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Carbon Dioxide Conversion Control Based on Microwave Plasma Technology

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***Abstract*—Carbon dioxide content in the atmosphere increases year by year and the seriousness of carbon dioxide emission has increased consequently. Fires, explosions and burnings at refineries, oil depots, and chemical stores. Moreover, due to the use of poor fuels in transportation, generators and heating systems, the dimensions of these negative consequences continue. This paper presents the carbon dioxide conversion control based on microwave plasma technology to reduce concentrations of carbon dioxide in the atmosphere and convert it to useful materials and maintain the dynamic equilibrium of carbon dioxide formation and conversion. Paper presents the argon gas flow rate controller to decrease the argon gas flow gradually on plasma microwave while ensuring the CO_2 decomposes without or with a minimum amount of argon gas which this the most difficult step in the work.**

Keywords- Microwave, Plasma, Carbon dioxide, decomposition.

I. INTRODUCTION

Rapid growth in world population and industrial development has led to an increased usage of fossil fuels such as, petroleum and natural gas and the resulting formation of carbon dioxide [1], which is changing the earth's climate, air pollution and destroyed the organisms. Because of a large number of burnings and deforestation create a dynamic imbalance of carbon dioxide formation and conversion. This paper summarizes one of advanced technique which uses the industrial microwave plasma-assisted CO_2 dissociation.

The reduction technology of carbon dioxide can be divided into physics and chemistry-based methods [2]. In physics methods, carbon dioxide is captured and stored underground or under the sea using high pressure. While chemistry-based, carbon dioxide is converting to a useful fuel, however, there are several limitations [4]: catalysts are very expensive and the lifetime of the reaction is limited, the reaction must be carried out under high temperature and high-pressure environment, reaction times can be several hours to several days depending on the types of catalysts. According to these limitations, plasma technology is presented for carbon dioxide conversion. Plasma is the mixture of various species such as atoms, electrons, ions and free radicals which generate by collision excited and ionized molecules due to electric fields with accelerated electrons. These active species generated can recombine to form new products.

Plasma technology can be microwave plasma, RF plasma, or DC plasma according to the operating pressure. Waveguide based plasma has been subjected to increase attention during the last decade [5]. Microwave plasma has particular characteristics that allow splitting with high energy efficiency. Electrons are the driving force in plasma; they take energy from the microwave and transfer their energy via collisions which are carried out to break the very stable CO_2 molecule. The experimental work aims to maximize the conversion of CO_2 while minimizing the (Ar) gas that is required to achieve this transformation.

II. LIQUID FUEL PRODUCTION FROM CO_2 USING MICROWAVE PLASMA

German scientists Franz Fischer and Hans Tropsch, discovered in the 1920s a way to convert coal to a mixture of gases (syngas) and then to liquid hydrocarbon fuel as shown in Fig.1. The syngas is passed over a catalyst, high temperature, and pressure. Microwave plasma is used to produce syngas [6], which is a more economic method to reduce temperature, pressure and avoid catalyst poisons. The decomposition of carbon dioxide by ionized gases can generate syngas inside the reactor of microwave plasma. High frequencies (2.45GHz) in the range of the microwave, and at atmospheric pressure, can be used in the decomposition of carbon dioxide and for H_2 production which is the building base for fuels as shown in Fig.2. Such a mechanism can be elaborated by combining two reactions [7].

$$CO_2 \Leftrightarrow CO + 1/2\, O_2 \quad (1)$$

$$(2n+1)\, H_2 + n\, CO \Leftrightarrow C_n H_{2n+2} + n\, H_2O \quad (2)$$

Where (1) is the dissociation of CO_2 in carbon monoxide and oxygen and (2) is the Fischer-Tropsch process, it will be able to produce hydrocarbons from CO_2.

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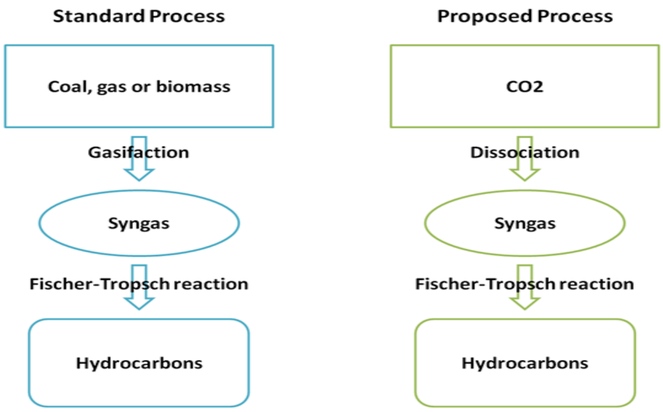

Fig. 1. Fischer-Tropsch process.

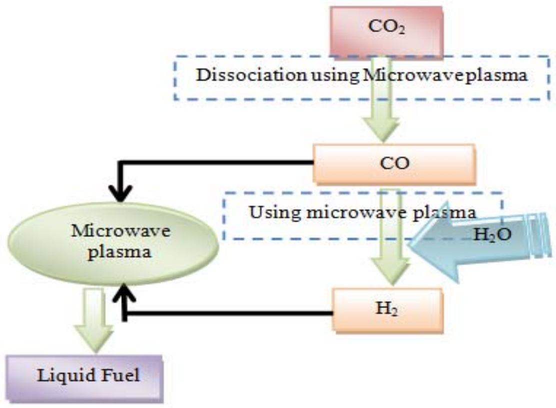

Fig. 2. The flowchart and block diagram of CO_2 breakdown to the fuel using plasma microwave.

III. Microwave Plasma for CO_2 Decomposition

CO_2 activation by microwave plasma technology has been an interesting subject for researchers for example [9-11] as shown in Fig.3. A microwave plasma technology operates at 896MHz or 2.45Hz and also be applied at ISM frequencies such as 5.8GHz. The Microwave consists of a water-cooled magnetron powered by 2kW power supply, a circulator, a tuning section which is required to reduce the reflected power, and the nozzle section. Fig.4 shows the block diagram of the atmospheric pressure microwave plasma system. The plasma is formed by a high electric field generated by the microwave power, between the waveguide aperture, and the gas nozzle. The nozzle was made of metal and it is positioned across the cavity. Plasma induces physical and chemical reactions with gases at low temperatures and atmospheric pressure [8], which causes the molecule to be broken as shown in (3).

$$CO_2+e^- \longrightarrow CO+O+e^- \qquad (3)$$

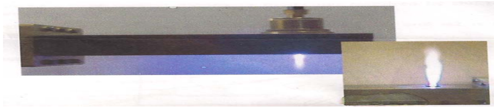

Fig. 3. Microwave induced plasma Argon (left), Helium (right).

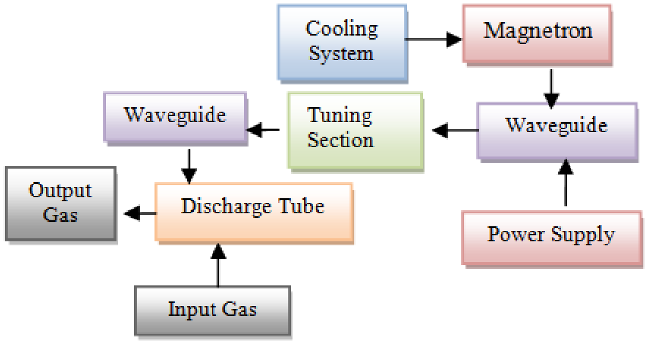

Fig. 4. Block diagram of the atmospheric pressure microwave plasma system.

Plasma is commonly an ionized gas. For CO_2 decomposing, we applied a fast electric discharge-flow system to the CO_2/Argon(Ar) mixtures. The decomposition efficiency and the decomposition products of CO_2 were analyzed using quintox device and visible emission spectroscopy. In this case, still we need to CO_2 decomposition happened with minimum amounts of argon gas after the ignition and CO_2 decomposition. To achieve that we use flow controller on argon gas that feeds the microwave according to the decomposition conditions.

Fig. 5. Quintox devices are used to make a gas measurement.

Quintox device is used for gas measurement as shown in Fig.5, and the LabVIEW software is used for the online monitoring and quintox interfacing to the system. LabVIEW: Laboratory Virtual Instrument Engineering Workbench is used for measurement, automation, control, data acquisition, and data analysis. It is consists of a front panel and block diagram. In the front panel, the controls and data displays for the system are placed by choosing objects from the controls palette. Block diagram contains source code which is used for simple functions to advanced acquisition and analysis. Fig.6 shows the Labview front and block diagram.

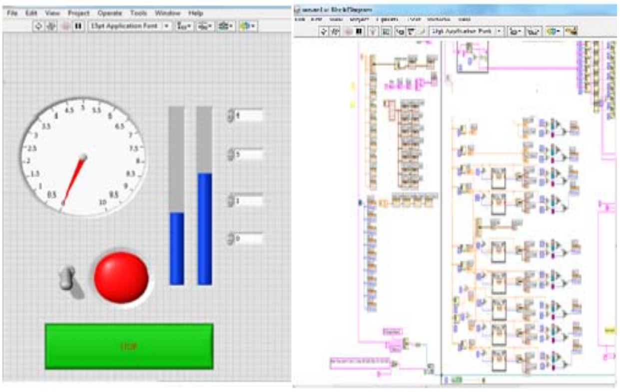

Fig. 6. Labview front and block diagram

IV. Argon Gas Flow Rate Controller and Experimental Work

The comparisons between the gases (CO_2, CO, C) concentration is the base to make the control decision to feed more or less Ar gas that feed the plasma microwave as shown in Fig.7.

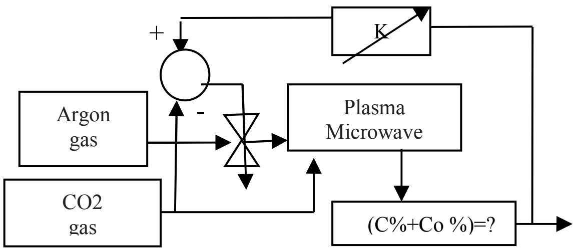

Fig. 7. Ar gas control that feeds the plasma microwave system.

The summarization of the experimental work:

1. The system is tuned to be in minimum reflected power.
2. Initially the plasma is ignited with pure Ar gas.
3. Then CO_2 gas is injected and its flow rate is slowly increased.
4. Then the Ar flow rate was reduced.
5. The presence of CO_2 changes the discharge characteristics dramatically, the plasma glow visibly changes to blue.
6. The optical emission spectrum changed with addition CO_2 and gives an indication of the size of the CO_2 decomposition as shown in Fig.8.
7. A quintox device is used to measure the CO_2, CO , and C which are the results of decomposition .
8. The Ar flow rate controller makes a decision based on decomposition percent as shown in Fig.7.
9. The important step and a big challenge is the continuation of CO_2 decomposition with the absence of Ar gas or at least a minimum of it. In our observations, it can do that and especially when the chosen Ar controller gain (K) is done carefully in a way suitable for plasma conditions.

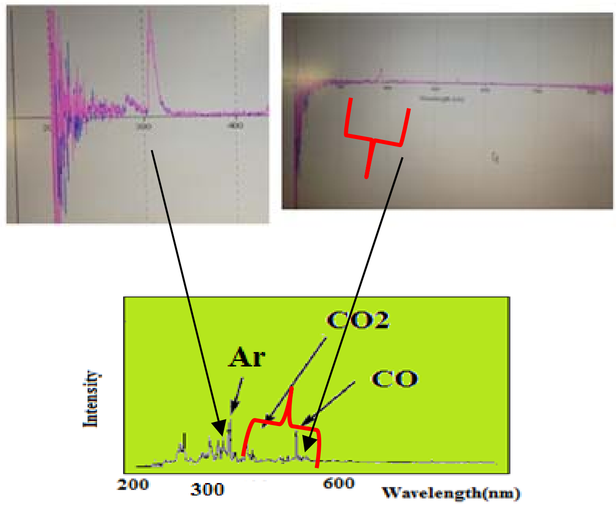

Fig. 8. Emission spectrum of the plasma.

The absence of the Ar lines in Fig. 8 indicates that the Ar is becoming ionized and is serving as the electron producer, and carbon appears from CO_2 or CO. Hydrogen gas has then has been added through the microwave plasma mixture with water vapor decomposed for further reaction to get the fuel, as shown in Fig.9.

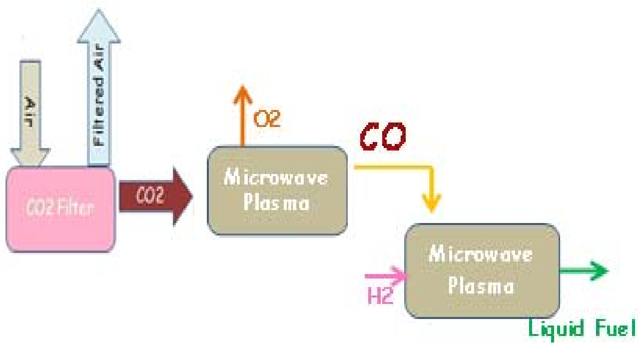

Fig.9 CO_2 to neutral liquid fuel.

V. Conclusions

Plasma-based technology for carbon dioxide conversion is an active method for dealing with CO_2 decomposition especially if it was combined with microwave technology. Continuation of CO_2 decomposition with the absence of Ar gas or at least a minimum of it is a big challenge and it can deal with that through Ar controller in which help the plasma conditions to be active in the minimum requirement of Ar gas.

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