FLOW FIELD SIMULATION AND ANALYSIS OF BAG FILTER FOR AGRICULTURE SEWAGE
/
农业污水袋式过滤器内流场特性仿真分析

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Abstract: *According to the agriculture sewage in the process of filtering impurity, medium pressure drop is not allowed to exceed 0.02MPa requirements. Using computational fluid dynamics (CFD) technology to study the porosity of bag filter, the inlet velocity of filter and the agriculture sewage viscosity change, which influence the pressure drop. The calculation results show that the higher the porosity, the higher outlet back-pressure and the agriculture sewage viscosity is higher，so when it flows through the filter, its pressure drop is higher. CFD technology can replace a part experimental study and it can provide guidance for the filter bag selection and replacement.*

Keywords: *agriculture sewage, bag filter, flow field, pressure drop, porosity, numerical simulation*

摘要： *针对农业污水在过滤杂质流程中，介质压降不许超过 0.02MPa 的要求，利用 CFD 技术研究过滤袋孔隙率、过滤器出口被压、过滤器进口流速和农业污水粘度的变化对压降的影响，计算结果表明：孔隙率越大，出口被压越大，进口流速越大，农业污水粘度越大，农业污水流经过滤器后的压降越大。CFD 技术可以替代部分的试验研究，并对过滤袋的选择和替换提供指导。*

关键词： *农业污水，过滤袋，流场，压降，数值仿真*

INTRODUCTION

At present, in view of global water shortages, urban sewage and rainwater recycling problem has aroused people's wide concern. Urban sewage and rainwater recycling are reused for non-potable water, such as agricultural irrigation, watering road, supplement waterscape, building water [2,3,7]. But the wastewater usually needs to filter. To meet the requirements of water quality, some pollutants must be removed, such as suspended solids, pathogenic bacteria/viruses, turbidity, organic matter, including nitrogen, phosphorus and other plant nutrients [6].

Qi et al [8] analyzed the reason which made the air current distribution uneven and proposed the improvement of which modifies the structure of inlet and adds guide plate in the lower-case. They obtained the flow field, the streamline and granule path which were around improvement with the software of CFD. The conclusion may provide the reference to performance, improve and design of fabric filters. Rocha [5] used CFD techniques to review the distribution of volumetric outflows in the bags and pressure drop for a more efficient and economic filtering operation, and provided an inferior operational pressure drop and a better distribution of fluids between the bags. A numerical simulation of CFD for bag filter was conducted to replace the experimental study by Fu et al [1], the numerical results shown that the main reasons of flow field non-uniformity are the higher inlet velocity and unreasonable bag chamber structure and the computer results are basically consistent with experimental ones, which indicated that CFD technology can replaces some test studies. Li et al [4] used CFD method to compute the velocity field between the bag filter, they analyzed the influence of different distances between the air nozzle and the filtering bag and different injecting times on the dust-cleaning effect, and supplied theoretical basis to design the optimal pulse bag filter.

前言

目前，针对全球性水资源短缺问题, 城市污水与雨水的再利用问题已引起人们的广泛关注。城市污水与雨水的再利用目标为非饮用水，诸如农业灌溉、浇洒道路、补充水景、建筑用水等场合[2,3,7]。但污水和雨水一般需要过滤。为满足水质要求而被去除的污染物通常为悬浮物、浊度、有机物、病原菌/ 病毒, 甚至还包括氮、磷等植物性营养元素[6]。

齐银等人[8]分析了过滤袋内气流分布不均匀的原因，并提出在了改进入口结构和增加导流板的方法。并通过 CFD 软件的计算获得了流场、极限流线和颗粒的运动轨迹，获得成果为提高过滤袋的性能提供了参考。Rocha, S.M.S[5]等人运用 CFD 技术回顾了过滤袋经济操作时的内流流场的分布和压力降，并给出不利操作和合理操作时的过滤袋内压力分布。付海明[1]等人使用数值计算 CFD 软件取代实验，进行过滤袋的仿真计算，计算结果表明；流场分布不均匀的主要原因是较高的进口速度和不合理的过滤袋角部结构，并且计算结果与实验结果吻合较好，说明 CFD 技术可以取代一些实验研究。李志华等人[4]使用 CFD 方法计算了袋式过滤器的内流场，并分析了不同距离在气嘴和滤袋及不同射流时间内对灰尘清理效果的影响，并提供了用于优化设计过滤袋的理论基础。

According to several papers from the specialty literature [1,7], sifting of intermediate products is affected by several factors, the most important being: size and shape of the grist particles, character of the relative motion of the particles on the sieve surface, characteristics of sifting sieve fabric, revolution of plansifter, and the amount of material that reaches on the sieve.

Before agriculture sewage irrigating into farmland, impurity needed to be filtered by using bag filter (as shown in Fig.1). The permeability of bag filter will change, so this paper uses CFD technology to do numerical simulation about filter internal flow field, according to the filter bag porosity, outlet pressure, inlet velocity, agriculture sewage viscosity, so as to provid references for replacement cycle of the filter bag and for prediction of pressure drop loss.

根据专业论文文献[1]和[7]的论述，中间产品的筛选是受几个因素的影响，最重要的是：谷物颗粒的大小和形状，粒子在筛面的相对运动特性，筛布的特性，平面筛的旋转，筛上材料的数量等。

农业用污水在灌溉农田前需要用过滤袋（如图 1）滤掉杂质，使用过程中，过滤袋的渗透性会发生变化，因此本文使用 CFD 技术对过滤袋空隙度、出口压力、进口流速、农业污水粘度对过滤器内流场进行了数值仿真，从而为过滤袋的更换周期和压降损失的预估提供了参考。

Fig. 1 - Bag Filter

MATERIAL AND METHOD

Table 1 shows the basic characteristic parameters of flowing medium (agriculture sewage). Fig.2 is a three-dimensional geometric model of the filter, inlet diameter and outlet diameter are 160mm, the diameter of the container is 610mm, the height of the container is 1260mm. The length of the filter bag is 820mm and its diameter is 160mm, thickness is 2.8mm.

As shown in Fig. 2, geometry model of the filter is a single container and a single filter bag. The cylindrical structure which in the middle of figure is filter bag, when we do the numerical simulation, we assume it as porous materials.

The following statistics is part of the grid information of inlet liquid: inlet liquid grid of filter is 223600, outlet liquid grid of filter is 139500, and the total number of bag filter grid is 139700. The grids are divided by using ANSYS-ICEM software, self-adaption tetrahedral mesh as a main part and making grid of filter bag's part flow region becomes dense. All the wall surface of filter are divided in boundary layer. The quality of grid as shown in Fig.3-d, the minimum quality coefficient is 0.4, which fully meets the computational fluid dynamics software CFX to mesh quality requirements.

The boundary conditions are as follows；Reference pressure is 0.1 MPa. Fluid temperature is 40. Heat transfer option is isothermal. Turbulence model is k-epsilon. Wall function is scalable. Area porosity is isotropic. Loss model is isotropic loss. Loss velocity type is superficial. Inlet normal speed is 0.421 m/s. Inlet turbulence intensity is 5%. Outlet average static pressure is 3.5 MPa.

材料与方法

表 1 为流动介质（农业污水）的基本特性参数。图 1 为过滤的三维几何模型，进口直径和出口直径为 160mm，容器直径 610mm，容器高度 1260mm，过滤袋长 820mm，直径 160mm，厚度 2.8mm。

如图 2 所示，本过滤器的几何建模为单容器、单过滤袋。图中中间的圆筒结构为过滤袋，数值仿真是假设为多空介质材料。

过滤器的进液结构部分网格信息统计如下：过滤器进液网格 22.36 万，过滤器出液网格 13.95 万，过滤袋部分网格总数 13.97 万。网格采用 ANSYS-ICEM 软件进行网格划分，自适应四面体网格为主体，过滤袋部分流域进行网格加密，过滤器所有壁面进行了边界层划分。网格质量如图 3-d 所示，最小质量系数为 0.4，完全满足流体计算动力学软件 CFX 对网格质量的要求。

边界条件如下；参考压力为 0.1 MPa. 流体温度为 40℃. 热传导方式为等温过程。 湍流模型为 k-epsilon. 壁面函数为可扩展。多孔介质为各向同性 。损失模型为各向同向损失模型。 损失速度形式为表面型。进口法向速度为 0.421 m/s. 进口湍流强度为 5%. 出口平均静压力为 3.5 MPa.

Table 1

Basic Characteristic Parameters of Flow Medium

Category	Data	Category	Data
Medium	Agriculture Sewage	Medium density	1010 kg/m^3
concentration	15000PPM	Dynamic viscosity	494 mPa.s
viscosity	494mPa.s	Specific pressure heat capacity	4178 J/kg.k
Operation temperature	40℃	Coefficient of thermal expansion	5.405×10-4k^{-1}
inlet pressure	3.5MPa	Heat conductivity coefficient	66.35×10-2W/mk
Maximum flow	150m3/h	Porosity of filter bag	0.45

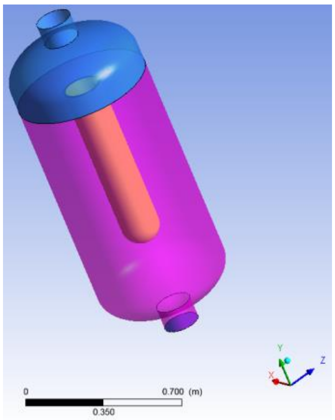
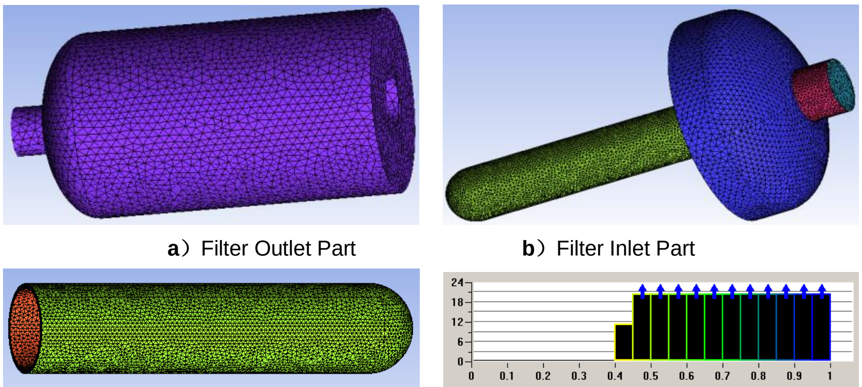


Fig. 2 - 3D Perspective of Filter



a) Filter Outlet Part

b) Filter Inlet Part

c) Bag Filter Part

d) Quality Of Grid Information

Fig. 3 - Three-Dimensional Mesh of Filter

1. Theoretical Basis

- **Navier-Stokes Equations**

The general Navier-Stokes equations written in a Cartesian frame can be expressed as:

1. 基本理论

- **纳维-斯托克斯方程**

一般纳维斯托克斯方程用笛卡尔坐标进行书写如下：

$$\frac{\partial}{\partial t}\int_{\Omega} U d\Omega + \int_{S} \vec{F}_I \cdot d\vec{S} + \int_{S} \vec{F}_V \cdot d\vec{S} = \int_{\Omega} S_T d\Omega \tag{1}$$

Where Ω is the volume and S is the surface, U is the vector of the conservative variables. $\vec{F}_I$ and $\vec{F}_V$ are respectively the inviscid fluid and viscous flux vectors. E and q_i the total energy and the heat flux components. κ and S_T are respectively the laminar thermal conductivity and the source terms.

- **Standard $k-\omega$ Model**

The turbulence kinetic energy k, and its rate of dissipation, ω, are obtained from the following transport equations:

其中Ω代表体积，S代表面积，U代表保守变量的矢量。$\vec{F}_I$ 和 $\vec{F}_V$ 分别代表非粘性和粘性流动矢量。E 和 q_i 分别代表总能和热流量元素。 κ 和 S_T 分别代表层流带热系数和源项。

- **标准 $k-\omega$ 模型**

湍流动能为k，它的耗散率为ω，两个变量可以通过下面输运方程获得：

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + G_k + G_b - \rho\varepsilon - Y_M + S_k \tag{2}$$

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_i}(\rho \varepsilon u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] + G_{1\varepsilon}\frac{\varepsilon}{k}(G_k + C_{3\varepsilon}G_b) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} + S_\varepsilon \tag{3}$$

In these equations, G_K represents the generation of turbulence kinetic energy due to the mean velocity gradients, G_b is the generation of turbulence kinetic energy due to buoyancy. Y_M indicates the contribution of

式中，G_K 是指由层流速度梯度而产生的湍流动能，G_b 表示由于浮力引起的湍动能的产生项，对于不可压缩流体， Y_M 可压湍流中脉动扩张值，对于不可压流体，

the fluctuating dilatation in compressible turbulence to the overall dissipation rate. $C_{1\varepsilon}$, $C_{2\varepsilon}$ and $C_{3\varepsilon}$ are constants. σ_k and σ_ε are the turbulent Prandtl numbers for k and ε, respectively. S_k and S_ε are user-defined source terms.

The turbulent (or eddy) viscosity, μ_t is computed by combining k and ε as follows: $\mu_t = \rho C_\mu \frac{k^2}{\varepsilon}$

Where C_μ is a constant. The model constants $C_{1\varepsilon}, C_{2\varepsilon}, C_\mu, \sigma_k$ and σ_ε have the following default values: $C_{1\varepsilon} = 1.44, C_{2\varepsilon} = 1.92$, $C_\mu = 0.09$, $\sigma_k = 1.0$, . $\sigma_\varepsilon = 1.3$.

$C_{1\varepsilon}$, $C_{2\varepsilon}$ 和 $C_{3\varepsilon}$ 为经验常数项。σ_k 和 σ_ε 分别为与耗散率 ε 和湍动能 k 对应的 Prandtl 数。S_k 和 S_ε 是用户自定义源项。

湍流粘性（涡粘性）μ_t 是通过 k 和 ε 的合并计算得出，如式：$\mu_t = \rho C_\mu \frac{k^2}{\varepsilon}$

其中 C_μ 是常数。. 模型常量 $C_{1\varepsilon}, C_{2\varepsilon}, C_\mu, \sigma_k$ 和 σ_ε 的默认缺省值分别为：$C_{1\varepsilon} = 1.44, C_{2\varepsilon} = 1.92$, $C_\mu = 0.09$, $\sigma_k = 1.0$,. $\sigma_\varepsilon = 1.3$。

2. Numerical Simulation Results and Discussion

The simulation calculation cases include change of porosity, outlet pressure, inlet velocity and viscosity of fluid. Porosities are respectively 0.2、0.3、0.45、0.6、0.8, outlet pressures are respectively 0.5 MPa, 1.5 MPa, 2.5 MPa, 3.5 MPa, inlet velocities are respectively 0.168m/s, 0.421 m/s, 0.841 m/s, 1.682 m/s, 2.522 m/s, viscosities are respectively 0.001 mPa.s, 0.05 mPa.s, 0.1 mPa.s, 0.25 mPa.s, 1.5mPa.s.

2. 数值模拟结果和讨论

仿真计算案例包括改变孔隙度、出口压力、进口流速和流体粘性。孔隙度分别为 0.2、0.3、0.45、0.6、0.8 取值，出口压力分别为 0.5MPa、1.5 MPa、2.5 MPa、3.5 MPa，进口流速分别为 0.168m/s、0.421 m/s、0.841 m/s、1.682 m/s、2.522 m/s，粘性分别为 0.001 mPa.s、0.05 mPa.s、0.1 mPa.s、0.25 mPa.s、1.5mPa.s。

Influence of Porosity on Pressure Drop

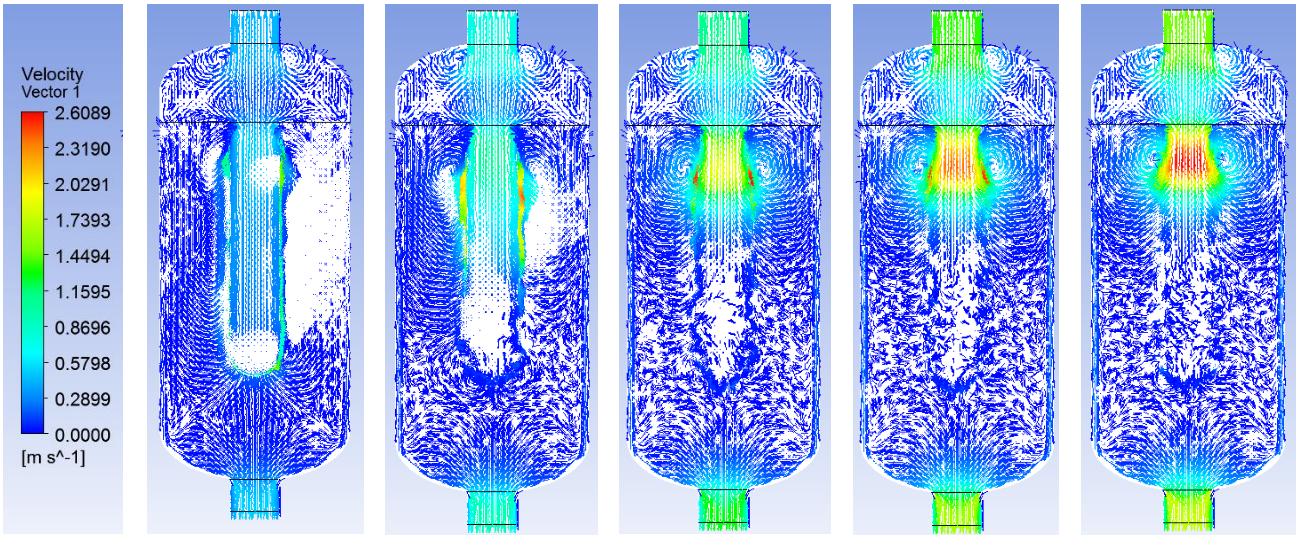
- **Porosity VS Velocity Vector Distribution**

Porosity directly affects the flow velocity distribution of the filter, as is shown in figure 4, Imports around have whirlpool, have obvious local pressure loss. Inlet velocity is larger, after entering the filter, the space increases suddenly, the liquid will be slow down. After the liquid medium enters into the filter bag, due to narrow the space of flows, speed suddenly increases, now the liquid medium enters into the tapering bore channel and flow, and there is no small loss. The speed at the outlet increased with the increase of porosity, and in this case the loss is smaller than the import losses.

孔隙度对压降的影响

- 孔隙度——速度矢量分布图

孔隙度直接影响过滤器流动速度分布，由图 4 可知，进口四周有旋涡产生，有明显的局部压力损失。进口速度较大，进入过滤器后，空间突然增大，液体减速。液体介质进入过滤袋后，由于流动空间的缩小，速度由突然加速，此时输入渐缩孔道流动，也有不小的损失。出口处速度随着孔隙度的增加而增加，此时损失相对进口为小。



Porosity =0.2 Porosity =0.3 Porosity =0.45 Porosity =0.6 Porosity =0.8

Fig.4 - Effect of filter bag porosity on flow field velocity vector distribution

- **Porosity in comparison with total pressure distribution diagram**

The total pressure of filter inlet has obvious gradient change, after the liquid moves through the inlet into the cylinder, which space increases suddenly, so liquid becomes expansion and deceleration, pressure increases and velocity decreases. The orifice around has whirlpool, there is the greater pressure loss. Another place of the greater pressure loss is the inlet part of the filter bag, because of the whirlpool around inlet. As the porosity increases, the variation of the inlet pressure is not obvious (expect the porosity is 0.2). But the total pressure loss at the inlet of the filter bag gradually retreats to the outlet of filter bag.

Along with the porosity increasing, the pressure loss is increased slightly. But overall, the total pressure loss doesn't change much, remaining at around 360Pa. The total pressure loss is calculated using the CFD technology and can reflect the change of pressure drop in the filter bag.

- **孔隙度——总压分布图**

过滤器进口有明显的总压力梯度变化，液体由进口进入筒体后，空间突然增大，液体膨胀减速，压力增加，速度减小。在孔口四周有漩涡产生，此处压力损失较大。另一处损失较大的地方为过滤袋进口部分，近袋口处有漩涡产生。随着孔隙率的增加，进口压力变化并不明显（孔隙度为 0.2 除外）。但是过滤袋进口处的总压损失渐渐退至滤袋口部。

随着空隙度的增加压力损失略有增加，但是总体来说，总压损失变化并不大，保持在 360Pa 左右。说明利用 CFD 技术计算的总压力损失能够反映压降在过滤袋内的变化规律。

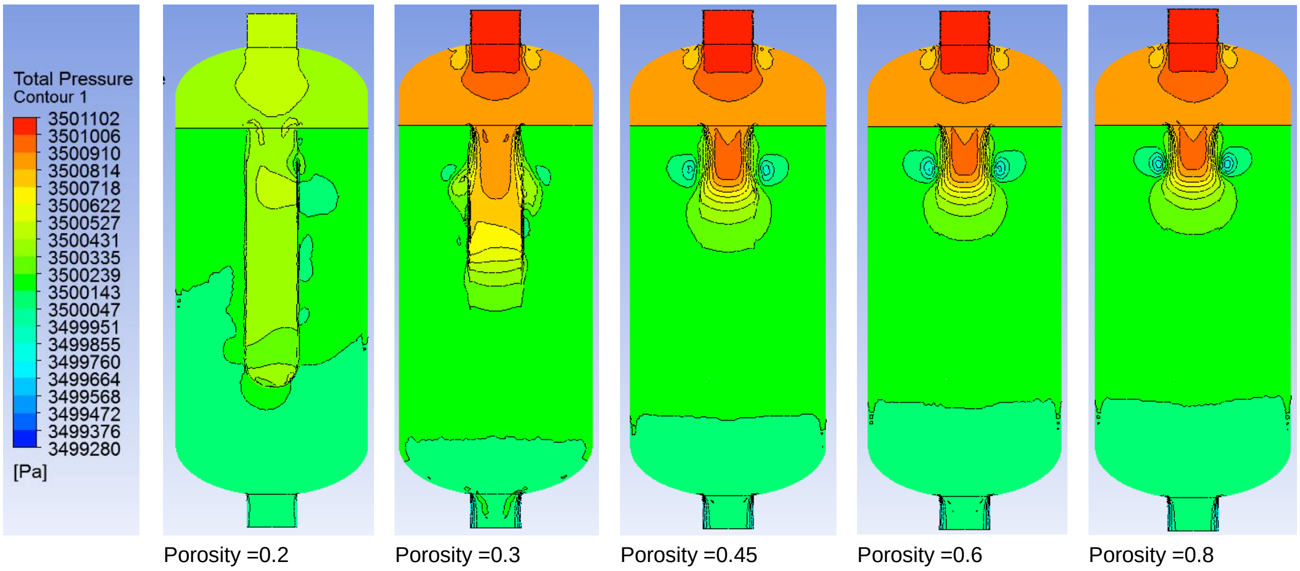


Fig.5 - Effect of filter bag porosity on flow field total pressure distribution

3. Influence of Outlet Pressure on Pressure Drop

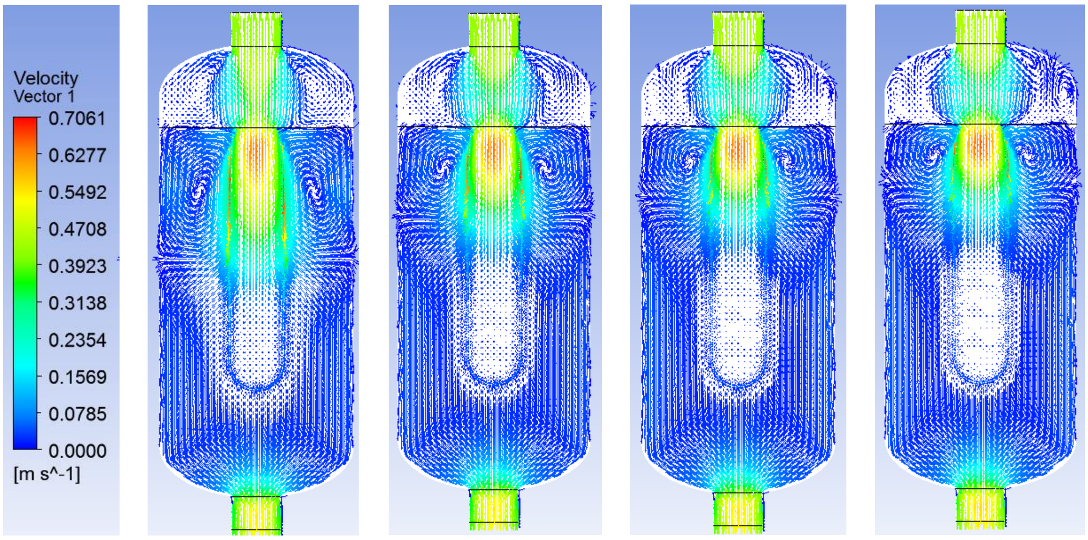
- **Outlet Pressure VS Velocity Vector Distribution**

The outlet pressure is refers to setting back pressure in the liquid orifice of filter, which is respectively calculated according to 0.5MPa, 1.5MPa, 2.5MPa, 3.5MPa. As is shown in Fig.6, with the increasing of the back pressure, the whirlpool scale at the bag mouth around becomes smaller. This is caused by the downstream pressure that is relatively large. The velocity vector distribution in inlet and outlet of the filter are similar.

3 出口压力对压降的影响

- **出口压力——速度矢量分布图**

出口压力是指在过滤器出液孔口处，设置的背压，分别按 0.5MPa、1.5MPa、2.5MPa、3.5MPa 进行分别计算。由图 6 可知，随着背压的增加，滤袋口部四周的漩涡尺度变小，这是因为下游压力较大所致。过滤器进口与出口处的速度矢量分布规律比较相似。



Pressure=0.5mPa Pressure =1.5mPa Pressure =2.5mPa Pressure =3.5mPa

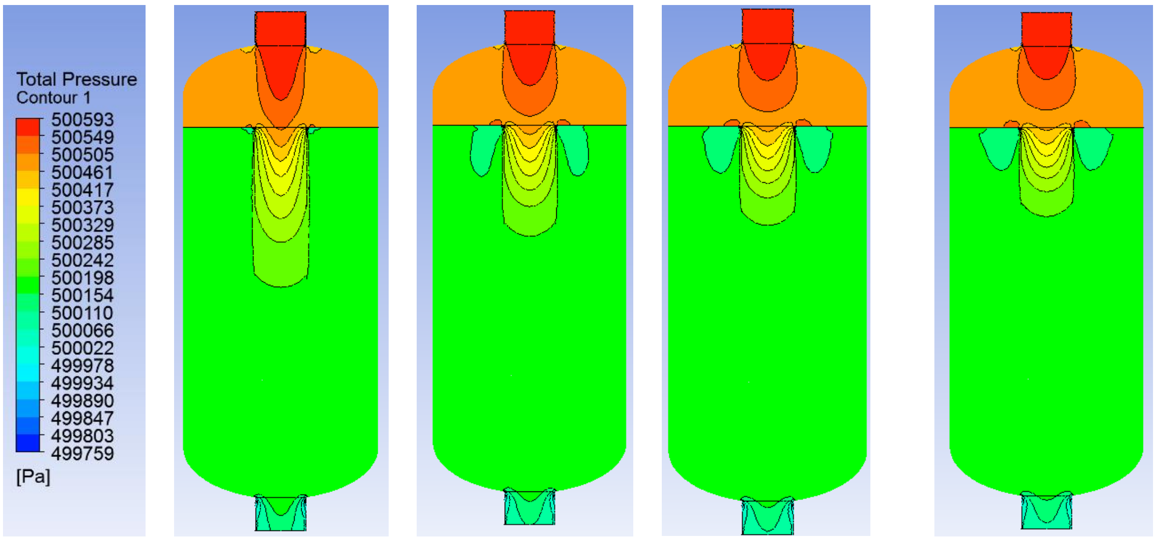
Fig.6 - Effect of outlet pressure on the velocity vector distribution

- **Outlet Pressure Vs Total Pressure Distribution**

Fig.7 is the contour map of total pressure on the cross section of the filter in different back pressure. With the outlet pressure increasing, the total pressure drop increases. Especially the filter bag near the inlet has apparent change and the higher back pressure is, the earlier pressure is reduced. The outlet pressure is from 0.5MPa to 1.5MPa, the pressure loss increases rapidly, pressure loss increases in processes which are from 100Pa to 550Pa and from 1.5MPa to 3.5MPa, the pressure tends to be stable, which is basically maintained at around 580Pa.

- **出口压力——总压分布图**

图 7 为不同被压下，过滤器中截面上的总压力等值线图。随着出口被压得增加，总压力下降幅度增加，特别是滤袋进口附近有明显的变化，背压越大，压力降低的越早。出口压力在 0.5MPa 到 1.5MPa 时，压力损失增加较快，压力损失从 100Pa 增加到 550Pa，从 1.5MPa 到 3.5MPa 的过程中，压力趋于稳定，基本保持在 580Pa 左右。



Pressure =0.5mPa Pressure =1.5mPa Pressure =2.5mPa Pressure =3.5mPa

Fig.7 - Effect of outlet pressure on flow field total pressure distribution

4. Effect of outlet Velocity on the Pressure Drop

- **Outlet Velocity Vs Velocity Vector Distribution**

This paper carries out simulation calculation on different inlet velocity 0.168m/s, 0.421 m/s, 0.841 m/s, 1.682 m/s and 2.522 m/s by using CFD. It can be seen

4. 出口流速对压降的影响

- **出口流速——速度矢量分布图**

分别进行了 0.168m/s、0.421 m/s、0.841 m/s、1.682

from figure 8 that velocities vector changes along with the increase of speed. The greater inlet velocity is, the greater high speed area which in filter bag is. When the speed reaches 2.522m/s, there is great velocity in the filter bag. The greater inlet velocity is, the greater whirlpool which in the vicinity of Bag of entrance is. When the velocity is maximum, most of the cylinder space have full of turbulence.

m/s 和 2.522 m/s 进口流速的 CFD 仿真计算。由图 8 可以看出速度矢量随速度增加后的变化规律。进口流速越大，滤袋内的高速区越大，当速度达到 2.522m/s 时，整个滤袋内都保持较高的速度。进口速度越大，袋口附件的漩涡越大，最大速度时，漩涡充满大部分的筒体空间。

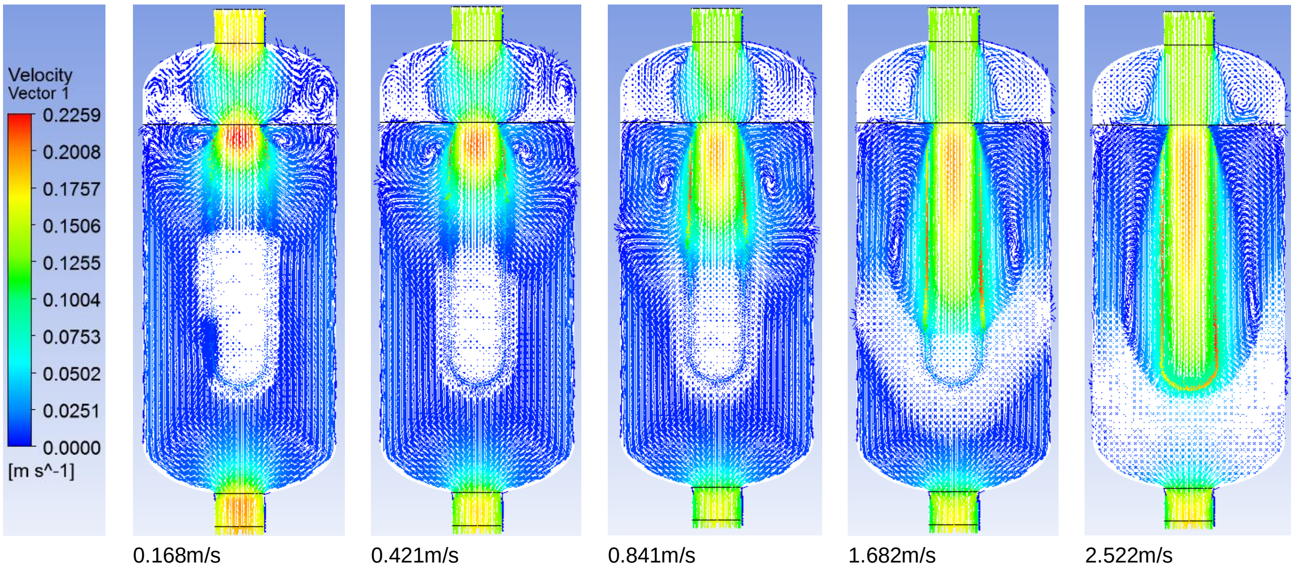


Fig.8 - Effect of outlet velocity on flow field velocity vector distribution

- **Inlet Velocity Vs the Total Pressure Distribution**

Fig.9 is the total pressure contour map under different inlet velocities. With the increase of the inlet velocity, total pressure areas are also larger. The total pressure gradient is larger, so that the total pressure loss is bigger. With the increase of inlet velocity, which increases from 0.1m/s to 2.6m/s, the pressure drop is increased rapidly and they is non-linear positive correlation. Changes in growth amplitude are large, which range from 170Pa to near 10000Pa and across 2 orders of magnitude.

- **进口流速——总压分布图**

图 9 是不同进口流速下的总压力等值线图，随着进口速度的增加，总压值较大的区域也大，总压力梯度较大，说明总的压力损失较大。随着进口流速的增加，从 0.1m/s 增加到 2.6m/s，压降也急剧增加，二者相关性为非线性正相关。而且增长幅值变化很大，从 170Pa 到近 10000Pa，跨越了 2 个数量级。

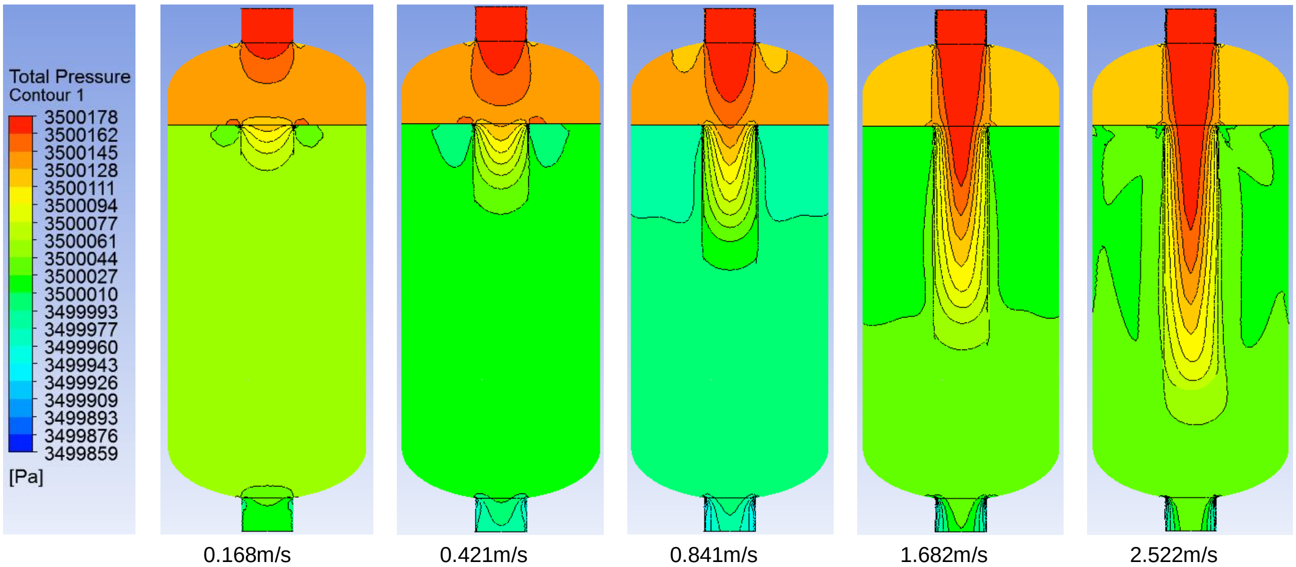


Fig.9 - Effect of inlet velocity on flow field total pressure distribution

5. Effect of Viscosity on Pressure Drop

- **Viscosity Vs the Velocity Vector Distribution**

Viscosity represents the macroscopic properties of fluid which is linked by a stress applied to the fluid and the resulting deformation rate in a certain relationships; it shows the internal friction of fluid. As for numerical viscosity, it is equal to the fluid shear stress which is under the unit of velocity gradient. The velocity gradient is also called fluid motion angle deformation rate, so it also shows the relationship between shear ratio and angular distortion rate.

Fig.10 shows the two-dimensional vector flow chart of filter cross section under different viscosity.

When the viscosity is small, the whole flow field has strong turbulence and at this moment the flow loss is smaller.

As the viscosity increases, there are more and more rules of flow pattern. Most of the region is the laminar region, but the inlet of cylinder and filter bag have an obvious vortex.

5 粘性对压降的影响

- **粘性——速度矢量分布图**

粘性是施加于流体的应力和由此产生的变形速率以一定的关系联系起来的流体的一种宏观属性，表现为流体的内摩擦。黏度数值上等于单位速度梯度下流体所受的剪应力。速度梯度也表示流体运动中的角变形率，故黏度也表示剪应力与角变形率之间比值关系。

图 10 为不同粘度下的过滤器中截面二维矢量流动图，小粘度时整个流场紊流较强，此时损失较小。随着粘性的增加，流谱越来越规则，大部分区域为层流区，但是在筒体进口和滤袋进口处均有较明显的漩涡。

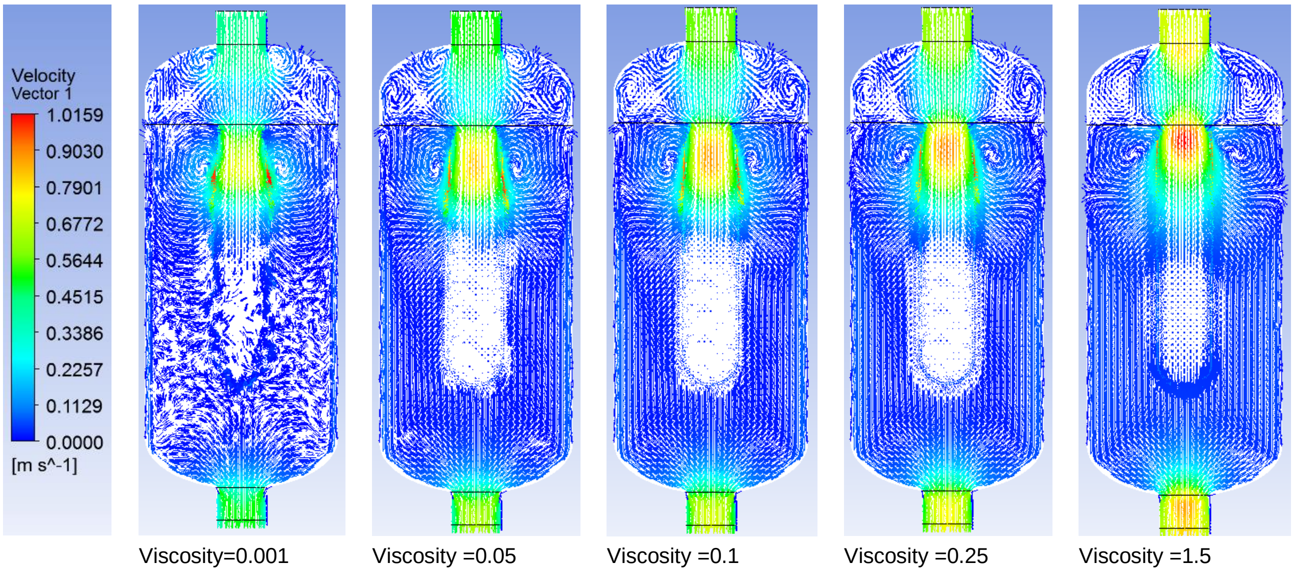


Fig.10 - Effect of viscosity on flow field velocity vector distribution

- **Viscosity Vs the Total Pressure Distribution**

Fig.11 shows the total pressure contour map of different viscosities. In the vicinity of the inlet filter bag, the viscosity is smaller so that the pressure gradient is greater, and the flow pattern has a greater mess.

With the increase of fluid viscosity, flow spectrum was shifted to the laminar flow pattern, but if the viscosity is greater, so the pressure loss is also greater.

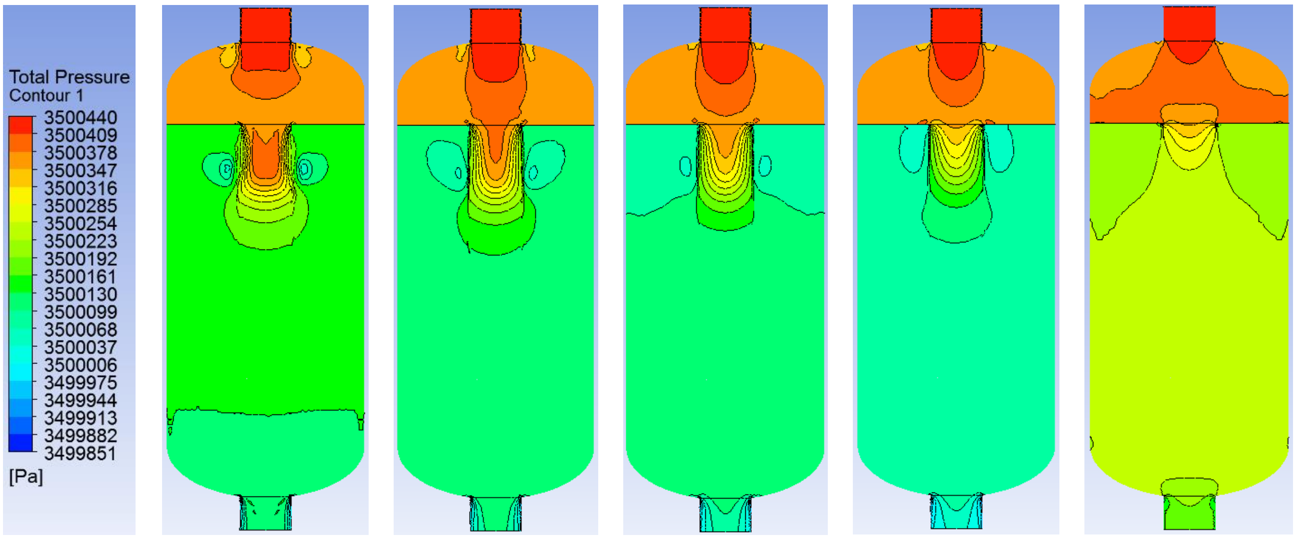
As the viscosity increases, and the pressure drop is also increased, and the whole curve is approximately direct proportion with linear increasing.

Filter viscosity is respectively 50cP, 495cP, 1500cP, pressure losses are respectively 370Pa, 600Pa, 920Pa.

- **粘性——总压分布图**

图 11 表示不同粘度下的总压等值线图，在滤袋进口附近，粘度越小，压力梯度越大，流谱越紊乱，随着粘度的增加，流谱渐渐转向层流流谱，但是粘度越大压力损失越大。

随着粘性的增加，压力降增加，整体曲线近似线性地正比例增加。过滤器粘度为 50cP，495cP，1500cP 时，压力损失分别为 370Pa，600Pa，920Pa。



Viscosity =0.001 Viscosity =0.05 Viscosity =0.1 Viscosity =0.25 Viscosity =1.5

Fig.11 - Effect of viscosity on flow field total pressure distribution

CONCLUSION

In this paper, the filter bag is simplified as a porous medium material. Filter bag is established into CFD numerical simulation model, and numerical calculations are performed about the effects of porosity, outlet back-pressure, inlet velocity and viscosity on the pressure. The calculation results show that;

The total pressure loss which is calculated by using the CFD technology can reflect the change regulation of pressure drop in the filter bag.

With the increase of porosity, pressure loss increased slightly, but overall, the change of total pressure loss is not large, remaining at around 360Pa.

The outlet pressure is from 0.5MPa to 1.5 MPa and the pressure loss increases rapidly, it increases from 100Pa to 550Pa. In the process from 1.5MPa to 3.5MPa, the pressure tends to be stable, it basically maintained at around 580Pa. With the increase of inlet velocity, which increases from 0.1m/s to 2.6m/s, the pressure drop is increased rapidly and there is non-linear positive correlation. Changes in growth amplitude are large, which range from 170Pa to near 10000Pa and across 2 orders of magnitude. As the viscosity increases, and the pressure drop is also increased, and the whole curve is approximately the direct proportion of linear increasing.

REFERENCES

[1]. Fu H.M., Zhao Y.J., (2010) - *Dynamic test and optimization of flow field in bag filter*. Journal of Central South University. Volume 41, Issue 2, pp.799-806;

[2]. Hao X.D., Vander J.H.J.M., (2003) - *New Way of Wastewater Resourced*. Water & Wastewater Engineering, Volume 29, Issue 6, pp.27-29;

[3]. Luo y., (2003) - *Introduction to membrane filtration sewage directly used for agricultural irrigation technical measures*. Gansu science and technology, Volume 19, Issue 11, pp.14-15;

[4]. Li Z.H., Liu J.F., Jiao L., (2011) - *The numerical simulating research about the pulse cleaning process of bag filter*. Asian Workshop on Polymer Processing 2011, Qingdao, China, pp.509-514

结论

通过将过滤袋简化为多空介质材料，建立对应袋式过滤器的 CFD 数值仿真模型，进行孔隙率、出口被压、进口流速和粘性对压降影响的数值计算，计算结果表明；

利用 CFD 技术计算的总压力损失能够反映压降在过滤袋内的变化规律。随着空隙度的增加压力损失略有增加，但是总体来说，总压损失变化并不大，保持在 360Pa 左右。出口压力在 0.5MPa 到 1.5MPa 时，压力损失增加较快，从 100Pa 增加到 550Pa，从 1.5MPa 到 3.5MPa 的过程中，压力趋于稳定，基本保持在 580Pa 左右。随着进口流速的增加，从 0.1m/s 增加到 2.6m/s，压降也急剧增加，二者相关性为非线性。而且增长幅值变化很大，从 170Pa 到近 10000Pa，跨越了 2 个数量级。随着粘性的增加，压力降增加，整体曲线近似线性地正比例增加。

参考文献

[1]. Fu H.M., Zhao Y.J., (2010) -*袋式除尘器流场动态测试及优化*. 中南大学学报， 卷.41, 期.2, p. 799-806;

[2]. 郝晓地,Vander J.H.J.M., (2003) -*污水资源化新途径—直接膜过滤用于农业灌溉*. 给水排水, 第 29 卷，第 6 期，27-29;

[3]. 罗瑛, (2003) -*浅谈直接膜过滤污水用于农业灌溉的技术措施*,甘肃科技, 第 19 卷，第 11 期，39-15;

[4]. Li Z.H., Liu J.F., Jiao L.,(2011) -*脉冲式清洗过滤袋的数值仿真研究*，亚洲聚合物加工研讨会议2011，青岛，中国, 509-514.

[5]. Rocha S.M.S., Vieira L.G.M., Aguiar M.L., Damasceno J.J.R., (2010) - *Fluid dynamics study of the influence of direction of the gas flow in fabric filter*. Materials Science Forum, 7th International Latin-American Conference on Powder Technology, Brazil, pp.520-524;

[6]. Ueda T., (1996) - *Treatment of domestic sewage from rural settlements by a membrane bioreactor*. Water Science and Technology, Volume 34, Issue 9, pp.189-196;

[7]. Xing W., (2013) - *Adsorbent modified filter bag in the application of the irrigation and drainage*. Technology of Soil and Water Conservation, Volume 32, Issue 2, pp.13-15;

[8]. Yin Q., Hu M.Y., Zhang J., Hou W.L., (2009) - *Computer simulation of air flow distribution characteristics in inner filtering fabric filters*. 2009 WRI World Congress on Computer Science and Information Engineering, United States, pp.419-423.

[5]. Rocha S.M.S., Vieira L.G.M., Aguiar M.L., Damasceno J.J.R., (2010) -*影响织物过滤器气流方向流体动力学研究*， 第七届拉丁美洲粉体力学技术国际会议，巴西，520-524;

[6]. Ueda T., (1996) -*Treatment of domestic sewage from rural settlements by a membrane bioreactor*. Water Science and Technology, Vol.34, No.9, 189-196;

[7]. 邢伟, (2013) -*吸附剂改良过滤袋在农田排水渠中的应用*, 水土保持应用技术, 第 32 卷，第 2 期，13-15;

[8]. Yin Q., Hu M.Y., Zhang J., Hou W.L., (2009) - *计算机过滤织物过滤器内部气流分布特征的模拟，*2009年计算机科学和信息工程WRI世界大会, 美国, 419-423.