HYDROGEN AND NATURAL GAS MIXTURE

Itsuki Uehara
National Institute of Advanced Industrial Science and Technology, Japan

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Summary

Addition of hydrogen to natural gas has been shown to have a beneficial effect in terms of improving combustion properties and reducing polluting emissions. A trade-off between the reduction of NOx emission and increase of backfiring, which is inevitable for burner combustion of pure hydrogen, is thereby avoided. A hydrogen–natural gas mixture as a town gas is a possible approach to the introduction of hydrogen use into the energy field. Furthermore, the broad flammability limits and fast flame propagation velocity of hydrogen aid complete combustion of mixtures of hydrogen and natural gas in internal combustion engines of both spark and compression types, and allow the engines to be operated at the lean-burn ranges. Lean-burn operation maintains emission of nitrogen oxides, carbon monoxide and total hydrocarbons at a much lower than that for natural gas only. Internal combustion engines operating at or near the lean limit are a possible technology for solving environmental problems due to pollutant emissions from vehicles in urban areas.

1. Introduction

The use of hydrogen as an additive to hydrocarbon fuels is an approach to the introduction of hydrogen into energy fields. Town gases manufactured from hydrocarbons and coals always contained a considerable amount of hydrogen. Now, most town gas consists of natural gas or methane. Addition of hydrogen to natural gas presages a gradual transition to the age of hydrogen as an energy carrier. Another possible use of hydrogen as an additive is in fuels for internal combustion engines. Addition of hydrogen to natural gas engines has been shown to have beneficial effects in terms of improving combustion properties and reducing polluting emissions, especially in lean-burn operation. A significant reduction in emission of nitrogen oxides, carbon monoxide, and hydrocarbons from automobiles is expected when fueled with this mixture. A transportation system using natural gas containing hydrogen would be an effective way of mitigating environmental issues in urban areas as well as introducing hydrogen into the energy supply infrastructure.

2. Burner Combustion of Natural Gas Mixed with Hydrogen

Natural gas consists mainly of methane. Combustion properties of hydrogen and methane are given in Table 1. Hydrogen has wider flammability limits, a faster burning velocity and a smaller minimum ignition energy than methane. Owing to these properties, the flame in burner combustion of hydrogen–air mixtures, with and without premixing, is hard to extinguish due to flame lifting and easy to backfire. The burner combustion is accompanied by generation of a considerable amount of nitrogen oxides (NOx), about 500 ppm. Although the NOx concentration decreases largely by increasing the premixing ratio of air, the increase of the air ratio causes the likelihood of backfiring. The suppression of NOx generation and backfiring is a trade-off, and is called “a dilemma in hydrogen combustion using burners.”

In contrast, when hydrogen is burned as a mixture with natural gas, in principle, its favorable and unfavorable combustion characteristics bring about the following positive features. The burner combustion proceeds stably due to the increase of the flammability limits and the reduction in backfire and ignition energy. A large thermal energy with a small burner is obtainable due to the increase of the combustion energy per volume. Generation of NOx can be suppressed without causing backfiring in a larger premixing ratio of air.

In industrial areas, hydrogen is mostly burned together with other fuels. However, conventional burners are not adaptable for mixtures of hydrogen and natural gas in homes for safety and environmental reasons. Improvement of burners for hydrogen–natural gas mixtures in home use is under research with respect to stable and reliable combustion at acceptably low emission levels of NOx and total hydrocarbons (THCs). A NOx emission level of 5 to 50 ppm is currently obtainable. Aspects of catalytic combustion such as suitable catalysts, burner structures, and combustion conditions are also under study. The resulting lower combustion temperature leads to a further decrease of NOx emission.

Property	Hydrogen	Methane	Propane
Density of gas at NTP[a)] (kg m^{-3})	0.0838	0.6512	1.87
Heat of combustion[b)] (low) (MJ m^{-3})	10.78	39.72	99.03
Heat of combustion[b)] (high) (MJ m^{-3})	12.75	35.80	91.21
Flammability range (limits) in air[c)] (%)	4.1 - 75	5.3 – 15	2.1 – 10
Stoichiometric composition in air[c)] (%)	29.53	9.48	4.02
Minimum ignition energy (mJ)	0.02	0.29	0.26

Minimum self ignition temperature[d] (K)	858	813	760
Adiabatic flame temperature in air (K)	2318	2158	2198
Burning velocity[d] (cm s^{-1})	237	42	46
Detonability range in air[c] (%)	18 – 59	6.3 - 13.5	3.1 – 7.0
Energy of explosion of gaseous fuel[b] (MJ m^{-3})	9.9	32.3	93

a) NTP = normal temperature and pressure (293.15 K, 0.1013 MPa).
b) 273.15 K, 0.1013 MPa).
c) in a volumetric ratio.
d) a stoichiometric mixture.

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Table 1. Combustion properties of hydrogen, methane, and propane.

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Biographical Sketch

Itsuki Uehara, born April 4, 1950, in Kyoto Prefecture, Japan, graduated from Nagoya Institute of Technology in 1973. He received his ME degree in chemical engineering from Nagoya University in 1975 and Doctor of Engineering degree in electrochemistry from Kyoto University; has worked for Osaka National Research Institute on hydrogen energy systems and applications of hydrogen storage alloys (1975–1999); has worked as the Chief of the Central Research Institute, Toyama Industrial Technology Center (1999-2001); is presently the Human Resource Coodinator, National Institute of Advanced Industrial Science and Technoloy;and has published some 100 papers and 5 books.