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CFD ANALYSIS FOR A THERMAL PLANT CHIMNEY SYSTEM

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ABSTRACT

Thermal power plants have been designed and developed due to the growing energy needs of human communities, as electric energy generation solutions based on fossil fuel combustion. Due to the large emissions of carbon dioxide released into the atmosphere, these plants are less and less used today, being gradually replaced by more environmentally friendly solutions. This paper presents a model of a thermal system evacuation system that is analyzed using the ANSYS CFX program in order to highlight the atmospheric discharge of smoke produced by combustion. The results are presented in terms of the smoke velocity circulation for each of the three exhausts of the system as well as current path-lines in the atmosphere.

KEYWORDS: thermal power plant, chimney system, smoke, three-dimensional modeling, CFD

1. INTRODUCTION

Over time, solutions have been developed for the energy needs of a growing population.

Such solutions were represented by the construction of thermal power plants using fossil fuels for electricity generation. Based on the conversion of the thermal energy obtained from the fuel combustion, electricity is generated in electric generators powered by steam turbines.

The fuels used are in solid form (coal, biomass), liquid (fuel oil) or gaseous (natural gas).

Due to the thermal power plants, electricity can be produced continuously, having the possibility of building in all regions, offering safe operation, the construction time is very short, and the amortization achieved relatively in a short period of time, on average in a few years.

However, the disadvantages are obvious and are represented by high fuel consumption, which can have as consequence the resources exhaustion, the need to create a well-developed flow of transportation and storage of fuels used.

But the biggest drawback for the use of thermal power plants is the high degree of environmental pollution and insufficient recovery of waste such as ash or tailings dumps resulting from combustion.

2. THEORETICAL ASPECTS AND OPERATION PRINCIPLE

The construction of the thermal power plants has been carried out as close as possible to the fuel sources with which they were designed to function.

Thus, they are found in large coalfields, or in nearby regions, in areas with large hydrocarbon reserves that are in operation.

Moreover, many of the thermal power plants have been built close to large urban agglomerations for a direct connection with industrial consumers, but also households, in order to provide the necessary electricity and the thermal heating possibilities.

Table 1. The Hydrocarbon reserves distribution

Country	Ponds with hydrocarbons in service	Coal basins
Saudi Arabia	Persian Gulf	
Azerbaidjan	Baku	
China	North East Region	North East Region
Germany		Nordrhein Westfalen Sachsen, Brandenburg
Kazahstan	Nordul Mării Caspice	
Irak	Persian Gulf	
Iran	Persian Gulf	
Poland	Silezia	
Romania	Ploiesti	North Oltenia, Petrosani Region
Russia	Volga, Ural Region, West Siberia	Moscow, Ural Region
SUA	Mexic Gulf, Midlands	Midlands, West Virginia, Pittsburg
Ukraine	Donetk	

Thermal power plants were built close to large ports, which use maritime imported fuels such as power plants units in the ports of France, Germany, Italy, Japan and the Netherlands.

In the last period, a continuous production capacity increase has been registered regarding the classic thermal power stations where the turbines can exceed the installed capacity of 1000 MW, as well as the efficiency in the production of electric power.

For the cases where the thermal energy resulting from the thermal plant operation is used, a yield of more than 60% is obtained, otherwise the operating efficiency is quite low.

Large power plants with high installed capacity were built in the following countries: Germany (Hamburg, Boxberg, Gebersdorf), Russia (Konakovo, Moscow), US (Bull Run, Ravenswood, Paradise), Ukraine (Dnepropetrovsk), Romania (Rogojelu, Isalnita, Turceni, Braila). [3]

For example, in 2013, 45% of Germany's electricity production was achieved in coal-fired power plants by burning coal.

Coal is a resource that is abundant in many regions of the globe, so it has been exploited for long periods of time. It is used in the power industry for power generation in thermal power plants, with over 40% of the total electricity being used worldwide using coal as fuel.

Thermal power plants are in operation mainly due to the growing energy needs of developing countries.

In the future, it is desirable to minimize the use of coal for the production of electricity, as well as to improve the conditions for evacuating the flue gases directly into the atmosphere by upgrading the installations used and increasing the efficiency in relation to the amount of fuel used.

The following methods for a cleaner coal utilization can be considered: [4]

- efforts to reduce the amount of air pollution through power generation in thermal plants;
- measures to avoid atmospheric pollution making use of different practices regarding chemical processes of cleaning coal of minerals, coal gasification or smokestack scrubbers.

It should be noted that most such processes create new waste pollution streams.

The coal burning process has been demonstrated to be one of the principal causes of anthropogenic climate change and global warming, according to the United Nations Intergovernmental Panel on Climate Change. [4]

The concept of clean coal is said to be a solution to climate change and global warming by coal industry groups, while environmental groups believe the claim is misleading and inaccurate. [4]

Greenpeace is a major opponent of the concept because emissions and wastes are not avoided, but are transferred from one waste stream to another. [4]

The 2007 Australian of the Year, paleontologist and environmental activist Tim Flannery made the assertion that "Coal can't be clean." [4]

There are no coal-fired power plants in commercial production or construction which capture all carbon dioxide emissions. [4]

It has been estimated that it will be at least fifteen to twenty years before any commercial-scale clean coal power stations (coal-burning power stations with carbon capture and sequestration) are commercially viable and widely adopted. This time frame is of concern to environmentalists because of the belief that there is an urgent need to mitigate greenhouse gas emissions and climate change to protect the world economy. Even when CO_2 emissions can be caught, there is considerable debate over the necessary carbon capture and storage that must follow. [4]

In October 2008, the European Parliament's Environment Committee voted to support a limit on CO_2 emissions for all new coal plants built in the EU after 2015. The so-called "Schwarzenegger clause" applies to all plants with a capacity over 300 MW and limits their annual CO_2 emissions to a maximum of 500 grammas per kilowatt hour. [5]

The new emissions standard essentially rules out traditional coal plant technologies and mandates the use of Carbon Capture and Storage technologies. [5]

The atmospheric air pollution from coal-fired thermal power plants sulfur dioxide, nitrogen oxides, particulate matter (PM), and heavy metals, leads to smog, acid rain, toxins in the environment, and numerous respiratory, cardiovascular, and cerebral-vascular effects. [6]

3. CONSTRUCTION MODEL FOR A THERMAL PLANT

It is presented a model for the flue gas exhaust system of a power plant which results from the use of fossil fuels. It is illustrated the main assembly units used in the process of generating electricity due to steam-driven turbines, having a discharge tower, a cooling tower and the electric burner generator as shown in the schematic representation (figure 1).

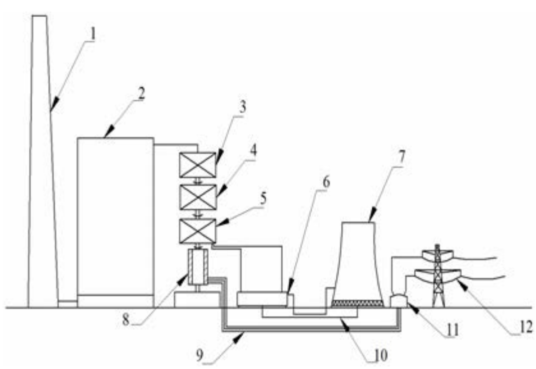


Figure 1 Schematic representation of a thermal power plant

The main component parts of the thermal plant are as follows:
1 - chimney;
2 - fuel combustion system and steam preparation;
3 - high pressure steam turbine;
4 - medium pressure steam turbine;
5 - low pressure steam turbine;
6 - condenser;
7 - cooling tower;
8 - AC electric generator;
9 - electrical conductor;
10 - water connection pipe-lines;
11 - Voltage transformer;
12 - high voltage lines.

4. CFD ANALYSIS FOR THE CHIMNEY SYSTEM

For a virtual model of the flue gas exhaust system to atmosphere of a power plant used for producing electrical energy, a numerical analysis was performed in order to highlight the amount of gases emitted into the atmosphere and the flow lines, depending on the declared wind speed and direction. The simplified model is shown in Figure 2.

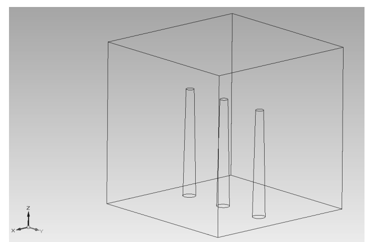


Figure 2 The exhaust system simplified model

The analysis is carried out using the ANSYS CFX Academic program.

The exhaust system composed of three towers was modeled within the surrounding enclosure representing the atmosphere that was defined as a fluid region.

The mesh network with triangular shaped elements was made, having 41898 knots and 232056 elements, represented in Figure 3.

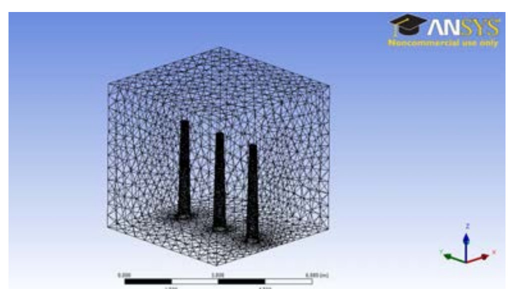


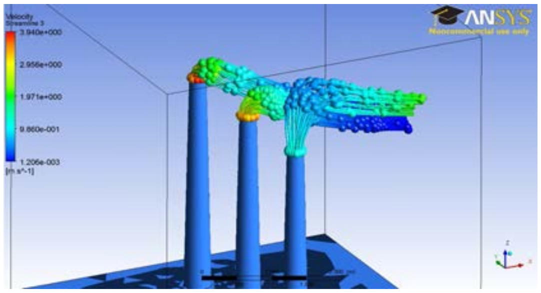
Figure 3 The achieved mesh network

The results are presented in terms of the exhaust gas velocity for each of the three towers, depending on the initial input data.

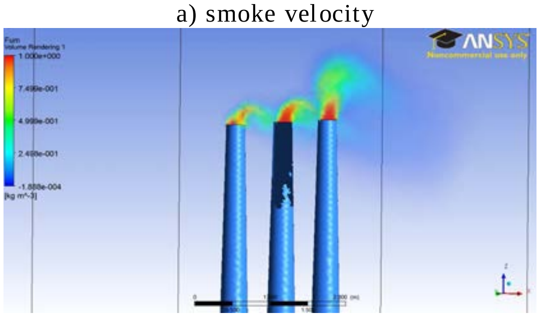
The fluid region is represented by the surrounding area of the evacuation towers, the fluid being declared as air at 25 degrees Celsius at a pressure of 1 atm. An additional variable was declared as the evacuated smoke having a kinematic diffusivity of 1e-5 [m2/s]. The exhaust velocity at tower 1 was declared at 0.5 [m/s] at tower 2 of 0.8 [m/s], while for tower 3 a speed of 1.3 [m/s] was declared.

A wind variable that operates from the OX direction at a speed of 2 [m/s] was introduced.

The analysis is of the transient type having a total time of 30 seconds.



a) smoke velocity



b) smoke density distribution

Figure 4 The obtained result values on exit

The results are presented in terms of the smoke evacuation velocity and density when evacuated into the atmosphere (Figure 4).

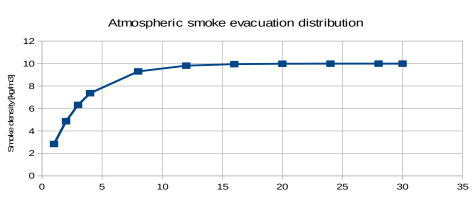
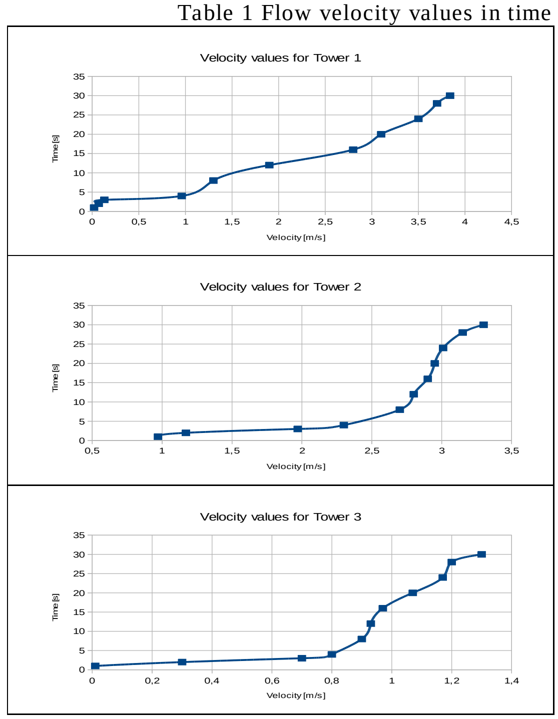


Figure 5 The smoke density distribution in time

In order to represent the smoke distribution within the atmosphere at the exit, the diagram of Figure 5 was represented, which shows the smoke density on the discharge in time.

Moreover, the diagrams for the exhaust velocity values in time for the three towers are presented in Table 1.

Table 1 Flow velocity values in time



5. CONCLUSIONS

The thermal power plants have been in operation for many years all over the world, as they have used fossil fuels that have been in a continuous extraction. It is known the relatively low yield in the production of electrical energy and the disadvantage related to the massive pollution of the atmosphere and the environment by the direct emanation of the gas mass and combustion.

It is desirable to progressively reduce the use of these solutions for energy production and replacement with more efficient solutions.

Renewable energy solutions based on water force, wind or direct sun action units have to be developed and implemented.

The CFD analysis regarding the flow through the exhaust system was performed on the virtual model and the results were presented in terms of exhaust velocity and smoke density.

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