Multi-electrode Designed Shape for Small Scale Plasma Incinerator

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Abstract. Currently electronic waste has increased due to the growth of an industrial economy. Conventional method of waste destruction was to use burner that heats up and finally forming hydrocarbon to an atmosphere. Recently, plasma technology is an alternative method that has an efficiency and safe to use as a mean for waste destruction due to its higher temperature. This research is an improvement design of electrodes tip used for plasma head assembly using small scaled power supply. The designed shape and materials such as graphite, steel and tungsten were simulated and used to evaluate the generated plasma. In addition, electrode designed group were compared for a current density and current distribution from a simulation which will also determine for a plasma length, temperature and durability of material on actual experimental. Electrode shape was designed with sharp cornered that has cross sectional area indicated that it has highest current distribution at the tip of electrode surface. Based on the simulation results, the proposed designed electrode was capable of highest current density when compared with others. The simulated and experimental results have been shown to agreed well for plasma length and temperature.

1. Introduction

Currently, plasma technology is very effective and efficient for waste destruction. Plasma have high energy and high temperature as the fourth state of matter. Electrodes were designed to have highest current density for plasma torch. High current DC power supply and compressed air were used for creating a plasma generator [1]. Electronic waste nowadays has increased considerably from economic growth. Then, the methods of waste management were to use electronic waste as a landfill [2]. However, as for environmental concerned the landfill can be dangerous to the underground water and toxic soil. Other method of waste destruction can be the used of heat from hydrocarbon fuel burners [3].

Plasma technology was used as an alternative method for waste destruction recently. So, this research investigates the shape of electrode designed that have the contribution to the plasma current density compare with other electrode types based on computer simulation. Then the proposed electrode was used to design and implement a plasma tip generator. The comparison of current density and testing plasma length, temperature and durability of material were studied.
2. Material and method

2.1. Materials
Plasma generator has used varied materials for burner electrode. The chosen electrode material must have highest conductivity and highest molten point. This research proposed the use of an electrode material such as graphite, steel and tungsten due to its characteristic properties \([4-5]\). Electrodes materials will be compared in terms of durability as well as plasma length for a plasma torch incinerator. A computer simulation software, COMSOL was used for this research.

2.2. Electrode design
Plasma generator was studied, and electrodes were designed in various types in the past. This research investigated on multiple electrode group that has the designed with shape, arrangement and are numbered as shown in figure 1. Type A electrode design was sharp [6], type B electrode design was curved [7], type C electrodes design were multiple conductors [8] and type D electrode that have been designed with the tapered shape with cylindrical tip. Therefore, the expectation of cross-section area of the electrode will directly affect the distribution of current density. Arrangement of electrode was to develop from finding current distribution that was suitable for cross-section area at the electrode tip with computer simulation. Using DC supply voltage of 240 V, DC current at 40 A, compressing air at 0.5 bar, electrode gap was 1 mm, steel electrode material was used [9]. Current distribution of each multiple electrode groups was simulated to produce a plasma torch.

![Electrode type A B C and D.](image)

**Figure 1.** Electrode type A B C and D.

2.3. Implementation of plasma generator
The plasma generator was divided into 3 parts: DC power supply, gas feeder and proposed electrodes as shown in figure 2. The DC power supply voltage of 240 V, compressing was air at 0.5 bar, using air
gap of 1 mm respectively [10]. Materials used are steel, graphite and tungsten were fabricated for a proposed electrode. Furthermore, input current was varied from 15 to 40 A of each test. Then, experimental testing was to compare for a plasma length, temperature and durability of material.

![Figure 2. Electrodes, gas feeder and power supply.](image)

### 3. Results and discussion

#### 3.1. Current density

Table 1 revealed the plasma torch current density at the tip of electrode from a simulation on each multiple electrode group regardless of materials types. The current density distribution indicated into 2 aspects, they are, electrode arrangement and its shape. Electrodes arrangement affected the current density, and electrode with cornered shape that has cross sectional area indicated that it has highest current density distribution at the tip of electrode surface. From experimental results with various electrode type, the current density of type A, B, C and D that were distributed at cross-sectional area of electrode tip were $6.52 \times 10^6$, $2.21 \times 10^6$, $9.31 \times 10^4$ and $7.39 \times 10^6 \text{ A/m}^2$ respectively. Moreover, figure 3 has shown that the shape of the proposed electrode has significantly delivered great magnitude of current distribution. The simulation has also found that electrode design with the cornered shape will deliver highest current density plasma. From figure 3, it was observed that current density of type A and C was distributed at the electrode tip except that type C was multi electrodes. Moreover, current density of type B was distributed at the cross-section area along curve of the electrode tip. The current density of type D was distributed at the cylindrical of the electrode tip and provided the highest value.

![Figure 3. Current distribution of electrode type A, B, C and D.](image)

| Types                  | A-Sharp Electrode(A/m²) | B-Curved Electrode(A/m²) | C-Multiple Electrode(A/m²) | D-Proposed Electrode(A/m²) |
|------------------------|-------------------------|--------------------------|---------------------------|---------------------------|
| Current density        | $6.52 \times 10^6$      | $2.21 \times 10^6$       | $9.31 \times 10^4$        | $7.39 \times 10^6$        |
3.2. Plasma length and temperature

Figure 4 showed the plasma length and temperature of plasma with varied input current from 15 to 40 A. The plasma length and temperature measurement results were obtained from the high-speed video recording. Plasma length was measured by standard ruler that was mounted at the base. For the temperature measurement, the comparison between color temperature shade of plasma torch and international standard shade was used to indicate the plasma temperature. For experiment, the test has varied material including graphite, steel and tungsten for plasma length and temperature investigation. According to the measurement results, there were a clear upward trend in the length and temperature at input current of 40 A that provide the longest length and highest temperature. The results obtained were measured from the length of highest colour temperature. It can be observed that, steel electrode (a) the plasma generated with a length of 37 mm and temperature of 7500 K. As for tungsten electrode (b), the plasma length and temperature were at 27 mm and 7500 K respectively. In case of graphite electrode (c), plasma length obtained was at 21 mm with temperature of 7500 K. It is noticed that the temperature value of each material was relatively close at 7500 K approximately.

![Figure 4. Plasma torch from various materials.](image)

From figure 4, steel was the material that generated highest plasma temperature due to its lowest melting point. On the other hand, the length of the plasma developed, graphite has been shown to provide longest length of plasma torch among other materials. As for the material durability, the merit order are tungsten, steel and graphite. Further observation was found that electrodes damages were molten as for steel and tungsten case. Graphite electrode, however, the material was brittle and have been found cracked finally. Material selection could be chosen according to the application as well as the compromised between the current density distribution and its durability.

4. Conclusion

In conclusion, the development of the designed electrode for enhancing the plasma torch performance was investigated. From the results, the proposed electrode designed delivered the highest current distribution when compared with other type. It was also found that the current density distribution at the tip of electrode surface were of highest value. Thus, the proposed electrode was chosen and fabricated for plasma generator. Results obtained from actual test and computer simulation have agreed well with each other. It was indicated that plasma incinerator with long plasma length and high temperature with small scale DC power supply could be utilized. Graphite electrode was chosen for an upward trend for the highest temperature plasma torch as well as better current density performance among other materials.

Acknowledgments

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