附件 2

2025 年黑龙江工程师学院
工程师职称资格申报书

高　　校：哈尔滨工程大学

所在学院：动力与能源工程学院

专业类别：能源动力

黑龙江工程师学院制

2025 年 5 月

填 写 说 明

一、本表仅为黑龙江工程师学院工程师职称资格申报使用，须如实填写；

二、申报书中填写内容原则上不得涉密，如存在涉密技术或数据，须做脱密处理，所在单位须严格审核；

三、申报书涉及签名均须用蓝、黑色墨水笔，亲笔签名；

四、申报书中用宋体小四号字撰写，可另附页或增加页数，A4 纸双面打印。

黑龙江工程师学院工程师职称资格申报书

申报人基本信息			
姓　　名	赵泯玮	联系电话	15246273398
出生年月	2000 年 6 月	政治面貌	共青团员
身份证号	230302200006304733	学　　号	S322037028
高　　校	哈尔滨工程大学	所在学院	动力与能源工程学院
所属专项	龙江专项	专业类别	能源动力

联合培养信息			
联合培养（入企实践）单位名称	中国船舶集团有限公司第七〇三研究所		
入企实践时间	2023　年　9　月至　2024　年　9　月（共　12　月）		
校内导师	邓福泉	职务/职称	副教授
企业导师	李雅军	职务/职称	研究员
项目名称	燃氢燃烧室正向设计与试验验证		
项目来源	□校企联合攻关项目 □企业揭榜挂帅项目 √企业自研项目 □企业导师自研项目 □其他_____		

课程学习情况					
课程学习平均成绩	按课程学分核算的平均成绩： 86.8 分				
业绩代表成果（至少选填一项）					
校企合作项目	名称		合同金额	排名	是否通过验收/校企双导师认可
重点重大项目	名称		合同金额	排名	应用成果
					简述经济/社会效益；具有一定创新或实用的科学建议（100字之内）
科技成果设计、应用与转化	名称	类型（产品或样机设计、科技成果应用转化推广和解决行（企）业技术难题等）		应用成果	
				简述取得的经济效益和社会效益（100字之内）	
理论创新	名称		类别（包括论文、专利、软件著作权、著作、标准、规范等）	发表时间/专利授权时间	刊物名称/专利授权号	排名
	贫氧条件下钝体火焰动力学数值模拟研究		EI论文	2024年	航空动力学报	1
	A Flame Cartridge for High Temperature Gasification Cracking of Liquid Ammonia		国际发明专利	2023年	ZA202300119B	2
	Numerical simulation study on the dynamics of bluff-body flames under oxygen-lean conditions		SCI论文	2023年	Energies	2
	Experimental study on combustion stability of a gas turbine model combustor under oxygen-lean		SCI论文	2024年	Proceedings of the Institution of	2

	conditions			Mechanical Engineers, Part A: Journal of Power and Energy	
	Exploring Vortex-Flame Interactions and Combustion Dynamics in Bluff Body-Stabilized Diffusion Flames: Effects of Incoming Flow Velocity and Oxygen Content	SCI 论文	2024 年	Processes	2
	Theoretical Analysis on Thermodynamic and Economic Performance Improvement in a Supercritical CO2 Cycle by Integrating with Two Novel Double-Effect Absorption Reheat Power Cycles	SCI 论文	2024 年	International Journal of Energy Research	2
获奖	名称	级别 （包括国家级、省部级）	类别 （包括科学技术类、工程类、涉及（勘察）类、工程咨询类等）	获奖时间	排名

工程实践总结

一、问题来源与研究现状

（简要说明专业实践研究课题的问题来源与研究意义、国内外研究现状及行业应用现状，字数500字左右）

燃气轮机作为现代能源系统的核心动力装备，在航空推进、电力生产和工业驱动领域具有不可替代的战略地位。当前，天然气燃气轮机凭借其清洁低碳特性已在能源领域占据主导地位，但传统天然气燃料中含有碳元素导致燃烧过程仍产生大量CO_2排放。氢燃料因不含碳元素，能够实现零碳排放，是一种理想的替代能源。电解水制氢技术可将风电、光伏等可再生能源的过剩电力转化为化学能储存，为构建新型电力系统提供重要支撑。采用纯氢燃烧方案需要设计全新的燃烧室，成本高、周期长。而掺氢燃烧方案只需改造燃烧室头部结构，兼具工程周期短与经济成本低的优势，能快速降低碳排放，是未来向纯氢燃气轮机过渡的有效途径。在碳达峰、碳中和的全球共识下，掺氢燃烧技术正成为燃气轮机低碳化发展的关键技术路径。因此，开展天然气掺氢燃烧技术研究十分必要。

然而，掺氢燃烧技术的工程化应用面临重大技术挑战。氢气和天然气的物理化学性质差别很大，氢气的层流火焰速度和绝热火焰温度远高于甲烷，高掺氢比（氢气体积分数）燃料的火焰传播速度剧增容易导致火焰向上游传播至预混段内，诱发回火现象，导致燃烧模式从扩散燃烧变为预混燃烧，不仅造成NOx排放指标急剧恶化，更导致燃烧室头部结构烧蚀，局部高温区的形成使NOx生成速率呈指数级增长。这些特性对燃烧室头部设计提出了严苛要求，需在维持燃烧稳定性的前提下，防止回火现象的发生并降低NOx排放。目前在宽掺氢比下实现高效、清洁燃烧组织十分具有挑战性。

二、解决的关键问题（字数300字左右）

为了实现在宽掺氢比下燃烧室的高效、清洁燃烧，首先对燃烧室结构进行气动和结构参数设计，得到初始的边界条件及燃烧室结构。采用数值模拟方法，探究单流道燃料孔几何参数对燃料与空气掺混均匀性的影响，得出掺混均匀性最佳的燃料孔几何结构。基于设计的旋流器初始结构，分析了旋流器几何参数对流场结构、掺混均匀性、燃烧性能和排放的影响，通过对旋流器结构进行逐步优化，得到燃烧性能最佳的燃烧室结构。最后，基于优化后的旋流器结构，探究不同工况下燃料分配方案对燃烧性能和排放的影响，得到不同工况下燃烧性能最佳的燃料供给策略，为天然气掺氢低排放燃烧室的设计提供参考。

三、策略分析及工作量描述

（主要包括理论的比较、分析及技术路线描述、说明具体的工作量与复杂度，字数 800 字左右）

为了实现在宽掺氢比下燃烧室的高效、清洁燃烧，以天然气掺氢模型燃烧室为研究对象，探究不同掺氢比下旋流器结构参数对燃料掺混均匀性、燃烧性能、污染物排放等的影响，得到燃烧性能最佳的燃烧室结构。在此基础上，探究不同工况下燃料供给策略和掺氢比对掺氢燃烧室燃烧性能和污染物排放的影响，得到不同工况下燃烧性能最佳的燃料分配方案。具体研究内容如下：

（1）为了得到模型燃烧室的边界条件及初始结构，针对某型燃气轮机燃烧室的设计工况与经验公式，对掺氢燃烧室的气动及结构参数进行设计，确定模型燃烧室的边界条件及初始结构。在此基础上开展燃料孔结构参数对单流道中燃料与空气掺混均匀性的影响规律研究，得到掺混均匀性最优的燃料孔结构参数。

（2）为了得到宽掺氢比下高效、清洁燃烧的燃烧室最优结构，在获得模型燃烧室初始结构的基础上，采用数值模拟方法研究不同掺氢比下旋流器几何参数对天然气掺氢模型燃烧室内流场组织、燃料掺混均匀性、燃烧和排放特性的影响规律，经过逐步优化，得到燃烧性能最佳的旋流器结构。

（3）为了得到不同工况下高效、清洁燃烧的燃料供给策略，基于优化后的旋流器结构，开展不同工况下燃料分配方案对天然气掺氢模型燃烧室的燃烧和排放性能研究，分析不同掺氢比下燃料分配方案对燃烧室燃烧性能的变化规律。得到不同工况下燃烧性能最佳的燃料供给策略。

四、实践成果

（主要围绕效率、质量和成本等方面，突出成果成效、突出经济社会效益、突出对行业发展的发挥作用等方面简要阐述，字数200字左右）

为了实现宽掺氢比（0-45%）下天然气掺氢燃气轮机燃烧室的高效、清洁燃烧，根据设计工况和经验公式开展了天然气掺氢模型燃烧室的气动设计和结构设计，得到天然气掺氢模型燃烧室头部配气方案和初始结构。通过数值模拟方法探究了燃料孔结构参数（燃料孔孔径、孔数、布置方式、轴向位置）对单流道燃料掺混均匀性的影响规律，得到了燃料掺混均匀性较好的燃料孔布局方案。通过数值模拟方法探究了不同掺氢比下旋流器结构参数（主燃一、二级叶片角度、分级轴向距离、空气分级比）对模型燃烧室燃烧性能和排放的影响规律，通过逐步优化得到宽掺氢比下燃烧性能最佳的燃烧室结构方案。在此基础上，探究了不同工况和掺氢比下燃料供给策略对模型燃烧室燃烧性能和排放的影响规律，得到了不同工况下燃烧性能最佳的燃料分配方案，为天然气掺氢低排放燃烧室的设计提供参考。

本人承诺

个人声明：本人上述所填资料均为真实有效，如有虚假，愿承担一切责任，特此声明！

申报人签名：赵泯涛

日　　期：2025.5.9

校内导师意见

该生实践报告详实规范，如实呈现了其在实践期间的收获与成长。其在项目中积极主动、踏实肯干，展现出良好的专业素养和实践能力，达到了专业实践的预期目标。

导师签字：邓福泉

日　　期：2025.5.11

企业导师意见

1. 研究生的工作态度良好，具有很好的团队协作和沟通表达能力。
2. 研究生了解本行业的发展前沿，对从事的实践内容认知清楚。
3. 研究生在实践中的研究对项目起到了支撑作用。

导师签字：李雅星

日　　期：2025.5.9

校企评价结果

（由学生就读高校的学籍所在学院以及参与专业实践的企业，联合对申报学生专业实践成绩、业绩代表成果进行评价认定）

学生专业实践考核成绩： 91 分

☑优秀　☐良好　☐一般　☐及格　☐不及格

学生满足的业绩代表成果情况：

☑研究生课程学习平均成绩 80 分及以上

☐校企合作项目　☐重点重大项目　☐科技成果设计、应用与转化

☑理论创新　☐获奖

所在学院公章：

副院长（签字）：杨晓涛

学生入企期间开展的专业实践情况：

☑学生实践信息属实　☑学生实践内容符合校企实践计划要求

☑学生取得的业绩代表成果与专业实践内容相关

实践部门公章：

负责人（签字）：李雅星

专业评议组组长评议意见
（专业评议组组长汇总本组组员评审情况，形成对该学生的评议意见，并在评审委员会会议中进行口头汇报） 评议结果： □推荐　　□需答辩　　□不推荐 组长签字： 日　　期：
黑龙江工程师学院意见
单位公章： 日　　期：
黑龙江省人力资源和社会保障厅意见
单位公章： 日　　期：

附件 3

佐证材料清单

姓名	赵泯玮	所在高校	哈尔滨工程大学
所属专项	龙江专项	专业类别	能源动力

材 料 目 录

序号	材料名称 （按照审批表填写顺序装订）	份数 （份）
1	课程成绩单（含课程学习情况证明）	1
2	校企合作项目材料	
3	重点重大项目	
4	科技成果设计、应用与转化	
5	理论创新	6
6	省级及以上获奖	

注：相应申报材料按照顺序统一装订，此清单粘贴在档案袋上。

申报人签字：赵泯玮　　提交时间：2025.05.12

哈爾濱工程大學
HARBIN ENGINEERING UNIVERSITY

哈尔滨工程大学研究生成绩证明

学　　号：	S322037028	姓　　名：	赵泯玮
性　　别：	男	入学年月：	2022年9月
专　　业：	能源动力		
学位层次：	硕士	学习形式：	全日制

序号	开课学年/学期	课程编号	课程名称	课程类别	学分	学时	成绩	备注
1	2022秋季	202010320702	学科前沿与进展专题	专业必修课	0.5	8	优秀	
2	2022秋季	202032013001	中国特色社会主义理论与实践研究	公共必修课	2.0	36	84	
3	2022秋季	202010320001	论文写作指导	专业必修课	1.0	16	良好	
4	2022秋季	201910310309	现代热工测试技术A	专业必修课	3.0	56	90	
5	2022秋季	202032013003	第一外国语（英语）	公共必修课	3.0	60	80	
6	2022秋季	202032020003	数值计算	公共必修课	2.0	32	79	
7	2022秋季	201910410011	人工智能原理与方法	选修课	2.0	38	86	
8	2023春季	201910310301	高等传热学	专业必修课	3.0	51	85	
9	2023春季	202010313007	燃气轮机控制与健康管理技术	选修课	2.0	32	87	
10	2023春季	202032013002	自然辩证法概论	公共必修课	1.0	18	84	
11	2023春季	201910310308	高等燃烧学A	选修课	3.0	48	89	
12	2023春季	202032012001	工程伦理	公共必修课	1.0	18	90	
13	2023春季	201910310304	流动与传热数值计算	专业必修课	2.0	32	85	
14	2023春季	202032020013	不朽的艺术：走进大师与经典	选修课	2.0	35	优秀	
15	2023春季	202032020020	英文科技论文写作与学术报告	选修课	2.0	30	优秀	
16	2023秋季	202010320593	文献综述与开题报告	文献综述与开题报告	2.0	0	合格	
17	2024春季	202010312599	专业实践	专业实践	6.0	0	合格	
18	2024秋季	202010320594	中期检查	中期检查	1.0	0	合格	
19	2024秋季	202010320591	学术活动	学术活动	1.0	0	合格	

总学分：39.5

成绩审查签字(盖章)：

校审查意见：

校长印：

哈尔滨工程大学研究生院 专用章

百分制和五分制对应关系：优秀=90-100；　良好=80-89；　中等=70-79；　及格=60-69；　不及格=0-59

哈尔滨工程大学

2025-05-12

电子成绩单学信网验证：https://www.chsi.com.cn/cjdyz/index

课程学习情况证明

学籍所在学院（公章）：　　年　月　日

专业课程信息 （前沿理论课程、实践类课程、案例课程、学科交叉课程中至少必修1门）					
课程类型	课程名称	课程性质 （必修/选修）	学分	成绩	是否 校企共建
前沿理论课程	学科前沿与进展专题	必修	0.5	优秀	否
实践类课程	现代热工测试技术	必修	3	90	否
案例课程	燃气轮机控制与健康管理技术	选修	2	87	是
学科交叉课程	人工智能原理与方法	选修	2	86	否

能力素养类课程信息 （工程伦理、研究方法类、标准与知识产权类必修，工程管理类、职业素养类选修）			
课程名称	课程性质 （必修/选修）	学分	成绩
工程伦理	必修	1	90

研究生课程学习平均成绩	
按课程学分核算的平均成绩：　86.8　分	专业排名/专业总人数：　14/108

REPUBLIC OF SOUTH AFRICA

PATENTS ACT, 1978

PUBLICATION PARTICULARS AND ABSTRACT

[Section 32(3)(a) – Regulation 2291)(g) AND 31]

OFFICIAL APPLICATION NO.		LODGING DATE	ACCEPTANCE DATE
21 01	**2023/00119**	22 2023/01/03	47

INTERNATIONAL CLASSIFICATION

51	F23R

FULL NAME(S) OF APPLICANT(S)

71	Harbin Engineering University No.145,Nantong Street, Nangang District,Harbin, Heilongjiang Province, China

FULL NAME(S) OF INVENTORS(S)

72	1. Deng Fuquan 2. Zhao Minwei

EARLIEST PRIORITY CLAIMED

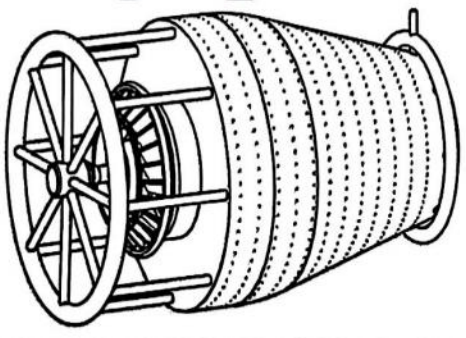
COUNTRY		NUMBER		DATE	
33		31		32	

TITLE OF INVENTION

54	A FLAME CARTRIDGE FOR HIGH TEMPERATURE GASIFICATION CRACKING OF LIQUID AMMONIA

57	The present invention belongs to the technical field of gas turbines and relates to a flame tube for high temperature gasification cracking of liquid ammonia, the structure of which comprises: a liquid ammonia annular tube, a gaseous ammonia annular tube, a gas collection chamber and a flame tube. The flame barrel comprises: an inner wall of the flame barrel, an outer wall of the flame barrel, a flame barrel cavity and a cooling hole conduit. The liquid fuel in the liquid ammonia annular tube enters the flame barrel cavity through the duct, exchanges heat with the flame barrel inner wall and the cooling gas duct, and the gas after high temperature gasification and cracking enters the gaseous ammonia annular tube through the connecting tube at the front of the flame barrel, and finally enters the combustion chamber for combustion through the central duct and nozzle. According to the technical solution of the present invention, it can solve the problems of difficult ignition of liquid ammonia fuel, insufficient combustion and unstable flame; the use of liquid ammonia can effectively reduce the storage space of fuel and solve the problem of relatively difficult transportation and storage of gaseous ammonia fuel. At the same time, the present invention can enhance the cooling gas heat exchange and reduce the temperature of the flame cylinder wall.

PATENT IMAGE



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Research Article

Theoretical Analysis on Thermodynamic and Economic Performance Improvement in a Supercritical CO_2 Cycle by Integrating with Two Novel Double-Effect Absorption Reheat Power Cycles

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To enhance the overall performance of recompression supercritical carbon dioxide- (sCO_2-) based systems, two new double-effect absorption reheat power cycles (DARPC) were developed in this study. These methods are based on the typical absorption power cycle (APC). For the proposed sCO_2/DARPC systems, a parametric analysis of the thermodynamic and economic performances, as well as additional parametric optimisations, were performed quantitatively. The results indicate that replacing the APC subsystem with DARPC subsystems can enhance the total function of the sCO2 system even further, owing to the increased H_2O vapour created in the separator and the reheating process, which adds to the greater net power output. Furthermore, compared to the DARPC2 subsystem, the DARPC1 subsystem may produce more H_2O vapour from the generator and separator, resulting in an increase in net output power. When compared to a single sCO_2 power cycle, multiobjective optimisations showed that the sCO_2/DARPC1 and sCO_2/DARPC2 systems could increase the exergy efficiency by 12.95% and 11.51% and decrease the total product unit cost by 9.67% and 8.37%, respectively. Furthermore, the sCO_2/DARPC1 and sCO_2/DARPC2 systems can achieve improvements in exergy efficiency of 4.95% and 3.61% and a total product unit cost of 4.52% and 3.15%, respectively, compared with the sCO_2/APC system.

1. Introduction

The sustained growth of the global economy has resulted in an ongoing escalation in energy demand, leading to a continuous rise in the utilization of fossil fuels and consequently causing a considerable increase in carbon dioxide emissions [1]. In response to the urgent challenge posed by climate change and the need to mitigate carbon emissions, there is now a critical necessity for transitioning from fossil fuels to renewable energy sources. Because nuclear energy is low-carbon [2], affordable [3], dependable, and ecologically benign, it emits minimal greenhouse gases during its operation and plays an increasingly important role in facilitating the global transition towards sustainable energy. Due to the low corrosion of CO_2 on boiler materials, there is no need to use expensive nickel-based alloys, and there is no phase change of CO_2 in the supercritical CO_2 cycle, no need for equipment such as condensers, and lower investment in initial investment, operation, and maintenance [4, 5]. Furthermore, since CO_2 is nontoxic and environmentally friendly, the supercritical CO_2 Brayton cycle (sCO_2) is thought to be a better option for nuclear reactors [6–8] operating at temperatures between 500°C and 900°C than the steam Rankine cycle [9] and helium Brayton cycle [10]. The sCO_2 power cycle also prevents contact between water and Na in nuclear reactors [11]. It is important to note that the CO_2 stream needs to be cooled before it enters the compressors [12] in order to benefit from the desirable physical and transport characteristics of the CO_2 near the critical point (31.3°C, 7.39 MPa) for lowering the compressor power consumption

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Theoretical Analysis on Thermodynamic and Economic Performance Improvement in a Supercritical CO_2 Cycle by Integrating with Two Novel Double-Effect Absorption Reheat Power Cycles

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Article

Numerical Simulation Study on the Dynamics of Bluff-Body Flames under Oxygen-Lean Conditions

Fuquan Deng [1,2], Minwei Zhao [1], Shunchuang Qin [1], Zhaokun Wang [2], Yongliang Xie [3], Hongtao Zheng [1], Xiao Liu [1,*] and Feng Zhang [4,*]

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Abstract: As modern aeroengine combustors advance towards high temperatures, afterburners are inevitably affected by diminished oxygen content in incoming flows, thus affecting combustion efficiency, instability, and flammability limits. In this study, the dynamic combustion characteristics of V-shaped bluff body-stabilised diffusion flames were investigated using a large eddy simulation method with an oxygen mass fraction range of 14–23% and temperatures ranging from 900 to 1100 K. The results show the significant effects of oxygen content and inflow temperature on the flame/flow behaviours downstream of the bluff-body flame holder. In a separated shear layer, two distinct modes of flow/flame shedding are observed when varying the oxygen content and inflow temperature. The results show that BVK instability governs the far-field wake flow/flame features, whereas the oxygen concentration and temperature significantly affect their oscillation amplitudes. In addition, variations in the incoming oxygen content and temperature shift the axial position of the transition from KH instability to BVK instability. Finally, a spectral analysis is conducted to investigate the characteristics of pressure and heat release pulsations under different scenarios. This study highlights the importance of oxygen content on the combustion dynamics of bluff body-stabilised diffusion flames at various temperatures, which is essential for optimising combustion efficiency and stability in practical applications.

Keywords: oxygen content; bluff-body diffusion flame; vortex shedding; dynamic combustion characteristic; large eddy simulation

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1. Introduction

As current aeroengine technology advances towards higher temperatures [1–3], heat capacity, and efficiency [4,5], the oxygen content in the incoming flow of the afterburner is reduced significantly. The decline in oxygen content significantly affects the combustion reaction rate and flame propagation speed, thus resulting in significant changes in the combustion dynamics, including vortex–flame interactions, vortex-shedding patterns, flame morphology, exothermicity, and pressure pulsations, which significantly affect the combustion efficiency, flame stability, and burn flammability limits [6–9]. The fundamental causes of combustion dynamics are complex phenomena encompassing various aspects, including the flow field structure [10], vortex motion [11], fuel injection [12], atomisation [13], evaporation, turbulent mixing [14], and chemical reactions [15]. Therefore, the effect of oxygen content on the combustion dynamics of bluff body-stabilised diffusion flames must be investigated.

Researchers have emphasised the substantial effect of oxygen ratio on flame behaviour. Liu et al. [16] performed numerical simulations to investigate the flame characteristics and

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Numerical Simulation Study on the Dynamics of Bluff-Body Flames under Oxygen-Lean Conditions

by Fuquan Deng [1,2], Minwei Zhao [1], Shunchuang Qin [1], Zhaokun Wang [2], Yongliang Xie [3], Hongtao Zheng [1], Xiao Liu [1,*] and Feng Zhang [4,*]

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贫氧条件下钝体火焰动力学数值模拟研究

赵泯玮[1]，田培森[2]，黄鑫波[1]，赵宁波[1]，郑洪涛[1]，邓福泉[1,*]

（1. 哈尔滨工程大学 动力与能源工程学院，哈尔滨 150001；
2. 哈尔滨工程大学 机电工程学院，哈尔滨 150001）

摘　　要：为探究含氧量对加力燃烧室动态燃烧特性的影响，采用大涡模拟方法研究了不同压力（0.1~0.3MPa）下含氧量（14%~23%）对加力燃烧室流场结构、火焰形态、释热脉动以及压力脉动的影响。研究表明：不同压力下含氧量对钝体火焰稳定器后的火焰和流场均具有显著影响；随着压力和含氧量的变化，在剪切层中观察到BVK和KH两种不同的不稳定特征，燃烧室下游的流动主要由BVK不稳定主导；随着含氧量降低，火焰摆动幅度增大，燃烧室中的OH基浓度降低，火焰温度减小；此外，含氧量和压力的变化还影响KH不稳定向BVK不稳定转变的位置；在BVK不稳定主导下，压力脉动和放热脉动的主频一致，在KH不稳定主导下，放热脉动没有明显的主频。

关 键 词：加力燃烧室；钝体火焰稳定器；动态燃烧特性；大涡模拟；燃烧不稳定
中图分类号：V231.2　　**文献标志码**：A

Numerical simulation study on the dynamics of bluff-body flames under oxygen-lean conditions

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ZHENG Hongtao[1]，DENG Fuquan[1,*]

（1. College of Power and Energy Engineering, Harbin Engineering University, Harbin 150001, China;
2. College of Mechanical and Electrical Engineering, Harbin Engineering University, Harbin 150001, China）

Abstract: To investigate the effect of oxygen content on the dynamic combustion characteristics of an afterburner, a Large eddy simulation method was used to study the effects of oxygen content (14% -23%) at different pressures (0.1-0.3 MPa) on the flow field structure, flame morphology, exothermic pulsation, and pressure pulsation of the afterburner. Research has shown that the oxygen content at different pressures has a significant impact on the flame and flow field behind the bluff body flame holder; As the pressure and oxygen content change, two different instability characteristics, BVK and KH, were observed in the shear layer. The flow downstream of the combustor is mainly dominated by BVK instability; As the oxygen content decreases, the flame oscillation amplitude increases, the concentration of OH groups in the combustor decreases, and the flame temperature decreases; In addition, changes in oxygen content and pressure also affect the location of KH instability transitioning to BVK instability; Under the dominance of BVK instability, the dominant frequency of pressure pulsation and exothermic pulsation is consistent, while under the dominance of KH instability, exothermic pulsation has no obvious dominant frequency.

Key words: afterburner; bluff body flame holder; dynamic combustion characteristics; large eddy simulation; combustion instability

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Experimental study on combustion stability of a gas turbine model combustor under oxygen-lean conditions

Shunchuang Qin[1], Minwei Zhao[1], Zhihao Zhang[1], Hui Tang[2], Ningbo Zhao[1], Xiao Liu[1], Hongtao Zheng[1] and Fuquan Deng[1,2]

Abstract

Flue gas recirculation has emerged as a promising low-NOx emission technology in advanced gas turbines, while the slower oxidation rate induced by the low oxygen content could potentially cause combustion instability. We conducted an experimental investigation in a single-nozzle swirl combustor to examine the impact of oxygen content, inlet flow rate as well as temperature on combustion instability under oxygen-lean conditions. The results show that reducing oxygen content from 23.3% to 21% leads to reduced amplitudes of pressure pulsation and exothermic pulsation, indicating improved combustion stability. However, further reduction in oxygen content to 18.6% causes a decrease in the combustion reaction rate, resulting in an increase in the amplitude of pressure pulsation. As the oxygen content drops to below 18.6%, the exothermic intensity decreases, which results in a decrease in the amplitude of pressure pulsation. Besides, under oxygen-lean conditions, increasing the inlet temperature is conducive to reducing the amplitude of pressure pulsation and enhancing combustion stability. Additionally, as the incoming flow rate increases from 7.4 to 9.9 m/s, the refined fuel atomization and improved uniformity of oil-gas mixing contributed to decreased pressure pulsation amplitude. Nonetheless, when the incoming flow rate further increases to 12 m/s, the amplitude of exothermic and pressure pulsation increases.

Keywords

Swirl combustor, flue gas recirculation, oxygen lean, combustion instability

Date received: 27 July 2023; revised: 13 March 2024; accepted: 22 March 2024

Combustion instability is a frequent problem in turbine combustion chamber.[1–3] When the flow field fluctuates, a large amount of exothermic pulsation may occur leading to unstable combustion,[4–6] which will cause severe engine vibration, damage key components of combustion chamber, and seriously affect engine performance.[7–9] Therefore, combustion instability is one of the main technical challenges in the development of engines. To address this issue, engineers need to thoroughly investigate combustion instability during the design and testing process to ensure the reliability and good performance of the engine.

Operational parameters also have significant impacts on combustion stability. Fritsch[10] conducted an experimental study on the combustion stability characteristics of a single-nozzle swirl combustor under different inlet temperatures and equivalent ratios. Their results suggested that the flame stability deteriorates with increasing equivalence ratio under fuel-lean conditions, while it is enhanced with increasing equivalence ratio under the fuel-rich condition. Bonciolini[11] studied the effect of fuel flow rate on combustion instability of single-nozzle swirl combustor. They found that changes in the fuel flow rate show a great impact on combustion instability. As the fuel flow rate increases, the exothermic heat in the combustion chamber increases, and the combustion stability first deteriorates and then improves. Besides, oil/gas ratio also shows great influences on the combustion stability, but the range of fuel-gas ratio for stable combustion is quite different when increasing fuel quantity and when decreasing fuel quantity, that is, combustion stability shows hysteresis. Vignat et al.[12] adjusted the pressure loss of the combustion chamber by changing the geometry of the swirler, and explored the effect of pressure loss on combustion instability. Their results showed that, as the pressure loss decreases, the operating range of combustion instability becomes narrow and the amplitude of pressure pulsation increases. Preethi[13] carried out a study on the influences of fuel types on the combustion instability in an annular combustor, and found that the amplitude and frequency of combustion instability depend on the fuel injection models and fuel type, and the injection of liquid fuel can cause a change in the ignition delay time,

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Experimental study on combustion stability of a gas turbine model combustor under oxygen-lean conditions

Shunchuang Qin , Minwei Zhao , Zhihao Zhang , Hui Tang , Ningbo Zhao , Xiao Liu , Hongtao Zheng , Fuquan Deng

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Abstract

Flue gas recirculation has emerged as a promising low-NOx emission technology in advanced gas turbines, while the slower oxidation rate induced by the low oxygen content could potentially cause combustion instability. We conducted an experimental investigation in a single-nozzle swirl combustor to examine the impact of oxygen content, inlet flow rate as well as temperature on combustion instability under oxygen-lean conditions. The results show that reducing oxygen content from 23.3% to 21% leads to reduced amplitudes of pressure pulsation and exothermic pulsation, indicating improved combustion stability. However, further reduction in oxygen content to 18.6% causes a decrease in the combustion reaction rate, resulting in an increase in the amplitude of pressure pulsation. As the oxygen content drops to below 18.6%, the exothermic intensity decreases, which results in a decrease in the amplitude of pressure pulsation. Besides, under oxygen-lean conditions, increasing the inlet temperature is conducive to reducing the amplitude of pressure pulsation and enhancing combustion stability. Additionally, as the incoming flow rate increases from 7.4 to 9.9 m/s, the refined fuel atomization and improved uniformity of oil-gas mixing contributed to decreased pressure pulsation amplitude. Nonetheless, when the incoming flow rate further increases to 12 m/s, the amplitude of exothermic and pressure pulsation increases.

Keywords

Swirl combustor, flue gas recirculation, oxygen lean, combustion instability

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Exploring Vortex–Flame Interactions and Combustion Dynamics in Bluff Body-Stabilized Diffusion Flames: Effects of Incoming Flow Velocity and Oxygen Content

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Abstract: An afterburner encounters two primary features: high incoming flow velocity and low oxygen concentration in the incoming airflow, which pose substantial challenges and contribute significantly to the deterioration of combustion performance. In order to research the influence of oxygen content on the dynamic combustion characteristics of the afterburner under various inlet velocities, the effect of oxygen content (14–23%) on the field structure of reacting bluff body flow, flame morphology, temperature pulsation, and pressure pulsation of the afterburner at different incoming flow velocities (0.1–0.2 Ma) was investigated in this study by using a large eddy simulation method. The results show that two different instability features, BVK instability and KH instability, are observed in the separated shear layer and wake, and are influenced by changes in the O_2 mass fraction and Mach number. The oxygen content and velocity affected the oscillation amplitude of the downstream flow. As the O_2 mass fraction decreases, the flame oscillation amplitude increases, the OH concentration in the combustion chamber decreases, and the flame temperature decreases. Additionally, the amplitude of the temperature pulsation in the bluff body flame was primarily influenced by the temperature intensity of the flame and BVK instability. Moreover, the pressure pulsation is predominantly affected by the dynamic characteristics of the flow field behind the bluff body. When the BVK instability dominated, the primary frequency of the pressure pulsation aligned with that of the temperature pulsation. Conversely, under the dominance of the KH instability, the temperature pulsation did not exhibit a distinct main frequency. At present, the influence of oxygen content and incoming flow rate on the combustion performance of the combustion chamber is not clear. The study of the effect of oxygen content on the combustion characteristics of the combustion chamber at different incoming flow rates provides a reference for improving the performance of the combustion chamber and enhancing the combustion stability.

Keywords: oxygen content; dynamic combustion characteristic; vortex shedding; diffusion combustion; computational fluid dynamics

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1. Introduction

The afterburner is a critical component for thrust augmentation in military aircraft engines [1], enabling a substantial increase in the engine thrust from 60% to 70%. The airflow entering the afterburner is the exhaust gas from the main combustor in the aero-engine, which contains one-quarter less oxygen than pure air. Low oxygen content is detrimental to stable combustion [2–5], significantly reducing the combustion reaction rate and flame propagation speed in the afterburner [6–8]. Moreover, the incoming flow velocity in the afterburner is exceptionally high, and minor perturbations can potentially lead to combustion instability [9–13]. Combustion instability manifests as periodic pressure and

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Exploring Vortex–Flame Interactions and Combustion Dynamics in Bluff Body-Stabilized Diffusion Flames: Effects of Incoming Flow Velocity and Oxygen Content

by Mingmin Chen [1], Minwei Zhao [1], Zhihao Wang [1], Xinbo Huang [1], Hongtao Zheng [1] and Fuquan Deng [1,2,*]

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