

IMPROVING THE PERFORMANCE OF ASPHALT PLANT COMPONENTS USING CFD

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Abstract. *The current market of asphalt plants increasingly demands equipments with lower energy consumption, more compact dimensions in order to facilitate its transportation, easier maintenance and technological innovations. This paper will present the research and development work at the company CIBER Equipamentos Rodoviários with the introduction of the CFD (Computational Fluid Dynamics) technique using the CFX-5 software. Analysis performed on the rotary aggregate dryer, bag house, cyclone and exhausting manifolds will be described. Special focus will be given to an aggregate dust mass flow meter, bag houses and an air pre-cleaner, which were designed using CFD, leading to more compact dimensions and better efficient than previous cyclones. The computer simulation predictions of the fluid flow inside these components are improving their performance, reducing the energy losses, reducing their dimensions and providing a better understanding of some critical erosion points. Even for these complex flow fields, the numerical results are in accordance with field measurements, highlighting the enormous potential of the CFD benefits on the asphalt plants design.*

Keywords. *CFD, Asphalt Plant, Design Improvements.*

1. Introduction

Historically, the asphalt plants industry has been developing its products using empirical methods. An experimental development of asphalt plant components demands time and is an expensive process that involves costs with construction, operation and measurement instruments (Abad (1991)). To reduce the design time and costs, CIBER's Research and Development Team recently started using CFD (Computational Fluid Dynamics) techniques on their product design.

Several complex processes are involved during the asphalt production as combustion, solids drying, liquid and solid mixture, solid-air separation and filtration, pneumatic transport of particles and many others (Abad (1991) and Asphalt Institute (1989)). Numerical analysis using CFD allows a detailed understanding of the physical phenomena involved and the chemical process inside the equipment, being faster and cheaper when compared to any other development method. The lead-time of a new equipment development has become smaller, and for some cases it only demands the construction of one prototype, showing the benefits of this type of analysis.

The text that follows describes the successful experience of CIBER using CFD as an engineering tool for the design of several equipments, helping the company to offer the market products with lower energy consumption, more compact dimensions and in accordance with environmental regulation laws that are becoming more restrictive every day (Myers (1997) and ACGIH (1998)).

All the simulations presented on this paper were performed using the commercial code CFX-5.5 (AEA Technology (2002)). This code applies the Element Based Finite Volume Method (Schneider and Raw (1987) and Maliska (2003)) for unstructured grids with a fully implicit coupled solver. This coupling includes mass and momentum equations and the phase coupling in the case of multi-phase flows, *i.e.*, solves the whole system of equations for both phases simultaneously.

2. Filtering systems

During the drying process of aggregate matter inside the rotary dryer, a great quantity of dust is carried by the combustion gases exhaustion. This dust must be separated from the air in an efficient manner because the air will be delivered to the atmosphere (in accordance to environment regulation laws) and the dust should be recovered for the bitumen production process. Basically, the air filtering equipment is divided in a pre-collector system (which separates bigger particles) and a bag house. Computer simulation of the flow inside the filtering equipments as cyclones, bag houses and a new one created by CIBER denominated as “SE” (static separator), were carried out. Some of these examples are presented below.

2.1. Bag house

The previous bag house model manufactured by CIBER had some internal air distribution problems that could only be verified during its operation. It was observed on site that some filtering elements (bags) had a very short lifetime. The main cause for this problem was directly connected to the position of these elements and the airflow field inside the bag house. In order to gain a better knowledge of the airflow pattern and understand how a bad air distribution was related to this problem a numerical simplified single-phase simulation of the flow inside the bag was performed (Fig.1).

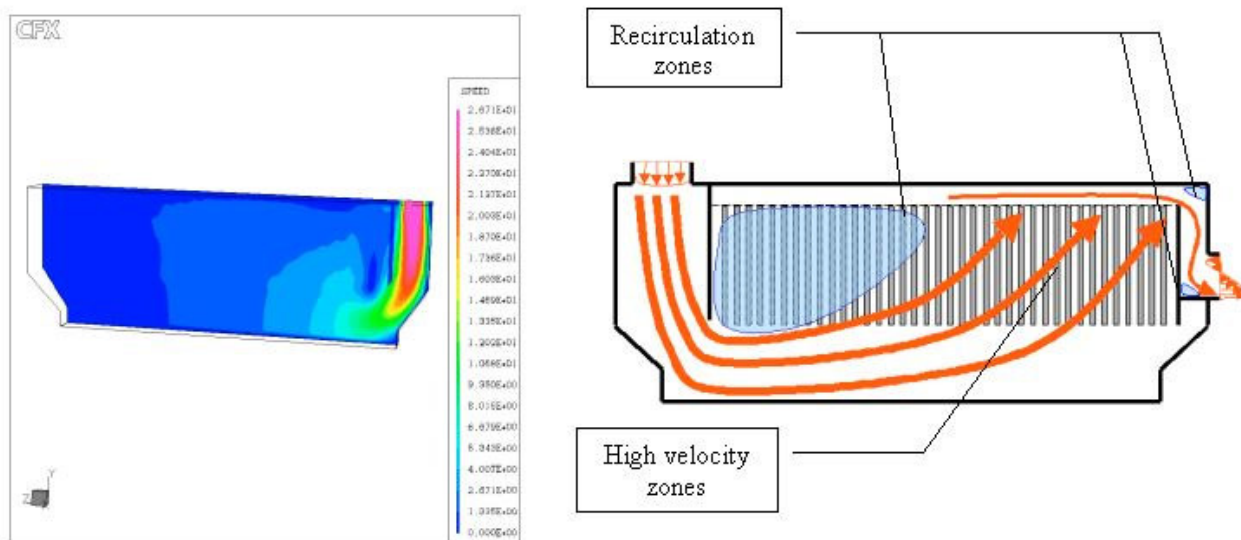


Figure 1. Air speed distribution inside the bag house.

The simulation showed that the air had a very non-uniform distribution originated by the abrupt air inlet shape. It could also be verified by these results that the bags with high wear were located in regions of high velocities, just as it was verified by the practical knowledge (ACGIH (1998), Mesquita et all (1988), Macintyre (1990) and Silva (1960)). As a first approach to develop a new bag house design, it was decided to improve the air inlet. A new design of bag house with an improved air inlet was carried out. Several geometries to the air inlet were tested and a fine solution was achieved (Fig.2).

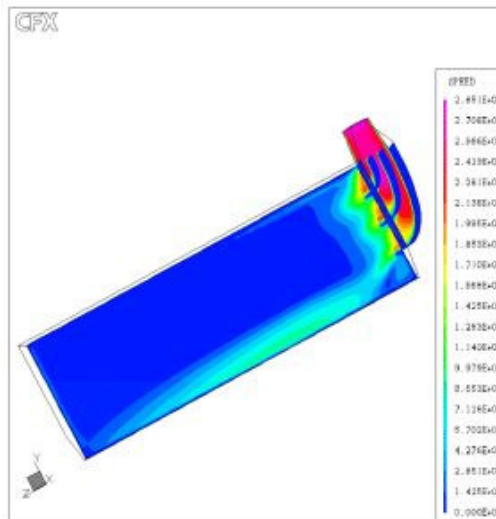


Figure 2. New airflow distribution.

The new shape of the air inlet device is now capable to provide a more uniform distribution of the airflow field, avoiding problems of excessive bag wear and high pressure loss. This had increased the efficiency of the bag house, making also possible the reduction of its dimensions. The new design was tested in one of CIBER asphalt plants and the tests showed a significant increase of the lifetime of this filtering elements as well as the efficiency of the bag house. Table 1 shows the measured pressure loss data from the new bag house configuration compared to the previous one.

Air inlet configuration	Pressure loss (Pa)
Old geometry	850
Improved geometry	350

Table 1. Measure data from bag house models.

Another consequence of improving the aerodynamics inside the bag house was the reduction of the exhaust fan energy consumption, leading to a more economical asphalt plant.

2.2. Modular Bag House®

The development of a new model of bag house system that has a better energetic efficiency, lower dimensions and also incorporates some facilities for its manufacturing, results in the so called “Modular Bag House System”. Due to the fact that this new concept incorporates all these characteristics, its production, operation and maintenance costs are much lower when compared to the previous ones.

This new bag house model solved the main problems of the previous filter. Basically, with the introduction of a calming chamber it was possible to decrease the mean speed value of the airflow around the bags (ACGIH (1998) and Mesquita et al (1988)). The lower speed throughout the filtering medium and the homogeneous distribution of the air-dust flow increases the lifetime of the bags and decreases the pressure loss of the bag house.

The compactness of the model was achieved as a result of these improvements on the flow pattern and also by the use of pleated bags, which have about five times more filtrating area than the smooth ones. The use of polyester pleated bags has also some limitations with the high gases temperatures presented on asphalt plants combustion gases, needing a very accurate temperature control system. The automatic control system used in the equipment allowed the safe use of polyester bags, avoiding the bag failure due to high temperature (burning) or low temperature (hydrolysis) operation.

The virtual prototyping using CFD allows visualizing the flow inside the bag house and test several geometric configurations in order to reach a better air distribution, reducing the abrasion potential and the pressure loss. Figure (3) shows the streamlines and vector fields for a numerical analysis of a two-phase air-dust flow inside the equipment. The filtering medium was treated as a momentum sink linearly proportional to the flow velocity through the bag ((ACGIH (1998), AEA Technology (2002) and Piesch (2000)).

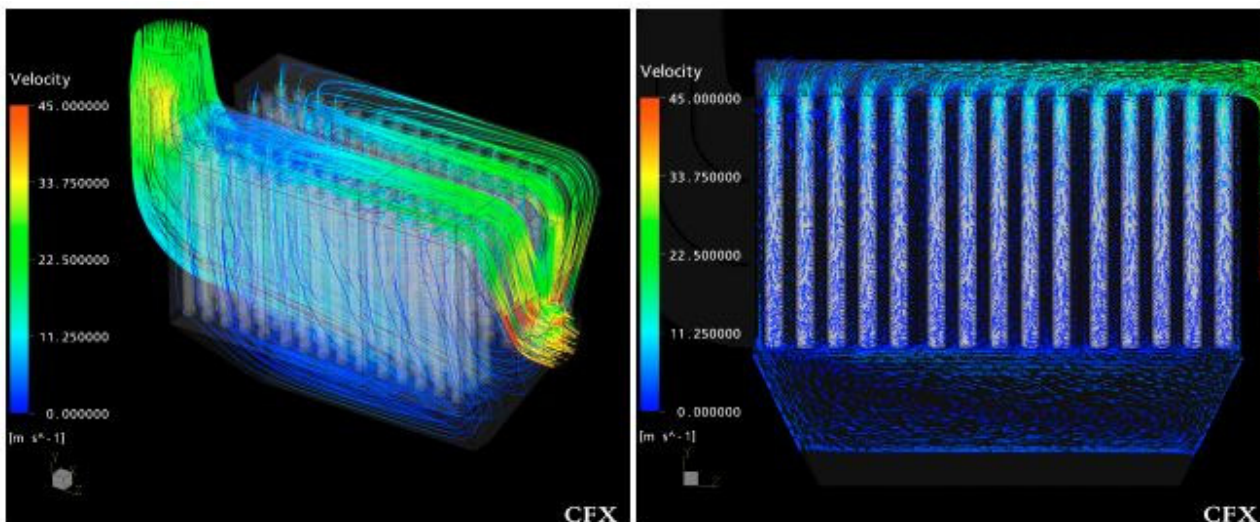


Figure 3. Velocity distribution inside the modular bag house.

Figure (4), presented next, illustrates the concept of this new design. This new “Modular System”, is easy to manufacture and fast to assembly. Its design was made with the main help of CFD analysis, providing the flow field with some “desirable” characteristics.

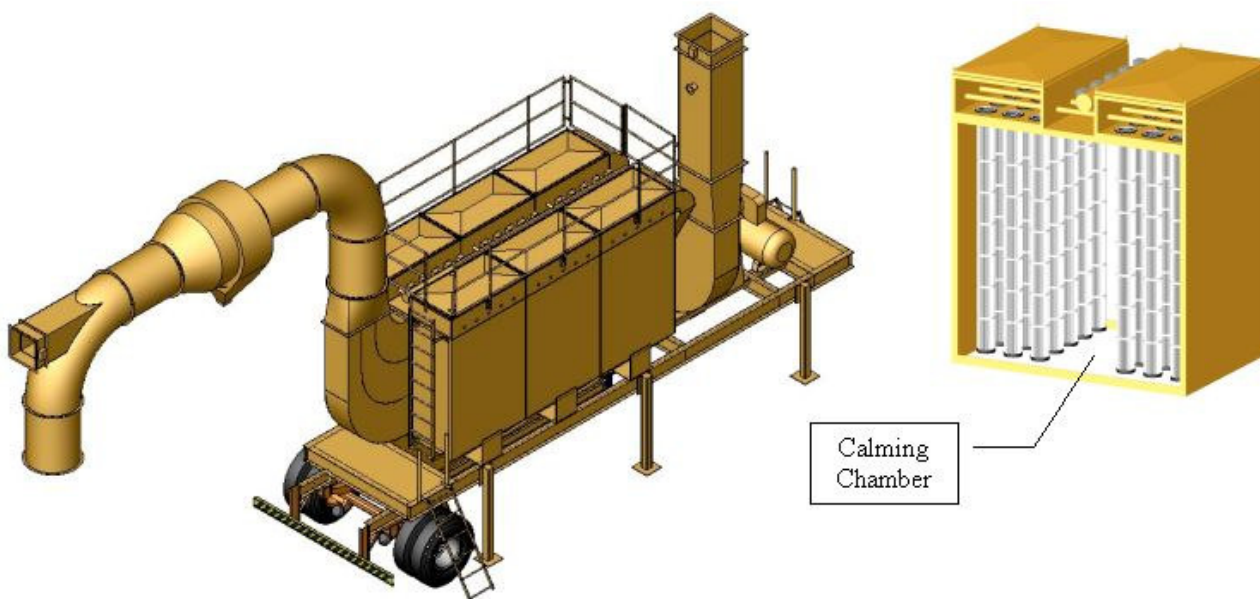


Figure 4. CIBER Modular filter and a module in detail.

2.3. Cyclones

In asphalt plants filtering process, it is quite common to use an air pre-cleaner, before the bag house, in order to separate the biggest fraction of the dust. The reason for that is to increase the filtering elements lifetime and recover part of the dust to the asphalt mixture. Cyclones were used for such task for a long time with success in several industrial fields (ACGIH (1998), Mesquita et all (1988), Macintyre (1990) and Silva (1960)). With the help of CFD, CIBER have tried to make some geometry improvements on these components in order to increase the dust collecting efficiency.

The possible addition of a cone at the overflow was verified (Fig.5) using a two-phase flow CFD model (air and dust).

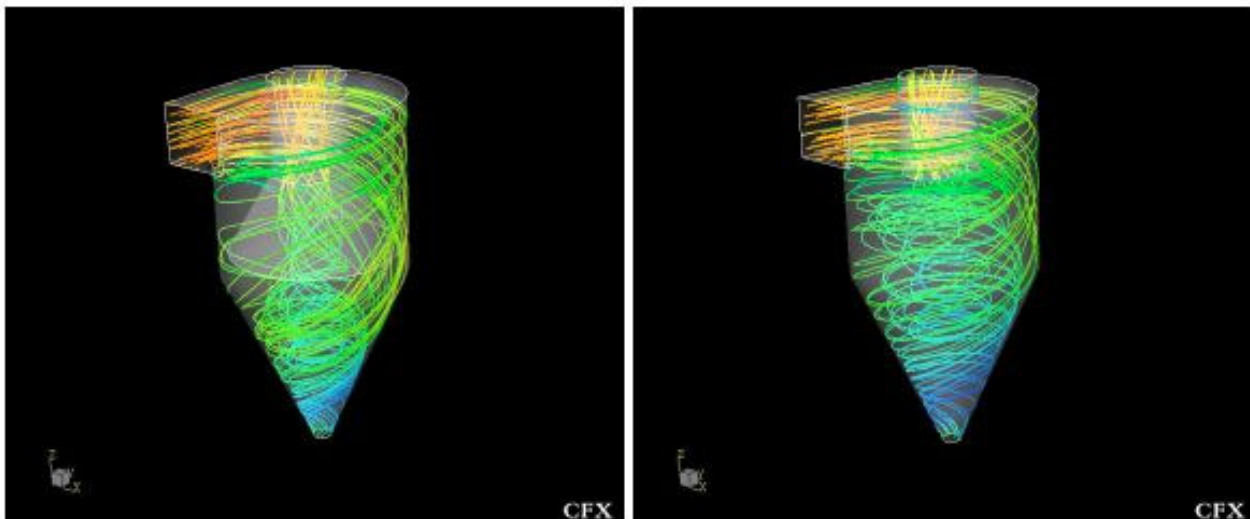


Figure 5. Comparison between the two geometries.

The CFD analyses have indicated that the addition of the cone was not an efficient design improvement, since it didn't cause significant changes in the values of collecting efficiency and pressure loss.

Table 2 shows the results of a numerical analysis for the cyclones.

Geometrical configuration	Collecting efficiency (%)	Pressure loss (Pa)
Cyclone with a cone at the over flow	26	45
Cyclone without the cone	29	47

Table 2. Predicted collecting efficiency and pressure loss for the two geometries using a 25 µm dust size.

2.4. Pre separator SE®

Looking for a compact solution that could substitute the cyclone, a component that demands a supporting structure (Fig.7) and thus demands more room at the plant's limited space, CIBER has developed a dust separator that is connected directly to the exhaust piping called pre separator "SE". SE works with the principle of inertia, since dust is much denser than the air (Mesquita et al (1988) and Macintyre (1990)). The dust recovered in the SE is ready to be added to the asphalt mixture, thanks to its high temperature when leaving the rotary dryer. Figure (6) show's the geometry of the component.

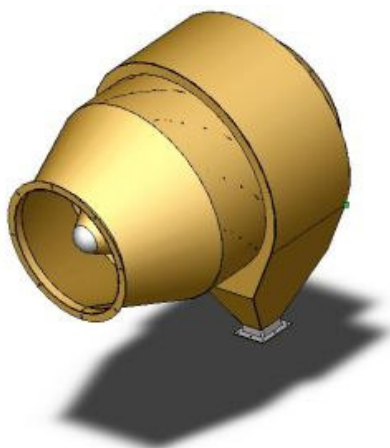


Figure 6. Geometry of SE.

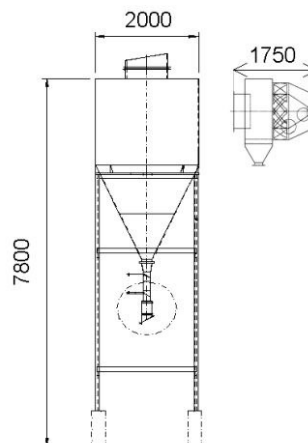


Figure 7. Dimensions comparison (in millimeters) between the SE and the cyclone used in asphalt plants.

A CFD model of the two-phase flow inside the SE was built in order to predict the dust collecting efficiency (Fig.8) and also the abrasion intensity (Fig.9) on this mechanical component caused by the contact with high speed dust particles (Dubbel (2001)).

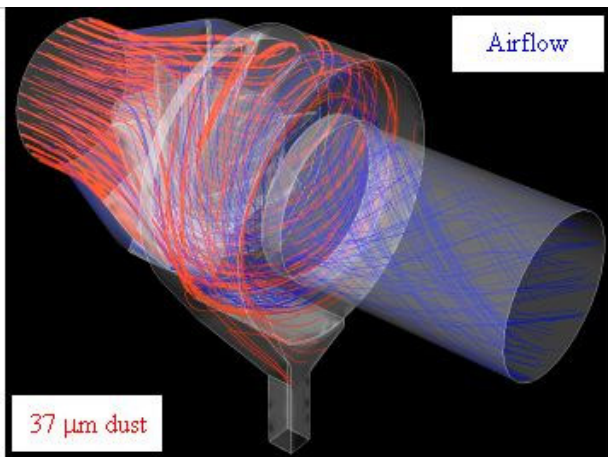


Figure 8. Dust recovering inside the SE.

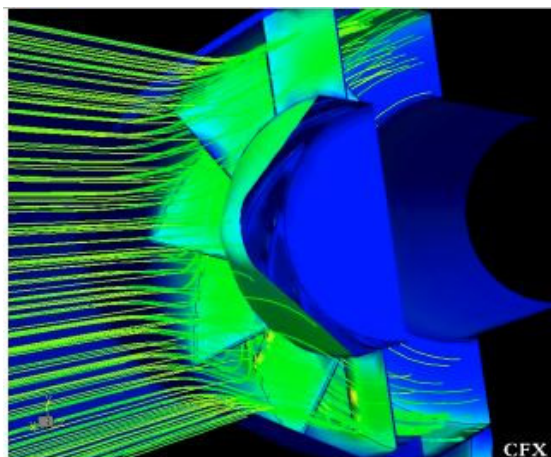


Figure 9. Speed contact with metallic parts and mass fraction present on the walls.

The simulations showed a good dust collecting efficiency (better than the CIBER cyclone model) and also indicated that the maximum dust speed was not higher than 30 (m/s), what is a liable value for the erosion process. The experimental analysis of the SE was accomplished on site in an asphalt plant at Bento Gonçalves (RS-Brazil). These studies validate the numerical results, not allowing particles bigger than 50 μm to pass through the SE.

The most important impact that CFD brought to the asphalt plant design at CIBER was the possibility to test virtually more “compact” equipments, allowing using all components of asphalt plant on a single platform. Figure (10) shows the result of this extensive work of compaction and performance study that substitutes the previous asphalt plant layout compounded of three platforms by a smaller one.

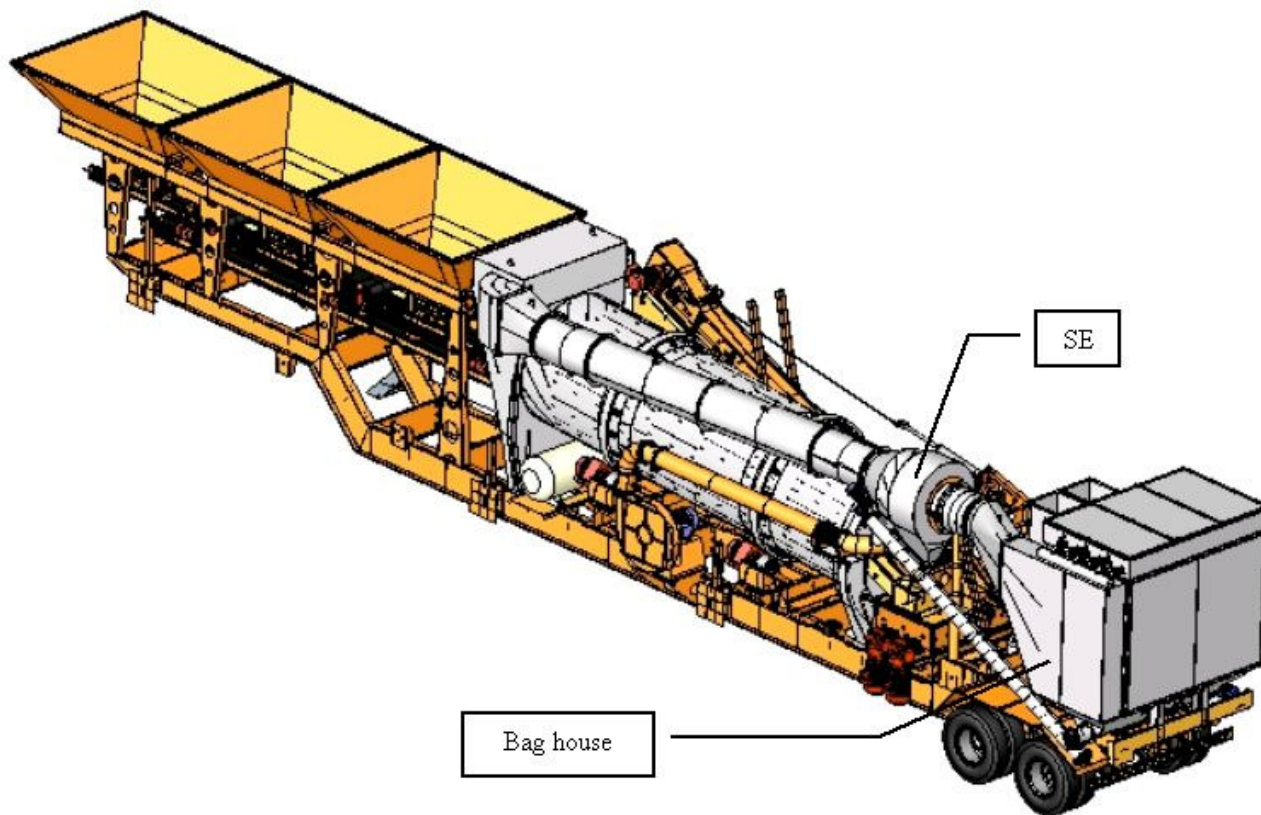


Figure 10. Single platform asphalt plant®.

Applying the same design concepts used for the modular bag house system, with pleated bags and improving the airflow distribution, it was reached, for a single platform asphalt plant (Fig. 10), with the help of CFD, a very compact bag house (Fig. 11). The bag house filtration parameters such as the air to clothe ratio was kept the same as applied for the modular bag houses (approx. $1.5 \text{ m}^3/\text{min.m}^2$). This new resultant bag house is an important benchmark for the asphalt plant industry, being the smallest one already produced for up to 120 ton/h asphalt plants.

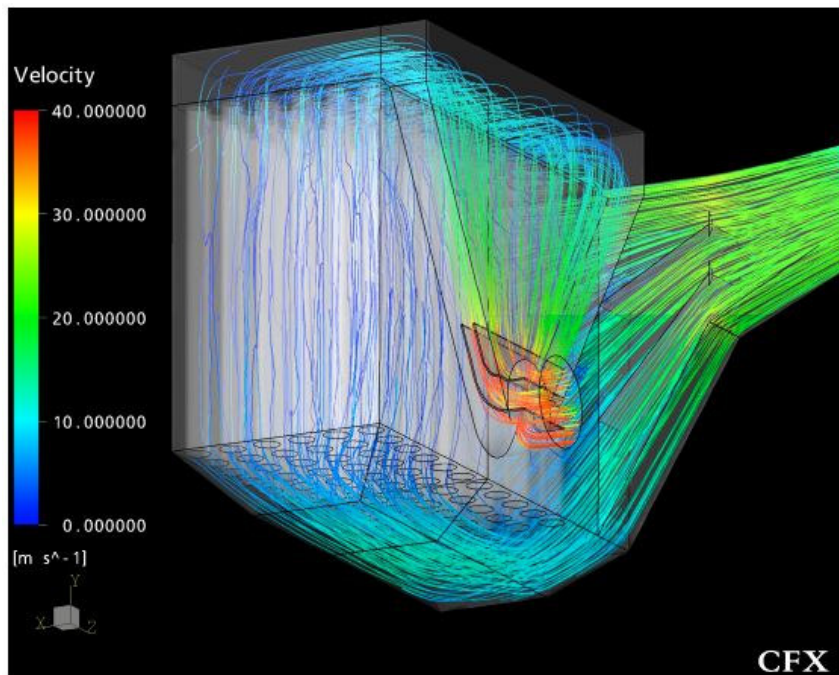


Figure 11. Bag house of the single platform asphalt plant.

3. Dust impact mass flow meter®

Another good example that was improved with the aid of CFD was the dust mass flow-measuring device. This equipment is based on the impact caused by the dust flow over a chute. This chute has its support located on just one side and at the other one has its reaction measured by a load cell. The signal generated by this load cell is converted into a value of mass flow. Figure (12) shows the geometry and a sketch of the mechanism.

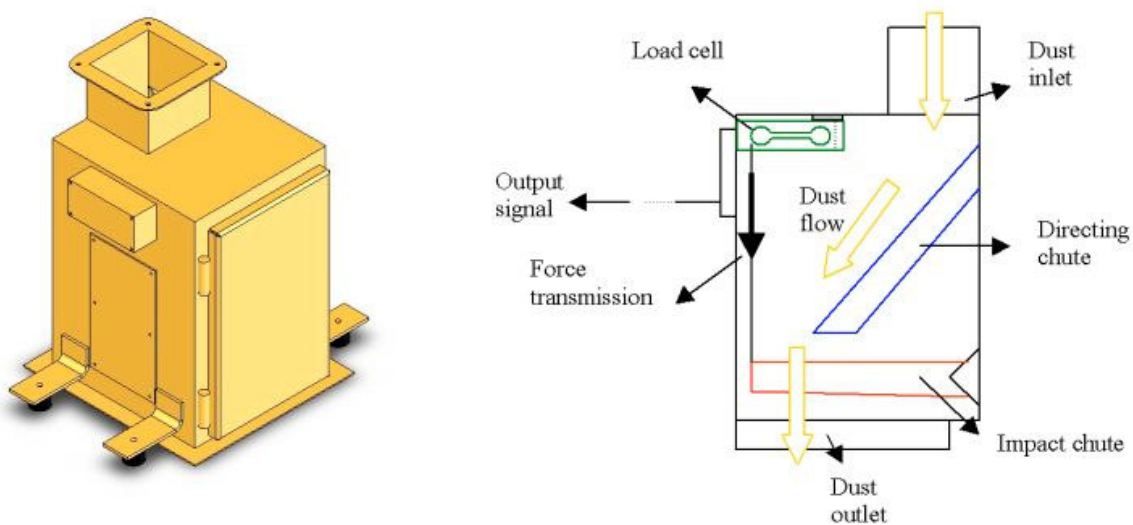


Figure 12. External view and sketch of the dust flow meter mechanism

The development of this measuring equipment was motivated by the cost reduction. Equipments like these ones are available on the market having a very expensive price. Simulating the dust flow with a CFD package, it was possible to achieve a very refined geometry, which was easy to manufacture, and could provide enough accuracy for such process (Abad (1991) and Asphalt Institute (1989)).

Numerical simulations were carried out to establish a correlation curve between load force and the dust mass flow. Figure (13) shows the simulated dust flow over the impact chute. The numerical simulated curve differed about 1.0 % from the on site calibrated curve achieved with another reference equipment.

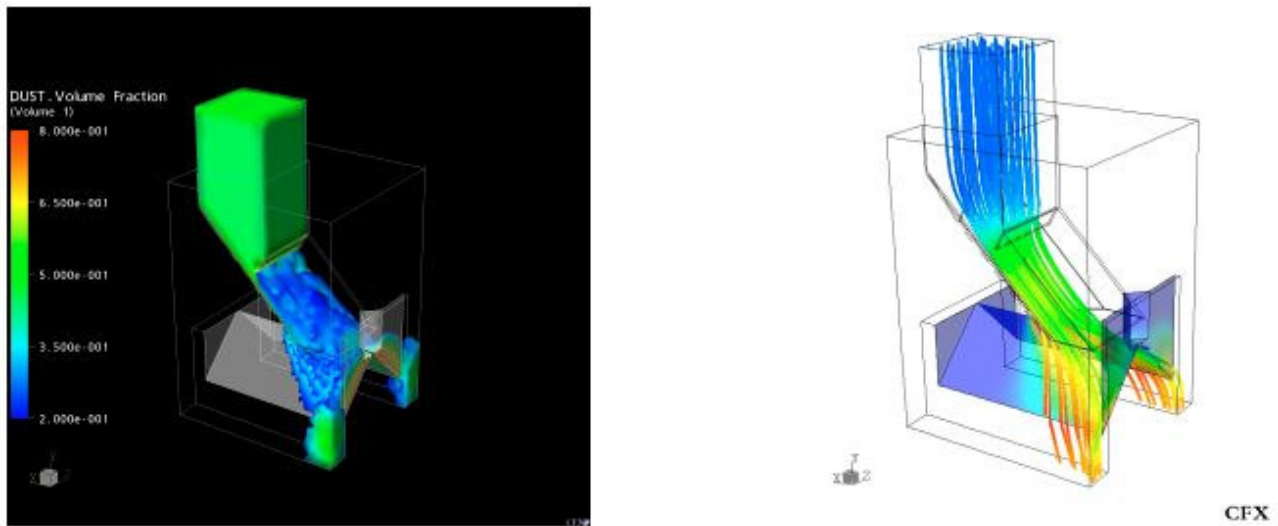


Figure 13. Dust flow inside the device (dust volume fraction and velocity streamlines).



Figure 14. Experimental data acquisition and experimental run.

It is important to mention that due to the use of a CFD preliminary study, only two physical prototypes were needed for this design, resulting in a very fast development cycle.

4. Rotary dryer

The rotary dryer is commonly called the “heart” of the asphalt plant (Nonhebel et al (1971) and Key (1978)) and it’s always oversized to assure a good drying of the aggregated material. The design of the rotary dryer is normally accomplished of just one-dimensional analytical analysis with the need of many empirical inputs that are very difficult to estimate. However, a complete CFD design of a rotary dryer involves several complex physical problems. Heat, mass transfer, combustion, rotating domains, multiphase and multi-component transient flows are found inside a very complex 3D geometry.

The first approach done by CIBER to simulate this problem had the main goal to enhance the flight design, because it plays an important role on the aggregate exposure to the convective and radioactive heat during the drying process (Nonhebel et al (1971) and Kee (1978)). An initial 2D study of just one section was done in order to gain some information about the process. It is important to stress that the design of such equipments is mainly done based on engineering experience and up to now it was very hard to find in the literature any deep study about flights.

Figure (15) shows the aggregate fall near the burner. Studies like this are helping CIBER to decide for specific flight shapes. A physical prototype of a new set of flight is been carried out. The final drum design is showed in Figure (16).

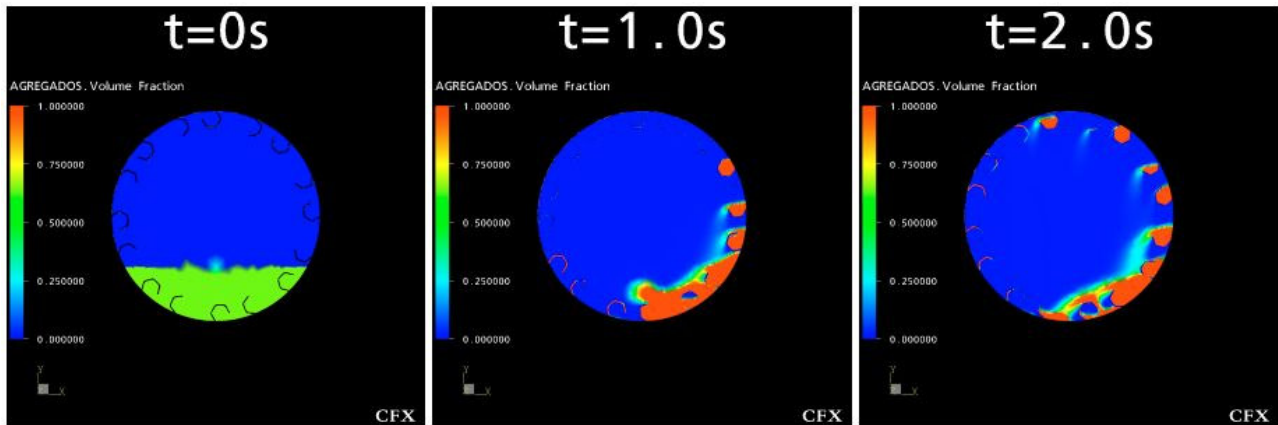


Figure 15. Aggregate fall near the burner.



Figure 16. Design of the rotary dryer.

Looking for a future efficiency improvement, CIBER is now planning to simulate the whole 3D complex phenomena including heat mass transfer during the aggregate drying process. With this model it's possible to modify the parameters, which can improve the dryer's efficiency. Figure (17) shows the surface mesh already prepared for this case. The construction and validation of this complex model is now the main goal of the CIBER research and development team.

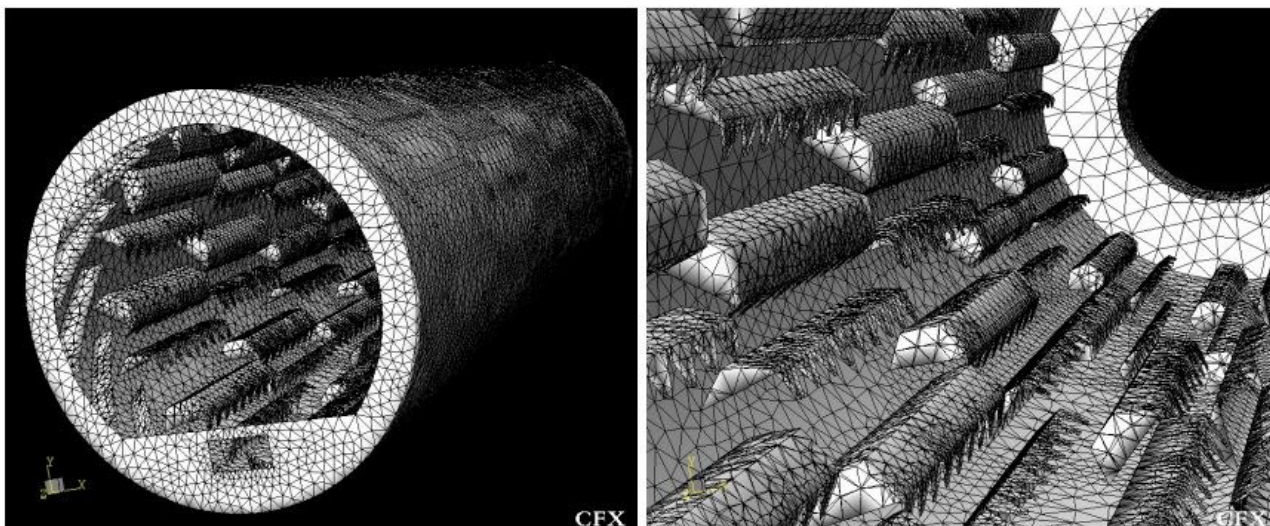


Figure 17. Surface mesh for a detailed simulation of a rotary dryer.

5. Conclusion

This paper presents the benefits of the introduction of a CFD tool applied to an old methodology of asphalt plant design. Several components of this very complicated system had its efficiency increased and its size reduced due to a better understanding of the flow physics. By using CFD for virtual testing, the engineers could get deeper information about the flow field distribution for the first time and thus design new concepts of several equipments, which had proven impossible for decades. This present work illustrates that a better understanding of the involved phenomena using a CFD tool, leads to more reliable and efficient equipments as well as reduces the design cycle and the costs involved.

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