VIRTUAL PROTOTIPING IN POWER PLANTS DESIGN

Maksimova E.I., Buvakov K.V., Novoseltsev P.Y.
Scientific Supervisor: Prof. Dr. Zavorin A.S.
Tomsk Polytechnic University, Russia, Tomsk, Lenin str., 30, 634050
E-mail: khaustovsa@tpu.ru

ВИРТУАЛЬНОЕ ПРОТОТИПИРОВАНИЕ ПРИ ПРОЕКТНОМ МОДЕЛИРОВАНИИ ЭНЕРГОУСТАНОВОК

Максимова Е.И., Буваков К.В., Новосельцев П.Ю
Научный руководитель: Заворин А.С., д.т.н., профессор
Национальный исследовательский Томский политехнический университет,
Россия, г. Томск, пр. Ленина, 30, 634050
E-mail: khaustovsa@tpu.ru

The paper describes the software developed by authors for virtual prototyping. The software allows to estimate boiler operation by visual and math tools in real conditions of operation on design stage. Moreover it performs pre-operational checks of efficiency of the main units and equipment with minimum effort. The designed software is hybrid CAE/CAD system and allows estimation of possible engineering solutions efficiency in the design process. Functionality of the developed software allows the designer to work out the different units of power plants in real time, to design its appearance, and, also, to make optimizations of structural elements based on mathematical calculations. With the use of the designed software existing layouts of water-heater fire tubes for burning methane were analyzed. The results of performed analysis can be used for modernization suggestions of the considered fire-tube boilers, as well as for new boiler units design.

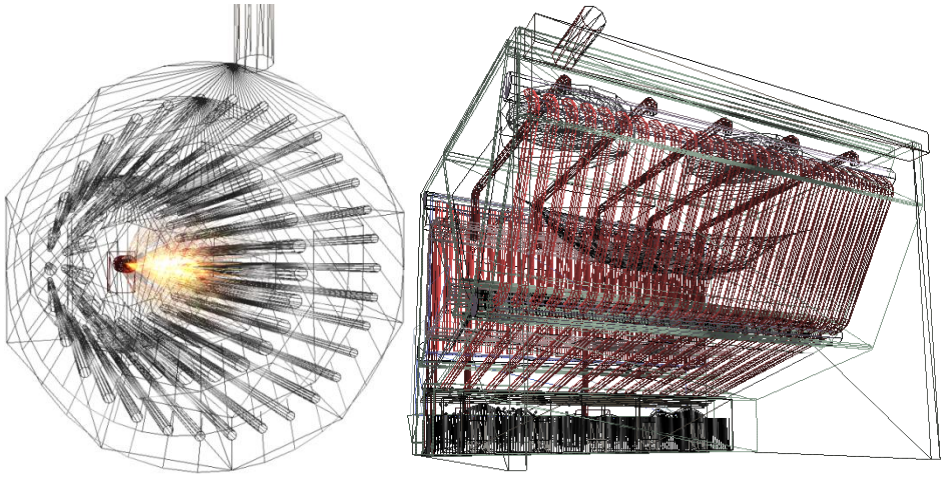
Modern power engineering is inseparable from the use of computer technology. For visual simulation of ergonomics and design of constructed units as well as functional assessment of aerodynamic and hydrodynamic characteristics shown to be effective virtual prototyping technology that allows even at the design stage to analyze the operational efficiency of production with less labor, and solve a wide range of other engineering tasks. In particular, for virtual prototyping it is possible to analyze all the connections in the equipment and to penetrate into the essence of the process, it is often not possible even through field tests of prototypes. Modeled production cycle allows the designer to delve deeper into the details of the displayed processes and mechanisms that will reveal undesirable elements.

The indisputable advantage of virtual prototyping is a graphic visualization of the modeled processes and other benefits that enable visually demonstrate all that is impossible to convey in the drawings. Graphic expression of three-dimensional objects in two-dimensional plane is not so clear and its perception requires the development of spatial imagination. The addition of the three-dimensional model can be easily separated drawings any component or structure entirely. In general, virtual prototyping leads to a reduction in the duration of the technical preparation of serial production of power plants, and, consequently, to reduce production costs.

In Tomsk Polytechnic University developed an application software product (certificate of state registration of the computer №2012614067), approved for the simulation of gas flaring in the flame tubes of boilers (Fig. 1a) and technological processes of processing of low-grade fuels in industrial installations (Fig. 1b). The software product is a hybrid CAE / CAD-system and allows the design process to assess the effectiveness and efficiency of the possible engineering solutions.

Hybrid modeling, implemented in the editor allows you to combine wireframe, surface and solid geometry, and use different types of parametric modeling. This provides a number of ready-made solutions for computer-aided engineering calculations and parametric design of standard heating surfaces of heat exchangers

(superheater tubes, plate heat exchangers, handing out and collecting reservoirs, pipes and arbitrary cross-section shape). Intelligent three-dimensional drawing editor allows the user to directly during the presentation of applied arbitrary graphical information on any surface displayed scene. Using this system greatly simplifies the process of defining boundary conditions and geometrical characteristics of the complex trajectories and also facilitates the perception of the physical meaning of the described phenomena and processes.



a) b)

Fig. 1. Examples of visual modeling using the developed program. a - modeling of gas flaring in the fire tube boiler; b - modeling processing low-grade fuel for industrial applications

Research methods and tasks

Developed software for virtual prototyping has been used as a research tool. The research problem includes finding the solution of engineering problems and optimization of power plants design: calculation, analysis and computer simulation of physical and technological processes based on research tool and implemented in it quasi-one calculation methods. Implemented in software product the quasi-1d technique and algorithm for engineering calculating heat transfer during a vortex combustion in boiler tubes is given in [1]. Size evaluation of the flame based on the basis of the basic equations of Zel'dovich and DA Frank-Kamenetzky theory and on the basis of speed depending on the temperature of the flame burning in the core. The algorithm of size evaluation of the flame is described in detail in [2].

The following optimization problems have been formulated on the basis of numerical investigation of combustion chamber flame tube boilers [3]:

- the most complete combustion of the fuel should be provided within the scope of the furnace;
- the size of the torch should be appropriate to exclude its overlapping of heating surface which shields the combustion chamber in order to avoid sedimentation and unburnt soot on the walls of the furnace;
- combustion chamber should have a high specific heat absorption with minimal aerodynamic drag.

Results of the research

The existing designs of flame boiler tubes when burning pure methane have been analyzed (Table. 1). Basing on the analysis has been concluded that the aerodynamics of the reversing combustion flame vortex promotes combustion with minimum flow resistance. In turn, the specific heat absorption of the flame tube with

reversing organization of the combustion will be at a maximum when direct-flow fuel supply, as the core burning will be at a maximum distance from the output segment. In addition, according to the results of the numerical experiment with the mathematical model presented in [3], it was found that reversing organization with direct-flow fuel supply creates the most favorable conditions for stable combustion and uniform distribution of heat flows with minimal aerodynamic drag. The uniform distribution of heat flows, in turn, favors the reliable operation of the boiler under the terms of incrustation and permit operation of the boiler at a lower cost for water treatment [4]. Involved power of burner when reversing organization of combustion can vary over a wide range without significantly changing the dimensions of the flame [2], which makes it a convenient parameter for optimization, as well as expands the potential range of load control.

Table 1

Analysis of combustion chamber design

The design parameters of the combustion chamber		Performance characteristics of the firebox with optimum combustion organizations				
The length of the cylindrical fire tube, mm	The inner diameter of the fire tube, mm	Heat power range, kW $Q_{min}..Q_{max}$	Specific heat absorption of the flame tube, MJ/m3		Aerodynamic drag of firebox, Pa	
			case of Q_{min}	case of Q_{max}	case of Q_{min}	case of Q_{max}
1300	584	150..500	19,7	12,1	4,5	50,4
1550	884	300..350	19,7	12,4	18,2	182
1900	980	400..1200	19,9	12,9	32,3	290

Conclusion

Developed software for virtual prototyping, which allows the design phase and the calculation method to assess visual workflows and power equipment under actual operating conditions, and also to make pre-operation inspection of their basic health units and units with less effort.

Functionality developed software allows the designer in real time to work out in detail the various units, not only to design their layout and appearance, to make optimization of structural elements on the basis of mathematical calculations.

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