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Study of the Influence of Using Bulkheads on the Fabric Filter Performance

Lidia R. da Vitória, Fabio A. R. Perreira*, Sandra M. S. Rocha, Rafael Sartim, Karla H. Simon, Daniel C. Ribeiro

Universidade Federal do Espírito Santo, Av. Fernando Ferrari, 514, Vitória-ES, Brazil.
fabio.a.pereira@ufes.br

Currently, controlling the pollution emission is increasingly challenging, whether due to the severity of environmental legislation or the need to collect dry material to return to production. Among the many existing equipment for the control of atmospheric emissions, the fabric filters have been diffused in the industrial environment mainly for their cost-benefit ratio. However, although the fabric filter has a high dry particulate collection efficiency, some challenges in the optimization of this equipment need to be worked on, mainly in relation to the design of new filters or upscaling the existing ones, which is expensive and costly to perform experimentally. The present study considered a small fabric filter at industrial scale: 5.3 m high; 1.8 m deep; 2.0 m wide. The Computational Fluid Dynamics (CFD) was sought to obtain a better understanding of its flow field considering the inclusion of solid and perforated bulkheads in three inlet configurations (conventional feed, triple lower feed and triple concentric feed). It was observed that the bulkheads set-up promotes a better distribution of the flow through the sleeves, quantified by an average velocity reduction of 19 % for the solid bulkhead and 47 % reduction for the perforated bulkhead. Other variables, such as the mass flow rate and pressure over the bags, showed a similar behavior. Focusing the layout influence, it is highlighted that the triple lower feed showed the best flow distribution among the bags, highlighting the best performance with the perforated bulkhead, behavior which was also observed in the other configurations. With a qualitative perspective of better flow distribution, the decrease at the average velocity through the sleeves allows the association to the bags wear reduction; outstanding the importance of flow field understanding at project and optimization of fabric filters.

1. Introduction

The treatment of atmospheric emissions is rising not only by environmental legislation, but also to recover high added value raw materials, has made environmental control equipment increasingly interesting to the industry. Filtration is one of the oldest unitary operations used for gas cleaning and particle collection, due to its high efficiency, low operating cost and low sensitivity to changes in operating conditions. In this context, the fabric filter was commonly found in the industrial environment as equipment for the control of particulate material, its popularity can be credited to 99 % collection efficiency over a wide particle size range, and its low operating cost. The observed challenges regarded to fabric filters is the equipment design since its correct operation depends on the choice of filter media, process variables and equipment geometry. Therefore, the design of this equipment should not be based on previous experiences, that is, it should be developed particularly for the application in which it will be used (Yilmas et al., 2014). The equipment design through the empirical method is still used by some industries. However, the use of advanced computational technologies to project and minimize the costs of product development and design is an emerging methodology. The Computational Fluid Dynamics (CFD) awakens ideas, reveals, and prevents pitfalls, all at a much lower cost than empirical strategies, as well as allowing the simulation and analysis of flows in the computer (Knop, 2010).

Thus, it is obtained as a positive point for the simulations in CFD the minimization of the efforts in relation to the trial and errors, because for the validation of the results found in these simulations only a few experiments are necessary (Maliska, 2004). Pereira et al. (2015) states that CFD simulations provide results that allow the analysis of the flow field behaviour within a fabric filter, considering important phenomena such as turbulence

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and pressure drop. The authors evaluated the influence of the layout inlet in the mass flow, filtration velocity and pressure drop and concluded that Computational Fluid Dynamics provides both qualitative and quantitative data necessary for the operational analysis of industrial equipment.

In this context, this work presents results of air flow inside an industrial fabric filter through CFD simulations. Three different configurations were tested; the insertion of solid and perforated bulkheads, in order to analyse the influence in the filtration velocity and in the air flow distribution aiming determine which configuration would present the best performance.

2. Methodology

The development of this work was based at Computational Fluid Dynamic strategy, using commercial software ANSYS FLUENT v15.0. This tool uses numerical methods to solve the governing equations, which are the conservation equation of mass, momentum and turbulence.

These numerical methods are responsible for solving one or more differential equations (in this work the equations of conservation of mass and momentum) replacing the existing differential equations by algebraic expressions. When the analytical solution is not possible, and it is decided to make a numerical approximation of the differential equations, it is accepted to have the solution for a discrete number of points, with a certain error, and the higher the number of points, should lead to smaller error (Maliska, 2004). In the case of ANSYS FLUENT v15.0 the strategy implemented is the Finite Volume Method, to obtain the approximate equations, that satisfies the conservation of the property in level of elementary volumes (Maliska, 2004).

For turbulent flows, as is the case of the present work, the governing equations are not enough to describe the flow behaviour, so it is necessary to use turbulence models. The URANS (Unsteady Reynolds Averaged Navier-Stokes) was adopted, which applies the time properties averages to model the flow (Verteeg and Malalasekera, 2007).

The geometry used was based on an industrial bag filter, its dimensions are: 5.3 m high; 1.8 m deep; 2.0 m wide. It was used 49 bags set to promote a geometry simplification and thus a less element mesh. It is important to say that the same filtration area (75 m²) was enforced. The bags dimensions were 0.3 m in diameter and 3.0 m high. The proposed layouts in this work are arrangements previously studied (Pereira et al. 2016), in order to allow the comparison of the results of the presence of bulkheads with the solutions for equipment without this artifice. In the Figure 1 the chosen inlets are presented: conventional feed (a), triple concentric feed (b) and triple lower feed (c).

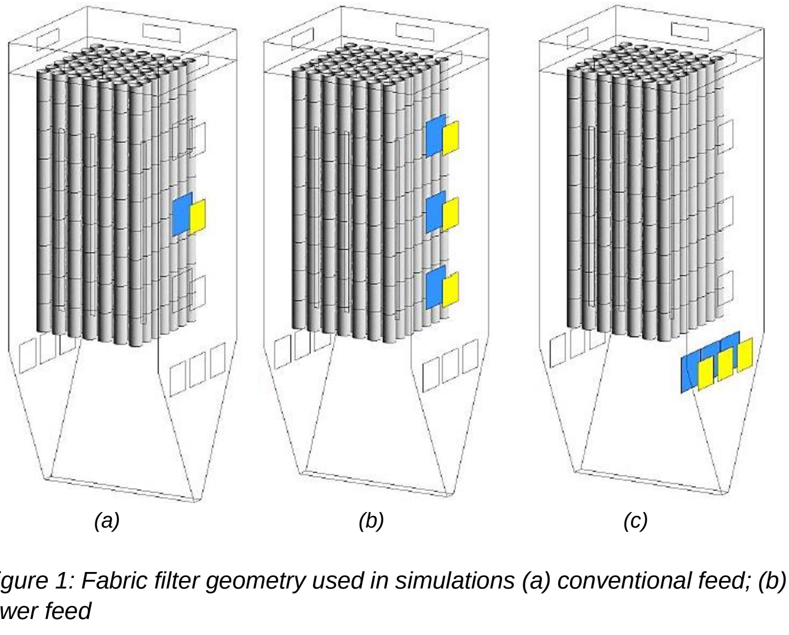


Figure 1: Fabric filter geometry used in simulations (a) conventional feed; (b) triple concentric feed and (c) triple lower feed

In each layout a bulkhead was inserted, corresponding to the input model. The bulkheads of each case were 25 % larger than their respective inlets, solid bulkheads and perforated bulkheads were tested. These bulkheads were placed at 0.2 m from the entrances and the adaptations were performed in Ansys ICEM geometry software. The fluid used was air with fixed density (1.23 kg/m^3) and dynamic viscosity (1.79 ×10^{-5} Pa s). At the inlet, a uniform velocity profile of 22.84 m/s was imposed for the “conventional” design and “triple inlet” design, the value was divided by three. The bags properties were the thickness of 2.5 $\times 10^{-3}$ m and permeability of 5.87 $\times 10^{10}$ m^2.

The domain was discretized using an unstructured mesh approach, using the octree technique. To secure mesh independent results, a grid independence study was conducted using as monitored variables the mean velocity and pressure over the bags. The study reported that a 527.609 element was the optimal discretization scheme. The turbulence model employed was the realizable k-ε which has been proving its robustness and accuracy in rotational flows (Wilcox, 1998).

The use of unsteady version of RANS was due to convergence difficulties with steady state solution. The reason is probably concerned to high frequency fluctuations of the gas jet at inlet. The simulations were conducted through a suitable time to reach the flow steady state. In this case, 15 s suited for all simulations. The chosen timestep was 0.002 s, being defined using a fraction of residence time and calibrated by iterative process stability.

Appling the segregated strategy to solve the governing equations, algorithms were used (Patankar and Spalding, 1972); such as: SIMPLE to implement the pressure-velocity coupling and second order advection schemes (Second Order Upwind - Barth and Jespersen, 1989) to other equations, including the turbulence model (Fluent, 2015).

3. Results and discussion

The strategy developed in this work follows the proposal initially developed by Rocha (2010) where results obtained by the CFD technique were compared with experimental data. The presented results are the continuity of Rocha et al. (2014) and Pereira et al. (2016) methodology that extend the use of computational fluid dynamics to industrial scale fabric filters. The actual contribution is the presence of bulkheads, especially on the change in flow field among the bags and the respective influence over the main operating variables.

For each layout investigated, the streamlines were obtained: for filters without bulkheads (Figure 2), with solid bulkheads (Figure 3) and with perforated bulkheads (Figure 4).

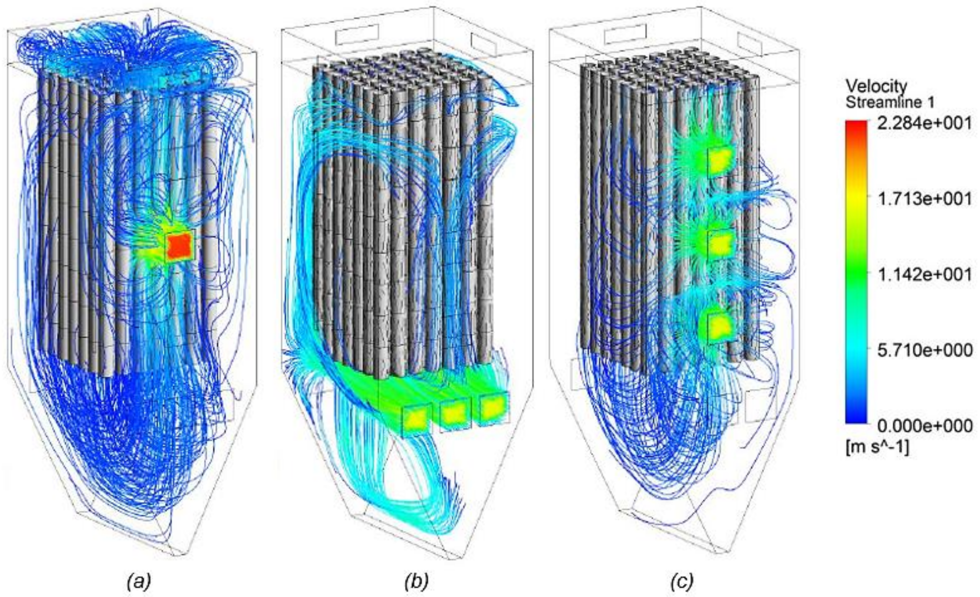


Figure 2: Without bulkhead simulations (a) conventional feed; (b) triple concentric feed and (c) triple lower feed

The bulkheads insertion promoted a better flow distribution, mainly in the case of perforated bulkhead, as shown in the figures below.

This change in flow distribution is beneficial, because it generates a larger effective filtration area, that is, a region that previously filtered a large portion of the flow, it can now filter out a smaller amount, which can presume the reduction of bags premature wear. While regions that were underutilized, with this flow redistribution, became more used, projecting that the bags wear should be more homogeneous. These factors are expecting to extend the bags lifetime.

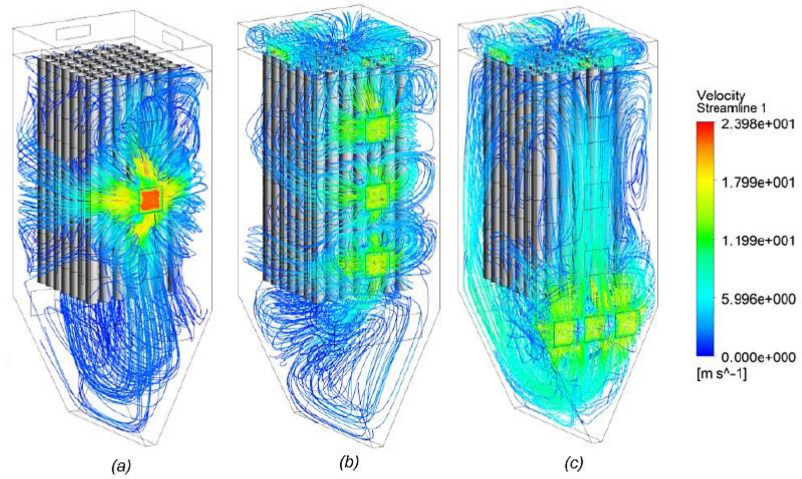


Figure 3: Solid bulkhead simulations (a) conventional feed; (b) triple concentric feed and (c) triple lower feed

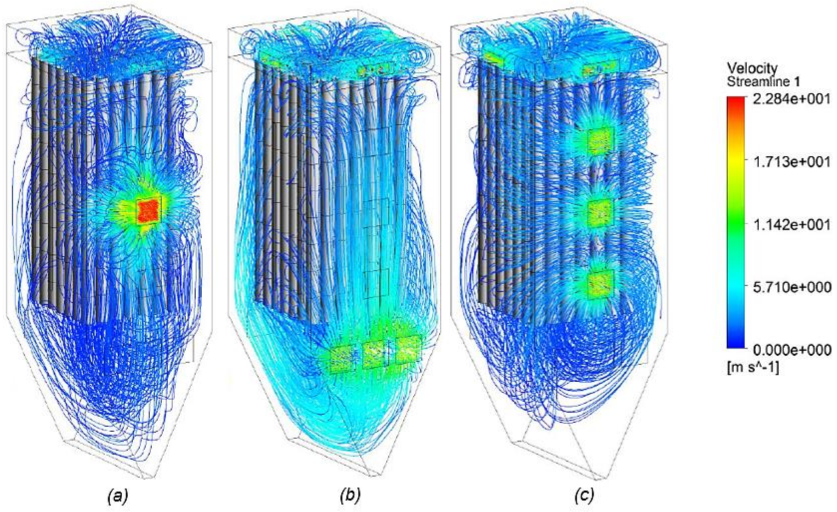


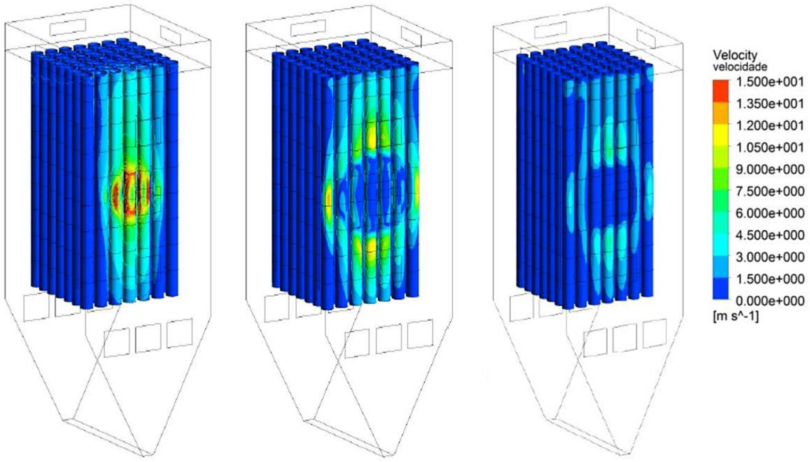
Figure 4: Perforated bulkhead simulations (a) conventional feed; (b) triple concentric feed and (c) triple lower feed

The maximum values obtained from the parameters verified in this work are presented in Table 2. These values were observed on the bags surface.

Table 2: Maximum values obtained from the main analysed parameters

Bulkhead	Feed	Velocity (m/s)	Mass Flow (kg/(m^{2}s))	Pressure (Pa)
Without	Conventional	16.6	2.59	442.2
	Triple concentric	5.1	0.48	144.6
	Triple lower	3.0	0.46	114.5
Solid	Conventional	10.8	1.49	224.0
	Triple concentric	2.8	0.25	121.8
	Triple lower	3.7	0.18	112.7
Perforated	Conventional	6.1	0.67	170.7
	Triple concentric	2.4	0.16	111.5
	Triple lower	2.3	0.16	108.6

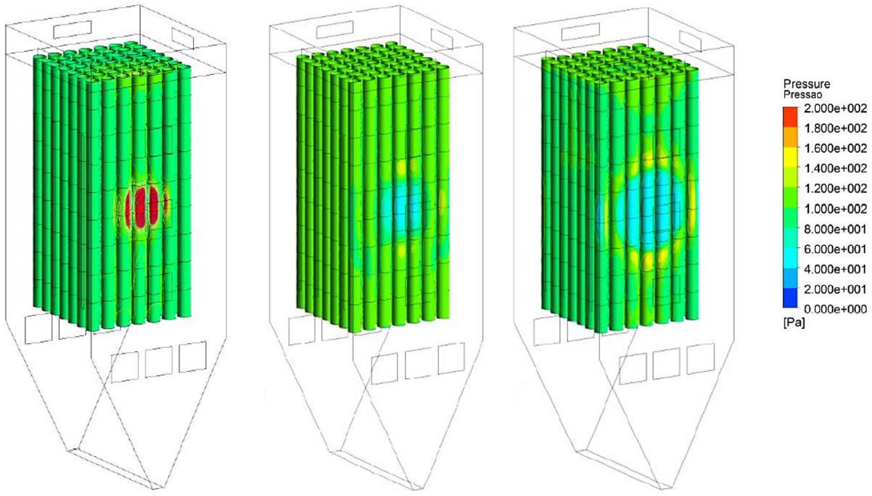
Generally, the bulkheads insertion reduced the maximum values of velocity, mass flow and pressure (over the bags), as desired. It was observed that, the perforated bulkhead obtained the best performance. Observing that were the most reduced the flow impact over the bags. The fabric filter that obtained the best performance is the one with triple lower feed and perforated bulkhead. In this case, there were a reduction of 23.3 % at the velocity, 65.2 % of the mass flow rate and 5.15 % at the operational bag pressure. Reducing filtration velocity is very important, because it reduces the penetration the particles in the bags and this way, eases the cake removal (the thickness of particles settled over the bags) at the time of filter cleaning. In addition, for lower filtration velocities, the filtration time increase in subsequent cycles and reducing the pressure drop (Rocha et al., 2014). Consequently, since the pressure drop will be lower, the number of cleaning shutdowns decrease, and this reduces the cost of operation. The Figure 5 shows the velocity distribution on the bags in the filter with conventional feed without bulkhead (a), with solid bulkhead (b) and with perforated bulkhead (c).



(a) Without bulkhead *(b) Solid bulkhead* *(c) Perforated bulkhead*

Figure 5: Comparison of filtration velocity distributions

It was possible to observe that the highest velocities reach mainly in the first row of bags, in all cases. The case without bulkhead 5 (a), the higher velocities are concentrated in the central part of the first row of bags. With the insertion of bulkheads, 5 (b) and 5 (c), a more homogeneous velocity distribution was observed in the first row of bags, since the filter side bags began to receive a higher velocity, while in the central region there was a reduction of the velocity. This allows a more uniform wear of the bags. It's important to highlight, that the other fabric filters follow a velocity distribution behavior very close to that shown above. The Figure 6 shows the pressure distribution on the bags in the filter with conventional feed without bulkhead (a), with solid bulkhead (b) and with perforated bulkhead (c). Comparing 6 (a) with 6 (c), a considerable pressure reduction is observed. This reduction allows a decrease in the local pressure drop, which leads to increased filtration time and reduced number of cleaning stops.



(a) Without bulkhead *(b) Solid bulkhead* *(c)Perforated bulkhead*

Figure 6: Comparison of pressure distributions

The mass flow rate distribution over the bags follow a behavior similar to the velocity distribution. This also applies to behaviour change due to the insertion of the bulkheads. A smaller mass flow and with a more homogeneous distribution, means that the cake will be more uniform, since the particles amount reaching the bags is uniform also.

Considering the flow field and surface bag pressure results obtained by Pereira et al. 2016, the insertion of bulkheads does not compromise the benefits generated by changing the inlet positions, since the triple lower feed continues to achieve the best performance.

4. Conclusions

The present work development reiterated the importance of knowing the flow field behavior inside fabric filters aiming not only the project but also the optimization and upscaling process. The presence of bulkheads placed close to filters inlet promoted a better flow distribution among the bags when compared with the original configuration (without bulkheads). This concept implies a more uniform filtering operation, avoiding heterogeneous bags wear. This effect was quantified through the main operational variables, observing the reduction of the velocity, the mass flow rate, and the local pressure. The overall average velocity was reduced in 19 % for solid bulkhead set-up, and a 47 % decrease using perforated bulkhead configuration. The mass flow rate and local pressure, over the bags, followed the tendency, presenting lower values due to the presence of bulkheads. The benchmark with two previous work, Rocha et al. (2014) and more recently Pereira et al. (2016), outstand that the presence of bulkheads does not changed the pattern among the inlet configurations. The triple lower feed remains the better inflow layout, closing the analysis of the industrial fabric filter case, evidencing the flow field importance concerning to bags wear, and the respective operational lifetime.

References

Barth T. J., Jespersen D., 1989, The design and application of upwind schemes on unstructed meshes, Technical Report AIAA-89-0366, 27th Aerospace Sciences Meeting, Reno, Nevada, USA, 12 p.

FLUENT Inc., 2015, Fluent v15 User’s Guide, Centerra Resource Park, Lebanon, ANSYS Fluent Theory Guide v15, Canonsburg, PA, USA. 2070 p.

Knop K., Kögel A., Schrooten T., 2010, Perfecting the design of bag filters. Global Cement Magazine,14-18.

Maliska Clovis R., 2004, Transferência de Calor e Mecânica dos Fluidos Computacional. 2nd ed. LTC, Rio de Janeiro, Brazil (in Portuguese). 460 p.

Patankar S. V., Spalding D. B., 1972, A calculation procedure for heat, mass and momentum transfer in 3-D parabolic flows. International Journal of Heat and Mass Transfer, 15, 1787-1806.

Pereira T. W. C., Marques F. B., Pereira F. A. R., Ribeiro D. C., Rocha S. M. S., 2016, The influence of the fabric filter layout of in a flow mass filtrate. Journal of Cleaner Production 111, 117-124.

Rocha S. M. S., 2010, Study of the influence of velocity and filtration cycles on the formation of the gas cleaning cake in a bag filter. PhD Thesis (in Portuguese), Universidade Federal Uberlândia, Brazil, 168 p.

Rocha S. M. S., Marques F. B., Pereira F. A. R., Ribeiro D. C., 2014, Applications of CFD Techniques in the Design of Fabric Filters. Chemical Engineering 39, 1369-1374.

Verteeg, H. K; Malalasekera, W., 2007, An Introduction to Computational Fluid Dynamics: The Finite Volume Method. 2nd ed. Harlow, England, 503 p.

Yilmaz O., Anctil A., Karanfil T., 2015, LCA as a decision support tool for evaluation of best available techniques (BATs) for cleaner production of iron casting, Journal of Cleaner Production, 105, 337-347.

Wilcox D. C., 1998, Turbulence Modelling for CFD. D C W Industries. 2nd Edition, USA, 540 p.