Fabric Filter Optimization using Computational Fluid Dynamics

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1 Abstract:

Optimal filter performance requires proper gasflow and dust distribution on the filtration area. Fabric Filters are especially sensitive to uneven flow, as premature bag wear immediately increases particle emissions. In addition, upgrading existing installations has become more challenging due to strict emissions regulations and common physical and dimensional restrictions on existing equipment, so proper flow distribution becomes critical in maximizing overall fabric filter performance. Computational Fluid Dynamics (CFD) modelling of the gas flow is becoming a valuable tool in designing, testing and comparing different solutions. In the present study, focus is placed on CFD modelling of different Fabric Filter designs, resulting in custom gas distribution modifications for each. The study demonstrates that CFD is a flexible and a cost effective alternative method to the traditional approach of model or full-scale tests on new Fabric Filters, Electrostatic Precipitators to Fabric Filter conversions and in Air Pollution Control (APC) equipment in general.

2 Introduction

Strict environmental regulations are requiring optimized and more conservative filtration equipment designs for new installations in order to meet the required filtration efficiency and reliability. However, existing equipment is also expected to comply with new regulation challenges, but extensive modifications or expansions to obtain more conservative design parameters are usually not economically or physically feasible.

An area of increased interest is to improve the performance of filtration equipment by means of optimizing gas flow distribution to achieve maximum capacity and reliability. This is done by modifying and testing gasflow through different designs of gas distribution internals. During the past ten years, FLSmidth Airtech has replaced intuitive solutions, physical model testing and traditional trial and error field experiments by performing Computational Fluid Dynamics (CFD) analyses [1, 2, 3, 4, and 5]. This solution is used to optimize a wide range of Air Pollution Control (APC) and related equipment, including Electrostatic Precipitators (ESP's), Fabric Filters (FF's), Gas Suspension Absorbers (GSA's), Gas conditioning Towers (GCT's), and gas-gas mixing equipment. Today, detailed computer modelling of gas distribution screens, bags and static mixers is possible, allowing design modification and testing of equipment to resolve flow behaviour problems [6]. In Fabric Filters, CFD modelling is important for both new and retrofit filters to achieve flow uniformity, compartment-to-compartment flow balance, pressure loss reduction, increased bag life, etc. These simulation models can extend from the inlet ductwork through the entire filter to consider every detail that can affect the gas flow behaviour, such as guide vanes, screens, internal supports, filter bags and other possible restrictions to flow.

Many different Fabric Filter designs from numerous filter suppliers are in operation today, and most have potential improvements that can make a significant difference in overall performance, filtration efficiency and filter bag durability. FLSmidth Airtech has developed a Fabric Filter CFD analysis, which is used for new design development, but is also successfully applied for existing installations, regardless of original fabric filter brand or manufacturer.

In general, the overall process involves three steps:

1. Plant visit for inspection of equipment
2. Design improvement and testing by Computational Fluid Dynamics modelling
3. Upgrade contract

A major contribution to a successful overall result is the design optimization part carried out by CFD simulations (item 2 above), making this the focus area of the present paper.

The details of the CFD modelling process are discussed and several upgrade case stories are presented. The results are discussed with respect to findings and achievements, including filter bag life, compartment-to-compartment flow balance, increased reliability, etc. Furthermore, an example of a conversion of Electrostatic Precipitator to Fabric Filter is presented, where it was found that optimal positioning of internals is a key factor to achieve for a cost effective solution. Finally, the advantages using CFD for APC equipment in general is discussed in view of the traditional approach of model or full-scale tests.

3 Simulation model

The present study is based on application of the commercial CFD code STAR-CD [7]. Modelling fluid flow via CFD requires specification of the geometry through a computational grid, the necessary models to present the physics of the problem, numerical solution strategy and specification of boundary conditions. Special considerations are necessary in order to model the permeable filter bags.

In general, a CFD run includes four steps:

Step 1: 3-D Computer model for CFD, typically via SolidWorks
Step 2: Model meshing, which divides the model into millions of small computational cells
Step 3: Pre- and post-processing including model setup, runs and plots
Step 4: Reporting findings and conclusions

The typical 4 steps in a full CFD run are shown in Figure 3-1.

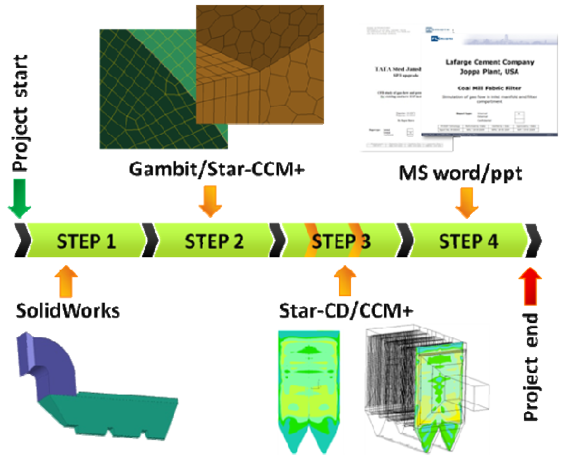


Fig. 3-1: Individual steps in a CFD simulation.

3.1 Geometry and Flow Conditions

The modelled geometry (computational mesh) and by that the full filter flow simulation model includes all details that can affect the gas flow field. This includes guide vanes, gas distribution screens, wall plates to protect the bags from direct dust impact, and other flow obstructions. The computational meshes consist of between 7,500,000 and 12,000,000 computational cells depending on the actual case. The large number of computational cells results in very high resolution of the flow (or pressure) field in the filter, considering the actual operational data for each case.

A uniform velocity profile is assumed at the inlet of the computational mesh, so the inlet or initial position of the model must be carefully selected. This is a common approach and is expected to be a good approximation because the downstream restrictions will control and determine the flow development.

3.2 Modeling strategy

This section describes the background for the numerical analysis including model description and modelling procedure. Only the main principles are described. See [8, 9] for a more detailed description of CFD modelling.

The flue gas flow is modelled as steady, incompressible, and isothermal, with fluid properties identical to a flue gas at the given filter temperature. Turbulence is modelled by the standard k-ε model [10], which is widely used for industrial internal flows. The high Reynolds number form is used in conjunction with the so-called “law of the wall” representation of the boundary layer flow. This choice is based on the best compromise between accuracy and boundary layer resolution.

Guide vanes, gas distribution screens, wall plates, and other flow obstructions are modelled as baffle-computational-cells (solid baffles) that are effectively zero-thickness, two-dimensional cells that otherwise act as solid cells and are placed at a distance equal to the actual dimensions in the filter.

Investigations showed that it is important to model all the bags in the filter section with the actual dimensions in order to obtain accurate physical flow distribution. Porous media models in the full area of the bags or a smaller number of bags with larger dimensions than the original bags turned out to be unacceptable in view of local flow behaviour in the filter section. Hence, the present model has a very high resolution of the filter section, which also results in a high number of computational cells. The bags' surfaces are modelled as a thin membrane with a boundary condition equal to the laminar pressure drop across the bags $\Delta P = \rho \times v_f \times C_{P,L}$ where ρ denotes the flue gas density, v_f the filtration velocity, and $C_{P,L}$ the laminar pressure loos coefficient. This model is a good approximation in view of the low filtration velocity. The pressure loss coefficient $C_{P,L}$ is an empirical constant, which is based on full-scale measurements. The pressure loss coefficient used in the calculations reflects bags with a medium to high dust layer.

The boundary condition at the outlet specifies that the exit mass flow is fixed from overall continuity considerations and at walls and at solid baffles, "no slip conditions" are specified.

3.3 Model approximations

The main purpose of the CFD study is to analyze the gas flow distribution and pressure loss. Uncoupled, three-dimensional particle movement calculations and coupled particle concentration calculations (dust concentration distribution throughout the filter) are not included in the present analysis. However, the effects of these assumptions are being studied.

The study is limited to time independent (steady state) calculations. Clearly, complex flows suggest the need for unsteady calculations. However, investigations comparing steady state and unsteady results indicated that, with the model at hand, steady state calculations could be performed to provide highly accurate results.

Mechanical operations like cleaning of the bags and bag movement due to the flow (fluid structure interaction) are not considered.

3.4 Summary of simulation model

Overall, FLS Airtech considers that the numerical settings and models applied by the FLS Airtech filter gas flow simulation model are the best possible in account of accuracy, methodology, and computing time.

4 Retrofit filter modelling

The retrofit CFD modelling part is slightly different from the procedure of new equipment order execution or R&D projects, since all geometrical details are usually not available in advance and more interaction with the customer during the project execution is required. The typical process in a CFD retrofit project is as follows:

1. Registration of available drawings, field verification of the actual geometry and possible post-installation modifications.
2. Generation of 3-D CAD geometry model for CFD (SolidWorks)
3. Evaluate possible modifications in 3-D geometry model (in advance review)
4. CFD model meshing
5. Pre- and post-processing including numerical model setup (flow physics, turbulence and boundary conditions), flow calculation of "As build" case and preparation of plots
6. Flow calculation of "in advanced review" modified case
7. Evaluation
8. Preliminary report to client and discussion of practical possible modifications
9. As a result of step 8, implement final modification in CFD model (update of 3-D geometry model and re-meshing)
10. Final flow calculation and report
11. Preparation of workshop drawings for the modification work

Note that a retrofit project includes several additional steps, including a discussion of the preliminary runs with the client. This is important in order to obtain a realistic, practical and optimal solution. New equipment or an R&D project can be cut down to four main steps (items 2, 4, 5, and 10), as shown in the general CFD run diagram of Figure 3-1.

5 Results and discussions

Three retrofit modelling cases (sections 5.1 to 5.3) and one Electrostatic Precipitator to Fabric Filter (ESP to FF) conversion case – (section 5.4) are presented in this paper. Each case includes:

- Problem description
- CFD model and actual operation data
- Presentation of results
- Discussion of findings and achievements

The retrofit case presents three FLSmidth Airtech modifications:

- Inlet manifold guide plate system
- Internal plate work system
- Hopper guide plate system

The ESP to FF case describes a standard FLSmidth Airtech conversion where high focus is placed on positioning of the gas distribution internals in order to obtain a cost effective solution.

5.1 Case study 1 – Cement Plant Kiln-Raw Mill Filter

Problem description:
The filter was originally retrofitted from an Electrostatic Precipitator to a Fabric filter and the existing shell and support structure limited the size of the converted unit. Some very large girders in the hopper together with the anti-sneakage plates (partition plates) running from the bottom of the girders to the bottom of the hoppers were left in place. Bag wear and repeated filter bag failures were experienced after only 3 months of operation.

CFD model and actual operation data:
The filter unit is a two bay, single compartment design with dampers at the inlet flange of the inlet manifold and with a partition plate through the center of the inlet manifold. The CFD model of the filter is shown in Figure 5-1. Note that in this case the outlet manifold is not included, as focus is placed on inlet manifold, filter compartments, and particularly the gasflow velocities approaching the bags.

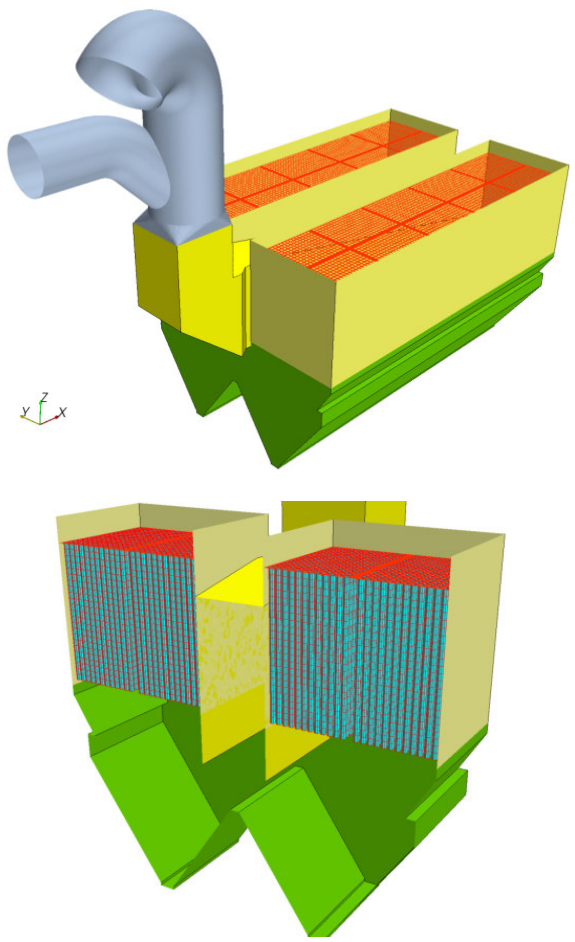


Fig. 5-1: CFD model of Case study 1.
Upper: Full Filter.
Lower: Filter section with visible bags.

The actual operation data for Kiln only mode (worse case) is given in Table 5-1.

CASE 1	Cement Kiln/Raw mill
Filter type:	Other brand
Bags design: Number of bags [-] Number of bags /comp. [-] Bag length [mm] Bag diameter [mm]	 4320 2160 4495 152
Operational data: Gas flow rate [Am^3/s] Temperature [^oC] Static pressure [mmWG] Air-to-cloth ratio [m/min] Dust load [g/Am^3] $V_{filter\ inlet\ flange}$ [m/s]	 230.3 150 -480 1.49 60 22.6

Table 5-1: Filter design and operational data.

Results:
The present flow simulation model of the cement plant kiln/raw mill filter includes upstream ducting from kiln and raw mill, inlet manifold, slots to right and left hoppers, hoppers with partition plates, and right and left filter compartments with all bags. The "As build" design and the optimal modified design are shown in Figure 5-2.

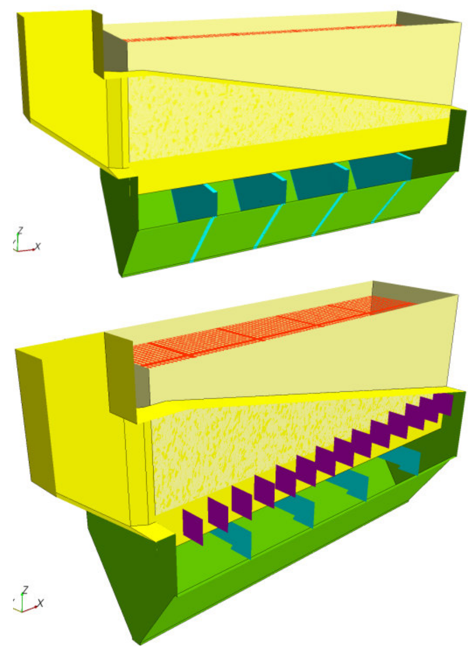


Fig. 5-2: CFD Study 1
Upper: As build design.
Lower: Modified design based on CFD study.

The full modification includes a custom FLSmidth Airtech guide plate system in the inlet manifold, hopper wall baffles, and partial removal of the hopper partition plates.

Figure 5-3 shows the velocity distribution in the inlet manifold for the as-build design and for the modified design. In the slot to the hopper, the velocity distribution has been highly optimized by installing a guide plate system in the inlet manifold (modified design). Peak velocities in the inlet manifold are up to 50 m/s, which is very high compared to the ideal mean gas velocities at inlet flange of 22.6 m/s. The high peak velocities are originating from the ducting upstream the filter and are far above generally accepted maximum velocities.

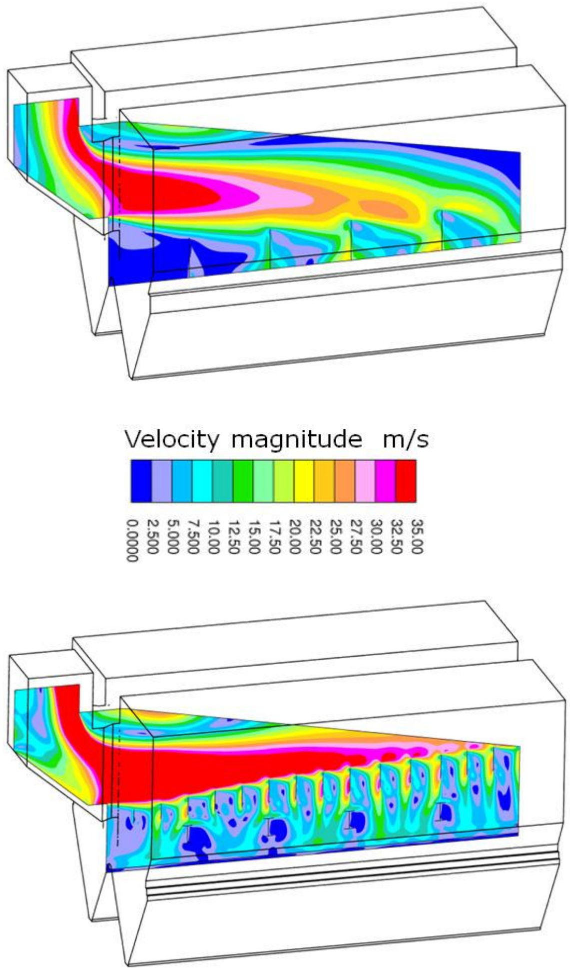


Fig. 5-3: Velocity distribution in vertical cross section in inlet manifold.
Upper: As build design.
Lower: Modified design.

The gas distribution pattern has been highly improved with the modified design (Figure 5-4). The peak gas velocity approaching the bags is now reduced to 4.5 m/s, which is still above the recommended velocity for newly designed FLSmidth Airtech filters. It should be noted that the overall design parameters for hopper mean slot velocity, can velocity, and filtration velocity (Q/A) are 26%, 31%, and 49% higher than the recommended FLSmidth Airtech maximum values, respectively. For normal operation (raw mill only) the peak gas velocity approaching the bags is 3.8 m/s and ideal hopper slot mean velocity, can velocity, and filtration velocities (Q/A) are 5%, 7%, and 22% higher than FLSmidth Airtech maximum recommended values, respectively.

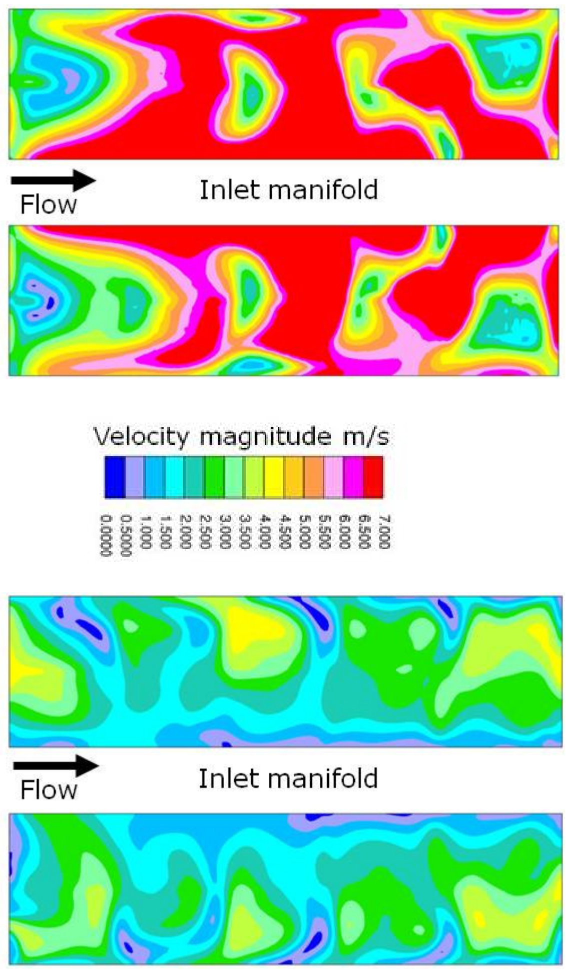


Fig. 5-4: Velocity distribution in horizontal cross section of filter section, 200 mm below bottom of bags.
Upper: As build design.
Lower: Modified design.

Figure 5-5 shows the velocity distribution in the filter section in a cross section 1500 mm above the bottom of the bags. A highly improved distribution is obtained with the modified solution.

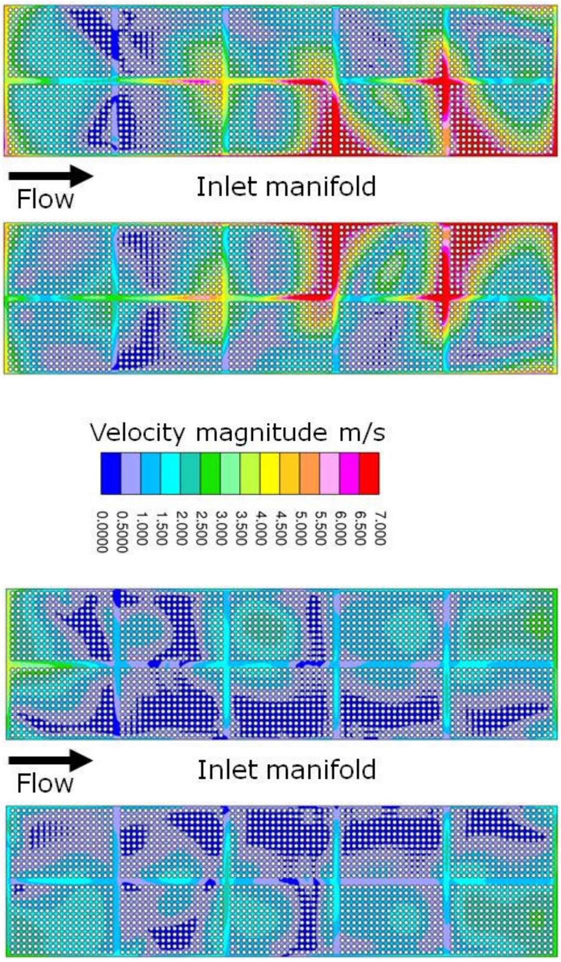


Fig. 5-5: Velocity distribution in horizontal cross section, 1500 mm above bottom of bags.
Upper: As build design.
Lower: Modified design.

<u>Findings and achievements:</u>
Computer modelling and CFD analysis was performed, revealing significant problems in localized flow velocities and flow distribution.

The CFD analysis helped determine and test the modifications, yielding excellent results. It should be noted that the design parameters, including filtration velocity and can velocity are much higher than recommended values for new FLSmidth Airtech filters. The CFD study allowed testing of several possibilities, including removal of some existing distribution plates in order to distribute flow uniformly throughout the array of bags. The plant now has more than 1 year bag life, which is still not comparable to modern fabric filters, but represents an increased filter bag life of 400%.

Another finding from the CFD analysis is that the ductwork in front of the filter presents significant pressure losses and can be greatly improved.

5.2 Case study 2 – Cement Plant Clinker Cooler Filter

<u>Problem description:</u>
The plant has an adequately sized clinker cooler Fabric Filter. However, unacceptable bag wear problems were experienced, with a section of the filter presenting repeated bag failures due to abrasion. Several intuitive solutions were implemented by the plant, but the problem was simply moved, not resolved.

Different solutions were tested through CFD studies to find the right solution. It required a combination of vanes at the compartment inlets and flow restrictors at the outlets to balance compartment-to-compartment flow distribution.

<u>CFD model and actual operation data:</u>
The filter unit is a 12-compartment design with dampers at each compartment inlet and outlet. The CFD model of the filter is shown in Figure 5-6. In this case, the outlet manifold is included in the model, with focus placed on the velocities approaching the bags, and on the compartment-to-compartment flow balance.

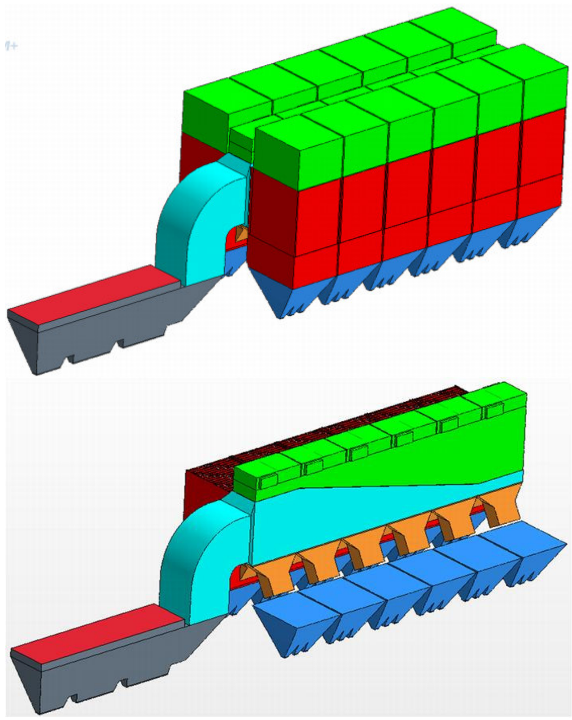


Fig. 5-6: CFD model of Case study 2.
Upper: Full Filter.
Lower: Right filter side removed. Inlet/outlet manifolds and ducting to filter compartments now visible.

The actual operation data for the Clinker Cooler filter is given in Table 5-2.

CASE 2	Cement Clinker Cooler
Filter type:	Other brand
<u>Bags design:</u>	
Number of bags [-]	3456
Number of bags /comp. [-]	288
Bag length [mm]	4267
Bag diameter [mm]	133
<u>Operational data:</u>	
Gas flow rate [Am^3/s]	125
Temperature [^oC]	200
Static pressure [mmWG]	-70
Air-to-cloth ratio [m/min]	1.21
Dust load [g/Am^3]	28
$V_{mean,filter\ inlet}$ [m/s]	15.3

Table 5-2: Filter design and operational data.

<u>Results:</u>
The Clinker Cooler CFD model includes heat exchanger hopper, inlet ductwork, inlet manifold and all filter compartments including all bags, top boxes, and outlet manifold. The “As build” design and the optimal modified design are shown in Figure 5-7.

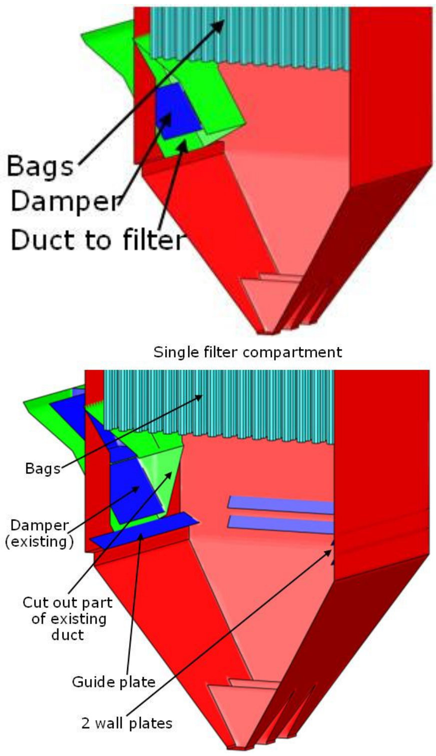


Fig. 5-7: CFD study 2.
Upper: As build design.
Lower: Modified design based on CFD study.

The full modification includes a baffling system modification in the inlets, cut out part of the inlet duct in the filter compartments, and hopper wall baffles.

Figure 5-8 shows the velocity distribution in the mid-plane of compartment 6 (right and left). High cross flow velocities at the bottom of the bags are observed for as-build design, which may result in bags movement and bag-to-bag wear. The flow distribution in the filter compartment hoppers has been highly improved by the modified design, resulting in much lower peak velocities

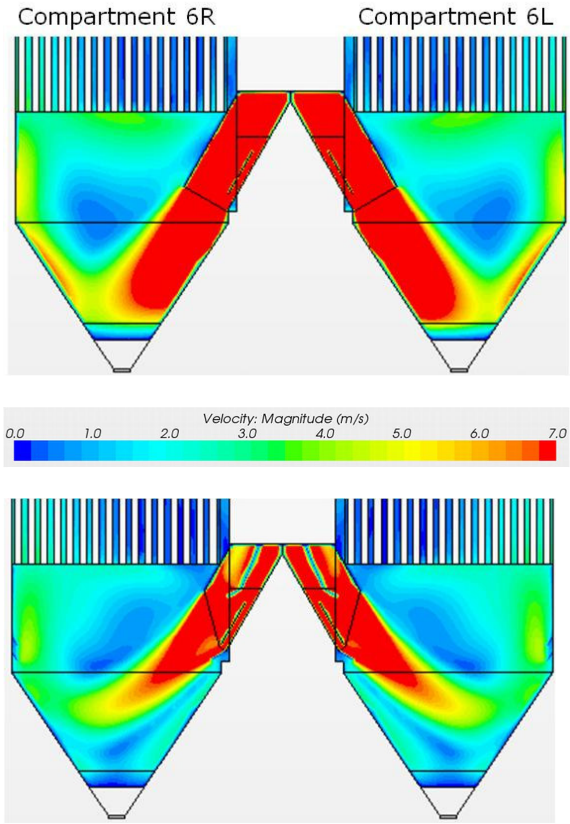


Fig. 5-8: Velocity distribution in vertical mid-plane cross sections of no. 6, right and left filter compartments.
Upper: As build design.
Lower: Modified design.

Peak gas/dust velocities approaching the bags are above generally accepted values (approx. 6 m/s in some areas of end compartments) for as-build design as shown in Figure 5-9.

Clearly, the modified design shows improved gas/dust velocity distribution approaching the bags. Peak velocities are now below 2.5 m/s and in accordance with new FLSmidth Airtech filters.

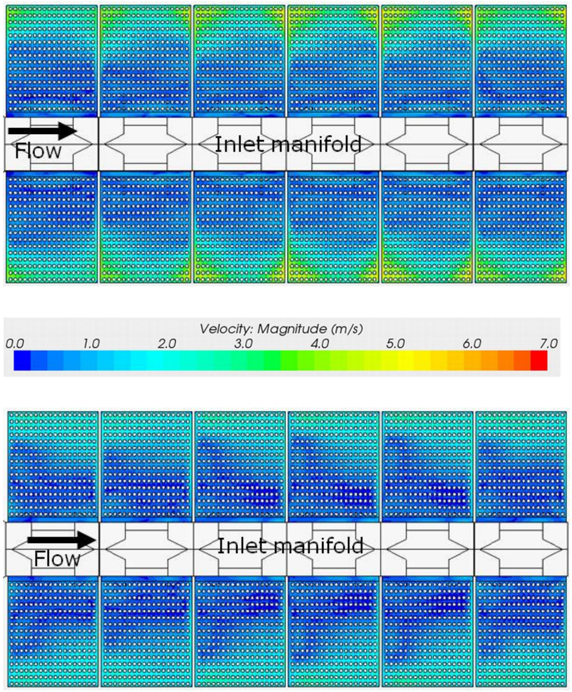


Fig. 5-9: Velocity distribution in horizontal cross section of filter section, 500 mm above bottom of bags.
Upper: As build design.
Lower: Modified design.

It was also found that compartment-to-compartment flow balance was outside general accepted limits (+/- 10%) for as-build design, but only for compartments 1 R & 1L (Table 5-3). As a rule of thumb, the small fraction of particles below approximately 5 μm will be affected by the unbalance. However, the large particles will follow their own path. The flow balance has been highly improved by implementing restriction plates between the top boxes and the outlet manifold. The optimized flow balance is now clearly in accordance with newly designed FLSmidth Airtech filters.

Compartment No.	1L	2L	3L	4L	5L	6L
% Balance	88	100	101	103	105	109
% Balance	85	98	100	102	104	106
Compartment No.	1R	2R	3R	4R	5R	6R

Compartment No.	1L	2L	3L	4L	5L	6L
% Balance	99	100	101	101	101	100
% Balance	96	99	101	101	101	100
Compartment No.	1R	2R	3R	4R	5R	6R

Table 5-3: Compartmental flow balance. R and L denote right and left side considering flow direction in inlet manifold.
Upper: As build design.
Lower: Modified design.

Findings and achievements:
The solutions analyzed and recommended were based on minimizing the number of gas distribution internals due to the abrasive nature of clinker dust, which requires Hardox material. For other applications, a hopper guide vane system could be a more effective solution (Case 3).

It should be noted that there was a concern about the recommended flow restriction plates at the outlet manifold, which may cause slightly higher overall pressure loss. However, this should prove to be an acceptable compromise in order to better utilize the total filtration area and maximize fabric filter performance.

5.3 Case study 3 – Cement Plant Kiln-Raw Mill Filter

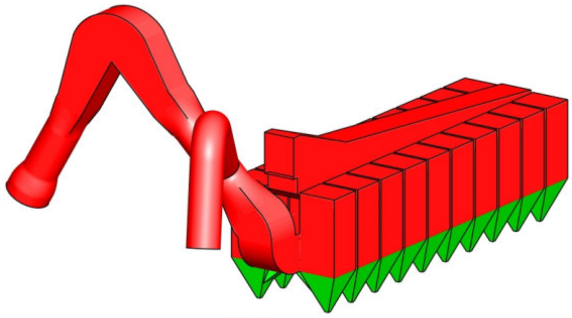
Problem description:
Bag wear problems were observed in some areas after a few months of filter bag operation. The plant also reported other issues such as unbalanced flow, a significant difference between overall differential pressure and compartmental differential pressure, as well as dust build-up in the inlet manifold and in the compartment inlet elbows.

CFD investigations with different designs were analyzed for design operation conditions, finding the optimal solution with a different hopper distribution plate system.

CFD model and actual operation data:

The filter unit is a 20-compartment design with dampers at the inlet of the bend to the filter sections and in the outlet manifold. The CFD model of the filter is shown in Figure 5-10. Note that in this case the outlet manifold is included in the model as the outlet is on the same side as the inlet, likely contributing to the inadequate compartment - to - compartment flow balance. Focus is placed on the velocities approaching the filter bags and on the compartment-to-compartment flow balance.

The actual operation data for combined mode (worse case) is given in Table 5-4.



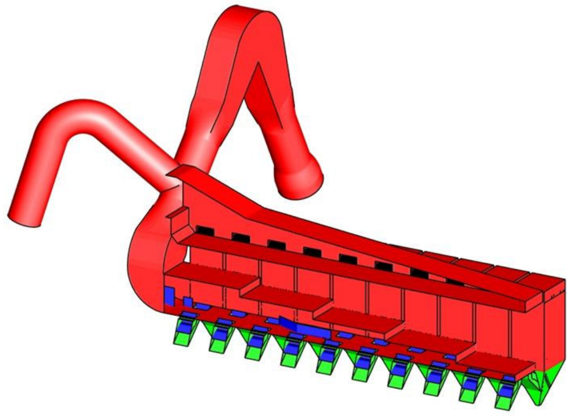
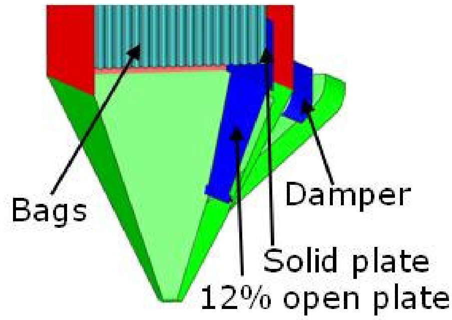


Fig. 5-10: CFD model of Case study 3.
Upper: Full Filter.
Lower: View into inlet and outlet manifold with visible dampers and flow distribution devices.

CASE 3	Cement Kiln/Raw Mill
Filter type:	Other brand
Bags design:	
Number of bags [-]	5700
Number of bags /comp. [-]	285
Bag length [mm]	6400
Bag diameter [mm]	127
Operational data:	
Gas flow rate [Am^3/s]	264.1
Temperature [^oC]	150
Static pressure [mmWG]	-100
Air-to-cloth ratio [m/min]	1.15
Dust load [g/Am^3]	100
$V_{mean,filter\ inlet}$ [m/s]	18.2

Table 5-4: Filter design and operational data.

Results:
This retrofit CFD model includes inlet ductwork, inlet manifold with internals and dampers, all filter compartments including the bags, and outlet manifold. The "As build" design and the optimal modified design are shown in Figure 5-11.



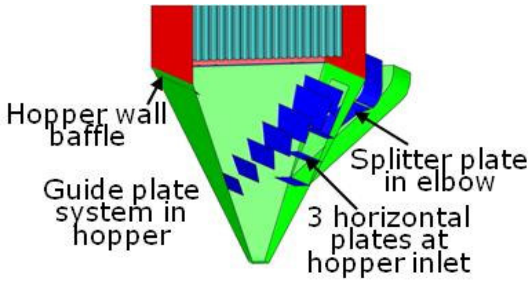


Fig. 5-11: CFD study 3.
Upper: As build design.
Lower: Modified design based on CFD study.

The full modification includes a custom FLSmidth Airtech hopper guide plate system modification, baffling system in the inlets, and hopper wall baffles.

Figure 5-12 shows the velocity distribution in the mid-plane cross section of compartment 2 (right and left). Gas/dust velocities approaching the bags for the as-build design are well above generally accepted values (> 7 m/s) in some areas. Figure 5-13 (as-built) illustration also shows large areas of high velocities, indicating the likelihood of bag wear around the first row of filter bags and to some extent to the last row of bags.

The CFD analysis indicated that the gas velocity is high at the bottom of the inlet manifold, except at the furthest pair of compartments, where velocity is very low, causing dust build-up (not shown on Figures). In addition, the support design for the gas distribution plate at hopper inlets causes dust build-up, although the velocity is high in this region.

The modified design shows that peak gas/dust velocities approaching the bags are within FLSmidth Airtech design values for new filters (Figures 5-12 lower and 5-13 lower), so filter bag life is expected to increase. Risk of dust build-up in the elbows to hoppers is not present in the modified design since the plate at hopper inlet has been removed. There may still be some risk of dust build-up in the inlet manifold at the end compartments due to low velocities.

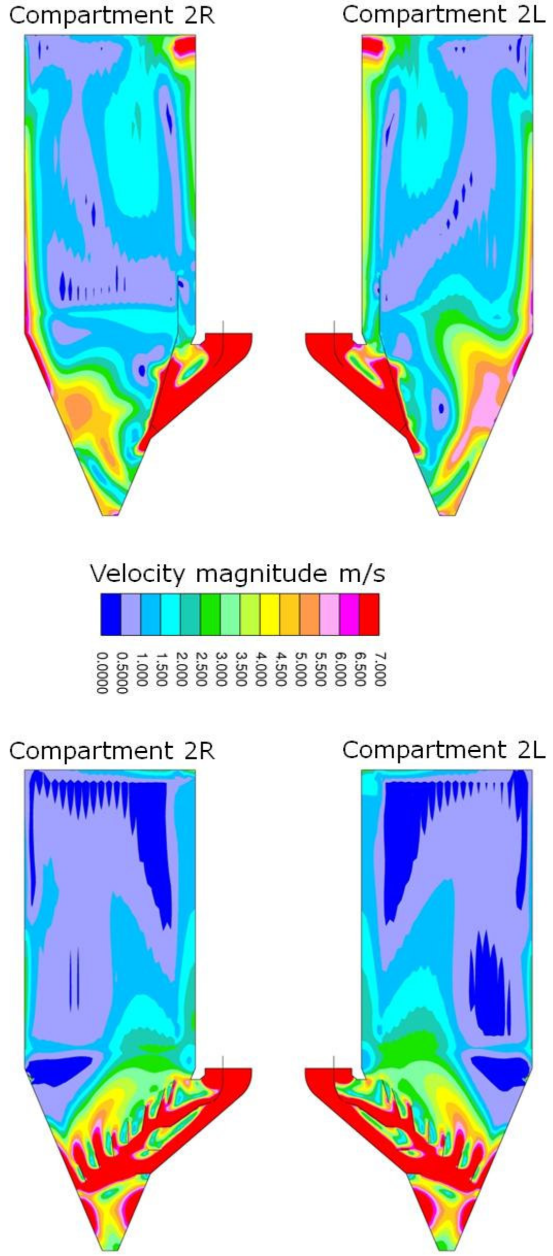


Fig. 5-12: Velocity distribution in vertical mid-plane cross sections of no. 2 right and left filter compartments.
Upper: As build design.
Lower: Modified design.

Figure 5-14 shows the gas/dust velocities approaching the bags in a cross section 200 mm below the bags. Clearly, the flow approaching the bags from the hopper has decreased for the modified design.

Compartment-to-compartment flow balance for Case 3 also turned out to be unacceptable, with an unbalance of up to 15% in some compartments. Similar to the Case 2 study, this was solved by implementing restriction plates at the outlet of the top box.

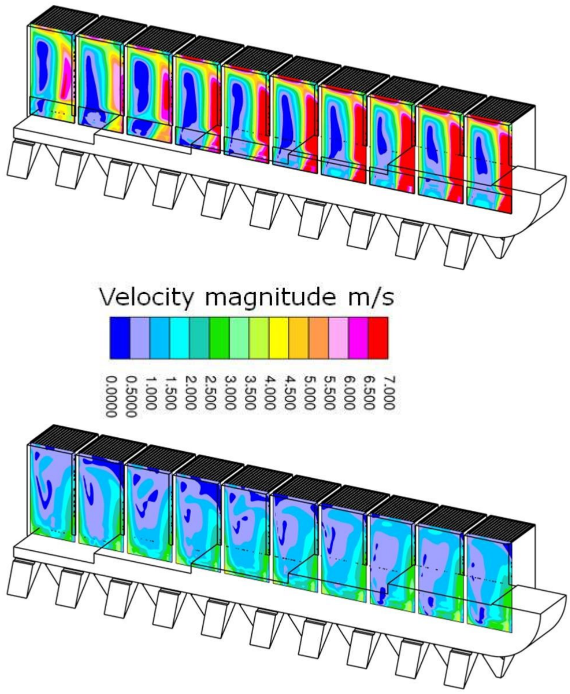


Fig. 5-13: Velocity distribution in vertical cross section, 30 mm in front of bags of no. 2 right and left filter compartments.
Upper: As build design.
Lower: Modified design.

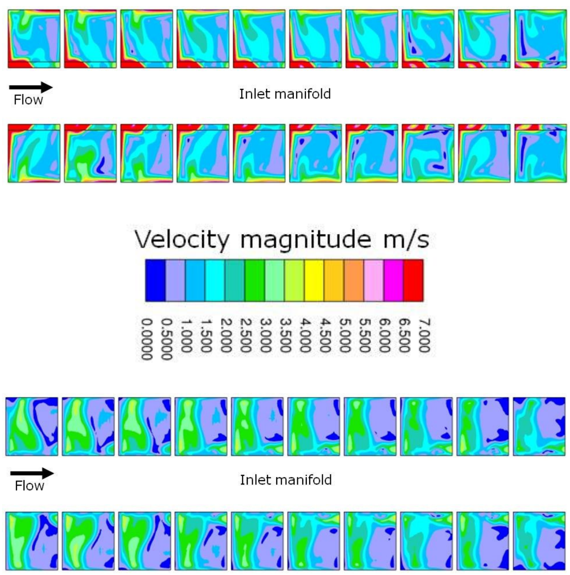


Fig. 5-14: Velocity distribution in horizontal cross section of filter section, 200 mm below bottom of bags.
Upper: As build design
Lower: Modified design.

Findings and achievements:
Several problems were identified by this CFD study, which demonstrated the possibilities of investigating problem areas in high resolution.

The recommended modifications have not been implemented, but the illustrations allowed other minor adjustments and the problem has been partially solved.

5.4 ESP to FF conversion Cement Plant Kiln-Raw Mill Filter

Introduction:
Electrostatic Precipitators (ESPs) have been traditionally used for removal of particulate matter in APC applications for decades, and they have always been sized and designed according to the emission requirements at the time of construction.

Older ESP’s are requiring extensive maintenance efforts to comply with new regulations. The high maintenance cost and newer emission standards make it difficult to meet the performance requirement on such a small footprint, so a viable option for improving the efficiency of these APC devices is to convert the old and small ESP casings to Fabric Filters.

In recent years, converting existing ESP casings to a Fabric Filters have become more and more common. However many factors have to be taken into account in a conversion project. One important factor is the flow distribution internals. It is essential that gas flow be being evenly distributed around the filter bags and in such a manner that no high velocity streams of gas impinge directly on the bag surfaces. In addition, it must be decided on whether to implement a side or bottom gas entry or a combination of both. The present case considers an FLSmidth Airtech conversion where the gas enters the housing from the side, as shown on the layout drawing (Figure 5-15.)

CFD model and actual operation data:
The filter unit is a 4-compartment design with dampers at the inlet of the bend to the filter sections and in the outlet of the top box. The CFD model of the filter is shown in Figure 5-16. Note that in this case the outlet manifold is not included in the model. Focus is placed on inlet ductwork, filter compartments, and especially the velocities approaching the bags.

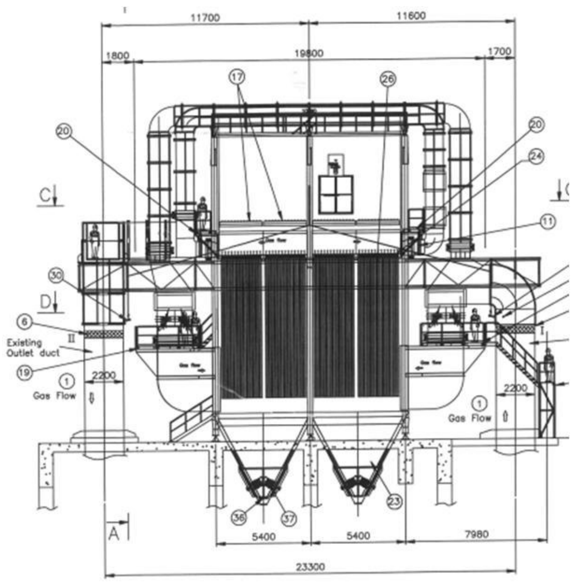


Fig. 5-15: General Arrangement Drawing of Electrostatic Precipitator conversion to Fabric Filter.

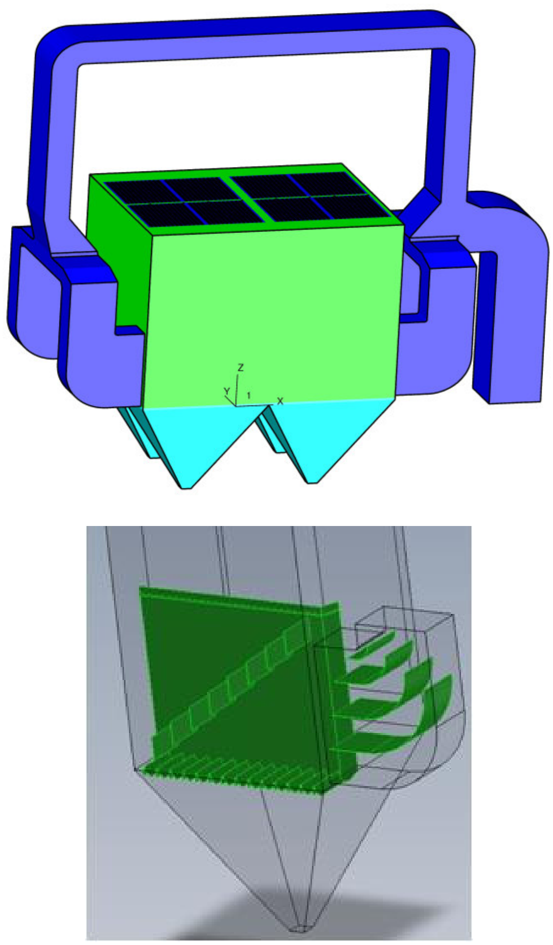


Fig. 5-16: CFD model of ESP to FF conversion.
Upper: Full Filter.
Lower: Standard FLSmidth Airtech retrofit filter guide plate system.

The actual operation data for design load is given in Table 5-5.

ESP to FF CASE	Cement Kiln/Raw Mill
Filter type:	FLS retrofit
Bags design: Number of bags [-] Number of bags /comp. [-] Bag length [mm] Bag diameter [mm]	 1872 468 8000 127
Operational data: Gas flow rate [Am^3/s] Temperature [^oC] Static pressure [mmWG] Air-to-cloth ratio [m/min] Dust load [g/Am^3] $V_{mean,filter\ inlet}$ [m/s]	 94.1 90 -200 0.94 70 17.8

Table 5-5: Filter design and operational data.

Results:
The flow simulation of the conversion includes a custom FLSmidth Airtech retrofit design containing inlet ductwork with dampers, elbows and guide vanes into each filter compartment, and the 4 filter compartments, including all bags.

The gas distribution internals include a completely new retrofit design with adjustable hopper profiles, a well-proven guide plate system, and a solid plate at the lower part of the compartment (see Figure 5-16). This design had already proved to work well on new filters in operation and was successfully applied and tested in this modification. In the results presentation below, focus is placed on peak gas/dust velocities approaching the bags in the filter compartments.

Figure 5-17 shows the velocity distribution in the mid-plane of the gas duct outside the bag array. The footprint was very limited and high gas velocities enter the duct in front of the bags, but the illustration shows that the gasflow is well distributed by the gas distribution internals.

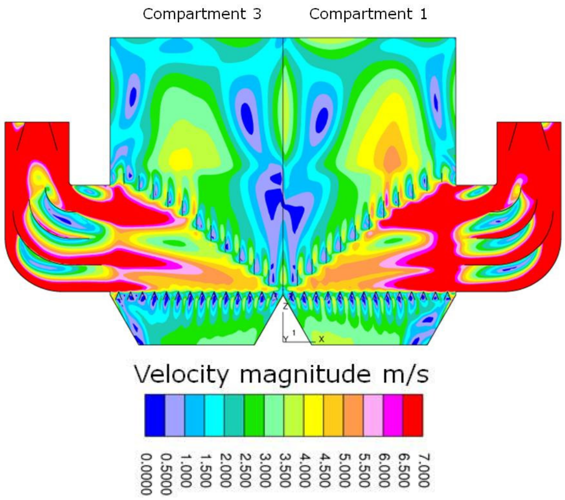


Fig. 5-17: CFD results of channel (outside filter bag array) mid-plane vertical cross section of compartments No. 1 and 3.

Figure 5-18 shows the gas velocity distribution approaching the bags from the frontal side (cross section 25 mm in front of the bags). The velocity distribution in the filter section is very acceptable and a design with high safety margin has been obtained. For design airflow conditions, gas/dust velocities approaching the bags are well below 2.5 m/s.

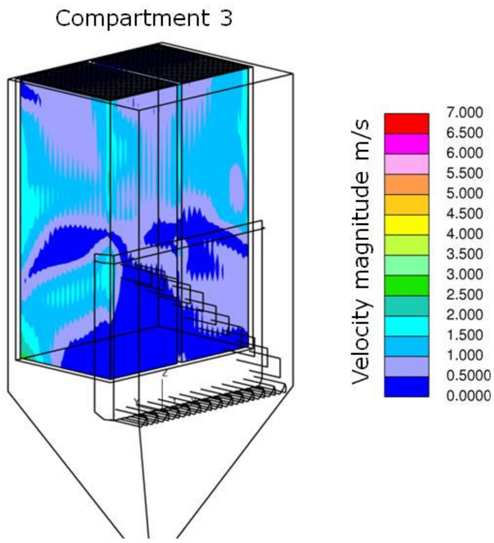


Fig. 5-18: Velocity distribution in vertical cross section 25 mm in front of bags, compartment. No.3.

The gas velocities approaching the bags from the bottom are shown in Figure 5-19 (upper figure – 200 mm above the bottom of the bags). Figure 5-19 (lower figure) shows the velocities approaching the bags in a cross section 6000 mm above the bottom of the bags, which is above the gas distribution screen.

The illustrations show that the gas/dust velocities approaching the bags are below 2.5 m/s throughout the array of filter bags, which is considered very acceptable.

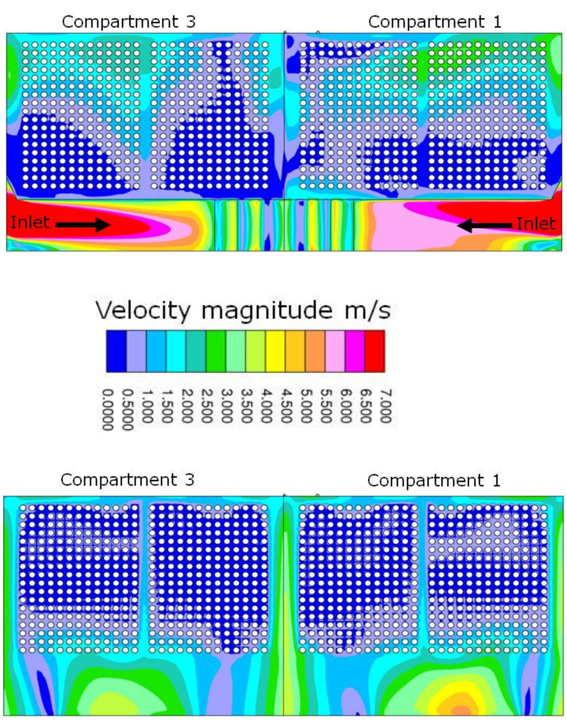


Fig. 5-19: Velocity distribution in filter compartments No. 1 and 3.
Upper: Horizontal cross section 200 mm above bottom of bags.
Lower: Horizontal cross section 6000 mm above bottom of bags.

Conclusions:
The present CFD case investigated the gas velocity distribution in a very restricted foot print conversion of Electrostatic Precipitator to Fabric Filter. The study has demonstrated that the gas velocities approaching the bags are below allowable levels, so performance guarantees can be met.

The filter has been in operation for 6 months without any bag damage. Based on the present investigation of the gas distribution and taking past FLSmidth Airtech experience into account, a long filter bag life is projected.

The gas distribution design with side entry and with possibilities for adjustment between bottom and side entry is promising and can be used on other retrofit and especially on other Electrostatic Precipitator to Fabric Filter conversions. As previously mentioned, a similar design has proven to be successful on newly constructed FLSmidth Airtech filters.

6 CFD versus traditional approach

The common procedure of attempting improvements by implementing full-scale, intuitive solutions can be uncertain, time consuming and expensive. In addition, process equipment availability for implementing modifications is usually limited to one shutdown per year, so a partial or imperfect solution can present problems long before any additional modifications can be made.

Physical model building and testing is also extremely expensive and time consuming, so compromises of possible solutions are made in order to determine an acceptable solution within one or two iterations.

With CFD modelling, we have the flexibility to test different solutions and have definite results within a short time, allowing multiple iterations to determine and fine-tune the ideal solution for the particular problem.

In summary, CFD modelling allows us to find the right solution in a more effective manner. The fact that the result is commonly less expensive than traditional methods is a bonus to the technical advantages.

7 Conclusions

CFD modelling of Air Pollution Control equipment allows easy simulation of flow behaviour and pressure losses, and enables testing of different design modifications of internal components. CFD makes it possible to visualize system deficiencies in detail, which is far more efficient and cost effective than traditional model scale or actual, full-scale tests.

CFD simulation and testing has become an important tool to optimize the performance of Air Pollution Control equipment. The steps from idea to final design or from problem identification to solution have now become effective and efficient. CFD simulations offer a cost effective and efficient alternative, particularly when considering and evaluating several possibilities. After completion of the pre-processing steps, the actual calculations can run overnight on inexpensive computing hardware.

This paper has presented some details on how an optimal solution can be found, regardless of the particular equipment layout or problem.

Four different retrofit solutions of gas distribution internals have been presented:

1. Inlet manifold guide plate system due to single compartment design,
2. Minimum baffling system due to abrasive dust
3. Hopper guide plate system due to gas flow entry from the hopper
4. Effective filter compartment guide plate system due to flow entry from the side (ESP to FF conversion).

The FLSmidth Airtech retrofit concept based on CFD analyses is promising and the perspectives are:

- Pinpointing a definite solution in a single CFD analysis
- Flexible design with easy adjustment of gas and dust distribution
- Optimal gas/dust velocities approaching the bags
- Optimal flow balance
- Minimum pressure loss
- Long bag lifetime
- Low cost modifications

8 Literature

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