrical discharge machining process. III. The variable mass, cylindrical plasma model. Journal of Applied Physics, 1993, 73, 7900-7909.

[8] Tonshoff, H.K.; Friemuth, T. In-process dressing of fine diamond wheels for tool grinding. Precision Engineering, 2000, 24, 58-61.

[9] Yeo, S.H.; Tan, H.C.; New, A.K. Assessment of waste streams in electric-discharge machining for environmental impact analysis. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 1998, 212, 393-401.

[10] Boyko, W.J., P.N. Keliher, and J.M. Patterson, Emission spectrometry. Analytical Chemistry, 1982, 54, 188-203.

[11] Kellens, K. et al. Preliminary Environmental Assessment of Electrical Discharge Machining, in Glocalized Solutions for Sustainability in Manufacturing, J. Hesselbach and C. Herrmann, Editors. 2011, 377-382.

[12] Muthuramalingam, T. ; Mohan, B. Influence of Discharge Current Pulse on Machinability in Electrical Discharge Machining. Materials and Manufacturing Processes, 2013, 28, 375-380.

[13] Kannan, G.R. et al. Studies on biodiesel production and its effect on DI diesel engine performance, emission and combustion characteristics. International Journal of Ambient Energy, 2011, 32, 179-193.

[14] Jose, M.; Sivapirakasam, S.P.; Surianarayanan, M. Analysis of Aerosol Emission and Hazard Evaluation of Electrical Discharge Machining (EDM) Process. Industrial Health, 2010, 48, 478-486.

[15] Sivapirakasam, S.P.; Mathew, J.; Surianarayanan, M. Constituent analysis of aerosol generated from die sinking electrical discharge machining process. Process Safety and Environmental Protection, 2011, 89, 141-150.

[16] Sivapirakasam, S.P.; Mathew, J.; Surianarayanan, M. Multi-attribute decision making for green electrical discharge machining. Expert Systems with Applications, 2011, 38, 8370-8374.

[17] Pandian, M.; Sivapirakasam, S.P.; Udayakumar, M. Investigation on the effect of injection system parameters on performance and emission characteristics of a twin cylinder compression ignition direct injection engine fuelled with pongamia biodiesel–diesel blend using response surface methodology. Applied Energy, 2011, 88, 2663-2676.

[18] Yeo, S.H.; Kurnia, W.; Tan, P.C. Critical assessment and numerical comparison of electro-thermal models in EDM. Journal of Materials Processing Technology, 2008, 203, 241-251.

[19] Yeo, S.H.; Tan, P and W. Kurnia, Effects of powder additives suspended in dielectric on crater characteristics for micro electrical discharge machining. Journal of micromechanics and microengineering, 2007, 17, N91–N98.