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3D-modeling of the rotary table for tool SVM1F4 with non - clearance worm gearing

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Summary. Procedure of the building 3D- models of the rotary table for feed's drive the tool SVM1F4 with vertical and horizontal axis's of the rotation in system KOMPAS - 3D is realized.
The offered design non - clearance worm gearing with zeroizing lateral clearance and is completed its calculation in module APM Trans. Complex calculation tense-deformed conditions worm by method final element is executed in module APM FEM, integrated in CAD KOMPAS - 3D.
Key words: rotary table, worm gearing, non – clearance, 3D-model, equivalent stress.

INTRODUCTION

For automated manipulation workpiece and cutting instrument of the different sizes and the forms in machining centre with NC use the additional elements, supplied mounting base: pallets, device satellite, rotary and pulsing tables [3, 4, 15].

In condition production all greater amount standard size tool and constant change to configuration of the processed details perspective is a designing and production of the table range of the rotary tables, equipped hydro mechanical drive [16, 17].

PUBLICATION AND METHOD ANALYSIS

The rotary table renders the significant influence upon softness and accuracy of the positioning tool [1, 21]. The calculation of the balance to relative softness of the carrier system (NS) tool SVM1F4 has shown that workpiece and its springy relationship with rotary table form before 22% (from the general softness NS) under loading power of the weight of the nodes and loading in zone of the processing equal 10000 N on all three coordinates (X, Y, Z) [21]. Relative softness of the table rotary before 36%, but springy relationship of the table rotary with crusade table before 10% under the same condition loading.

Accuracy of the positioning the table is connected with reduction clearance in worm gearing of the drive of the table, caused by their wear-out in process of the usages.

The questions to geometries, kinematics, strenght of the worm gearing with cylindrical worm have found the reflections in multiple publication. So, in work [9, 13, 22] are stated general questions to geometries and kinematics of the worm gearing. The contact lines, curvatures worker surfaces and localization of the contact were considered in works [14, 19, 20, 23]. The problems of increasing to load rating capacity and efficiency worm gearing discussed in study [2, 7, 10, 12]. The problem of the exception of the disadvantage zones of the gear-tooth is dedicated to work [11].

However specified studies pertained to worm gearing with specified lateral and radial clearance in gear-tooth. In persisting article are stated some results of the study non clearance worm gearing with reference to metalcutting tool, where is required synchronizing the rotations worm and wheel, including, at reversing.

Together with that for realization complex calculation main element of the drive of the rotary table necessary using developed toolbox of the modern systems by designing with use the final element method for full belief about field of the stress and displacement in space 3D [18, 24].

OBJECTS AND PROBLEMS

The purpose of the work is an improvement of the process of the designing the rotary tables with non clearance worm gearing on the base 3D-modeling and increasing level accounting procedures at estimation stress-deformed conditions.

THE MAIN SECTION

The most important requirements to unit, realizing moving the presenting in multi-objective tool is [15]:

- high (before 2 nm) accuracy positioning the rotary table when use the systems to correction,
- accuracy of the reversing, for ensuring the dynamic compensation of inaccuracy,
- a realization minimum (before 5 nm) of the pulsed displacement,
- a reduction outraging influence from drive, including source to energy, before possible value.

In specialized vertical multi-objective tool with NC models SVM1F4, the instrument equiped by automatic change and rotary table is realized performing the large number different technological operation without reset up of the processed details.

The table rotary operated executed in the manner of independent node, set up on table tool in two positions with vertical and horizontal axis, depending on locations processed to surfaces. In CAD KOMPAS [5, 6] is built by 3D-model of the rotary table consisting of more than 300 details (Fig.1).

The table consists of housing, in which is found worm pair, sending motion from high torque of the engine on executive organ – face plate. Table rotary management is realized by means of NC through circular detector (indutoksin). Rotating face plate on given corner is checked by optical sensor, set up on vertical axis of the rotary table. Fastening the details to table rotary is produced on T-slot. Change worker's velocities face plate table rotary is produced is smoothness within from 0,1 before 3,5 min^{-1}, speed displacement forms 6,5 min^{-1}. In the event of location of the table rotary with horizontal axis for maintenance console located detail is used tailstock.

For increasing of accuracy of the basing worm wheel about in drive of the rotary table it is not enough to use only one cone-shaped fit surface. Necessary also to provide basing on face. For ensuring the synchronizing worm and worm's wheel about necessary to realize the design an non clearance worm gearing. The article is offered one of the variant of the decision of this problem.

Zeroizing lateral clearance in worm tooth gearing by possible by offsets worm toward, parallel axis's worm wheel (Fig. 2).

Herewith in contact will be simultaneously both sides of the wrap of worm with surface two nearby teeth worm's wheel. We shall consider got thereby non clearance worm gearing in two aspects - geometric and power. For determination of the value of the shift of worm - U, is used accounting scheme, submitted for Fig. 3.

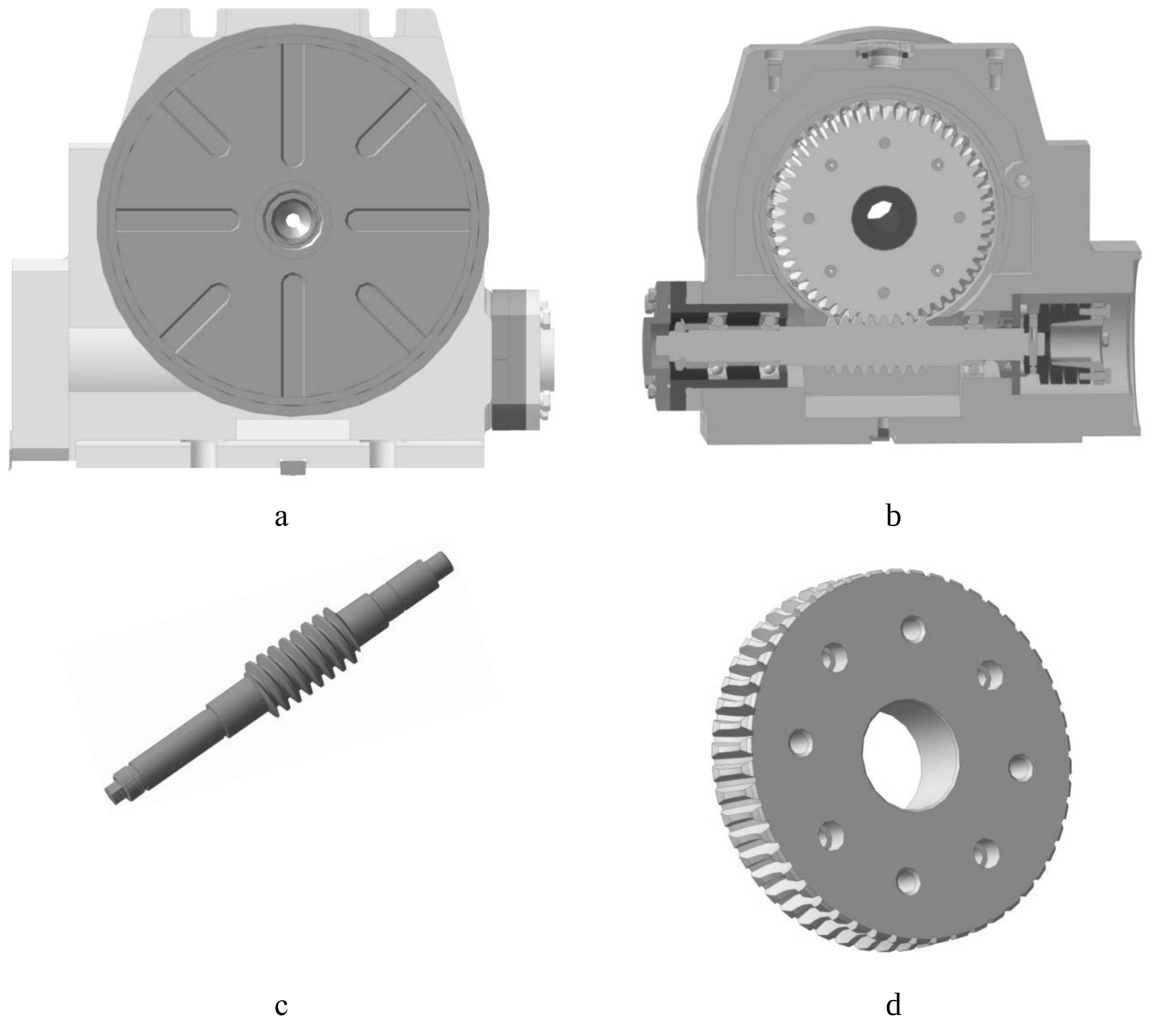


Fig. 1. 3D-model rotary table:
a – principal view, b-sectional view of table,
c – worm shaft, d – worm wheel

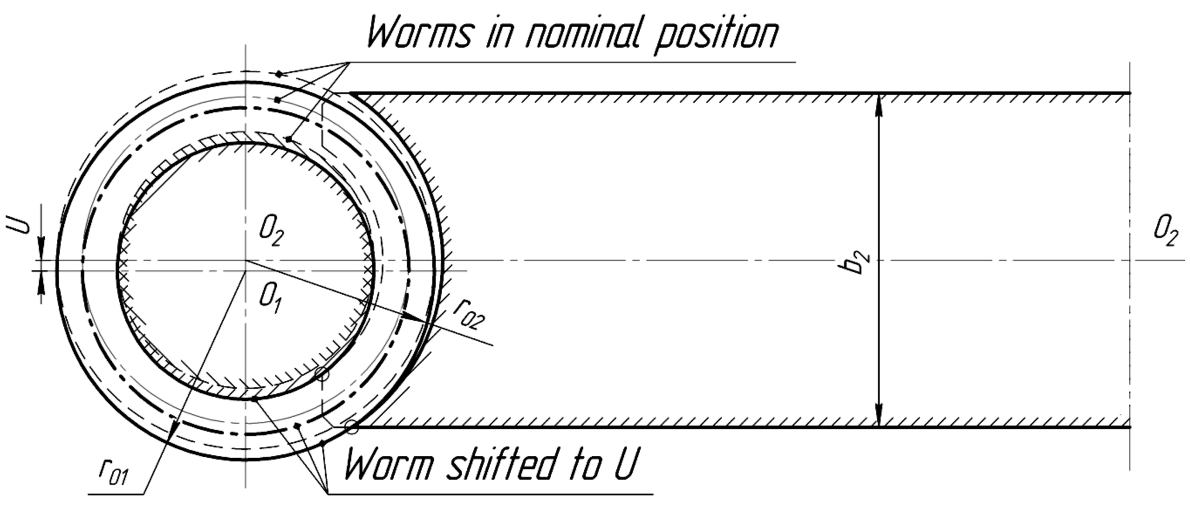


Fig. 2. Design gearing with zeroizing lateral clearance

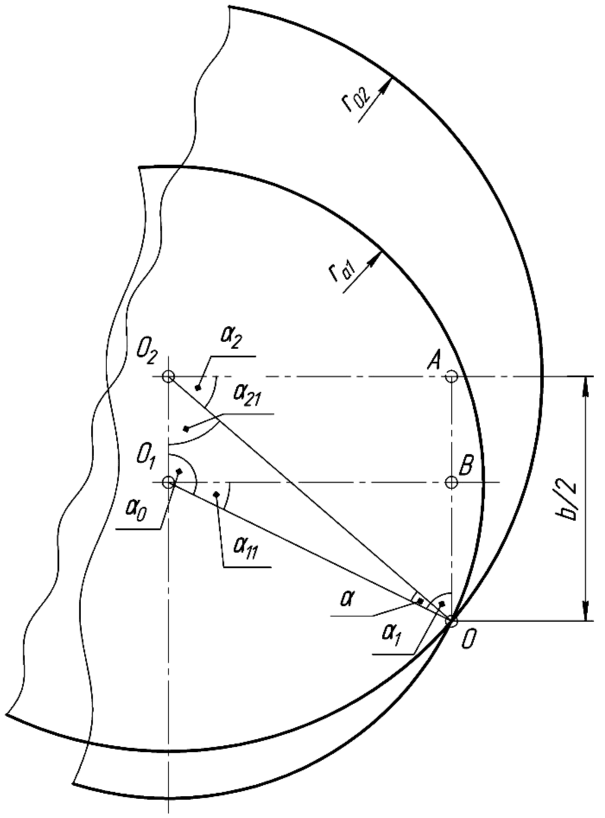


Fig. 3. To determination of the shift of worm

For clarity elements gearing - a correlation between radius r_{a1} and $r_{02} = r_{a1} + \Delta$, ($\Delta = 0{,}2 \cdot m$ – a radial clearance), are given not in that proportion, which exist in real gearing (the values u and α_1 on fig. 3, were practically not discernible). The known are: $r_{a1} = 0{,}5 \cdot m \cdot (q+2)$ – a radius of the tops whorl worm, $r_{02} = r_{a1} + \Delta = m \cdot [0{,}5 \cdot (q+2) + 0{,}2]$ – a radius of the arc to circumferences, outlining tops teeth wheel about in axis section, $b_2 \le 1{,}5 \cdot r_{a1} = 0{,}75 \cdot m \cdot (q+2)$ – a width ring worm wheel, (m and q – a module and coefficient of the diameter worm). From ΔO_2OA follows that:

$$\alpha = \arcsin\left(\frac{b_2/2}{r_{02}}\right).$$

From ΔO_1BO:

$$\alpha_1 = \arccos\left[\frac{\sqrt{r_{02}^2 - (b_2/2)^2}}{r_{a1}}\right], \quad \alpha_{11} = \pi/2 - \alpha_1.$$

follows that

$$\alpha_0 = \pi/2 + \alpha_{11} = \pi - \alpha_1, \quad \alpha_{21} = \pi/2 - \alpha_2.$$

From ΔO_2O_1O:

$$\alpha = \pi - (\alpha_0 + \alpha_{21}) = \alpha_1 + \alpha_2 - \pi/2.$$

As a result, from ΔO_2O_1O, where known two sides – r_{a1} и r_{02}, as well as corner between them α, is found sought shift worm:

$$u = \sqrt{r_{a1}^2 + r_{02}^2 - 2 \cdot r_{a1} \cdot r_{02} \cdot \cos\alpha}. \qquad (1)$$

Calculations on dependencies (1) for worm gearing with different parameter of the tooth system have shown that

$$u/d_1 \approx 0{,}02...0{,}03,$$

that is to say, for forming non clearance gearing it is enough to provide the possibility of the shift worm parallel axis wheel on value , equal 2… 3% from its reference diameter.

Naturally that worm must be in displaced position at action of the external loads. Under determined direction of tangential force on worm F_{t1} worm will try to return in non shift position (the dotted scene on Fig. 2). This will bring about appearance clearance in gearing that break accuracy to synchronizing the rotation worm and wheel. Counteract such shift can springs of the compression, installed in plain support of the worm's shaft. The efforts of the springs $F_П$ calculate from condition of the balance of the system of power, expressed on Fig. 4.

On condition of the balance of force: $2 \cdot F_П + G = F_{t1}$, whence

$$F_П \ge (F_{t1} - G)/2, \text{ N}.$$

After transformations, shall get

$$F_П \ge T_2 \cdot \frac{tg(\gamma + \varphi')}{d_2} - \frac{G}{2}, \text{ N}, \qquad (2)$$

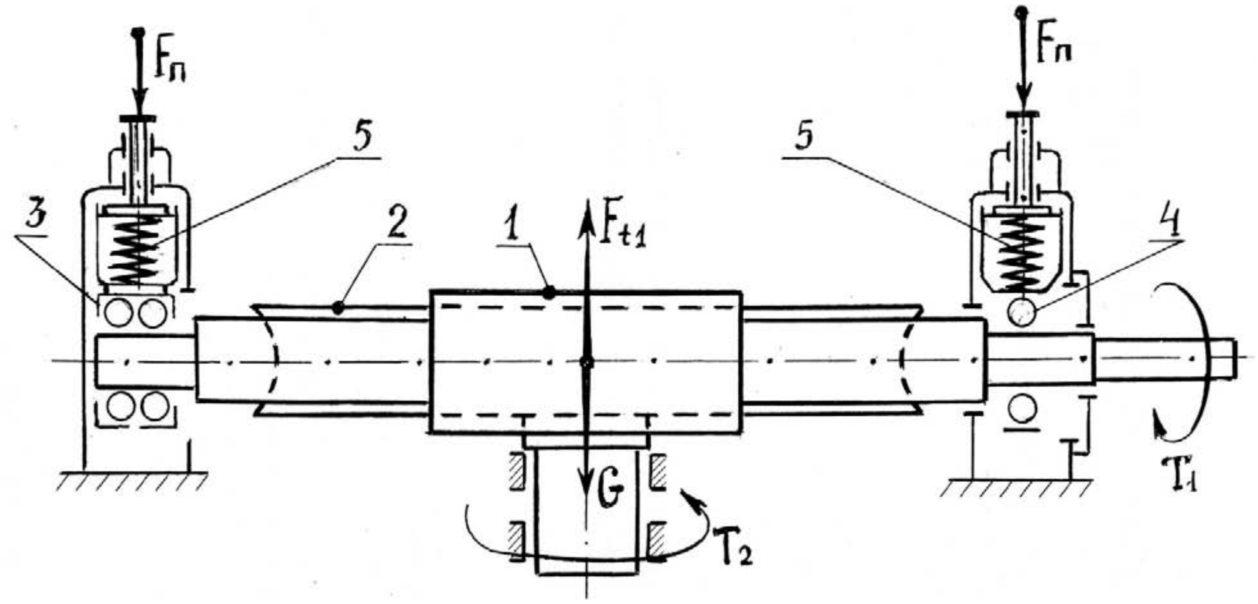


Fig. 4. To calculation of power of the compression of the springs: 1 – worm, 2 – worm wheel, 3 and 4 – a bearings in plain supports of the shaft of worm, which compression the spring 5, T_1 *and* T_2 – a rotating moments on shaft of worm and wheel, G – a weight of the shaft of worm in assembly

$d_2 = m \cdot z_2$ – reference diameter worm wheel, m, $\gamma = arctg(z_1 / q)$ – reference corner of the ascent wrap worm, grad,

φ' – adduction corner of friction in tooth system, grad.

$$\eta \approx tg\gamma / tg(\gamma + \varphi').$$

$$F_{\Pi} \geq T_2 \cdot \frac{tg\gamma}{d_2 \cdot \eta} - \frac{G}{2}. \quad (3)$$

At conclusion of the correlation (2) is used approximate variant calculation efficiency worm pair:

$$\eta = \frac{tg\gamma}{tg(\gamma + \varphi')} - \frac{\pi}{2} \cdot f_{np} \cdot \frac{\varepsilon_S}{z_2},$$

here: $f_{np} = B - C \cdot V_S$ – adduction factor of friction at swing teeth on wrap, B and C – on [1],

$$\varepsilon_S = \sqrt{[0{,}17 \cdot z_2 + 0{,}34 \cdot (x+1)]^2 - (0{,}16 \cdot z_2)^2} - $$
$$- 0{,}058 \cdot z_2 + 1{,}01 \cdot (1 - x),$$

- a factor of the overlapping of the worm gearing in average face of the planes wheel, (x – a factor of the shift worm).

The calculations show that elaborated variant (3) differs from drawn near variant (2) not more, than on 5… 6%.

For tool SVM1F4, where rotation of the table is realized by worm gearing with parameter:

$$a_W = 98\ mm,\ m = 3{,}15\ mm,\ q = 12{,}5,$$
$$z_1 / z_2 = 1/50,\ x = 0,\ b_2 = 34\ mm,$$

shift u and required power of the spring take value:

$$u = 0{,}824\,mm,\ accounts\ \ for$$
$$2{,}1\%\ \ from\ d_1 = 39{,}375\ mm,$$
$$F_{\Pi} \approx 156\ H.$$

Extended design calculation of the worm gearing (WG) shall realize in module of the designing the mechanical gearing of the rotation APM Trans [8, 24]. Under given external load, material worm and wheel, type thermal treatment shall define the main geometric parameters of the gearing: power, acting in her, parameters of the checking the position of the lateral surfaces, as well as tolerances and fit in tooth system (Fig. 5).

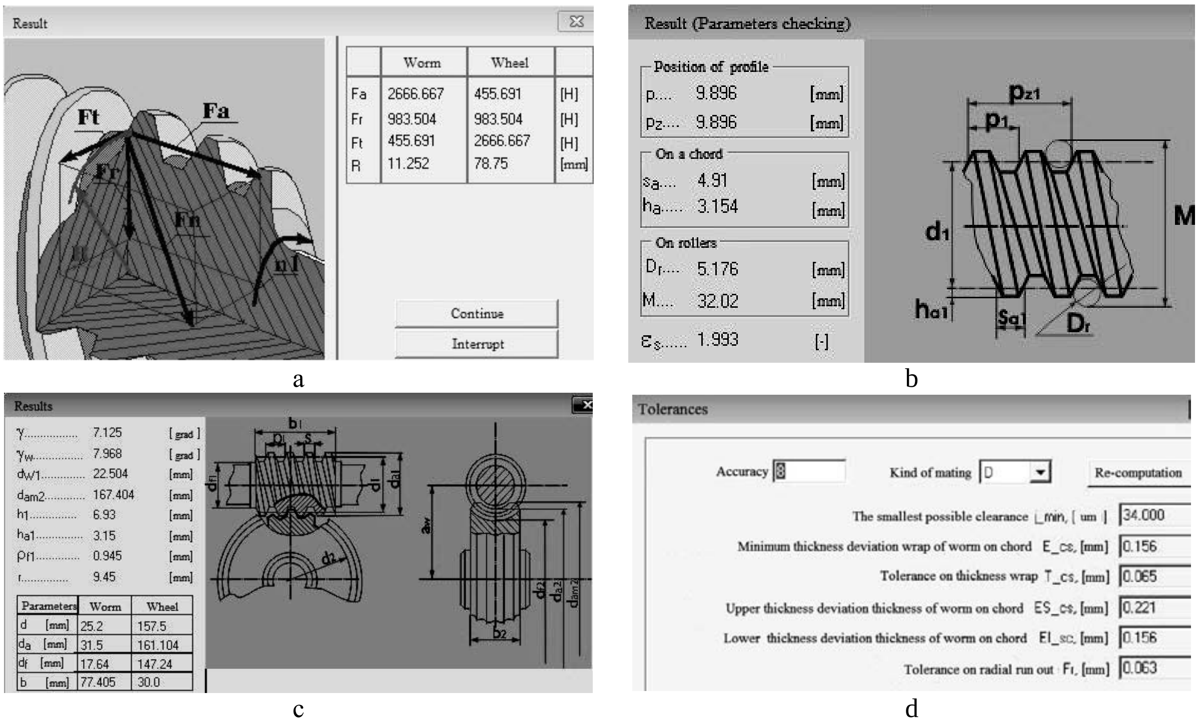
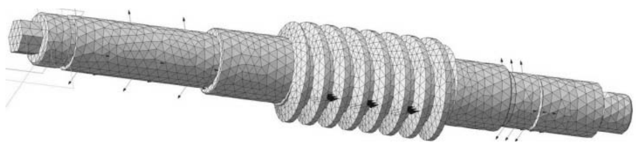


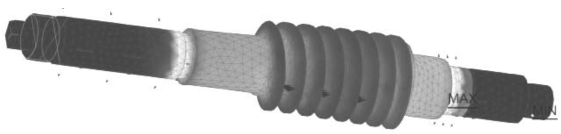
Fig. 5. The results of the calculation WG in module APM Trans: a – force in tooth system, b – a parameters of the checking, c – a geometric parameters, d – a tolerances in tooth system

Name	Value
Maximum length sides element, mm	5
Maximum factor thickenings on surfaces	1
Factor rarefy in volume	1,5
Quantity final element	11515
Quantity nodes	3430

a



b



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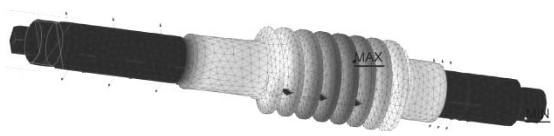

d

Fig. 6. Result of FEM-analysis: a – characteristic separate into final element, b – finite element grid, c – field of stress, d – field of displacement

For more full description to geometries to designs of the worm gearing, kind, attached to her loads and characteristic of the material to designs is used finite element method. Herewith continuum medium of the under investigation object is prototyped by partition it on final elements, in each of which behavior of this medium is described by means of separate set chosen function (satisfying condition to continuity), presenting itself displacement in specified area.

At study of the designs worm facility APM FEM [24] and buildings finite-element grid (Fig. 6,b), number finite element has formed 11515, and number of the nodes for rod element more than 3000 (Fig. 6, a).

In system APM WinMachine as finite element is used rod element, each of two nodes which has 6 degrees of freedom. The interaction finite element is with each other realized through their nodes on determined law, with provision for which is formed matrix to stiffness, which is reduced to system of the algebraic equations, both separate finite element, and designs as a whole. The joint decision of the got systems of the equations is realized searching for of the values of displacement (Fig. 6, d) and values of the stress (Fig. 6, c) , which will exist in each of final element of the designs. The most further summation result from separate finite element is defined and the general deformation to designs in different directions, and deformation separate its element, and appearing internal stress in separate its parts.

CONCLUSION

1. Complex research to designs rotary table specialized vertical multi-objective tool with NC models SVM1F4 with use 3D modeling CAD KOMPAS and engineering analysis of the construction with use finite element method are realize.

2. 3D-model of the rotary table with non clearance in system KOMPAS-3D, giving real belief about designs is built.

3. By means of module APM FEM is realized calculation of the values of the stress and deformation in any point of the designs, as with provision for influences external load, so and with provision for own weight each of element.

4. Calculation rod element to lead with provision for all concentrator of the stress that allows more exactly define the values acting stress. The broad spectrum of the possibilities of the module APM FEM allows greatly to perfect the quality of the designing element drive tool, vastly reduce the weight to designs, consequently and reduce its cost. With use of this module possible to design near-by to equal strength on criterion of strength and stiffness.

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3D-МОДЕЛИРОВАНИЕ ПОВОРОТНОГО СТОЛА СТАНКА МОДЕЛИ СВМ1Ф4 С БЕЗЗАЗОРНОЙ ЧЕРВЯЧНОЙ ПЕРЕДАЧЕЙ

Олег Кроль, Святослав Шевченко,
Иван Сухорутченко, Андрей Лысенко

Аннотация. Реализована процедура построения 3D- модели поворотного стола привода подач станка СВМ1Ф4 с вертикальной и горизонтальной осями вращения в системе КОМПАС - 3D.
Предложена конструкция беззазорной червячной передачи с обнулением боковых зазоров и осуществлен ее расчет в модуле APM Trans. Выполнен комплексный расчет напряженно-деформированного состояния червяка методом конечных элементов в модуле APM FEM, интегрированного в САПР КОМПАС - 3D.
Ключевые слова: поворотный стол, беззазорная передача, эквивалентное напряжение, 3D-моделирование.