

# Mathematical packages and problems of knowledge transfer

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Three revolutionary events stand out in historical process of knowledge transfer development from one generation to the next: writing appearance, invention of book printing, and implementation of computer technologies. We are the witnesses and participants of the third one.

As a rule, any reformation accompanies crises of different intensity and different extend of sickness during withdrawal. Speaking about computer technologies, there is a crisis in this field called conditionally “a nightmare of the inherited software”.

Imagine a firm, a corporation, or a university that have developed and collected a wide range of programs for 30-40 years: with different degree of complexity, for calculation or simulation broad-ranging processes, mechanisms, and techniques in various sciences and technologies, for database development and management. New computers with new operating systems are being substituted for worn out and outdated equipment. Computers are being joined the local networks, which, in turn, don't keep out of “globalization” and are being connected to the Internet. As a result of computer modernization, old applications often don't launch in the new or upgrade workstation computers and servers. Sometimes it is impossible to read a program from a media (a punched card, a punched tape, various floppies) because the new computers have no relevant readout devices<sup>1</sup>. Such programs are rejected or people spend time and finances to buy or develop a utility (an emulator) to launch them. But it's not so very serious. The problem is that the specialists who developed these programs leave “a firm, a corporation, or a university” and the new, younger ones can't upgrade or adapt the applications. The reasons are insufficient code documenting, lack of appropriate development software, and just inability to read the program written in an outdated (dead) language. Even if a programmer manage to recreate or upgrade an old application with great difficulty using an old or a new programmer language, codes, which only programmers can understand, “a nightmare of the inherited software” would appear again later.

There is one more problem.

Scientific articles, monographs, student's books, work-books always contain formulas, tables, plots, figures... Nowadays this “illustrative material”<sup>2</sup> is prepared on a computer, too. Special editing programs are developed to insert formulas into the text, such as Word Equation,

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<sup>1</sup> For some reason it is considered that analog recording would be lost eventually, but a digital one is agelong. It is an illusion.

<sup>2</sup> The formulas are hard to call illustrations. In many books formulas dominate, whereas the text is a comment (an illustration)

LaTeX and others. Although, the formulas inserted into the text are still “dead” because they could be used only if a reader takes a calculator or writes a program. Alas, the formulas themselves can’t calculate. It is known, if there is a gun on the scene, it must fire: a formula in the text should calculate. The “dead” formulas often contain errors. The authors of this article have collected a great deal of misprints in different reference books of respectable Russian and foreign publishing houses. For example, instead of  $0.0_2387$  was printed 0.02387 (in first notation 2 is a subscript marked a number of repeated zeroes); instead of 27.39 was printed 72.93 (a typical error of a keyboard operator), etc<sup>3</sup>. It is practically impossible to reveal such mistakes during traditional galley proofreading of “paper” guides, which are often but not always published with a corrigenda<sup>4</sup>. Nevertheless, mistakes will be mistakes and they keep affect negatively in “historical process of knowledge transferring from man to man, from generation to generation”.

This article discusses the technologies that allow us to master some of listed situations.

The history of using computers for scientific and technical calculation can be conveniently divided into three stages:

- Work with absolute codes
- Programming using high-level languages (ALGOL, FORTRAN, Pascal, C, BASIC, etc)
- Using mathematical packages such as Mathcad, Maple, Matlab, Mathematica, MuPAD, Derive, etc<sup>5</sup>.

There are no clear boundaries between listed stages (information technologies). Working in mathematical program one may insert a table, as the need arose, or some user functions written in C language, which codes contain fragments of assembler. Besides, absolute codes are still using in calculators, which are of great utility in scientific and technical calculations. Here it is better to consider not isolated stages of computer technique development but a range of workbenches that expand and interweave. This tendency results in sharp decrease of time required for creating calculation methods and mathematical models, leads to refusal of a programmer as an additional link between a researcher and a computer, to openness of

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<sup>3</sup> “etc” hides one more “error of a keyboard operator”. Computers and word standards now make us to refuse using comma as a separating character between integer and fraction parts of numbers. Thereby, books and articles often contain two formats of numbers – see two pair of numbers above this footnote.

<sup>4</sup> Nowadays such continuously refilled corrigendums of certain books appear in the Internet

<sup>5</sup> However, Excel just as Matlab hold the half-way position between programming languages and mathematical packages.

calculations, enable us to see not only result, but all formulas in traditional notation and also all intermediate data reinforced by plots and diagrams.

Today large number of computers (workstations), laptops, palmtop computers, and smartphones has connection with the Internet or the Intranet, wireless or wire-line. There is a lot of information in the Internet: texts, plots, tables, figures and also “alive” calculations that enable us to input the data and get a result. It is not infrequent that such calculations are performed on high-power computers with calculating process paralleling. This speeds up the calculation, if it is not limited to online data transfer rate. These calculations are easy to manage: put a password, perform pay access, make it possible to choose languages (English, Russian, etc.), correcting, enlarge, upgrade, etc.

It must be noted another important aspect of the “man-computer” problem. The high-level languages (and by the way, high-complexity) don’t tolerate “dilettantism” from a researcher. Many specialists in different fields (physics, chemistry, biology, engineering), students couldn’t use computers effectively due to difficulties in language studying. Programming demands maximum involvement that often leads to qualification loss in a main specialty, getting hooked on programming<sup>6</sup>. Mathematical packages followed by electronic tables were developing as an alternative to traditional programming languages. Many years’ experience of using Mathcad, Maple, Matlab, Mathematica, MuPAD, Derive, etc shows that they don’t induce such addiction. One can put off using program for a half - year or for a year but the main skills would not be lost and, if necessary, a problem would be solved quickly and correctly without engaging a programmer.

There is no rose without a thorn. The main limitation of the mathematical packages was that, as a rule, they couldn’t generate executable files, which could be launched without the original program. In particular, this prevented a progressive phenomenon - dividing those sitting in front of a screen into users and developers. Usually, specialists working with mathematical programs kept “subsistence production”: developed calculations for their own. They could give their results, and also on a commercial basis, only to those who had installed corresponding package.

The most popular package is Mathcad. The main reason of its popularity is Mathcad has a “low threshold of entrance”. If it is needed, a student, a post-graduate, an engineer, or a researcher can install Mathcad and solve his problems successfully after a few hours of training. Certainly, it would be true if a person is computer literate. Actually, other programs demand

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<sup>6</sup> For justice it should be noted that often a specialist-nonprogrammer became a highly experienced programmer and created not only successful applications but also systems programs.

special skills, which are not gained for “a few hours”. To work with Mathcad one also needs “special skills”. But he can acquire them step-by-step, during package studying: working with equations and set of equations, statistics functions, plotting, and others. If required, Mathcad can be expanded by special applications, which advance its usefulness and enable us to solve special problems. For example, plug-in WaterSteamPro ([www.wsp.ru](http://www.wsp.ru)) makes it possible to calculate thermophysical properties of heat carriers and working media in power engineering<sup>7</sup>.

We can say that Mathcad has no “threshold of entrance”<sup>8</sup> but just has a “ramp” with low angle of slope that allows a user to enter quickly and gradually any level of complexity of this program.

Moscow Power Engineering Institute has launched Mathcad Calculation Server (MCS) to solve the problem of knowledge transfer (which is known to be the main function of education) and to fulfil the educational innovation program. The server enables us to access the Mathcad documents via the Internet.

MCS technology allows us to solve the following problems:

- There is no need to install required version of Mathcad, check executable files for viruses and run them. We only have to connect computers to the Internet, access MAS server using Internet Explorer (version 5.5 and higher) or any browser installed in the palmtop computers or smart phones. This looks as if we work with Mathcad document: we can change source data, make calculation and get a result (save and print). Calculation method (formulas in traditional notation but not in the program form; this feature makes Mathcad widespread) and intermediate data can be visible or hidden partially or completely.
- New methods of calculation, open for studying<sup>9</sup>, become available instantly to all surfers of the Internet, or staff of a corporation, or researchers of a university. We should only give corresponding addresses to users. Moreover, information about suchlike calculations can appear in the databases of different search engines (yandex, google).

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<sup>7</sup> Figure 1 shows the function of the package WaterSteamPro called `wspDENSTP(p, T)`. It returns density of water and steam (DENSity) depending on pressure  $p$  and temperature  $T$ , which allows us to calculate dynamic viscosity using open algorithm.

<sup>8</sup> Mathcad has got “low threshold of entrance” in the juridical sense. One can always find an unregistered version of the program in the network or in a market. Many users study Mathcad on a piratical version and having learned its advantages buy a legal program or, at least, put a question of Mathcad purchase in their institute.

<sup>9</sup> Here is one more aspect of the Mathcad openness. From the 12-th version it becomes possible to save Mathcad file on a disk not only in the form of a binary code accessible only for Mathcad itself, but also as a text xml-file. This allows us to read and edit Mathcad documents in a usual editor. If Mathcad is not produced any more its files would not be lost. They can be used in the other programs.

- Any error, misprint, imperfection and assumption in a calculation noted by an author or users can be corrected quickly. It is also easy to upgrade and extend calculations, editing open formulas.
- The MAS technology does not exclude tradition capability to download Mathcad documents from a server for their upgrading or extending. We only should make a corresponding reference in a document. There are two ways of using mcd-files. We can transfer them only for calculations on a working station having Mathcad installed and lock documents with passwords. Another way is to give them freely or sell them for work without limitations.
- The MAS technology allows us to cut down expenses for software and solve the problem of licensing. As it was noted before, there is no need to install Mathcad to every computer for routine calculations, to equip all computer classrooms. Mathcad package is required now only for those who develop and upgrade documents. The others can use corporation or exterior server.

It should be noted that it needless to learn working with web-based Mathcad document. One can change the source data in the MCS-document using simple methods, having learned during surfing the network forums, playing games online or offline, etc.

Fundamental reference books are the important form of knowledge transfer in definite branches of science. Often one publication is used by several generations.

In 1999–2004 the publishing house of MPEI issued a set of reference books “Heat-and-power engineering” in four volumes edited by A.V. Klimenko and V.M. Zorin.

In 2005-2007 at MPEI the group under the direction of V.F. Ockov developed the site <http://twt.mpei.ac.ru/tthb> which contains many formulas, tables and plots from the reference books. Students, post-graduates, and teachers of heat-and-power engineering specialties are using widely these resources. They are used for training personnel, for practical work, for research and scientific projects.

In 2007 the publishing house of MPEI with financial support from Russian Foundation for Basic Research issued the fifth volume of the reference book “Online version of heat-and-power engineering handbook: instruments for creating and developing”. This publication aims to classify all the information concerning such web-sites and methods of their creating and support. Some parts of this handbook and some of its useful supplements have been published in the

Internet. It is a kind of “alive”, developing, “soft” issue of the reference book which is expanding constantly by the users of the site. Their works are now available to all prospective users.

The first chapter of the handbook describes Mathcad interface and publication methods of Mathcad-documents containing reference information in the Internet.

The second chapter represents “enlivening” techniques for formulas and calculation methods. It contains references to the online descriptions of Mathcad tools used for solving equations and sets of equations, algebraic and differential.

The third chapter deals with methods of plot approximation and their following online “enlivening”. It contains references to the sites solving statistics problems.

The fourth chapter discusses online “enlivening” of the tables.

The fifth chapter describes publication methods of calculations created in C language.

The addendum contains the list of the main reference online resources on the base of this technology and illustrations of the typical files.

This work (reference book plus Internet site) is a pioneer in many ways. Besides, it aims for optimum combination of “hard” and “soft” handbook editions, for elimination of their conventional disadvantages. Figures below show the typical documents of the guide with “alive” solutions.

Water and steam is known to be the main working medium in the power engineering. The thermophysical properties of these heat carriers are calculated upon the formula set developed by International Association for the Properties of Water and Steam (IAPWS – [www.iapws.org](http://www.iapws.org)). Figure 1 shows the site which allows us to calculate dynamic viscosity depending on pressure  $p$  and temperature  $T$  by formulas IAPWS of 2003. At that, the viewer can see all the formulas and all the intermediate data. This allows him to create his own program calculating such property of water and checkout it quickly having the control data from the Internet.

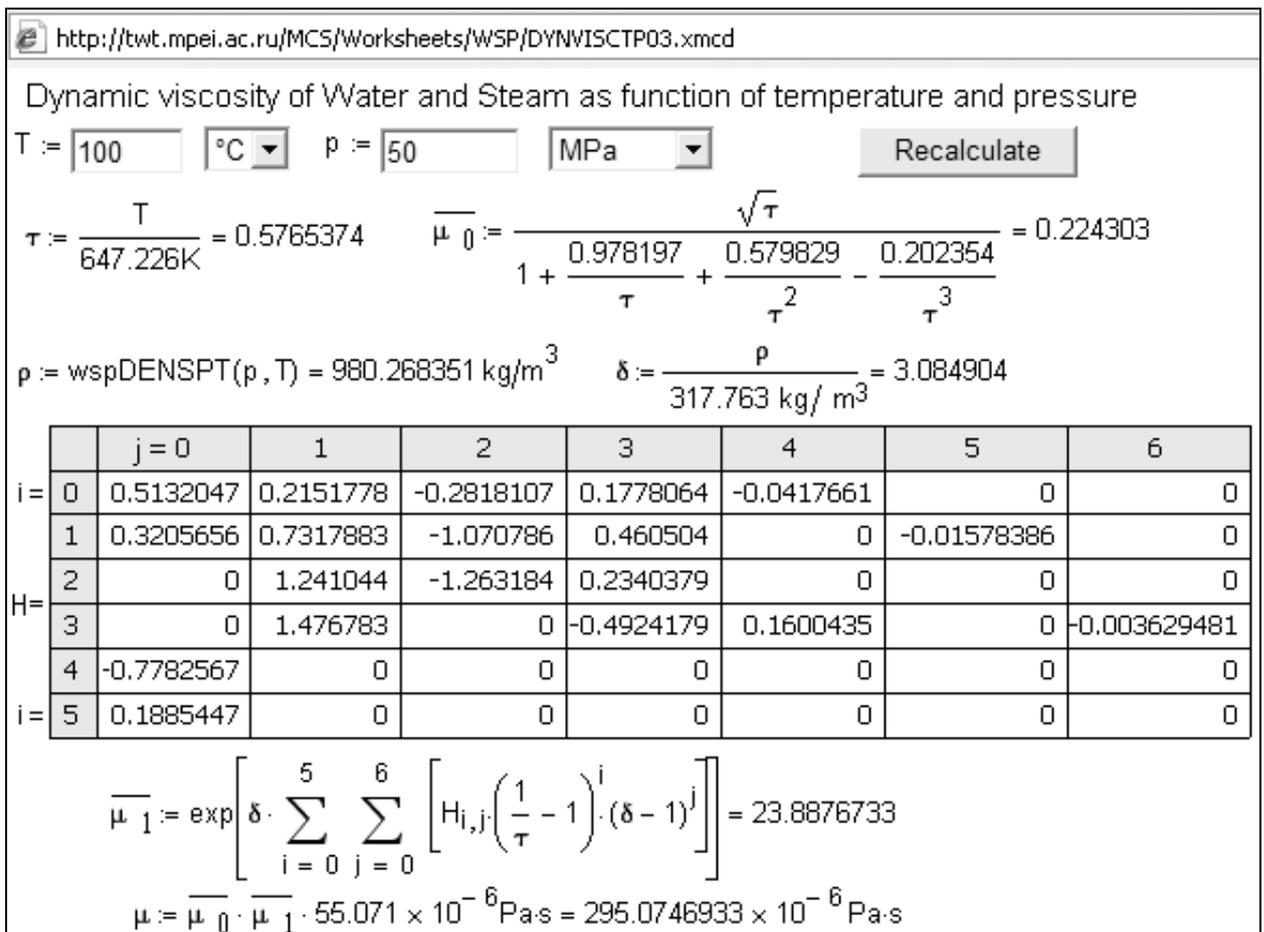


Fig.1 (<http://twt.mpei.ac.ru/MCS/Worksheets/WSP/DYNVISCTP03.xmcd>)

Such open alive calculations acceptable in the Internet are created for the other formulae sets certified by IAPWS. The site at <http://twt.mpei.ac.ru/ochkov/WSPHB/index.html> has a reference from official the site of IAPWS.

Some documents show only results, without intermediate data, which speed up calculation and save traffic of a surfer. The other pages show results on the plots and surfaces that allow us to size up influence of water and steam parameters (pressure, temperature, density, enthalpy, and entropy) to the calculated parameters.

One can download special programs from [www.wsp.ru](http://www.wsp.ru) and plug them in to the applications including Mathcad to have them offline.

Today the other working media and heat carriers are used in power engineering together with water and steam. In particular, power stations now install gas turbines, separately or together with steam turbines in the binary cycles. There are corresponding documents in which we can calculate thermo-physical properties of the gases and gas mixtures used as working media in gas turbine and steam-to-gas power installations.

Creating functions returned thermo-physical properties of the working media allowed us to develop and publish the site at <http://twm.mpei.ac.ru/TTHB/2/ThermCycleMCS.html> that collected references to the documents with «alive» calculations of thermal cycles. Figure 2 shows the site with Otto cycle calculation. The result is calculated by the formulae in the right bottom part of the figure.

Apparently, few people remember how this formula has been derived. The shown efficiency calculation is made upon principal laws and thermodynamic relations, by solving integral and algebraic set of equations (the Given-Find block). This allows us, on the one hand, to understand the logic of the calculation and, on the other hand, to take into account that specific heat capacity at constant pressure depends on temperature and pressure.

Suchlike online documents have been developed almost for all thermodynamic cycles. Moreover, the processes are represented by two-dimensional and three-dimensional “alive” plots in which we can choose axes (diagrams h-s, T-s, p-v, etc), see phases of the power unit work, for example the combustion engine worked by Otto cycle (see fig. 2).

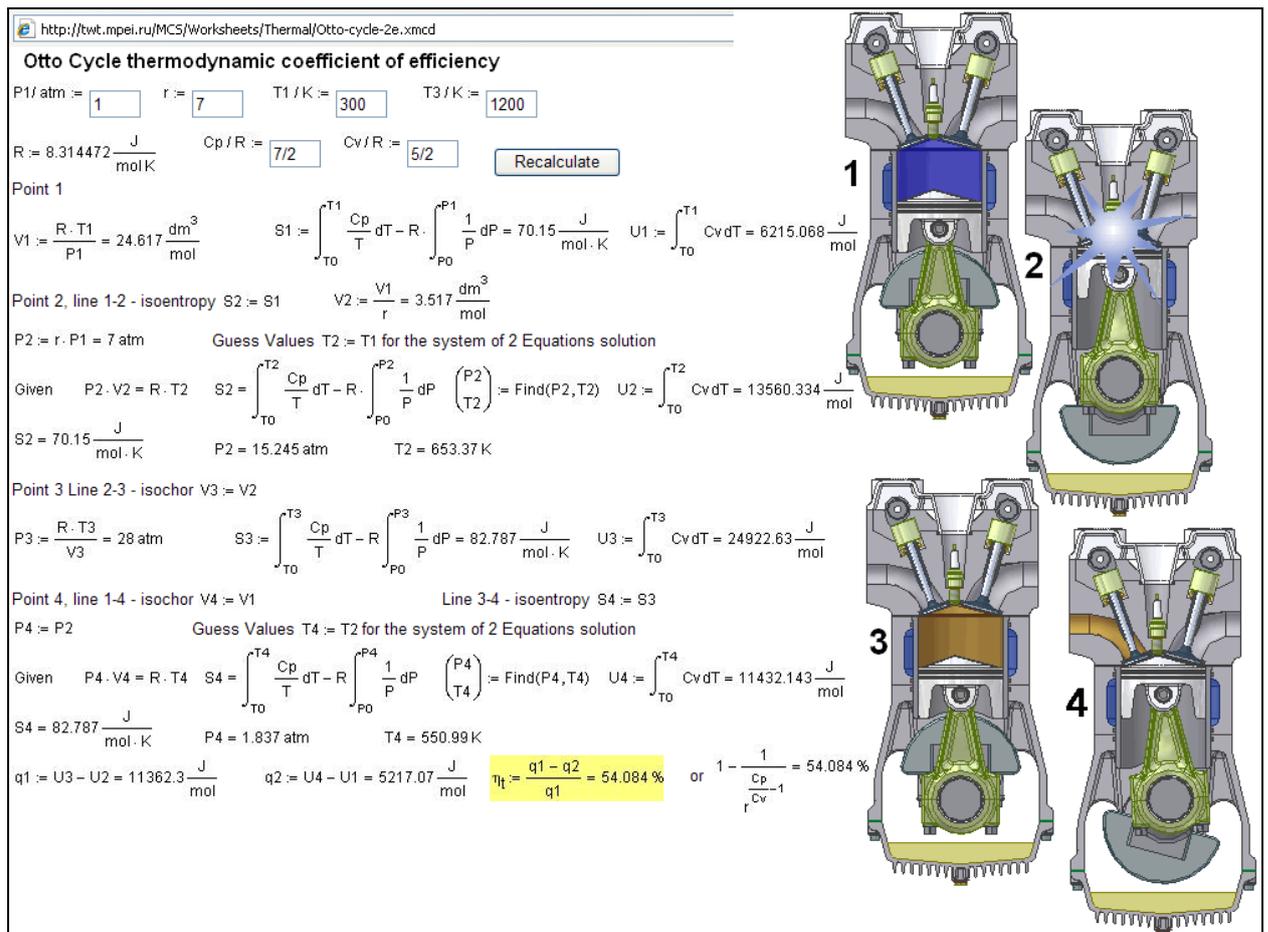


Fig. 2 ([http://twmmas.mpei.ac.ru/mas/Worksheets/Therm/Otto\\_anim.mcd](http://twmmas.mpei.ac.ru/mas/Worksheets/Therm/Otto_anim.mcd))

Figure 3 shows calculation of the temperature field and density of the heat flow at the wall of the circular pipe, at steady-state conditions. A site viewer can see the set of formulae in

traditional notation, change initial data and get a result, numerical and plot. Here, as in figure 2, the set of two equations is solved (Given-Find block). Similar calculations have been developed for many special cases of the heat transfer equation.

### Stationar Heat transfer in the tube with inner source of head

$\alpha_1 := 230 \text{ W/(m}^2 \text{ K)}$        $\alpha_2 := 150 \text{ W/(m}^2 \text{ K)}$

$t_{ж1} := 15 \text{ }^\circ\text{C}$        $\lambda := 0.12 \text{ W/(m K)}$        $t_{ж2} := 25 \text{ }^\circ\text{C}$

$r_1 := 10 \text{ mm}$        $r := 17 \text{ mm}$        $r_2 := 25 \text{ mm}$

$q_V := 30 \text{ kW/m}^3$

Recalculate

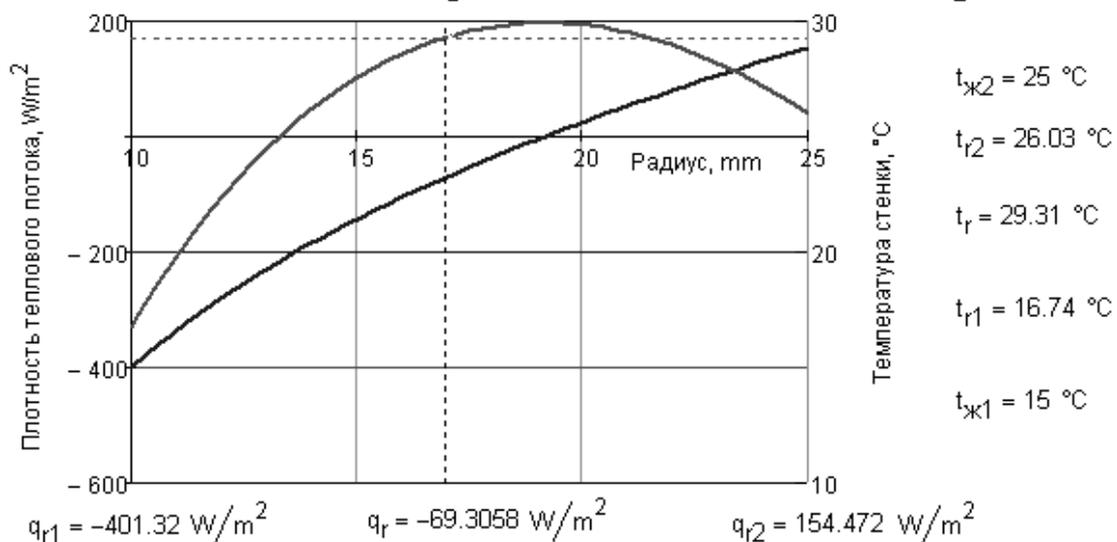
Given

$$\alpha_1 \cdot (t_{ж1} - t_{r1}) = \frac{2\lambda \cdot (t_{r1} - t_{r2})}{r_1} \left[ \frac{q_V \cdot r_1^2}{4\lambda \cdot (t_{r1} - t_{r2})} + \frac{1}{2} \cdot \frac{1 - \frac{q_V \cdot r_1^2 \cdot \left[ \left( \frac{r_2}{r_1} \right)^2 - 1\right]}{4\lambda \cdot (t_{r1} - t_{r2})}}{\ln \frac{r_2}{r_1}} \right]$$

$$\alpha_2 \cdot (t_{r2} - t_{ж2}) = \frac{2\lambda \cdot (t_{r1} - t_{r2})}{r_2} \left[ \frac{q_V \cdot r_2^2}{4\lambda \cdot (t_{r1} - t_{r2})} + \frac{1}{2} \cdot \frac{1 - \frac{q_V \cdot r_1^2 \cdot \left[ \left( \frac{r_2}{r_1} \right)^2 - 1\right]}{4\lambda \cdot (t_{r1} - t_{r2})}}{\ln \frac{r_2}{r_1}} \right] \begin{pmatrix} t_{r1} \\ t_{r2} \end{pmatrix} := \text{Find}(t_{r1}, t_{r2})$$

$$t(r) := t_{r1} + (t_{r2} - t_{r1}) \left[ \frac{q_V \cdot r_1^2 \cdot \left[ 1 - \left( \frac{r}{r_1} \right)^2 \right]}{4\lambda \cdot (t_{r2} - t_{r1})} + \frac{1 + \frac{q_V \cdot r_1^2 \cdot \left[ \left( \frac{r_2}{r_1} \right)^2 - 1\right]}{4\lambda \cdot (t_{r1} - t_{r2})}}{\ln \frac{r_2}{r_1}} \right] \cdot \ln \frac{r}{r_1}$$

$$q(r) := \frac{2\lambda \cdot (t_{r1} - t_{r2})}{r} \left[ \frac{q_V \cdot r^2}{4\lambda \cdot (t_{r1} - t_{r2})} + \frac{1}{2} \cdot \frac{1 - \frac{q_V \cdot r_1^2 \cdot \left[ \left( \frac{r_2}{r_1} \right)^2 - 1\right]}{4\lambda \cdot (t_{r1} - t_{r2})}}{\ln \frac{r_2}{r_1}} \right]$$



## **Conclusion**

Mathematical packages installed on the Internet servers enable us to solve the problem of “knowledge transfer from a generation to generation” upon online open “alive” calculations. The online version of the reference books “Heat-and-power engineering” is an example of knowledge transfer to the new generation of researches, working in power engineering field.

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