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# THE CAM-SYSTEM TECHNOLOGICAL CAPABILITIES OF THE CYLINDRIC WORM LATHE PROCESSING IN THE CNC LATHES

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# ТЕХНОЛОГІЧНІ МОЖЛИВОСТІ CAM-СИСТЕМ ПРИ ТОКАРНІЙ ОБРОБЦІ ЦИЛІНДРИЧНИХ ЧЕРВ'ЯКІВ НА ВЕРСТАТАХ З ЧПУ

**Purpose**. To reduce the time of development of the control programme for the multi-pass worm processing in the CNC lathes.

**Methodology.** The comparative analysis of the technological capabilities of the popular *CAM*-systems, and the special programme development and its experimental testing at one of the machine-building enterprise has been carried out.

**Findings.** We have raised the efficiency of programming of the control programme for the multi-pass coil cutting on the worm in the CNC lathe machines. A special macroprogramme for the cylindrical worm combined coil cutting scheme has been developed. The time required for development of the control programme for the multi-pass worm processing under the cutter in the CNC lathes has been reduced by seven times. The results are the most efficient for the worm combined coil cutting scheme. In the short-term outlook we plan: to develop the macroprogrammes for the double-enveloping worm processing in the CNC lathes; and to enhance the macroprogramme for the cylindrical worm processing.

**Originality**. We have determined and substantiated the ways of improvement of the computer-assisted design tools for the control programmes to turn the worm in the CNC lathe machines.

**Practical value.** We have simplified the requirements to the qualification level of the developer of the control programme so that CNC machine operator meets the requirements. The macroprogramme developed allows each CNC lathe machine operator to develop the combined multi-pass coil cutting along the cylindrical worm independently, without a programme engineer's participation. The offered approach has a significant value for the small and medium business enterprises along with the mining machine builders.

**Keywords:** *single-throated cylindrical worm gear, CAD/CAM-systems, CNC/CN lathe machines, control programme, macroprogramme*

**Challenge problem.** At the current speed of the present-day machine building development the industry flexibility and the ability to implement fast the new design and engineering solutions is obtaining a greater significance. Such requirements to the manufacturing technologies can be fulfilled by using CNC equipment that can simultaneously provide high capacities, industry flexibility and effective mastering as opposed to the general-purpose or the automated machines The mentioned strengths of the CN lathes are very significant at the preparations in manufacturing the polysurface parts, to which the screw surface of the worm belongs. At the same time the worm processing in the common screw-lathe is mostly popular at the mining machine-building enterprises.

The processing in CN lathers is more preferable for increasing the manufacturing capacities However, to achieve this goal both fast and efficient control program development should be provided.

The advanced CAM-systems obtained have the restricted capabilities in the development of the control programmes for the screw surface processing. The *ESPRIT CAM*-system is the only exception from the kind.

**Analysis of latest achievements and publications.** The works [1–2] deal with a programme package allowing to develop the control programme for cutting the cylindrical worms in terms of the minimum given data.

**Earlier unsolved items of the general problem.** However, in terms of this programme package or the advanced CAM-system use the independent (individual) programme should be developed and, certainly, a programmer for developing such a programme is required. Searching the variant for the alternative control programme development and implementation is a burning task for the

high-variety production of the single-throated worm gear mechanisms.

The **objective** of this work is a selection and implementation of the progress approaches in developing the control programmes for the multi-pass processing the worms in the CN lathes.

**Basic research material and complete result proof presentation.** Fig. 1 shows the typical cylindrical worm draft and the technical requirements to its production.

The accuracy norms for the single-throated cylindrical worm gear and worm couples (not in case) being followed accordingly to the GOST 1903694 are prescribed by the National Standard GOST 367581.

Studying of the technological peculiarities of the worm screw surface processing in CN lathers showed us the upper edge restrictions for the cutting speed under these terms. The restrictions exist due to the lathe capacities and the screw line step since the cutting input is equal to the screw line step. The formation of any screw surface in the CN lathe (fig. 2) is based on the use of the special programme functions that allow for the equipment parameters.

The simplest function is the screw cutting with the regular step. CN-system of the *Fanuc series oi-TC* contains this function is G32. When applying this function, each cutting pass, idle travel of the cutter with its return to the start trajectory point and the travel for the cutter positioning before each new cutting pass are programmed (fig. 3). The control programme (CP) based on the G32 function will have a block structure with the number of the blocks equal to the number of the formation passes. The manual development of the control programme based on the G32 function use can be recommended only for the worm gap formation made during one or three passes. Otherwise the cumbersome control programme comprising the repeating elements can lead to the programming errors and the machine breakdown [2].

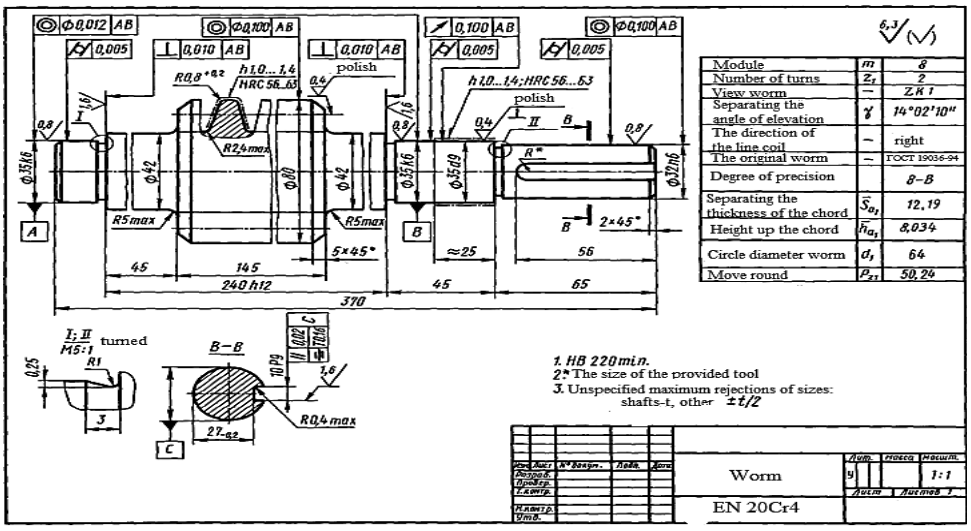


*Fig. 1. The Worm Draft and Technical Requirements*

*Fig. 2. The Worm Processing in the CN Lathes*

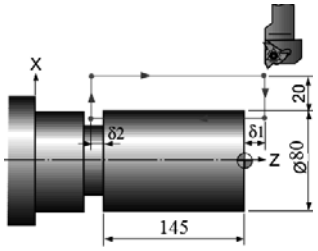


*Fig. 3. Scheme of the Screw Surface Formation Cycle: $\delta_1$ – cutter acceleration section; $\delta_2$ – cutter slow down section*

The calculation formulae for $\delta_1$ and $\delta_2$

$$\delta_1 = \frac{3.6 \cdot L \cdot n}{1800}; \quad (1)$$

$$\delta_2 = \frac{L \cdot n}{1800}, \quad (2)$$

where $L$ – screw length; $n$ – spindle revolution rate.

The approaches suggested by the*CAM*-systems for developing the control programmes were considered: *ESPRIT, NX8, SprutCAM.*

The *ESPRIT CAM*-system has:

- a very simple interface;
- a big cutter library, the own cutter with various geometries can be created at need;
- a sufficient module quantity for the 3, 4 и 5-axis processing of the various parts.

The *ESPRIT CAM*-system does not comprise the individual module for the worm coil processing, but it has the screw cutting module which is appropriate not only for

processing the various cuttings but also for the cylindrical worm processing.

The most principal and important advantage of the *ESPRIT CAM*-system lies in a very powerful and distinct visualization system that allows to see, analyse and correct the whole worm processing with the accuracy up to 0.001 mm (fig. 4, 5).

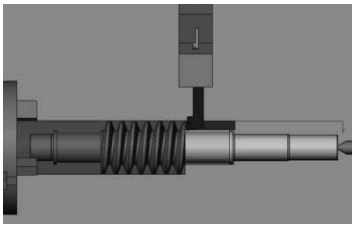

*Fig. 4. The Visualization of the Cylindrical Worm Processing in the CN lathe in the ESPRIT CAM-system*

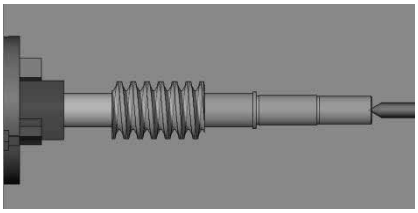

*Fig. 5. The Visualization of the Processed Cylindrical Worm Coils in the CN lathe in the ESPRIT CAM-system*

*NX8* is a *CAD/CAM/CAE*-system for the design and engineering preparation of the production.

*NX8* is one of the most popular and powerful *CAD/CAM/CAE*-systems in the world. As the one *CAD/CAM/CAE*-solution, *NX* allows to perform in the same environment:

- simulation of the ingot, parts, tools, rigging and equipment;
- drafts;
- routing;
- analysis of the metalware and parts against the various loads etc.;
- 3, 4 and 5-axis processing of the various parts.

*NX8* does not have a special module for the worm screw processing as well, but it has the screw cutting module as well as the *ESPRIT* does.

As we suggest, the weakness of the *NX8* in comparison with the *ESPRIT CAM*-system lies in the much lower visualization level. During the turning operations the worm coils cannot be distinctly seen (fig. 6), so that *NX* is not fully applied for the multi-pass processing of the cylindrical worm design.

Also, as we believe, one of the principal weakness of the *NX8* is a complicated interface causing the problems in operating this very programme. The numerous functions witin the system are not obviously grouped into the relative clusters.

*SprutCAM* is the automated design system to develop the control programmes for the multi-coordinative devices with any CN. In the *SprutCAM* the complete integration with the following design packages is performed: *AutoCAD*, *Alibre Design, Inventor, Rhinoceros, SolidEdge, SolidWorks, КОМПАС-3D* etc.

The developing companies of the *SprutCAM* and *ESPRIT* programme packages are the partners, so that strengths and weaknesses of their *CAM*-systems are rather similar.

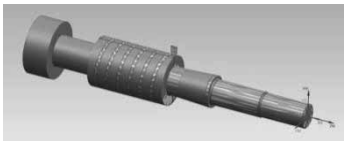

*Fig. 6. The Visualization of the Processed Cylindrical Worm Coils in the CN lathe in the CAD/CAM/CAE-system NX8*

*SprutCAM* also does not have a special worm coil processing module but when the screw cutting module obtained it can be applied for these purposes (fig. 7, 8).

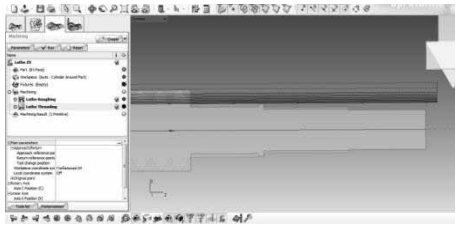

*Fig. 7. The Visualization of the Cylindrical Worm Processing in the CN lathe in the SprutCAM-system*

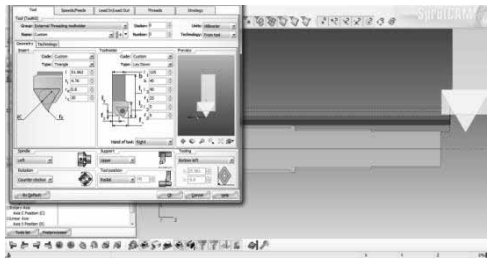

*Fig. 8. The Visualization of the Selection Wide Range and the Cuttier Formation in the SprutCAM-system*

The analysis o the most powerful and popular *CAM*-systems brought us to the conclusion that they do not have the special worm coil processing module and also are restricted in the processing mode selection and options. All the systems are equipped with the screw cutting module, but only the *ESPRIT* and *SprutCAM* suggest the easy-to-work interface, a great selection range of the cutters and, what is the most important thing, the powerful and accurate visualization. They allow the programmer to develop the control programme to cut the screw on the worm.

Nevertheless, not every enterprise can afford purchasing these *CAM*-systems. Moreover, such enterprises want a developing of the special macroprogramme allowing the CN lathe operator the fast and efficient developing the control programme for the multi-pass cylindrical worm cutting without the programmer's participation.

Such a macroprogramme should be based on the definite technological processing scheme.

The authors used the combination cutting scheme (fig. 9), that provides the good chip-making conditions and the cutter smooth wear at the rough processing, and at the finishing processing it provides the required accuracy and roughness [3].

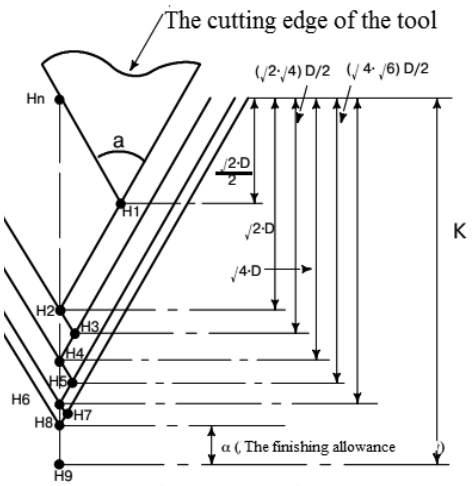


*Fig. 9. The Combined Cutting Scheme [3]*

The user's macroprogramme functions also allow to use the variables, arithmetical and logical operations and conditional jumps (for the further facilitating the control programme developing).

The results of the performed work are carried out as the special macroprogrammes (tables 1, 2).

*Table 1*

The Universal Macroprogramme for the Combined Scheme of the External Multi-Pass Cylindrical Worm Cutting

| Programme Start | Programme Proceeding |
|---|---|
| *O0001(THE WORM)* | *#4=0.* |
| *G19* | *#5=8.034* |
| *T606G55* | *#6=1.8* |
| *G97M3S50* | *#7=54.24* |
| *M08* | *G00 X100.0 Z10.0 :* |
| *#1=011060.* | *G76 P#1 Q#2 R#3 :* |
| *#2=0.1* | *G76 X80.0 Z-145.0 R#4 P#5 Q#6 F#7* |
| *#3=0.2* | |
| *Notations:*<br>*#1=01* – repetition number at the finishing processing (from 1 to 99);<br>*#1=10* – bevelling quantity;<br>*#1=60* – cutting edge angle; coil profile angle in the axial section;<br>*#2=0.1* – minimal cutting depth (given wit the radius value);<br>*#3=0.2* – finishing allowance;<br>*#4=0.* – screw line radius discrepancy;<br>*#5=8.034* – discrepancy between the diameters of the worm top and depth; worm coil height;<br>*#6=1.8* – cutting depth in the first pass (radius length);<br>*#7=50.24* – screw line step; coil pass (equal to G32). | |

The macroprogramme can be adapted for any screw surface processing along with the inside screw.

*Table 2*

The Macroprogramme for the Combined Scheme of the Multi-Pass Trapezoid Internal Screw Surface Cutting

| Programme Start | Programme Proceeding |
|---|---|
| *O0001(NTS.1 INTERNAL TAPPING)* | *G32Z-65.F24.Q240000* |
| *G1901D38.E103.5L100.K0.* | *G0X103.* |
| *T606G55* | *G0Z#6* |
| *G97M3S50* | *G0X#1* |
| *G0X103.Z50.* | *G32Z-65.F24.Q0* |
| *M08* | *G0X103.* |
| *#1=103.5* | *G0Z#6* |
| *#1=103.5* | *G0X#1* |
| *#2=128.3* | *G32Z-65.F24.Q120000* |
| *#3=0.5* | *G0X103.* |
| *#4=10.* | *G0Z#6* |
| *#5=1.7* | *G0X#1* |
| *#6=#4+#5* | *G32Z-65.F24.Q240000* |
| *#6=#4+#5* | *G0X103.* |
| *N1* | *IF[#1 GE #2]GOTO2* |
| *N3* | *#1=#1+#3* |
| *G0X103.* | *GOTO1* |
| *G0Z#4* | *N2* |
| *G0Z#4* | *#2=128.5* |
| *G0X#1* | *#3=0.03* |
| *G32Z-65.F24.Q0* | *IF[#1 GE #2]GOTO4* |
| *G0X103.* | *#1=#1+#3* |
| *G0Z#4* | *GOTO3* |
| *G0X#1* | *N4* |
| *G32Z-65.F24.Q120000* | *G0Z50.* |
| *G0X103.* | *M65* |
| *G0Z#4* | *G30U0W0* |
| *G0X#1* | *M30* |
| *Notations:*<br>*#1=103.5* – initial diameter;<br>*#2=128.3* – finishing diameter;<br>*#3=0.5* – cutting depth per pass;<br>*#4=10.* – initial cutting trapezium point against Z;<br>*#5=1.7* – trapezium profile breakdown. | |

The CN lathe operator should perform the simple actions: set the initial and finishing diameters, cutting depth, initial point and the profile breakdown range on the control panel. Beside the programme developing without the programmer's participation, the macroprogramme also allows the operator to match any cutter from available.

**Conclusions.** The task of the speed and efficiency growth in developing the control programme for the multi-pass cylindrical worm cutting in the CN lathes is solved.

The results of the work performed are implemented as the special macroprogramme that led to the control programme development time reduction by seven times in average at the enterprise. At the same terms the control programme is developed directly by the NC lathe operator without the programmer's participation.

In the next-time perspective the development of the macroprogrammes for the double-enveloping worm processing in the CNC lathes is planned.

**References / Список літератури**

**1.** Kuznetsov, Ye.Yu. and Yamnikov, A.S. (2010), "System of automated programming CNC lathes for multi-pass cutting of warm coils", *Izvestiya TulGU*, Ser. Technical Sciences, Tula, Publishing house of the Tula state University, Vol. 1, pp. 97–104.

Кузнецов Е.Ю. Система автоматизированного программирования токарных станков с ЧПУ для многопроходного нарезания витков червяков / Е.Ю. Кузнецов, А.С. Ямников // Известия ТулГУ. Сер. „Технические науки". – 2010. – Вып. 1. – С. 97–104.

**2.** Kuznetsov, Ye.Yu. (2011), "Software for automated development of control programs for multi-pass cutting of coils worms CNC", *Izvestiya vuzov*. *Engineering*, no. 5. pp. 54–59.

Кузнецов Е.Ю. Программное обеспечение для автоматической разработки управляющих программ для многопроходного нарезания витков червяков на станках с ЧПУ // Известия вузов. Сер. „Машиностроение". – 2011. – № 5. – С. 54–59.

**3.** Kuznetsov, Ye.Yu. (2012), "Select the direction of the cutting cutter when multi-pass cutting of coils worms", *Izvestiya TulGU*, *Ser*. *Technical Sciences*, Tula, Publishing house of the Tula state University, Vol. 1, pp. 350–353.

Кузнецов Е.Ю. Выбор направления врезания резца при многопроходном нарезании витков червяков // Известия ТулГУ. Сер. „Технические науки" – 2012. – Вып. 1. – С. 350–353.

**Мета.** Зменшення часу розробки управляючої програми для багатопрохідної обробки черв'яків на токарних верстатах з ЧПУ.

**Методика.** Порівнювальний аналіз технологічних можливостей відомих *CAM*-систем, розробка спеціалізованої програми та експериментальна перевірка на одному з машинобудівних підприємств.

**Результати.** Розроблена спеціалізована макропрограма для комбінованої схеми нарізання витків циліндричного черв'яка. Зменшено час складання управляючої програми для багатопрохідної обробки черв'яків різцем на токарних верстатах з ЧПУ у 7 разів. Найбільш відповідним варіантом до використання визнана комбінована схема нарізання витків черв'яка. У перспективі планується:

- розробка макропрограми для обробки глобоїдного черв'яка на верстатах з ЧПУ;

- удосконалення макропрограми для обробки циліндричних черв'яків.

**Наукова новизна.** Визначені та обгрунтовані напрями вдосконалення засобів автоматизованого проектування управляючих програм для токарної обробки черв'яків різцем на токарних верстатах.

**Практична значимість.** Знижено рівень вимог до кваліфікації розробника управляючої програми від рівня інженера-програміста до рівня оператора верстата з ЧПУ. Розроблена макропрограма дозволяє кожному оператору токарного верстата з ЧПУ самостійно, без участі інженера-програміста складати програми комбінованого багатопрохідного нарізання витків циліндричного черв'яка. Запропонований підхід має суттєве значення для підприємств малого та середнього бізнесу, у тому числі для підприємств гірничого машинобудування.

**Ключові слова:** *циліндрична черв'ячна передача, CAD / CAM-системи, токарні верстати з ЧПК, керуюча програма, мікропрограма*

**Цель**. Сокращение времени разработки управляющей программы для многопроходной обработки червяков на токарных станках с ЧПУ.

**Методика.** Сравнительный анализ технологических возможностей известных *CAM*-систем, разработка специализированной программы и экспериментальная проверка на одном из машиностроительных предприятий.

**Результаты.** В работе решена задача повышения эффективности составления управляющей программы для многопроходного нарезания витков червяка резцом на станках с ЧПУ. Разработана специализированная макропрограмма для комбинированной схемы нарезания витков цилиндрического червяка. Сокращено время составления управляющей программы для многопроходной обработки червяка резцом на токарных станках с ЧПУ в 7 раз. Наиболее подходящим вариантом к использованию признана комбинированная схема нарезания витков червяка. В перспективе планируется:

- разработка макропрограммы для обработки глобоидного червяка на станках с ЧПУ;

- усовершенствование макропрограммы для обработки цилиндрических червяков.

**Научная новизна**. Определены и обоснованы направления совершенствования средств автоматизированного проектирования управляющих программ для токарной обработки червяков на станках с ЧПУ.

**Практическая значимость.** Понижен уровень требований к квалификации разработчика управляющей программы от уровня инженера-программиста до уровня оператора станка с ЧПУ. Разработанная макропрограмма позволяет каждому оператору токарного станка с ЧПУ самостоятельно, без участия инженера-программиста составлять программы комбинированного многопроходного нарезания витков цилиндрического червяка. Предложенный подход имеет существенное значение для предприятий малого и среднего бизнеса, в том числе для предприятий горного машиностроения.

***Ключевые слова:*** *цилиндрическая червячная передача, CAD/CAM-системы, токарные станки с ЧПУ, управляющая программа, макропрограмма*

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