A Practical Approach to Pollution Reduction in Isfahan Province Steel Making Plants

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Introduction

Today, in addition to environmental effects, air pollution has economical, social and political consequences. Such a problem is more striking in metropolitans where accumulating population, vehicles and industries, altogether produces large amounts of pollution. A discernible example is Isfahan city and province.

Isfahan has one of the largest steel-producing facilities in the entire region as well as facilities for producing special alloys. Isfahan contains a major oil refinery and a large aircraft manufacturing plant. Unfortunately, on the other side, this city is one of most polluted cities in Iran. In recent years, this problem turned to be more severe due to climate changes. Consequently, finding clean and efficient solutions to contaminant industries is crucial.

It should be noted that among the mentioned industries located in Isfahan, steel making plants play a major role in air pollution. In fact, in every metric ton of steel produced, 10 to 25 kilograms of dust is accumulated. Further, a large portion of exhaust gases of electric arc furnaces (EAF) consists of CO, NO_x and So_x, which proved to be a threat to human health and environment. Thus, control and reduction of pollution production in steel making plants is essential.

Until now, various clean air solutions to EAFs and fume de-dusting systems, have been developed. Definitely, there is no question that de-dusting systems are crucial. However, the costs and outlay of fume extraction systems operation should be no higher than absolute necessary. To be practical, the most important goals are high efficiency, compliance with prescribed threshold values and low consumption of energy. One reliable and feasible method to ensure the functionality and efficiency of these systems are Computational Fluid Dynamic (CFD) simulations. In such a modeling, the effect of various parameters can be studied, which leads to improved designs and higher efficiencies. Therefore, developing models for de-dusting systems of steel making plants would be a useful practice.

Despite several studies in the field of modeling and optimization of fume extraction systems, no one has addressed the problem of turbulent reactive two-phase flow in industrial fume de-dusting systems and investigations are limited to approximate zero or one dimensional thermodynamic solutions. The present study aims to fill this gap in literature. In this paper the Mobarakeh Steel Making Plant is examined and the effect of operating parameters on the overall fume de-dusting system performance and efficiency is investigated.

Materials and Methods

The mathematical model of processes inside the fume extraction system is constituted of four different parts: swirling turbulent flow, Heat and mass transport by convection, chemical reactions and radiation. Hence, in order to model the problem, five sets of equations should be solved: continuity, momentum, energy (including radiation), species transport and turbulent flow modeling equations (in time averaged form).

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Further, in the aim of simplicity some assumptions including steady-state incompressible flow and negligible transient effects are made. Moreover, in the calculation of turbulence terms, in averaged form equations, boussinesq method is used.

It should be noted that, the computational domain covered the entire system and a 3D model of the system is generated. A total number of 3,600,000 tetrahedral elements are used for simulation. Efforts were made to keep the wall parameter y+ in the desired range (30–60). Further, the number of meshes is tested to ensure the mesh independence of the numerical solutions.

Results and Discussion

In the aim of model validation, fume extraction system of ''Mobarakeh Steel Making Palnt" of Iran has been selected. As there is no data available for fluid flow and properties inside the system, temperature and composition of exhaust gases were compared with operational parameters. This comparison showed a maximum error up to 3 percent in predicting temperature and up to 11 percent in predicting the mass fraction of oxygen in expelled gases. Therefore, an acceptable agreement between the developed model and the actual system was observed.

After the validation of developed model, the model was implemented to study the effect of various system parameters and the flow patterns in different parts of the fume extraction system. Besides, the effect of gap size (as the most important controlling variable) was investigated on the temperature and composition of exhaust gases. In table 1, the variations in the mass fraction of various chemical species along the system different sections, is shown.

Table 1: The mass fraction of chemical species in different sections of fume extraction system

	Ar(%)	CO(%)	CO2(%)	N2(%)	H2(%)	H2O(%)	O2 (%)
T. E. Fume Inlet	0.0095	0.14	0.131	0.524	0.0279	0.038	0.127
T.E Air Inlet	0.001	0	0	0.71	0	0	0.211
S.C Inlet	0.004	0.0065	0.107	0.71	0.001	0.0265	0.147
W. C. D. Inlet	0.004	3.9e-09	0.114	0.71	6.17e-10	0.0276	0.125
W. C. D. Outlet	0.004	3.9e-09	0.114	0.71	6.17e-10	0.0276	0.147

The obtained results show that, increasing the volume of excess air, leads to a change and reduction in the emission of CO. However, at the same time, in such a condition excess air will have a higher chance for reaction with Hydrogen and Carbon Mono-Oxide, which results in higher rates of exothermic reactions, higher temperatures and the increasing velocities of products. Consequently, the possibility of deposition and settlement of dust particles in gravitational settling chamber is reduced (due to its higher velocities) and efficiency of particle collection descends.

The de-dusting system includes various types of filtration for dust particles. The bigger particles are separated from main flow in settling chamber which is gravitational settler and small particles are eliminated using bag filters. So it is very important to calculate the collection efficiency of settling/combustion chamber in a variety of particle size distributions. The results are depicted in a column diagram (see Fig. 1). A careful examination of this diagram reveals that only particles with a diameter greater than 5 μm are eliminated from the main flow in a significant percent and the collection efficiency falls below the 30 percents for the sizing of below 1μm. This incompetent behavior is due to the structure of gravitational settlers, which depend mainly on gravity for collection of the particles. In such systems, the particle-laden gas stream enters the expansion section of the system. Expansion of the gas stream causes the gas velocity to be reduced. At reduced gas velocities (in the range of 0.3–3.0 m/s) the larger particles are acted on preferentially by gravity and fall into the dust hoppers. However, the terminal velocity is much smaller for smaller particles and they have enough time to travel through the settling chamber and not to fall into the lower down dust collectors. As a result, this particles need to be omitted from bulk, in bag filters.

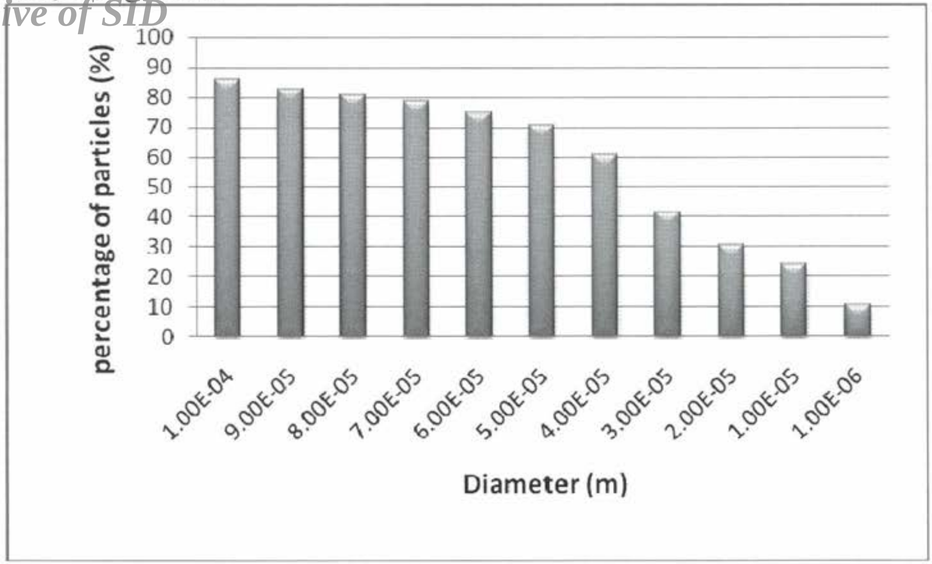

Fig. 1: Column diagram of the percentage of particles versus diameter of particles.

Moreover, a careful examination of the flow patterns in settling chamber, distinct the effect of sharp edges in settling chamber geometry, on system performance. In other words, the abrupt changes of geometry, results in the formation of vortical flows inside the domain and thus an increase in residence time of particles and deposition performance.

It should be noted that, the mentioned bag filters are very sensitive to high gas temperatures and might be damaged at excessive degrees. Consequently, controlling the gas temperature before theses filters is crucial. In fume extraction systems different control equipments are incorporated. One of the most efficient and effective devices is the air gap on the EAF tilting elbow which its size can be alternated by a sliding sleeve. It can be deduced from the simulation results that, the increase in air gap size, leads to the reduction of CO due to the increasing rate of combustion. This phenomenon, in turn, results in an increase in gas temperature, which is not desirable due to metallurgical consideration of different system elements.

Key words

Practical Approach, Steel Making Plant, De-dusting Solutions, Computational Fluid Dynamics