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Review Article

Recent advances in cleaner hydrogen productions via thermo-catalytic decomposition of methane: Admixture with hydrocarbon

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ABSTRACT

A continuous increase in the greenhouse gases concentration due to combustion of fossil fuels for energy generation in the recent decades has sparked interest among the researchers to find a quick solution to this problem. One viable solution is to use hydrogen as a clean and effective source of energy. In this paper, an extensive review has been made on the effectiveness of metallic catalyst in hydrocarbon reforming for CO_X free hydrogen production via different techniques. Among all metallic catalyst, Ni-based materials impregnated with various transition metals as promoters exhibited prolonged stability, high methane conversions, better thermal resistance and improved coke resistance. This review also assesses the effect of reaction temperature, gas hour space velocity and metal loading on the sustainability of thermocatalytic decomposition TCD of methane. The practice of co-feeding of methane with other hydrocarbons specifically ethylene, propylene, hydrogen sulphide, and ethanol are classified in this paper with the detailed overview of TCD reaction kinetics over an empirical model based on power law that has been presented. In addition, it is also expected that the outlook of TCD of methane for green hydrogen production will provide researchers with an excellent platform to the future direction of the process over Ni-based catalysts.

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Contents

Introduction

The combustion of fossil fuels such as coal, oil, gasoline and natural gas satisfy the energy demands of industry and domestic users. However, they will run out momentarily due to the rapidly increasing demands [1]. Furthermore, the global warming, greenhouse effect, hole in ozone layer, acid rains and environmental pollution are the drastic effects caused by the fossil fuel combustion [2]. USA, Japan, and Germany are leading the race of CO_2 emissions as they have well stabilized industrial sectors [3]. The concentration of CO_2 in the atmosphere has increased drastically from 396 ppm to 400 ppm in recent few years. Moreover, it is estimated that these emissions will increase from 30 billion metric tons to 43 billion metric tons in 2035 [4]. The average temperature of the earth according to climate forecasts may increase from 274 to 279 K if the increasing greenhouse gas emissions are not critically considered [5]. Extensive solutions have been reported by the researchers to reduce the hazardous effects of increasing concentration of CO_2 in the atmosphere by establishing various methods of CO_2 capture such as absorption, cryogenic and membrane processes [6]. Another method has been reported by using photo-catalytic reactors [7] to convert excessive CO_2 into useful products such as CH_4 and CH_3OH. The invention of few high energy efficient green fuels that reduce the emissions of poisonous gases during combustion is also quoted as an active solution to control greenhouse effect. The search for alternative high energy efficient green fuels has been broadly investigated by many researchers in the past. H_2 has been termed as one of the greenest and lightest fuel that can fill in the energy gap which will be created in the upcoming future. Because of hydrogen's abundance, lightweight, low mass density, high calorific value and non-polluting nature make it a unique source of energy. Moreover, it has been published that H_2 has the highest heat of combustion, i.e. 142 kJ g^{-1} as compared to petroleum and wood that exhibit 43–35 and 18 kJ g^{-1} respectively [8].

The annual H_2 consumption in 2006 was around 50 million tons including industrial and domestic usage. Around 50% of this consumption was attributed to NH_3 industries, 37% in petroleum refineries, 7% in CH_3OH production and 6% in other fields. It has been reported that the H_2 produced in existing date has to be multiplied 100 times approximately to meet the world's demand for fossil fuels presently [9]. It is believed that H_2 will play a vital role in fulfilling the extensive energy requirements. However, H_2 cannot be found freely in the atmosphere instead of in the form of bonds with other molecules that indicate its reactivity. Therefore, it must be extracted from other primary energy sources like coal, natural gas, water or other heavy hydrocarbons [10]. Global statistics illustrate that the significant amount of H_2 is being produced by the reforming of natural gas, i.e. 48%, electrolysis of water gives 30%, 18% from burning petroleum products and 4% by coal. The significant contribution to the production of H_2 is from natural gas since there are vast reservoirs of CH_4 in deep seabed especially in industrialized countries like United States [11]. Natural gas has been named as the primary energy

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