Вісник Тернопільського національного технічного університету
https://doi.org/10.33108/visnyk_tntu
Scientific Journal of the Ternopil National Technical University
2019, № 1 (93) https://doi.org/10.33108/visnyk_tntu2019.01
ISSN 2522-4433. Web: **visnyk.tntu.edu.ua**

UDC 621.914

COMPUTER MODELLING OF POWER LOAD OF FACE MILL CUTTERS WITH CYLINDRICAL RAKE FACE OF DURING DIFFICULT-TO-CUT MATERIALS MACHINING

Larysa Hlembotska; Nataliia Balytska; Petro Melnychuk; Oleksandr Melnyk

State University «Zhytomyr Polytechnic», Zhytomyr, Ukraine

***Summary**. The paper deals with the problem of determining the power characteristics of face milling process by computer modelling in DEFORM 3D environment. The influence of the rake face shape of round face mill inserts on the contact area of the chips with the inserts surface, the conditions of the chip removal, the dynamic power loads both during the inserts entry into the workpiece and after the cutting are investigated. The efficient use of inserts with cylindrical rake face in the face mills designs proved, as these results in the decrease of the chip contact area with the inserts surface and improvement of the chip removal conditions. It results in the reduction of the tool dynamic force load, both at the time of entrance to the workpiece, and during cutting. Using computer modelling of the milling process for parts flat surfaces made from hardened high-strength steel and titanium alloy, strength characteristics are determined for the operation conditions with the stepped face mill with cylindrical rake face of the inserts and the standard mill with round inserts. For the stepped face mill the reduction of both impact loads during the entrance the insert to the workpiece and the average values of the component Pz of the cutting force is confirmed in comparison with the standard mills for the various processed materials. The reduction of torque from component Pz action creates the premises for reducing the effective power of the main movement of the machine drive, what can be used for machining with increased depth of cutting on low power machines. This may be another way of increasing the efficiency of the face milling of difficult-to-cut materials.*

***Key words**: face milling, cutting forces, torque, difficult-to-cut materials, computer modelling, cylindrical rake face of the inserts.*

https://doi.org/10.33108/visnyk_tntu2019.01.070 *Received 03.04.2019*

Statement of the problem. The process of face milling is characterized by significant fluctuations in the cutting forces, especially at the insert input and output in/from the contact area with the workpiece. The main reason for this can be both the simultaneous input and output of all points of the cutting edges in the workpiece, which occurs during the orthogonal cutting, and the cutting edge beat.

This problem is especially important for cutting difficult-to-cut materials (DCM) requiring the development of new tools designs with "softened" cutting dynamics, in order to reduce the derivatives of force changes and instantaneous speeds during machining process. One of the ways to solve this problem while machining flat surfaces of parts is reasonable application of stepped face mill cutter of oblique cutting with cylindrical rake face of the inserts. The making of the substantiated decision concerning application of new structural solutions for face mill cutters requires the definition and analysis of cutting process power characteristics for the investigation of their dependence on the tools design parameters, which is an important scientific and technical task.

Analysis of the available investigation results. Power characteristics of the cutting process are determined by the cutting modes, the geometry of the tool, the properties of the machined and tool materials, and other conditions.

The main part of the investigations concerning determination of the cutting forces during face milling is focused on the mill cutters with flat rake inserts surface, which has found the absolute application.

The stress-strain state in the cutting area during the machining using tools with flat rake face of the cutting elements was investigated in the papers [1−3]. It was found that the decrease of the rake angle leads to the increase of cutting forces due to the decrease of shear angle and increase of the contact area of the chip with the rake face of cutting tool inserts. In addition, the reasons for increasing the average stress in the cutting area are the conditions for non-free cutting and material strain strengthening [3, 4].

Thus, one of the possible ways to reduce stresses in the cutting area, and hence cutting forces, is to choose the optimal insert shape.

Papers concerning the investigation of the characteristics of mechanical materials processing under oblique cutting [5−8], which improve the conditions of chip remove, reduce the cutting forces fluctuations and improve the quality of the machining surface, are presented in the scientific literature.

There are a large number of shapes and configurations cutting inserts for face mills. To overcome the negative phenomena occurring during difficult-to-cut materials cutting, it is reasonable to use round inserts, which results in reduction of the cutting forces, increase of the machining productivity by ensuring the possibility of assignment higher feed speeds and obtaining machined surface of high quality [6, 9−12]. When using cutters with convex front surfaces, i. e., with cylindrical front face, the cutting forces are reduced, consequently, reducing the stresses in the cutting area due to the difference in the chip flow of [13]. This results in the reduction of the cutter wear intensity and, as the result, increasing the cutting tool stability, machining productivity and quality.

Therefore, it is necessary to investigate the possibility of applying the cylindrical rake face of inserts for conditions of oblique face milling.

Modelling of power dependences of the face milling process makes it possible to investigate the influence of the insert rake face shape on the value of shock load at the moment of cutter penetration into the workpiece while machining using standard face mill with flat rake face of the inserts and face mill with cylindrical rake face.

The objective of the work is to substantiate the effectiveness of the using inserts with cylindrical rake face for face mills while machining flat surfaces of the parts made from difficult-to-cut materials based on power characteristics analysis, which were obtained as a result of computer modelling of the milling process.

Statement of the problem. Determination of the power characteristics of the face milling process during inserts penetration into the workpiece by the experimental method is impossible due to the inertia of the cutting process itself. In view of this, computer modelling of power characteristics for face milling with flat and cylindrical rake faces of inserts while processing difficult-to-cut materials using special engineering software complex DEFORM 3D was carried out.

DEFORM 3D is designed to analyse various machining processes, including mechanical, and makes it possible to check, process and optimize technological processes resulting in production time reduction, processing quality improvement and cost price reduction.

The calculation of a chip formation process was carried out using the finite element method in DEFORM 3D program by means of implicit integration of the motion equations. The standard algorithms were adapted to the initial conditions, by setting the corresponding models of the machined material and the boundary conditions.

Solid models of standard face mill with round inserts [14] and face mill with cylindrical rake face of the inserts (mills diameter is D = 200 mm, number of the inserts is z = 12, width of machined surface is B = 80 mm, cutting scheme – generator, $\gamma = -8°$, d_{ins} = 12,7 mm, displacement of the milling axis relatively to the axis of the workpiece symmetry ε = 10 mm), tool material – hard alloy ВК8 (WC), as well as workpiece material (the analogue of high strength steel 38XC(38CrSi)). All non-essential elements for this investigation were excluded from the models – the fasteners of the cutting units.

The calculation takes into account the influence of temperature on material density ρ, specific heat C_V and thermal conductivity λ.

Mechanical behavior of the machining material was described by Johnson-Cook equation:

$$\sigma_s = \left(A + B\left(\varepsilon^p\right)^n\right)\left(1 + C\ln\left(\dot{\varepsilon}^p / \dot{\varepsilon}_0{}^p\right)\right)\left(1 - T^{*m}\right), \quad T^{*m} = \left(T - T_0\right)/\left(T_{пл} - T_0\right), \tag{1}$$

where the material constants reflect its ability:
A, B, n – to deformation strengthening; *C* – to high-speed strengthening;
m – to temperature weakening; ε^p – effective plastic deformation;
$\dot{\varepsilon}^p / \dot{\varepsilon}_0{}^p$ – intensity of plastic deformation rate;
T_0 – room temperature, $T_{пл}$ – melting point.

The constants of this equation were taken from DEFORM 3D library for the analogue material (Table 1).

The criterion of viscous fracture under the condition of damage accumulation is described by equation:

$$\bar{\varepsilon}_f{}^p = D_0 e^k , \tag{2}$$

where material constant D_0 reflects the effect of the stress state on the boundary plastic deformation to fracture.

Table 1

Consolidated table of the coefficients determining equation, the equation of plasticity, the elastic and the thermophysical constants at normal temperature

Material	*E, GPa*	μ	*A, MPa*	*B, MPa*	*n*	*C*	*m*	$T_{пл}$	D_0	*k*	*λ, W/(m*°C)*	*C_V, kJ/(kg*°C)*	*ρ*, kg/m³
Steel 38XC (38CrSi)	212	0,3	1200	891	0,2	0,02	0,64	1527	1	0	41,7	0,361	7850

In order to save calculation resources 90° sector, limited by the cutting surface and the cylinder, in such a way that the distance from the cutting surface to cylindrical restrictive surface of 3−5 feed values was «cut» from the workpiece. This condition minimized the influence of the boundary conditions on the results of calculating the chip shape and cutting forces. The model boundary conditions provided the rigid fastening of the workpiece with 3 degrees of freedom in units located on the surfaces of the workpiece «cutting».

The tool reproduced face mill macrogeometry geometrically precisely and was considered absolutely rigid. Cutting edge was considered absolutely sharp. Load was given in the form of kinematic boundary conditions of the tool: restriction of movement along the mill axis, rotation relatively to the mill axis of with frequency, relatively to the given cutting speed, motion in the plane perpendicular to the mill axis with the feed rate.

The finite-element mesh of the workpiece was formed by tetrahedral elements of the second order. The workpiece model with the mesh consisting of 35804 units and 153964 tetrahedral elements of the second order (Fig. 1).

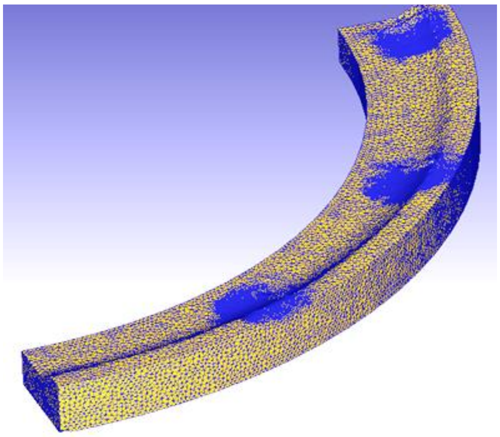


Figure 1. Workpiece model with finite-element mesh

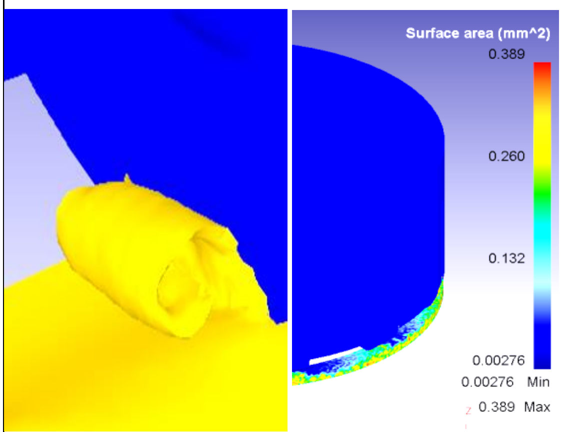
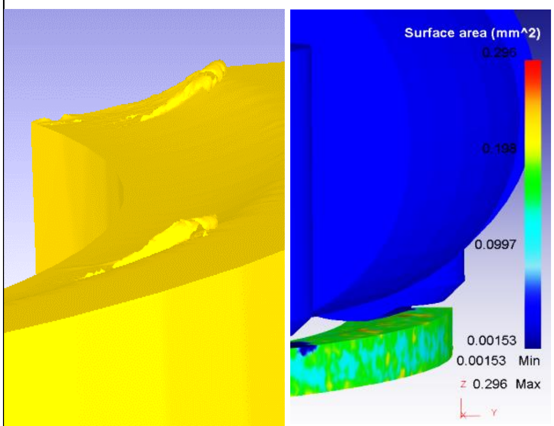
The characteristic size of the elements was uneven in the workpiece volume and was selected in such a way in the area of chip forming that the thickness of the chip was not less than three elements. Finite-element mesh was periodically rebuilt in order to reduce the elements distortion during deformation.

Analysis of numerical results. Were chosen identical cutting conditions: rotation speed n = 200 min^{-1}, feed s = 80 mm/min, depth of cut t =1 mm. In order to investigate the influence of the insert rake face shape on the shock load value at the moment of cutting-in the workpiece while machining using the standard face mill with inserts flat rake face and the face mill with cylindrical rake face.

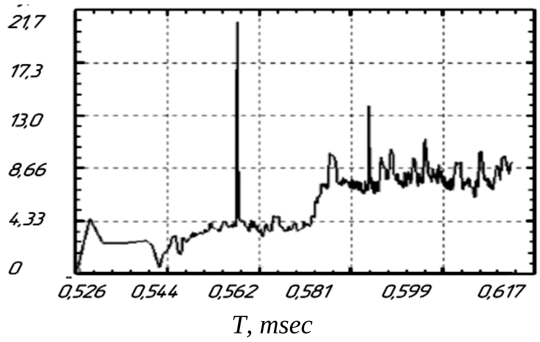
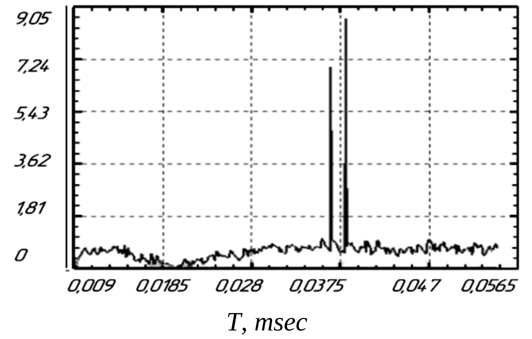
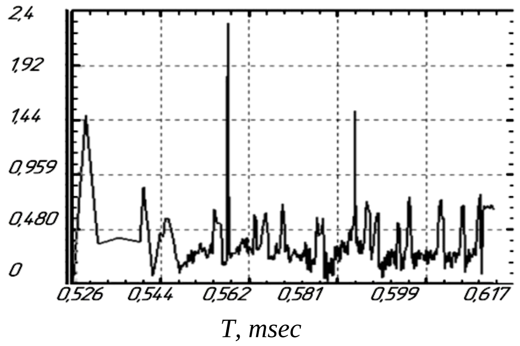
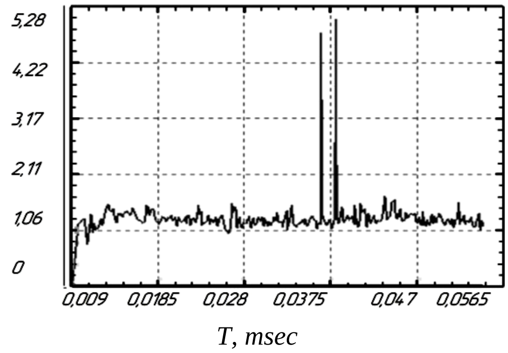
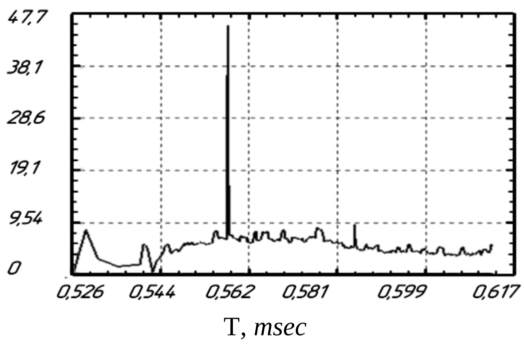
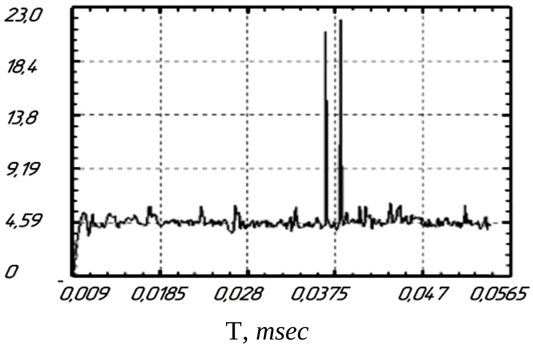
As the result of computer modelling of the face milling process, the following results were obtained (Table 2).

Table 2

The results of computer modelling of face mill cutters power load in DEFORM 3d

	Standard face mill with round inserts with flat rake face	Face mill with cylindrical rake face of inserts
	1	2
Chips remove and contact area of the chips with rake surface		

Continuation the table 2

	1	2
Radial cutting force P_x, kN		
Axial cutting force P_y, kN		
Tangential cutting force P_z, kN		

The results of the investigation. The obtained results (Table 2) show that while cutting with the tool having cylindrical rake face, the chip flows in the direction of cutting edge inclination angle increase causing improvement of quality of machined surface.

For the specified conditions, the maximum contact area of the chip with cylindrical rake face of the face mill is 31.42% less than for the face mill cutter with flat rake face.

When using the face mill with cylindrical rake face of the inserts while shock penetrating into the workpiece, the cutting force components P_X and P_Z were reduced in 2.4 and 2.07 times respectively, at the same time the force P_Y increased by 2.17 times. However, the use of inserts with cylindrical rake face causes decrease in the average values of the component cutting force P_Z by 2 times, and component P_Y increase in 1.8. This conforms with the results of the author's previous investigations, that is, physical modelling of the face milling process using inserts with different shapes of the rake faces [13].

It should be noted that dynamic components of cutting forces decreased (up to 20 times) indicating significant increase in the milling process stability.

Thus, computer modelling of the face milling process confirmed the effectiveness of the use of face mills with cylindrical rake face resulting in the decrease of chip contact area with the insert rake face and the improvement of the chip remove conditions so that dynamic force load on the inserts reduces, both at the moment of cutting-in the workpiece, and while cutting.

However, the use of face mills with cylindrical rake face of inserts imposes restriction on the cutting depth (about 1 mm), since its maximum value depends on the cutter geometric parameters. That is, the generate cutting scheme can be used only for the conditions of finish and semi-finish milling. Therefore, for large cutting depths, it is necessary to apply stepped cutting scheme (Fig. 2), the choice and development of which is dedicated to the work of the authors [15].

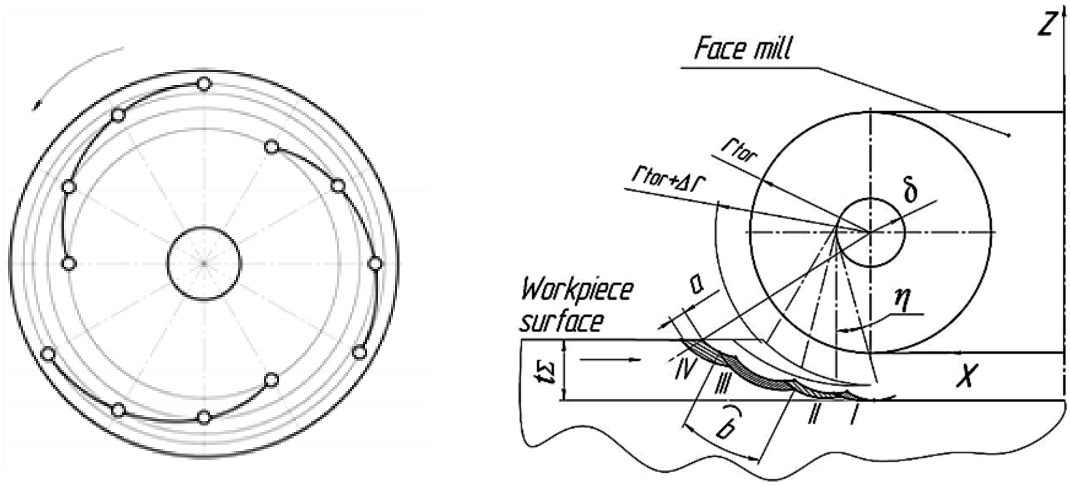


Figure 2. Stepped cutting scheme: torus radius: r_{tor}; displacement of the cutting unit axis: δ; shift value of the insert flat flank face center: Δ*r*; cutting edge engagement thickness: a; cutting edge engagement width: b; inclination angle of the cutting unit axis node to the milling cutter toroidal body axis: η_i [15]

Therefore, it is necessary to verify experimentally the mutual influence of such factors as the cylindrical shape of the insert rake face and the stepped cutting scheme on power characteristics of face milling process of the parts flat surfaces made from the DCM.

For computer modelling of the cutting process, two grades of difficult-to-cut materials of different groups were selected: high-strength steel 38ХС (38CrSi), hardened to hard index 40‒45 HRC, and titanium alloy ВТ1-0, as the representative of viscous materials group.

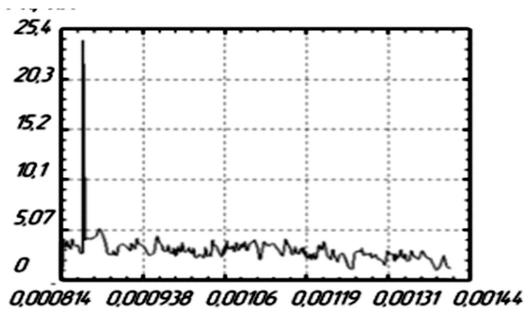
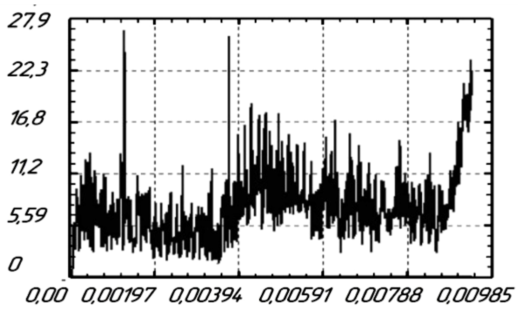
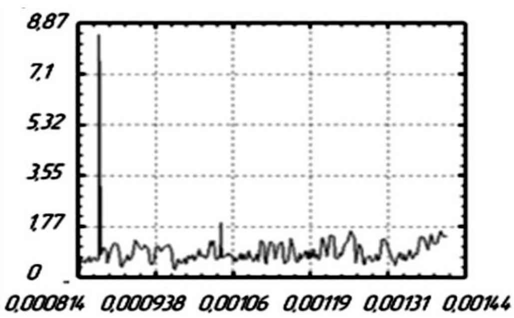
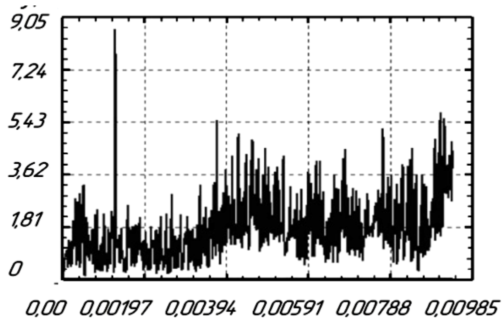
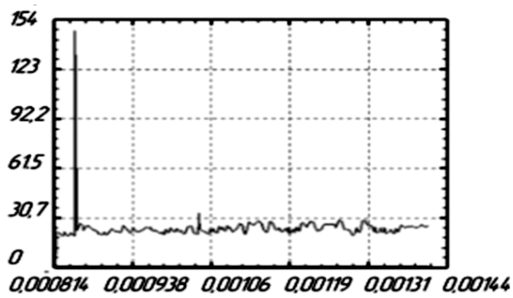
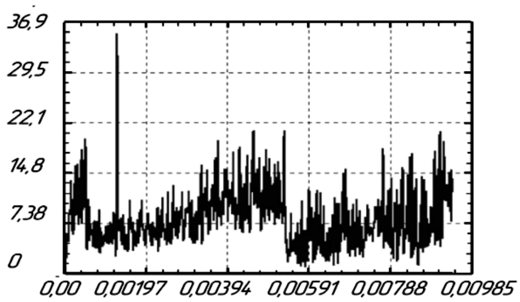
The authors in paper [15] determined the rational geometric parameters and the feed value of the stepped face mill of the developed design for cutting conditions with 3 mm depth by the mathematical modelling.

The power characteristics (Table 3.) during the stepped face milling [15] with the inserts cylindrical rake face ($\gamma = -16°$, $\alpha = 16°$, $d = 11$ mm) and the standard face mill with round inserts for the same cutting conditions ($t = 3$ mm, $s = 80$ mm/min, $n = 160$ min^{-1}) were determined in DEFORM 3D environment with using computer simulation of the face milling process of parts flat surfaces made from high strength steel 38ХС (38CrSi).

For the face mill of the mentioned construction, the cutting edge inclination λ value for active area boundary points of the cutting edges is $\lambda = 8{,}38 \ldots -66°$, that is, the oblique cutting conditions [15] are implemented.

Table 3

Cutting forces in high-strength steel 38XC (38CrSi) machining

	Standard face mill	Stepped face mill
Radial cutting force P_x, kN	 *T, sec*	 *T, sec*
Axial cutting force P_y, kN	 *T, sec*	 *T, sec*
Tangential cutting force P_z, kN	 *T, sec*	 *T, sec*

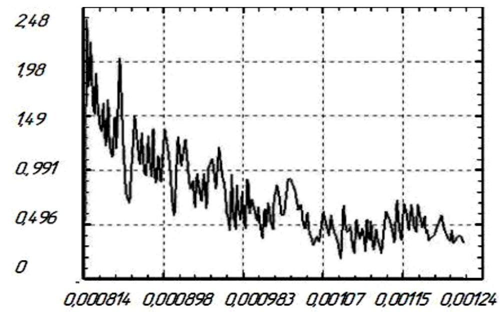
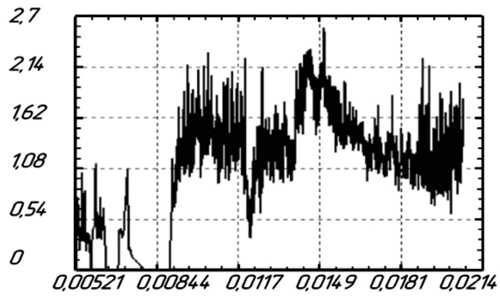
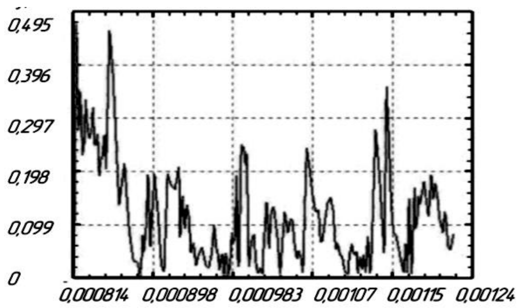
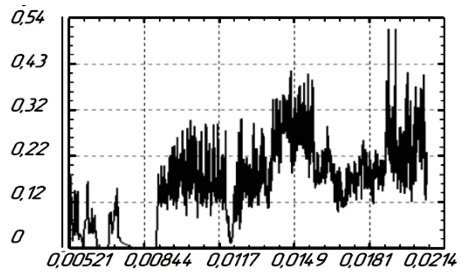
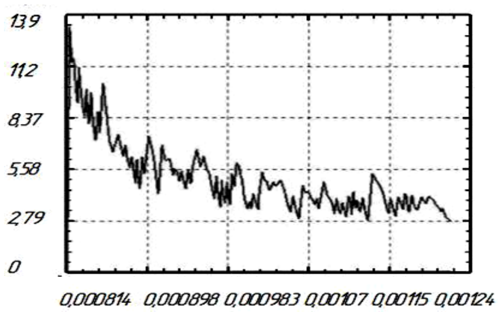
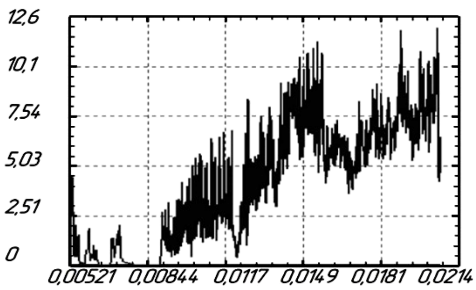
The obtained results prove that, while machining the high-strength steel, the developed mill cutter provides the shock loads reduction during cutting – in by 4.17 times for P_Z force, compared with the standard mill; while the forces P_X and P_Y is not changed significantly.

Decrease in the average values of the cutting force component P_Z by 1.5 times, increase in P_X – by 2.8 times and P_Y – by 2.7 times is also observed.

Similar investigations for conditions of titanium alloy BT1-0 machining were carried out, their results are presented in Table. 4 ($t = 3$ mm, $s = 80$ mm/min, $n = 160$ min^{-1}).

Table 4

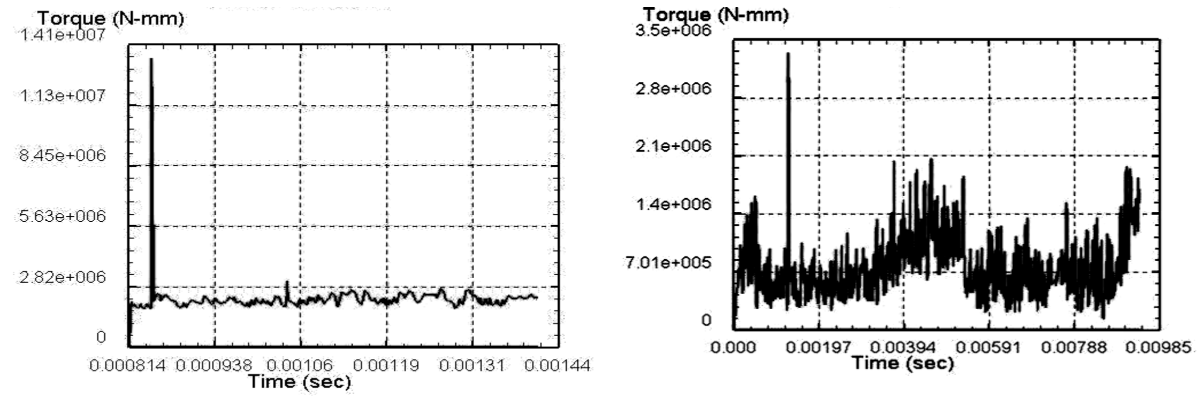
Cutting forces during titanium alloy BT1-0 machining

	Standard face mill	Stepped face mill
Radial cutting force P_x, kN	 *T, sec*	 *T, sec*
Axial cutting force P_y, kN	 *T, sec*	 *T, sec*
Tangential cutting force P_z, kN	 *T, sec*	 *T, sec*

The carried out investigations indicate that during titanium alloy BT1-0 machining, the developed mill cutter provides in the impact loads reduction during cutting – in by 1.1 times for P_Z force and increase of P_Y force by 1.09 times, and P_X force – is not changed significantly.

The results of computer modelling also indicate the decrease in average values of the cutting force P_Z component by 1.41 times, increase in P_X – by 2.6 times and P_Y – by 1.09 times.

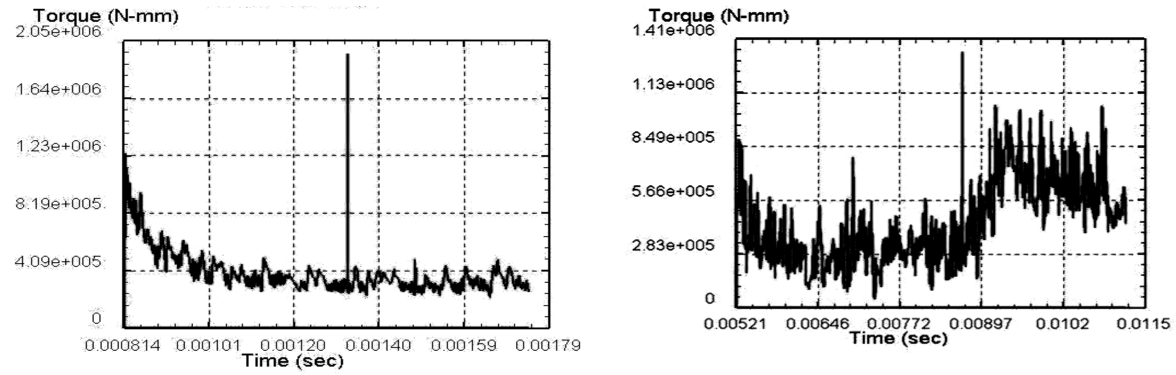
In DEFORM 3D environment for the above-mentioned cutting conditions, the torque in case of machining with face mills of standard and developed design was also determined (Figures 3, 4).



a *b*

Figure 3. Torque during high-strength steel 38XC (38CrSi) machining with:
a) standard face mill, b) stepped face mill

It is evident from Figure 3 that the torque value during impact while cutting-in the workpiece at high-strength steel 38XC (38CrSi) machining with stepped face mill is 4,03 times less than at machining with standard mill; here the average torque value is 1.61 times smaller respectively.



a *b*

Figure 4. Torque during titanium alloy BT1-0 machining with:
a) standard face mill, b) a stepped face mill

Similarly, it was determined that during titanium alloy BT1-0 machining the torque value during impact while cutting-in the workpiece with stepped face mill is 1.45 times less than by standard mill machining (Fig. 4); however, the average torque value is less than 1.03 times.

Thus, the torque reduction generates the preconditions for reducing the effective power of the machine main motion drive which can be used for machining with increased cutting depths on light-duty machines. It is another way to increase the effectiveness of DCM face milling and improve the machining energy efficiency.

Conclusions. Computer modelling of the face milling process proves the reasonableness of the cylindrical rake face use for face mill cutters with generating cutting scheme. This ensures the reduction of dynamic cutting force component up to 20 times.

The reasonableness of the use of stepped face mill with insert cylindrical rake face for difficult-to-cut materials rough milling is proved. It is determined that while machining the high-strength steel and titanium alloy the impact loads during cutting-in are reduce by

4.17 times and for P_Z force by 1.1 times and the average values of P_Z component − by 1.5 and 1.41 times, respectively, in comparison with the standard face mill.

Computer modelling of the cutting process of parts made of high-strength steel and titanium alloy with stepped face mill proved the reduction of torque value during cutting-in the workpiece by 4,03 and 1,45 times, and also average values of torque − by 1,61 and 1,03 times respectively in comparison with the standard face mill.

References

1. Maslenikov I. A., Sokolov Yu. A., Kopaev V. N. Issledovanie napryazhennogo sostoyaniya zony struzhkoobrazovaniya s pomoshh'yu programmnogo kompleksa ANSYS Workbench, Obrabotka metallov rezaniem. No. 5−6 (71−72). 2012. Pp. 18−23. [In Russian].
2. Manovickij A. S. Raschet ugla sdviga v statike pri ortogonal'nom svobodnom rezanii maloplastichnyx uglerodistyx splavov. Protsesy mekhanichnoi obrobky v mashynobuduvanni. 2013. No. 14. Pp. 101–114. [In Russian].
3. Belozyorov V. A., Uteshev M. X., Kaliev A. N. Mexanika deformirovaniya i razrusheniya pri rezanii. Tom II. Obrabotka instrumentami iz STM. Tyumen': TyumGNGU, 2012. 128 pp. [In Russian].
4. Zheleznov G. S. Opredelenie ugla sdviga pri rezanii metallov, Izvestiya Vuzov. Izd. “Mashinostroenie”. No. 4–6. 1998. Pp. 105–108. [In Russian].
5. Vyhovskyi H. M., Melnychuk P. P. Osoblyvosti kosokutnoho bezvershynnoho rizannia. Visn. Zhytomyr. inzh.-tekhnol. in-tu. Tekhn. nauky. 1999. No. 10. Pp. 134−145.
6. Klimenko S. A. Povyshenie proizvoditel'nosti finishnoj obrabotki detalej lezvijnym instrumentom, Visnyk ZhDTU. Tekhnichni nauky. 2017. Vol. 2. No. 2 (80). Pp. 56–66. https://doi.org/10.26642/tn-2017-2(80)-56-66
7. Vyhovskyi H. M. Kolyvannia syl rizannia pry obrobtsi detalei tortsevymy stupinchastymy frezamy. Visn. Zhytomyr. inzh.-tekhnol. in-tu. Tekhn. Nauky. 1999. No. 9. Pp. 28−32.
8. Ghorbani H., Moetakef-Imani B. Specific cutting force and cutting condition interaction modeling for round insert face milling operation. The International Journal of Advanced Manufacturing Technology. 2016. Vol. 84. Issue 5−8. P. 1705–1715. https://doi.org/10.1007/s00170-015-7985-2.
9. Petrosyan G. M., Chin' Min' Ty. Sily pri frezerovanii torcovoj frezoj s cilindricheskimi perednimi poverxnostyami rezhushhix e'lementov. Chistovaya obrabotka detalej mashin. Saratov. 1976. Vol. 2. Pp. 9–15. [In Russian].
10. Denisov E. P. Povyshenie e'ffektivnosti processov tocheniya na osnove primeneniya instrumentov s cilindricheskoj perednej poverxnost'yu: dis. kand. texn. nauk.po special'nosti 05.03.01. Tula, 2004. 188 pp. [In Russian].
11. Manoxin A. S., Klimenko S. A. Sily rezaniya pri tochenii stali ШХ15 bezvershinnym instrumentom iz kiborita, Protsesy mekhanichnoi obrobky v mashynobuduvanni. 2010. № 8. Pp. 127–136.
12. Mel'nijchuk Yu. A., Klimenko S. A., Manoxin A. S. Vliyanie rezhimov obrabotki na sily rezaniya pri tochenii detalej iz zakalennoj stali instrumentom s cilindricheskoj perednej poverxnost'yu. Nadiinist instrumentu ta optymizatsiia tekhnolohichnykh system. 2011. No. 28. Pp. 39–43.
13. Melnychuk P. P., Hlembotska L. Ye. Modeliuvannia sylovykh zalezhnostei pry tortsevomu frezeruvanni, Visnyk Ternopilskoho derzhavnoho tekhnichnoho universytetu. Ternopil. 2008. No. 3. Pp. 78–87.
14. GOST 24359-80. Frezy torcovye nasadnye so vstavnymi nozhami, osnashhennymi plastinami iz tverdogo splava. [Konstrukciya i razmery]. [In Russian].
15. Hlembotska L., Melnychuk P., Balytska N., Melnyk O. Modelling the loading of the nose-free cutting edges of face mill with a spiral-stepped arrangement of inserts. Eastern-European Journal of Enterprise Technologies. 2018. № 1/1 (91). 2018. Pp. 46–54. https://doi.org/10.15587/1729-4061.2018.121712.

Список використаної літератури

1. Маслеников И. А., Соколов Ю. А., Копаев В. Н. Исследование напряженного состояния зоны стружкообразования с помощью программного комплекса ANSYS Workbench. Обработка металлов резанием. № 5−6 (71−72). 2012. С. 18−23.
2. Мановицкий А. С. Расчет угла сдвига в статике при ортогональном свободном резании малопластичных углеродистых сплавов. Процеси механічної обробки в машинобудуванні. 2013. № 14. С. 101–114.
3. Белозёров В. А., Утешев М. Х., Калиев А. Н. Механика деформирования и разрушения при резании. Обработка инструментами из СТМ / под ред. М. Х. Утешева. Том II. Тюмень: ТюмГНГУ, 2012. 128 с.
4. Железнов Г. С. Определение угла сдвига при резании металлов. Известия Вузов. Машиностроение. № 4–6. 1998. С. 105–108.
5. Виговський Г. М., Мельничук П. П. Особливості косокутного безвершинного різання. Вісн. Житомир. інж.-технол. ін-ту. Техн. науки. 1999. № 10. С. 134−145.

6. Клименко С. А. Повышение производительности финишной обработки деталей лезвийным инструментом. Вісник Житомирського державного технологічного університету. 2017. Том 2. № 2 (80). С. 56–66. https://doi.org/10.26642/tn-2017-2(80)-56-66
7. Виговський Г. М. Коливання сил різання при обробці деталей торцевими ступінчастими фрезами. Вісн. Житомир. інж.-технол. ін-ту. Техн. науки. 1999. № 9. С. 28−32.
8. Ghorbani H., Moetakef-Imani B. Specific cutting force and cutting condition interaction modeling for round insert face milling operation. The International Journal of Advanced Manufacturing Technology. 2016. Vol. 84. Issue 5−8. P. 1705–1715. https://doi.org/10.1007/s00170-015-7985-2
9. Петросян Г. М., Чинь Минь Ты. Силы при фрезеровании торцовой фрезой с цилиндрическими передними поверхностями режущих элементов. Чистовая обработка деталей машин. Саратов. 1976. Вып. 2. С. 9–15.
10. Денисов Е. П. Повышение эффективности процессов точения на основе применения инструментов с цилиндрической передней поверхностью: дис. … канд. техн. Наук: 05.03.01. Тула, 2004. 188 с.
11. Манохин А. С., Клименко С. А. Силы резания при точении стали ШХ15 безвершинным инструментом из киборита. Процеси механічної обробки в машинобудуванні. 2010. № 8. С. 127–136.
12. Мельнийчук Ю. А., Клименко С. А., Манохин А. С. Влияние режимов обработки на силы резания при точении деталей из закаленной стали инструментом с цилиндрической передней поверхностью. Надійність інструменту та оптимізація технологічних систем. 2011. Вип. 28. С. 39−43.
13. Мельничук П. П., Глембоцька Л. Є. Моделювання силових залежностей при торцевому фрезеруванні. Вісник Тернопільського державного технічного університету. 2008. № 3. С. 78–87.
14. ГОСТ 24359-80. Фрезы торцовые насадные со вставными ножами, оснащенными пластинами из твердого сплава. Конструкция и размеры.
15. Hlembotska L., Melnychuk P., Balytska N., Melnyk O. Modelling the loading of the nose-free cutting edges of face mill with a spiral-stepped arrangement of inserts. Eastern-European Journal of Enterprise Technologies. 2018. № 1/1 (91). 2018. Pp. 46–54. https://doi.org/10.15587/1729-4061.2018.121712.

УДК 621.914

КОМП’ЮТЕРНЕ МОДЕЛЮВАННЯ СИЛОВОГО НАВАНТАЖЕННЯ НОЖІВ ТОРЦЕВИХ ФРЕЗ З ЦИЛІНДРИЧНОЮ ПЕРЕДНЬОЮ ПОВЕРХНЕЮ ПРИ РІЗАННІ ВАЖКООБРОБЛЮВАНИХ МАТЕРІАЛІВ

Лариса Глембоцька; Наталія Балицька; Петро Мельничук; Олександр Мельник

Державний університет «Житомирська політехніка», Житомир, Україна

Резюме. *Вирішено задачу визначення силових характеристик процесу торцевого фрезерування шляхом комп’ютерного моделювання в середовищі DEFORM 3D. Досліджено вплив форми передньої поверхні круглих ножів торцевих фрез на площу контакту стружки з передньою поверхнею ножа, умови стружковідведення, динамічні силові навантаження як під час входу ножів у заготовку, так і після врізування. Підтверджується доцільність використання ножів із циліндричною передньою поверхнею в конструкції торцевих фрез, оскільки це зумовлює зменшення площі контакту стружки з передньою поверхнею ножа та покращення умов стружковідведення, в результаті чого забезпечується зменшення динамічного силового навантаження на ножі, як у момент врізування в заготовку, так і під час різання. Оскільки застосування генераторної схеми різання для торцевих фрез з циліндричною передньою поверхнею ножів накладає обмеження по глибині різання, то для умов оброблення з глибиною різання понад 1 мм запропоновано ступінчасту схему різання. За допомогою комп’ютерного моделювання процесу фрезерування плоских поверхонь деталей із загартованої високоміцної сталі й титанового сплаву визначаються силові характеристики для умов роботи ступінчастою торцевою фрезою з циліндричною передньою поверхнею ножів та стандартною фрезою з круглими пластинами. Для ступінчастої фрези підтверджується зменшення як ударних навантажень під час врізування ножа, так і середніх значень складової* P_z *сили різання порівняно зі стандартною фрезою для різних оброблюваних матеріалів. Зменшення крутного моменту від дії складової* P_z *створює передумови до зменшення ефективної потужності привода головного руху верстата, що може бути використане для оброблення зі збільшеними глибинами різання на верстатах малої потужності. Це може бути ще одним напрямом підвищення ефективності торцевого фрезерування важкооброблюваних матеріалів.*

Ключові слова: *торцеве фрезерування, комп’ютерне моделювання, DEFORM 3D.*

https://doi.org/10.33108/visnyk_tntu2019.01.070 *Отримано 03.04.2019*