



The application of Microsoft Excel in teaching courses of mechanical engineering

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Abstract: *The applications of information technologies in the field of mechanical engineering are various and numerous. This paper presents the application of basic computer software i.e. Microsoft Excel in solving a series of calculations in the field of mechanical engineering which can be encountered during studies, or later in practice. Using the knowledge and literature both in these areas and in the field of information technology, this software is used through an interactive application to calculate the geometric characteristics of standard profiles, as well as the calculation of the efficiency and state parameters of the thermodynamic cyclic processes. The examples shown in this paper will provide students a great help in the preparation of assignments from these fields of study, and also teachers when reviewing them.*

Keywords: *geometric characteristics; cyclic processes; Microsoft Excel*

1. INTRODUCTION

The teaching process of mechanical engineering courses of the Faculty of Technical Sciences in Čačak is based on the theoretical lectures and exercises in which the practical problems are solved. In the exercises, students get homework, graphical and design assignments in which they are solving a variety of practical problems that they may encounter in the future.

Due to the increased number of students and wish to improve the efficiency of teaching, it is generated the need for using a variety of applications and tools to allow students to study more effectively and improving their skills, and enabling a more efficient work and review of students papers by a teacher.

As these practical problems can include a series of computing and can be very comprehensive, it is generated a possibility of using a certain type of tools to process data through a series of formulas and conditions that may be encountered in accordance to the diversity of students personal assignments.

Within the framework of this paper, it will be presented the application of Microsoft Excel tools for solving problems in the field of strength of materials, as part of the teaching course of the Technical Mechanics 2, and problems in the field of the thermodynamic cyclic processes in heat engines within the course of the thermodynamics.

2. IMPLEMENTATION OF TOOLS IN THE FIELD OF THE STRENGTH OF MATERIALS

2.1. Task description

In the field of Strength of Material, within the course Technical Mechanics 2, students receive a variety of tasks as problems that may be encountered in practice, among which is the determination of the geometrical characteristics of the flat cross-section (profile), i.e. a moment of inertia.

When bending, torsion beams, etc., stress and strain of the carriers, caused by the action of the force depends on the geometrical characteristics of the cross-section. These characteristics are precisely expressed as areas and moments of inertia of the cross section. [1]

In the context of the task that should be solved, students receive the appropriate configuration of complex cross-section composed of three defined standard profiles (L, U, I, or Z profile), and for the thereby obtained complex profile it is necessary to determine moments of inertia, the principal axes ellipse radii of inertia, and moments of inertia for the principal axes according to the calculated angle of rotation. The whole process is, for the practical reasons, performed in a tabular way. An example of a possible cross-section that student may receive are shown in Fig. 1.

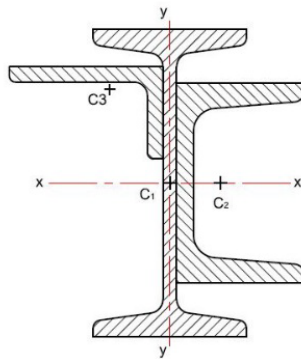


Figure 1. An example of a complex profile composed of I, L and U profile

The first step is to separate the complex profile into the standard profiles for which tabular geometric characteristics data and dimensions are known. From these tables shall be adopted areas, dimensions, axial and centrifugal moments of inertia for the center axis of gravity of standard profiles. [1-3]

The second step is to determine the center of gravity (centroid) of the complex profile (cross-section) in relation to an arbitrary adopted axes x and y over the term:

$$x_c = \frac{S_y}{A} = \frac{\sum A_i \cdot x_i}{\sum A_i}, y_c = \frac{S_x}{A} = \frac{\sum A_i \cdot y_i}{\sum A_i} \quad (1)$$

where S_x and S_y are static moments of inertia, A_i profile area, x_i and y_i distances from the centroid of the profile to the arbitrarily adopted coordinate system that are determined based on the dimensions and drawings of standard profiles which make up the complex profile. [1,2]

After determining the centroid of a complex section, the next step is to determine the moments of inertia of each individual profile for the arbitrarily adopted axes by using Steiner's theorem:

$$I_x = \sum I_{\xi i} + \sum A_i y_i^2; \quad I_y = \sum I_{\eta i} + \sum A_i x_i^2; \quad I_{xy} = \sum I_{\xi \eta i} + \sum A_i x_i y_i \quad (2)$$

where $I_{\xi i}$, $I_{\eta i}$ and $I_{\xi \eta i}$ are moments of inertia of the individual standard profiles, with values which are obtained from tables [3], taking into account the position profile relative to its centroid coordinate system (if the standard profile is rotated by 90 degrees, then the positions of axial moment of inertia I_{ξ} and I_{η} are changed – as is the case with L profile in Fig. 1).

There is one more condition that must be fulfilled, which is that the centrifugal moment of inertia has a negative sign for the L and Z profile, if their legs are located in the second and fourth quadrant of the coordinate system of its focal axis. The cross-section shown in Fig. 1, contains the L profile that meets this requirement, and a negative centrifugal moment of inertia is generated in the table for this profile.

All the above conditions are taken into consideration when developing Excel document.

After the centroid of profile is determined – coordinates x_c and y_c relative to arbitrarily adopted axis, moments of inertia for the centroid axis can be determined according to the Steiner's theorem [1,2]:

$$I_{\xi} = I_x - y_c^2 \cdot A; \quad I_{\eta} = I_y - x_c^2 \cdot A; \quad I_{\xi \eta} = I_{xy} - x_c \cdot y_c \cdot A \quad (3)$$

The principal moments of inertia are determined using the equation:

$$I_{1,2} = \frac{1}{2}(I_{\xi} + I_{\eta}) \pm \frac{1}{2}\sqrt{(I_{\xi} - I_{\eta})^2 + 4I_{\xi \eta}^2} \quad (4)$$

The position of the principal axes of inertia 1 and 2 determines by the angle α , in relation to the centroid axis of profile. This angle can be calculated according to the formula:

$$\alpha = \frac{1}{2} \arctg \left(-\frac{2 \cdot I_{\xi \eta}}{I_{\xi} - I_{\eta}} \right) [rad] \quad (5)$$

The ellipse of inertia radiuses can be calculated using the equation:

$$i_{1,2} = \sqrt{\frac{I_{1,2}}{A}} \quad (6)$$

2.2. Application of Microsoft Excel tool for solving problems in the field of strength of materials

The reason for the creation of software tools which are used in solving problems is that the student can check their assignments in a quick and efficient way, but also to have the opportunity to examine the utilization of a given cross-section that is used for a specific purpose in a structure, or to adopt such a dimension of profiles that are needed to achieve the functionality of the designed profile with a minimum cost of material.

To be suitable for use, it is necessary that such a software tool be as much interactive as possible in a relation between user and computer.

For example, in the configuration shown in Fig. 1, the dimensions of any I, L and U profiles cannot be classified, because it can lead to collisions between the profiles I and U, if, e.g., the dimension between the arms of I profile is less than the height of U profile. According this, another condition is introduced, which goal is to prevent the user to make such a mistake. If this condition is true, the field 1 will contain the text "OK", Fig. 2. If an incorrect entry occurs, the text will appear as shown in Fig. 3.

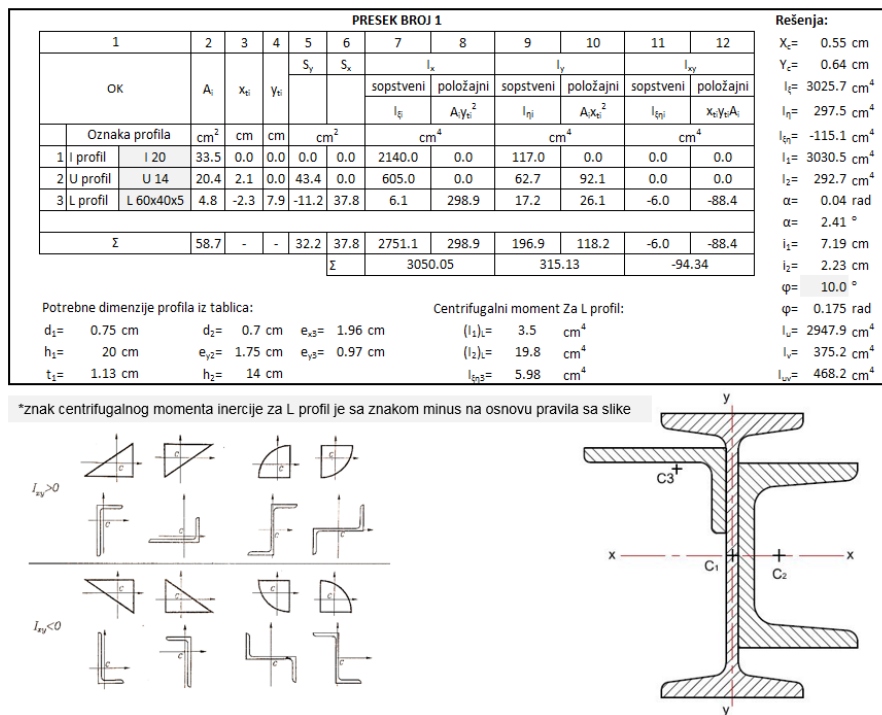


Figure 2. The appearance of the table for calculating geometric characteristics of profile

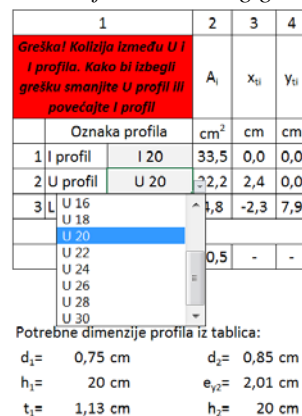


Figure 3. An example of error due to inappropriate selection of standard profiles

The drop-down menu for each profile is made using "Data Validation" [4], and selecting the appropriate of profile from the worksheet containing the database table of standard profiles.

The required dimensions and characteristics of the profile are automatically generated from the table after selecting profile from the drop-down menu by using the tool "VLOOKUP" which uses a profile name as key and table of appropriate profile on the other table database worksheet [5,6].

Shaded fields are interchangeable, which means that it is enough to choose the standard profiles from the drop-down menu, and the program automatically calculates all the geometric parameters of a given complex profile.

3. IMPLEMENTATION OF TOOL IN THE FIELD OF THE THERMODYNAMICS

Thermodynamics is available to students within the course of Thermotechnics, in which students, among other things learn thermodynamic cyclic processes.

Students in this course have homework in which they receive the corresponding cyclic process and its input parameters. Based on these data, the students are calculating the remaining state parameters of characteristic points in the process - p, v, T , change of internal energy - Δu , amount of work - w and the amount of heat - q for the each state change as well as the efficiency of a given cycle process - η . [7]

Cycles are closed processes that consist of the four changes of state. Every change of state are derived from the general polytropic change of state $p \cdot v^n = const.$ [8]

Table 1. Values of the polytropic exponent of each state change [7]

State change	General polytropic $p \cdot v^n = const.$	Isochoric $v = const.$	Isobaric $p = const.$	Isothermal $T = const.$	Isentropic (adiabatic) $s = const.$
Polytropic exponent n	n	$\pm\infty$	0	1	κ

For similar reasons as in course of the strength of materials, we came to idea for creating a tool in Microsoft Excel to calculate the thermodynamic parameters of a series of cycle processes.

The users of this tool can easily check their data calculations by entering the input parameters of the process and choosing an ideal gas that runs the process from drop-down menu. In addition to checking the accuracy of solving the original problem, a developed program allows the user to make an analysis of the effect of the input parameters and different types of ideal gas on thermodynamic efficiency of the process simply by changing it. [7,9]

The window layout of used tool for calculating the parameters for the Otto-cyclical process is shown in this paper.

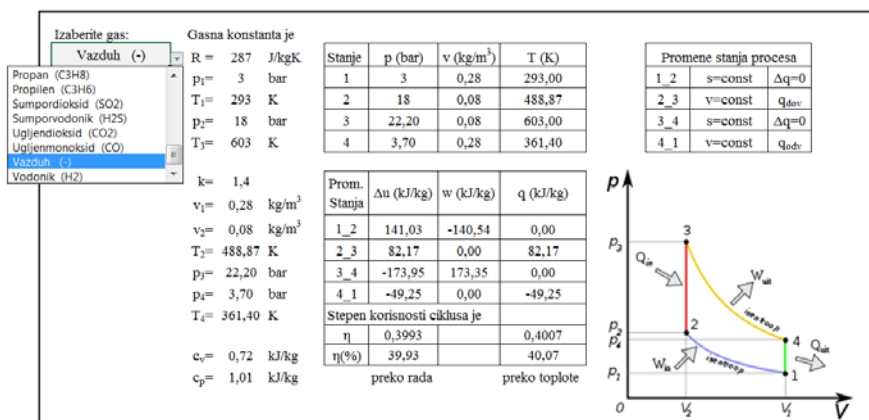


Figure 4. Window layout for calculating parameters and utility of Otto-cyclical process

4. CONCLUSION

This paper presents the possibilities of applying Microsoft Excel software in teaching techniques which not only that allows a very simple and quick way of resolving particular problems, it also allows interactive impact analysis of various parameters on the outputs of the developed tool. In this way it is possible to carry out a series of analysis and selection of the best profile dimensions in the problem of the Strength of Materials, as well as certain thermodynamic conditions that will result in a maximum efficiency of the cycle processes within the field of thermodynamics. Developed programs include many examples of both cases and cover a large part of the theoretical and practical problems.

This software tool could be improved by expanding the database of input data, in order to render the centroid axes, principal axes and the ellipse of inertia as well as automatic drawing p - v and T - s diagrams of the cycle processes according to the already entered the calculated data parameters.

LITERATURE

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