



NUMERICAL SIMULATION OF HIGH EFFICIENCY POROUS BURNER
FOR LIQUID FUEL COMBUSTION WITHOUT SPRAY ATOMIZATION

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Abstract

The non-sprayed porous burner (NSPB) of liquid kerosene has been numerically investigated. The self-sustaining evaporation without any fuel being atomization before combustion of NSPB compared to conventional burner is one of the most prominent advantages among one. A homogeneous combustion within a porous medium is used instead of heterogeneous combustion in a free space of conventional sprayed burner. This system consists of two pieces of cylindrical porous inert media which are the fuel-preheated porous medium (FP) and the porous combustor (PC). These are positioned at co-axially with a small space separating them to serve as a mixing chamber. At a steady state condition, the two porous media are coupled with radiative heat transfer emitted from the PC to the FP. The numerical modeling of late mixing porous burner (LMPB) begins with liquefied petroleum gas (LPG) to investigate the non-preheated air and preheated air, then the numerical model of NSPB is performed. The FP utilizes as preheating porous in LMPB and purposes as preheating and evaporating for the liquid fuel in NSPB. The numerical modeling is found to have potential to predict important information for LMPB and NSPB, such as temperature of solid and fluid phases, evaporation front, flame position, and the burner performance. The key parameters i.e., the firing rate (FR) and equivalence ratio which affect the burner performance and temperature profiles, are studied. The results indicate that, the benefit of LMPB and NSPB are safety combustion and enhanced the same radiant output efficiency as a normal premixed porous burner which can replace a conventional burner in a near future. Furthermore, the experimental study is conducted for the model validation. The

numerical results show adequate agreement with the experimental results in terms of temperature profile and radiant output efficiency.

Keywords: Porous / Combustion / Liquid fuel / Non-sprayed

หัวข้อวิทยานิพนธ์	การสร้างแบบจำลองทางคณิตศาสตร์ของหัวเผาวัสดุพอรุน สมรรถนะสูงเพื่อการเผาไหม้เชื้อเพลิงเหลวชนิดไม่มีการสเปรย์
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บทคัดย่อ

หัวเผาวัสดุพอรุนเพื่อการเผาไหม้น้ำมันก๊าดชนิดไม่มีการสเปรย์ (NSPB) ถูกศึกษาโดยแบบจำลองทางคณิตศาสตร์ การระเหยเกิดขึ้นอย่างสมบูรณ์ภายในวัสดุพอรุนโดยปราศจากการใช้หัวฉีดความดันสูงซึ่งมีข้อดีว่าการเผาไหม้ของหัวเผาน้ำมัน โดยทั่วไป การเผาไหม้แบบเป็นเนื้อเดียวกันภายในวัสดุพอรุนจะถูกใช้แทนที่การเผาไหม้แบบไม่เป็นเนื้อเดียวกันที่เกิดขึ้นในการเผาไหม้หัวเผาแบบสเปรย์ทั่วไป ระบบประกอบด้วยวัสดุพอรุนทรงกระบอกสองชั้น คือวัสดุพอรุน FP และ วัสดุพอรุน PC ซึ่งติดตั้งโดยมีห้องผสมกันอยู่ ที่สภาวะคงตัววัสดุพอรุน PC จะแผ่รังสีความร้อนมายังวัสดุพอรุน FP แบบจำลองของกรณีการเผาไหม้เชื้อเพลิงก๊าซหุงต้ม (LMPB) ในกรณีที่ไม่มี การอุ่นและมีการอุ่นอากาศจะถูกพัฒนาขึ้นในขั้นต้น จากนั้นจึงเป็นการสร้างแบบจำลองทางคณิตศาสตร์ของการเผาไหม้น้ำมันก๊าดชนิดไม่มีการสเปรย์ (NSPB) ในกรณี LMPB วัสดุพอรุน FP จะถูกใช้เป็นอุปกรณ์อุ่นเชื้อเพลิง ส่วนในกรณี NSPB วัสดุพอรุน FP จะทำหน้าที่ในการอุ่นและระเหยน้ำมันเชื้อเพลิง จากผลการคำนวณพบว่าแบบจำลองทางคณิตศาสตร์ทั้งกรณี LMPB และ NSPB สามารถทำนายข้อมูลที่สำคัญ ได้แก่ อุณหภูมิของแข็งและของไหล ตำแหน่งการระเหย ตำแหน่งเปลวไฟ และสมรรถนะของหัวเผาได้ พารามิเตอร์สำคัญที่มีอิทธิพลต่อกับโครงสร้างของอุณหภูมิ และสมรรถนะของหัวเผาได้แก่ อัตราการป้อนเชื้อเพลิง และสัดส่วนผสม ได้ถูกศึกษาด้วย ผลการศึกษาชี้ให้เห็นว่าหัวเผา LMPB และ NSPB ให้การเผาไหม้ที่ปลอดภัย และให้ประสิทธิภาพการแผ่รังสีอยู่ในช่วงเดียวกับหัวเผาวัสดุพอรุนแบบผสมมาก่อนแบบทั่วไป รวมทั้งมีความยืดหยุ่นในการใช้งานสำหรับตอบสนองความต้องการของอุตสาหกรรม ซึ่งในอนาคตสามารถนำมาใช้ทดแทนหัวเผาที่มีอยู่ได้ นอกจากนี้การศึกษาด้วยการทดลองได้ถูกทำขึ้นเพื่อตรวจสอบความแม่นยำของแบบจำลองทางคณิตศาสตร์โดยผลการคำนวณ

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คำสำคัญ: วัสดุพอรอน / การเผาไหม้ / เชื้อเพลิงเหลว / ไม่มีการสเปรย์

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LIST OF SYMBOLS

A	=	area (m^2), frequency factor of combustion (s^{-1})
c	=	specific heat (J/kg.K)
d_p	=	diameter of particle (m)
D	=	diffusion coefficient (m^2/s)
exp	=	exponential function
E_n	=	exponential integral function
FR	=	firing rate (kW)
h	=	enthalpy (J/kg)
h_o	=	heat of reaction (W/m^3)
h_v	=	volumetric heat transfer coefficient ($\text{W/m}^3.\text{K}$)
I	=	incident radiation intensity (W/m^2)
L	=	length of mixing chamber (m)
\dot{m}	=	mass flow rate (kg/s)
Nu	=	Nusselt number
Pr	=	Prandtl number
q_r	=	radiation heat flux (W/m^2)
r	=	radius (m)
R	=	Universal gas constant (J/mol.K)
Re	=	Reynolds number
t	=	time (s)
T	=	temperature (K, $^{\circ}\text{C}$)
u	=	interstitial gas velocity (m/s)
U	=	overall heat transfer coefficient ($\text{W/m}^2.\text{K}$)
V	=	volume (m^3)
w	=	reaction rate ($\text{kg/m}^3.\text{s}$)
x	=	distance (m)
y	=	product mole fraction

Greek symbols

α	=	area to volume ratio (m^2/m^3)
ε	=	porosity

κ	=	absorption coefficient (m^{-1})
λ	=	thermal conductivity (W/m.K)
λ_e	=	effective thermal conductivity (W/m.K)
ρ	=	density (kg/m^3)
σ	=	Stefan – Boltzmann constant ($\text{W/m}^2.\text{K}^4$)
τ	=	optical thickness = κx

Superscripts

+	=	positive direction
-	=	negative direction
n	=	net

Subscripts

0	=	ambient
a	=	air
ai	=	air inlet of air jacket
ao	=	air outlet of air jacket
ad	=	adiabatic
b	=	black body, boiling
f	=	fluid
F	=	fuel
FP	=	fuel-preheated porous medium
g	=	gas
l	=	liquid
mix	=	mixture
p	=	particle
PC	=	porous combustor
s	=	solid
v	=	volumetric, vapor
w	=	wall