DESIGN AND CHECK OF THE MECHANICAL COMPONENTS
BY THE PC APPLICATION

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The paper focuses especially on comparison of available programs for design and check of the mechanical components. The main aim of the paper is to analyse in the introductory part the individual programs from the perspective of content and functionality and consequently to compare the results experimentally in selected cases. The paper evaluates simplicity or complexity of work with the individual software types on the basis of input requirements [Bicejova 2016a]. The conclusion summarizes the issue and experience acquired in designing and in checking of the mechanical components.

KEYWORDS
design, calculation, program

1 INTRODUCTION
The paper deals with comparison of the selected software types for design and check of the mechanical components on the basis of diverse aspects. Comparison of the respective software types rests in general description of functions and option pursuant to experience acquired through their application. Evaluated are other aspects influencing the selection of the program for design and checks of the mechanical parts such as extend of deviation among the results of the selected types of problems [Mascenik 2016a]. The principal idea of the paper is to point out certain advantages or disadvantages of use of available software types for design and check of the mechanical components for a standard user on the basis of which there exists higher probability of selection of the correct software for calculation of random structural task.

2 SOFTWARE ANALYSIS FOR DESIGN AND CHECK OF MECHANICAL COMPONENTS
The introduction presents basic information on programs which shall be consequently compared in case of the selected types of problems. The information refers to versions of the particular program, content, types of the individual calculations, standardized parts and functions [Krenicky 2010]. Mentioned are the programs such as MITCalc, TDS Technik, Mechsoft and module Design Accelerator of the Autodesk Inventor program [Bicejova 2013a].

2.1 MITCalc
Program MITCalc (Fig. 1) is ranked among tabular calculators (Mechanical, Industrial and Technical Calculations). It works under the program of Microsoft Excel which must be installed. The program contains a broad scale of design and check calculations for everyday practice [Salokyova 2016a]. The integrated environment of the program offers the individual types of calculations (in metric and in inch units):

- **toothing**: spur, conic, screw, planetary gearings,
- **belts and chains**: V-belt and toothed belts or roller chains,
- **springs**: 15 types of springs (extension spring, forcing spring, helical spring, etc.),
- **support, shaft and profile**, connections: screwed connections, shaft connections, force shaft connections, welded connections, pin connections,
- **bearings**: antifriction bearings SKF, INCH, FAG
- **plates and shells** [Mascenik 2016b].

![Figure 1. Working environment of the MITCalc program](image)

2.2 TDS Technik
TDS Technik (Fig. 2) represents an engineering extension for the selected CAD systems yet it can operate as an independent unit. It is issued as the extension for the systems by the companies of Solidworks (Solid Edge ST, SolidWorks), of Autodesk (AutoCAD, AutoCAD LT, AutoCAD Mechanical), Techsoft (ZWCAD), Bricsys (BricsCAD) or of Siemens (NX Unigraphics). The software disposes of a good basis although it does not rank among the products of large companies.

![Figure 2. Working environment of TDS Technik](image)
Bill of materials: Generation and modification of bill of materials (sorting, printing, export of data, etc.). The tool can be used also for data import from the configuration of the Solid Edge program [Mascenik 2014a,b].

2.3 MechSoft

The Mechsoft program (Fig. 3) represents the implementation of design and structures of the mechanical products. It offers a complete set of guides by means of which mechanically correct parts are automatically generated by setting several simple or complicated mechanical attributes. Mechsoft contains extensive set of calculations involving standard mathematical equations and physical theories. Majority of the mechanical calculations automatically generate parametric components being inserted into a set [Mascenik 2016c]. Other calculations can be inserted into the set and connected with the parameters occurring in the application or in administrator of the connections. The connected reference information documents contain relations, algorithms and theory for each calculation. The method of calculations and of mutual connections conforms to the management concept of the program development [Puskar 2013]. The Mechsoft program is gradually developed in individual versions:

- MechSoft for AutoCAD
- MechSoft for Desktop
- MechSoft LT Technical
- MechSoft PROFI LT
- MechSoft for inventor [Bicejova 2016b,c].

Basic user interface consists of four basic categories, i.e. part guide, calculation guide, knowledge database and individual parts (over one million of standardized parts included in more than 1500 standards). The program works with standards such as ISO, Din, BS, NF, STN, CSN and JIS.

Program contains the following types of calculations:

- Design and calculation of a screwed connections.
- Design and calculation of pins and journals (safety pins and journals, cross pins and journals, radial pins and journals).
- Design and calculation of supports and suspension stays.
- Design and calculation of plates.
- Design and calculation of shafts.
- Design and calculation of toothed wheels (front wheels, conic wheels, worm wheels).
- Design and calculation of bearings (ball bearings, tapered roller bearings, roller bearings, spherical-roller bearing, needle roller bearing).
- Design and calculation of belts (V-belts, toothed belts) and chains (roller chains).
- Design and calculation of splines.
- Design and calculation of cams (rotary cams, feed cams, cylindrical cams).
- Design and calculation of connections with equilateral involute splines.
- Design and calculation of brakes (drum brakes, disc brakes, band brakes, cone brakes).
- Design and calculation of gripping connections (split hub, unilaterally slotted hub and bevel hub).
- Design and calculation of a working screw.
- Design and calculation of springs (forcing springs, tension springs, disc and helical springs).
- Design and calculation of welds (abutting welds, fillet welds, hole and slot welds, point welds).
- Design and calculation of soldered connections (spayed connections, abutting connections, lapped and stepped connections).
- Calculation of tolerance and location [Balazikova 2016].

![Figure 3. Working environment of the MechSoft program](image1)

2.4 Module Design Accelerator of the Autodesk Inventor Program

Design accelerator represents an extension of the Autodesk Inventor program (Fig. 4). The program allows fast generating of complicated parts and functions on the basis of technical data such as transfer ratio, torque, force and material properties. It consists of partial generators, mechanical calculators and engineering manual. The mechanical calculators employ standard mathematical formulae and theories to help the user design the components. The manual included in the model contains mechanical theory, formulae and algorithms applied in structure of the machines [Gaspar 2013].

![Figure 4. Working environment of the Autodesk Inventor program](image2)

3 EXPERIMENTAL DETERMINATION OF DEVIATIONS OF THE RESULTS AMONG THE SELECTED SOFTWARE TYPES

Determination of deviation of the calculation results was performed on the basis of four selected types of examples:

- Calculation of a screwed connection torque.
- Calculation of intensity of shear stress acting in the welded connections.
- Calculation of pressure in involute spline of a shaft and inevitable minimal and functional length of spline.
• Calculation of shear forces and bending moment of the support [Bicejova 2013b].

To assure more thorough comparison of results among employed software types a manual calculation of three selected problems is presented further.

### 3.1 Manual Calculation of Pressure in Involute Spline of the Shaft and Inevitable Minimal Functional Length of the Spline

It is the case of calculation of the pressure in the involute spline (Fig. 5) when only half of the tight pen height is taken into consideration [Mascenik 2011].

#### Figure 5. Model of the shaft connection with the hub by a tight spline

The following values are given:

\[ \begin{align*}
    p & = 6 \text{ kW}, \\
    n & = 720 \text{ rev. min}^{-1}, \\
    d & = 42 \text{ mm}, \\
    l & = 45 \text{ mm}, \\
    p_{\text{DOW}} & = 80 \text{ MPa} \\
    p_{\text{bsh}} & = 12x8
\end{align*} \]

Calculation of shaft torque:

\[ Mk = \frac{p}{\omega} = \frac{6000 \text{ W}}{75.398 \text{ rad. s}^{-1}} = 79.58 \text{ Nm} \]

Calculation of pressure in the involute spline:

\[ \begin{align*}
    l_s & = l - b = 45 \text{ mm} - 12 \text{ mm} = 33 \text{ mm} \\
    P_v & = 2, Mk \\
    2.795,810^3 \text{ Nmm} \\
    K & = \frac{2.795,810^3}{42 \frac{1}{2}} \frac{33 \text{ mm}}{} \\
    28,708 \text{ MPa} & \leq 80 \text{ MPa} \rightarrow \text{SATISFACTORY} \\
    p_v & = 28,708 \text{ MPa}
\end{align*} \]

Calculation of minimal functional length of the spline:

\[ \begin{align*}
    \frac{2. Mk}{d, \frac{1}{2}, l_s} & \leq p_{\text{DOW}} \rightarrow l_s = \frac{2. Mk}{d, \frac{1}{2}, p_{\text{DOW}}} \\
    2.795,810^3 \text{ Nmm} \\
    42 \frac{1}{2} \frac{80 \text{ MPa}}{} \\
    l_s & = 11,842 \text{ mm}
\end{align*} \]

### 3.2 Manual Calculation of Magnitude of Shear Stress in the Welded Connection

In the individual calculation of the fillet weld the entire length of the weld is taken into consideration. The task of the problem is to detect the magnitude of shear stress of a T-fillet weld stressed by perpendicular shear (through acting of normal force) [Mascenik 2012].

The following values are given:

\[ \begin{align*}
    F_N & = 8 \text{ kN} \\
    l & = 50 \text{ mm} \\
    z & = 6 \text{ mm} \\
    R_s & = 235 \text{ MPa} \\
    k & = 1,5 \\
    a & = 0,75
\end{align*} \]

Calculation of partial (normal) stress from tractive force and height of the fillet weld with \( \beta \) standing for coefficient of thickness of the fillet weld (Fig. 6):

\[ \begin{align*}
    a = 0,7, z = 0,7,6 \text{ mm} = 4,2 \text{ mm} \\
    \beta = 1,3 - (0,03 x) = 1,3 - (0,03 \times 6) = 1,12 \\
    \tau_L & = \frac{F_N}{a \cdot l} \\
    19,047 \text{ MPa} & \leq 1,12 \cdot 235 \text{ MPa} \\
    25,396 \text{ MPa} & \leq 175,47 \text{ MPa} \\
    \tau_V & \leq \tau_{DOW} \rightarrow \text{SATISFACTORY}
\end{align*} \]

### 3.3 Manual Calculation of Torque of the Screwed Connection

To perform calculation of the screwed connection (Fig. 7) by a through-bolt in the selected programs it is inevitable to insert inevitable coefficients into calculation such as coefficient of tightness (pre-stress) of the connection, coefficient of input force, coefficient of friction in the connection and entered coefficients (coefficient of friction between a matrix and a support plate, and coefficient of friction of the threads of the screwed connection) [Halko 2013].

#### Figure 6. Scheme of the welded connection

Calculation of final (comparing) stress:

\[ \begin{align*}
    \tau_V & \leq \tau_{DOW} \\
    19,047 \text{ MPa} & \leq 1,12 \cdot 235 \text{ MPa} \\
    25,396 \text{ MPa} & \leq 175,47 \text{ MPa} \\
    \tau_V & \leq \tau_{DOW} \rightarrow \text{SATISFACTORY}
\end{align*} \]

#### Figure 7. Scheme of the screwed connection

The values of the coefficients are selected according to the determined intervals according to structure and operating conditions of the connection. The task of the problem is to
detect the magnitude of the inevitable torque of the screwed connection so that axial force \( F \) is reached [Murcinkova 2013].

The following values are given:

\[
\begin{align*}
\text{Screw M20x2.5} \\
F &= 5000N \\
d_m &= 35 \text{ mm} \\
d_2 &= 21 \text{ mm} \\
d_3 &= 18,376 \text{ mm} \\
f_m &= 0.1 \\
f' &= 0.115
\end{align*}
\]

Calculation of friction diameter \( D_f \):

\[
D_f = \frac{2d_3^2 - d_2^2}{3d_m^2 - d_2^2} = \frac{2 \times 35^2 \text{mm} - 21^2 \text{mm}}{3 \times 35^2 \text{mm} - 21^2 \text{mm}} = 28.583 \text{ mm}
\]

Calculation of gradient angle \( \gamma \) and angle \( \varphi' \) and coefficient of friction \( f' \) in threads in case of which \( f_m \) is coefficient of friction between the matrix and the support plate:

\[
f' = f_m \cos \frac{\varphi'}{2} = 0.1 \cos^{30°} = 0.115
\]

\[
tg \gamma = \frac{p}{\pi \cdot d_2} = \frac{2.5 \text{ mm}}{\pi \cdot 18,376 \text{ mm}} = 2^°35.9' \rightarrow 2.598^\circ
\]

\[
f' = tg \gamma' \cdot \varphi' = \arctg f' = \arctg 0.115 = 6^°33' \rightarrow 6.55^\circ
\]

Calculation of torque on the basis of the moment to eliminate the friction in threads \( M_{t_f} \) and the moment to eliminate the friction between the support plate and the matrix \( M_{t_m} \):

\[
M_{t_f} = \frac{F \cdot \gamma \cdot \varphi'}{2} = \frac{5000N \cdot 2.598°}{2} = 7398 \text{ Nm}
\]

\[
M_{t_m} = \frac{F_m \cdot \pi}{2} = \frac{5000N \cdot 0.1}{2} = 7146 \text{ Nm}
\]

\[
M_{t_u} = M_{t_f} + M_{t_m} = 7398 \text{ Nm} + 7146 \text{ Nm} = 14544 \text{ Nm}
\]

\[
M_{t_u} = 14.544 \text{ Nm}
\]

4 DETERMINATION OF DEVIATIONS OF THE PROBLEM
RESULTS AMONG SELECTED SOFTWARE TYPES

The following tables (see Tables 1-5) contain the results of the selected calculated types of problems. In the final presentation the results are rounded to two decimal numbers which is sufficient for reaching the basic accuracy.

\[\text{MC - Manual calculations, } \quad \text{MC - MITCalc,} \quad \text{TT - TDS Technik,} \quad \text{MS - MechSoft,} \quad \text{DA - Design accelerator.}\]

| M | MC | TT | MS | DA |
|---|----|----|----|----|
| Mu [Nm] | 14.54 | 15.54 | 17.7 | 16.36 | 14.85 |

Table 1. Results of calculations of tightening torque of a screwed connection

| M | MC | TT | MS | DA |
|---|----|----|----|----|
| Normal stress [MPa] | 19.05 | 19.05 | 23.18 | 24.5 | 25.4 |
| Reference stress [MPa] | 19.05 | 19.05 | 23.18 | 24.5 | 25.4 |

Table 2. Results of calculation of shear stress in a welded connection

\[
\begin{align*}
\text{Pressure} & \quad \text{[MPa]} \\
\text{Min. length of a spline [mm]} & \quad \text{[mm]}
\end{align*}
\]

\[
\begin{array}{cccccc}
\text{M} & \text{MC} & \text{TT} & \text{MS} & \text{DA} \\
\text{Pressure} & 28.71 & 35.5 & 28.71 & 28.71 & 31.9 \\
\text{Min. length} & 11.84 & 14.7 & 11.84 & 11.84 & 13.158
\end{array}
\]

Table 3. Results related to calculations of pressure in involute spline of the shaft and of minimal functional length of a spline

In consequence of absence of the coefficients in the calculation, negligence of cross-section and material properties of the support in the calculation of shear forces and of bending moment of the support the deviation of differences among the individual calculations is zero [Salokyova 2016b].

\[
\begin{align*}
\text{Ay [N]} & \quad 850 & 850 & 850 & 850 & 850 \\
\text{By [N]} & \quad 850 & 850 & 850 & 850 & 850 \\
\text{Mo(x)} [\text{Nm}] & \quad 212.5 & 212.5 & 212.5 & 212.5 & 212.5 \\
\text{Mo(x)} [\text{Nm}] & \quad 212.5 & 212.5 & 212.5 & 212.5 & 212.5
\end{align*}
\]

Table 4. Results of calculations of shear forces and bending moment of the support

\[
\begin{array}{cccccc}
\text{MC} & \text{TT} & \text{MS} & \text{DA} \\
\text{Program working on own platform} & \text{No} & \text{Yes} & \text{Yes} & \text{No} \\
\text{2D/3D output} & \text{Yes} & \text{Yes} & \text{Yes} & \text{Yes} \\
\text{Possibility to generate the results} & \text{No – only in the form of printing by the Excel program} & \text{Yes} & \text{Yes} & \text{Yes} \\
\text{Possibility to create connections among parts} & \text{No} & \text{Yes} & \text{Yes} & \text{Yes} \\
\text{Possibility to create bills of materials} & \text{Yes} & \text{Yes} & \text{Yes} & \text{Yes} \\
\text{Connection with company database} & \text{No} & \text{Yes} & \text{Yes} & \text{No} \\
\text{Extensiveness of calculations} & \text{High} & \text{Low} & \text{High} & \text{High} \\
\text{Variability of calculations} & \text{High} & \text{Low} & \text{High} & \text{High} \\
\text{System requirements} & \text{Low} & \text{Low} & \text{Low} & \text{High} \\
\end{array}
\]

Table 5. Comparison of the individual types of the selected software types

5 CONCLUSIONS

The introduction of the presented paper contains basic categorization and types of the splitters. Selected were the parameters for the design of device which complies with the requirements for processing of the wooden substance. The core of the paper introduces the design of the individual parts. The design of the cutting mechanism was performed structurally [Mascenik 2014b]. Other parts such as basic frame and hydraulic mechanism, conical gearing and the clutch were designed as well. All of these parts were modelled and calculated by means of programs. The final part defines relation
between the length of cutting substance and revolutions of the feeding roller.

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