As Easy as CFD

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EXPLAIN HOW COMPUTATIONAL FLUID DYNAMICS (CFD) CAN HELP TO OPTIMISE PLANT COMPONENTS.

Introduction

CFD makes it possible to predict system behaviour in detail, far exceeding traditional and costly test setups. Heat transfer, pressure loss behaviour, velocity profiles, particle tracking velocimetry, flow phenomena and vaporisation processes are analysed using CFD simulation. CFD simulation programs have therefore developed into important tools for the analysis and optimisation of surfaces and instruments through which particles flow.

Today, development processes must be effective and efficient. Effective computer simulations offer an alternative to costly, conventional development processes, comprising constructive development, prototype construction and experimental validation (in several cycles). CFD simulations are based on numerical fluid mechanics, the purpose of which is to solve fluid mechanics problems using numeric methods. The models used are based on Navier-Stokes equations, Euler equations and potential equations. Intensiv-Filter optimises bag filters and plant components through the networking of 3D CAD systems (SolidWorks) with the in-house CFD program (CFX). Here, maximum synergies are achieved during necessary production steps. After completion of the preprocessing steps, the actual flow calculation is processed overnight on high-capacity PCs.

The typical component optimisation process using CFD is as follows:

- 3D geometry generation (SolidWorks).
- Preprocessing:
  - Importing 3D geometry.
  - Generation of the solid through which flow passes.
  - Grid generation.
  - Input of operating parameters (definition of flow/boundary conditions).
- Solver flow calculation start.
- Post processing.
  - Evaluation and/or visual presentation of the results.

The flow behaviour in ducts and filtering separators is disturbed by the existence of elbows, cross-sections and changes in direction. This leads to turbulences and zero-flow areas. Their optimisation is vital for the efficiency of the plant, concerning:

- Turnover, yield and selectivity of reactors.
- Product quality.
- Availability of devices by avoiding operational disturbances on the basis of soiling and wear.

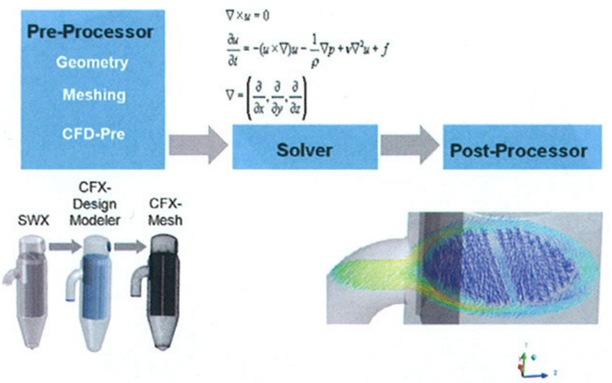

Figure 1. Typical components of CFD simulation.

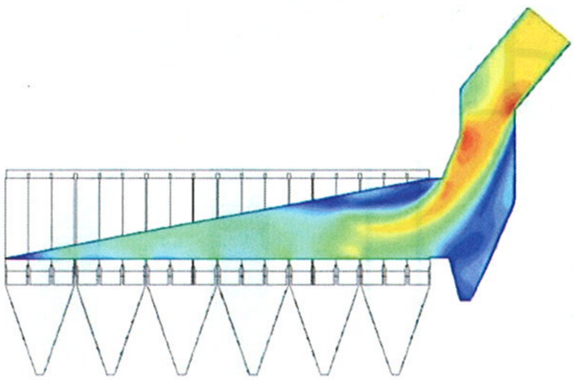

Figure 2. Initial situation and alternatives of the inlet stream.

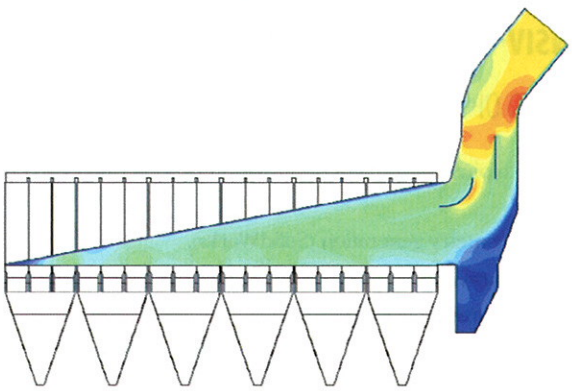

Figure 3. Realised design.

- Operational safety and energy consumption.

The following examples demonstrate the integration of a flow simulation in process engineering and constructional development, based on various dust removal installations.

New bag filter installation

In November 2009, Intensiv-Filter designed a new bag filter for a volume flow above 1.2 million m^3/h. As well as the Projet mega® bag filter, Intensiv-Filter was responsible for the pipes, the dust transport system, the fan, steel works and the entire assembly. By the time planning was underway, Intensiv-Filter had carried out various flow simulations in the area of the filter inlet. The aim was to determine the flow distribution into the filter.

Figure 2 shows the initial situation of the filtering installation on the example of the inflow area.

The variant that was eventually implemented (Figure 3) clearly illustrates the significant flow optimisation that can be achieved by constructional changes. Baffles were constructed accordingly and placed at the optimal position after the evaluation and determination of the CFD data; thus the recirculation zone and the flow field were homogenised in the main ductwork. The execution of the raw gas duct was also improved on the basis of the flow optimised parameters. Due to the homogeneous inflow, a much lower pressure drop could be realised, which leads to a lower energy consumption in the future.

Optimisation of an existing bag filter

In spring 2009, Intensiv-Filter was asked to assist in the optimisation of an existing bag filter designed by a third party. A double row bag filter was installed to dedust a two-stage preheater kiln with partial bypass of kiln gases around the raw mill. A gas cooling system was also installed.

The bag filter required this optimisation because of its high-pressure loss, which reduced production capacity. Steps were taken to reduce the overall pressure loss of the filter, such as increasing cleaning pressure and decreasing cleaning cycle time; however, these led to high consumption of compressed air.

The following short term actions were recommended:

- Change all blowpipes into a sufficient coanda injector or ideal nozzle system.
- Install a JetBus Controller® with regulation of compressed air and variation of cleaning cycle.
- Replace all filter bags.

Assuming that the inhomogeneous distribution into the filter was the main reason for the poor performance, Intensiv-Filter performed a CFD analysis.

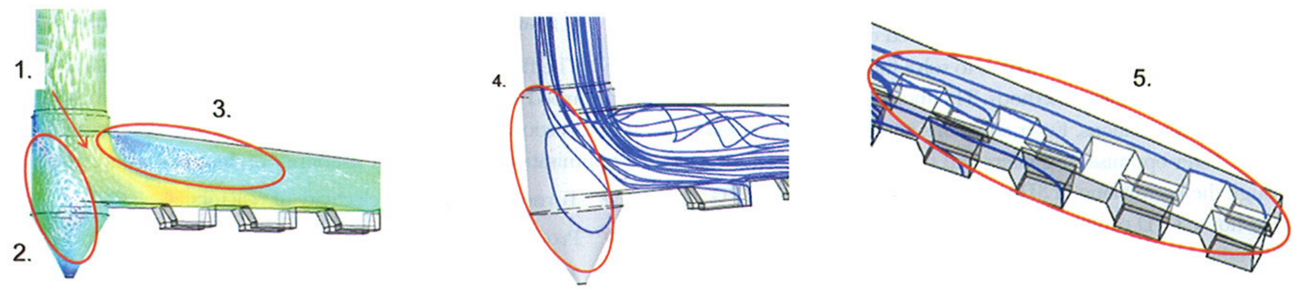

Figure 4. Inhomogeneous distribution into the filter

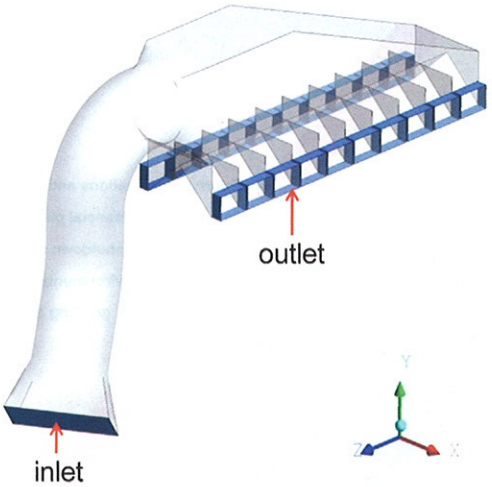

Figure 5. Basic geometry of the raw gas ducting.

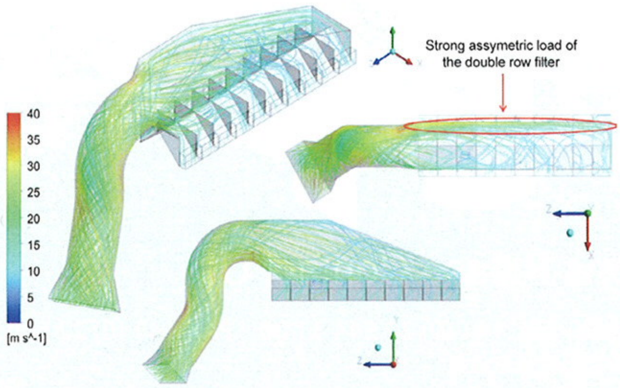

Figure 6. Strong asymmetric load of the double row filter.

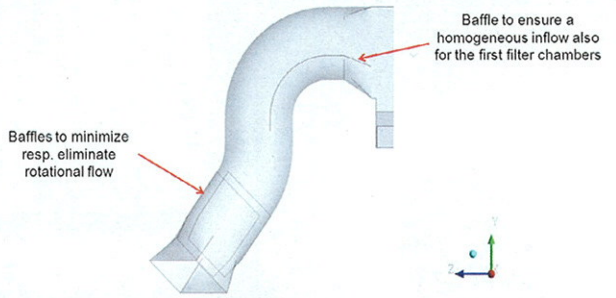

Figure 7. Optimisation of the raw gas ducting.

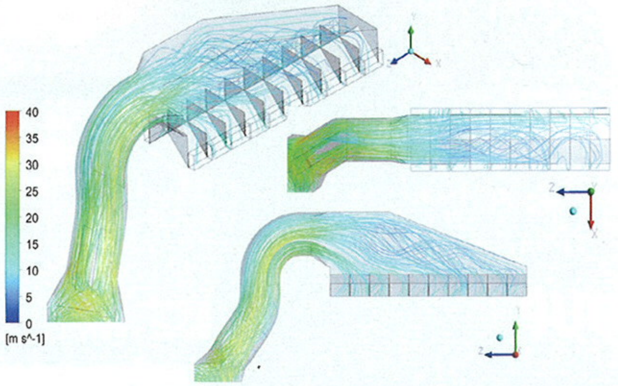

Figure 8. Homogeneous distribution into the filter due to correct design and position of baffles.

Figure 4 shows the results of the analysis:

1. Contraction of the volume flow.
2. Creating a dead spot in the preseparator.
3. Further distinctive creation of dead spots in the upper area of the main raw gas duct.
4. Poor efficiency in the preseparator.
5. Unbalanced dust load causes poor efficiency in the back raw gas segments.

The inhomogeneous distribution into the filter and the resultant inhomogeneous dust load are design errors. Missing baffle plates can lead to high velocities and unbalanced dust load on the bags. Directing the gas immediately into the hopper causes turbulences and increases the amount of dust. The results of the CFD analysis were confirmed by DP measurements, which indicated that the pressure loss of the chambers close to the inlet was significantly higher than at the end of the filter.

Current project - optimisation of raw gas ducting

Intensiv-Filter recently received an order for a double row filter for product recovery within a cement clinker grinding process. The roller mill with integrated classifier generates a rotating flow in the subsequent ductwork. The given layout of the ductwork on site additionally enforces the rotational movement of the air flow. To eliminate possible negative effects - such as wear or inhomogeneous distribution into the filter, which may further lead to malfunctions of the filter - Intensiv-Filter decided to optimise the raw gas ducting using CFD simulations.

Figure 5 illustrates the basic geometry of the raw gas ducting; Figure 6 displays a prediction of the system behaviour. Besides the assumed rotating flow in the raw gas duct, a strong asymmetric load of the double row filter is visible. The rotational movement of the air flow will promote wear, and the flow pattern in front of the filter chambers has a negative impact on the function of the filter. The task for the engineers was to improve the flow in the duct as well as the inflow of the filter without changing the general layout of the ductwork.

As a result of several simulations with different baffles at different positions, Figure 7 shows the design and positioning of two baffles in the straight part of the duct. In addition, the design of a further baffle directly in front of the raw gas duct of the filter itself is visible. The baffles in the straight part of the duct are designed to minimise and eliminate the rotational flow caused by the roller mill and classifier. The baffle directly in front of the filter also ensures a homogeneous inflow in the first chamber of the filter.

Figure 8 demonstrates the influence of the baffles on the flow pattern. Rotational flow is eliminated and a nearly homogeneous distribution into the filter is provided. CFD simulation has proven to be an effective tool in avoiding design mistakes and ensuring the functionality of the dedusting solution within the cement plant.

Conclusion

Efficient commercial CFD program packages enable flow and thermal simulations, as well as the optimisation of plant components. In addition to the acceleration of process engineering and constructional project work during the design and realisation of industrial dust removal installations, CFD also serves as a tool for fundamental developments.