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SOFTWARE TOOL FOR DETERMINING OF METAL MILLING PARAMETERS

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Abstract: *This paper presents an original software tool for the calculation of cutting parameters in metal milling, named* ***Det****ermining* ***Mil****ling* ***P****arameters (DetMilP). Developed in the RAD Studio programming environment, this software tool calculates cutting parameters and provides the user predictions about the process. Additionally, it allows the creation and management of a database for cutting tools, the search and insertion of tool parameters from various suppliers through an adapted search engine. The software also has the facility to launch ChatGPT to provide the users a quick technical support. The results of the calculations can be exported as a report or text file. The text file can be imported into the CAM module of the Creo software, facilitating the direct use of calculated parameters in CNC programs.*

Keywords: *Software tool, RAD Studio, Milling process, Milling parameters, Specific cutting force, Cutting force, CNC program.*

1. INTRODUCTION

Nowadays, the cutting processes are the most used in industry due to the performance offered to parts made from different materials, but also due to the diversity and complexity of surfaces obtained. In this context, the constant concern to improve performance and reduce manufacturing costs is a priority for industry, researchers and experts.

Among the cutting processes, the milling process stands out for its complexity, providing high precision and the possibility of manufacturing almost all types of surfaces [1]. The performance of this process is influenced by several factors, including cutting parameters. The correct selection and calculation of the cutting parameters is an important step, as they have an influence on cutting forces, tool wear and the quality of the manufactured surface [1-4].

The milling process therefore requires careful selection and calculation of the cutting parameters, to ensure an optimal process and a balance between productivity, costs and the quality of the parts obtained. Considering that the manual determination of cutting parameters is a laborious and error-prone process, the integration of software tools that perform the calculation of these parameters, adapted for CAM modules of specialized software, can optimize the manufacturing processes, significantly reduce time, costs and possible human errors [5, 6].

Based on what has been mentioned previously, it highlights the need for the development of an accessible software tool, able to calculate cutting parameters automatically, to provide users predictions about the manufacturing process and the possibility to integrate the results into CAM modules of specialized software.

2. PRESENTATION OF THE NEW SOFTWARE TOOL

The software tool named **Det**ermining **Mil**ling **P**arameters (DetMilP), presented in this paper, allows to the user to perform calculations of the milling cutting parameters and provides predictions about the process, the possibility to create and manage tools database, search and insert tool parameters through an adapted search engine, integration of ChatGPT™ for quick technical support and to export the results as a report or text file, which can be used by importing it into the Computer Aided Manufacturing (CAM) module of the Creo™ software, both to avoid errors and for quick integration of the calculated cutting parameters into the CNC programs. DetMilP has been developing in the RAD Studio programming environment, using Object Pascal programming language and has a friendly and intuitive graphical user interface. RAD Studio is an proper environment for developing engineering applications, due to the fact that they can be developed quickly (through visual drag-and-drop design), various databases can be easily integrated, applications can be developed for different platforms (Windows, macOS, iOS, Android and Linux) and the possibility to interact with various acquisition boards, microcontrollers etc. [9].

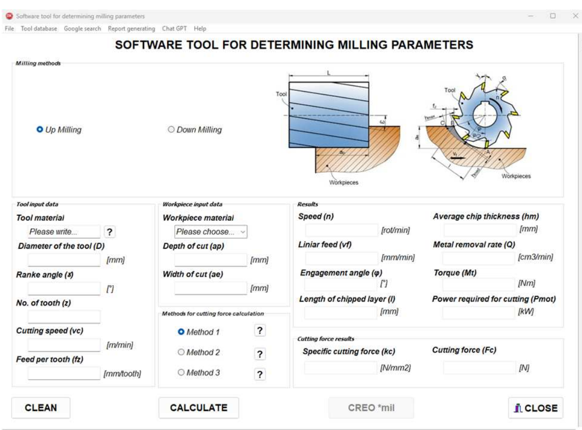


Fig. 1. Main interface of the DetMilP software tool.

2.1 Description of the DetMilP software tool interface

The interface, shown in Figure 1, is divided into seven sections:

1. Menu Bar - from this section the user has access to the following main options:

- **File** - allows file management and includes the following options:
  - *Open* - open an existing file containing previously saved data;
  - *Save* - saves the changes made in the program directly to the current file;
  - *Save as* - allows the saving of data in a new file, giving the possibility to specify the location and file name;
  - *Exit* - allow to close the application.
- **Tool database** - this option provides the user the possibility to manage a database of the tools used for milling (Fig. 2) and includes the following options:
  - *Insert* - through this command, the parameters of a selected tool from the database will be transferred to the main interface, Tool input data section;
  - *Add Tools* - allows new tools to be added to the database;
  - *Edit Tools* - using this command, it is possible to edit an existing tool through its parameters from the database;
  - *Delete Tools* - allows deleting of a tool from the database.

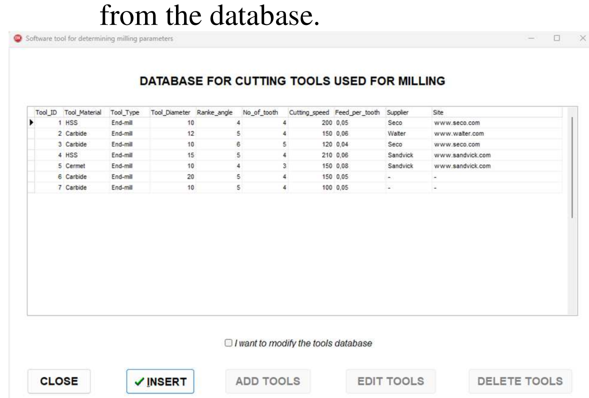


Fig. 2. Tools database of the DetMilP software tool.

- **Google search** - this option allows the user to search directly on the internet using different keywords. By selecting this option, an integrated and adapted search engine will be launched from the software tool and the user can search on the tool suppliers websites and the parameters identified are filled in and transferred manually to the main interface, *Tool input data* section. The specific graphical representation of the window is presented in Figure 3.

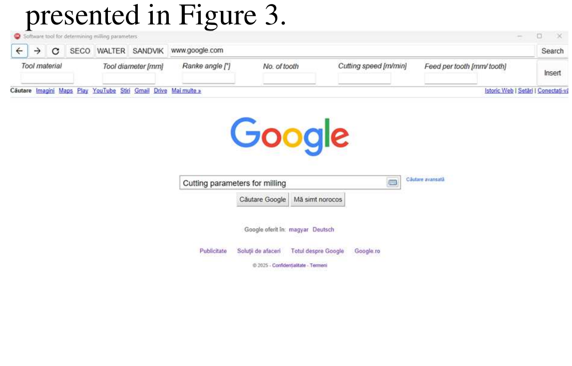


Fig. 3. Google search window of the DetMilP software tool.

- **Report generating** - the user has the possibility to generate reports in PDF format using the Fast Report module integrated in the DetMilP (Fig. 4), which contains all the input data, and the results obtained. This option can be used only after the results are displayed on the main window of the software tool.

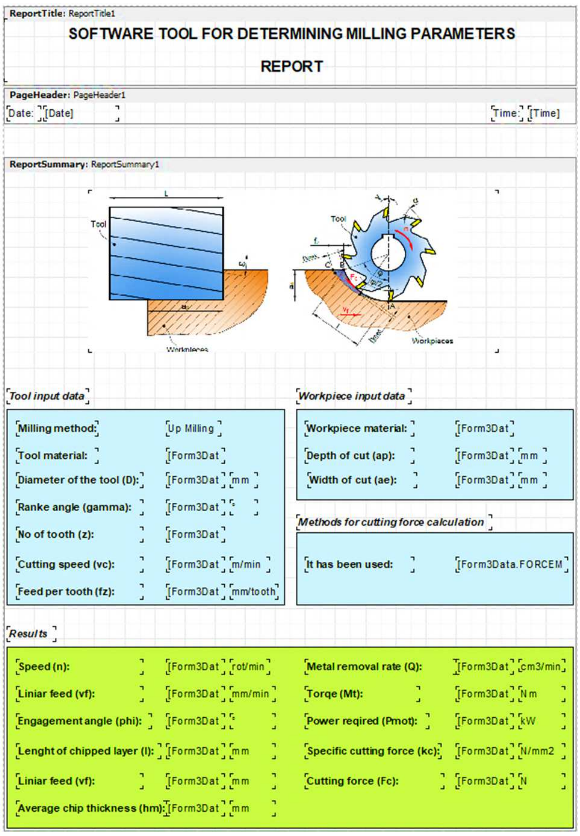


Fig. 4. Report generating the interface of the DetMilP software tool.

- **Chat GPT** - if the user needs quick technical support offered by an AI application, this option can be launched, which will present an external browser for using ChatGPT™.
- **Help** - includes a contact option for technical support when there are problems with functionality.

2. Milling methods - according to Fig. 1, the user must choose one of the two milling methods (*Up Milling* or *Down Milling*) depending on the real situation of the practical application.

3. Tool input data - in this section the user must input the following cutting tool data: *Tool material, Diameter of the tool, Rake angle, Number of teeth, Cutting speed* and *Feed per tooth.*

4. Workpiece input data - this section allows to the user to choose the manufactured material from a drop-down list and insert the depth and width of cut.

5. Methods for cutting force calculation - the user has the possibility to choose one of the three available methods for determining the cutting forces. These methods are based on empirical formulas for the determination of the cutting forces.

6. Results - in this section the results of the calculations are displayed.

7. Control area - includes the following commands:

- **Calculate** - when this button is pressed, the software tool automatically checks if all input data are correctly inputted, otherwise the user will be warned. If the data has been correctly inputted, the results will be displayed and the *Creo * mil* and *Report generating* button will be activated.
- **Creo * mil** - this button is activated only when the results are displayed. Pressing it will automatically generate a text file (* .mil) which contains the results of the cutting parameter calculations. This file can be imported into the CAM module of the Creo™ software system to provide quick integration of the calculated parameters into the CNC programs.
- **Clean** - when this button is pressed, it deletes both the inputted and calculated data.
- **Close** - allows to close the application.

2.2 Block diagram of the DetMilP software tool

In order to understand how the DetMilP software tool works, a block diagram is shown in Fig. 5. When the executable file (DetMilP.EXE) is run, the interface of the DetMilP software tool, shown in Fig. 1, will be displayed. In the first step, one of the two milling methods, previously presented, is chosen depending on the application. Next, the user has to enter the specific tool data. If these are known, they can be entered manually. If the input data is not known, the user can choose to use the cutting tool parameters from the software database.

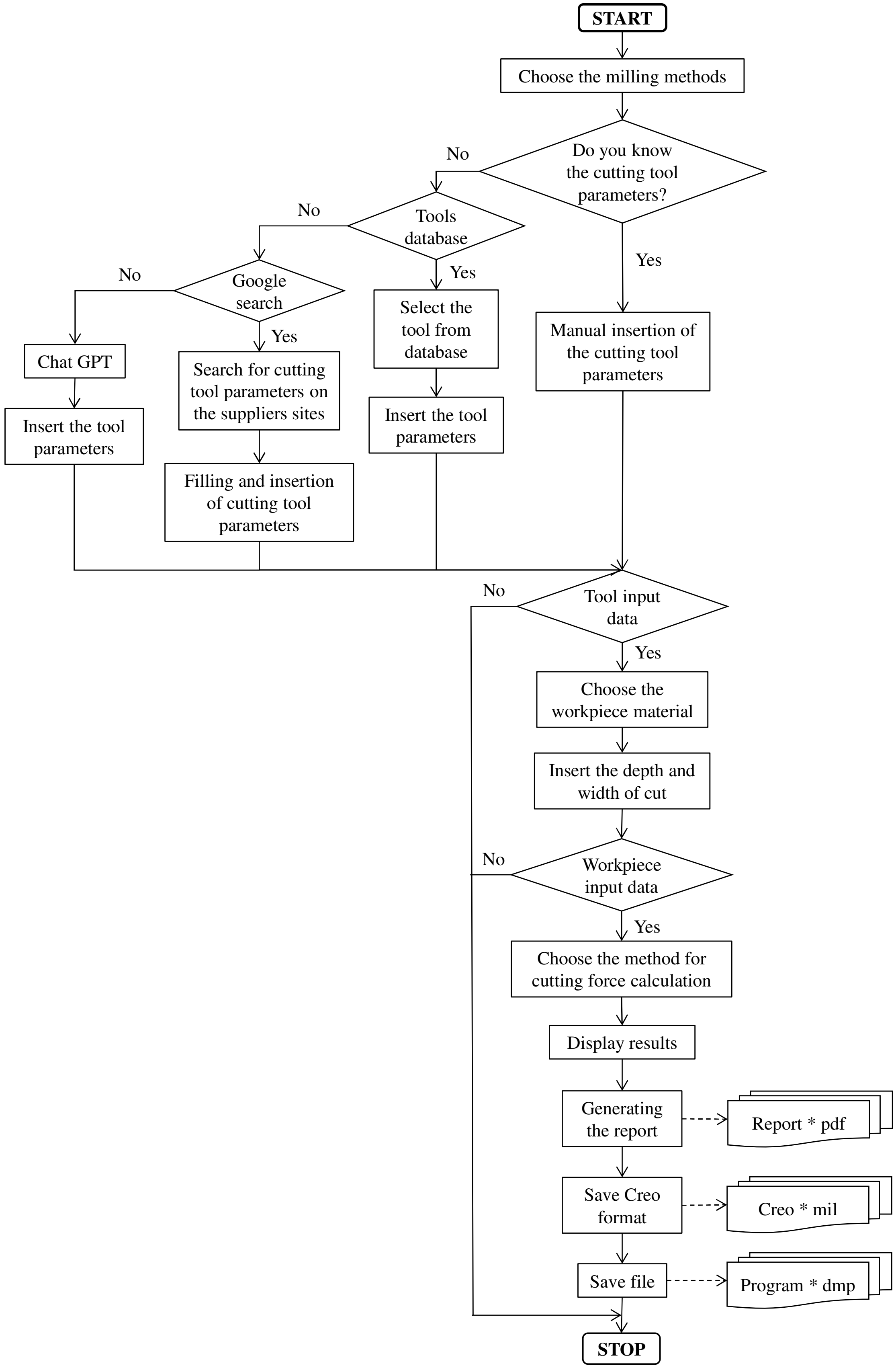
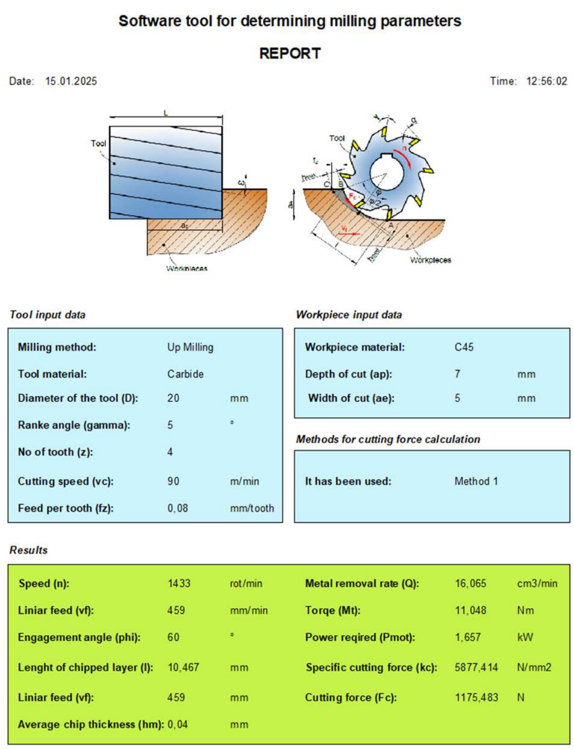


Fig. 5. Block diagram of the DetMilP software tool.

If the user does not want to use a tool from the database, could be used the *Google search* engine. This option allows the user to browse through the suppliers tool websites to identify the parameters, which will be filled in specific fields and manually inserted using the Insert button in the main interface. If this method is not wanted, the user can use the *Chat GPT* option, which provides quick technical support. Pressing the button will open a *ChatGPT™* web page in the user's browser.

After filling in the input data of the tool, the next step is to input the specific data to the workpiece material. It will choose the type of material and insert the width and depth of cutting. Next, it will choose one of three methods for calculation of the cutting forces. As presented above, these methods are based on three empirical formulas for determining the cutting forces.



Software tool for determining milling parameters

REPORT

Date: 15.01.2025 Time: 12:56:02

Tool input data

Milling method:	Up Milling	
Tool material:	Carbide	
Diameter of the tool (D):	20	mm
Ranke angle (gamma):	5	°
No of tooth (z):	4	
Cutting speed (vc):	90	m/min
Feed per tooth (fz):	0,08	mm/tooth

Workpiece input data

Workpiece material:	C45	
Depth of cut (ap):	7	mm
Width of cut (ae):	5	mm

Methods for cutting force calculation

It has been used:	Method 1

Results

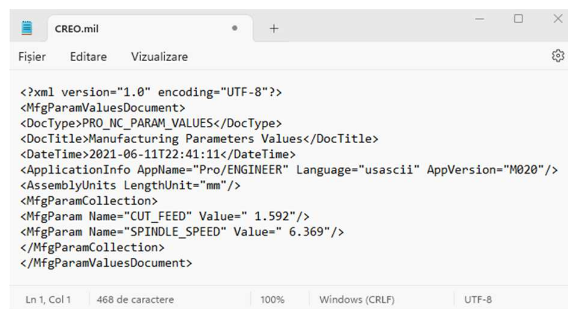
Speed (n):	1433	rot/min	**Metal removal rate (Q):**	16,065	cm3/min
Liniar feed (vf):	459	mm/min	**Torqe (Mt):**	11,048	Nm
Engagement angle (phi):	60	°	**Power reqired (Pmot):**	1,657	kW
Lenght of chipped layer (l):	10,467	mm	**Specific cutting force (kc):**	5877,414	N/mm2
Liniar feed (vf):	459	mm	**Cutting force (Fc):**	1175,483	N
Average chip thickness (hm):	0,04	mm			

Fig. 6. Report generated in the DetMilP software tool.

When the *Calculate* button is pressed, the software checks automatically whether the input data entered by the user is correct. If input data has been entered incorrectly, the user will be warned with an error message which contains clear instructions on how to solve the problem. If data has been entered correctly, the results will be displayed. A very important point to note is that the user cannot change the results manually.

When the results are displayed, the *Report generating* and *Creo * mil* buttons are activated. *Report generating* can be used to create reports which contain all the input data inserted by the user as well as the results obtained from the calculations (Fig. 6) and *Creo * mil*, generates a text file containing the calculated cutting parameters (Fig. 7) which can be imported into the CAM module of Creo™.

If it is desired to save the data to a file again, the command *Save As* from *File* should be used. Or if the user has already saved the file and made later changes and wants to save the current status, he can use the *Save* command. With *Open* from the *File* menu, it is possible to open an existing saved file.



CREO.mil

Fișier Editare Vizualizare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Ln 1, Col 1 | 468 de caractere | 100% | Windows (CRLF) | UTF-8

Fig. 7. Creo *mil generated in the DetMilP software tool.

2.3 Methods

In the DetMilP software tool, mathematical relations taken from the literature, have been used to calculate the parameters of the cutting parameters for milling. Therefore, in this subchapter, the formulas and theoretical principles implemented in the algorithm are presented in Table 1.

Each formula was implemented within the DetMilP software tool. The necessary parameters are inputted by the user through the graphical interface, and the calculations are automatically performed by the DetMilP software tool.

For determining the cutting forces in milling process, three different formulas were used, because each of them treats different aspects regarding the tool, the workpiece material and the cutting process itself.

Table 1

Used formulas in the software tool [1, 7, 8]**.**

Parameters	Formula
Speed (n)	$n = \frac{1000 \cdot vc}{\pi \cdot D}$ [rot/min] where: vc – cutting speed [m/min]; D – diameter of the tool [mm].
Liniar feed (vf)	$vf = fz \cdot z \cdot n$ [mm/min] where: fz – feed per tooth [mm/tooth]; z – number of tooth; n – speed [rot/min].
Engagement angle (φ)	$\varphi = 90° + \arcsin\frac{ae-(D/2)}{(D/2)}$ [°] where: ae – width of cut [mm]; D – diameter of the tool [mm].
Lenght of chipped layer (l)	$l = \frac{\pi \cdot D \cdot \varphi}{360°}$ [mm] where: φ – engagement angle [°]; D – diameter of the tool [mm].
Average chip thickness (hm)	$hm = fz \cdot \sqrt{\frac{ae}{D}}$ [mm] where: fz – feed per tooth [mm/tooth]; ae – width of cut [mm]; D – diameter of the tool [mm].
Metal removal rate (Q)	$Q = \frac{ae \cdot ap \cdot vf}{1000}$ [cm^3/min] where: ae – width of cut [mm]; ap – depth of cut [mm]; vf – liniar speed [mm/min].
Specific cutting force (kc) – Method 1	$kc = \frac{kc_{1.1}}{hm^{mc}} \cdot K_\gamma \cdot K_{vc} \cdot K_{sp} \cdot K_{ver}$ [N/mm^2] where: $kc_{1.1}$ – specific cutting force for 1 mm^2 chip cross section [N/mm^2]; hm – average chip thickness [mm]; mc – material constant; K_γ – correction factor for the rake angle; K_{vc} – correction factor for the cutting speed; K_{sp} – correction factor for the tool wear; K_{ver} – correction factor for the chip compression.
Correction factor for the rake angle (K_γ)	$K_\gamma = 1 - \frac{\gamma - \gamma_0}{100}$ where: γ – Rake angle [°]; γ_0 – Base rake angle [°].
Specific cutting force (kc) – Method 2	$kc = \frac{1-0,01 \cdot \gamma_0}{hm^{mc}} \cdot kc_{1.1}$ [N/mm^2] where: γ_0 – orthogonal tool rake [°]; $kc_{1.1}$ – specific cutting force for 1 mm^2 chip cross section [N/mm^2]; hm – average chip thickness [mm]; mc – material constant.
Specific cutting force (kc) – Method 3	$kc = \frac{kc_{1.1}}{hm^{mc}}$ [N/mm^2] where: $kc_{1.1}$ – specific cutting force for 1 mm^2 chip cross section [N/mm^2]; hm – average chip thickness [mm]; mc – material constant.
Cutting force (Fc)	$Fc = (ae \cdot hm) \cdot kc$ [N] where: ae – width of cut [mm]; hm – average chip thickness [mm]; kc – specific cutting force [N/mm^2].
Power required for cutting (Pmot)	$Pmot = \frac{Q \cdot kc}{60000 \cdot \eta}$ [kW] where: Q – metal removal rate [cm^3/min]; kc – specific cutting force [N/mm^2]; η – machine efficiency [0,7…0,95].
Torque (Mt)	$Mt = \frac{Pmot \cdot 30000}{\pi \cdot n}$ [Nm] where: Pmot – power required for cutting [kW]; n – speed [rot/min].

3. CASE STUDY

In order to validate the accuracy and utility of the DMP software tool, further on, a comparison will be made between the results obtained through the application and those calculated manually, using the same input data. The following input data were established:

- Milling method: Up Milling;
- Tool material: Carbide;
- Diameter of the tool (D): $\phi 20$ [mm];
- Number of tooth (z): 4;
- Cutting speed (vc): 90 [m/min];
- Feed per tooth (fz): 0.08 [mm/tooth];
- Workpiece material: C45;
- Depth of cut (ap): 7 [mm];

- Width of cut (ae): 5 [mm].

Additional parameters:

- Specific cutting force for 1 mm^2 chip cross section ($kc_{1.1}$): 1680 [N/mm2];
- Material constant (mc): 0.26;
- Correction factor for the rake angle (K_γ): 1.01;
- Correction factor for the cutting speed (K_{vc}): 1;
- Correction factor for the tool wear (K_{sp}): 1.2;
- Correction factor for the chip compression (K_{ver}): 1.25.

By using the formulas from Table 1, the results of the calculation are presented in Table 2 (column 2).

Also, the calculations were performed using the software tool and the methods considered to determine the cutting force. The results are presented in Fig. 8, Fig. 9 and Fig. 10 and in Table 2 (column 3).

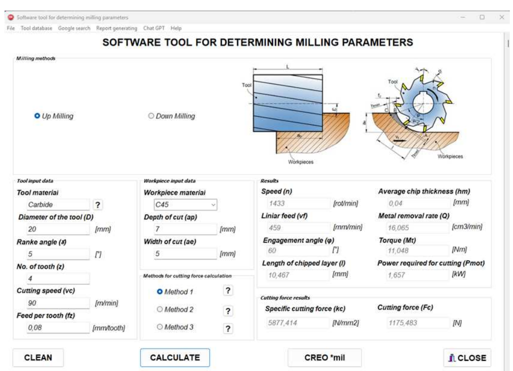

Fig. 8. Method 1 for calculating the cutting forces.

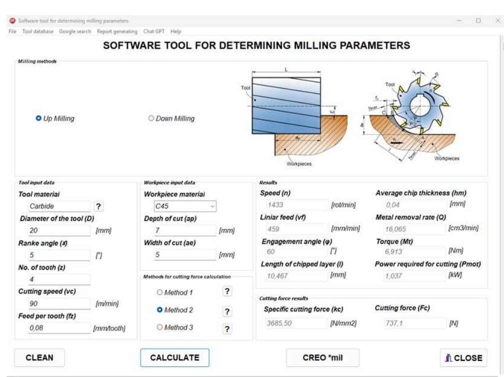

Fig. 9. Method 2 for calculating the cutting forces.

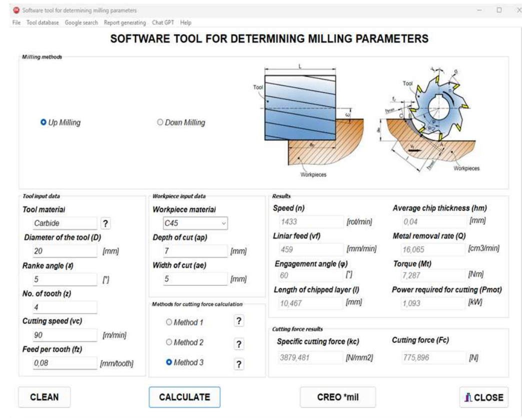

Fig. 10. Method 3 for calculating the cutting forces.

To compare the results calculated manually and the results calculated using the DetMilP, these have been centralized in Table 2.

Table 2

Comparing the results for software tool validating.

Parameters	Manual calculation	DetMilP calculation	Difference
n [rot/min]	1432.39	1433	0.04%
vf [m/min]	458.36	459	0.14%
φ [°]	60	60	0%
l [mm]	10.47	10.467	0%
hm [mm]	0.04	0.04	0%
Q [cm^3/min]	16.042	16.065	0.14%
kc1 [N/mm^2]	5877.41	5877.414	0%
kc2 [N/mm^2]	3685.50	3685.50	0%
kc3 [N/mm^2]	3879.48	3879.481	0%
Fc1 [N]	1175.48	1175.483	0%
Fc2 [N]	737.1	737.1	0%
Fc3 [N]	775.89	775.896	0%
Pmot1	1.65	1.657	0%
Pmot2	1.037	1.037	0%
Pmot3	1.091	1.093	0.18%
Mt1	11.02	11.048	0.18%
Mt2	6.913	6.913	0%
Mt3	7.273	7.287	0.19%

Analyzing the data from Table 2, it can be concluded that the results obtained with the DetMilP application are almost identically with those manually calculated, which practically validate the algorithms implemented in the software tool.

4. CONCLUSIONS AND FUTURE RESERCH

Based on what is previously presented, it can be said that DetMilP software tool like a stand-alone application is very useful, accessible and quite easy to use. This study has highlighted the main functionalities and benefits of the new software tool, as well as the validity of the results obtained. The application reduces significantly the time needed for the calculation of the cutting parameters and provides predictions about the process. Based on the cutting force values, the user can adjust the parameters for good efficiency. It also allows the user to create and manage a database, which contains the cutting tool parameters making it easy to reuse and organize the data for future calculations and projects.

To improve and extend the functionalities of the application, future research will aim to integrate advanced calculation methods, based on artificial intelligence, which will allow users to optimize the cutting parameters and to develop an additional module for the simulation of the cutting process and tool wear estimation.

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Instrument software pentru determinarea parametrilor la frezarea metalelor

Această lucrare prezintă un instrument software original pentru calculul parametrilor de așchiere la frezarea metalelor, numit **Det**ermining **Mil**ling **P**arameters (DetMilP). Dezvoltat în mediul de programare RAD Studio, acest instrument software realizează calculul parametrilor de așchiere și oferă predicții cu privire la desfășurarea procesului. Acesta mai permite crearea și gestionarea unei baze de date pentru sculele așchietoare, căutarea și inserarea parametrilor sculelor de la diverși furnizori, printr-un motor de căutare adaptat. Software-ul are integrată facilitatea de lansare a ChatGPT™ pentru a oferi utilizatorilor suport tehnic rapid. Rezultatele calculelor pot fi exportate sub formă de raport sau fișier text. Fișierul text poate fi importat în modulul CAM al sistemului software Creo™, facilitând utilizarea directă a parametrilor calculați in programele CNC.

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