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Application of Fuel Cell in Power Plant to Reduce the Carbon-dioxide Emission.

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Abstract
This article reviews the use of Molten Carbonate Fuel Cells (MCFC) in a natural gas or coal based power plant to capture CO_2 from the exhaust of the gas turbine having an anode and a cathode section. In this, cathode section of Molten Carbonate Fuel Cells (MCFC) intakes the flue gases of gas turbine. Then CO_2 is moved from the cathode to anode side, concentrating the CO_2 in the anode exhaust. A steam generator is used then to recover the heat from this concentrating CO_2 stream and sent to a cryogenic CO_2 removal section. This arrangement ultimately show the potential to achieve a high carbon capture ratio, while taking the advantage from the introduction of the fuel cell, the power output increases and ultimately reduces the emission of major greenhouse gas.

Keywords— MCFC, Cryogenic

Introduction

The twin problems of global warming, caused by an increase atmospheric carbon dioxide (CO_2) concentrations, and limited fossil fuel resources have stimulated research in the utilization of CO_2. These problems would be partially alleviated by the development of artificial photochemical systems that could economically fix CO_2into fuels or useful chemicals. This study shows the fascinating effects due to peculiarity of the mutual interactions between gas turbine and fuel cell. The arrangement of turbine in tandem with fuel cell helps to reduce the amount of exhaust CO_2 in the atmosphere [1]. This reduces the proportion of CO_2 in the composition circle of greenhouse gases.

Fuel cells are electrochemical devices that convert chemical energy accumulated in the fuels into electrical energy directly, promising power generation with high efficiency and low environmental impact [2]. Generally, a fuel cell comprises an anode and a cathode separated by an electrolyte, which serves to conduct electrically charged ions. Molten carbonate fuel cells operate by passing a reactant fuel gas comprising carbon dioxide and oxygen is passed through the cathode [3].The approximate operating temperature of molten carbonate fuel cell is 650 °C (1200 °F) [4].The main motto of this high temperature is to increase the conductivity of carbonate electrolyte. It also allows the use of low cost metal cell components. This high temperature operation is also eliminates the use of noble metals catalysts for the electrochemical oxidation and reduction processes [5].Fig 1,shows the pictorial view of operation of a molten carbonate fuel cell. The half cell chemical reactions are given as:

H_2 + CO3=⟶ H_2O + CO_2 + 2e (at the anode)

½ O_2+ CO_2 + 2e-⟶ CO3= (at the cathode)

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The overall cell reaction is:

$H_2 + ½ O_2 + CO_2$ (cathode) $\rightarrow H_2O + CO_2$ (anode).

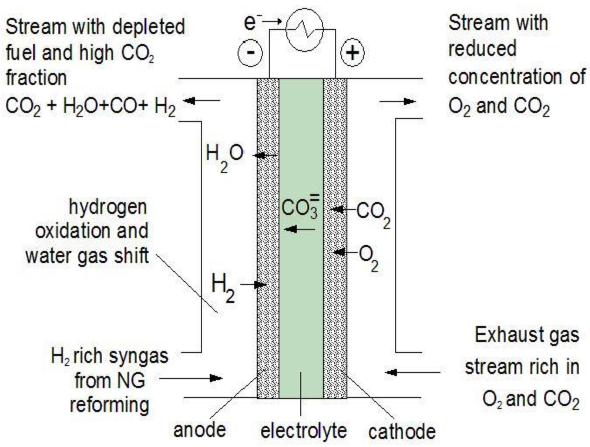

Figure 1

MCFCs operate more efficiently with CO_2 containing bio-fuel derived gases. Performance loss on the anode due to fuel dilution is compensated by cathode side performance enhancement resulting from CO_2 enrichment [6].The anode of MCFC is made of a nickel-ZrO_2 cermets alloy [7]. Cr is added to eliminate the problem of anode sintering. For the effective working of cathode section, the most appropriate material for cathodes should have high electrical conductivity, structural strength and low dissolution rate in molten alkali carbonates to avoid precipitation of metal in the electrolyte structure. The most suitable alloy is f lithiated NiO [8, 9].

In this review paper, the use of molten carbonate fuel cell in tandem with gas turbine is highlighted which not only helps to increase the power output of the plant but also immaculate the stain of pollution to great extent from power plant by decreasing the amount of exhaust carbon dioxide as reviewed from past works. A number of approaches have used to limit carbon dioxide content in the flue gases from fossil fuel power plant. However, they are successfully prevailed because they increases the initial installation cost of the power plant.

In the approach presented here, the seizing of carbon dioxide is possible with the help of an active component called MCFC, which adds power to the plant energy balance while acting as a carbon dioxide concentrator [10, 11, and 12]. The gas turbine exhausts are used as cathode feeding for a MCFC, where CO_2 and O_2 are transferred (as CO_3+ ions) from the cathode side to the anode side, fed with reformed syngas from natural gas (Fig. 1)[1]. In such a way CO_2 is concentrated in the anode exhaust gases, making easier its separation. Since while transferring the CO_2, the fuel cell produces "CO_2-free" extra power, the overall energy balance for CO_2 separation becomes positive and the specific emissions can be reduced compared to more conventional methods using chemical absorption such as with amines [1].The performance of MCFC mainly depends upon intake temperature, pressure, reactant gas composition and utilization, impurities, current density and cell life.

The primary disadvantage of current MCFC technology is durability. The high temperatures at which these cells operate and the corrosive electrolyte used accelerate component breakdown and corrosion, decreasing cell life. Secondly, the MCFC generates a stream mainly comprises of CO_2 and water at the anode outlet , but still containing significant fraction of residual , non-oxidized , CO and H_2 .The two main methods devised to recover the heating value of CO and H_2 while preserving high CO_2 purity in the stream, have been proposed by previous works [13,14]:

(1)Burning CO and H_2 in the presence of oxygen and recovering the heat for steam generation in favor of power plant.

(2)Adopting a removal section composed by a cryogenic plant and removing CO_2 from the more volatile CO and H_2 and finally the combustible species are recycled to the power plant.

Plant Description

As molten carbonate fuel cell works efficiently with fuel such as natural gas, coal, methane or biogas [15, 16].a simplified view of natural gas combined cycle is given. In this cycle a MCFC is placed between the gas turbine and a heat recovery steam generator (HRSG)[17].

The gases from the turbine exhaust are directly feed into the MCFC at cathode where CO_2 is shifted from cathode to anode concentrating the CO_2 in the anode exhaust gases. The fuel cell works at atmospheric pressure and is fed with a syngas generated within a fuel reformer, fed with a mixture of de-sulphurized [18] and preheated natural gas and low pressure steam extracted from the steam turbine.

The reformer can be either integrated within the fuel cell or external to the fuel cell. When the reformer is integrated with the fuel cell the configuration becomes compact but less complex by the point of view of plant layout. It allows to efficiently exploit the heat generated by the fuel cell to heat up the reformer and sustain its endothermic reactions .Methane conversion is higher than 99% even at relatively low temperature (650°C) in internal reforming[22]. But when the reformer is outside to the fuel cell, the configuration becomes more bulky and requires additional heat exchangers to transfer heat to the reformer, loosing something in terms of efficiency. This configuration is adapted to different fuels and is more reliable than first option [19].

When the reformer is integrated within the fuel cell, the cathode and anode streams are kept separated in order to avoid the dilution of co2 which was concentrated at the anode [3].

Air separation unit (ASU) is used to provide pure oxygen to burner which helps to recover the heating value of spent anode fuel by producing a hot gas stream. The heat from the steam is extracted by a steam generator, avoiding mixing with the cathode exhausts. This stream is easily compressed and cool to obtain a liquid stream ready for underground sequestration, only after the steam in the stream is condensed almost completely. Some amount of steam from the HRSG (heat recovery steam generator) is used to preheat the fuel feeding the gas turbine and the MCFC [20].

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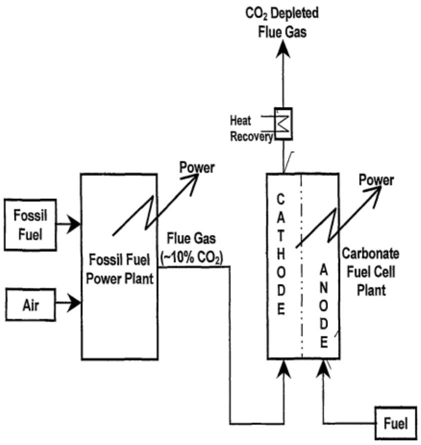
The plant has MCFC in a combined cycle, with CO_2 separation via oxygen combustion [21], while in the other way the CO_2 separation is done with cryogenic process. In cryogenic compression –liquefaction CO_2 separation method, the temperature of the stream is made low enough that most of the CO_2 is condensed and separated by gravity from the gaseous combustible species included in the mixture which have a much lower boiling point [14].In the second method, the exhaust of the cell anode is cooled in the HRSG and then further cooled to ambient temperature and finally to a CO_2 removal section. In both configurations, the cathode exhaust stream is cooled by the HRSG, so that the MCFC operates in a so-called "hybrid" configuration [23], releasing exhaust heat to the steam bottoming cycle. This allows improving the efficiency (at least before CO_2 capture) with respect to the level of the original combined cycle. Moreover, in both cases the cooled exhaust gas can be sent to the stack or partially recycled to increase the CO_2 concentration at the MCFC cathode side and enhance the fraction of CO_2 captured [3,11].The pictorial representation of the power plant is shown in the figure given below:



Also, utilization factor of carbon dioxide in the fuel cell plays an important role in defining the performance of such plants. Mathematically,

U CO_2 = (flow rate of CO_2 transferred through the cell as carbonate CO_3 + ions) / CO_2 flow rate introduced at the cathode inlet

As the cycle we proposed is designed to capture CO_2, so it is important in principle to work at high U CO_2; but in order to avoid excessive voltage losses and to remain in a safe operating range for the stability of molten carbonates , it is also necessary to avoid working with a too low CO_2 fraction. A constraint is typically set on the minimum CO_2 fraction at cathode outlet, which should not go below 1-1.5% and the resulting optimized U CO_2 is in the range 60-75% [24].

As compared to other type of hybrid cycles, the use of fuel cell in continuous with gas turbine has the advantage of much higher power share from the fuel [25].

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Conclusion

After study all the works, it is easily estimated that the introduction of MCFC in a natural gas or coal based power plant not only reduces the amount of from the exhaust but also increases the power output of the plant.The paper reveals only on theoretical concepts of power plant theory which serves as a backbone for the study.Also the initial cost of implementing will be very high but as compared to the value of environmental protection obtained through the proposed power plant,it is just a investment towards a sustainable protection. However, the various optimization techniques and methods are pending to calculate and optimize the approximate results.

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