AUTOMATIC DETERMINATION OF GRINDING TOOL PROFILE FOR HELICAL SURFACES MACHINING USING CATIA/VB INTERFACE

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În conformitate cu cerințele specifice din industria auto şi adoptării principiilor de modelare CAD folosind macro-uri, se poate dezvolta un model parametric de suprafață evolventică elicoidală. Acest model conține cunoştințele şi experiența designerilor prin definirea dependențelor relaționale, a regulilor, controalelor, legilor matematice şi a altor caracteristici funcționale esențiale. În interacțiune cu un sistem PLM, aceste macro-uri permit utilizatorului stabilirea şi gestionarea parametrilor, observarea executării tuturor comenzilor în funcție de valorile inițiale şi generarea automată a profilului sculei, având ca scop determinarea parametrilor pentru rectificarea suprafețelor elicoidale.

According to the specific requirements in automotive industry and adopted principles of CAD modeling using macros, a parametric model of involute helical surface that corresponds to skeletal cylindrical helix is developed. This model represents knowledge and experience of designers through definition of relational dependences, rules, checks, mathematical laws and other functional features which represent essential knowledge. In interaction with PLM system, macros enable user to set and manage parameters, observe execution of all commands according to initial values and automatic tool profile generation aimed at determination of parameters for helical surface grinding.

Keywords: skeletal helix, helical surface, grinding tool, macros.

1. Introduction

Increasing requirements for higher flexibility of product and manufacturing process development impose demands for systems and technologies that have a high degree of automation of all activities during process development. Thus, application of various software tools and technologies for the automation of design, analysis, testing and products manufacturing occupy a key

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position. These software tools and technology are described with the abbreviation PLM and regard to the Product Life Cycle Management.

1.1. Product value

The product development in the shortest possible time means reduction and optimization of all phases of product development, especially the early phases of conceptual design (Fig. 1).

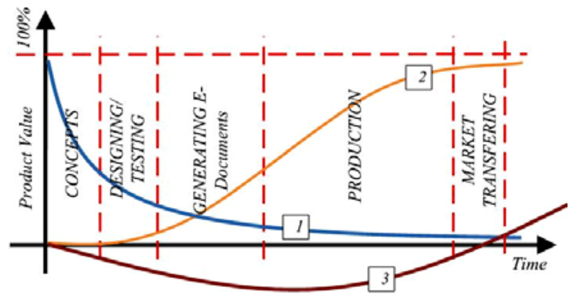


Fig. 1. Influence of product development phase on product value

Conceptual stage of product development starts before the design stage. Within this stage, forming, testing and analysis of alternative solutions are accomplished. Series of iterations select the best solution for the detailed design and technological development. The opportunities for impact to the cost of the product (curve 1) are just in the first stages of development. Application of PLM system becomes very significant, since the automation of relevant procedures and processes in early stages enables to greatly reduce time and unnecessary costs. Value of the product (curve 2) is low in the initial phases, and reaches its maximum with transferring products on the market. Investment costs (curve 3) are dominant in the stage of the product production. These costs may affect the development and implementation of modern production systems and technologies.

2. Knowledgeware technologies

Software tools that enable the implementation of knowledge supported technologies of design, engineering and production (CAD, CAE, and CAM systems, respectively) are usually integrated into the PLM system, or they are part of the standard tools for application development (for example, C++, Visual Basic, Visual Basic for Applications, Java etc.).

Each product embeds some knowledge, experiences of experts involved in product development, or belonging to the factory that develops and implements the product. Set of software components that contains expert knowledge, adjoined to model of the product is known under the name of "knowledgeware" and is one

of the key technologies of modern PLM systems. The main constitutional element of portable expert systems is knowledge feature (Fig. 2).
Mathematical term for knowledge features is relation. Hence, it may have the form of formulae, (sets, databases) rules, control structures (check, verification, behavior), and tables [5].

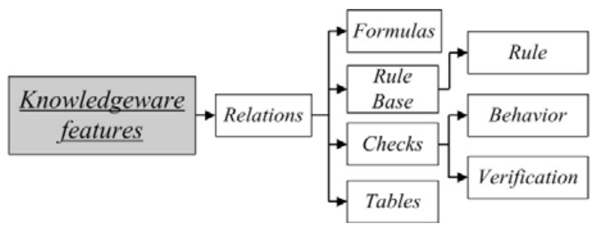
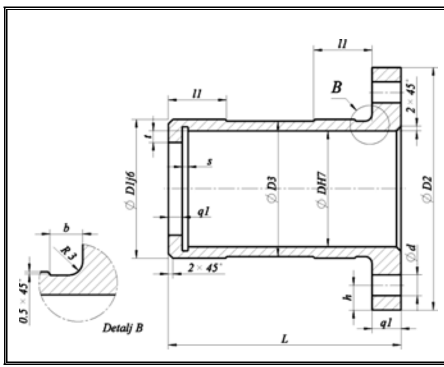


Fig. 2. Structure of knowledgeware features

2.1. Types of parameters

The basis for the implementation and development of knowledge-based technology is a parametric description of the computer representations of real geometric object with dimensional, physical, functional, and other sets of parameters. Thus, the parameters can be defined as variables whose values completely describe the current model. There are two basic types of parameters (constraints): dimensional parameters and geometric parameters [5].

In general, the values of parameters can be set by the system, directly and indirectly. Each parameter has a value that belongs to a category: integer, real, sign, logical, physical, geometric etc. Keeping dimensional relationships between certain elements of the sketcher profile of 2D features, as well as between 3D features within the model, means to provide the explicit functional or relational dependences (Fig. 3).



D [mm]	62	65..75	80..100	110..145	150..220
D [mm]	9	9	11	11	11
Δ [mm]	4..5	6..8	8..10	10..12	
n	4			6	

$q_1 = 1.2\delta$; $q_2 = (1.3...1.5)\delta$; $h = (1...1.2)d$;

$D_1 = D + 2\delta$; $D_2 = D_1 + 4d$; $D_3 = D_1 - 0.6$ [mm];

l_1=20...30 [mm]; t=4...8 [mm]; b=5...8 [mm]

Fig. 3. Relational dependences of dimesional parameters

Relations define values of depending parameters based on independent variables and parameters. Application of known mathematical laws and functions, facilitates to a great extent description and creation, as well as management and modifications of the most geometric shapes or profiles of line segments, and the whole process becomes significantly easier. Traditional methods for designing involute profiles of gear elements (Fig. 4) are automated using involute equation projected on the horizontal and vertical direction.

`X`=`(db)`/2*(cos(`t`*PI*1rad)+sin(`t`*PI*1rad)*`t`*PI)

`Y`=`(db)`/2*(sin(`t`*PI*1rad)-cos(`t`*PI*1rad)*`t`*PI)

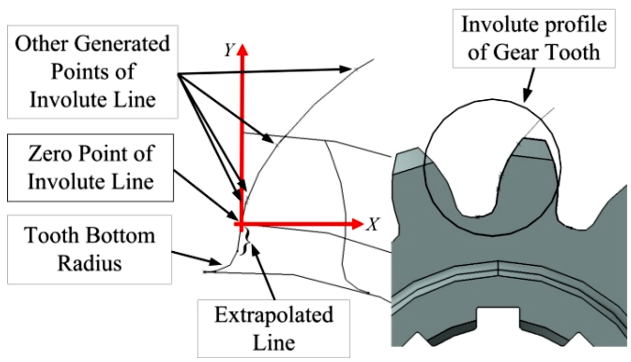


Fig. 4. Involute profile of gear tooth generated with functional law

3. Macros

To keep model consistency during the process development, but also during every later modification, it is necessary to apply control mechanisms [4]. Control mechanisms are formed by relational and functional dependence, as well as the procedures of checks and rules. During model creation some, procedures can be repeated.

To speed up the process of modeling and facilitate job, developer use macros. A macro is a group of commands or functions organized in one command [7]. Creating a macro is done automatically by running a command for recording all activities of modeling. Each intervention on model is recorded, and therefore it is very important to avoid unnecessary operations.

4. Complex surfaces modeling

Shaping and machining of complex surfaces is a great challenge for the designers, and engineers. There are many opinions about the classification of complex surfaces, parametric methods for their description, as well as approaches for their machining. There is no official standard, which considers this area.

Guidelines for the design of complex configurations of high quality products are accepted from the automotive industry.

Most of car manufacturers in the world use the CATIA PLM system as a basic system for digital product development. In any case, parametric description of complex surfaces is based on a parametric description of points and curves (2D or 3D) and operations over them (Fig. 5) [1].

Latest versions of this software have improvements for parameterization of complex surfaces and capability for modeling very complex geometrical surfaces based on the NURBS curves (e.g. inner panels etc.).

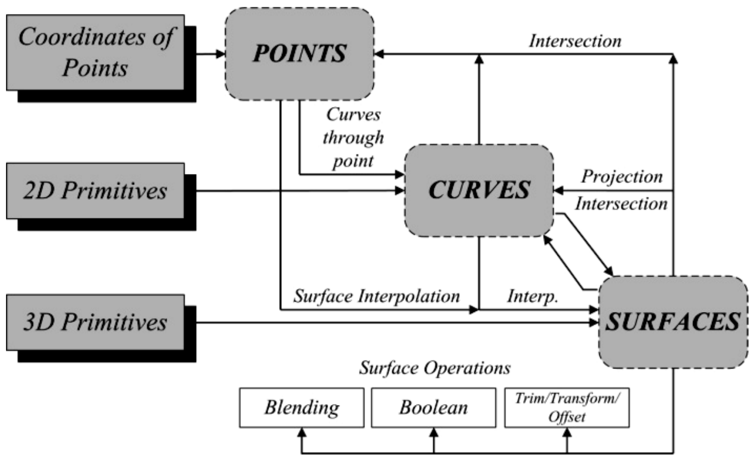


Fig. 5. Principles of complex surfaces modeling

5. Cylindrical helix and helical surfaces

Shape and dimensional characteristics of helical surfaces, regardless of application, are caused by geometric and dimensional description of screw profile and helix lines defined in a particular plane (usually normal on axis of helix line). Cylindrical helix is a regular curve α in the E^3, such that the angle θ between the tangency unit vector T and a fixed unit vector k, and $T \cdot k = \cos\theta = \text{constant}$. Cylindrical helix is a regular curve α with curvature $k>0$, if $\tau(s)/K(s)= \text{constant}$; (Fig. 6).

Helical surface is a 3D surface that describes a rolling line around the cylinder axis. In the context of the contemporary PLM systems and tools for optimization and analysis of surfaces, it is possible to determine the curvature and torsion line of cylindrical surfaces.

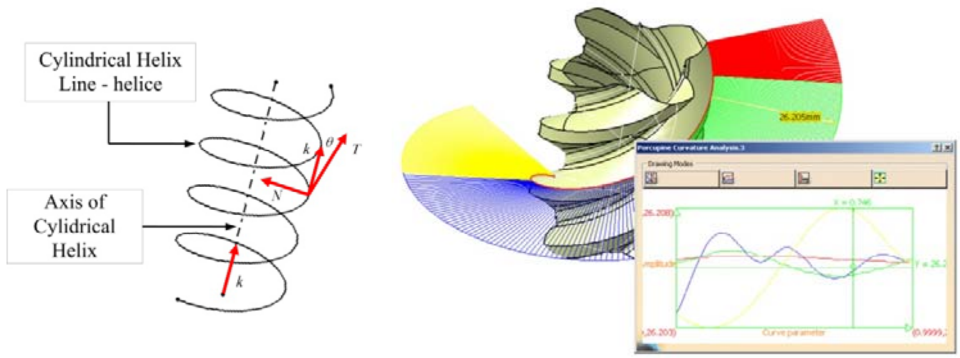


Fig. 6. Cylindrical helix and analysis of curvature and torsion of helical surface

Fundamental technical application of helical surfaces (Fig. 7) belongs to the standard machine elements, first of all, screw joints, elastic elements (helical springs) and gear boxes (worm pairs).

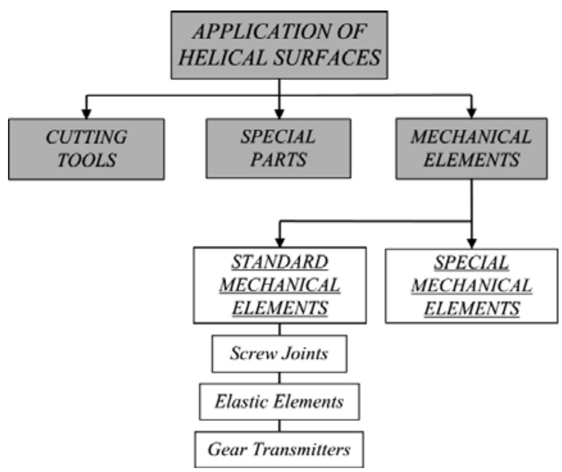


Fig. 7. Technical application of helical surface

6. Tools for helical surfaces machining

Precision manufacturing and design of helical surfaces depend on choice of regime, by development of cutting tools geometry, and technological equipment. Many problems that occur during the process of technological design are mainly related to the selection of tools, especially in defining the tool's profile. Tools for creating and/or machining of helical surfaces are specially designed for the required forms of helical surface profiles [6].

Tools designers determine the required tools profile based on the known profile of helical surface with sufficient precision. The obtained profile provides creation of tool for machining required theoretical form of helical surface. According to some authors [7], a number of methods which can determine with great precision the sections of tools designed for machining helical surface, are classified into: analytical, graphical and graph-analytical methods.

The actual profile of a helical surface differs from the theoretical profile, and it is a result of the imperfection of technological equipment and geometry of cutting tools, mentioned above. This problem becomes more complex since the tool of cutter profile does not match with the profile of helical surface.

In the case of definition of a disk tool profile, whose axis is perpendicular to the vertical line and nominal profile of helical surface given in the normal plane of the helix, it is possible to determine the profile of tools which is different from the section profile of helical surface (Fig. 8).

The position of all points of helical surface is determined by three coordinates x_{zi}, y_{zi} and z_{zi} of the system of axes x_z, y_z and z_z based on projection zero point on helix axis $O_z(0,0,0)$. If we fix one point with coordinates $A(-P,0,R)$ and set it through the normal plane of the generic helix, it will lie on the plane x_a - z_a of tool axis system (point O_a).

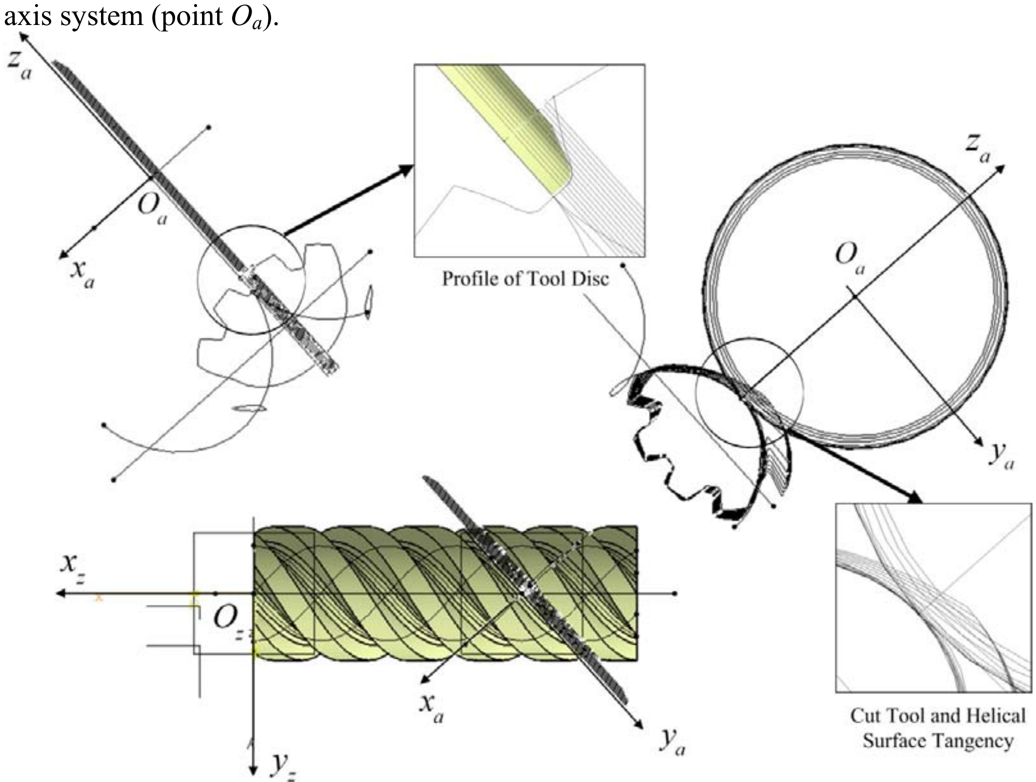


Fig. 8. Geometrical analysis of grind tool and helical surface tangency – generation of tool profile

Many line segments are created by forming a set of parallel planes, normal on tool axis x_a and cross-sections of the helical surface. For a specific case, the distance between the parallel planes is 0.2 [mm]. The next stage of graphical determination of a tool profile includes definition of conditions of tangency between concentric circles, and each line segment on all cross-sections respectively. Each of these circles intersects planes of tool x_a - z_a in series of discrete points. Their joining with special spline curves makes half tool profile. This avoids obtaining a profile by approximation that includes profile description using series of straight lines, which would affect the accuracy. The created profile of tool differs from the profile of helical surface, which is the goal of this analysis.

Very interesting are the graphical methods in the sense of modern CAD system, whose application is aimed to achieve the following effects: automatic generation of all types of planar and spatial line, increase the total robustness of the helical surface model and description of its features, embedding of experience and knowledge using technology for knowledge formalization, application of macros for an unlimited number of automatic repeat of all procedures of design, maximum universality. All these effects are regardless of the shape and plane in which the profile is defined, capability for generating different types of profile tools, integration with CAM systems etc.

6. CATIA and Visual basic interface

There are many approaches that can be used for saving design actions performed over the model during the modeling process [7]: Application of macros, Application of VBA macros („Visual Basic Application“), Application of Visual Basic and VB.NET programming tool, Integration of Visual Basic and CAA RADE (“Component - Application - Architecture - Rapid - Application - Development - Environment”).

The CATIA PLM system allows programming in Visual Basic Editor (integrated in the system), which expands possibilities for creation of effective application (Fig. 9). Creating macro requires the user to know basic principles of object oriented programming and Visual Basic programming language.

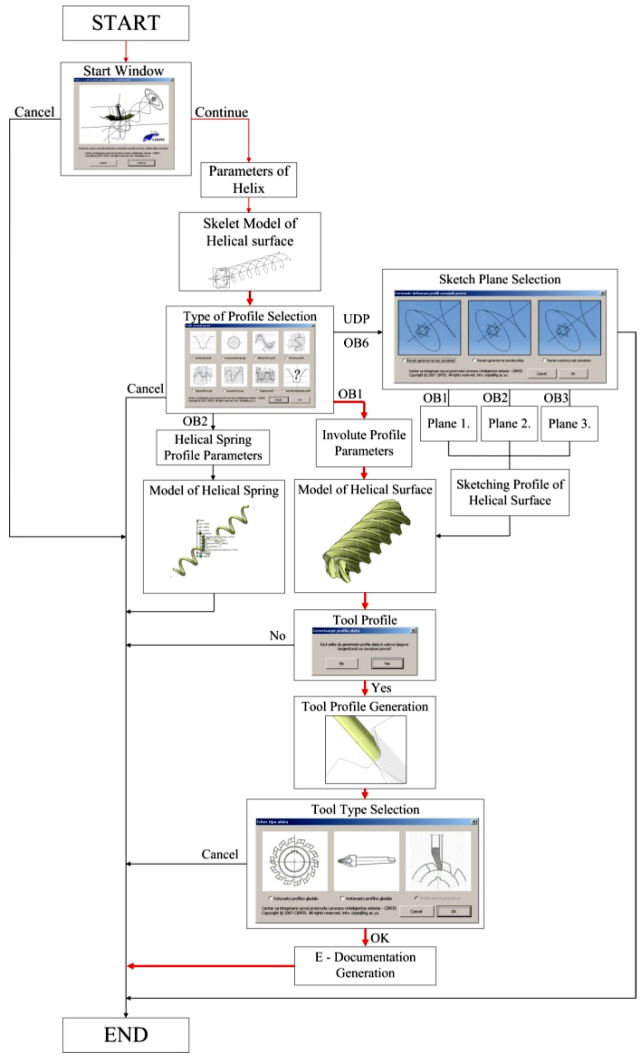


Fig. 9. Algorithm of .catvba macro

A macro is a set of ordered procedures and provides execution of code or part of whole procedure, defined by user actions (click, double click etc.). Therefore, it is important to note that the recorded code is used for description of command buttons, because it directly causes their execution [6]. During recording of process modeling, some actions and activities are not crucial for obtaining models. Also, very often, macro does not record important activities that are necessary and the code must be manually written. When recording a macro, it is not recommended to activate many modules, use another or cancel command, and set general options. Recording macros should be stopped only after completion of command or exit from any of the modules.

The execution of the created macro can be realized in PLM system CATIA by activating one command. Determination of grinding tool profile is finished after embedded calculations, according to the declared parameters (Fig. 10).

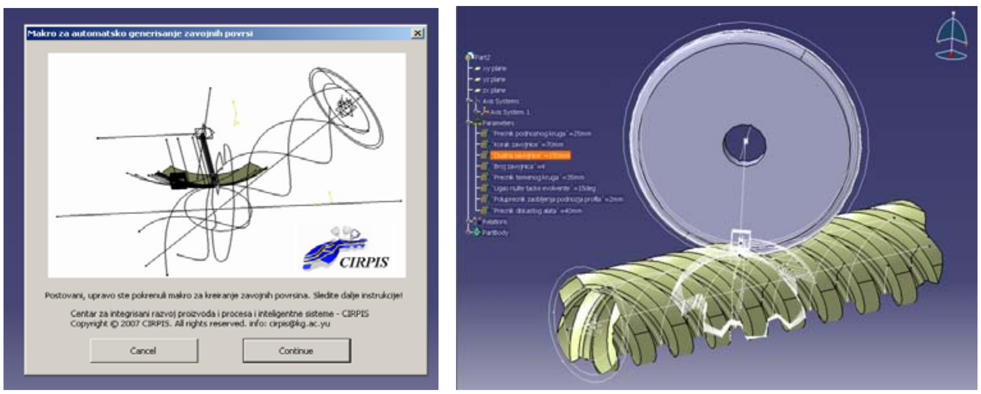


Fig. 10. Macro execution in PLM system CATIA

Knowing the characteristics of this approach, each macro recorded by any of these methods can be greatly optimized [3]. Each feature of knowledge created during macro recording has a specific code. For example:

```
Set relations1 = part1.Relations
Set rule1 = relations1.CreateProgram("Rule of the pattern", "/*Rule created by
SC 3/3/2009*/", "/*Rule created by SC 3/3/2009*/" & vbCrLf & "" & vbCrLf & ""
& vbCrLf & "if `Number of coils` == 1 " & vbCrLf & "" & vbCrLf & "{" & vbCrLf
& "PartBody\CircPattern.1\Activity = false" & vbCrLf & "}" & vbCrLf & "else" &
vbCrLf & "{" & vbCrLf & "PartBody\CircPattern.1\Activity  = true" & vbCrLf &
"}")
rule1.Rename "Rule of the pattern"
part1.Update
```

Traditional methods for generating profiles for helical surface machining ment many hours of work and these methods were inflexible. The designed macro optimizes time turning hours in seconds and generates profile automatically with a capability to choose different profiles (Fig. 11). Specified principles and modeling techniques allow creation of many alternative designs without excessive efforts with aim at focus on the functional aspects of design.

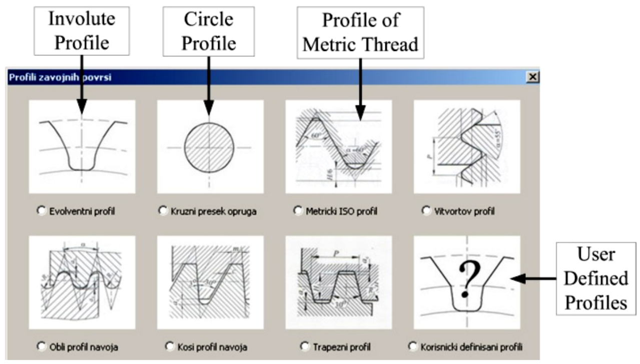


Fig. 11. Profiles of helical surfaces

This reduces the total time of product development and prevents numerous errors that occur within traditional design approaches.

7. Concluding remarks

From the aspect of conceptual engineering, information content is available to all services and teams of product development (design, assembly, throughout to finance and marketing). All activities carried out during the modeling of helical surface and generating profile of involute tool profiles were recorded by the series of macros. Using the Visual Basic programming language all macros are integrated into a single .Catvba file. Running macros by simply activating one command and work with user-defined forms make work very comfortable. The developed macro has a large number of advantages: direct application in industry for different profiles of helical surfaces, high level of flexibility and interactivity to users and applications, integration with other systems for product development, application in a variety of operating systems, possibility to use it for unlimited number of times, saving time and budget etc.

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