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Transient behaviour of a small methanol reformer for fuel cell during hydrogen production after cold start

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Abstract

The cold start transient characteristics of a small methanol reformer for a fuel cell were investigated. The main parameters studied were the oxygen to methanol mol ratio (O/C), fuel supply rate, heating power and heating temperature. The composition of the gas produced by the reformer was analysed. The main aim of this paper was to determine a favorable combination of the parameters for obtaining rapid hydrogen production during the transient behaviour of the reformer.

A small methanol reformer with fuel, air and water injectors, heaters and a catalyst was constructed. Vaporised methanol was injected into the reformer, which then flowed into the catalyst. For the purpose of enhancing the response of the cold start transient reaction, eight glow plugs were mounted at the inlet of the catalyst to control the flow temperature together with the adjustment of the oxygen to methanol mol ratio.

The best response from cold start was obtained with 960 W heating power, 80 °C heating temperature, 14 mL/min methanol and 70 L/min air supply rates among the experimented parameters. Under this operation setting, hydrogen was produced after 220 s from cold start with the production rate stabilising after 4–5 min and eventually reaching the highest concentration at 350 °C. Generally, hydrogen commenced production at a catalyst outlet temperature of 100 °C and stabilised at 350 °C.

Keywords: Methanol reformer; Partial oxidation; Cold start; Transient performance; Hydrogen production

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Nomenclature

B	bias limit
N	repeated measurements
S	standard deviation
$S_{\bar{x}}$	average precision
t	a parameter; a function of measurement times and average precision
U	measurement uncertainty
U_{RSS}	measurement uncertainty derived by root sum square method
β	bias error
δ_k	total measurement bias
ε_k	precision error

Subscripts

k	source of error
RSS	root sum square
$\bar{x}$	average value of total measurements

1. Introduction

Severe air pollution in cities is a common problem faced by countries worldwide. Although it is generally accepted that electrifying vehicles is one of the most efficient methods in reducing this problem, this method has never quite been popularised due to the difficulties in maintaining a constant supply of electricity such as battery lives, battery recharging times etc., while the vehicle is in transit.

The fuel cell, which uses hydrogen to generate electricity, is generally regarded as the most prospective method of powering vehicles. The main consideration is, thus, the source of the hydrogen and the method of storing it. The traditional method of storing gas in pressurised metal cylinders is not ideal as hydrogen is highly combustible. It is only very recently that a hydrogen storage canister was developed, which enabled safe storage of hydrogen and, therefore, the usage of fuel cells in electrical cars. Alternatively, if a small reformer that can produce hydrogen on board a car were available, this would undoubtedly be a more efficient and safer method of powering electrical cars. With a reformer, the main design considerations are its physical dimensions, its response rate after cold start and its transient response during acceleration.

Hydrogen can be extracted by the reforming process from methanol, natural gas, fossil fuel etc. The methods of reforming include partial oxidation, auto-thermal, steam reforming and so on [1]. Hydrogen obtained from methanol possesses the desirable characteristics of ease of decomposition and a low reaction temperature of approximately 250 °C and is, thus, a suitable method for steam reforming [2].

The Energy and Resources Laboratories of the Industrial Technology Research Institute of Taiwan has published some papers since 1993 on research of reformers for fuel cells. Cheng [3] proposed a set of design criteria and did a literature review of the development of the reformer.