C377/289

Computer aided design of waste heat boilers

T MARAVIĆ, MSc, **M STEVANOVIĆ**, BSc and **B VLAH**, BSc
TPK - Industry of Thermopower Plants, Process Equipment and Boilers, Zagreb, Yugoslavia

SYNOPSYS: This paper outlines the industrialy based example of CAD-system for waste heat boilers, which has been developed in TPK- Zagreb (Industry of Thermopower Plants, Process Equipment and Boilers - Zagreb, Yugoslavia).

Thermodinamical and aerodinamical calculations of waste heat boilers is a complex and extensive computational problem, and up till now they have been made only for determined load conditions. But, in practice, boilers are working under different conditions, and at the same time it is necessary to react quickly to market requirements and design new types of such waste heat boilers.
Advances in mathematical modelling techniques and computer simulation have brought new possibilities and new approaches in the engineering design process. Thus we have developed our own system for automatic designing and modelling of waste heat boilers, which makes possible the following :

- to generate alternative possible solutions, and to select (after several iterations) a solution that will best satisfy various criteria (constraints of technical feasibility, economics, etc.)

- to simulate different variants of boiler's operation.

Thus the designer has a great number of the quality data at his disposal which enable him to make high-quality conclusions and better decisions.

The system has been realized for smoke and watertube waste heat boilers in horizontal and vertical arrangement for production of hot water or superheated steam. Thus it is possible to define independently heat exchange assemblies with bare tubes or tubes with increased surfaces.

Thermodinamic calculations are based on the terms of normative and FDBR method. The program incorporates standards for materials and semi-finished products as well as regulations for strength calculations of the plant components essential for the

exploitation safety (JUS, DIN, ASME). In addition , all necessary diagrams and tables are transformed in the form mathematically suitable for use by computers.

The interpretation of results is adapted to spefic types of users and directly suitable for enclosing to the standard documentation.

The programmes are realized in the FORTRAN programming language on the computers IBM 4361 and IBM PS-2.

1. INTRODUCTION

The lack of energy supply and the need to economize with its exploatation (and, in our country, the limited investments in new power projects) have stimulated numerous attempts to make use of the energy sources already exploited but lightly and unjustly neglected. It is evident that a large number of power units has certain unused possibilities. In addition to this, the possibilities of using the by-products as power supplys often appear in the process of production. The above indicators imposed the need for investigating the possibilities of utilizing the neglected energy sources. Thus, among other things, the need for the development of waste-heat boilers (utilizers) has arisen. The design of such boilers requires great efforts from the designer, mainly in two fields :

- the design of the waste-heat boilers itself;
- the adjustment of the boiler to the very specific requirements of the ordering party regarding location, type of heat-source used and required parameters of the boiler itself.

Different types of fuel can be used as heat-sources and during the design is made a great number of tables, diagrams and nomograms for determining thermophysical characteristics of medium, various coefficients and corrective factors as well as a certain number of iterative procedures have to be used - just as with other such installations. Moreover, regulations connected with building power plants, standards of the semi-products' producers as well as technological possibilities of our company also have the limiting effect. Since in each new plant new parameters are considered (location, source of energy, etc.) the designer cannot use the existing documentation and he is in fact expected to design a new product. To realize all this quite a long period of time is needed and this, consequently, makes the plant more expensive. This is why TPK - Zagreb, which among other things designs and produces such plants as well, has undertaken to develop a

system for designing and modelling of waste-heat boilers. Two parameters have been taken into consideration :

- the need for such installations on the market;
- the flexibility of the system by unification and standardization of assemblies and parts.

2. BASIC CHARACTERISTICS OF THE SYSTEM

As can be seen from the title, the system has been conceived for design and modelling of waste-heat boilers. In both phases two basic types of waste-heat boilers have been taken into consideration :

1) Waste-heat boilers with heating assemblies only (hot water waste-heat boilers)
2) Waste-heat boilers which, in addition to heating assemblies have also got some other assemblies (evaporator, preevaporator, cooler, etc.) (Steam waste-heat boilers).

as well as two basic positions of waste-heat boilers : horizontal and vertical.

The following have been treated in all variants :

1. Waste-heat boilers with longitudinal flow (smoke tube waste-heat boilers).
2. Waste-heat boilers with cross flow with :
   - bare tubes;
   - finned tubes;
   - studded tubes;
   with in line or staggered arrangement.

The following are the elements upon which, in the design phase, the solutions are chosen :

1. Exchange surface - must take possible the heat exchange with required reserves.
2. Housing of boiler - must make possible the regular installation of assembles and satisfy the safety requirements.
3. By-pass - solving the problem of ducts, if required.
4. Hydrodynamic and aerodynamic criteria.

In case of modelling of a waste-heat boilers the dominant criteria are the same as in its design, only the approach is different - the system checks the above four criteria for the already known geometry of waste-heat boiler. Some of the modules used in the phase of design are used here as well, but the difference is in the fact that the program completes its work at the moment when in the design phase the generating of satisfactory variants would begin. In designing the system for

design and modelling of such boilers we have tried to apply the principles of group design, so that the generating of satisfactory variants of boiler is based on putting together the satisfactory variants of assemblies. In addition to that, data bases of standard semi-products, technological possibilities and regulations required for such plants have been built into the system.

3. ALGORITHM OF THE SYSTEM

a) Design phase

1) Chosing the system with a certain number of heat exchanges assemblies (heater, preevaporator, evaporator, superheater, cooler). This phase makes it possible to choose between hot water and steam waste-heat boilers.
2) Defining each of the assemblies chosen as :
   2.1) Assembly with longitudinal flow
   2.2) Assembly with cross flow with :
   - bare tubes
   - tubes with increased surfaces and with adequate arrangement of tubes.
3) Conceiving the waste-heat boilers as a package unit with separate assemblies, according to the criteria of location space available.
4) Design of assemblies (each assembly separately) according to :
   - thermodynamic criteria
   - hydrodynamic criteria
   - aerodynamic criteria
   - criteria of strenth and meeting the requirements of regulations.
5) By-pass design, in case such solution is required. The location of by-pass is taken into consideration (whether it will be a part of package solution or not).
6) Testing the strenth of the elements in assemblies.
7) Incorporatign the chosen assemblies in an integral construction while satisfying the spatial criteria.
8) Testing the strenth of other elements. According to the above steps the system generates a number of solutions which satisfy the required conditions of design. Because of that the ninth item is also defined in the algorithm.
9) The criterium of determining the validity of the suggested solution into which the parameters for choosing the optimal solution can be built.

b) Modelling phase

1) Defining geometric parameters of boiler by considering:
   - location of waste-heat boilers
   - types of basic element (types of tubes)
   - arrangement of tubes in a bundle

- dimensions of the basic element
- connections between the assemblies

2) Modelling the process with thus defined geometry with the aim to realize functional parameters (achieving certain output, pressure, temperature, strength, etc.)

4) REALIZATION OF THE ALGORITHM

The realization of the system has been performed according to the defined characteristics of the model and in the following fields :

- thermodynamics
- aerodynamics
- hydrodynamics
- strength analysis

From the field of thermodynamics the following have been realized :

- analysis of fuel
- analysis of combustion for given excess air ratio and climate conditions.
- analysis of combustion products
- output boiler as well as efficiency factor
- physical properties of working medium
- physical properties of smoke gases
- heat transfer
- heat transfer in case of two-phase medium

Empirical terms in accordance with the normative method and FDBR method of calculation have been used in the realization.

From the field of aerodynamics the following has been realized:

- aerodynamics estimation on the side of smoke gases

From the field of hydrodynamics the following has been realized:

- hydrodynamic estimation on the side of working medium

From the field of strength analisys the following have been realized :

- design of elements in accordance with valid regulations (JUS, DIN, ASME)
- control of elements of pressure parts : tubes, covers, dished ends, flanges, prestessed bolts, shells, (using the same regulations)
- estimation of plates, stiffeners and hangers
- estimation of safety elements

It should be particularly stressed that most of the programmes used in this package can also be used apart from it, it other programs or programmes or programme packages. In realizing the programme various iterative procedures have been used

(Newton-Raphson's method, method of bisection) as well as various interpolation and extrapolation methods (spline, Newton, Bessel, etc.)

The necessary controls have also been built into the programmes both in the above stated numeric procedures and in other parts of the package. The programs generate codes of two types of errors:

1. Fatal error - errors which are such that the continuation of program would necessarily cause either an interruption or wrong result. In that case the performance is stopped.
2. Warning errors - errors which point out that some of the requirements have not been met, but the program is not interrupted.

In both cases the program automatically approaches the error file and writes out a message informing about the type of error, place of its emergence and parameters which caused it.

5. REALIZATION OF INPUT - OUTPUT

In a large number of programs packages the input of data can cause serious problems to users (because of the fear from making error, ignorance of the programme, bad leading through the system of input data or inadequate instructions). Because of that we have tried, in creating input module, to achieve a "friendly" relationship between man and computer. The module for input of data contains three possibilities of work :

1) Studying
2) Slow mode of operation (the computer leads the user through pannels, offering the available options).
3) Quick mode of operation - designated for the users who are well acquainted with the system and do not need additional explanations.

The user is also able to correct errors in already input data without breaking the performance of the program.

While modelling the output of the results of the programme we had the following in mind:

1) To whom the output is designated;
2) The results of each module of the programme must be visible to the user.

Thus, in accordance to the first requirement, six different types of output have been made:

- for the designer;
- for the buyer;
- for inspection authorities;
- for the commercial treatment;
- for power-generating instructions;
- for advertising purposes;

Each of them contains information required exclusively by the particular group of users.

The second requirement has arisen mainly from the need for using particular modules apart from the whole.

6. CONCLUSION

The CAD of waste-heat boilers has been developed to operate at all stages of waste-heat boiler design : in proposal design, at the initial design stage and detail design stage of the project. It has been found out that when the system is used, the design times for the various stages are reduced and it is possible to automate a great number of the routine tasks related to design.

According to that we have achieved the following :
- offering time has decreased about four times;
- design time has decreased three times;
- project team has been reduced on one third;
- costs of making technical documentation has decreased about 20 %
- manufacturing cost has decreased about 25 % (because of using standardized assemblies and parts);

At the same time, the modular system of the package make it possible to extend the possibilities of the system by means of implementation of new regulations and rules for such units, as well as by implementation of new optimization methods.

REFERENCES :

1. Ledinegg, Dampferzeugung Dampfkessel Feuerungen,Springer--Verlag,Wien,New York,1966
2. Jahrbuch der Dampferzeugungstechnik, Band 2, Vulkan - Verlag-Essen, 5.Ausgabe 1985/86,
   VGB Techniche Vereinigung der Grosskraftwerksbetreiber e.V.,Essen und des
   FDBR Fachverband Dampfkessel-,Behälter-und Rahrleitungsbau e.V.,Düsseldorf
3. Chisholm, Two-phase flow in pipelines and heat exchangers, George Godwin, London and New York, 1983
4. Schwaigerer, Festigkeitsberechnung im Dampfkessel -,Behälter-und Rohrleitungsbau, Springer-Verlag, Berlin, Heidelberg,New York,Tokyo, 1983
5. Agroskin,Dmitrijev,Pikalov, Hidraulika, Tehnička knjiga, Zagreb, 1973
6. Strehlow, Combustion Fundamentals, McGraw-Hill Book Company,1985
7. Truckenbrodt, Lehrbuch der angewandten Fluidmechanik, Springer-Verlag, Berlin,Heidelberg,New York,Tokyo, 1983
8. Isachenko,Osipova,Sukomel, Heat Transfer,Mir publishers, Moscow,1980
9. Reznikov,Lipov, Steam boilers of thermal power stations, Mir publishers, Moscow, 1985

10. Teplovoi raschot kotelnikh agregatov - normativni metod, Energia, Moskva, 1973
11. Fran Bošnjaković, Nauka o toplini I, Tehnička knjiga, Zagreb, 1978
12. Fran Bošnjaković, Nauka o toplini II, Tehnička knjiga, Zagreb, 1976
13. Standards : JUS, DIN, ASME