

改变进气流量实现可调回流区位置的研究

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摘 要: 提出了一种实现回流区可调的新方法, 并对其特点进行了研究。根据流体力学的规律, 实现了无移动部件和无高温部件(钝件)情况下回流区的可调性, 满足不同油品正常燃烧时对回流区的要求, 特别是在研究不同掺水率的“水包油”型乳化油的燃烧特性时, 其特点更为突出。此研究还为工业应用提供了支持。实验和计算结果表明, 此回流区可以适应不同油品的要求。

关 键 词: 可调回流区; “水包油”型乳化油; 燃烧器

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1 引 言

能源与环境是当今社会发展的两大问题, 世界各国均予以高度重视。随着我国工业化进程的加快, 未来原油的需求将呈增加趋势。我国自 1993 年成为石油净进口国以来, 进口量逐年增大。为此, 国家每年要花大量的外汇来进口石油, 不仅给国家造成了严重的经济负担, 而且, 如果我国继续依靠进口来弥补石油的缺口, 则我国对国际石油市场依存度将越来越高, 这对我国的经济安全将产生重大影响。因此, 节约和替代燃料油是缓解石油供需矛盾的重大战略措施之一。

我国超稠油的储藏量约 38 亿吨, 目前辽河油田年产 270 万吨^[1]。今后随着需求的增长, 其产量还可增加。这种油的粘度极高, 在常温下, 基本上呈固体状态, 故称其为超稠油。这种超稠油实际上属原油, 但无提炼价值, 随着燃料油市场的需求和国家能源战略的调整, 人们想把它制成“水包油”型乳化油作燃料油使用, 现在已研制成功, 称其为“CR 燃料油”, 它由超稠油经过加温、与水在乳化剂的作用下经过机械剪切作用而形成的乳化油, 含水量在 30%, 且为“水包油”型(O/W)。

对于“水包油”型的乳化油, 传统的观点认为不能很好的燃烧, 分析原因, 主要是因为“水包油”型乳

化油不能使油滴发生二次雾化。另一方面, 由于水分蒸发使炉膛温度降低, 导致燃烧的不稳定, 但是如果能够很好的组织高温烟气回流, 加热燃料, 使燃料中的水快速蒸发, 则燃烧也会稳定。因此, 需要一个回流区位置可调的燃烧器来研究“水包油”型乳化油的燃烧特性。

几十年来, 在航空和民用工业的燃烧装置中, 普遍采用传统的旋流燃烧器和钝体燃烧器来稳定火焰, 如果燃烧区的温度高, 燃烧就稳定。因此关于回流区的研究是关系到一种火焰稳定装置稳定火焰能力大小的关键课题, 这在今天仍然一直是一个十分活跃的研究领域。文献[2]研究了助燃空气旋转技术对回流区的影响, 实现了几秒钟点燃重油或渣油, 并且避免了冒黑烟的问题。文献[3]详细论述了不同火焰稳定的方法, 同时提出了一种新型的火焰稳定方法——大速差同向射流方法来稳定火焰, 通过达到接近声速的高速射流来形成回流区。在此基础上, 本文提出了一种新型的实现回流区的方法——改变进口空气流量的方法, 来实现回流区的可调性, 并从实验和数值分析两方面对此方法进行了研究。

2 原 理

本文研究的目的是: 对回流区的特性进行研究, 寻找适合燃烧含水量大的水包油型乳化油的回流区。为了能够在实验中方便调节回流区的大小, 使其可以适应不同的油品对回流区的要求, 提出了可调节回流区的设想, 它既能方便调节, 又要结构简单没有活动部件和高温部件, 以免受热变形和卡死。从流体力学中, 我们知道, 流体在突扩管道中流动时, 在突扩管道的台阶面后方会形成回流区, 因此要形成回流区, 必须有突扩管道或台阶面, 而要使回流区的位置能够移动和调节大小, 则要求台阶面能够移动, 但是如果从机械上实现, 则会出现活动部

件;另外,两束速度不同的同心射流,由于速度不同,特别是速度差较大时,会形成回流区,而其位置则与两股射流的速度有关。从上面的流体流动规律中得到启发,将其用到设计中。可调回流区燃烧器的设计思想如下:将燃烧用风分配成 3 部分,根部风、一次风和二次风。根部风用来保护喷嘴,一次风用来调节回流区的位置和大小,而二次风用来形成回流区,为了有利于燃烧和回流区的形成,二次风被高速的一次风吸入,因此在二次风下游形成一高温烟气回流区。实验时 3 部分风的大小由阀门控制,可以通过阀门来改变其大小,从而达到调节回流区的目的。基于此原理,我们设计并制造了一个燃烧器来研究不同油品的燃烧特性,并实现了 30% 含水量的“水包油”型乳化油的正常点火与燃烧。同时,为了能够说明其特点,结合实验使用的参数使用流体力学软件对流场进行了计算。

3 实验研究

实验中,在计算的基础上设计了一个可调回流区的燃烧器,即:一维卧式炉燃烧系统,炉体为 $\Phi 600 \text{ mm} \times 3000 \text{ mm}$ 的直筒,为双层结构,可以对空气进行加热,在尾部有冷却水,烟气经过冷却后由引风机引出,在炉体的前端与燃烧器相接,将空气分为 3 股:根部风 Q_g 、一次风 Q_1 和二次风 Q_2 ,二次风经过炉体夹层加热后,再送入炉膛供给燃烧。喷嘴架在燃烧器与炉体的交接处,由供油系统提供燃烧所用的燃料。同时在燃烧器的头部装有高能点火器,通过放电来点燃燃料。油枪的位置和配风的位置如图 1。

中,保持总风量不变的情况下,改变 3 种风的比例,如一次风和根部风较小时,则可以观察到回流区的位置靠近喷嘴,喷嘴的喷雾淹没在火焰中;当一次风和根部风逐渐增加时,则回流区逐渐远离喷嘴,雾化炬变得清晰可见。如果继续增加一次风和根部风,则火焰被吹向下游,继而被吹灭。

4 模型的描述

计算的燃烧器模型如图 1 所示。对于 100 kg/h 液体燃料(如柴油、汽油和重油等)理论计算的完全燃烧所需空气量约为 1440 kg/h,取过量空气系数 1.1,则所需空气量为 1580 kg/h,下面对冷态流场进行数值模拟来研究回流区与风的分配比例之间的关系。

在计算中,使用标准的 $k-\epsilon$ 模型来描述气相湍流流动;对于控制方程的边界条件,其入口按流量和结构取均匀入口条件;出口为充分发展流,沿轴线方向一阶导数为零;轴线处按对称条件处理,即垂直于轴线的速度为零,其它变量沿法线方向梯度为零;壁面处按无滑移条件处理;近壁处按壁面函数法处理(由于本文的目的不是研究计算方法本身,而是仅用 Fluent 软件获得其结果,因此模型本身的细节从略)。

5 计算结果

表 1 为计算所选择风的流量。共计算了 5 种工况,来说明其特点。

表 1 计算所选择风的流量

工况	根部风流量 Q_g	一次风流量 Q_1	二次风流量 Q_2
1	0	0	1580
2	0	500	1080
3	200	300	1080
4	200	660	720
5	1080	300	200

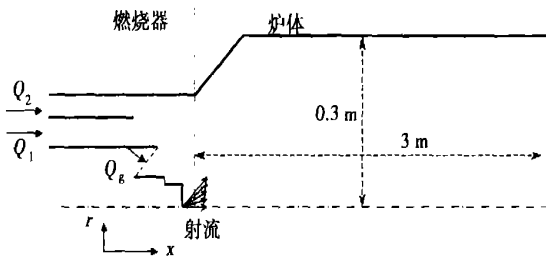


图 1 燃烧器中各部分风的位置分布

在此燃烧器上,通过调节 3 部分风的比例来调节回流区的位置,不但可以燃烧柴油等轻质油品,也可以燃烧重油及其乳化油,研究其燃烧特性。实验

图 2~图 6 是不同工况下的流场分布。从图中可以看出,对于不同风的分配比例,回流区的形成及位置有很大区别,每一种工况条件下(见图 2),回流区向后缩进一次风的通道中,这就是实验中出现的喷嘴被淹没在回流区中。这样,热烟气极易把通道和喷嘴烧坏,因此需要将回流区推向远离喷嘴,如第

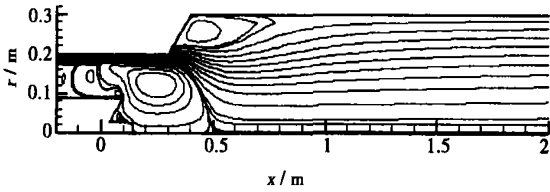


图 2 工况 1 的流场分布

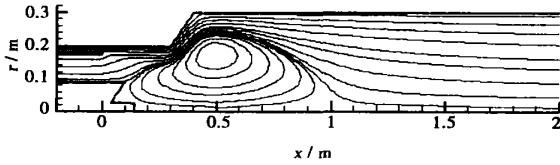


图 3 工况 2 的流场分布

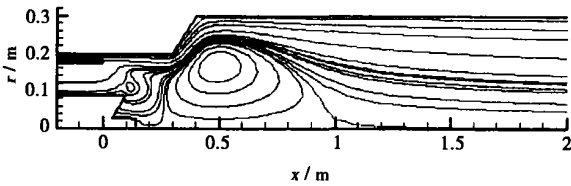


图 4 工况 3 的流场分布

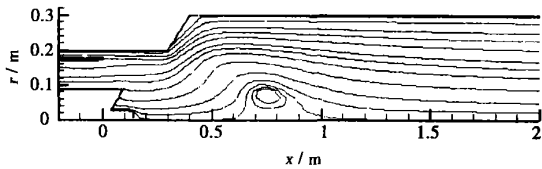


图 5 工况 4 的流场分布

二种(见图 3)和第三种工况(见图 4), 在第二种工况中, 回流区还离喷嘴较近, 因此要增加一点根部风来保护喷嘴, 但是当一次风增大到工况 4(见图 5)时, 回流区又被吹向下游, 也不利于火焰的稳定, 因此存

在一个恰当的风的比例, 使回流区的位置适合燃烧所研究的燃料油。由于实验的燃料油的燃烧特性是未知的, 因此实验时需要调节不同的风流量来调节回流区的位置, 以满足燃烧各种不同燃料的需要, 同时得到此种油品的燃烧特性。当根部风足够大时, 回流区又被转移到紧贴炉壁的位置(见图 6), 这又是一种稳定火焰的方法。此时, 火焰高温区贴近壁面^[4]。

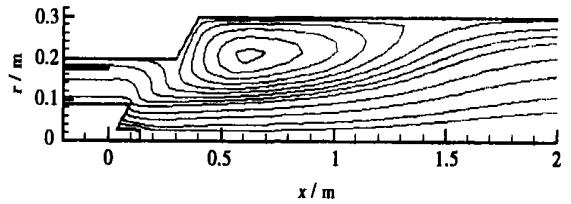


图 6 工况 5 的流场分布

6 结 论

提出了一种实现可调回流区位置的新方法, 并对其特点进行了研究。根据流体力学的规律, 实现了无移动部件和无高温部件(钝体)情况下回流区的可调性, 并设计和制造了一燃烧器来研究不同油品的燃烧特性。同时, 使用 Fluent 软件对回流区的特点进行了计算, 从实验和理论上说明了此回流区确实可调。

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occupies a middle position between the above-cited two elements, resulting in a volatility expressed as $As > Cd > Cr$. Tests have proved that with a rise in temperature the volatility of these elements also gradually increase, and $As \gg Cd > Cr$. **Key words:** trace element; release; As; Cd; Cr

高温低氧燃烧过程中 NO_x 排放规律研究 = **A Study of NO_x Emission Mechanism during a High-temperature and Low-oxygen Combustion Process** [刊, 汉] / ZHONG Shui-ku, MA Xian-guo (Power Engineering Institute under the Shanghai University of Science & Technology, Shanghai, China, Post Code: 200093), ZHAO Wu-fei, SHUI Xiang-rong (Shanghai No. 711 Research Institute, Shanghai, China, Post Code: 200011) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(5). — 483 ~ 486

An experimental investigation was conducted of the NO_x emission mechanism during the process of high-temperature and low-oxygen combustion. The NO_x emission mechanism was identified under various air-preheating temperatures and different oxygen-contents of preheated air. Meanwhile, CFD (computational fluid dynamics) general software has been employed to perform a numerical calculation of the NO_x emission concentration during the high-temperature and low-oxygen combustion process, resulting in the acquisition of some general law-conforming relationships. **Key words:** high-temperature air combustion, NO_x emission, experimental investigation, numerical calculation

木屑在固定床焚烧中 HCl 的控制研究 = **Research on the Control of HCl during the Incineration of Sawdust in a Fixed Bed** [刊, 汉] / JIANG Xu-guang, LI Xiang-pai, CHI Yong, et al (Education Ministry Key Laboratory on Energy Clean Utilization and Environmental Engineering under the Thermal Energy Engineering Institute of Zhejiang University, Hangzhou, China, Post Code: 310027) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(5) — 487 ~ 490

Through tube-furnace tests the dechlorination effectiveness of various dechlorinating agents was investigated. By comparing the dechlorination results of the one and the same dechlorinating agent under various operating conditions the optimum dechlorination conditions were determined. The results of tests indicate that the dechlorination efficiency of calcium-based absorbents is higher than that of magnesium-based absorbents. The optimum dechlorination conditions of CaO can be given as follows: combustion temperature 500 - 600 °C, residence time 5 - 15 min. At a high temperature section the dechlorination efficiency of CaO is reduced drastically due to the high-temperature hydrolysis of dechlorination product $CaCl_2$. **Key words:** HCl, sawdust, combustion, CaO, absorbent, combustion dechlorination, pollution control

基于模糊方法的垃圾焚烧炉燃烧控制系统 = **Combustion Control System of a Fuzzy Logic-based Municipal Solid Waste (MSW) Incinerator** [刊, 汉] / SHEN Kai, LU Ji-dong, LIU Gang, et al (National Key Laboratory on Coal Combustion under the Huazhong University of Science & Technology, Wuhan, China, Post Code: 430074) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(5). — 491 ~ 494

As an item of mature technology for refuse waste-heat utilization refuse incineration systems have found increasing applications in China. The combustion process control of a refuse incinerator constitutes the basis for the stable operation of such incinerators. The authors have conducted a study of the refuse incineration process by making use of a fuzzy method-based control strategy. The fuzzy control algorithm of refuse incineration is briefly described and compared with conventional PID (proportional, integral and differential) control algorithm. The continuous operation of a specific unit based on the recommended algorithm has been realized with a relatively high effectiveness. **Key words:** refuse incineration, fuzzy control, incinerator, fuzzy method

改变进气流量实现可调回流区位置的研究 = **A Study of the Realization of an Adjustable Recirculation-zone Location through the Change of Inlet Airflow Rates** [刊, 汉] / FU Wei-biao, GONG Jing-song (Department of Engineering Mechanics, Tsinghua University, Beijing, China, Post Code: 100084) // Journal of Engineering for Thermal En-

ergy & Power. — 2004, 19(5). — 495 ~ 497

A new method for realizing an adjustable recirculation zone is proposed along with an investigation of its specific features. On the basis of fluid mechanics theory the possibility of adjusting a recirculation zone is realized in the absence of moving elements and high-temperature components (bluff body) to meet the requirement of various kinds of oil with regard to the recirculation zone during their normal combustion. The above-mentioned features are more pronounced, especially in the case of studying the combustion characteristics of “oil-in-water” type of emulsified oil with different water dilution rates. The present study also provides further support for industrial applications. The test and calculation results indicate that this recirculation zone can adapt to the requirements of various ranks of oil. **Key words:** adjustable recirculation zone, “oil in water” type emulsified oil, burner

电站锅炉鳍片管省煤器鳍片尺寸优化模型 = **Optimization Model for Economizer Fin Size in a Utility Boiler** [刊, 汉] / YAN Wei-ping, MENG Xue-mei, LU Yu-kun (Power Engineering Department, North China University of Electric Power, Baoding, China, Post Code: 071003) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(5). — 498 ~ 501

On the basis of heat exchange mechanism and heat transfer control equations of finned tubes a mathematical model is derived for the selection of fin sizes with the maximum heat transfer under the condition of a given fin-metal mass. The objective is to optimize the height and thickness of rectangular straight fins under the typical operating conditions of a utility boiler economizer. Moreover, with the economizer of a utility boiler serving as an object of study the optimization method and procedures are outlined along with a calculation and analysis of the influence of flue-gas flow speed and pollution factor on the optimized sizes. **Key words:** utility boiler, economizer, finned tube, fin size optimization

内可逆四热源吸收式热泵生态学最优性能 = **Ecological Optimal Performance of Endoreversible Four-heat-source Absorption Type of Heat Pumps** [刊, 汉] / QIN Xiao-yong, CHEN Lin-gen, SUN Feng-rui (Department of Nuclear Science and Engineering, Naval Engineering University, Wuhan, China, Post Code: 430033) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(5). — 502 ~ 505

On the basis of an energy-analysis viewpoint established were the ecological criteria reflecting the optimal compromise between four-heat-source absorption heat-pump heating load and entropy production rate. An analysis is given of the ecological optimal performance of endoreversible four-heat-source absorption heat-pumps under a linear (Newtonian) heat transfer law. The following items were derived: the optimization relationship between the ecological objective and pump heating factor; the maximum ecological objective value and its corresponding pump heating factor; pump heating load and entropy production rate. Ecological optimal selection scope of the cycle main parameters was determined. By way of numerical sample calculations analyzed was the relationship between pump heating rate objective and ecological objective. Calculation results indicate that the ecological criteria are a candidate optimization objective having a long-term effect for the optimal design of absorption heat-pumps. **Key words:** four-heat-source absorption heat-pump, ecological criteria, pump heating load, pump heat production factor, entropy production rate

新型喷嘴结构下蒸汽喷射式热泵性能的数值研究 = **Numerical Study of the Performance of Steam-jet Heat Pumps with an Innovative Nozzle Structure** [刊, 汉] / ZHANG Shao-wei, SANG Zhi-fu (Mechanical and Power Engineering Institute under the Nanjing Polytechnical University, Nanjing, China, Post Code: 210009), XU Hai-tao (Jiangsu Suyuan Environmental Protection Engineering Co. Ltd., Nanjing, China, Post Code: 210024) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(5). — 506 ~ 509

By using a CFD (computational fluid dynamics) numerical simulation method a comparison study was conducted of the influence of a conventional nozzle structure and an innovative one on the operating performance of a steam-jet heat pump.