1. Introduction

A safe and healthy work environment is highly essential for the employees of an industry to perform their job effectively and efficiently. Long term exposure to occupational hazards can cause severe health problems to workers. Emissions of toxic gases and particulates are one of the major occupational hazards, especially associated with metal working industries. It was observed that occupational exposure to such components caused health effects such as Asthma, Inflammation of the Respiratory Tract, Lung Disease, and problem to Blood, Kidneys, Stomach, Immune System, Reproduction and Liver. Use of metal working fluids is one of the main causes of such hazards releases.

EDM is such a process having the hazard potential of toxic emissions. The wide use of hydrocarbon based dielectric fluids such as kerosene, paraffin oil, synthetic EDM oils etc increases the severity of the problem. Characterization of emissions is essential for the complete hazard profiling of the process having emission of toxic substances. Characterization of hydrocarbons released from die sinking EDM is presented in this work. The main objectives of the work is to sample the particulates and gases present in the zone respective for breathing of the die sinking EDM operator for analyzing the effect of parameters of process.
on the exposure, to characterize the hydrocarbons present in the aerosol and gases using GC/MS and to compare the concentration of hydrocarbon with the permissible exposure limit values. Traditionally the main focus of the researchers working in the area of electric discharge Machining is the manufacturing aspects of the process i.e., Surface Roughness (SR), Tool Wear Rate and Material Removal Rate (MRR). A few researchers have studied about the safety and process’s environmental characteristics. Following is the review of work done in this area.

Report an occurrence of irritant contact dermatitis in the aerospace industry from (EDM). 20 workers have been performing EDM developed irritant contact dermatitis originating through the dielectric fluid utilized in EDM, a form of precision metal machining which is extensively utilized in making mould and precision engineering. Hydrocarbons are present in Dielectric fluid. Their experience has been noticed that irritant contact dermatitis from dielectric fluid could only be prohibited by easy precautionary measures similar to personal hygiene and health education.

When compared the use of distilled water and kerosene as dielectrics on EDM characteristics of Ti-Al-4v. They found that MRR is higher and wear ratio seems to be lower on using distilled water compared to kerosene and also debris size in distilled water is higher on compared with kerosene. A survey on the use of water based and gaseous dielectric fluid has been conducted by EDM became a process which is international later on to the discovery of the significance of the dielectric fluid, that influences factors namely productivity and quality.

Health, safety and Environment seem to be significant factors specifically when oil dependent fluids have been used. Water dependent dielectrics might alternate oil dependent fluids in applications like die sinking. Gaseous dielectrics like oxygen could be used as substitute.

Reported hygienic characterization utilizing emission dependent monitoring by some technical adjustment at working processes or machine tools to reduce the risk.

Tools for work and work pieces utilized possess a well-built effect towards aliphatic compounds and metals but does not over organic compounds (BTEX) that are volatile and Polycyclic Aromatic Hydrocarbons (PAHs) in air emissions. Rise in the level of dielectric (mineral oil) beyond the location of processing declines chromium, BTEX, PAH and nickel emissions. Highest quantity of chromium is attained very earlier to the restricting values of aliphatic compounds were gone beyond. Environmental and safety aspects of this process are reported by, they have determined hazard potentials associated with the EDM process.

They concluded that fumes vapors and aerosols are depending upon the material removing principle, the work material and dielectric by. And also irregular sinking produces lots of aerosols and fumes aerosols than by finishing wire cutting. This work revealed that dielectric seems to be a predominant feature to generate hazardous material. Whenever mineral oil and various byproducts produced by oil and its additives dissociation) will develop. They also explained how to dispose the waste generated from the EDM process. Disposal methods are centrifuging, conditioning, drying, super fix filtration and adsorption. A review conducted by on current research trends in electric discharge machining process highlighting the importance of environmental aspects along with quality and productivity aspects. The literature available in the field of environmental characteristic of the process, EDMS hypothetically predicts the hazard potentials of the process and components of emissions by. Even though some studies have been conducted to quantify the components of emissions from the process a comprehensive study is not present in the literature. Moreover no literature explained about the characterization of hydrocarbons generated by EDM process.

2. EDM Process

EDM is known to be the highly accurate processes of manufacturing, brought up in the 1940’s. EDM earned significant due to its capability of sharing too hard and brittle materials that are complicated in machining involving traditional techniques and for producing greater quality of the surface that is finished. Later on when introducing CNC EDM in the 1980, automatic unattended machining could now be executed and the extend of applications for EDM has been broadened more. EDM also known as “Spark Machining” employs thermal energy produced because of an electric spark struck among tool and electrode machine, the work piece. Thermal energy has been employed to minute part of the surface of the work piece. Sparking occurs in region wrapped up by a dielectric material. Cutting tool is detained in nearest proximity to the machining part. Vaporization and Fusion of the material later on get rid of the material. In die sinking EDM process the tool and work piece are held inside a nonconductive dielectric fluid. For EDM, the dielectric fluid insulates and cools the
electrode and work piece, conveys the spark, and flushes away the removed metal. When pumping of the fluid via the electrode end, particles would kick off, and mostly gather at the edges.

2.1 Environmental and Safety Aspects of EDM
High temperatures and pressure in the channel for discharge of this process could end up in production of a number of reaction products of the dielectric which could emit from the dielectric surface as gases or particulates. Substances that are hazardous are part of this emission which could focus in the air that surrounds. Subsequently, substances that are hazardous could focus in the dielectric itself. Operating personnel has been shown for these emissions when actual process of production occurs. The emissions from this process may contain toxic substances like, PAH, BTEX, Metal particle etc. Apart from the exposure to substances that are hazardous, the process called EDM is having the risk of fire hazard when hydrocarbon based dielectric fluids are used.

3. Health Effects of Possible Emission

3.1 Polycyclic Aromatic Hydrocarbons (PAH)
PAH are hydrocarbons having more than one fused aromatic rings and can be attached to dust particles and few could evaporate voluntarily. PAH enters human body by inhalation, skin contact and ingestion. Dominating health effect of occupational PAH exposure is lung cancer.

3.2 Benzene Toluene Ethyl and Xylene (BTEX)
Benzene, Toluene, Ethyl and Xylene (BTEX) is a group of volatile organic compounds. Exposure to BTEX can occur by ingestion, inhalation or absorption through the skin. Liquid that is colorless emitting sweet odor is Benzene. Toluene is a clear, colorless liquid with distinctive smell. Ethyl benzene is a colorless, flammable liquid that smells like gasoline.

3.3 Metallic Particles (Nickel and Chromium)
EDM is used for shaping most of the ferrous alloys consisting nickel. Nickel particles which can be bound to particulates cause's adverse health effects like allergic reactions, asthma and lung effects. Animal studies show that the following are the health effects due to nickel exposure. Information of the respiratory tract, lung disease, problems to immune system, stomach, kidneys, blood, reproduction and liver. Nickel and its compounds are known carcinogens. Lung and nasal sinus Cancers are also resulted.

4. Threshold Limit Value
It's the maximum level of concentration below which workers are allowed to work without causing any adverse effect. The Table 1 shows the TLV of welding fumes recommended by ACGIH. It's the time –weighted average concentration for a normal eight hours day or 40 hours week below which orkers are allowed to work without causing any adverse effect. It's the maximum level of concentration below which persons can be exposed for a period of up to 15 minutes without causing any adverse effect9–11. TLV-C (ceiling limit) is the maximum level of concentration, should not exceed at any point of time.

Table 1. Tlv’s of some of the hydrocarbons

| Sl. No | Constituents                             | Threshold Limit Value (TWA) |
|--------|------------------------------------------|-----------------------------|
| 1.     | Polycyclic Aromatic Hydrocarbons         | 0.2mg/m³                    |
| 2.     | Benzene                                  | 1.6mg/m³                    |
| 3.     | Ethylene Benzene                         | 10ppm                       |
| 4.     | Toluene                                  | 50ppm/188mg/m³              |
| 5.     | Xylene                                   | 100ppm/434mg/m³             |
| 6.     | Aliphatic Hydrocarbons                   | 400ppm                      |
| 7.     | Tetradecane                              | 5mg/m³                      |
| 8.     | Phenol                                   | 5ppm                        |
| 9.     | Tridecane                                | 5mg/m³                      |
| 10.    | Pentadecane                              | 5mg/m³                      |
| 11.    | Cyclopropananonanoic Acid                | 10ppm                       |
| 12.    | Docosane                                 | 200ppm                      |
| 13.    | Tetracosane                              | 5mg/m³                      |
| 14.    | Benzaldehyde                             | 0.461ppm                    |
| 15.    | Decane                                   | 5mg/m³                      |

5. Gas Chromatography / Mass Spectrometry
A gas chromatograph is an instrument for analyzing chemically in order to separate chemicals present in a
sample that is complex. For measuring the individual molecules split up, a mass spectrometer changes them to ions hence that they could be just moved and manipulated by magnetic and electric fields externally. Gas Chromatography-Mass Spectrometry (GC-MS) is a hyphenated technique; comprising of two analytical procedures in series known to be a Gas Chromatography (GC) separation subsequently Mass Spectroscopy (MS) detection. Objective of the GC step is to split up multiple compounds present within a sample as they arrive at the MS detector one at the time.

6. Taguchi Method for Optimization of Process Parameters

Process parameters optimization is the key in the Taguchi method to achieve targeted output with no cost increase which is due to the process parameters optimization could be to betterment the characteristic of quality and optimal parameters of process attained from Taguchi method are insensitive to the changeable factors of noise. Essentially Classical parameters design of process is intricate and tough to use. Particularly a huge amount of experiments has to be performed on rise in the parameter of process. For solving this task, the Taguchi method utilizes a extraordinary design of orthogonal arrays for studying the complete process parameter space with a little number of experiments only. Taguchi method suggests the usage of the function of loss for measuring the quality deviation characteristic from favored value. Design of Taguchi parameter could optimize the performance via the design parameters setting and bring down the system fluctuation functionality to source variation.

7. Sampling of Gases and Aerosols

Gases and particulates were sampled separately for using personal air sampling pump. The sampling was done in zone of breathing of the EDM operator. It is a perfect method of evaluating worker exposure to airborne particulate matters and gases. The sampling device is placed as close as possible to the breathing zone of the worker (defined as a hemisphere in front of the shoulders with a radius of 6-9 in). So the date collected closely approximates the concentration in haled. In order to measure the total particulate fume and gases generated in the EDM process the sampling equipment is selected as per the standard procedure. Sampling pump is a collection device, light weight and capable of drawing between 5 to 5000ml/min for particulate collection over a general working day. It’s a battery operated device capable of operating up to 6 days. To sample the organic vapour present in the work atmosphere the activated charcoal tube is used. The vapors are absorbed by the charcoal kept in glass tubes. It’s used to hold the filter paper and provide with an orifice, allows the air to be sampled. It is normally of 37mm diameter and selection depends on the type of particulate to be sampled. Filter paper is made of polyvinyl chloride material and the size is 5µm pore size and 37mm diameter used to collect the particulate.

8. Experimental Procedure for Aerosol Sampling

In this a die-sinking EDM was utilized as the experimental equipment for machining the carbon high chromium steel using kerosene as the dielectric. The electrode material is made of copper. The particulate in emissions from the process are collected using a Poly Vinyl Chloride (PVC) of 37mm diameter. System of sampling utilized for the process was air sampler (SKC) where air flow rate will be set 2.5lit/min. The filter paper is kept tightly in a holder and the pipe was connected to both sampler and filter paper. The weight of the filter paper is measured before starting the experiment. The velocity of the sampler was kept 2.5lit/min and the filter paper is used to collect the dust particles coming out from the process. The sampling duration for the experiment was 180 min. After the sampling duration the sampler was switched off and the filter was taken out. Filter paper weight has been measured later on completion of the experiment. Particulates in emission have been estimated from the provided formula.

\[ COP = \frac{(W_b - W_a) \times 1000}{t \times v} \text{mg/m}^3 \]

Where \(W_a\) and \(W_b\) are the filter paper weight (mg) prior to and later sampling.
\(t\)- Duration of Sampling (min)
\(v\)- Sampler flow rate (lpm)
The glass wool end of the adsorbent was fully broken and charcoal was transferred in to a dry vial. 2 ml of the
appropriate solvent was transferred into a vial were the solvent used is carbon disulphide and that solution was agitated and mixed thoroughly. A clean 10ml syringe which was connected to a syringe filter holder in which a syringe filter of membrane PTFE, 13 mm diameter and 0.22µm pore size was cleaned using carbon disulphide solution was drawn into the syringe and then transferred into and clean dry vial by filtering the solution using that membrane and then stored it by capping it with PTFE lined cap. The same process was repeated for all the other gas samples also and labeled them with the appropriate sample numbers.

9. Experimental Procedure for Gas Sampling

In current a die-sinking EDM finds its place of application as the experimental equipment for machining high carbon high chromium steel using kerosene as the dielectric. The electrode material is made of copper. The gases in emissions from the process are collected using an activated charcoal adsorbent tube. System of sampling utilized in the process is known to be air sampler (SKC) where the rate of flow of air will be positioned to 0.2lit/min. The adsorbent is kept tightly in a holder and the pipe was connected to both sampler and adsorbent holder.

The sampler is calibrated for 0.2lit/min before starting the experiment. The sampling duration for the experiment was 180min. After the sampling duration the sampler was switched off and the adsorbent was taken out. The sampler was calibrated once again after completion of the experiment. Remove the PVC filter from the cassette and drop that into a dry vial transfer 2ml of the appropriate solvent into a vial. Here the solvent used is carbon disulphide and agitate and mix that solution thoroughly. A clean 10 ml syringe which is connected to 0.22µm pore size was cleaned using carbon disulphide then draw the solution into the syringe and then transfer that into an clean dry vial by filtering is using that membrane and then store it by capping it with PTFE lined cap.

Repeat this process for all the other aerosol samples also and label them with their appropriate sample numbers. Electric discharge machine utilized in this examination is a traditional die sinking EDM manufactured by victory Electro mesh of T3822 model die sinking machine. The electric discharge machine was used in this work to drill a blind hole of diameter 25mm with a depth of not more than 10mm into a rectangular block of LM25 composite material of dimension 60mm x 40mmx15mm electrode material used was copper with diameter 25mm; kerosene was used as a dielectric fluid in this study.

10. Design of Experiment

In current study, experiment was planned using Taguchi orthogonal array. Optimization of parameters of process is the key in the Taguchi method to achieve desired output devoid of increase in cost which is due to the optimization of process parameters could betterment the characteristics of output and the optimal parameters of process attained process parameter design is intricate and tough to be used. In particularly, huge number of experiments has to be performed with the rise in process parameter. For solving this task, the Taguchi method utilizes a peculiar design of orthogonal arrays for studying the complete process parameter space with a few numbers of experiments only. Taguchi method suggests the usage of the loss function for measuring the quality deviation characteristic from preferred value. Taguchi parameter design optimizes the performance via the design parameters setting and declines the performance of system fluctuating to source variation. Peak current, dielectric level, flushing pressure and pulse duration, are the primary parameters providing for the particulates concentration in the process of EDM. Huge amount of trails have been performed in finding the feasible limits of working of EDM parameters of process, depending on the conducted trials, the extend of parameters of process namely current has been chosen as 2-7 A, the duration of pulse has been selected as 2-520µsec, the level of dielectric was chosen as 40 – 80mm and the pressure of flushing has been chosen as 0.3 – 0.7kg/cm2. Parameters of process and their levels have been established in Table 2.

Table 2. Process Parameters and Their Levels

| Symbol | Parameters      | Unit | Level 1 | Level 2 | Level 3 |
|--------|----------------|------|---------|---------|---------|
| A      | Current        | A    | 2       | 4.5     | 7       |
| B      | Pulse Duration | µs   | 2       | 261     | 520     |
| C      | Dielectric Level | Mm | 40      | 60      | 80      |
| D      | Flushing Pressure | kg/cm² | 0.3 | 0.5     | 0.7     |
10.1 Selection of Orthogonal Array (OA)
Prior to choosing a specific orthogonal array for being utilized as a matrix to perform experiments, the subsequent points were preferred:

- Number of parameters and interactions of interest;
- Number of levels for the parameters of interest.

Nonlinear behavior, if available among the process parameters, could only be learnt if higher than two levels of the parameters has been utilized. Hence, every parameter has been analyzed at three levels. For limiting the study, it has been confirmed not to look into the second order interactions within the parameters of process. Every three level parameter possess 2 degrees of freedom (DOF = Number of Levels – 1), the total degrees of freedom for 4 parameters everyone at three levels is \(8 = 4 \times (3-1)\). As per Taguchi’s method, the total degrees of freedom of a chosen Orthogonal Array (OA) ought to be higher than or equal to the total degrees of freedom necessary for the experiment. So \(L_9\) OA Table 3 possessing \((8 = 9-1)\) degrees of freedom have been chosen for the current analysis.

10.2 Analysis of Hydrocarbons
The hydrocarbons present in the gases and aerosol were analyzed using GC/MS. Gas chromatography is a technique of choosing to introduce materials that are volatile into a mass spectrometer and their association of techniques is known to be random Gas Chromatography Mass Spectrometry (GC-MS). In GC-MS a sample solution is injected into the port of injection of a GC. Sample components flow via the column at various rates. On exiting a column, the samples are directed into the mass spectrometer where recording of mass spectrum takes place. On introducing the solution of sample into the port of injection, it has been vaporized right away due to the presence of elevated temperature (up to \(\sim 300^\circ\)C) and low pressure (\(\sim 10^{-4}\) to \(10^{-7}\) torr). Sample gets conveyed via tubing length by a Helium gas which is a carrier gas. As the sample components travel via the column, interaction occurs to a choice of degrees with the phase that is stationary relying on their affinity for this material. As an outcome, numerous compounds would travel in numerous speeds via the capillary tubing and would leave out from the column HP 5 later on a distinct time of retention. Oven temperature possessing the capillary column could be restricted time. Oven temperature possessing the capillary column could be restricted for optimizing the separation. On passing the When the mobile phase via the detector, a signal has been generated associated with the concentration of a specific compound.

11. Results and Discussion
The aerosol and gas samples were collected as per the ASTM 3686 standard \(L_9\) orthogonal array was used to conduct experimental runs for aerosol sampling. Previous studies showed that major constituents of aerosol are metallic particles (Iron, Chromium, and Copper). In the present work the concentration of hydrocarbons attached to the aerosol was determined using GC/MS. The experimental matrix and total concentration of aerosol and total concentration of hydrocarbons presented in the Table 4.

| Sl. No. | Current (A) | Pulse Duration (µs) | Dielectric Level (mm) | Flushing Pressure (kg/cm²) | Concentration of Fumes (mg/m³) |
|--------|-------------|---------------------|-----------------------|-----------------------------|-------------------------------|
| 1.     | 7           | 520                 | 60                    | 0.3                         | 5.05                          |
| 2.     | 4.5         | 261                 | 80                    | 0.3                         | 2.13                          |
| 3.     | 7           | 2                   | 80                    | 0.5                         | 2.4                           |
| 4.     | 2           | 520                 | 80                    | 0.7                         | 0.64                          |
| 5.     | 4.5         | 2                   | 60                    | 0.7                         | 1.22                          |
| 6.     | 2           | 261                 | 60                    | 0.5                         | 0.77                          |
| 7.     | 7           | 261                 | 40                    | 0.7                         | 4.12                          |
| 8.     | 4.5         | 520                 | 40                    | 0.5                         | 1.98                          |
| 9.     | 2           | 2                   | 40                    | 0.3                         | 0.82                          |

11.1 Effect of Peak Current
Peak current is a significant parameter in EDM process which controls the discharge energy. Figure 1 shows the variation of concentration of fumes in the breathing zone of the operator. Rise in the peak current causes an increase in temperature in the discharge channel simultaneously causes increase in emission which in turn increases the concentration of hydrocarbons as shown in Figure 2.

11.2 Effect of Pulse Duration
Figure 1 shows the disparity of concentration of fumes with pulse duration and Figure 2 shows the disparity of concentration of hydrocarbons with pulse duration. It shows that concentration of fumes and hydrocarbons are increasing with increase of pulse duration. It is the duration of current allowed to flow per cycle. The total amount of emissions and hydrocarbons increases with rise in pulse duration at short pulse durations but not for high values. The longer pulse duration causes arcing and reduces the work piece’s melting rate and evaporation rate.
11.3 Effect of Dielectric Level

Level of dielectric above the process is an important factor as far as the environmental aspects are concerned. Figure 1 and Figure 2 shows that, concentration of emissions and hydrocarbons are increasing with increase of dielectric level. It is theoretically expected that the hydrocarbons increase with increase in dielectric level. The increasing tendency found here may be due to the increase in the length of temperature gradient in the dielectric fluid which causes breakage of more hydrocarbon bonds which in turn causes increase in emissions.

11.4 Effect of Flushing Pressure

Figure 1 and Figure 2 the variation of concentration of emissions and hydrocarbons with change in flushing pressure. Rise in flushing pressure end up in a decline in concentration of emissions has been seen which occurs because of turbulence in the medium as an outcome of raised flushing pressure, that simultaneously affects the fumes diffusion in the dielectric fluid.

11.5 GC/MS Analysis of Aerosol Sampling

The concentration of compounds identified using GC-MS are presented in Tables 5 to 11. The compounds with MS quality higher than 85 % is classified under confirmed and others are tentative.

The Figures 3 to 9 shown is a chromatogram which has x axis Retention time taken and y axis the abundance. The area below the peaks gives the concentration of the components. At every peak there is different compound with different concentrations. In the graphs each peak will have different hydrocarbons with different quality. The concentration of the hydrocarbon can be known by its area under that peak.
Table 6. Conformed and Tentative Compounds of aerosol Sample (Exp. No. 2)

| Conformed Compounds | Concentrations mg/m³ | Tentative Compounds | Concentrations mg/m³ |
|---------------------|----------------------|---------------------|----------------------|
| Benzene             | 0.01656              | Dodencane           | 0.00877              |
| Tetradecane         | 0.02782              | Nonane              | 0.00234              |
| Phenol              | 0.02645              | Decane              | 0.00032              |
| Tridecane           | 0.0077               | Eicosane            | 0.13523              |
| Pentadecane         | 0.00721              | Tetratetracontane   | 0.11002              |
| Cyclopropane        | 0.00021              | Tetracontane        | 0.01342              |
| Nonoic Acid         | 0.0042               | Coprostane          | 0.01542              |
| Docosane            | 0.0023               | Benzoic acid        | 0.001234             |
| Tetracosane         | 0.02782              | Tetracosane         | 0.02343              |
| Benzaldehyde        | 0.12027              | Total Hydrocarbons  | 0.310184             |

Table 7. Conformed and Tentative Compounds of Aerosol Sample (Exp. No. 3)

| Conformed Compounds | Concentrations mg/m³ | Tentative Compounds | Concentrations mg/m³ |
|---------------------|----------------------|---------------------|----------------------|
| Benzene             | 0.03984              | Dodencane           | 0.0497               |
| Tetradecane         | 0.05028              | Nonane              | 0.06792              |
| Phenol              | 0.04321              | Decane              | 0.02136              |
| Tridecane           | 0.10152              | Eicosane            | 0.02421              |
| Pentadecane         | 0.0102               | Tetratetracontane   | 0.07032              |
| Cyclopropane        | 0.00234              | Tetracontane        | 0.05148              |
| Nonoic Acid         | 0.06423              | Coprostane          | 0.04362              |
| Docosane            | 0.16596              | Benzoic acid        | 0.00859              |
| Tetracosane         | 0.05916              | Tetracosane         | 0.05132              |
| Benzaldehyde        | 0.53674              | Total Hydrocarbons  | 0.38852              |

Table 8. Conformed and Tentative Compounds of Aerosol Sample (Exp. No. 4)

| Conformed Compounds | Concentrations mg/m³ | Tentative Compounds | Concentrations mg/m³ |
|---------------------|----------------------|---------------------|----------------------|
| Benzene             | 0.0921               | Dodencane           | 0.03122              |
| Tetradecane         | 0.0321               | Nonane              | 0.06812              |
| Phenol              | 0.04205              | Decane              | 0.08432              |
| Tridecane           | 0.03465              | Eicosane            | 0.02813              |
| Pentadecane         | 0.00281              | Tetratetracontane   | 0.03524              |
| Cyclopropane        | 0.06272              | Tetracontane        | 0.0321               |
| Nonoic Acid         | 0.02895              | Coprostane          | 0.02832              |
| Docosane            | 0.0175               | Benzoic Acid        | 0.03542              |
| Tetracosane         | 0.00231              | Tetracosane         | 0.04625              |
| Benzaldehyde        | 0.31519              | Total Hydrocarbons  | 0.38912              |

Figure 5. Graphics Report of Aerosol Sample (Exp. No. 3) by Using Gas Chromatography / Mass Spectrometry Analysis.

Figure 6. Graphics Report of Aerosol Sample (Exp. No.4) by Using Gas Chromatography / Mass Spectrometry Analysis.

Figure 7. Graphics Report of Aerosol Sample (Exp. No.5) by Using Gas Chromatography / Mass Spectrometry Analysis.
Table 9. Conformed and Tentative Compounds of Aerosol Sample (Exp. No. 5)

| Conformed Compounds | Concentrations mg/m³ | Tentative Compounds | Concentrations mg/m³ |
|---------------------|----------------------|---------------------|----------------------|
| Benzene             | 0.02936              | Dodencane           | 0.02989              |
| Tetradecane         | 0.00321              | Nonane              | 0.001821             |
| Phenol              | 0.03364              | Decane              | 0.002176             |
| Tridecane           | 0.002271             | Eicosane            | 0.02783              |
| Pentadecane         | 0.002341             | Tetratetracontane   | 0.02837              |
| Cyclopropane Nanoic Acid | 0.00821        | Tetracontane        | 0.001534             |
| Docosane            | 0.02316              | Coprostone          | 0.01539              |
| Tetracosane         | 0.014                | Benzoic acid        | 0.03597              |
| Benzaldehyde        | 0.000921             | Tetracosane         | 0.01715              |
| Total Hydrocarbons  | 0.117113             | Total Hydrocarbons  | 0.160131             |

Figure 9. Graphics Report of Aerosol Sample (Exp. No. 9) by Using Gas Chromatography / Mass Spectrometry Analysis.

Table 10. Conformed and Tentative Compounds of Aerosol Sample (exp. no. 2)

| Conformed Compounds | Concentrations mg/m³ | Tentative Compounds | Concentrations mg/m³ |
|---------------------|----------------------|---------------------|----------------------|
| Benzene             | 3.655009             | Dodencane           | 4.003316             |
| Tetradecane         | 7.402984             | Nonane              | 7.502804             |
| Phenol              | 3.54544              | Decane              | 4.29519              |
| Tridecane           | 0.0021096            | Eicosane            | 1.84407              |
| Pentadecane         | 0.0004762            | Tetratetracontane   | 12.67962             |
| Cyclopropane Nanoic Acid | 2.453865       | Tetracontane        | 0.0005614             |
| Docosane            | 2.74417              | Coprostone          | 1.06284              |
| Tetracosane         | 0.74450              | Benzoic acid        | 0.084815              |
| Total Hydrocarbons  | 19.14855             | Total Hydrocarbons  | 31.47322             |

Figure 8. Graphics Report of Aerosol Sample (Exp. No. 2) by Using Gas Chromatography / Mass Spectrometry Analysis.

Table 11. Conformed and Tentative Compounds of Aerosol Sample (exp. no. 2)

| Conformed Compounds | Concentrations mg/m³ | Tentative Compounds | Concentrations mg/m³ |
|---------------------|----------------------|---------------------|----------------------|
| Benzene             | 3.655009             | Dodencane           | 4.003316             |
| Tetradecane         | 7.402984             | Nonane              | 7.502804             |
| Phenol              | 3.54544              | Decane              | 4.29519              |
| Tridecane           | 0.0021096            | Eicosane            | 1.84407              |
| Pentadecane         | 0.0004762            | Tetratetracontane   | 12.67962             |
| Cyclopropane Nanoic Acid | 2.453865       | Tetracontane        | 0.0005614             |
| Docosane            | 2.74417              | Coprostone          | 1.06284              |
| Tetracosane         | 0.74450              | Benzoic acid        | 0.084815              |
| Total Hydrocarbons  | 19.14855             | Total Hydrocarbons  | 31.47322             |
11. Conclusion

The important lack of knowledge about this hydrocarbon is mainly due to the complexity of the phenomena occurring during EDM, but also to the experimental difficulties encountered for its characterization. The EDM hydrocarbon is small, weakly, of short duration, in a difficult environment, of stochastic nature and poorly reproducible. To our knowledge, this work is the first systematic investigation of the EDM hydrocarbon with various techniques for using gas chromatography mass spectrometry analysis. Considering the significant experimental difficulties related to it, the first success of this work is simply to have shown the applicability of hydrocarbon analysis to the EDM discharges, particularly gas chromatography mass spectrometry. The efforts made for the application of the analysis have been well rewarded. The results obtained are found to be extremely rich, and have permitted us to draw interesting conclusions about the physical properties of this hydrocarbon, and also about the different phases of the EDM process in general. The analysis results are compared with the exposure limit values or threshold limit values specified by the standard agencies and appropriate control measures were suggested in acceptable level.

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