Scientific Visualizatio n as a Tool for Power Engineering Education

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Abstract

This paper deals with the application of scientific visualization methods in the field of power engineering education. Behavior of various parts of a power plant is simulated and the results of these simulations are visualized. The visualization of processes that run in a power plant gives the students an opportunity to understand better the nature of these processes. This approach solves one of the main problems in power engineering education: the students usually have no chance to see various types of power plants in practice. The existence of models and their corresponding visualization allows students to perform experiments with various devices and in such a way acquire a much deeper knowledge about the subjects taught.

Keywords*: power engineering, power plant, visualization, particle models.*

1. Introduction

Production of electrical energy plays an important role in national economies around the world. Therefore it is necessary to pay attention to the education of highly qualified professionals in the field. They should be able both to design and to run power plants of various kinds. Education of these experts is very costly and, moreover, very complicated. One of the crucial problems is the lack of practical experience the students can gain during their study. Only practical experience can help the students deeply understand the nature of physical processes that run in a power plant. The traditional way of education is mostly based on mastering the theory of these processes, which creates a good base for their later deep understanding in practice. In some cases real models of some parts of power plants are used, where the students can perform experiments. This approach has several disadvantages - first of all these models are rather costly. Also parameter settings during experiments are usually accompanied by various problems.

The solution to the problems stated above is to use computer-based models of power plants. Currently there exist commercially available models that offer the possibility to perform virtual walkthroughs in a power plant. Such a walkthrough can give students some idea about the configuration of a power plant and also about the size of single appliances in a power plant. Performing such a walkthrough, students can get a feeling about mutual relations between single parts of power plant, which allows them to understand globally the process of electricity production. Nevertheless, this approach does not say anything about the processes running inside single parts of a power plant. The solution to this problem is to create models of processes running in power plants. These models should have both the simulation part and the visualization part.

2. Models of power plant components used in power engineering education

At Czech Technical University in Prague a project has been running for several years where these models are developed and implemented. Their applicability to education has been extensively tested. The aim of the project is to develop a set of models (and corresponding program modules) that would allow us to simulate various modes of operation of each part of a power plant. These modules should be of a special nature as it would be important to combine these modules into a functional model. For example: it is possible to assemble complex models of various power plants types that are characterized by different types of boilers, different types of coal transport systems, etc. Such an approach can significantly improve the quality of education, as a variety of single power plant types is usually not available in one country. Only by means of these models is it possible to acquaint students with all possible aspects of design and operation of power plants in a very general way.
The project as a whole is a large scale project which means that the final state will be reached within several years. Nevertheless, several modules currently exist

which are used independently in education with a high degree of success. This paper will deal with the current state of the art of the project mentioned. The simulation and visualization modules use traditional visualization techniques (mostly based on the use of particle systems). Some simulations and visualizations are unique because of the very specific nature of the processes investigated. It was necessary to develop special simulation and visualization techniques that allowed us to investigate the behavior of these processes - professional simulation and visualization software mainly did not cover specific requirements linked up with the processes simulated.

As the system is targeted to education, there are some special features in which this system differs from traditional simulation and visualization systems used in the given field. The traditional techniques mainly stress the accuracy of modeling and visualization. This approach results in a very time consuming calculations that give results after very long time. Our approach has been slightly different in some cases: to use simulation and visualization techniques that have lower accuracy and thus lower requirements for computational time. This offers very flexible feedback to students as they can see the results immediately (mostly in real time). In such a way students can get a feeling about the dynamics of the process simulated (and visualized).

The next step in using the system developed could be the use of professional specialized software (like FLUENT) and comparing the results obtained from our system with the results obtained by a professional system. A good exercise would be to modify existing algorithms used in our system in order to improve the match with the results obtained by professional software. Such an approach is not always possible because some models in our system are quite unique and they have no counterpart in professional systems. In this situation students compare the simulated results with real situations. They can compare the model and the reality and again explain why these differences exist. The experience gained could be used in the future for system improvement.

3. Description of existing modules

The already existing modules cover the most important parts of the electricity production pipeline. This means that the student using all these modules can get a complex idea about mutual relations between single stages of electricity production.

The modules available are as follows:

- Heat transport in nuclear reactor cooling system

In this case the data obtained by simulation of nuclear fission (here a commercial software product has been used) are visualized by a special module. This module is a good example of a situation where sophisticated commercial visualization software exists. The problem is that this commercial software runs on powerful workstations which means that this software is not suitable for education on a larger scale. Our software allows us to visualize heat flow and temperature distribution. The solution was based on the use of finite elements for the reactor body description and visualization of temperature and heat flow within these elements.

- Combustion processes in fluidized bed boilers

The problems related to fluidized bed boilers are rather complex. In the module a particle system was used. The particles represented coal particles during the combustion process. The attributes of particles changed according to the degree of their burning out. The visualization is then quite simple. Due to the simplicity of the particle model it is possible to generate animated sequences in real time and in such a way to observe and investigate the dynamics of the combustion process (Fig.1). Comparison has been made with simulations and visualizations made by means of a mathematical model that was based on the theory of fluid dynamics.

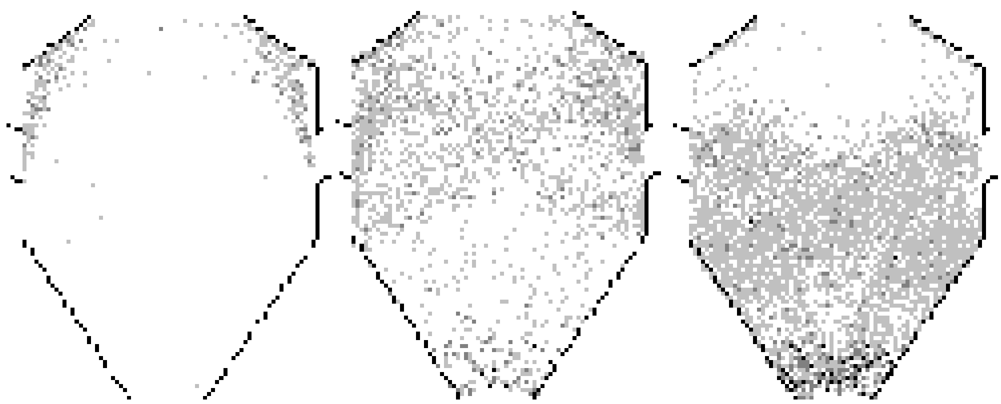

Fig. 1 Visualization of various combustion modes

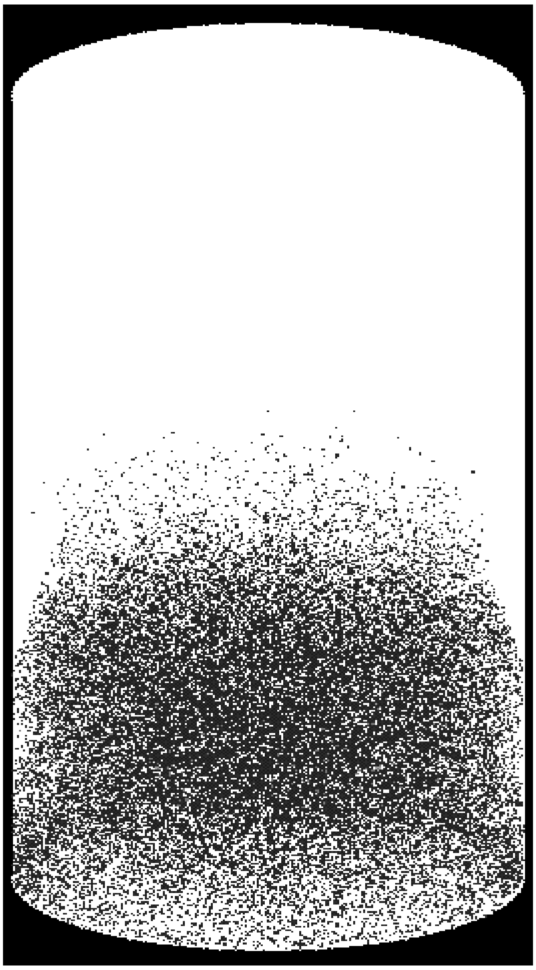

Fig. 2 Visualization of combustion process in vortex furnace

This model provides a more general approach to the studied phenomena. Nevertheless it is computationally expensive and each change of parameters requires it to perform new simulations (that are computationally costly). The particle model implemented allows us to perform changes of parameters dynamically with immediate visualization. Students can follow immediately the influence of the parameter changes just being made. This feature means the particle model is superior in terms of its use in education.

- Combustion processes in vortex furnace

The experience gained with the preceding boiler system has been used to create the model of a combustion process in a vortex furnace. One of the principal parameters of this boiler system is the configuration of an air velocity field that influences the trajectory of coal particles in the furnace. As in the previous example it is possible to set parameters of the boiler interactively by means of a properly designed user interface.

Also in this case the use of the particle model brings the same advantages as in the previous case. Due to some optimization in the program it is possible to work with several thousand particles (Fig. 2) at the same time (and visualize them). Such a large number of particles gives very extensive information about the situation in the furnace during the course of simulation.

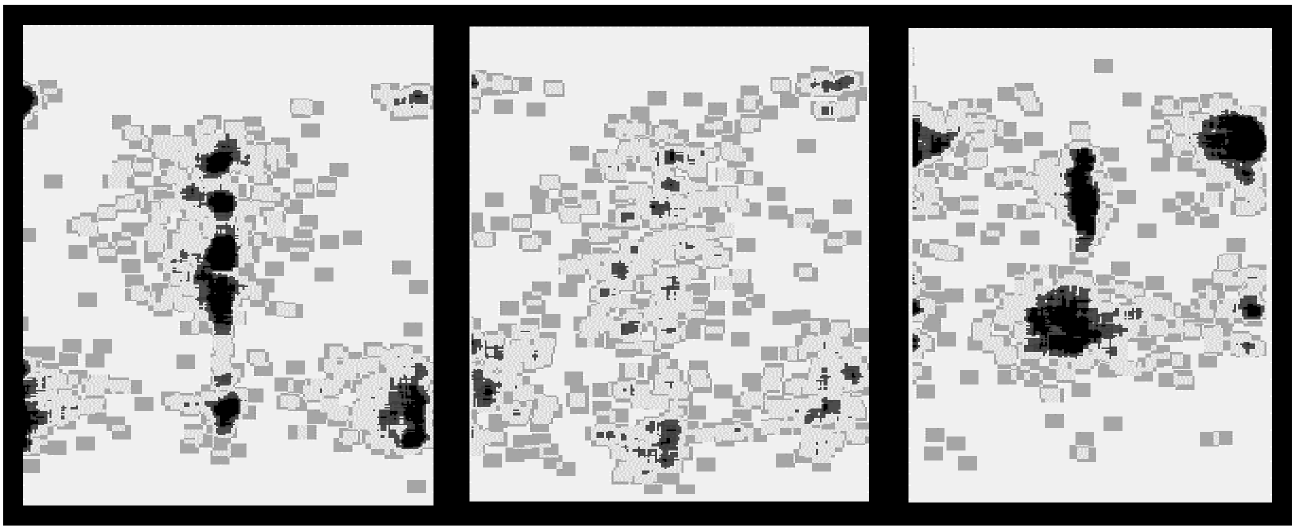

Fig. 3 Visualization of the number of collisions

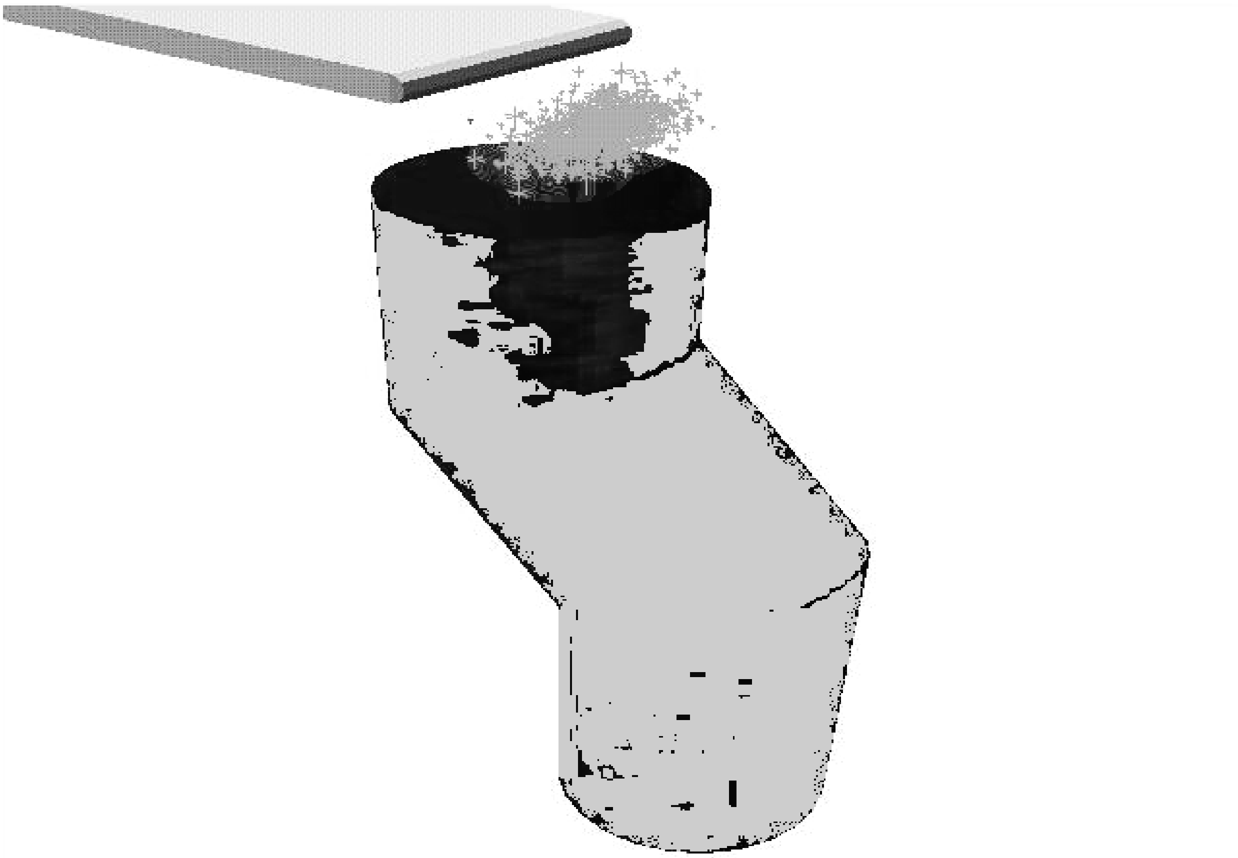

Fig. 4 Visualization of the coal transport in the given pipe configuration (including collisions)

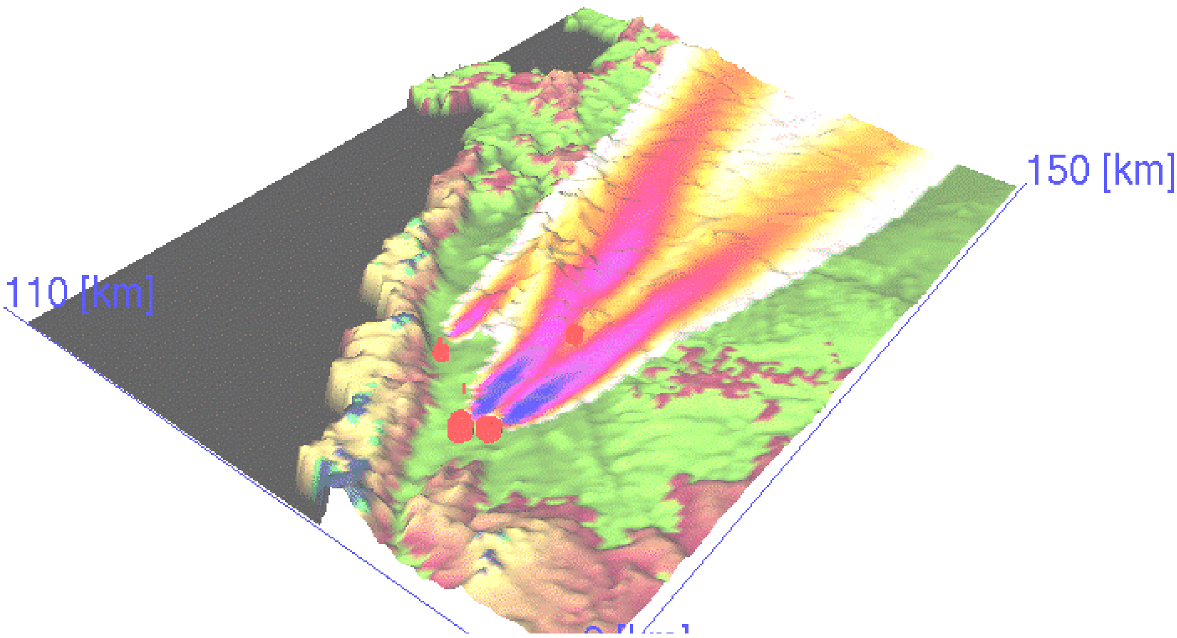

Fig. 5 Distribution of pollution from three sources

- Coal transport system

The system allows us to investigate behavior of coal particles during their transport in a coal dryer. The configuration of pipes the dryer consists of (Fig. 4), determines the extent of collisions of coal particles with the inner surface of the pipes. The number of these collisions determines the level of damage to the transport system. Another factor that influences the coal transport are parameters of coal like its humidity, granularity etc. The system allows the user to set interactively all these parameters and in such a way to simulate the coal transport process. The result of simulation and visualization is a picture where the distribution of collisions is shown.

The Figure 3. shows the visualization of the number of collisions of coal particles with the inner surface of the pipe through which the coal is being transported.

- Moving granular bed gas cleanup filters

The mentioned cleanup filter has been modeled. The model describes the behavior of granules (they have spherical form) - how they move in the filter during the time period of filter operation. Also here the process has several parameters that influence the efficiency of the pollutant separation. The user can experiment with various parameter settings and in such a way better understand the nature of the gas cleaning process. This problem as a whole is currently under intensive investigation and includes calculation of powers acting on single sphere in various positions inside the filter. Another feature under investigation is the calculation of friction processes between spherical granules inside the filter. The simulation of the granular bed gas filter is the most complex one of all problems investigated and mentioned in this paper.

- Simulation and visualization of pollutants distributed from a stack in a power plant

A model has been implemented that describes the pollutant distribution in an area near the power plant. The terrain profile is taken into account, and also the meteorological situation and characteristics of the power plant (and the stack in particular) are taken into account (Fig. 5). It is possible to simulate the influence of several power plants in a specific area where the share of pollution caused by each single power plant is calculated. The system has also been used in the course where the suitability of a location for a new power plant was tested.

4. Implementation

Most of the modules described were implemented in the MS Windows environment. The fact that most of the modules are available on the MS Windows platform is very important as these modules can be widely used due to wide availability of this platform. There are no specific demands on hardware. Nevertheless in the case where some dynamical effects are simulated, the appropriate computational power is of great importance. Great attention was paid to the development of a proper user interface keeping in mind that the modules could be used also by users who do not work in the field of computer science - so their knowledge about using computers could be defined as a casual user level.

5. Evaluation

From the examples given above it is possible to see that the modules already in use cover in cover several single stages of the electricity production. In such a way it is possible to see how the situation in one stage influences the situation in the next one - and also its global influence on the electricity production process, including the consequences for the environment.

By means of these program modules extensive teaching materials were prepared. Thanks to the flexibility of parameter settings in each of these modules, it was easy to generate a wealth of teaching material that was used both in lectures and in seminars. As an example it is possible to give the course ”Combustion and Boilers” where the visualization of the combustion process allows students to understand the mutual influence of all parameters that take part in controlling the combustion process. In such a way it is possible to determine ill-suited combinations of parameters (these combinations should be avoided in practice). The dynamics of the combustion is shown in the system by means of suitable visualization techniques.

In the framework of another course called ”Environmental Problems of Power Generation” the model of plum rise dispersion was used. Also in this case student could get a much better sense of the nature of the problem. Students could better feel the influence of each single source of pollution to the environmental situation in the given area. This means, for example, that the influence of the planned power plant can be determined in advance by means of the model implemented.

Some other models mentioned have been used to a limited extent (up to now) in the framework of seminars (e.g. for PhD students) and in specialized labs. This approach allows us to prepare the use of existing modules for regular courses. A very important

benefit is that the simulated results can be in many cases compared with the real data obtained in some cooperating power plant. This creates a very intensive feedback between the research at the university and practice. The environment created for university students in this way is, according to our experience, very stimulating and students get more involved both in research and in study.
Because the usage of these materials is quite new, there is still not enough data for the qualitative evaluation of the impact of this new approach on the quality of education. An evaluation strategy will be developed in the framework of future work. Nevertheless it is possible to say that this new approach led to a much better understanding of processes running in a power plant, which resulted in better results on exams in single courses.

6. Conclusion and future work

Due to the pilot nature of the program modules implemented, there is still a lot of work to be done in order to improve them. Moreover there are many parts of power plants of various types that should also be covered by corresponding modules. As an example, we can give modules for the heat transport and temperature distribution in boiler furnaces of various types, ash particle transport through boiler convection heat exchanges, etc. Some future developments should be the result of consultations with experts working in power plants in order to establish the real needs for some new models.

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