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OVERVIEW OF SOME NON-TRADITIONAL CUTTING SCHEMES

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Abstract: *The desire to search for new opportunities for optimizing the machining of hard-to-machine materials used in current industries - mechanical engineering, military production, space production, automotive and etc., challenges engineering specialists to look for unconventional cutting patterns, which in turn must provide productivity, extend tool life and reduce temperature load. An overview of some non-traditional cutting schemes in the turning and lathe-milling machining has been made. The kinematics of the execution of cutting schemes and the machine tools on which they could be performed without requiring the purchase of expensive equipment and large-sized machine tools are considered. Non-traditional schemes consider the possibility of applying two rotational movements – one on the tool and one on the workpiece.*

Key words: *unconventional cutting schemes, machining with rotating part and tool, turn-milling operations*

1. INTRODUCTION

The dynamic development of industry, the desire to meet the requirements of Industry 4.0, as well as in connection with the unstable geopolitical situation, which provokes a discussion about the development and financing of military, space (in connection with the production of satellites) and machine-building production, requires engineering specialists to go beyond the traditional metalworking and look for new opportunities and solutions to increase productivity, reducing tool wear and reducing the resources required for processing difficult-to-machine materials [1-4].

In recent years, non-traditional cutting schemes have become of interest which with the help of modern machine tools and cutting tools, make it possible to solve technological problems that were difficult in the past and for this reason have not been widely used [5-8]. A look at non-traditional cutting schemes was made as early as the 80s of the last century, but more serious research in this area began in the 90s [9-12]. The main application of non-traditional cutting schemes is aimed at machining hard and hard-to-machine materials, machining rotary asymmetrical parts and controlling tool wear [13-15]. The development and automation of machine tools and technological equipment nowadays allow for new in-depth research of non-traditional cutting schemes and the enforce of their wider use in the manufacturing industry. During traditional machining, cutting tools are subjected to intense mechanical and thermal stress, because during machining the temperature is concentrated at the cutting insert corner.

Cutting hard-to-machine steels causes greater wear on the cutting tool, as their processing is accompanied by greater cutting forces and due to the formation of built-up edge, a higher cutting temperature develops and as a result the adhesive tool wear and diffusion tool wear occurs. Increasing the wear resistance of cutting tools is possible by applying innovative methods, among which is the cutting scheme with simultaneous rotating tools and workpieces. This technology stands out for the possibility of a more uniform heat rate of the tool and a decrease in heat in the cutting area, due to the uniform and distribution along the periphery of the cutting insert. When applying non-traditional cutting schemes with simultaneous rotating tools and workpieces, heat dissipation is achieved, since no point of the tool is in contact with the workpiece during the entire machining time (Fig.1 and Fig.2).

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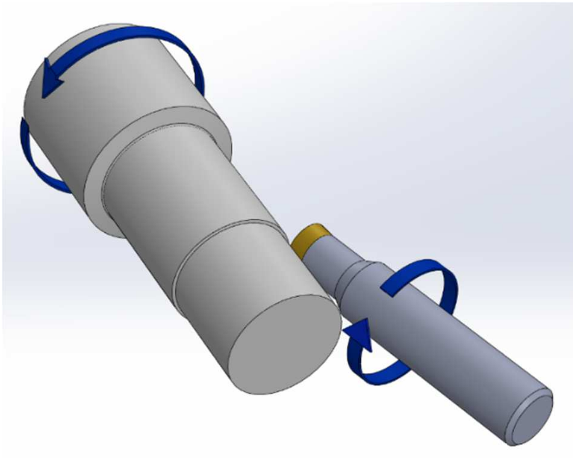

Fig.1. Unconventional cutting scheme with simultaneously tool and part rotating of a lathe machine

This article presents opportunities for applying some non-traditional cutting schemes in order to reduce tool wear, in order to reduce the heat rate in the cutting zone and increase productivity when machining hard-to-machine steels compared to traditional cutting schemes for rotary parts machining. The proposed cutting schemes have the opportunity to find wide application without the need to invest additional financial resources in the purchase of expensive multi-axis machine tools. The unconventional cutting schemes discussed in the publication are used mainly in fully automated metal-cutting machines, which fully comply with the requirements of Industry 4.0.

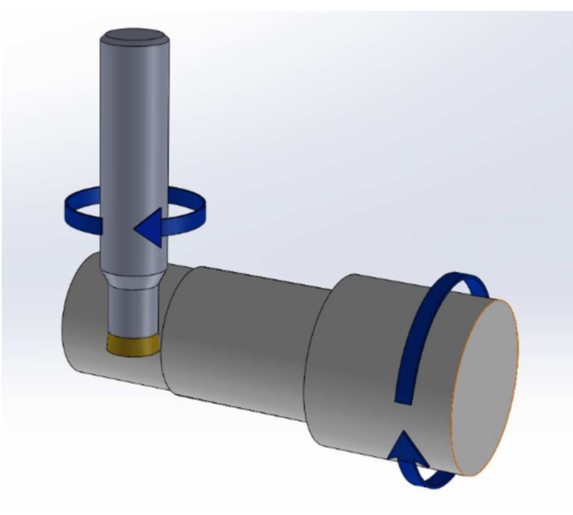

Fig.2. Unconventional tangential cutting scheme with simultaneously rotating tool and workpiece on a milling machine

2. APPLICATION OF SOME NON-TRADITIONAL CUTTING SCHEMES

Traditional cutting schemes have found wide application in various industries, but unfortunately, they are difficult to apply to the processing of hard and hard-to-machine steels due to the occurrence of physicochemical phenomena in the tool surfaces that contact the chips and the workpiece, which are mainly related to cutting tool wear. This is a production problem that has been referred to the scientific community, including the author team, which is why it is examining the specific case. In this regard, a review of existing publications on the topic and a presentation of the current state of the art have been made. During the tool wear, the geometric parameters of the cutting insert change, which affects the plastic deformation, cutting forces and temperature in the cutting area. The wear resistance of cutting tools is the ability of the tool material to resist material loss and wear while maintaining the initially assigned geometric parameters of the cutting edge for a long time.

When machining parts, in addition to guaranteeing the dimensions accuracy, roughness of the processed surface and shape accuracy, the aim is to achieve high productivity. An important factor affecting productivity is the cutting speed, related to the tool life. When applying traditional cutting schemes in order to increase productivity, with increasing of cutting depth or cutting feed, the cutting forces increase and the total amount of cutting heat generation increases. In order to maintain the required cutting tool life when machining hard and hard-to-machine materials, the cutting speed must be reduced. The application of non-traditional cutting schemes in the machining of stainless steels, hard-to-machine materials and heat-treated materials with high hardness makes it possible to increase productivity while extending the tool life. These unconventional cutting schemes can be applied both in machine-building industries and in automotive, shipbuilding, aerospace, military, medical and other industries.

In this regard, the attention of specialists in the cutting of materials field is directed to non-traditional turning and turn-mill processes. The purpose of applying these cutting schemes is to achieve high productivity with extended tool life and reduce the heat rate in the cutting zone, while not at the expense of ensuring the quality parameters of the processed surfaces [3, 7, 13, 16-19].

The proposed non-traditional cutting scheme of a lathe machine involves both rotating tools and a workpiece. This cutting scheme in turning ensures temperature distribution along the periphery of the round cutting insert and extends tool life. This is due to the fact that during cutting, due to the geometry of the cutting insert and the kinematics of the cutting scheme, there is no point on the cutting edge of the cutting insert which is in contact with the machined surface all the time.

In non-traditional turn-milling cutting schemes, a tangential cutting scheme is considered. The kinematic of the movements in the execution of this scheme includes a combination of two rotational movements – one of the cutting tool and the workpiece, and second of the feed movement of the cutting tool. It is specific that the axis of the tool and the axis of the workpiece are perpendicular to each other, and the cutting is performed with the periphery of the tool, as it is tangent to the machined surface of the workpiece. This cutting scheme is applied to reduce tool wear, to increase productivity but not reducing the resulting roughness.

3. KINEMATICS OF NON-TRADITIONAL CUTTING SCHEMES

With the development of technology and equipment, and with the progress of the machine tools kinematics, it becomes possible to apply the aforementioned non-traditional cutting schemes with more than one rotary movement.

3.1. Non-traditional cutting schemes for a CNC lathe machine

Fig. 3 presents the kinematics of the movements required to perform an unconventional cutting scheme of a CNC lathe machine, with simultaneous rotational movement of the tool and the workpiece [5, 20].

The movements that are performed in this cutting scheme are as follows:

- V_c - main rotational movement of the workpiece;
- V_{cr} - rotational movement of the tool;
  V_{fz} - straight-line feed move on the Z-axis direction. The V_{fz} feed move can be performed by the tool or by the workpiece and depends on the kinematics of the machine;
- Sx - a rectilinear positional movement on the the X-axis direction (performed by the tool). This movement is used to position the tool at the set cutting depth in a direction perpendicular to the axis of rotation of the workpiece;
- δ – angle of engagement of the rotary cutting tool, located between the axis of rotation of the cutting tool and the axis of rotation of the workpiece.

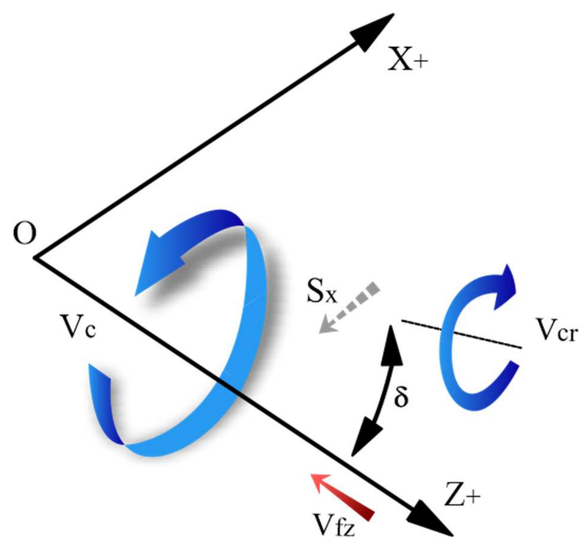

Fig.3. Unconventional cutting scheme implemented on a CNC lathe machine

3.2. Tangential cutting scheme implemented on a milling machine

The unconventional cutting scheme performed on a milling machine with simultaneous rotational movement of the tool and the workpiece with a tangentially positioned rotating tool is presented in Fig. 4, where:

- Vc - the main rotational movement of the cutting tool;
- Vcr - rotational movement of the workpiece (with the location of the workpiece rotation axis parallel to the X-axis);

- Vfx – rectilinear workpiece feed movement (obtained when the machine table moves along the X axis);
- Sy – rectilinear positional movement of the workpiece. This motion is performed for positioning the workpiece at the specified cutting depth in the direction perpendicular to the rotation axis of the workpiece;
- Sz - rectilinear positional movement of the tool along the Z axis.

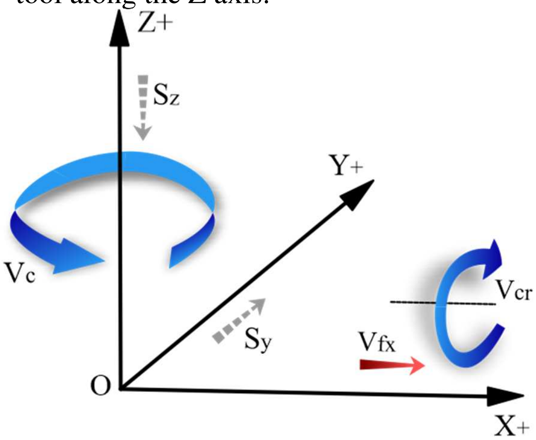

Fig.4. Unconventional tangential cutting scheme realized on CNC milling machine

4. TECHNOLOGICAL EQUIPMENT NECESSARY FOR THE IMPLEMENTATION OF NON-TRADITIONAL CUTTING SCHEMES IN LATHES AND MILLING MACHINES

To ensure the implementation of unconventional cutting schemes and to ensure the achievement of the desired processing effect, it is necessary to take into account the necessary equipment. This is an important point in relation to the complexity of the implementation of the respective cutting scheme and the financial resources that each of them will require.

In non-traditional cutting schemes performed on lathes and milling machines, the presence of two rotational movements performed simultaneously by the tool (Fig. 5) and the workpiece is specific.

For the implementation of the presented schemes, a tool has been developed that is designed to work with a round insert, which is mounted at the bottom of a cylindrical holder clamped in the rotating spindle [20].

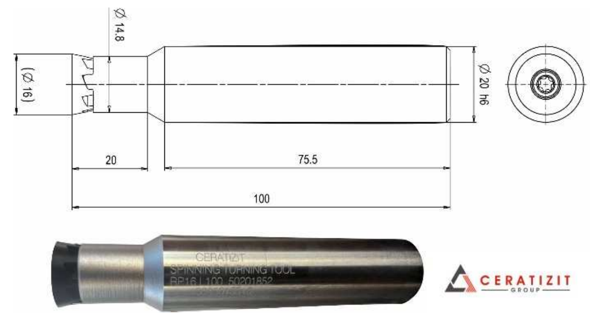

Fig.5. General view of rotary tool and dimensioning

For the implementation of non-traditional cutting schemes, several variants of technological equipment can be used, which include:

- a two-coordinate CNC lathe, with an additional device mounted on the tool board of the machine to ensure the rotational movement of the tool (Fig. 6);

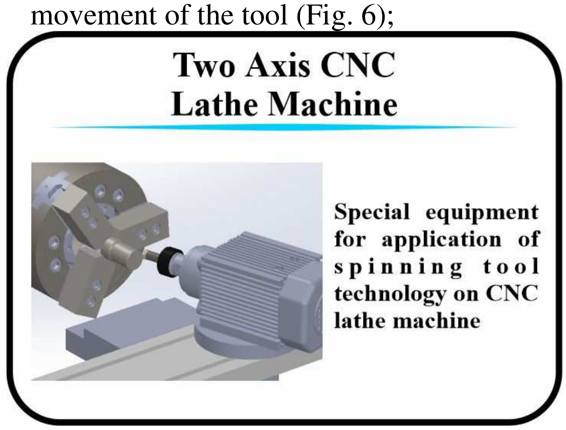

Fig.6. Lathe machine equipped with additional spindle for rotating simultaneously the workpiece and cutting tool

- a three-coordinate milling machine with an additional device mounted on the machine table to ensure the rotational movement of the workpiece (Fig. 7);

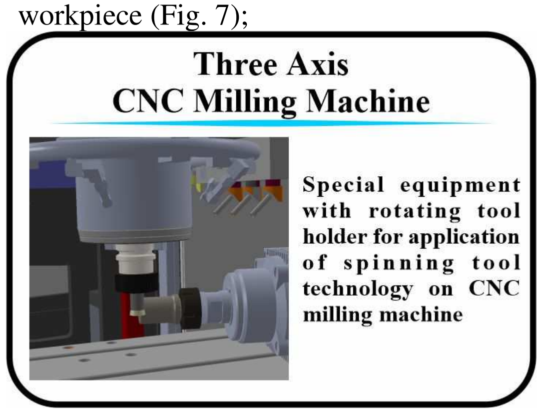

Fig.7. Milling machine equipped with additional spindle for rotating simultaneously the cutting tool and workpiece

- Multi-axis lathe-milling machine equipped with a milling spindle, necessary for attaching the rotating tool (Fig. 8).

In order to perform the unconventional cutting scheme with simultaneous rotating tools and workpieces on a two-axis CNC lathe or on a three-axis CNC milling machine, in addition to the round insert tool, it is necessary to have a device that provides the drive of the tool/workpiece.

Fig.8. Multi-axis lathe-milling machine equipped with milling spindle

In this regard, a fixture is available for attaching the rotating tool/workpiece by means of the additionally mounted fixture shown in Fig. 9.

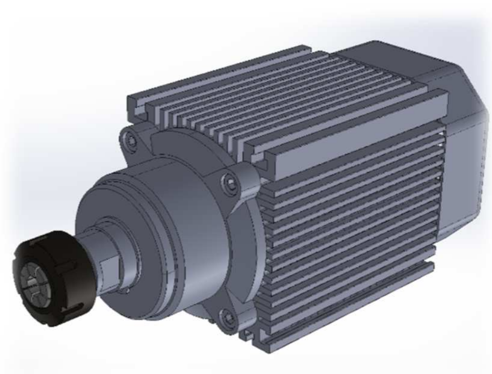

Fig.9. Additional spindle for driving the tool/workpiece

This device not only provides the ability for clamping and rotating the cutting tool, but also the ability to set it at a certain angle and adjust the rotational frequency.

To adjust the spindle speed, it is necessary to provide a spindle inverter that allows precise control of the rotary speed in order to adapt the spindle to the processing of different materials and operating conditions.

A spindle inverter is a highly efficient speed control device for electric motors, which provides precise regulation of the rotation speed of spindles in lathes and milling machines. It offers flexibility in adjusting various parameters, including rotational speed and torque, and provides efficient control of electric motors of different powers.

What has been discussed so far shows that in order to implement non-standard cutting schemes, it is needed to be used a special processing tool and additional devices to replace the expensive multi-axis machines.

The implementation of non-traditional cutting schemes on multi-axis machines has greater application possibilities and facilitates the implementation of non-traditional cutting schemes without the need to provide additional equipment and space for its installation.

5. ADVANTAGES AND DISADVANTAGES OF NON-TRADITIONAL CUTTING SCHEMES FOR LATHES AND MILLING MACHINES AND CNC LATHE-MILLING MACHINES

The non-traditional cutting schemes presented in this article are of large interest and they are already the subject of research for their successful implementation in modern machine production companies. The research is mainly focused on the application of non-traditional cutting schemes for machining hard and hard-to-work materials. Since the application of these cutting schemes, it is still being studied, this allows for multiple studies depending on the type of the workpiece material, the type of tool material, a cutting condition, a scheme of establishing the tool in relation to the workpiece, etc. The article summarizes the advantages and disadvantages which are presented in Table 1 without taking into account the specific cases. The results presented in comparative table 1 are based on an in-depth literature review and the expert experience of the authors.

Table 1

Advantages and disadvantages of non-traditional cutting schemes

Type of non-traditional cutting schemes	Advantages	Disadvantages
Unconventional cutting scheme performed on a CNC lathe	✓ Reducing the heat rate in the cutting zone; ✓ Increasing the cutting tool life; ✓ Increasing productivity; ✓ Reducing the cutting forces; ✓ Reducing friction; ✓ Increasing of the treated surface quality.	- No precise dependences have been established on the cutting conditions, and more specifically the frequency of rotation of the workpiece and the tool, at which optimal results are obtained from the point of view of: • the treated surface quality; • the process productivity; • the life of cutting tool. - Complex and individual design of the tool; - Limitation of the ratio of the cutting part radius to the expected workpiece geometry.
Unconventional cutting scheme in tangential machining of a CNC milling machine	✓ Eliminating the formation of continuous flow chip; ✓ Reducing the temperature in the cutting area and keeping it constant; ✓ Reducing radial cutting forces; ✓ Ensuring a longer cutting tool life; ✓ Reducing roughness and eliminating the need for the grinding process in some cases; ✓ More efficient chips removal from the cutting area.	- Error in the resulting shape (roundness deviation); - This cutting scheme is not cost-effective for single pieces or for low-volume production; - As the cutting depth and feed speed increase, the surface roughness also increases; - Programming with CAM software is complex (it needs to be careful about possible collisions and optimize tool paths); - It requires highly qualified specialists.
Non-traditional cutting scheme of a multi-axis CNC lathe-milling machine	✓ Ensuring a longer tool life; ✓ Increasing productivity; ✓ Ensuring the processing of large and heavy parts; ✓ Reducing of cutting forces; ✓ Reducing the heat rate in the cutting zone; ✓ The depth of cut has no significant impact on the cutting speed.	- Dependence of the quality of the surface on the ratio of the rotation speeds of the workpiece and cutting tool; - The dynamics of the cutting process are difficult for modeling; - Increasing surface roughness with increasing cutting depth; - As the diameter of the workpiece to be processed increases, the resulting roughness and the deviation from roundness increase too; - Requires expensive multi-axis CNC machines.

6. CONCLUSIONS

The problem of manufacturing enterprises related to the machining of hard and hard-to-machine materials direct the interest of the scientific field towards the search for non-standard solutions, such as non-traditional cutting schemes.

Unconventional cutting schemes with simultaneous rotating tools and workpieces allow for a wide range of applications. A difficulty in their use is the need for expensive individual cutting tool design and a limitation of the ratio of the radius of the cutting part of the tool to the expected geometry of the workpiece.

All three presented non-standard cutting schemes make it possible to increase productivity, extend tool life, reduce cutting forces and lower the temperature in the cutting area. As for the other advantages presented in Table. 1, emphasize the need for further research on these schemes in order to promote their implementation in production processes.

When applying non-traditional cutting schemes, the difficulty of ensuring the stability of the parts, the deviation from roundness, the need for highly qualified specialists to program the correct trajectory of the movements of the tool and the workpiece and above all, the scale of the production in which they are used should be taken into account.

Currently, there is a lack of sufficient data regarding the behavior of the cutting process under varying mode parameters and with different cutting tools and workpiece materials.

The future work on these issues and the obtaining of new experimental results are essential for a comprehensive understanding of the process dynamics and for optimizing these unconventional cutting methods for broader industrial application.

7. REFERENCES

[1] Matlygin, G.V., Savilov, A.V., Zarak, T.V., *Analysis of progressive machining technologies for rotating cutting tools*, Vestnik Irkutskogo gosudarstvennogo tehnicheskogo universiteta, Proceedings of Irkutsk State Technical University, 24(3), pp. 498–513, 2020, (In Russ.) https://doi.org/10.21285/1814-3520-2020-3-498-513

[2] Comak, Alpt., *Mechanics, Dynamics And Stability Of Turn-Milling Operations, Thesis for: Doctor of Philosophy - PhD Mechanical Engineering*, 2018, DOI: 10.14288/1.0368954

[3] Matlygin G., Savilov A., Pyatykh Al., Timofeev S., *The Impact of Cutting Modes on the Output Turn-Milling Parameters for High-Speed Steel*, Key Engineering Materials, 910, pp. 129-137, 2022, https://doi.org/10.4028/p-n6exa0

[4] Ezugwu, E. O., *Improvements in the machining of aero-engine alloys using self-propelled rotary tooling technique*, J. Mater Process. Technol., Elsevier, Volume 185, Issues 1–3, pp. 60-71, 2007, https://doi.org/10.1016/j.jmatprotec.2006.03.112

[5] Czán, A., Joch, R., Šajgalík, M., Holubják, J., Horák, A., Timko, P., Valíˇcek, J., Kušnerová, M., Harniˇcárová, M., *Experimental Study and Verification of New Monolithic Rotary Cutting Tool for an Active Driven Rotation Machining*. *Materials*, *15*(5), 1630, 2022, https://doi.org/10.3390/ma15051630

[6] Ikenaga, S., Okida, J., Inoue, H., Hosokawa, A., *Study of Chip Division in High Efficiency Machining with Active Driven Rotary Tool*, Proceeding of the JSPE Autumn Annual, meeting, B45, pp. 137–138, 2017. (in Japanese)

[7] Berenji, K.R., Kara, M. E., Budak, E., *Investigating High Productivity Conditions for Turn-Milling in Comparison to Conventional Turning*, Procedia CIRP, Elsevier, 77(1), pp. 259-262, 2018, DOI: 10.1016/j.procir.2018.09.010

[8] Joch, R., Czán, A., Holubják, J., Cedzo, M., Čep, R., *Effects of Process Cutting Parameters on the Ti-6Al-4V Turning with Monolithic Driven Rotary Tool*, Materials *Materials*, *15*(15), 5181, 2022, https://doi.org/10.3390/ma15155181

[9] Schulz, H., Spur, G. *High speed turn-milling—a new precision manufacturing technology for the machining of rotationally symmetrical workpieces*, CIRP Annals-Manufacturing Technology, 39, pp. 107-109, 1990

[10] Schulz, H., Kneisel, T, *Turn-milling of hardened steel—analternative to turning*, Ann CIRP, 43(1), pp. 93–96, 1994

[11] Budak, E., Altintas, Y., Armarego, E., *Prediction of Milling Force Coefficients from Orthogonal Cutting Data*, Journal of Engineering for Industry, ASME, 118, pp. 216-224, 1996

[12] Choudhury, S. K., Mangrulkar, K.S., *Investigation of orthogonal turn-milling for the machining of rotationally symmetrical work pieces*, J. Mater. Process. Technol., Elsevier, 99 pp. 120–128, 2000, https://doi.org/10.1016/S0924-0136(99)00397-0

[13] Uysala E., Karaguzelb U., Budaka Erh., Bakkalb M., *Investigating Eccentricity Effects in Turn-Milling Operations*, Procedia CIRP, Elsevire, 14, pp. 176 – 181, 2014, https://doi.org/10.1016/j.procir.2014.03.042

[14] Kara, M. E., Budak, Erh., Optimization of Turn-milling Processes, Procedia CIRP, 33(4), pp. 476-483, 2015, DOI: 10.1016/j.procir.2015.06.057

[15] Karaguzel, U., Uysal, E., Budak, Erh., Bakkal M., *Modelling of Turn-Milling Processes for Increased Productivity*, The 16th International Conference on Machine Design and Production, June – July, 2014, Izmir, Turkiye, https://scholar.google.com/scholar_lookup?title=Modelling%20of%20turn%20milling%20processes%20for%20increased%20product

ivity&publication_year=2014&author=U.%20Karag%C3%BCzel&author=E.%20Uysal&author=E.%20Budak&author=M.%20Bakkal

[16] Zhu, L., Jiang, Z., Shi, J., Jin, Ch., *An overview of turn-milling technology*, The International Journal of Advanced Manufacturing Technology, Springer Nature Link, 81, pp. 493–505, 2015, DOI: 10.1007/s00170-015-7187-y

[17] Savas, V., Ozay, C., *The optimization of the surface roughness in the process of tangential turn-milling using genetic algorithm*, The International Journal of Advanced Manufacturing Technology, Springer Nature Link, 37, pp. 335–340, 2008, DOI: 10.1007/s00170-007-0984-1

[18] Karagüzel, U., Uysal, E., Budak, E., Bakkal, M., *Analytical modeling of turn-milling process geometry, kinematics and mechanics*, International Journal of Machine Tools and Manufacture, Elsevier, 91, pp. 24-33, 2015, https://doi.org/10.1016/j.ijmachtools.2014.11.014

[19] Savas V., Ozay C., Ballikaya H., *Experimental investigation of cutting parameters in machiningof 100Cr6 with tangential turn-milling method*, Advances in Manufacturing, Springer Nature Link, 4(1), 2016, DOI: 10.1007/s40436-016-0134-9

[20] Vasileva, D., Avramova, T., Rusev, Sv., *Comparative Analysis Of Some Traditional And Nontraditional Cutting Schemes In The Turning Process*, International Journal of Manufacturing Economics and Management, ModTech Publishing House, IV (2), 2024, ISSN 2784-1278, https://doi.org/10.54684/ijmem.2024.4.2.36

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Prezentare generală a unor scheme de tăiere netradiționale

Rezumat: Dorința de a căuta noi oportunități pentru optimizarea prelucrării materialelor greu de prelucrat utilizate în industriile actuale - inginerie mecanică, producție militară, producție spațială, industria auto etc., îi provoacă pe specialiștii în inginerie să caute modele neconvenționale de așchiere, care la rândul lor trebuie să ofere productivitate, să prelungească durata de viață a sculelor și să reducă sarcina termică. A fost realizată o prezentare generală a unor scheme netradiționale de așchiere în prelucrarea prin strunjire și frezare. Este luată în considerare cinematica execuției schemelor de așchiere și mașinile-unelte pe care acestea ar putea fi efectuate fără a necesita achiziționarea de echipamente costisitoare și mașini-unelte de dimensiuni mari. Schemele netradiționale iau în considerare posibilitatea aplicării a două mișcări de rotație - una pe sculă și una pe piesa de prelucrat.

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