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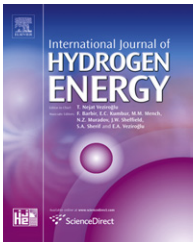

Cold start characteristics of proton exchange membrane fuel cells

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ABSTRACT

In this study, the effects of the start-up temperature, load condition and flow arrangement on the cold start characteristics and performance of a proton exchange membrane fuel cell (PEMFC) are investigated through in-situ experiments with the simultaneous measurements of the current and temperature distributions. Rather than the commonly recognized cold start failure mode due to the ice blockage in cathode catalyst layer (CL), another failure mode due to the ice blockage in flow channel and gas diffusion layer (GDL) leading to significantly high pressure drop through cathode flow field is observed at a start-up temperature just below the lowest successful start-up temperature. Three ice formation mechanisms are proposed, corresponding to the ice formations in cathode CL, GDL and flow channel. The general distributions of current densities and temperatures during the constant current cold start processes are similar to the constant voltage cold start processes, except that the temperatures at the end of the constant current cold start processes are more evenly distributed over the active reaction area because of the increased heat generation rates. The cold start characteristics are mainly dominated by the cathode flow, and changing the flow arrangement has unimportant impact on the cold start performance.

1. Introduction

Start-up from subzero temperatures, often referred to as cold start, is one of the most significant challenges for the automotive application of proton exchange membrane fuel cells (PEMFCs). Many experimental and numerical studies have been carried out recently to investigate the ice formation mechanisms and effects of design and operating conditions on the cold start performance [1–29].

It has been widely recognized that when the cathode catalyst layer (CL) is fully blocked by ice before the temperature reaches above the freezing point of water, the cold start process is failed, and vice versa. The previous experimental studies showed that the evolutions of the cell voltages and/or current densities during the various cold start processes generally follow an increasing/decreasing trend (e.g. [1,5,6,8–10]). The increasing trend of the measured cell voltages and current densities is caused by the temperature increments and ionomer hydrations, and the decreasing trend is caused by the ice formations in the cathode CLs. Accordingly, the previous numerical studies mainly focused on modeling the ice formation processes in cathode CLs (e.g. [20–28]), and the similar trend of the cell voltages and current densities were obtained through the numerical simulations. However, since most of the heat is generated in the cathode CL, and in the condition without external heating, the

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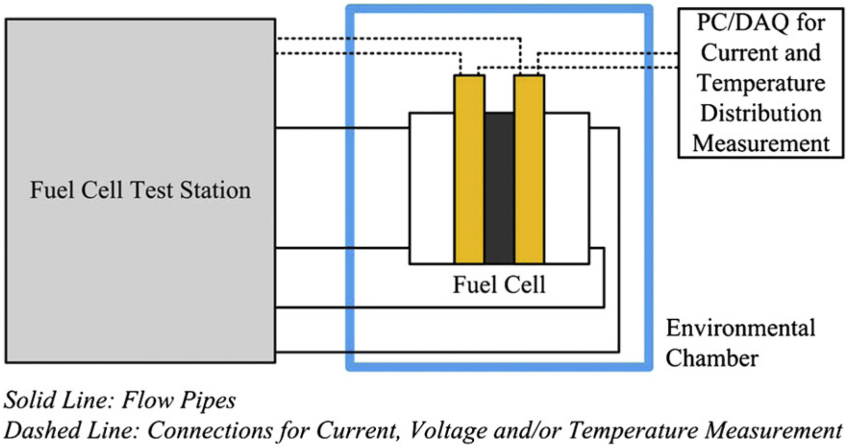

Fig. 1 – Schematic of the experimental setup.

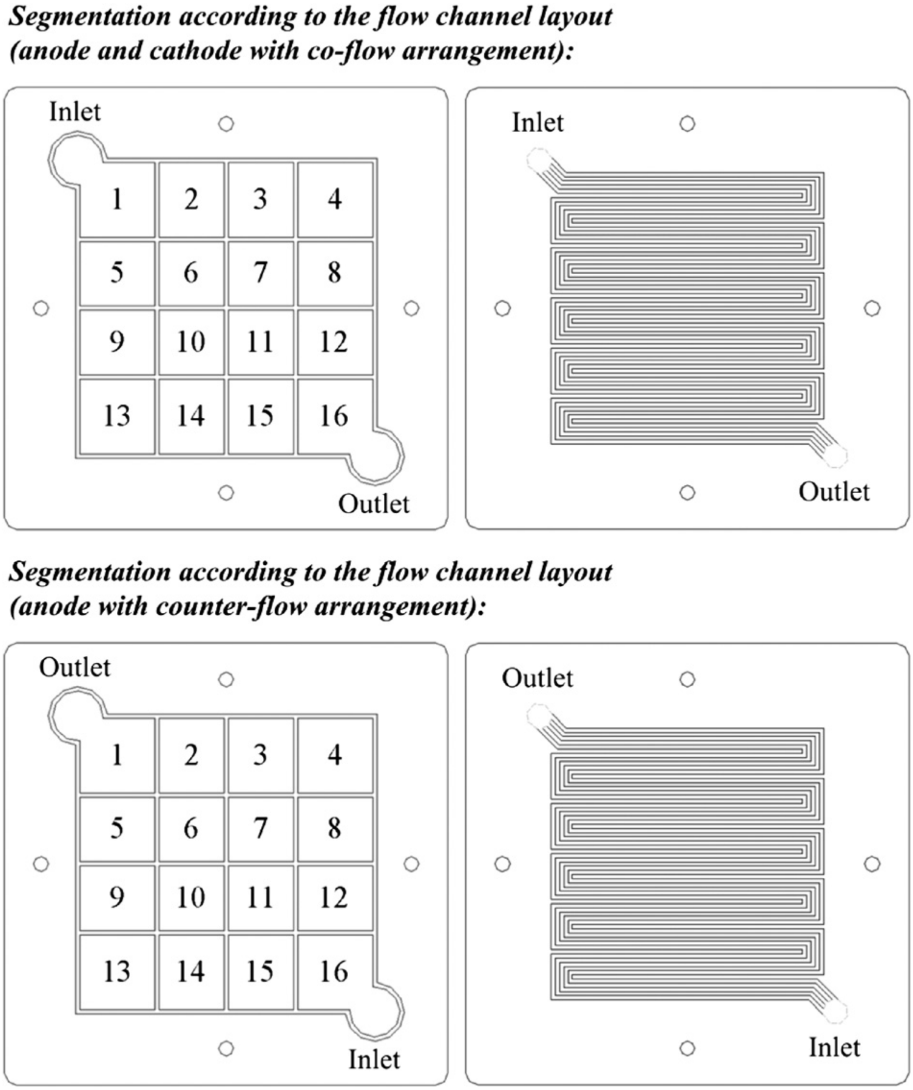

Fig. 2 – Segmentations of the cell assembly according to the flow channel layout for both the co-flow and counter-flow arrangements.