



Experimental investigation on wall temperature of an air-breathing kerosene/air pulse detonation combustor with impingement cooling

Xing-tao Wang, Jing-zhou Zhang*, Xiao-ming Tan

College of Energy and Power Engineering, Nanjing University of Aeronautics and Astronautics, 29 Yudao Street, Nanjing, Jiangsu 210016, China

ARTICLE INFO

Article history:

Received 26 July 2011

Accepted 28 February 2012

Available online 9 March 2012

Keywords:

Impingement cooling

Pulse detonation combustor

Temperature distribution

Experimental test

ABSTRACT

The design of a practical pulse detonation combustor requires the components to be capable of enduring the severe thermal environment created by repetitive detonations. In the present study, an air-breathing kerosene/air detonation combustor was designed and fabricated. And the temperature distributions on the combustor liner were measured at various operating frequencies (from 10 Hz to 50 Hz) for both natural cooling and jet impinging cooling cases. The results show that the temperature distribution on detonation combustor liner under natural cooling mode is seriously non-uniform and the hottest region appears corresponding to where transition from deflagration to detonation occurs. The temperature rise amplitude corresponding to 10 Hz increase at higher operational frequency is smaller than that at lower operational frequency. As expected, the maximum temperature on detonation combustor liner is decreased as the increase of coolant flow rate. The impinging distance between jet orifice tube and circular liner is of important influence on the reasonable temperature distribution of a cooled combustor liner.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Pulse detonation combustor is receiving increasing attention for potential application in the hybrid propulsion system where the detonative device is coupled to conventional turbomachinery. In this hybrid propulsion system (as seen in Fig. 1), a detonative combustor would be burned in a cyclic detonation process at higher working frequency and achieve near constant volume burning, improving thermodynamic cycle efficiency that lead to the increase in thrust-to-weight ratio and the decrease in fuel consumption [1–3]. When a detonation is initiated, a sharp pressure and temperature peak is observed for a short duration on the order of 0.1 ms, followed by a sharp decrease to a plateau region of constant values for duration of several milliseconds prior to a final decay to the lower fuel mixture fill pressure. The resulting hot gas temperature and pressure fluctuation distributions generated with every detonation at high frequency are viewed to be detrimental to the combustor liner material [4–8]. The design of a practical, long-life pulse detonation combustor requires the design of components that are capable of enduring the severe environment created by repetitive detonations [9,10].

Impingement cooling is an attractive technique that has been successfully used in aero-engine to increase the durability of hot

components such as turbine blades and combustor liners [11–13]. Although a considerable amount of researches have been conducted on the impingement cooling characteristics for combustor liner of aero-engine so that the design of impingement cooling systems could be optimized to produce the most effective cooling with a minimum amount of coolant, little work has been made on the impingement cooling efficiency for pulse detonation combustor where the liner is subjected to the severe thermal environment created by repetitive detonations. In order to optimize the impingement cooling systems, it is necessary to make intensive investigation on impingement cooling characteristics for detonation combustor.

In the current study, an air-breathing kerosene/air detonation combustor was designed and fabricated, and the temperature distributions on the combustor liner were measured at various operating frequencies (from 10 Hz to 50 Hz) for both natural cooling and jet impinging cooling cases. This paper summarizes an experimental research effort to characterize the temperature distribution feature on the pulse detonation combustor liner and the resulting jet impingement cooling effectiveness.

2. Experimental facilities

The schematic of the pulse detonation combustor test facility is shown in Fig. 2. It consists of devices of air and fuel supply, mixing chamber, detonation chamber, pulse spark generator, and data

* Corresponding author. Tel.: +86 25 84895909.

E-mail address: zhangjz@nuaa.edu.cn (J.-z. Zhang).