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水平管内油气水三相分层流截面含气率的研究

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摘　要: 以油气水三相混合物为工质, 对水平管内分层流动的平均截面含气率进行了理论与实验研究。通过对分层流动的简化动力学分析, 得到了截面含气率的理论模型, 计算值与实验值符合良好。结果表明: 影响分层流截面含气率的因素不仅包括折算气速和折算液速, 还包括油水混合物的含油率。

关　键　词: 水平管; 截面含气率; 油气水三相流; 分层流

中图分类号: O359; TQ022.4　　　文献标识码: A

1　引言

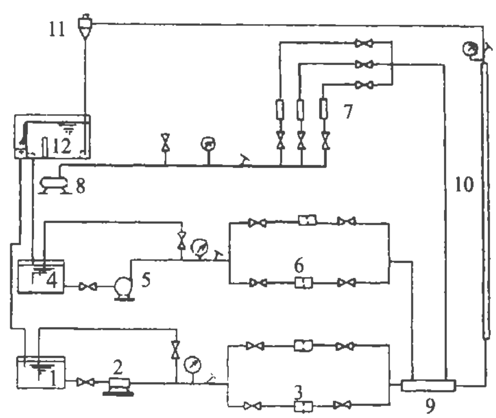
随着油气田的不断开采, 油气水三相流技术得到了越来越广泛的应用, 油气水三相流压降的计算是其中的一个重要分支。平均截面含气率的准确计算是油气水三相流重位压降和摩擦压降准确计算的前提[1~2], 由于油田地面混输管路中经常处于气液分层流动的形态, 因此油气水三相分层流动的截面含气率计算是油气集输管路设计中急待解决的问题[3]。

2　实验系统

实验在油－气－水三相流实验系统上进行[4], 如图 1 所示。其流程如下: 油(46 号机油)从油箱中经齿轮式油泵抽出, 经流量孔板测量后, 流入油气水三相混合器; 水从水箱中经离心式水泵加压, 经流量孔板测量后, 流入油气水三相混合器; 空气经空压机升压后, 用玻璃转子流量计计量, 然后也流入油气水三相混合器。在混合器内油气水三相充分混合后进入实验段进行实验测量后, 于旋风分离器分离出空气。剩下的油水混合物流进油水分离器, 分离出的油和水分别流回油箱和水箱, 以便循环使用。

实验段由实验管、与实验段内径相同的旁通管和与实验管内径相同的三个球阀及连接机构构成。实验管为有机玻璃管, 压差测量段长度为 1 500 mm, 规格为 Φ32 mm×3 mm。

实验参数范围如下: 压力: $P=0.1\sim0.6$ MPa; 温度: $T=5\sim30$ ℃; 气相折算速度: $U_{SG}=0\sim20$ m/s; 液相折算速度: $U_{SL}=0\sim2.5$ m/s。



1— 油箱; 2— 齿轮式油泵; 3— 油路孔板; 4— 水箱;
5— 离心式水泵; 6— 水路孔板; 7— 转子流量计;
8— 空压机; 9— 三相混合器; 10— 实验段;
11—旋风分离器; 12— 油水分离器

图 1　油气水三相流实验系统

在实验中, 空气的流量采用沈阳玻璃仪器厂生产的 LZB 型玻璃转子流量计来测量。油和水的流量使用锐边孔板来测量, 测量的所有信号均采用 3595 数据采集系统进行采集记录。

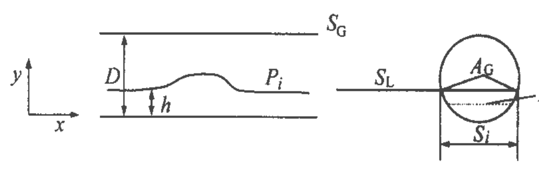


图 2　分层流流动结构示意图

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3 理论模型

在分层流动中，气相和油水混合物组成的液相具有明显的分界面，分为气体层和液体层。其流动结构见图2。图中S_G和S_L分别代表横截面上气体和液体与管壁的边界周长，S_i代表气液界面的周长。τ_G、τ_L和τ_i分别代表气相、液相与管壁之间的切应力和气液之间的摩擦切应力，A_G和A_L分别是气相和液相的流动截面积。列出各相的动量方程：

$$A_G\frac{\partial p}{\partial z}-\tau_G S_G-\tau_i S_i=0 \tag{1}$$

$$A_L\frac{\partial p}{\partial z}-\tau_L S_L+\tau_i S_i=0 \tag{2}$$

式(1)和式(2)分别除以A_G和A_L，再相减，可得

$$\frac{\tau_G S_G}{A_G}-\frac{\tau_L S_L}{A_L}+\tau_i S_i\left(\frac{1}{A_G}-\frac{1}{A_L}\right)=0 \tag{3}$$

根据截面含气率的定义，有

$$A_G=\alpha A \tag{4}$$

$$A_L=(1-\alpha)A \tag{5}$$

把式(4)、式(5)代入式(3)，得

$$\frac{1}{1-\alpha}\frac{\tau_L S_L-\tau_i S_i}{\tau_G S_G+\tau_L S_L}=1 \tag{6}$$

式(6)是截面含气率α的隐函数表达式，只有知道截面含气率，才能确定S_G、S_L、S_i和τ_i。由分层流动的几何结构可以得到截面含气率与管路中心角的关系：

$$\alpha=1-\frac{\theta-\sin(\theta)}{2\pi} \tag{7}$$

知道了中心角，可以算出气相和液相的管壁湿周和气液分界面的宽度。

$$S_G=D(\pi-\theta/2) \tag{8}$$

$$S_L=D\,\theta/2 \tag{9}$$

$$S_i=D\sin(\theta/2) \tag{10}$$

摩擦系数的计算如下：

$$\tau_L=f_L\rho_L U_{SL}^2/2(1-\alpha)^2 \tag{11}$$

式中f_L为摩擦系数。

$$f_L=C_L\left[\frac{dU_{SL}}{v_L(1-\alpha)}\right]^{-m} \tag{12}$$

式中$C_L=0.0791$，$m=0.32$，

$$\tau_G=f_G\rho_G U_{SG}^2/2\alpha^2 \tag{13}$$

式中f_G为气相与管壁的摩擦系数。

$$f_G=C_G\left(\frac{dU_{SG}}{v_G\alpha}\right)^{-n} \tag{14}$$

式中$C_G=0.0791$，$n=0.2$。

$$\tau_i=f_i\rho_G[U_{SG}/\alpha-U_{SL}/(1-\alpha)]^2/2 \tag{15}$$

$$f_i=0.0791\left(\frac{dU_{SG}}{v_G}\right)^{-0.1}\left[1+3\left(\frac{\rho_L}{\rho_G}\right)^{\frac{1}{3}}\right] \tag{16}$$

把式(8)～式(16)代入式(7)中，得到：

$$B=\frac{C\theta-0.0791\left(\frac{dU_{SG}}{v_G}\right)^{-0.1}\left[1+3\left(\frac{\rho_L}{\rho_G}\right)^{\frac{1}{3}}\right]\rho_G\left[\frac{u_{SG}}{1-B}-\frac{u_{SL}}{B}\right]^2\sin\left(\frac{\theta}{2}\right)}{C\theta+2D(\pi-0.5\theta)\frac{B^2}{(1-B)^2}} \tag{17}$$

式中，$B=\frac{\theta-\sin\theta}{2\pi}$，$C=C_L\left(\frac{du_{SL}}{v_L B}\right)^{-m}\rho_L u_{SL}^2$，

$$D=C_G\left[\frac{du_{SG}}{v_G(1-B)}\right]^{-n}\rho_G u_{SG}^2 \tag{18}$$

从式(17)中求出管路中心角后，即可按式(7)得到截面含气率。油水混合物表观粘度的计算取自蔡继勇拟合的关联式[5]。

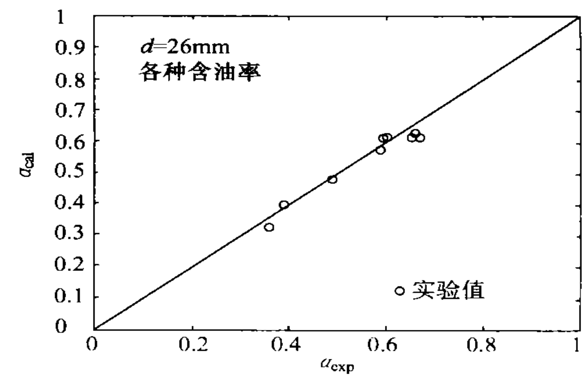

图3 截面含气率的计算值与实验值的比较

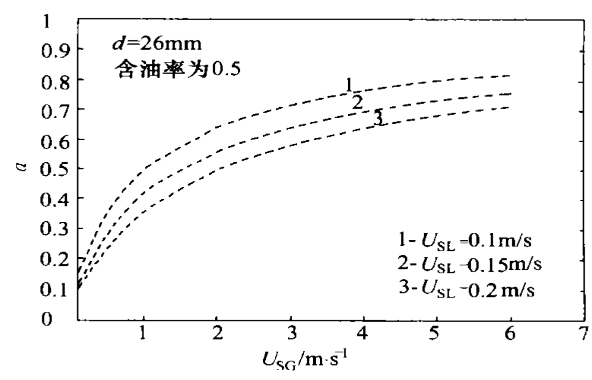

图4 截面含气率随折算气速和折算液速的变化规律

4 实验结果

由图3可知，截面含气率的理论值与实验结果符合良好。图4给出了分层流截面含气率随折算气

速和折算液速的变化规律。从图中可以看出, 当折算气速较小时, 截面含气率随折算液速的增加迅速增加; 当折算气速较大时, 截面含气率增加缓慢。图 5 给出了分层流截面含气率随油水混合物含油率变化的规律, 随着含油率单调增加, 分层流的截面含气率单调减小。当油水混合物从水包油态转变为油包水态时, 即液相物性变化明显时, 截面含气率减小明显。

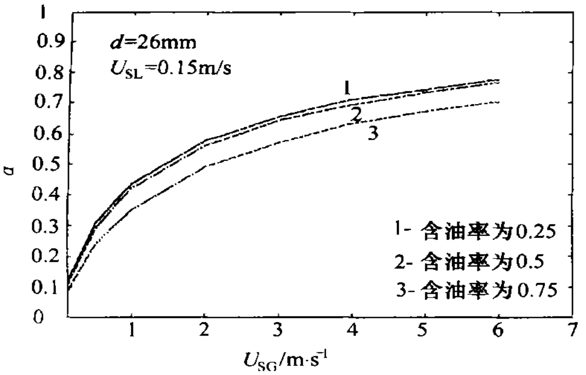

图 5　分层流截面含气率随油水混合物含油率的变化规律

5　结论

(1) 以双流体模型为基础, 通过对水平管内油气水三相混合物分层流动的简化动力学分析, 得到了水平管内分层流动截面含气率的理论模型, 计算值与实验值符合良好。

(2) 研究表明, 影响水平管内截面含气率的因素不仅包括折算气速和折算液速, 油水混合物的含油率对其也有一定影响。

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(渠　源　编辑)

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低于大部分煤粉灰熔点, 与低灰熔点煤灰熔点较接近, 垃圾灰熔点与成分的相互关系基本与煤粉灰的分布规律一致, 垃圾灰熔点可以表达为垃圾灰中各种矿物质及其低熔点共熔体的熔点的加权平均值。垃圾焚烧灰在受热面上的沉积与其受热面的工作温度和烟气温度有关, 由于垃圾灰中的低熔点共熔体含量较高, 在燃烧时易挥发或分解形成气溶胶, 在遇到相对低温的尾部受热面便冷却进而沉积下来, 因此沉积灰熔点与沉积位置受热面和烟气温度有关。

几种炉型不同程度都存在着受热面积灰或腐蚀问题, 腐蚀与积灰相互作用导致对受热面的破坏加剧, 蒸汽吹灰由于耗汽量较大, 垃圾焚烧炉不易采用。就目前而言, 还没有完善的吹灰设施彻底解决垃圾焚烧炉受热面的积灰问题, 有待进一步开发新一代的吹灰装置。热解焚烧炉在热解时携带大量固体颗粒, 即使燃烧温度达到 1 000 ℃也有相当一部分未完全燃烧的固体颗粒进入余热利用的尾部受热面, 造成受热面积灰严重, 以至在运行期间一个月停炉清灰一次, 严重影响了机组的正常运行, 相当一部分工作日运行负荷不足, 降低了运营商的经济效益, 同时减少了垃圾的处理量。从燃烧角度分析, 由于垃圾灰的灰熔点相对较低, 在热解焚烧炉或采用二次燃烧的垃圾焚烧炉中, 高温燃烧可以采用旋风炉、液态排渣炉, 让垃圾灰以液体的形式排出, 从而减少由于热解的燃烧方式造成的受热面严重积灰问题; 同时由于液态排渣炉的燃烧温度较高, 对抑制二恶英的排放有一定的作用。

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Journal of Engineering for Thermal Energy &Power. —2002, 17(4): 363~366

From the perspective of influencing factors of thermobalance construction and test conditions, etc., analyzed are the causes leading to differences in the test results of pulverized coal combustion characteristics obtained from different thermobalances. Meanwhile, some proposals are put forward to improve the comparability of test results of pulverized coal combustion characteristics obtained from different thermobalances. **Key words**: thermobalance, pulverized coal combustion test

水平管内油气水三相分层流截面含气率的研究=**A Study of the Void Fraction of Oil-gas-water Three-phase Stratified Flows in a Horizontal Tube** [刊, 汉] / ZHOU Yun-long, SUN Bin, CAI Hui, et al (Power Engineering Department, Northeast Electric Power Institute, Jilin, China, Post Code: 132012) //Journal of Engineering for Thermal Energy &Power. —2002, 17(4): 367~369

With an oil-gas-water three-phase mixture serving as a working medium a theoretical and experimental study was performed of the average-section void fraction of stratified flows in a horizontal tube. Through a simplified dynamic analysis of the stratified flows a theoretical model was obtained of the section void fraction. The calculated values agree well with experimental ones. It has been found that the factors having an influence on the section void fraction of the stratified flows include not only the reduced gas speed and liquid speed, but also the oil fraction of the oil-water mixture. **Key words**: horizontal tube, section void-fraction, oil-gas-water three-phase flow, stratified flow

竖直细小管内水—空气环状流蒸发换热特性研究=**A Study of the Evaporation Heat Exchange Characteristics of Water-air Annular Two-phase Flows in a Vertical Slender Tube** [刊, 汉] / YI Jie, LIU Zhen-hua, WANG Jing (Power and Energy Engineering Institute under the Shanghai Jiaotong University, Shanghai, China, Post Code: 200030) //Journal of Engineering for The0rmal Energy &Power. —2002, 17(4): 370~374

Through a theoretical analysis a study has been carried out concerning the evaporation heat exchange characteristics of water-air annular two-phase flows in a vertical slender tube. The study results indicate that in a slender tube the influence of gravitational force and gas-liquid surface tension force can be neglected. The evaporation heat exchange characteristics under a constant heat-flux density very approximate to those under a constant wall temperature. The results of calculation have also shown that the evaporation heat exchange of water-air two-phase annular flows in a vertical slender tube represents a very effective means of intensified heat exchange. **Key words**: annular two-phase flow, evaporation, intensified heat exchange, phase change

正倾斜叶片压气机叶栅二次流的数值研究=**Numerical Investigation of Secondary Flows in a Compressor Cascade with Positively leaned Blades** [刊, 汉] / WANG Hui-she, ZHONG Jing-jun, WANG Zhong-qi (Energy Engineering College under the Harbin Institute of Technology, Harbin, China, Post Code: 150001), ZHAO Gang (No.1 Engineering Division of Heilongjiang Thermal Power Co., Harbin, China, Post Code: 150001) //Journal of Engineering for Thermal Energy &Power. —2002, 17(4): 375~378

With the help of Beam-Warming's approximate and implicit factorization scheme and a MML algebraic turbulence model and by using the method of quasi-compressibility for the solution of a Reynolds-average quasi-compressibility N-S equation a numerical investigation was performed of the three-dimensional viscid flow field of a compressor cascade with positively leaned blades. The results of the investigation were compared with those of a linear cascade. It has been found that the generation and development process of the upper and lower channel vortex of the positively leaned cascade is distinctly different from that of the linear cascade. This has led to a weakening of the secondary flow at the positively leaned side, an expansion of the secondary-flow high loss zone at the negatively leaned side and a deterioration of the flow conditions. The separation of the boundary layer at the cascade top region has developed into a greater zone expanding to the cascade middle portion. The calculated results agree relatively well with the experimental ones. **Key words**: leaned blade, compressor cascade, secondary flow, quasi-compressibility N-S equation

带粒透平中叶片冲蚀的数值计算及振频变化预估=**The Numerical Calculation of Blade Erosion in a Particle-**