The Visualization of the Thermal Flow in a Glass Furnace

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Abstract: - This paper describes the computer software Viewer3D, which was developed at our faculty in the last year. The main feature of this program is visualization of a glass furnace model in a three-dimensional space, so it displays particular furnace geometric parts and an optional display of temperature distributions or velocity flows in a bath. Viewer3D has a simple user interface created by the MFC library and can visualize data files results derived from specific mathematical applications in the field of glass furnace modeling.

Key-Words: - Programming, Software, 3D visualization, Graphics, Modeling, Glass furnace

1 Introduction

It's been a trend for quite a long time to use mathematical models before implementation of construction and optimization in technological processes. These models are currently very sophisticated, based on many types of algorithms and the results are often very close to the existing reality. This also applies to the glass industry; the results of mathematical modeling help engineers to diagnose and analyze the furnace operation with a very high accuracy.

A very common example is calculation of the glass furnace model. On the basis of the input parameters and the analysis of all available results, glassworks proceed to build a new furnace or do a general servicing of an existing furnace. This process often substantially reduces the time and costs of the project, additionally removes the difficulties in the design and optimization of the melting furnace. The model can also accurately describe the heat distribution based on the burner system, which is located in the furnace combustion chamber. According to this information, we can locate the maximum temperature in the furnace and other zones, which are important for the melting of high-quality glass.

Our aim was to create a 3D visualization program that would be able to transfer data interpretation of the modeling results into a clearer graphical design. Technologists can then see the optimal design and construction of the glass melting process. It is now used for comparison and verification of the simulation and final results.

2 The Glass Furnace

Glass is normally produced in open-hearth furnaces in which the glass constituents are flame-heated from above to form a melt. The raw materials, sand, limestone, aragonite, dolomite, soda ash, alumina, and recycled glass are fed into the furnaces through a continuous or intermittent feeding system. [1]

Depending of the type of glass produced, the technology varies but the principle is the same. The melting temperature of raw materials is round 1200°C, and to achieve such temperatures in the bath, heat is obtained by oil or gas combustion in the combustion chamber. The losses through walls make the furnaces overall efficiency low (50%). [2]

Glass furnaces differ mainly by their preheating system of combustion air and by their shape. In Figure 1 we can see the combustion system principle of a side-port regenerative furnace.

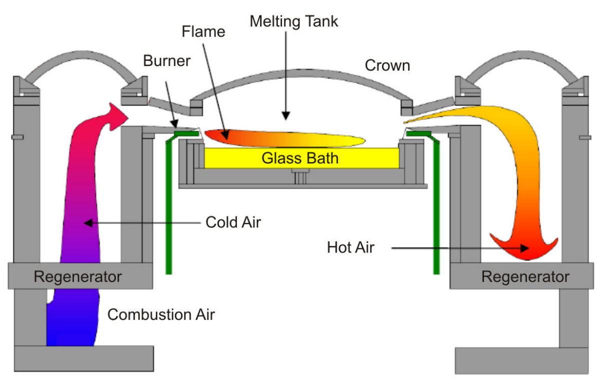

Fig. 1: A combustion system of a side-port regenerative glass furnace.

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Here the raw materials are loaded into the bath. The combustion chamber above the bath releases the heat and it melts the glass in the first part of the bath. The raw material is slowly driven towards the furnace; during this it is homogenized and refined. Then it can be finally used for forming. The regenerative systems are used for the storage of the combustion gases heat.

3 The Simulation of Processes in a Glass Furnace

Using computer simulations in the glass industry provides many technical and economic advantages for companies dealing with the construction or renovation of furnaces. The simulation also brings advantages to technologists in the manufacturing process, where they care for the normal operation of the glass furnace. The main benefits of using simulation include improvement of the glass quality and heat optimization of the glass bath.

The mathematical model assumes the observations of the melting glass temperature and velocity in the form of discrete three-dimensional arrays, which can be expressed by partial differential equations. The equations are approximated so that we are able to solve them by the methods of numerical mathematics. [1] [2].

The final model can indicate instability or critical areas in the furnace, which can be then optimized in terms of thermal load, speed and direction of the molten glass flow, quality of melting, sampling, etc. A very important aspect is temperature optimization, which determines the quality of glass and costs of the furnace maintenance.

Glass furnaces are currently using modern, highly sophisticated control systems, which can very well evaluate the actual situation and optimize the temperature in the furnace. The mechanism for setting and measurement is usually implemented with the use of PID controllers and servo valves, which control the glass and air flow supplied to the combustion system.

4 The Visualization Software

As mentioned above, our goal was to create the Viewer3D software, which can visualize the results of the mathematical modeling inside a glass furnace. In this chapter, we describe a programmer and user view on this software.

4.1 Programmer View

To get maximum benefits of the software, it was designed with a full 3D interface. The main part of the software window shows 3D environment, which contains the glass furnace model. This model is linked to the materials with their properties (temperature minimum and maximum, thermal conductivity, density, luminosity, etc.). Next, the only necessary thing is to determine positions, where we want to display the heat distribution. These places are defined by the planes coupled with other optional parameters.

The visualization is designed so that the model glass furnace is displayed fully 3D including cuts (planes) with the heat distribution. We use the perspective projection and the control is designed so that the model is able to be easily moved, rotated, zoomed in and out by the mouse buttons.

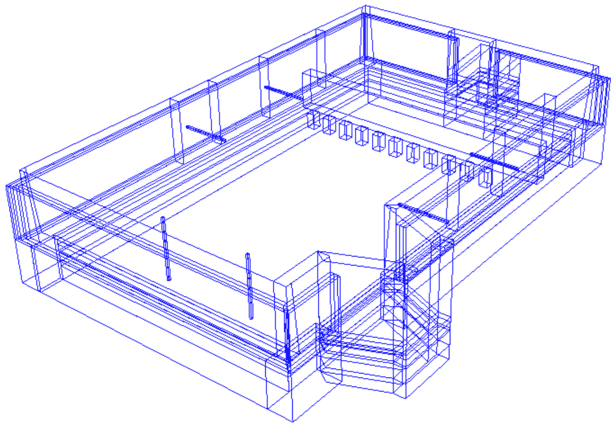

Fig. 2 : The 3D model of a glass furnace.

Viewer3D can work with two types of files. The first type is the group of four data files with the .d extension. This includes files ggri.d (basic information about the furnace model), gdbm.d (the list of materials and their properties), ggeo.d (the geometry shape of the glass furnace) and grsp.d (the parameters of all special areas). The second type of files has extension .v3d, which is the pure internal format of Viewer3D. We can also load and save to it. This file contains all information about the whole scene. It also can include the model of glass furnace and created planes with the temperature profiles. Our software is designed as SDI (Single Document Interface).

The shape of the furnace model is described by polygons. This is a standard representation by vertices, edges and faces. Figure 2 shows the model of this representation. It is the wireframe draw (without the faces) of the tested glass furnace.

Viewer3D was written in C++. C++ is the most used object-oriented programming language,

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featuring all advantages of object-oriented programming - encapsulation, inheritance, polymorphism, overloading and templates. [3] Since the program was designed for the Windows platform, we also used the MFC (Microsoft Foundation Class) extension. MFC is a library, which includes most Windows interface functions in complex C++ classes. [4]

The standard graphics Windows interface is slow. Therefore, especially in graphics programs are mostly used libraries, which replace graphics output. Viewer3D shows all graphics outputs via the OpenGL library. This multiplatform library is often used for creating computer games, CAD programs and scientific visualizations. [5]

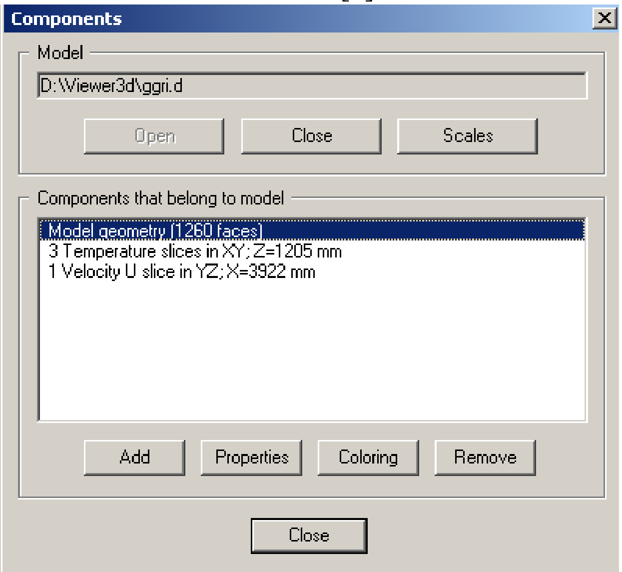

Fig. 3 : The dialog box Components

4.2 User View

The basic window contains the application menu with all functions, toolbar, status bar and mainly the scene. After starting Viewer3D, at first it is necessary to open a ggri.d file. Next, we can read a .v3d file with the all previous settings.

We can find the main setting in the Components dialog box (menu Edit-Component). This box is shown in Figure 3. Above is set the path to the current application's data model (ggri.d). It can be changed by clicking on the buttons Open or Close. The key Scales makes available another menu for the settings range of the temperature and its representation in the scene.

The next part is named Components that belong to the model. It contains a list of all components. Adding a new component is very simple by clicking on the button Add. The button Properties allows changing properties of each of them. A click on the button Coloring causes opening a new box, where we can define color palette for each component.

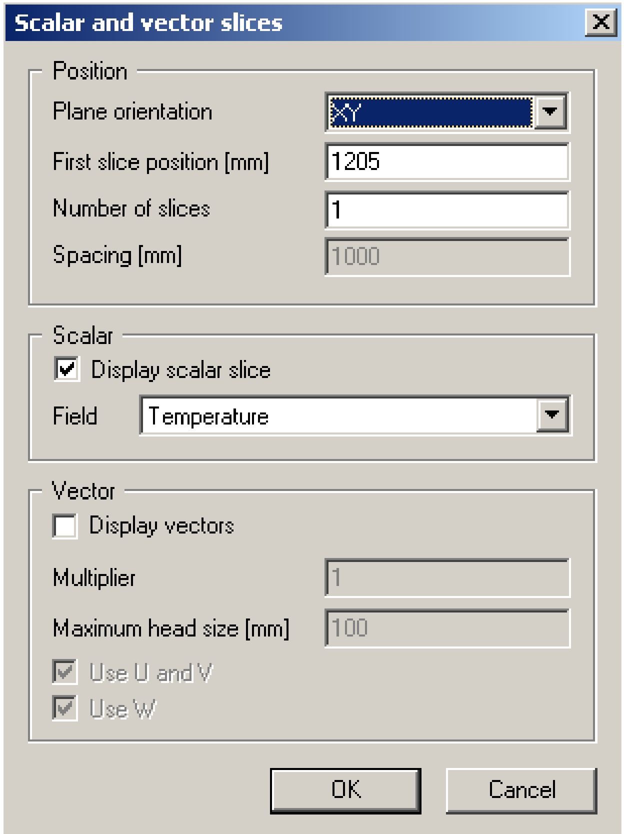

Fig. 4 : The dialog box Scalar and vector slices

A newly added component may be of two types. The first is named Model geometry and the second is Scalar and vector slice. In this application we can create any number of instances of these components, and each of them may have different parameters.

By selecting Model geometry, we can mainly set up the drawing of single components. By selecting Scalar and vector slices we can set up everything needed to define the type and location of the cutting planes (Figure 4). The Field type can be the temperature and velocity components. The Figure 5 shows one temperature cut inside the glass furnace.

There are additional possibilities of our software such as optional background color (menu Edit-Background Color), way of displaying (Solid or Wireframe in menu View) and the lighting of the scene (menu Light - we can place a point light source at any position in the scene).

5 Conclusion

Our contribution deals with the issues of glass melting technology visualization. To solve these issues, the Viewer3D software was designed and created at our faculty, which can effectively visualize specific data files incoming from

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mathematical applications, solve temperature distribution, optimize and simulate the velocity flow of a glass melt and other physical processes in a glass furnace model.

Viewer3D is written in C++ language and uses the MFC application library and the OpenGL graphics library. This software is fully functional, tested and debugged on different computer configurations. Our next idea for the future is to extend the program with additional features like improving the interface to visualize a combustion spatial model and a new tool, which allows the user to interactively move cuts in any direction.

6 Acknowledgements

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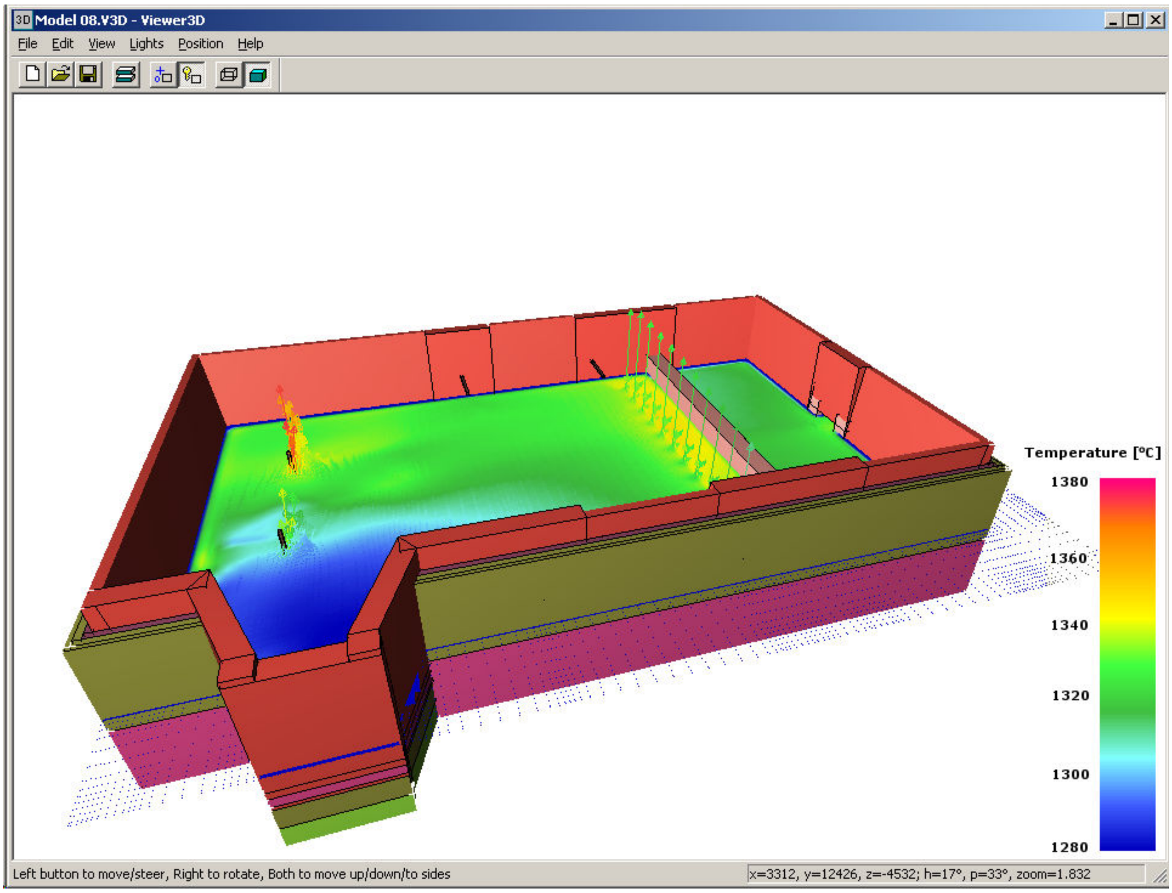

Fig. 5 : The glass furnace model with the distribution of heat on the defined plane.