Introduction

Nowadays engineering, scientific and technical calculations are carried out on computers. This naturally also applies to thermal calculations.

There are established and successfully operated powerful programs for such tasks , in particular, for the calculation of the thermodynamic cycle (for example, the program Thermoflow - see www.thermoflow.com). The programs are based on a "black box", in which raw data arrays are put, "close the lid" (press "calculate"), open the "lid of the box and take the response out of it" - this are the parameters of the design of the heating equipment.
But you always want to have at least a general idea of what is in the "black box", to know how the calculations are carried out, to see the intermediate results or all the formulas by which they are conducted. In addition, in order to open the lid of the box it is useful to study mathematical models embedded in the calculation. It is also necessary to remember that any kind of these powerful programs for thermal calculations like Thermoflow cannot be used very often for non-standard, but for current and operational tasks, which you can principally solve with "pen on paper", but to speed up the calculations and avoid errors the computer is used. In addition, we must remember that these "program - monsters" are very expensive, require complex and expensive servicing and that their study requires a lot of time and effort, which is never enough.

On the other hand, there are universal, cheap (and in some cases even free) and easy-to-learn programs for engineering, scientific and technical computing like Excel, Mathcad, Matlab, Maple, Mathematica, and others. The package Mathcad[1] is the best, because it has three advantages: universality, accessibility and cheapness. You can download a free version of Mathcad Express (see http://www.ptc.com/product/mathcad/free-trial). You can use one month the full version of Mathcad Prime for free and then it is shortened to Mathcad Express.
Excel is the most suitable program for accountants. Moreover you can also carry out complex calculations for scientific and engineering problems, but those calculations become confusing after a while for the author, not to mention those, who want to understand these calculations and to supplement them. This also applies to the above mentioned "programs - monsters", in which you can look at the source code and decompile it. Although it is almost impossible for an external to understand how the program works.

The language of package Matlab, which people often try to compare with the Mathcad, is not a mathematical one. It is a programming language, which is too difficult to master.
In addition, Matlab is not good for itself, but its highly specialized applications, which are also some "monsters" with their inherent disadvantages noted above, are good. We should also not forget that Excel and Matlab unlike Mathcad cannot work with physical quantities and units of measurement, which is very uncomfortable and prone to error. [1]

We can also say something about the math-programs Maple and Mathematica, which principally can also be used for engineering calculations. Primarily Maple and Mathematica are programs for symbolic math and computer analytic transformations. In heat-engineering calculations you basically use numerical mathematics, with some elements of symbolic transformations.

So Mathcad! Why is it so good for the thermal calculations? First, of course the fact that one of the authors, who educates thermal power engineering and works in the field of power engineering, is well aware of this package and even wrote a few books about it [2-15].

[11] It is soften also named engineering calculator (super calculator) or engineering office.

But there are, of course, also objective conveniences for the work with Mathcad. Here they are:

1. Good documentation of calculations.

You can print out the Calculation, which is made in the environment of Mathcad, and give it to an examination or review to someone, who has never worked on a computer. Mathcad calculations are similar to calculations made on paper by the system WISIWIG (What You See Is What You Get). What you see (on screen), you will get (on paper). Printouts of calculations made in Mathcad can be left in the archive in order to read them in 50-100 years. So you can understand what has been written in the past and reproduce it without much effort in a new software environment, which will be available by then. This is very important. Nowadays we can see a crisis in information technology (IT), which people name “nightmare of old software”. Imagine a company, corporation or university that developed and accumulated in 30-40 years of intensive use of computers a large number of programs of varying complexity to compute and simulate a variety of processes and also a lot of equipment and technology in various fields of science. New computers, which replace old outdated computers, come with new hardware and also new operating systems. Computers are combined in local area networks, which do not remain aloof from the process of "globalization" and integrate into the Internet - wired or wireless. The development of wireless computers to servers was the cause of the appearance of "clouds" in information technology, which will be discussed in the book. Modernization of the computer park often leads to the fact that older applications will refuse to run on new or upgraded computers, workstations and servers. Sometimes you just cannot read the program from the media (punched cards , punched tapes , floppy disks of different diameter, obsolete "flash cards", etc.) , because new computers do not have the appropriate reading devices ("UI"). Either you have just to abandon such programs and to create new ones from “zero”, or spend time and money to create or acquire a certain utility (emulator) to run old programs on new or upgraded computers. But it is not so bad. The real trouble begins when the professionals, who establish and maintain these programs leave the firms, corporations or universities and the younger people, who replace them, cannot upgrade the programs to new requirements. This stems from the lack of documentation of the code, the lack of appropriate software tools and a simple inability to correctly read a program written in the old style - ("dead") programming languages. If still having difficulties to manage to recreate or upgrade an old program using the old or new programming languages, the "nightmare of old software" will pop up again after a while.

2. Working with units of measurement

We have already mentioned that this is a very useful tool of Mathcad [1]. We add only that Excel, Matlab and other programming languages weaned us to work with measurement units or rather, have taught us to work with dimensionless quantities and their units (SI units - Pascal, Kelvin, Joule, Watt, etc.). Keep in mind that, again, it is very uncomfortable and prone to error in the calculation. Even the basic SI units are inconvenient: the basic unit of pressure (Pa) is very small and always requires multipliers like kilo or mega, the temperature in Kelvin is not easy to understand for normal people and requires translation into degrees Celsius. The unit of measurement is completely dedicated to the second study of this book.

3. A flexible system of variable names

The variables and functions in Mathcad with a few exceptions have the same names that were defined for them in various scientific and technical disciplines long before the appearance of computers. For example, the Greek letter η with different indices to represent the thermodynamics

efficiency (thermal, internal, relative, etc. - see the pictures of the book). This along with the use of traditional writing of mathematical operators and functions makes the “language” of Mathcad available to all people (see item 1 above) without any further comment. The remaining four features are common to other so-called mathematical programs (Matlab, Maple, Mathematica, SMath, Derive, etc.), but, nevertheless, we tell about these.

4. Numerical und symbolic mathematics

Mathcad allows us to use an extensive library of numerical methods in order to solve mathematical problems. There we can anticipate or complement the analytical solutions (successful or unsuccessful) of the problem. Mathcad package was originally designed as a package of numerical mathematics, which later was extended with symbolic kernel of the mathematics package Maple, which then (in the 13th version) has been replaced by the kernel of the symbolic mathematics package MuPAD. The same "biography" can be told about the numerical part of the package Matlab, which also had at the beginning the symbolic kernel of Maple and later was replaced by the same kernel from the package MuPAD. Packages as Maple and Mathematica were originally symbolic mathematic programs with elements of numerical calculations.

5. In Mathcad are quite powerful and flexible tools built in for creating flat and volume graphics, and animation. This allows you to visualize the initial, intermediate and final data, which contributes to better understanding of the calculation, the identification of possible errors and false solutions of the problem. Graphics help preparing calculations for publications, which we have also used in this book, for example, creating a chart of a thermodynamic cycle.

6. In Mathcad mathematical operations are performed on a worksheet like on an ordinary sheet of paper from left to right and top to bottom. But sometimes it is necessary to change the order of the calculation, for example, not performing some part of the calculation and perform some other or perform a selected group of operators several times. This possibility is provided in Mathcad and it is not only successfully used by advanced users, but also by those, who believed that they would never be able to program. With these programming tools Mathcad can solve quite complex problems that do not fit within the narrow confines of the sequential algorithm (from left to right and top to bottom). In Fig. 4.5 in the study 4 we can see the problem solving process by successive approximation in "manual mode", when the user makes himself in Mathcad the last approximation of the previous calculations. Fig. 4.1 shows how this routine work is automated by programming (“while”-cycle). We noted only the first feature (tool) for programming. Two others – one is the use of local variables and the other is the possibility of unification of operators in blocks that are executed as a single operator.

7. The functions of the Mathcad package are possible to expand in three different ways:

The first way. Attaching to Mathcad through the mechanism of DLL (dynamic-Link Library – “DLL”) for functions written, for example, in C programming language.

The second way is making a reference to another Mathcad document. After such a reference user-defined variables and functions will be available (visible, as programmers say) in the working document, that are stored in the document (file) to which the reference has been made. These and other Mathcad documents can be downloaded to your computer or local network and used as templates.

Third way. Mathcad tools allow the user quickly write and debug functions that return, for example, the properties of working fluids, based on the formulas, tables or graphics, taken from an external source - from paper or electronic books, as well as from the Internet.

These three features can and should be used in the calculation/document, for example, for functions with parameters as arguments to a specific point of a thermodynamic cycle and return the desired thermal properties of the working fluid at this point: specific enthalpy, specific entropy, density, specific heat (isobar or isochoric), thermal conductivity, viscosity, etc.

Without this it is impossible to calculate thermal engineering processes. After this description of Mathcad we start our book with study 1.