UDC 629.3.08 DOI: 10.30977/AT.2219-8342.2023.52.0.03

Technological methods of improving the quality and productivity of processing car engine parts

Kalchenko V.[1], Venzheha V.[1], Kuzhelnyi Ya[1], Klymenko V.[2]

[1]Chernihiv Polytechnic National University, Ukraine
[2]Kharkiv National Automobile and Highway University, Ukraine

Abstract. Problem. *The most high-precision parts of the car engine are camshaft and crankshaft, parts that require two-sided processing of the end surfaces: piston pins, valve springs. Traditional processing methods are used in their manufacture and repair. Therefore, taking into account the large volumes of car production, the improvement of existing and development of new processing methods is very important.* ***Goal.*** *The purpose of this work is the analysis and improvement of existing methods and the implementation for new ones of processing the specified parts to increase the productivity and accuracy of their processing.* ***Methodology****. The processing of support necks and cams is expedient to be carried out in one installation during deep high-speed grinding with crossed axes of the circle and camshaft due to stabilization of the cutting depth and feed along the contour with uneven rotation of the part. The method of high-speed milling of camshaft cams with crossed axes of the tool and parts on CNC machines is also promising. Root and connecting rod necks of crankshafts can be processed in one installation by deep high-speed grinding with crossed axes of the circle and the part due to stabilization of the depth of cutting and feed along the contour with uniform rotation of the part. For end surfaces, it is possible to introduce single-pass processing on double-sided end grinding machines with oriented grinding wheels with calibration areas.* ***Results.*** *The obtained results indicate a 25-30% increase in productivity and processing accuracy of the specified parts.* ***Originality.*** *It is used when processing the effect of the intersection of the axes of the tool and the part and carrying out a special correction of the tool, which allows to obtain a calibration area.* ***Practical value.*** *The proposed methods improve the parameters of accuracy, roughness and productivity of processing, which is an important scientific and practical task, whose solution will allow to increase the service life of car components and assemblies, reduce the cost of their production, and raise the level of competitiveness of products and services.*

Key words: *camshaft, crankshaft, piston pins, valve springs, high-speed milling, one-pass machining.*

Introduction

In the modern automotive industry, the requirements for the accuracy of machining of crankshafts and camshafts, which are widely used in automobile construction, tractor construction, shipbuilding, and other industries, are constantly increasing. At the same time, it is necessary to ensure high productivity of their processing, which requires the development of more effective universal methods of grinding parts. In conditions when the domestic engineering industry strives to become competitive and highly efficient, this problem acquires an important national economic significance. Research, improvement and implementation of new methods of grinding and high-speed milling with these parts can become one of the ways to solve this issue in a highly productive way while ensuring the high accuracy and quality of the processed surfaces.

Among the parts, a large group consists of parts that require high-precision two-sided processing of end surfaces. These are piston fingers, compression springs of clutch disks, semi-couplings, cardan shaft cross-pieces, coupling cross-pieces, rolling roller bearings, which require the processing of inner and outer rings and rollers. Increasing the accuracy and productivity of processing their end surfaces is an important scientific and practical task, the solution of which will allow both to increase the service life of nodes and aggregates, and to

make their products cheaper, and therefore to increase the level of competitiveness of products.

Analysis of publications

At domestic enterprises, the main and connecting rod necks are processed on machines of 3411, 3D4230, 3D4231, 3V423, LT-235 models of Kharkiv Machine-Building Plant "Harverst". Processing of all root necks on these machines is carried out in one facility in the circular grinding mode. Grinding each connecting rod neck requires re-installation of the crankshaft when its axis is aligned with the axis of rotation of the machine spindle. In case of reinstalling the crankshaft, an imbalance occurs, which re-quires its elimination, which reduces productivity.

For the first time, the Junker company (Germany) implemented the processing of the main and connecting rod necks in one institution [1, 2]. Processing of root necks is per-formed in the same way as on a circular grinding machine. When machining connecting rod necks, their contact with the circle occurs due to reciprocating movement in the plane that passes through the axis of rotation of the tool and the crankshaft, which ensures running-in of a neck in one revolution of the part.

In [3], based on three unified modules: tooling, orientation, and forming, a modular 3D modeling of tools, the process of allowance removal and forming during grinding with crossed axes of the crankshaft and wheel was carried out.

For the first time, the Junker company (Germany) implemented the processing of support necks and cams in one facility [4]. The processing of support necks is performed with a narrow circle, the height of which is less than its length, as on a circular grinding machine. When processing cams, contact with the circle occurs due to reciprocating movement in the plane that passes through the axis of rotation of the tool and the camshaft, which ensures the running-in of the cam in one revolution of the part.

In [5], based on six one-coordinate matrices, which describe movements along the X, Y, Z axes and rotations around them, 3D models of tools, the process of removing allowances and forming during the grinding of camshaft cams with crossed axes were developed shaft and grinding wheel.

Modernization of the VZ 208 F3 universal sharpening machine with CNC for high-speed milling of rotating surfaces was proposed in [6], and modular 3D modeling of tools, the process of allowance removal and forming during high-speed milling of cams with crossed axes of the tool and parts were carried out in work [7].

The company Saturn (Germany) [8] proposed processing on two-sided end-grinding machines of two ends of parts with a circular feed to the processing zone. Abrasive wheels without calibration areas are used, which re-quires multi-pass processing to obtain the necessary accuracy, which reduces the grinding performance.

The work [9] developed the theoretical foundations of one-pass two-sided processing of two ends with crossed axes of the grinding wheel and work pieces with the use of wheels specially profiled for this purpose.

Theoretical and experimental investigation of the process of two-sided grinding of the ends of parts with different diameters was carried out in [10].

Theoretical and experimental investigation of the process of two-sided grinding of round ends with oriented wheels with specially obtained calibration sections on grinding wheels that eliminate their error was carried out in work [11].

Purpose and Tasks

The purpose of this work is to increase the productivity and accuracy of processing of the main and connecting rod necks in one installation during deep high-speed grinding with crossed axes of the circle and the crankshaft due to the stabilization of the cutting depth and feed along the contour, as well as the support necks and cams of the camshaft , investigation of a new method of high-speed milling of cams of camshafts on CNC machines and grinding of end surfaces with crossed axes of the circle and work pieces using circles with calibration sections.

Processing of crankshaft

The processing of the main and connecting rod necks takes place in one installation during deep high-speed grinding with crossed axes of the circle and the crankshaft due to the stabilization of the cutting depth and feed along the contour with uniform rotation of the part.

This is achieved due to synchronous vertical and transverse movements of the grinding wheel when processing connecting rod necks.

With the new method of grinding after cut-ting, the rough allowance is removed by the end

of the circle, due to longitudinal movement, and the final grinding of the root and connecting rod necks is performed by the periphery.

With uniform rotation of the crankshaft 1 by an angle θ_d (see, Fig. 1, б) the point of contact 3 of circle 2 with detail 1 moves to an angle $\beta=\theta_d$ relative to the horizontal plane of the connecting rod neck 4. Due to the simultaneous vertical and transverse movements of the grinding wheel, a constant cutting depth t is ensured (see, Fig.1, a) (depth is equal to the allowance), feed along the contour and the area of the allowance to be removed. This increases productivity and processing quality. The contour feed is equal to

$$S_K = R_S \cdot \beta, \qquad (1)$$

where R_S – the radius of the connecting rod neck of the crankshaft (see, Fig 1, b), β – the angle between the contact points 3 and 3[1].

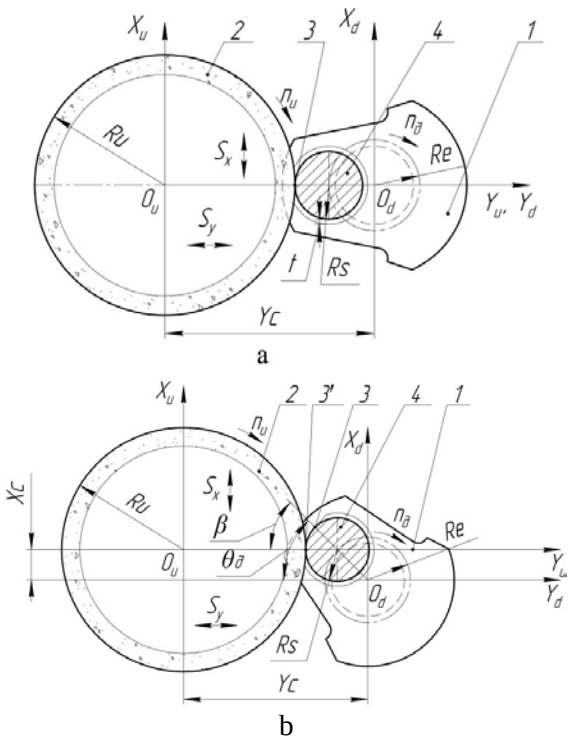

Fig. 1. Scheme of grinding connecting rod necks in a new way

This technique can be applied to the processes of grinding various cylindrical surfaces of a complex profile with crossed axes of the tool and the part.

Machining of camshaft cams

A new method of deep grinding of the camshaft with crossed axes of circle 2 and part 1 is proposed for processing cams of the camshaft, in which after cutting, the rough allowance is removed by the end of the circle, due to longitudinal movement, and fine grinding of the support necks and cams performed by the periphery, shown in Figure 2.

When the camshaft rotates, the contact point of the circle with the part moves due to the synchronous vertical and transverse movements of the tool. It is always located in a horizontal plane that passes through the axis of rotation of the circle and the center of curvature of the part, which ensures a constant depth of cutting along the contour. Uneven rotation stabilizes the supply along the contour compared to the method of processing with uniform rotation of the camshaft.

This allows to take into account only the shape of the part when grinding curved surfaces on CNC machines, excluding the influence of the radius of the tool and its wear on the accuracy of forming. The scheme of the process of high-speed milling of the camshaft 2, turned to an angle β by the tool 1 with cutting blades made of superhard materials, is presented in Figure 3.

The non-uniform rotation of the camshaft during cam milling stabilizes the removal of the allowance and the feed along the contour in the same way as the method of machining with uniform rotation.

This makes it possible to take into account only the shape of the part during milling, excluding the influence of the radius of the tool and its wear on the accuracy of forming, thanks to which the quality and productivity of processing increases.

Two-sided processing of end surfaces.

For two-sided processing of end surfaces, it is most appropriate to use two-sided end grinding semi-automatic machines, which require special settings for high-precision single-pass processing. The configuration scheme of the face grinding machine of 3342 ADO model for processing blanks is shown in Figure 4.

Grinding headstock 1 (see, Fig. 4) is oriented to the angles γ and ν in the horizontal and vertical planes. Abrasive wheel 2 is mounted on the grinding headstock and has a combined profile.

The central flat section 2.1 performs the main work of removing the allowance, and the peripheral section 2.2 is a calibration section, where the final accuracy of the processed surfaces is formed.

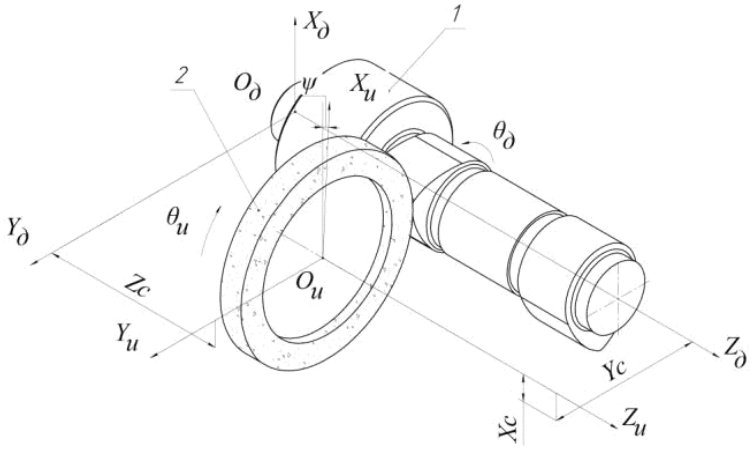

Fig. 2. Calculation scheme for grinding the camshaft

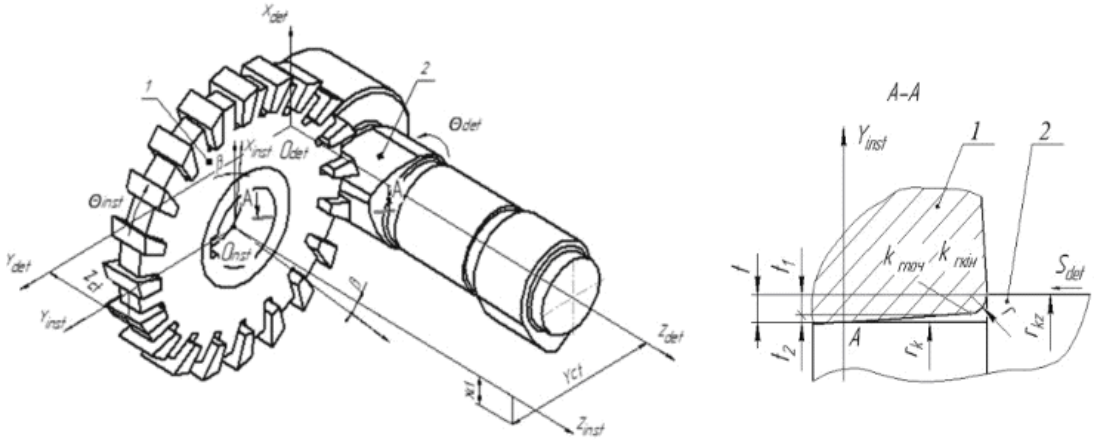

Fig. 3. Milling of the camshaft with crossed axes of the tool and the part

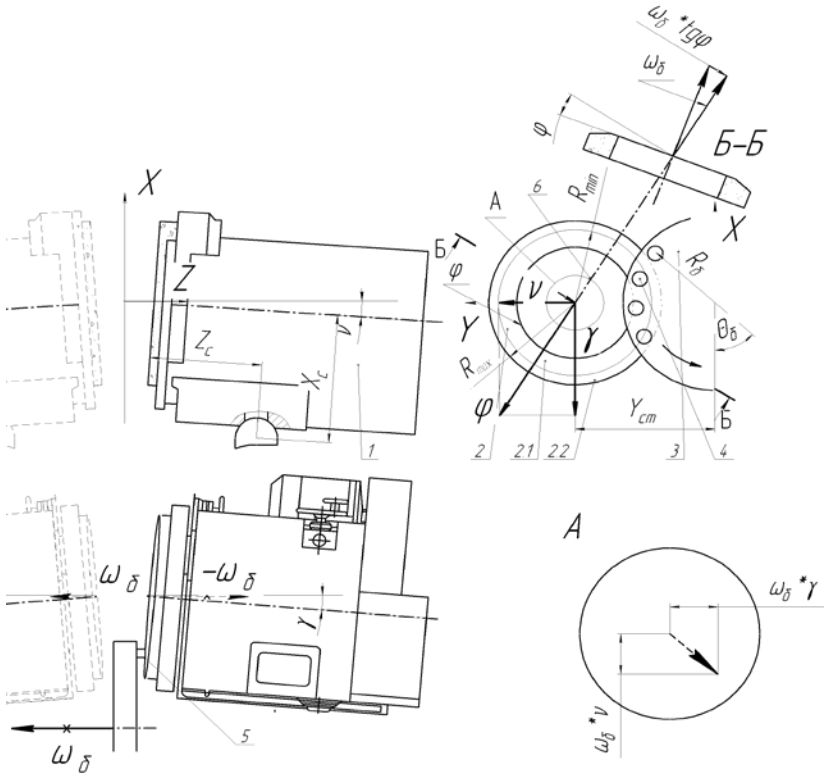

Fig. 4. The scheme for the processing of the double-sided face grinding machine 3342 ADO

Drum 3 serves for circular feeding of blanks to the processing area. It has holes 4 for placing blanks, in which a diamond pencil 5 for correcting circles can also be fixed. Line 6 defines the axis of total rotation of the grinding headstock.

Conclusions

A new method of grinding the main and connecting rod necks with the crossed axes of the crankshaft and the circle in one installation, and the support necks and cams of the camshaft, which provides stabilization of the cutting depth and feed along the contour, is proposed. At the same time, the cutting speed remains unchanged, which also contributes to improving the grinding conditions and increasing the accuracy and quality of the processed part. The proposed method of grinding curved surfaces on CNC machines, which takes into account only the shape of the part, excludes the influence of the radius of the tool and its wear on the accuracy of forming.

A new method of high-angle milling of cams on a modernized universal sharpening machine with CNC from a personal computer model В3208Ф4 by the periphery of an oriented tool with cutting elements made of ultra-hard materials was developed, which makes it possible to reduce the heat stress of the process, since the heat released under during processing, it is almost completely concentrated in the chip and does not stay for a long time in the processing zone, due to which the cutter and the part are little exposed to thermal influence. Surfaces of parts processed in this way have significantly smaller deviations from roundness, which brings this process closer to grinding.

A new method of two-sided processing of the end surfaces of car parts on two-sided end-grinding machines with a combined tool adjustment is proposed, which in the grinding work cycle distributes the entire allowance between the rough and finishing areas, increasing the working length of the contact arc of the parts with the wheel, which increases processing productivity, lowers the temperature in the processing zone. The high precision of the shape of the end of the part is formed on the calibration area at the exit from the processing zone.

References

1. Erwin Junker (2006) Grinding of crankshafts with cubic boron nitride wheelsю Junker maschinen prospectus for JUCRANK 1000, JUCRANK 3000, JUCRANK 5000, JUCRANK 6000 machines.
2. Erwin Junker (2012) CBN crankshaft grinding. Prospect firm «Junker maschinen» on machines «JUCRANK 1000», «JUCRANK 3000», «JUCRANK 5000», «JUCRANK 6S/L/XL».
3. Сіра, Н. М. (2017). Модульне 3d-моделювання інструментів, процесів зняття припуску та формоутворення під час шліфування зі схрещеними осями циліндричного вала й абразивного круга. *Технічні науки та технології,* 3(5), 67. Sira, N. M. (2017). Modulne 3d-modeliuvannia instrumentiv, protsesiv zniattia prypusku ta formoutvorennia pid chas shlifuvannia zi skhreshchenymy osiamy tsylindrychnoho vala y abrazyvnoho kruha. [Modular 3d-modeling of tools, processes of stock removal and shaping in grinding with crossed axes of cylindrical shaft and abrasive wheel] *Tekhnichni nauky ta tekhnolohii*, 3(5), 67. http://tst.stu.cn.ua/article/view/91588
4. Erwin Junker (2006) Grinding of camshafts with cubic boron nitride wheels. Junker maschinen prospectus for JUCAM 1000, JUCAM 3000, JUCAM 5000, JUCAM 6000 machines.
5. Кальченко В.І., Кальченко Д.В. (2013) Модульне 3D-моделювання інструментів, процесу зняття припуску та формоутворення при шліфуванні зі схрещеними осями ступінчастого вала і круга. *Вісник Чернігівського державного технологічного університету. Серія «Технічні науки»*.3 (67), 147-156. Kalchenko V.I., Kalchenko D.V. (2013) Modular 3D-modeling of tools, the process of removing the allowance and shaping during grinding with crossed axes of a stepped shaft and a wheel. *Bulletin of the Chernihiv State University of Technology. Series "Technical Sciences"*. 3 (67), 147-156.
6. Кальченко В.І., Кальченко В.В., Венжега В.І., Винник В.О. (2020) Модернізація універсально-заточувального верстата з ЧПК В3 208 Ф3 для високошвидкісного фрезерування поверхонь обертання. *Технічні науки та технології.* 1 (19), 9–17. Kalchenko V.I., Kalchenko V.V., Venzhega V.I., Vynnyk V.O. (2020) Modernization of the universal sharpening machine with CNC VZ 208 F3 for high-speed milling of rotating surfaces. *Technical sciences and technologies*. 1 (19), 9–17.
7. Слєднікова О.О., Винник В.О., Скляр В.М., Аксьонова О.О. (2020) Модульне 3D моделювання інструментів, процесу зняття припуску та формоутворення при фрезеруванні кулачків зі схрещеними

осями інструменту і деталі. *Технічні науки та технології* 2 (20), 27–34. Slednikova O.O., Vinnyk V.O., Sklyar V.M., Aksyonova O.O. (2020) Modular 3D modeling of tools, the process of allowance removal and forming when milling cams with crossed axes of the tool and the part. *Technical sciences and technologies*. 2 (20), 27–34.
8. Erwin Junker (2005) JUMAT – Rundschleifen. *Katalog «Junker maschinen»*.
9. Венжега В.І. (2009) Підвищення ефективності шліфування торців при схрещених осях деталі та круга з калібрувальною ділянкою: Дис. канд. техн. наук: Venzhega V.I. (2009) Increasing the efficiency of grinding the ends at crossed axes of the part and the circle with a calibration area: Diss. Ph.D. technical Sciences
10. Сіра Н.М., Кологойда А.В., Литвин О.О., Кальченко Д.В. (2018) Теоретичне та експериментальне дослідження процесу двостороннього шліфування торців деталей із різними діаметрами. *Науковий журнал «Вчені записки Таврійського національного університету імені В.І. Вернадського»*. 29 (68) 1, 19-26. Syra N.M., Kologoyda A.V., Lytvyn O.O., Kalchenko D.V. (2018) Theoretical and experimental study of the process of two-sided grinding of the ends of parts with different diameters. *Scientific journal "Scientific Notes of the Tavri National University named after V.I. Vernadsky"*. 29 (68). 1, 19-26.
11. Kalchenko D. (2018) Theoretical and experimental study of double-sided grinding process of round face ends by orientated wheels with calibrating sections. *Scientific Journal of TNTU. Manufacturing engineering and automated processes*.89(1), 100–112.

Kalchenko Volodymyr[1], DSci (Engineering), Professor of the Department of Automobile Transport and Sectoral Machine Building,
e-mail: vvkalchenko74@gmail.com
Phone: +38(095) 893-78-74
ORCID: http://orcid.org/0000-0002-9072-2976
Venzhega Volodymyr[1], PhD in Technical Sciences (Engineering), Associate Professor of the Department of Automobile Transport and Sectoral Machine Building,
e-mail: vivenzhega@gmail.com
Phone: +38(067) 851-62-70
ORCID: http://orcid.org/0000-0002-8857-349X
Kuzhelnyi Yaroslav[1], PhD in Technical Sciences (Engineering), Associate Professor of the Department of Automobile Transport and Sectoral Machine Building,
e-mail: k.y.v.immartal@gmail.com
Phone: +38(063) 720-44-70
ORCID: http://orcid.org/0000-0002-9850-7875
Klymenko Valeriy[2], DSci (Eng.), Prof., Head of Departament of Automobiles named after A.B. Gredeskul,
e-mail: valeriy.klimenko@gmail.com,
Phone.: +38(050) 845-65-29,
ORCID: http://orcid.org/0000-0002-7399-0397

[1]Chernihiv Polytechnic National University, 95, Shevchenka Str., Chernihiv, Ukraine, 14035.
[2]Kharkiv National Automobile and Highway University, Yaroslava Mudrogo str., 25, Kharkiv, Ukraine, 61002

Технологічні методи підвищення якості та продуктивності обробки деталей двигунів автомобілів

Анотація. Проблема. *Найбільш високоточними деталями двигуна автомобіля є розподільчий та колінчастий вали, деталі, що потребують двосторонньої обробки торцевих поверхонь: поршневі пальці, клапанні пружин. При їх виготовленні та ремонті використовуються традиційні методи обробки. Тому враховуючи великі обсяги виробництва автомобілів, вдосконалення існуючих та розробка нових способів має дуже важливе значення.* ***Мета.*** *Метою даної роботи є аналіз та вдосконалення існуючих та впровадження нових методів обробки вказаних деталей для підвищення продуктивності та точності їх обробки.* ***Методологія****. Обробку опорних шийок та кулачків доцільно проводити за один установ при глибинному високошвидкісному шліфуванні зі схрещеними осями круга і розподільчого вала за рахунок стабілізації глибини різання і подачі по контуру при нерівномірному обертанні деталі. Перспективним є також спосіб високошвидкісного фрезерування кулачків розподільчих валів зі схрещеними вісями інструмента і деталі на верстатах з ЧПК. Корінні та шатунні шийки колінчастих валів слід обробляти за один установ глибинним високошвидкісним шліфуванні зі схрещеними осями круга і колінчастого валу за рахунок стабілізації глибини різання і подачі по контуру при*

рівномірному обертанні деталі. Для торцевих поверхонь слід запровадити однопрохідну обробку на двосторонніх торцешліфувальних верстатах орієнтованими шліфувальними кругами з калібрувальними ділянками. ***Результат.*** *Отримані результати свідчать про підвищення продуктивності та точності обробки вказаних деталей на 25-30%.* ***Оригінальність.*** *Полягає у використанні при обробці ефекту схрещування осей інструменту та деталі та проведенні спеціальної правки інструменту, яка дозволяє отримувати калібрувальну ділянку.* ***Практичне значення.*** *Запропоновані способи покращують параметри точності, шорсткості та продуктивності обробки, що є важливою науково-практичною задачею, вирішення якої дозволить підвищити термін служби вузлів та агрегатів автомобіля, здешевити їх виробництво, підвищити рівень конкурентоспроможності продукції та послуг..*

Ключові слова: *розподільчий вал, колінчастий вал, поршневі пальці, клапанні пружини, високошвидкісне фрезерування, однопрохідна обробка.*

Кальченко Володимир Віталійович[1], д.т.н., проф. каф. автомобільного транспорту і галузевого машинобудування,
e-mail: vvkalchenko74@gmail.com ,
тел: +38(095) 893-78-74
ORCID: http://orcid.org/0000-0002-9072-2976
Венжега Володимир Іванович[1], к.т.н, доц. каф. автомобільного транспорту і галузевого машинобудування,
e-mail: vivenzhega@gmail.com,
тел: +38(067) 851-62-70
ORCID: http://orcid.org/0000-0002-8857-349X
Кужельний Ярослав Володимирович[1], к.т.н., доц. каф. автомобільного транспорту і галузевого машинобудування,
e-mail: k.y.v.immartal@gmail.com,
тел: +38(063) 720-44-70
ORCID: http://orcid.org/0000-0002-9850-7875
Клименко Валерій Іванович[2], д.т.н., проф., зав. кафедри автомобілів ім. А. Б. Гредескула,
e-mail: valeriy.klimenko@gmail.com,
тел.: +38(050) 845-65-29,
ORCID: http://orcid.org/0000-0002-7399-0397

[1]Національний університет «Чернігівська політехніка», 14035, Україна, м. Чернігів, вул. Шевченка, 95.
[2]Харківський національний автомобільно-дорожній університет, вул. Ярослава Мудрого, 25, м. Харків, Україна, 61002.