固体通量法的验证

马鲁铭[*]　高廷耀[**]

【提要】 理论和实践都证实，二沉池稳定运行时成层沉降区的污泥浓度小于进池的浓度，并不存在极限固体通量的限制断面。实验验证，运行时污泥供给率可以远大于求得的极限固体通量的值。

固体通量法作为设计连续流浓缩池和二次沉淀池面积的主要理论方法已被广泛介绍，但理论和实践均可证明该方法的结论不能成立。

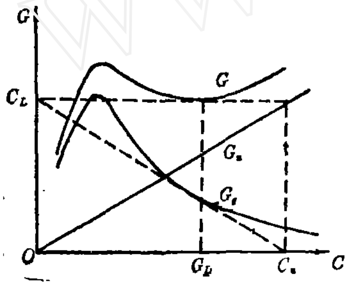

图 1　固体通量曲线

一、理论分析

（1）稳定运行工况只是固体通量曲线上的一点

对于理想的成层沉淀，有$V=f(c)$。二沉池稳定运行时$u=\text{const}$，则：

$$G=uc+Vc=uc+c\cdot f(c)=G(c) \qquad (1)$$

式中　G——固体通量；u——底流速度；

c——污泥浓度；

V——污泥颗粒集团沉速。

G虽然不是c的单调函数，我们可以把它分为几个单调的区域，在单调区域中$c=G^{-1}(G)$是单值函数。

在池中各断面物质守恒，即$G=\text{const}$，因为污泥沉速不可能跳跃式变化，得到：$c=\text{const}$。

也就是说稳定运行工况在固体通量曲线上是一个点。

（2）固体通量曲线上单调上升区域为稳定运行工况区域

设二沉池进水口之下有一微层，处于上断面i与下断面j之间。

在单调上升区域，当$c_j>c_i$时，有$G_j>G_i$。

当某一偶然因素使得该微层污泥浓度增加时，即$c_j>c_i$时，通过下断面j的固体通量G_j大于通过上断面的固体通量G_i，迫使微层浓度稀释到原浓度c_i。反之亦然。即运行工况稳定在固体通量曲线单调上升区域的某一个点上。

在单调下降区域，当$c_j>c_i$时，有$G_j<G_i$。

当某一偶然因素使该微层污泥浓度增加时，即当$c_j>c_i$时，通过下断面j的固体通量G_j反而小于通过上断面的固体通量G_i，使得该微层浓度不断增大，直至退出该单调下降区域进入单调上升区域。反之亦然。即运行工况点不可能稳定在固体通量曲线单调下降区域。

（3）成层沉降区污泥浓度小于进二沉池混合液浓度是稳定运行的必要条件

进水口断面处混合液分为二路，向上的流速为：

$$u_e=\frac{Q_e}{A-A_0} \qquad (2)$$

向下的流速为：

$$u=\frac{Q_u}{A} \qquad (3)$$

达到稳定运行时，固体通量G等于污泥供给率$\frac{Q_0c_0}{A}$：

$$G_n=uc_n+V_nc_n=\frac{Q_0c_0}{A} \qquad (4)$$

式中　Q——流量；A——二沉池面积

A_0——进水中心管断面积。

当加下标0、e、u、n时分别表示进二沉池的、上溢液的、底流量的、成层沉降区的相应值。

令 $$G_0 = uc_0 + V_0 c_0 \quad (5)$$

运行正常，溢流出水不带泥要求：

$$V_0 \geqslant u_e \quad (6)$$

即 $$V_0 \geqslant u_e = \frac{Q_e}{A - A_0} > \frac{Q_e}{A} \quad (7)$$

上式两边同乘c_0，同加uc_0，得：

$$uc_0 + V_0 c_0 > \frac{Q_e}{A} c_0 + uc_0 \quad (8)$$

将（3）式代入，得：

$$G_0 > \frac{Q_0 c_0}{A} = G_n \quad (9)$$

因为只有固体通量曲线上单调上升区域才是稳定运行工况区域，得到：$c_0 > c_n$ （10）

也可以从（9）式直接得到（10）式，理解为：进水混合液污泥浓度由于"自身沉淀性能"所传递的固体量必须大于要传递的固体量（污泥供给率）。因此，进水浓度必然一直稀释到c_n。

（4）固体通量法的逻辑错误

固体通量法隐含两个矛盾的前提：a)沉速仅仅是固体物质浓度的函数；b)在这个区域中固体物质浓度随深度递增。实际上在成层沉降区固体物质浓度不但没有增加，而且还下降了。浓缩只是在压缩沉淀区中进行，而影响压缩沉淀速度的主要因素是压缩区的高度和浓缩时间，这时不能假定沉速仅仅是浓度的函数。

二、实验验证

实践已证明，竖流式二沉池稳定运行时，存在着成层沉降区，在这个区域中$c_n < c_0$。在此我们只需验证固体通量法的结论：稳定运行时污泥供给率一定要小于或等于极限固体通量，即：$\frac{Q_0 c_0}{A} \leqslant G_L$。

试验流程如图2。

模型二沉池尺寸为：内径$D = 229$mm；高$H = 3020$mm。

静沉筒结构：内径$\phi 90$mm；高1500mm。三根$\phi 1.5$金属丝搅拌，转速1r/min。

模型二沉池已连续运行22个小时，泥水界面位置及各取样口处混合液的SV值都不再变化，说明运行已达到稳定状态。取样测定池中污泥浓度分布如图3所示，可见符合"双界面四段分布"规律，其中第三只取样点处于成层沉降区（$c_n = 2.41 < c_0 = 2.51$g/l）。由多次静沉实验得出的成层沉淀时沉速与浓度的关系以及由此得到的固体通量曲线绘于图4。结果证实：模型二沉池运行时的污泥供给率远远大于极限固体通量，即$\frac{Q_0 c_0}{A} = 8.57 > G_L = 6.85$mg/(cm²·min)，甚至大于八次静沉实验中七次固体通量值，由此证明固体通量法的结论不能成立。

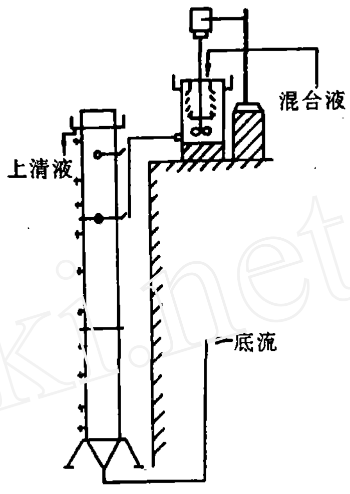

图 2 试验流程

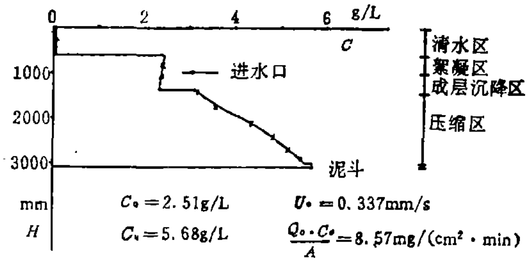

图 3 模型二沉池运行时池中污泥浓度分布

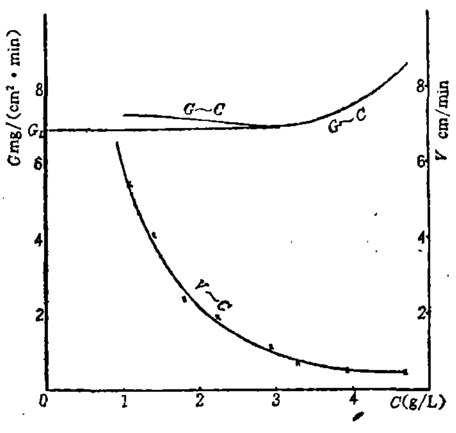

图 4 实测污泥浓度与成层沉淀沉速及其固体通量的关系曲线

㊀ 作者通讯处：*200237上海华东化工学院378信箱
**200092上海同济大学

STUDY OF GENTAMICIN FERMENTATION WASTE TREATMENT BY ANOXIC-AEROBIC SEQUENCING BATCH BIOLOGICAL ACTIVATED SLUDGE PROCESS ………… *Zhu Haochuan et al.* (**24**)

Abstract: Gentamicin fermentation waste, a high concentration organic wastewater containing antibiotic, is difficult to treat. This article describes a successful treatment of this kind of wastewater by anoxic—aerobic sequencing batch biological activated sludge process. The influent concentration (COD = 12000mg/L, BOD = 4000mg/L and NH_3—N = 160mg/L) and the removal efficiency (η_{COD}>90%, η_{BOD}>98% and $\eta_{NH_3\text{-}N}$>90%) are far beyond the usual limits, This process, featured by high efficiency, low energy consumption, easy control and stable function, is suitable for the treatment of high concentration organic wastewater with a small flow. The mechanism is discussed and the operating parameters are suggested in this paper.

AN EXAMPLE OF WASTEWATER TREATMENT OF PRINTED CIRCUIT PLATES ………… *Mu Chuanqi* (**29**)

Abstract: The wastewater of printed circuit plates discharged by Jingfeng Co. in Shenzhen was previously treated by conventional chemical method and the effluent failed to meet the standard until some renovations were made by the author such as that the reactor filled with steel chips was adopted. Both the contents of copper and nickel in the effluent are now below 0.5mg/L.

A BRIEF INTRODUCTION TO THE DESIGN AND OPERATION OF THE WASTEWATER RECLAIMATION AND REUSE STATION OF BEIJING HEAVY-DUTY MACHINERY FACTORY ………… *Huang Xiaojia et al.* (**30**)

Abstract: Through a tertiary treatment including coagulation, sedimentation and sulphonated carbon treatment, the COD and oil contents of the final effluent from Beijing Heavy—Duty Machinery Factory are reduced respectively from 100~200 mg/L to below 10 mg/L and from 20~50 mg/L to below 5mg/L, and the quality of the treated water meets the factory's controlled values for reuse.

NOMOGRAPH FOR THE HYDRAULIC CALCULATION OF SEWAGE PIPELINES ………… *Fan Jianjun* (**32**)

Abstract: Based on comprehensive study of the interrelations existing among the hydraulic parameters of the non—pressure uniform flow in round pipes, this article presents the nomograph for the hydraulic calculation of sewage pipelines. With the nomograph given in the paper, all the calculation of sewage pipelines can be easily and conveniently done.

VERIFICATION OF SOLID FLUX LAW ………… *Ma Luming et al.* (**34**)

Abstract: Both theory and practice prove that the sludge concentration in the zone settling area is below that of the influent during stable operations of the secondary clarifying tank and there doesn't exist a section of limiting solid flux. Experiments indicate that the sludge feed rate during operation can be much greater than the limiting flux value.

DISCUSSION ON WATER SEAL FAILURE ………… *Zhao shiming* (**36**)

Abstract: Taking into consideration of several prerequisites for water seal failure, this article analyses the main factors causing water loss from traps. The results indicate that seal failure will occur if the drainage in traps is not enough for the inevitable loss during the term of validity. The critical conditions of the failure can be expressed as follow: the loss head of induced siphon $h_i = 30 \pm \delta_1$ (mm); the maximum pressure