3D-modeling and optimization spindle's node machining centre SVM1F4

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S u m m a r y . The considered procedure of the building 3D- models spindle's heads with mechanism of the grip of the instrument and hydraulics block for orientation of the spindle in process of the change the instrument.
Stated problem of searching for of the optimum correlation parameter cantilever and interlinear support of the parts of the spindle specialized machining centre, providing maximum stiffness of the designed node
K e y w o r d s : machining centre, spindle's nodes , cantilever part, stiffness, 3D-modeling.

INTRODUCTION

Spindle's nodes (SN) is one of the main element processing centre, in significant measure defining accuracy and capacity of the process of the processing. Constant searching for of the new decisions for achievement of the high technical-economic factors brings about frequent change the models processing centre. So creators of the new technology must use all achievements in the field of analysis trend developments, 3D- modeling and optimization part of designed tool.

PUBLICATION AND METHOD ANALYSIS

Efficiency of the process of the creation machining tool depends on level quality formative nodes [1, 7, 9, 17]. Spindle's node (SN) being executive organ of the carryinging system machining centre, renders the solving influence upon stiffness, vibration resistance and capacity tool as a whole [2, 13, 14, 20]. The Estimation to accuracy spindle's node is realized with provision for that part, which contributes SN in total inaccuracy of the processing [12, 14]. These studies have shown that in shaping the factors to accuracy of the mutual location of the surfaces and accuracy of the form influence шпиндельного of the node forms accordingly 50... 80% and 60… 90 in general distribution to accuracy tool.

The Known work [3, 4], denoted consideration formative nodes tool as complex mechanical systems by means of complex of the models, including:

- elastisticity-deformation, defining loads, deformation and stiffness SN;
- dynamic, defining own frequencies and transmission functions of the system;
- vibratory, defining amplitude spectrum of the velocities and displacement.

But all these models considered SN in 2D-format and did not give the full belief about field of the stress and displacement in space 3D and did not expect use the FEM- method.

On the other hand work [10, 11] use technologies and toolbox 3D-modeling without consideration of the procedures of the taking the optimum decisions.

OBJECTS AND PROBLEMS

The purpose given work is increasing to level of the procedure of the designing formative nodes to account of the building unified solid and analytical models for optimization constructive parameters of spindle's nodes machining centre and finding the best relation between its cantilever and interlinear support parts.

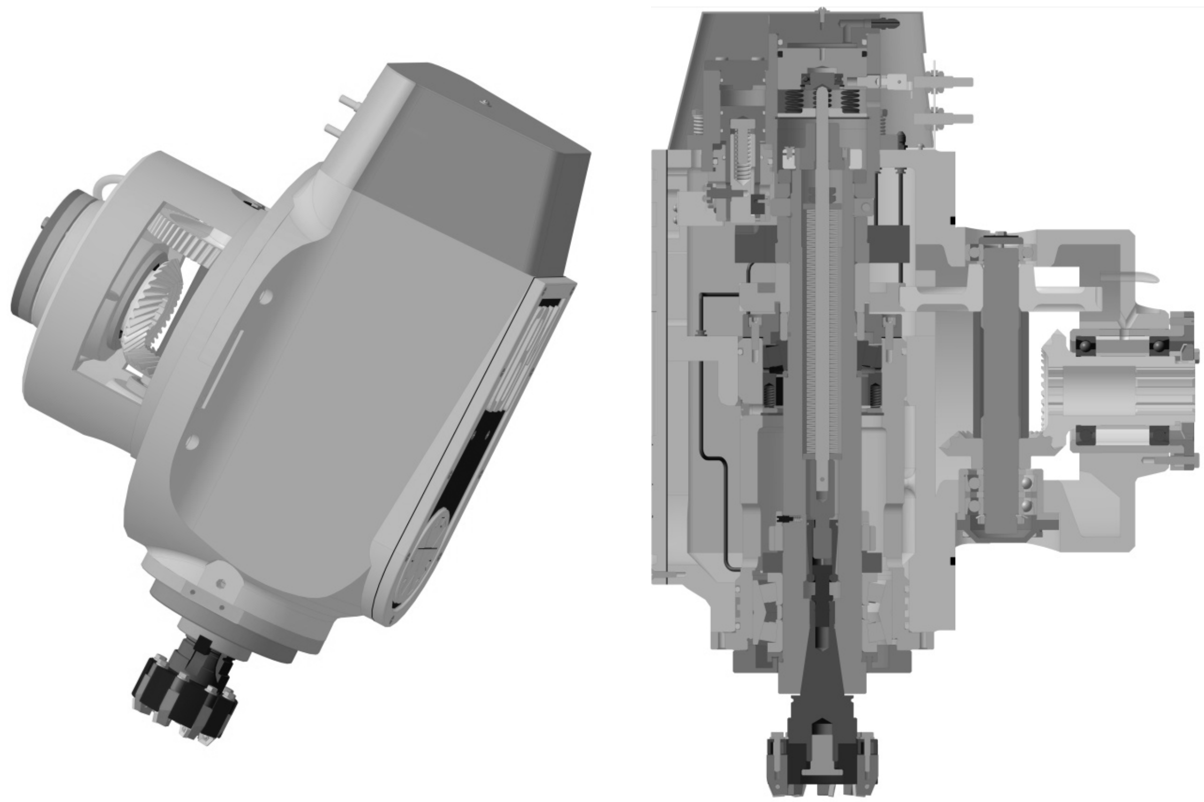
THE MAIN SECTION

Modeling spindles node shall consider on example vertical multiprocessing tool with automatic change the instrument to models SVM1F4, which is intended for large powered processing the gamma of the details from ferrous, alloying and light metals. He is equipped operated by additional thumb table, used for rotary indexing of the work, as well as for processing the details with constant or variable circular feed. The main unit, specifying efficiency and accuracy of the processing is spindles head with mechanism of the clamp of the instrument, equipped hydraulics block, intended for orientation of the spindle in process of the change the instrument.

Increasing of the requirements to increase of accuracy and quality of the processing does necessary undertaking the complex calculation stress-deformed conditions of the spindle, as the main formative node spindles heads. Efficiency of such calculation depends on full nesses 3D-presentations in system KOMPAS-3D [5, 6].

In process of the study is built solid model spindle's heads (fig.1) and two support spindle's node (fig.2). In lower bearing of the spindle is installed high accuracy radial-thrust dual in-line cone-shaped roller bearing, which perceives radial and two-way axial loads and is characterized by possible radial load in 1,7 times above, than beside corresponding to single-in-line bearing [2]. Except this, he provides raised stiffness support.

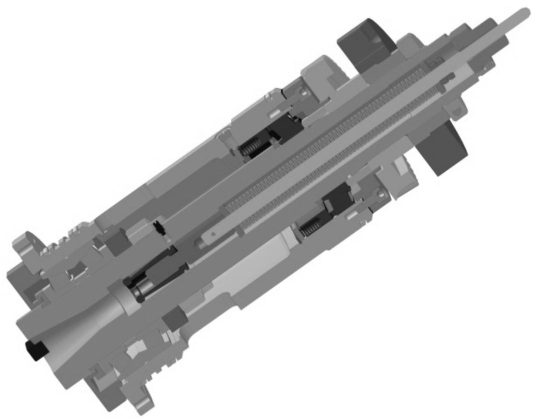
In upper support is installed radial-thrust cone-shaped bearing, which allows the separate montage an rings and its construction provides preload spring type (fig.3). The building 3D-models of the details was executed designing complex 3D-assemblies and nodes, falling into spindle's head (fig.3).



a b

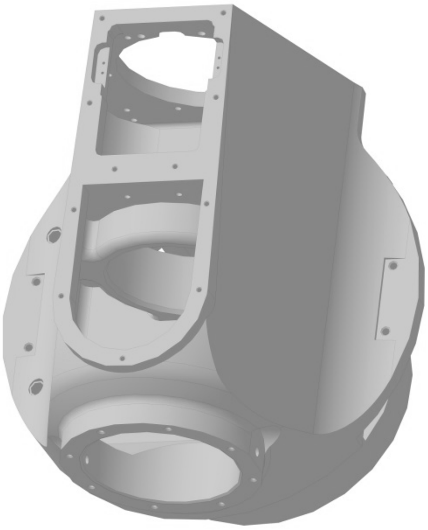
Fig. 1. Spindle's head machining centre SVM1F4: a – general view of unit; b – cross-section of head

a



b

Fig. 2. Spindle’s node of spindle’s head: a – general type of the node; b – a cross-section of the spindle



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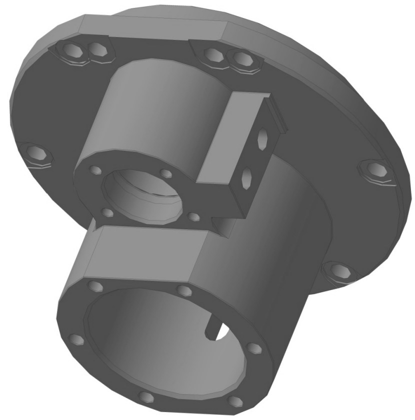

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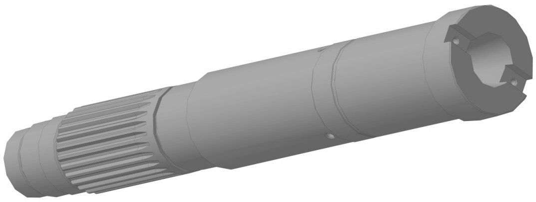
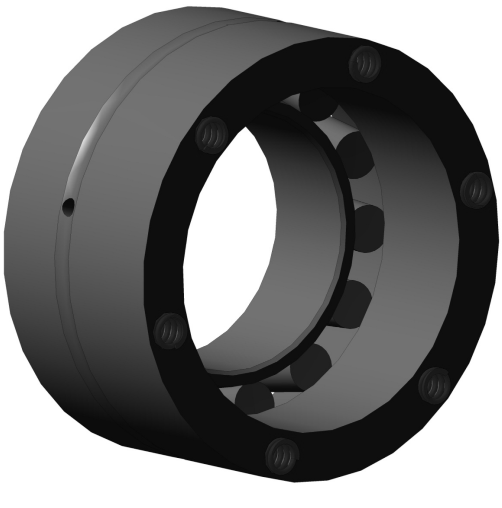


c



d

Fig. 3. The three-dimensional models of the details spindle’s head: a – case of the head; b – case hydraulics block; c – spindle; d – a special roller bearing with spring preload

The Complex engineering analysis tense-deformed conditions of the spindle tool shall realize by means of module APM FEM [15, 16, 19], equiped by generator finite-element net, falling into CAE-library, which realizes the decisions of the engineering problems by method final element (FEM). Fastening is realized in process of the designing in upper and lower supports and are assigned put loads; they are defined coinciding face (for FEM-analysis of the assembly); it is realized generation FE-nets by method MT Frontal (with using multicore processor); it is executed calculation and viewing result in type of the cards of the stress and displacement.

Within the module APM FEM are realized all afore-mentioned actions and are received:

- a field of the equivalent stress on Mizes (the quarter theory to strenght), submitted for fig. 4;
- a field of the displacement (fig.5) on set of the cross- sections of the spindle.

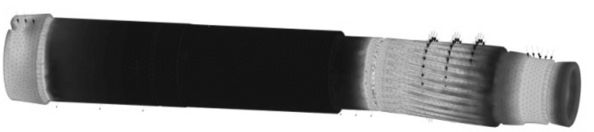


Fig. 4. Fields of the stress in cross-sections of the spindle

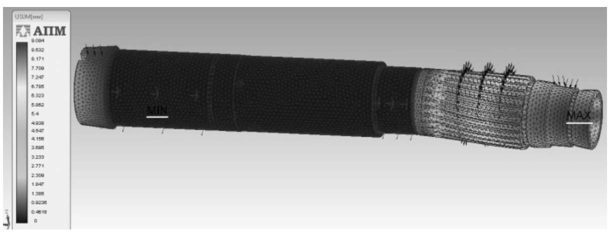


Fig. 5. Fields of the displacement of spindle

Efficiency to designing tool, taken optimal decisions is defined criteria to stiffness and vibration resistance. On optimal level such designs most influence render the sizes cantilever l_1 and interlinear support l parts.

For searching for of the optimum variant spindle's node on criterion of stiffness we shall build the mathematical model to designs SN, in the manner of systems of the expressions, linking different variable and controlling parameters of the node.

Two support spindle with console load by power P is displaced because of own deflection and because of deflection rolling contact bearing. Shift of spindle's end, conditioned deformation its bearing as support, possible present in the manner of [12, 18]:

$$y_1 = \frac{P}{j_a}\frac{(\lambda+1)^2}{\lambda^2} + \frac{P}{j_b}\frac{1}{\lambda^2},$$

where: j_a , j_b – stiffness accordingly upper and lower support; δ_a , δ_b - a deformation accordingly upper and lower support of the spindel;

$\lambda = \frac{l}{l_1}$ - parameter of the relative length of the span.

Deflection spindle's end as springy beam possible to present in the manner of:

$$y_2 = \frac{Pl_1^2 l}{3EJ_1} + \frac{Pl_1^3}{3EJ_2} = \frac{P}{j_0}(1+\lambda\frac{J_2}{J_1}),$$

where: $j_0 = \frac{3EJ_2}{l_1^3}$ - conditional stiffness of the cantilever part of spindle.

Adding separate softness end spindle, shall get general softness an spindle's node:

$$\delta = \frac{1}{j} = \frac{(\lambda+1)^2}{j_a\lambda^2} + \frac{1}{j_b}\frac{1}{\lambda^2} + \frac{1}{j_0}(1+\lambda\frac{J_2}{J_1}).$$

For spindles on rolling contact bearing of the entered restriction on the least distance between supports ($\lambda_{min} \geq 2{,}5$). This is connected with that running bearing under the most further reduction interlinear support distances intensifies running an spindle's end [8, 14]. In modern designing spindle's nodes on rolling contact bearing parameters to stiffness of the spindle in span are provided not below 250… 500, N/mkm.

On example vertical machining centre with automatic change the instrument to models SVM1F4 shall define the optimum correlation of the lengths console and interlinear support parts. Spindle's node of this centre is loaded by console power P = 400 N and presents the hollow shaft (d = 65 mm; d_0 = 28 mm) with standard end of the spindle. The upper and lower support are characterized following parameter to softness:

- linear: $A_p = Az = 4{,}21\cdot10^{-6}$ mm/N;
- angular: ap = $0{,}42\cdot10^{-8}$,1/N·mm; az = $0{,}48\cdot10^{-8}$, 1/N·mm.

By means of core symbol mathematicians systems MAPLE, shall define displacement an spindle's end, conditioned deformation its support, which possible present in the manner of

$$y_1 = \frac{0{,}001668(\lambda+1)^2}{\lambda^2} + \frac{0{,}001668}{\lambda^2}.$$

Running spindle's end as springy beam possible to present in the manner of:

$$y_2 = 0{,}0008533 + 0{,}000547\,\lambda.$$

General softness spindle's node, brought about console part, will form:

$$\delta = \frac{0{,}001668(\lambda+1)^2}{\lambda^2} + \frac{0{,}001668}{\lambda^2} + 0{,}0008533 + 0{,}000547\,\lambda.$$

Forming softness and the general softness designed spindle's node was submitted for fig.6.

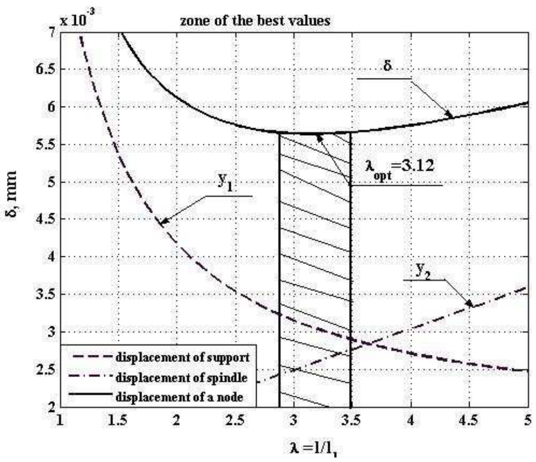


Fig. 6. Optimum correlations between linear size of the spindle

The value of the relative length of the span ($\lambda_{min} \geq 2{,}5$) is a restriction, but constructor necessary to take the optimum decision. For designing spindle's node tool SVM1 optimum correlation in accordance with fig.6 is λ_{opt}= 3,12. In most cases, the constructor uses the half-way decision so it is important alongside with proper values of the optimum, form the range of values, for which general softness will be excess small. The studies have shown that rational range of values of the correlations between linear feature forms the interval $2{,}6 \leq \lambda \leq 3{,}9$.

For estimation of the change the value of the shift of the spindle when increase interlinear support distances, is used module APM Shaft systems computer aided design APM WinMachine [19]

On the base epures interlinear support distances a conclusion about increase degree to deformation with growing interlinear support distances *l*. When increase λ on 20% (with 3,2 before 4) value displacement the spindle on consoles increases approximately on 8% (with 0,0052 before 0,0056 mm).

Together with that, necessary to note that with reduction of the length of the console part optimum value correlation λ_{opt} increases. In these cases optimum strategy will be an increase interlinear support distances, which can be limited from constructive considerations.

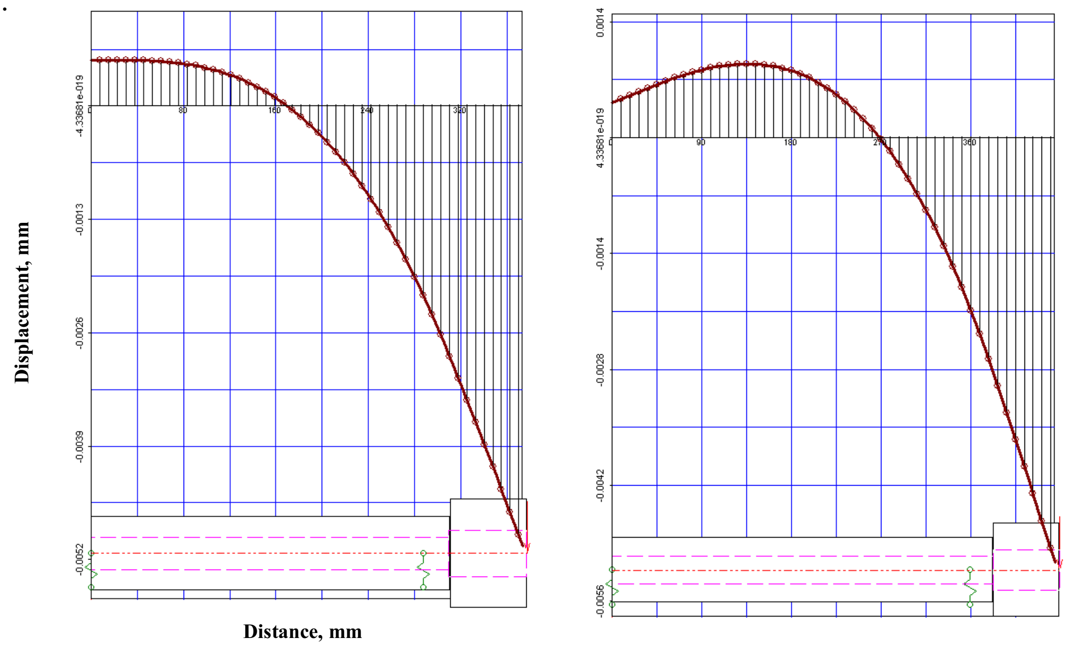


Fig. 7. Softness of the spindle under different interlinear support distances

CONCLUSIONS

In given work is presented procedure 3D - modeling spindle's node specialized machine centre with vertical spindle's head. Constructed by 3D-models of the separate details and assemblies spindle's node in CAD KOMPAS-3D is given estimation of the optimum correlation between size console and interlinear support parts. The formed model to softness spindle's node, allowing on stage of the draft designing to value the size designing node and optimum correlations. Numerical values of the optimum correlation are given between linear size and corresponding to value of softness of spindle's node.

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3D-МОДЕЛИРОВАНИЕ И ОПТИМИЗАЦИЯ ШПИНДЕЛЬНОГО УЗЛА МНОГООПЕРАЦИОННОГО СТАНКА СВМ1Ф4

Олег Кроль, Иван Сухорутченко

Аннотация. Рассмотрена процедура построения 3D-модели шпиндельной головки с механизмом зажима инструмента и гидроблоком для ориентации шпинделя в процессе смены инструмента.
Изложена задача поиска оптимального соотношения параметров консольной и межопорной частей шпинделя специализированного многооперационного станка, обеспечивающего максимальную жесткость проектируемого узла
Ключевые слова. многооперационный станок, шпиндельный узел, консольная часть, жесткость, 3D-моделирование.