Development of internet resources to assess the effectiveness of some GTP

V F Ochkov¹, E E Ustyuzhanin¹, S V Rykov², V V Shishakov¹, B E Znamensky¹, Aung Thu Ya Tun¹

¹ Moscow Power Engineering Institute (Technical University), Krasnokazarmennaya 14, Moscow, 111250, Russia
² Saint-Petersburg State University of Information Technologies, Mechanics and Optics, Kronverkskiy 49, Saint-Petersburg, 197101, Russia
E-mail: evgust@gmail.com

Abstract. The analysis of Internet resources is fulfilled. These resources contain such information as: (i) data on the thermal properties of substances, \( R = (\rho, h, s, \ldots) \), (ii) numerical data on the efficiency and other energy criteria, \( Z \), of power plants. Our analysis has shown some features of the resources. Currently the most of them have the form of text files. The second type of the resources represents a software in the form of “exe-file” and allows the client to calculate values of \( R \) using a mathematical formula (MF) at boundary conditions, \( Y = (P,T) \); the latter are the pressure and the temperature. In this case, the resource includes the program, which is closed to clients: there is no such option as “to copy MF formula” in the software. A group of researchers offers the software, which is designed to calculate \( R \) properties and has the form of the open interactive Internet resource (OS). A computational part of OS-resource includes: (i) MF formula, which associates the property \( R \) with the parameters \( Y = (P,T,\ldots) \), (ii) Mathcad-program \( \text{Code}(R,Y) \) containing MF formula. The interactive part of the OS-resource is based on the computer science and Internet technology (IT). The report analyzes the methodological techniques and IT-tools, which have to be used to create OS-resource. We have considered OS-resources, which have a complex structure and are focused on the joint use of (i) the code designed to calculate the efficiency of power plants and (ii) OS-resources those allow to calculate \( R(Y) \) at specified points of the power plant cycle. We have discussed some results obtained on the basis of these resources.

1. Introduction
There are a number of Internet resources (“client function”, “template” and others), which are used for thermodynamic (TD) calculations; the latter are associated with the calculation of the properties, \( R(Y) \), [1–3] here \( R = (\rho, h, s, T, \ldots) \) are thermophysical properties of the working fluid (the air, the water et al.) under different boundary conditions \( Y \). For example, properties, \( R(Y) = (R_1(Y), R_2(Y) \ldots) \), refer to specified points of the cycle implemented in gas turbine power plants (GTP) [4]. It possible to see some features of \( R(Y) \) in the case (task-1). Within the frames of task-1, an operator deals with the design of GTP (variant 1) and should make estimates of the energy criteria \( Z \) (\( Z_1 \) is the electric efficiency of the cycle, \( Z_2 \) is the internal efficiency, etc.) in relation to GTP (variant 1). The designer uses his own program, \( \text{Code}_{\text{GTP}}(Z,R,Y) \). There are some parts in the program name:

- \( \text{Code} \) is the part, which indicates that the program is written with the help of Mathcad;
• \textit{GTP}_1 \text{ indicates GTP (variant 1);}
• \textit{Z} indicates the criteria (\textit{Z}_1, \textit{Z}_2, \text{etc.});
• \( R = (\rho, h, s, T, \ldots) \) are thermodynamic properties of the working fluid at the given points of the cycle;
• \( Y = (P, T) \) are the boundary conditions including \((P, T, \ldots)\) values realized in the turbine of GTP.

At present in most cases, \( R(Y) \) values are selected by the designer from an external source including well-known WEB sites of organizations (JIHT RAS [2], NRU MPEI [3], NIST (USA) [5], CoolProp library (Technical University of Denmark) [6], SGTE [7], etc.). Let us consider:
(i) the common types of Internet resources related to \( R(Y) \), (ii) some issues related to the technology of creating these resources. Some of these WEB sites offer text files (TF-resources), which contain tabulated properties \( R = (\rho, h, s, \ldots) \) for a substance (R134a, H\textsubscript{2}O, the air et al). Referring to such a resource, the client receives \( R \) properties using primitive options:

- “to select a substance”;
- “to display the table, \( X = (R, P, T) \)”;
- “to copy the table \( X \)”.

The designer receives \( X \) array in the format “txt”. To calculate \( R(Y) \) values required, the designer must use the interpolation of the \( X \) values due to \( Y \) conditions and task-1. The term “text” shows that TF-resource does not use a computer program or some exe-file, which performs the calculation of \( R(Y) \) by some mathematical formula (MF).

There is a small part of the sites, which offers such programs as exe-file (ES-resource, closed Internet resource) to calculate \( R(Y) \), for example, ES-resources [2], which are designed to calculate \( R \) data of refrigerants. The available ES-resources do not provide following opportunities to clients:

- to get acquainted with the algorithm of calculating the property \( R \) the property \( R \);
- to copy MF formula, which is used to calculate \( R \) property;
- to copy the code which is used in ES-resource; the code is “protected” in the corresponding ES-resource.

Referring to the ES-resource, the client can choose trivial options among them:

- “to input parameter set \( U = (P, T) \)”;
- “to output the result \( X = (R, P, T) \)” to PC screen of the client.

Thus, ES-resources for calculating the properties of \( R \) of about ten substances (R134a, methanol, etc.) are posted on the websites of JIHT RAS and Standartinform (Russia), and ES-resources for calculating \( R \) properties of about fifty refrigerants and other substances are presented on the WEB site [6].

2. Client function development

A software is appeared recently in the form of open interactive Internet resources (OS). This software has distinctive features in comparison with TS-resource and ES-resource. Thus, OS-resources of the first type have been used to perform TD-calculations, which relates to \( R \) properties of working bodies.

Let us consider the question (A) “What form of software can be offered on the Internet for the client to adapt tabulated values of \( M = (R, P, T, \ldots) \) in comparison with the traditional scheme containing a number of stages (to search WEB site, to copy the table, \( M \), to interpolate, etc.)?”. 


Figure 1. Mathcad-field related to Res-csplain_1(h, U, (http : //klm), key(def)) and included Code_csplain(h, Y).

We use an example, which is connected with an adaptation of tabulated (h, P, T) air data (table M, figure 1).

To resolve the issue (A), we have composed the program Code_csplane_1(h, Y) in the first stage, here in the name of the program:

- **Code** is the name indicating the program, which is written using the Mathcad package;
- **csplain** is the name indicating a calculation method (the double spline interpolation of a rectangular array);
- 1 is the program number;
- h is the enthalphy of the air; h is computed under given boundary conditions Y.

**Code_csplain(h, Y)** allows us:

- to use table M and built-in Mathcad-function, csplanin_1(Zo, Y), which is intended for the spline interpolation of points entering M;
- to use Mathcad-function, den(p, t), which is designed to calculate h under conditions Y = (P, T, ...) partially shown in figure 1.

Figure 1 shows results of TD-calculations: $h = 526.4$ kJ/kg at $p = 1000$ kPa and $T = 400$ K. **Code_csplain_1(h, Y)** implements a unique features of the Mathcad package: the code let us use the units of values (kJ/kg, kPa) [8].

At the second stage of solving the question (A) we have to convert the program **Code_csplain_1(h, Y)** into the corresponding OS-resource (position 5, figure 2) [8, 9].
Figure 2. Tools and sources of the information, which are used in the formation of OS algorithm: 1 – the algorithm Algor-OS-csplain1($\rho$, $Y$, (http://klm), key(def)); 2 – the part associated with Mathcad formulas or Mathcad field; 3 – a text part or a text field; 4 – the part related to Informatics and Internet technologies; 5 – the resource Res-OS-csplain1($\rho$, $U$, (http://klm), key(def)); 6 – Mathcad tools; 7 – Mathcad program Code_cspain1($h$, $Y$); 8 – the technology “Mathcad Calculation Server-MCS”; 9 – “Microsoft Expression Web 3” package, as well as other IT operators; 10 – PC of a client (P); 11 – Internet; 12 – the server BS and WEB site; 13 – the individual program, Code_EK1($Z$, $R$, $Y$), of the client (II), A—BS administrator.

OS-resource has to be located on the remote server (BS) (position 12, figure 2). Note, the methodological basis for creating OS-resources (“client function”, “template”, etc.) is the corresponding OS-algorithm (position 1, figure 2) [9]. We give an illustration (figure 2), which shows some tools and sources of information [9]. These instruments should be used in the formation: (i) of OS-algorithm of the first type, (ii) of corresponding OS-resource.

This OS-algorithm is referred to as Algor-OS-csplain1($\rho$, $Y$, (http://klm), key(def)), here in the algorithm name:

- “Algor-OS” is the name indicating that the algorithm is open interactive and not “closed” algorithms;
- csplain is the name indicating the calculation method;
- $h$ is the enthalpy that is computed by this algorithm;
- $Y$ are boundary conditions including the input data $U = (P, T)$;
- (http://klm) is the URL address;
- key(def) is the key/password.

It is possible to see in figure 2 the structure of the OS-algorithm and its components, including:

- the part, which is referred to as Mathcad-field; it is related to Code_cspain1($h$, $Y$);
- text part or text field (position 3, figure 2) containing some reference information (the text described $R$ property, headings, comments on MF etc).
• part related to Informatics and Internet technologies including the technology “Mathcad Calculation Server MCS” and the package “Microsoft Expression Web 3”.

Back to the second stage, our analysis shows that this transformation procedure is not trivial. We have proposed “Combined method of formation of open interactive resources” [10] or the technology, which ensures the transformation of the traditional Mathcad-program in the appropriate OS-resource. The method attracts “Mathcad Calculation Server MSC” and “Microsoft Expression Web 3” as well as other IT-operators.

Along with trivial options, this OS resource allows the client:
• to build a 2D graph as well as 3D graphic of \( h(P,T) \);
• to input the key(\textit{def}), to copy MF formulas and \texttt{Code\_splain}(R,Y).

It is possible to consider \textit{Res-OS-splain\_1}(p,U,(http : //klm),\textit{key}(\textit{def})):
• as some resolution of the issue (A);
• as one of client functions [1, 8, 9], which are devoted to TD-calculations of \( R \) properties of working bodies.

3. Calculation of GTP efficiency
Let us turn to the second type of OS-resource, which we can create on the bases of the technology (section 2). This software is connected with GTP (variant 2) and developed in the form of a complex client function, which is focused on sharing:

• Mathcad-program \texttt{Code\_GTP\_2}(Z,R,Y), which let us realized modernization activities (1, 2, 3, ...), here 1 is the increase in the number of turbine stages \( (Y_4) \) compared to the single-stage GTP (variant 1), 2 is the increase in the degree of air compression \( (Y_2) \), 3 is the increase of the temperature at the inlet of turbine \( 1 \) \( (Y_3) \) and other actions;
• client functions those can be used to calculate \( R \) properties of the working body at given points of the cycle.

This OS-resource enables us to solve task-2, which is connected with the modernization of GTP (variant 2). We have created OS-resource in the form of \textit{Res-OS-GTP\_2}(Z,R,U,(http : //klm),\textit{key}(\textit{def})). GTP (variant 2) includes: (i) several gas turbine units, (ii) several compressor units, (iii) other blocs.

\texttt{Code\_GTP\_2}(Z,R,Y) includes a set of formulas. Among them equations to calculate \( Z \) criteria of the complex cycle [8]. These criterions include: \( Z_1 \) is the electric \( COP_e \), \( Z_2 \) is the internal \( COP_i \), \( Z_4 \) is the specific internal real work of the gas turbine bloc, \( Z_5 \) is the specific real input heat, \( Z_6 \) is the specific ideal work of the isentropic expansion in the gas turbine bloc, \( Z_7 \) is the specific ideal work of the isentropic compression in the compressor bloc.

\textit{Res-OS-GTP\_2}(Z,R,U,(http : //klm),\textit{key}(\textit{def})) let us fulfill TD calculation including:
• to determine the objective function, \( Z(Y) \), under constant \( Y = (Y_2,Y_3,...) \);
• to optimize the objective function, \( Z(Y) \), with the purpose of some modernizing GTP (variant 2);
to investigate the objective function, $Z_2(Y)$, if the arguments, $Y = (Y_2, Y_3, \ldots)$, change in the specified interval, $\Delta Y = Y_{\text{max}} - Y_{\text{min}}$.

TD-calculations have been fulfilled and values of $Z_2(Y)$ have been got under $Y$ conditions including: $Y_1 = 0.101 \text{ MPa}$ is the inlet pressure of the compression bloc, $Y_2$, $Y_3$, $Y_4$ is the number of stages in the compression bloc, $Y_5$ is the degree of an air compression in front of an intercooling unit, $Y_6$ is the number of turbine units, $Y_7$ is the degree of the gas expansion in front of the interim heat supply in a separate turbine unit etc.

In the first stage of the numerical experiment, we have studied $Z_2(Y_2, Y_3)$ as the function with two arguments. This cycle has a primitive thermal schema and uses the conditions: $Y_4 = 1$, $Y_5 = 1$, $Y_6 = 1$, $Y_7 = 1$. Values of $Z_2(Y_2, Y_3)$ are represented in figure 3.

A number of results have been obtained in the first stage. Firstly, the data let us find optimal thermodynamic cycles, which are characterized with the maximum values, $Z_{2,\text{max}}(Y_{2,\text{opt}}, Y_{3,\text{opt}})$, here $(Y_{2,\text{opt}}, Y_{3,\text{opt}})$ are optimal values. The local maxima of $Z_2(Y_{\text{opt}})$ function on some isolines are shown in figure 4 including the global maximum $Z_{2,\text{max}} = 46.05\%$.

It can be seen a cycle with $Z_{2,\text{max}}(Y_{2,\text{opt}} = 29, Y_{3,\text{opt}} = 1200 \, ^{\circ}\text{C}) = 38.6\%$. This variant is considered as the reference cycle with $Z_2 = 38.6\%$. This cycle has a primitive thermal schema and uses such conditions as $Y_2 = 29$, $Y_3 = 1200 \, ^{\circ}\text{C}$, $Y_4 = 1$, $Y_5 = 1$, $Y_6 = 1$, $Y_7 = 1$.

Secondly, we have determined some effects, $\Delta Z_2(Y_2, Y_3)$ those are associated with a modernization due to the variation of arguments $(Y_2, Y_3)$ in interval, $\Delta Y$. For example, it is determined a shift, $\Delta Z_2(Y_2, Y_3) = Z_{2,\text{M}} - Z_{2,\text{R}} = 7.7\%$, here $Z_{2,\text{M}} = 46.5\%$ is the value related to a modified scheme, $Z_{2,\text{R}} = 38.6\%$ is the value related to the reference cycle. The effect can be realized if a client uses the increases of $Y$ arguments ($\Delta Y_2 = Y_2 - Y_{2,\text{R}} = 43$, $\Delta Y_3 = Y_3 - Y_{3,\text{R}} = 700 \, ^{\circ}\text{C}$).

In the second stage of the experiment, $Res\text{-OS-}\text{GTP.2(Z,R,U,(http://klm),key(def))}$ let us investigate the the objective function, $Z_2(Y_2, Y_3, Y_4, Y_5, Y_6, Y_7)$. Additional arguments ($Y_4, Y_5,$

![Figure 3. Dependences of the criterion $Z_2$ on the parameters $Y_2$ and $Y_3$.](image-url)
Figure 4. The maximum values of $Z_2(Y_2, Y_3)$ function with respect to GTP (variant 2).

$Y_6$, $Y_7$) are connected with those related to some modernization measures. A set of numerical data on the objective function, $Z_2(Y)$, is elaborated along isolines. These data let us find optimal thermodynamic cycles of GTP (variant 2) upgraded, for example:

- the cycle, which is characterized with $Z_{2\text{max}}(Y_{\text{opt}}) = 47.6\%$, here $Y_{\text{opt}} = (Y_2 = 90, Y_3 = 1200 \, ^\circ\mathrm{C}, Y_4 = 2, Y_5 = 2.0, Y_6 = 3, Y_7 = 1.75)$;
- the cycle, which is characterized with $Z_{2\text{max}}(Y_{\text{opt}}) = 53.1\%$, here $Y_{\text{opt}} = (Y_2 = 100, Y_3 = 1700 \, ^\circ\mathrm{C}, Y_4 = 2, Y_5 = 3.0, Y_6 = 3, Y_7 = 1.75)$; this value can be considered as the global maximum in testing $Y$ intervals.

4. Conclusion
We have discussed some client functions, which are connected with $R$ properties of technologically important substances/matters and based on innovative Internet technologies. These functions have a form of OS-resources and can be used as an effective software for a GTP design. The resources complement traditional forms of an Internet information, which is reflected, for example, in the classification [1]. We note that some TD-calculations can be done now with the help of soft wares located on commercial disks [7, 12]. Such a software includes a closed program (exe-file) and does not provide some options, which can be got in OS-resources and let a client:

- to copy MF formula, which is used in the exe-file to determine $R$ property;
- to copy the whole code, which is involved in the exe-file.

For example, Thermo-Calc [7] can be bought in the form of a commercial disks. It possible to see an advertising of a free software code, OpenCalphad, which is elaborated by the Scientific Group Thermodata Europe; SGTE has been founded by a consortium of dedicated scientists establishing and putting forward computational thermochemistry.
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