TEKA. COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE – 2015, Vol. 15, No.3, 35-40

3D-modelling and investigating of spinle's node of angular head for multyoperation tool

O. Krol, A. Khmelnitsky

Volodymyr Dahl East-Ukrainian National University, e-mail krolos@yandex.ru

Received June 15 2015: accepted August 29 2015

Summary. The solution of the problem of constructing three-dimensional models of the spindle node of multioperational machine tool for model SF68PF4, using the module APM FEM, integrated in CAD KOMPAS-3D. Estimations of the stress-strain state, allowing to identify ways to improve the design of two-bearing spindle node. The analysis features 3D-models applied conic gears with circular tooth.

Key words: spindle node, 3D-modeling, APM FEM, KOMPAS-3D, multioperation tool.

INTRODUCTION.

Effective Editors 3D-modeling machine tool put into practice. Recently progresses integrated CAD KOMPAS-3D [7, 8, 18], equipped with its own parameterization module and study of stress-strain state of APM FEM, using the finite element method. [13, 22].

Along with the geometric modeling necessary to conduct a comprehensive technical analysis of the designed object using the tools CAE-analysis, and implementation of complex calculations on strength and stiffness criteria. We need a program which gives an idea of the tense-deformed state shaping machine parts and assemblies. This software package is known for CAD/CAE system APM WinMachine [23, 24].

Starting with version KOMPAS-3D v.13 its structure integrated module APM FEM, are part of a single development environment and analysis with the use of associative geometry model, a single library materials and in common with KOMPAS-3D interface [5, 17].

The aim of this work is to improve the effectiveness of the procedures the study of feasibility of forming properties of products due to the construction of solid models spindles and evaluation of elastic-deformation characteristics spindles multioperational machines equipped with modular accessories.

PUBLICATION AND METHOD ANALYSIS

Spindle units as the final link main drive of the machine are evaluated on a set of criteria: load capacity, accuracy, rigidity and reliability. There are a number of works that use approximate and refined methods of calculation, based mainly on the use of matrix calculus algorithms and numerical methods of initial parameters. For spindles of machine tools known types of circuits that allow to represent them in the form of individual modules of machine while achieving reduction in design time [6, 12, 14]. The use of these schemes involves constant reference to the designer of automated directories (databases), containing relevant information: the templates spindles, bearings directories, reference materials and other standards of accuracy.

The most common view of the spindle assembly [2, 3, 4] and refined using approximate methods of calculation, considering it as a deformable linear system in which the movement of the spindle units is expressed as a linear function of the applied forces can not solve a complex task. The main differences multioperational machines formed by the presence of specific sites and the principle of their construction, without the usual "hard" kinematic relations between the nodes of the machine [9]. One of the most critical parts of multioperational machines spindle, which depends on the perfection level of competitiveness of the designed equipment.

OBJECTS AND PROBLEMS

The purpose of the work is an improvement of the process of the designing the multioperational machine tools on the base 3D-modeling and increasing level accounting procedures at estimation stress-deformed conditions.

THE MAIN SECTION

The effectiveness of the process of creating machine tools depends on the quality of the forming units [19, 20]. The spindle unit (SHU) is the executive unit of the support system of the machine has a decisive effect on the stiffness, vibration and performance of the machine itself. Evaluation of the accuracy of the spindle assembly is carried out taking into account the part that contributes to the overall SHU error handling. These studies have shown that the formation of indicators of the accuracy of relative position of surfaces and form accuracy influence spindle unit is 50 ... 80% and 60 ... 90 % in the general distribution of precision machine. To analyze the performance design, selection of the optimal variant of the project and study the finite element method created 3D-model of the machine tool SF68PF3 (Fig. 1) with an angular spindle head (Fig. 2) in the CAD KOMPAS-3D [10, 11, 20]. Angle head machine tool SF68 allows you to expand the technological capabilities of milling-boring machines. Angle head is used for processing the grooves and ledges arranged in confined areas blanks planes. It implements a high-frequency treatment at a rotational speed up to 4000 min^{-1} with the possibility of rotation angle of the spindle 360^{0} in a horizontal plane. Moving from vertical spindle to spindle head angle is transmitted through the bevel gear. The most typical operations carried out with an angle head is milling of planes, grooves and ledges end mill. This head is equipped with a standard size set of end mills with a diameter in the range of 3 ... 25 mm.

Spindle angle head is mounted on two supports:

Front - 3182108 bearing - double row radial roller with short cylindrical rollers with tapered bore inner rings. The direction of perceived loads - radial. Allow adjustment of the radial clearance. Bearing complies with GOST 7634-75.

Rear: - bearing 246205 - ball bearings double, the outer ring which face each other wide ends, contact angle α = 26º. The direction of perceived loads - radial and axial both sides.

Set of bearing locks the shaft and carcass in both the axial direction and provides a rigid fixation of the angular shaft than the corresponding bearing 346205. Bearing complies with GOST 832-78.

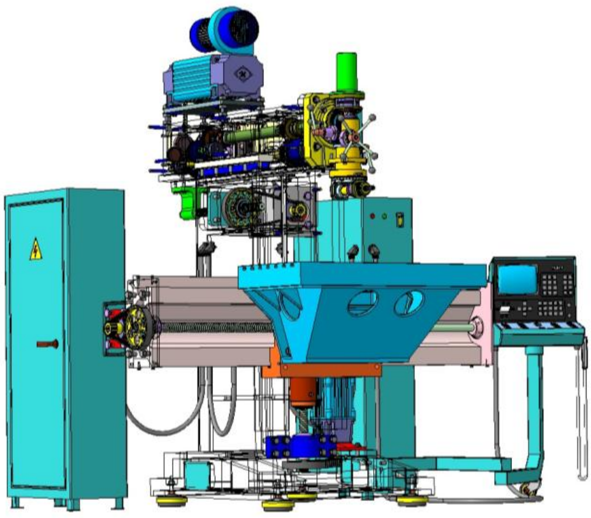

Fig. 1. 3D-model of the machine tool SF68PF3

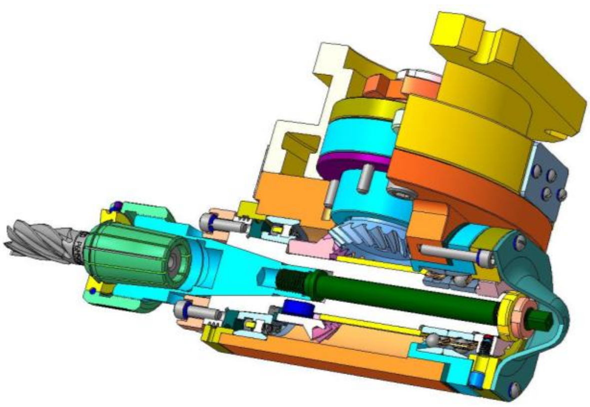

Fig. 2. 3D-model of the angular spindle head

In the process of constructing complex 3D-assembly was carried out construction of 3D-models of parts and assemblies belonging to the spindle (Fig. 3).

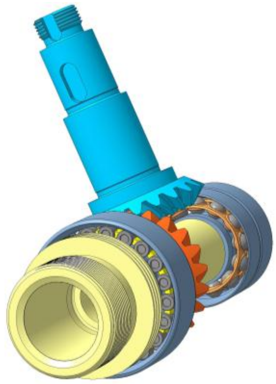

Fig. 3. 3D-model of parts and assemblies for the spindle

A comprehensive technical analysis of the stress-strain state of the machine spindle SF68 (Fig. 4a) is feasible with the help of the module APM FEM [18], equipped with a generator of finite element grid within the SAE - library that implements the solution of engineering problems using finite element method (FEM). The design process is carried out fixing the front and rear supports and set applied loads (4b); determined by matching edge (finite element analysis for the assembly); generates a finite element grid (Fig. 4c) by MT Frontal (c multi-core processor); calculates and viewing the results in the form of maps of stresses and displacements. In the course of the FEM it is possible to assess and analyze the partition at various depths of view (Fig. 4d).

The module APM FEM implemented all of the above actions and obtained:

- field Mises equivalent stress (the fourth strength theory) as shown in Fig. 6;
- the displacement field (Fig. 7) on the set of sections of the spindle;
- a safety factor of yield strength (Fig. 8).

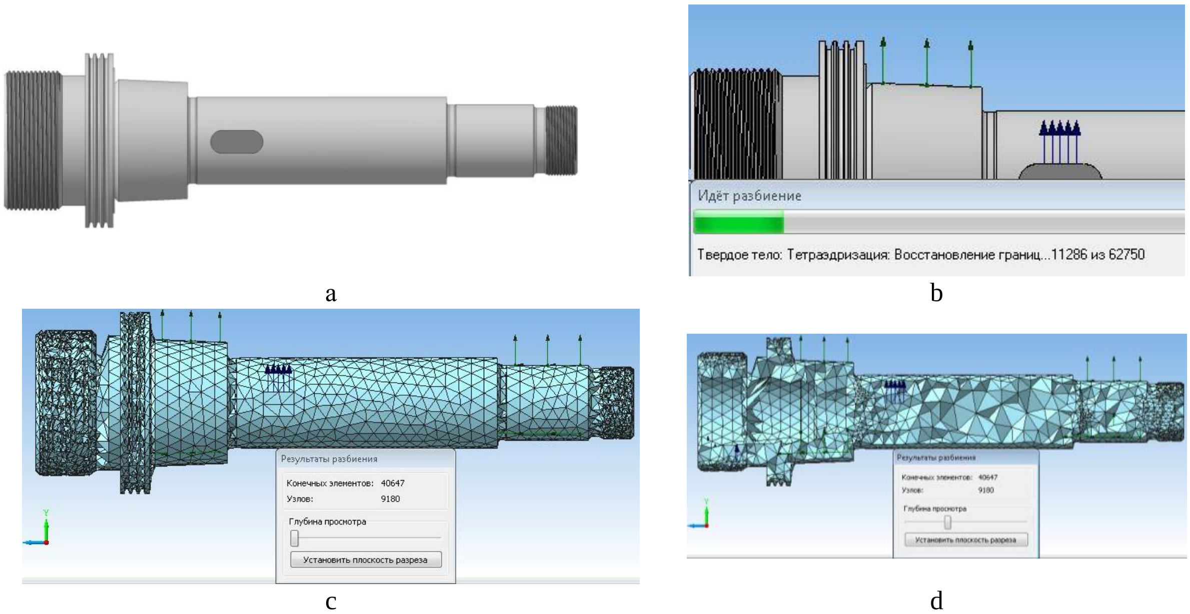

Fig. 4. Procedures for the finite element method: a – 3D - model of spindle, b – supports and loads acting on the spindle, c – finite-element grid, d – the depth of view

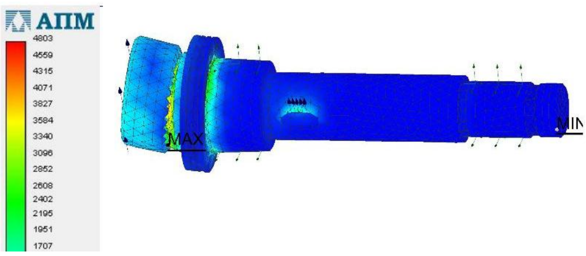

Fig. 6. Field Mises equivalent stress

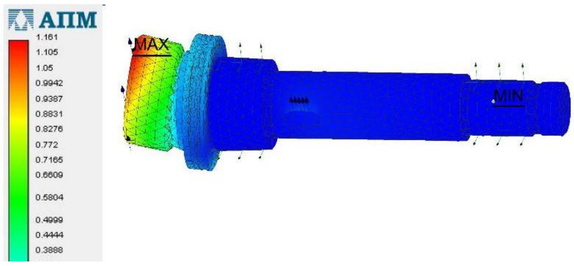

Fig. 7. The displacement field

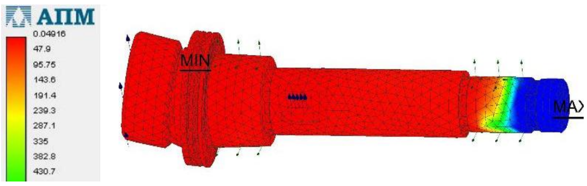

Fig. 8. Safety factor of yield strength

Features 3D - simulation gears

Modern CAD elements can simulate certain types of transmissions with sufficient accuracy visualization working surfaces (bevel gears, worms, pulleys, and so on.). In the simulation of bevel gears with circular tooth imaging is not complete - the teeth (or rather - cavity between them), the system does not generate, so these models are highly conditional [1, 15, 16]. For full 3D - model bevel gear with circular tooth must use other modeling techniques, one of which is shown below in Example KOMPAS-3D.

Profiling is carried out by cutting a tooth cavity, as is the case with the cutting teeth on the gear-cutting machines tool by removing material. Virtually cut is carried out on built and placed in the respective end section using the command "Cut cross-section element."

Thus it is necessary to take into account the following features circular teeth:

1. Along the cavity of the tooth is not stored geometric similarity profiles (cross-section is constantly changing in shape and size).

2. The trajectory is a spiral arrangement of sections of the surface, so the section occupied by complex spatial position.

The solution to this problem can be divided into the following stages:

1. Determination of the spatial position of face sections (planes on which they are based);

2. Calculation of additional geometric parameters of the gear, which is constructed on the basis of face sections;

3. The construction of cross-sections;

4. Actually cut.

For geometric constructions, as well as the calculation of the parameters of the equivalent cylindrical wheel must be known the following information defined in the standard geometrical calculations bevel wheel:

z - number of teeth of bevel gear;

δ - pitch cone angle of the conical wheels;

m_n - normal module;

β_n - pitch angle of the midline tooth bevel gear;

R - the mean cone distance;

h_a; h_f - the height of dividing head and legs of the tooth, respectively;

θ_a; θ_f - angle dividing heads and feet tooth bevel gear, respectively;

d_0 - diameter gear cutting head;

α_n - normal angle profile on the pitch circle of bevel gears with circular teeth.

The position of each section is determined by the cone distance R_x, having their value taken for each section. To obtain a surface cavity without sharp transitions between the sections, it is less than five sections.

In this outside section could be placed some distance from the ends of the ring bevel gear (2 … 5 mm), and the average computing section for convenience be positioned at the middle length of the taper of the distance R, then the parameters in this section are the average calculated for a conical wheel.

Positions of the planes, on which there are sketches of the cross sections determined by the points of intersection of the cylindrical surface (formed via the "surface extrusion") simulating the tool and having a corresponding diameter (d_0) and the position in space (with allowance β_n and spiral directions), and the surface of divider cone bevel gear.

Sketch of the cylindrical surface (circle) is built on the plane tangent to the pitch cone bevel gear. Circle is located so that at a point in the middle cone distance R (usually a mid ring gear) between the tangent to the circle at the point of the cone and passing through this point, forms an angle β_n (Fig. 9)

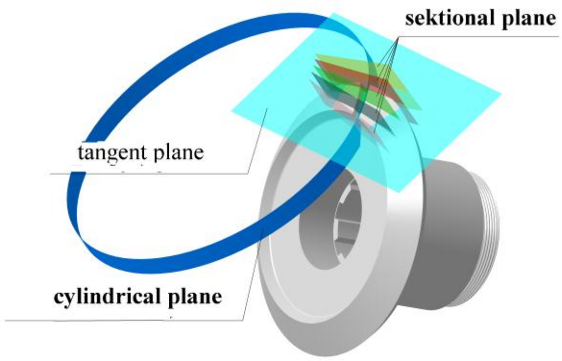

Fig. 9. Plane of section

Structural and geometric parameters of the equivalent cylindrical wheel are calculated for each section. Based on these data involute lining forming the side surface of a tooth in cross-section (Fig. 10).

The thickness of the tooth (to simplify calculations) is not calculated, and taken the graphical construction, based on the angular pitch of the equivalent cylindrical wheel. Experience has shown that when it is necessary to further expand the cavity by an amount approximately equal to the thickness of the upper allowance for the tooth bevel gear.

Structural and geometric parameters of the equivalent cylindrical wheel are calculated for each section. Based on these data involute lining forming the side surface of a tooth in cross-section (Fig. 10).

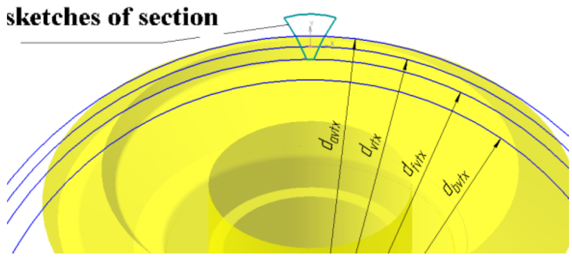

Fig. 10. Structural and geometric parameters

The thickness of the tooth (to simplify calculations) is not calculated, and taken the graphical construction, based on the angular pitch of the equivalent cylindrical wheel. Experience has shown that when it is necessary to further expand the cavity by an amount approximately equal to the thickness of the upper allowance for the tooth bevel gear.

After the construction of all sections used the command "Cut element on section" As a result, the hollow wheel is formed (Fig. 11). Then, using the command "array of concentric grid", the number of cavities is brought to the number z.

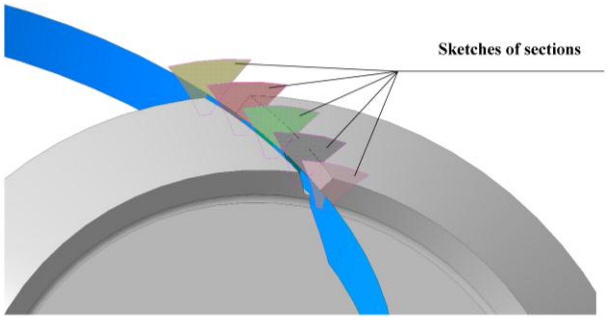

Fig. 11. Scetches of section

This method allows 3D - models of bevel gears with circular tooth with a high degree of similarity to the real wheels. Trench profiling described method has some simplicity and geometry errors, but they can be ignored, as they are sufficiently small and do not affect the visual perception of 3D - model (Fig. 12).

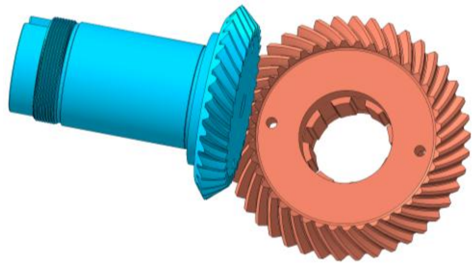

Fig. 12. 3D - models of bevel gears with circular tooth

CONCLUSIONS

1. A comprehensive study of the construction of a specialized vertical milling and drilling machine the second size models SF68PF3 using geometric modeling in CAD and engineering analysis KOMPAS designed object using the module APM FEM is realize.

2. Construct a 3D - model of the machine and its formative nodes in the system KOMPAS-3D, which gives a real idea of the design is the basis for design calculations and research performance of the machine.

3. The analysis features 3D-models applied conic gears with circular tooth is shown.

REFERENCES

1. **Andrijchuk N., Vyalikh A., Kovalenko A., Sokolov V. 2008.** Hydraulic and hydra-pnevmo drive. Textbook, East-Ukrainian National University named by V. Dahl, 320 (in Russian)
2. **Balasaniyan V.S., Vasiliev A.V., Figatner A.M. 1992.** The Bearings of spindle's nodes machining tool. Tool and instrument, 28-30.
3. **Balimont V.B., Gorelik I.G., Figatner A.M. 1987.** Calculations speediest spindle's nodes. Moskow, VNIITEMR, 52.
4. **Balimont, V.B., Zverev A.I. Danilichenko Y.M. 1987.** Mathematical modeling to accuracy of the rotation spindle's nodes. Moskow, Machine building, 154.
5. **Bulgakov V. 2012.** KOMPAS-3D V13 - the discharge is made! Main trends of SP1/V. Bulgakov// CAD and graphics, №1. 23-28.
6. **Bushuev V.V., Eremin A.A., Kakoilo A.A. 2012.** Machine tool: Book. Is.1, Moskow, Machine building, 608.
7. **Ganin N.B. 2012.** Three-dimensional designing in KOMPAS-3D. Moskow, DMK, 776.
8. **Ganin N.B. 2011.** Designing and calculation of strength in system KOMPAS-3D V13. Moskow, DMK, 320.
9. **Kolka I.A., Kuvshinskiy V.V. 1983.** Machine centre. Moskow, Machine building, 136.
10. **Krol O. 2013.** 3D-modeling of the rotary table for tool SVM1F4 with non - clearance worm gearing O. Krol, S. Shevchenko, I. Sukhorutchenko, A. Lysenko [Text] // TEKA Commision of Motorization and Energetic in Agriculture. –Vol.13. – № 4. – Lublin, Poland. 121-133.
11. **Krol O. 2013.** 3D-modeling and optimization spindle's nodes machining centre SVM1F4/ O. Krol, I. Sukhorutchenko [Text] // TEKA Commision of Motorization and Energetic in Agriculture. –Vol.13. – № 3. – Lublin, Poland. – 114-119.
12. **Kuznetsov Yu.N. 1990.** The Analysis of the dynamic system spindel - a patron - a detail of the turning automaton // Herald of machine building, 42-47.
13. **Magomedov A., Alekhin A. 2010.** Integrated finite element analysis in KOMPAS-3D/ A. Magomedov// CAD/CAM/CAE Observer, №8. – 32-36.
14. **Matalin A.A., Dashevskiy I.E., Knyazhitskiy I.M. 1974.** Machine centre. Moskow, Machine building, 320.
15. **Nosko P.L.,Breshev V.A., Fil H.V. 2010.** Structural synthesis and design variants for non-contact machine drives / Nosko Pavel and other //Commision of Motorization and Power Industry of Agriculture. Vol. XB, Lublin: 77-86.
16. **Nosko P.L., Breshev A.I., Fil H.V., Breshev V.A. 2010.** Developments in technology of non-contact drives for working machines / Nosko Pavel and other // Commision of Motorization and Power Industry of Agriculture. Vol. XC, Lublin: 209-216.
17. **Platonov L. 2012.** KOMPAS-3D as an effective tool in the hands of the designer/ L. Platonov// Equipment and tools for professionals, №2. – 21-27.
18. **Potemkin A. 2012.** How does Free-form-modeling in KOMPAS-3D V13/ A. Potemkin// CAD and graphics, №1, 48-54.
19. **Pronikov A.S., Borisov E.I. 1995.** Designing machine tool and machine systems: Reference book-textbook. In 3-h part. Is. 2. P. 1. Calculation and Designing nodes and element tool. Moskow, Machine building, 371.
20. **Push A.V. 1992.** Spindle's nodes. Quality and reliability.- Moskow, Machine building, 288.
21. **Push A.V., Zverev I.A. 2000.** Spindle's nodes. Designing and researching. Moskow, STANKIN, 197.
22. **Shelofast V.V. 2004.** Bases of the designing machine. Moskow, APM, 472.
23. **Shelofast V.V., Chugunova T.B.** The Bases of the designing the machines. Examples of the decision task. Moskow, APM, 472.
24. **Zamriy A.A. 2008.** Practical scholastic course CAD/CAE systems APM WinMachine. Moskow, APM, 144.
25. **Zverev A.I. 1988.** The Automatic calculation speediest spindle's nodes. Moskow, ENIMS. 153-157.

3-D МОДЕЛИРОВАНИЕ И ИССЛЕДОВАНИЕ ШПИНДЕЛЬНОГО УЗЛА УГЛОВОЙ ГОЛОВКИ МНОГООПЕРАЦИОННОГО СТАНКА

О. Кроль, А. Хмельницкий

Аннотация. Приведено решение задачи построения трехмерных моделей шпиндельного узла многооперационного станка модели СФ68ПФ4, с использованием модуля APM FEM, интегрированного в САПР КОМПАС-3D. Получены оценки напряженно-деформированного состояния, позволяющие наметить пути совершенствования конструкции двухопорного шпиндельного узла.

Отмечена особенность 3D-моделирования при проектировании и расчете конических передач с круговым зубом.

Ключевые слова: угловая головка, шпиндельный узел, твердотельная модель, САПР КОМПАС, модуль APM FEM.