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乳化燃烧技术中涡流共振乳化器的开发与应用

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摘 要: 乳化燃烧过程中需要将互不相溶的油和水均匀混合制成乳化液。为解决油水混合装置混合分散不均匀、寿命短、易堵塞、运行成本高、维护工作量大等问题, 考虑入口旋涡导流片和出口共振簧片的角度和数量, 设计了一种适用于互不相溶液体的涡流共振搅拌混合装置。该装置通过旋涡混合和高频共振使液体产生强制压缩, 形成细微分散液珠, 实现互不相溶的多种液体的均匀混合, 乳化油能稳定保存 3个月以上。搅拌器作为燃油乳化燃烧的混合装置, 被应用于改质煤焦油乳化燃烧中, 节油率由原来的 5.25%提高到 6.75%, 提高了 22%以上, 且该混合装置连续使用寿命可以达到 8年以上。

关 键 词: 涡流共振乳化器; 混合均匀; 煤焦油; 乳化燃烧
中图分类号: TF058 文献标识码: A

引 言

近年来, 乳化燃烧技术因其节能环保而得到广泛应用。乳化的效果在很大程度上取决于乳化器性能。工业企业经常要将两种或两种以上互不相溶的液体 (如油和水)以很细微的颗粒均匀地混合在一起, 以达到不同液体间的分散、乳化和浸润的目的[1]。目前, 常用的混合装置有: 机械搅拌混合装置、簧片哨乳化混合装置、多层滤网式混合装置、电超声波混合装置等。这些混合装置在实际应用中都或多或少地存在一些问题[2]。机械搅拌装置由于频率不高, 传动设备的转速一般不超过 3 000 r/min, 搅拌混合液体的颗粒大小不一, 分散不均匀, 易于分层。簧片哨乳化混合装置是将互不混溶的液体按比例通过喷嘴高速喷出, 迎面冲击固定在支座上的簧片, 使之产生振动发射出超声波, 以迫使液体激烈分散, 其频率约 5 000 Hz, 混合效果较机械搅拌好, 但因簧片寿命短, 实践中亦少采用。多层滤网式混合装置是将混合液体在流动中通过多层滤网时进行细微化混合, 不需要另外消耗电能, 但由于滤网孔径较小, 而有些液体 (如煤焦油、重油、沥青等)的粘度较大、流动性较差, 温度较低时容易结块, 有时液体中难免含有少量固体颗粒状杂质, 易将网孔堵塞, 运行维护工作量大, 实际应用困难。电超声波混合装置比上述 3种装置要好[3]。由于电超声波的频率高 (2×10^4 Hz左右), 在高频振荡下油、水等互不相溶液体可产生强制压缩, 乳化颗粒细小均匀, 不易分层, 具有较好的稳定性, 但该装置需要消耗较多的电能以产生高频振荡, 运行成本较高[4]。基于上述原因, 这几种混合装置在实际生产中的使用都难以达到实践要求。为此, 研究开发了一种适于互不相溶液体的可应用于乳化燃烧技术中的涡流共振乳化器, 应用该装置进行混合乳化不需消耗额外的电能或机械能。

1 高粘度油乳化燃烧中新型乳化器的设计

1.1 新型乳化器结构形式及设计原理

对于高粘度劣质油, 如重油、煤焦油, 采用乳化燃烧技术, 可大为改善其燃烧状况, 降低污染, 节约能源。适于油水乳化的涡流共振零搅拌细微混合装置如图 1所示。除保湿耐火纤维棉外, 其余部分均为不锈钢材质。当互不相溶的两种或两种以上液体由液体入口管流经该装置时, 在入口导流片的压缩下, 液体流速加快, 对四周液体产生雾化。同时, 在入口导流片的作用下, 液体以螺旋式旋转向前进入涡流共振盒, 由于容器容积突然增大, 液流外环部分在涡流共振盒内形成涡流, 液流中心部分液体仍然以较大的轴向速度前进, 并对共振簧片产生冲击, 使之产生振动发射出超声波, 以迫使互不混溶的液体激烈分散成超细微颗粒, 其频率约 5 000 Hz, 乳化混合效果很好。同时在该装置内部均匀分布的 3块共振簧片的顶部汇合成一点, 相互支撑, 不易磨损和振

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坏, 有效地保证了共振簧片的寿命。后续液体继续向前推动前面的液体流动, 经超声波作用分散形成的超细微颗粒只能在 3块共振簧片组成的中间空腔被剪切后通过, 这样液珠被再一次混匀。

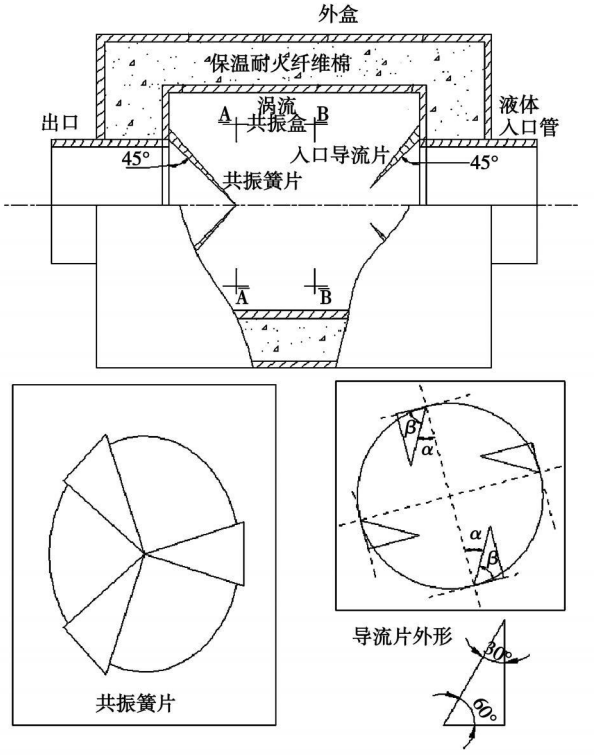

图 1　一种涡流共振细微混合装置

1. 2　内腔侧壁与导流片及共振簧片的设计角

导流片与液体流向之间的夹角为 α=30 ~60°, 与液体入口圆周切线之间的夹角为 β=45°, 如图 2所示。

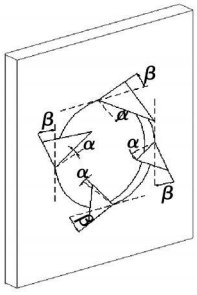

图 2　导流片与液体流向之间的夹角

当共振簧片与内腔侧壁呈 30°交角时, 油水混合物经过本装置搅拌混合后, 透光倍率为 800时, 两种介质的细微混合率达到 98. 20%, 如图 3所示; 当共振簧片与内腔侧壁呈 45°交角时, 油水混合物经过本装置搅拌混合后, 透光倍率为 250时, 两种介质的细微混合率达到 98. 50%, 如图 4所示; 当共振簧片与内腔侧壁呈 60°交角时, 油水混合物经过本装置搅拌混合后, 透光倍率为 100时, 两种介质的细微混合率达到 98. 45%, 如图 5所示。可见, 共振簧片与内腔侧壁交角为 45°时, 混合效果较好。

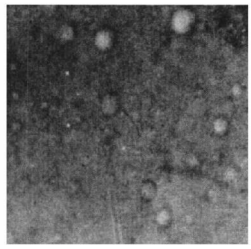

图 3　当共振簧片与内腔侧壁呈 30°交角时, 透光倍率为 800时拍摄的显微照片

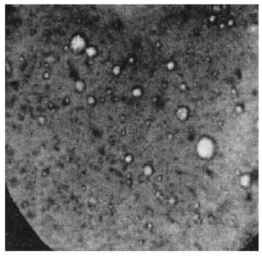

图 4　当共振簧片与内腔侧壁呈 45°交角时, 透光倍率为 250时拍摄的显微照片

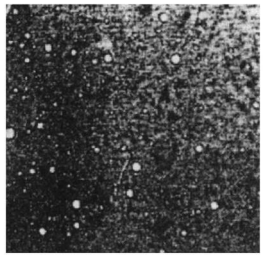

图 5　当共振簧片与内腔侧壁呈 60°交角时, 透光倍率为 100时拍摄的显微照片

2　新型乳化装置与目前产品的应用对比

燃油乳化燃烧新技术是将水按 8% ~28%的比例先加入油中, 制成油中水滴型乳化燃料[5]。由于油水是两种互不相溶的液体, 很容易分层。为此, 常规的做法是将乳化剂先加入水中, 然后逐步加油, 同时进行强烈搅拌使之细微混合形成乳化油。而本研究开发的液体零搅拌细微混合装置给管道增加的阻力很小, 不需外力搅拌, 也不需要消耗电能, 利用超

声振动原理和涡流细微混合原理实现了燃油和水这两种互不相溶的液体的零搅拌细微混合。

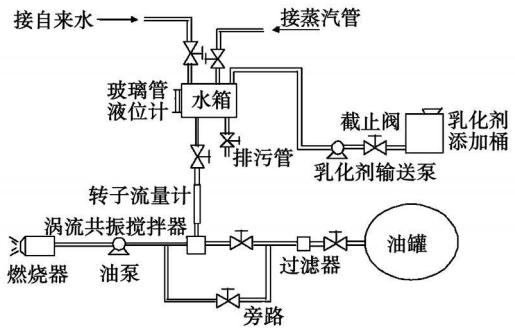

图 6 涡流共振乳化器在乳化燃烧中的系统图

图 7 采用涡流共振乳化器进行煤焦油乳化燃烧时的火焰情况

图 8 采用机械搅拌装置进行煤焦油乳化燃烧时的火焰情况

某厂 130 t/h煤粉锅炉改用煤焦油作为点火燃料,并采用本研究开发的适于互不相溶的液体涡流共振细微混合装置作为乳化器进行油水混合燃烧,乳化燃烧系统如图 6所示。应用该装置作为乳化器进行煤焦油与水混合乳化燃烧时燃烧火焰情况如图 7所示。而该厂以前采用机械搅拌进行煤焦油乳化燃烧时的燃烧火焰情况如图 8所示。从图 7和图 8的对比可以看出,采用涡流共振混合器作为煤焦油乳化燃烧的乳化器时,火焰长、颜色发白而明亮,无黑烟,燃烧完全;而采用机械搅拌设备作乳化器时,煤焦油的乳化燃烧火焰发黄而粗大,有少许黑烟。很显然,图 8的燃烧效果不如图 7。

可见,采用涡流共振混合器作为乳化器进行乳化燃烧时,不完全燃烧可燃产物的生成量大大减少,烟道着火现象得到有效抑制,氮氧化物的排放浓度大幅度降低,节油率也由原来的 5.25% 提高到 6.75%,节油率提高了 22%以上。

3 结 论

(1)采用涡流共振乳化器进行乳化燃烧比采用机械搅拌乳化器进行乳化燃烧时,节油率由原来的 5.25%提高到 6.75%,提高了 22%以上。

(2)由于该装置依靠漩涡混合和高频共振使液体产生强制压缩,乳化混合颗粒细微均匀,不易分层,具有良好的稳定性。乳化油能稳定保存 3个月以上。

(3)对于流动的互不相溶液体,利用混合液在管道中流动所具有动势,涡流共振混合装置不需要消耗额外的机械能或电能,即可实现乳化混合。

(4)涡流共振混合装置最薄弱的部分是受到液流强烈冲击的共振簧片,由于采用了 3块簧片相互支撑的保护结构,共振簧片的强度大大加强,连续使用寿命可以达到 8年以上。

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test system with the influence of the main controllable parameters during the design and operation of the system on the furnace temperature and fuel combustion efficiency being mesured. It has been found that the furnace temperature will rise with an increase of the primary air rate and dilution/mixing mass percentage content and decrease with an increase of the excess air ratio. The fuel combustion efficiency will increase with the primary air rate and dilution/mixing mass percentage content. It will increase first and then decrease with an increase of excess air ratio. When the excess air ratio is set at 1.7, dilution/mixing mass percentage content is 15% and the primary air rate is 75%, the furnace temperature will reach 880 ℃ with the fuel combustion efficiency being assessed at 97.4%.
Key words: waste incineration, biomass, furnace temperature, combustion efficiency

SOFC/MGT顶层循环混合发电系统改进 = Improvement of a SOFC/MGT (Solid Oxide Fuel Cell/Micro Gas Turbine) Top-level Cycle Hybrid Power Generation System [刊, 汉] / DUAN Li-qiang, HE Bin-bin, YANG Yong-ping (Education Ministry Key Laboratory on Power Plant Equipment Condition Monitoring and Control, North China University of Electric Power, Beijing, China, Post Code: 102206) // Journal of Engineering for Thermal Energy & Power. — 2010, 25(3). — 344 ~ 349

The measures for improving the hybrid power generation system of a typical top-level cycle SOFC/MGT (solid oxide fuel cell/micro gas turbine) were proposed and ceramic mesotron membrane was used to separate the reaction product at the positive pole of the cell pile in the first stage. The hydrogen thus separated was introduced onto the positive pole of the cell pile in the second stage to continue the electrochemical reaction after having been cooled, pressurized and preheated. The reaction product from the cell pile in the second stage and the gas remaining after the hydrogen separation were fed into the rear combustor to conduct a combustion reaction. In combination with a specific calculation case, a simulation analysis was performed of the above two-stage tandem power generation system. The research results show that because of an increase of the hydrogen quantity for electrochemical reactions, the hydrogen quantity for the combustion reaction will decrease, making it possible to remarkably lower the exergy loss of the whole system and thereby raising the power generation efficiency of the improved system by 2.92 percentage points, which is higher than the reference system at an identical utilization rate of the fuel cell piles and at a same turbine inlet temperature. The foregoing measure is regarded as an effective method for improving the SOFC/MGT hybrid power generation system.
Key words: solid oxide fuel cell, micro gas turbine, hybrid power generation system, top-level cycle, ceramic mesotron membrane

乳化燃烧技术中涡流共振乳化器的开发与应用 = Development and Application of an Eddy-current Resonance Emulsifier in Emulsification Combustion Techniques [刊, 汉] / DENG Sheng-xiang, LI Xin-hui, ZHOU Jie-min (College of Energy Science and Engineering, Central South University, Changsha, China, Post Code: 410083) // Journal of Engineering for Thermal Energy & Power. — 2010, 25(3). — 350 ~ 352

The emulsification combustion process is required to uniformly blend the mutually indissolvable oil and water to prepare a emulsification solution. To solve such problems in the oil/water mixer as discrete and nonuniform mixing, short service life, frequent jamming, high operation cost and heavy maintenance work load etc., the angle and number of the inlet eddy-current guiding plates and outlet resonant reeds to be installed were taken into consideration by designing an eddy-current resonance-agitation mixing device suitable for mutually indissolvable liquids. The device can force the liquids to produce a compulsory compression through an eddy mixing and high frequency resonance and to form fine liquid droplets, thus realizing a uniform mixing of multiple liquids mutually indissolvable. The emulsified oil can be stabilized and kept for more than 3 months. As a mixing device for fuel oil emulsification combustion, the agitator was used for denatured coal tar emulsification combustion. The oil saving rate can be increased from the original 5.25% to 6.75%, effecting an enhancement of more than 22%. The mixing device has a continuous service life of more than 8 years.
Key words: eddy resonance, emulsifier, homogeneous mixing, coal tar, emulsification combustion