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OPERATION OF REAL LANDFILL GAS FUELED SOLID OXIDE FUEL CELL (SOFC) USING INTERNAL DRY REFORMING

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***Abstract* – Biomass is one renewable energy source, which is independent from solar radiation and wind effect. Solid oxide fuel cells (SOFC's) are able to convert landfill gas derived from landfill directly into electricity and heat with a high efficiency. In the present work a planar 16cm^2 SOFC cell was operated with a real landfill gas from one of the largest Danish waste dump sites and additional carbon dioxide reforming agent at 750˚C, both with gas cleaning through an active carbon filter and without. The tests showed an electric efficiency up to ~60%. It was found that the active carbon filter was necessary to prevent poisoning and thereby to decrease the degradation rate.**

Index Terms* – *Landfill gas, Solid oxide fuel cell, Efficiency, Dry reforming, Poisoning

I. INTRODUCTION

For an electricity production based on 100% renewable energy sources options are needed which are independent of the fluctuating solar radiation and wind profiles. Considering biomass as renewable resource one option could be landfill gas derived from landfill. Landfill gas consists of carbon dioxide, methane and impurities as for example sulfur containing compounds. Most landfill gasses are unattractive for low efficient combustion engines due to their low heating values. Solid oxide fuel cells (SOFC's) could be a more efficient alternative to convert carbon containing fuels, like landfill gas, into electricity and the side product heat.

As pointed out in thermodynamic studies (e.g. Sasaki et al [1]) a reforming agent is needed to prevent carbon formation during the direct conversion of carbon containing fuels into electricity and heat in a SOFC. Beside the well-known reforming agent steam also carbon dioxide (dry reforming) can be used. The advantage is that landfill gas already contains a certain amount of the needed carbon dioxide. Furthermore, the dry reforming path in the SOFC was found to be less sensitive to sulfur contaminants in the biogas [2] and thus the demands for gas cleaning and system complexity might be less compared to steam reforming.

In the presented work a SOFC cell was operated with a real landfill gas from one of the largest Danish waste dump sites and additional carbon dioxide reforming agent at 750˚C. This study evaluates the effect in terms of the SOFC power density output and electric efficiency.

II. EXPERIMENTAL

An anode supported planar Ni-YSZ/YSZ/LSCF:LSM with a CGO barrier layer was used. The SOFC cell had an active area of 16cm^2 and was operated at 750˚C in an alumina test house equipped with gas supplies, current collectors and voltage probes. A detailed description can be found in reference [3]. Before entering the test house, the landfill gas was mixed with the reforming agent carbon dioxide and could pass or by pass an active carbon filter at room temperature. The landfill gas composition is shown in table 1.

TABLE I
APPROXIMATELY FUEL COMPOSITION

Component	Landfill gas				CO_2 RA*
	CH_4	CO_2	O_2	N_2	
Amount	23 vol%	15 vol%	1 vol%	28 vol%	33 vol%

*RA: Reforming agent

During this study two testes were carried out at a current density of 0.5A/cm^2 and a fuel utilization of ~63%. The cathode side was supplied with air during all tests. For test 1 the fuel was passed through the filter whereas for test 2 the filter was bypassed for 46 hours as illustrated in table 2. Before and after each test iv-curves were recorded under the same conditions.

TABLE 2

TEST PROCEDURE IN TERMS OF THE ACTIVE CARBON FILTER FOR TEST 1 AND 2.

Test	Filter on	Filter off	Filter on	Total time
1	130 hr			130 hr
2	2 hr	46 hr	202 hr	250 hr

III. RESULTS

The power density and the electric efficiency of test 1, passing the fuel through the active carbon filter, and test 2, by passing the filter, for 46 hours are shown in figure 1. The results of test one show a stable power density of approximately 0.4 W/cm^2 (black line) which corresponds to an efficiency of around 61% (green line). The degradation rate of the power output was calculated assuming linear behavior and was 1.1%/1000h. The power density of test 2 (blue line) starts at the same value as in test 1. After 2 hours (filter bypassed) the power density starts to decrease slowly and after approximately 20 hours more rapidly. After 48 hours of operating the SOFC, the power density had dropped by 0.04 W/cm^2 which corresponds to an efficiency loss of ~9% and a degradation rate of 239%/1000 h. After passing the fuel through the cleaning filter again, the power density still decreased for the next approximately 20 hours to a minimum of 0.34 W/cm^2, followed by a period of recovery to a power density of 0.36 W/cm^2. After 250 hours, the loss of power output was 0.04 W/cm^2 in respect to the initial power density of 0.4 W/cm^2. This corresponds to an electric efficiency drop of around ~5%.

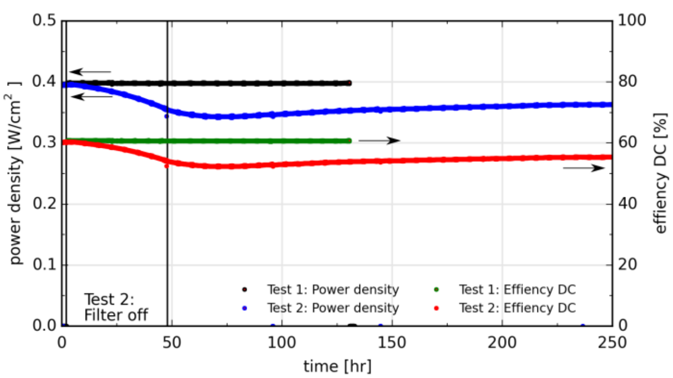

Figure 1: Power density and electric efficiency over time for test 1 and 2. For test1 the fuel was passed through the carbon filter were as for test2 the filter was bypassed in the initial 46 h [4].

Considering the area specific resistance (ASR) of the cells from the iv-curve recorded before and after test 1 one can conclude that the ASR had not changed. It was around 0.45 Ωcm^2 (see figure 2). The ASR recorded before test 2 is similar to the initial ASR value of test 1. However, after test 2 the ASR reached a value of 0.56 Ωcm^2, which corresponds to an increase of 24% in relation to the value before test 2. The constant ASR in test 1 and increase in test 2 correlate well with the power density drop and the efficiency drop as shown in figure 1.

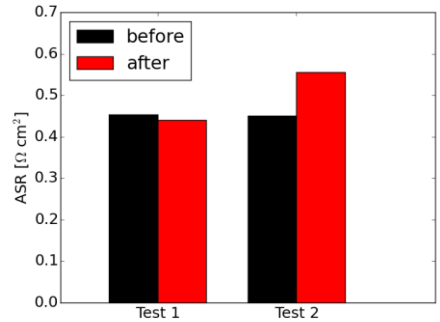

Figure 2: Comparison of the area specific resistance (ASR) of the iv-curves before and after test 1 and 2.

IV. CONCLUSION

In the current work, the operation of state of the art solid oxide fuel cell fueled with real landfill gas plus carbon dioxide using internal dry reforming was investigated. Gas cleaning using an active carbon filter was necessary to maintain a stable power output. While bypassing the cleaning filter resulted in significant degradation rates of 239%/1000 h, a stable operation with a small degradation rate of 1.1%/1000 h was achieved when cleaning the landfill gas.

V. ACKNOWLEDGMENT

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