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FORCE DEPICTION OF THE RADIAL SIZE CHANGE OF THE HELICAL SPRING HONE
СИЛОВИЙ ПОРТРЕТ ЗМІНИ РАДІАЛЬНОГО РОЗМІРУ ПРУЖНО-ГВИНТОВОГО ХОНУ

The article discloses the research principle of the deformation of helical spring deformed surface of a helical spring hone taking into consideration the results of theoretical, experimental and computer studies. As a result we got the system of equations which defines linear and angle loads in case deformation which appear on the helical spring surface. The scheme of definition of the torque performance while loading the helical spring deformed surface was suggested. The research enabled to build the force depiction of loads and spring deformation of helical spring deformed surface. We also suggested the scheme of definition of deformation force of the helical spring hone and its metering.
Key words: hole honing, force depiction, helical spring deformed surface, helical spring hone, adjustment of radial size.

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СИЛОВИЙ ПОРТРЕТ ЗМІНИ РАДІАЛЬНОГО РОЗМІРУ ПРУЖНО-ГВИНТОВОГО ХОНУ

В статі розглядається принцип дослідження деформації пружно-деформуємої оболонки пружно-гвинтового хона, враховуючі результати теоретичних, експериментальних та комп'ютерних досліджень. В результаті чого було отримана система рівнянь, яка визначає лінійні і кутові навантаження при деформації, котрі виникають в пружно-деформуємій оболонці. Запропонована схема визначення дії крутного моменту при дії навантажень на пружно-деформуєму оболонку. Проведені дослідження дали змогу побудувати силовий портрет навантажень та пружних деформації пружно-деформуємої оболонки. Також представлена схема визначення сили деформації пружно-гвинтового хону та його заміру.
Ключові слова: хонінгування отворів, силовий портрет, пружно-деформуєма оболонка, пружно-гвинтовий хон, регулювання радіального розміру.

Problem statement and analysis of research

The current research on deformation of compound bodies does not give accurate information about the change of the radial size while in the process of deformation [1]. So there are certain factors which make impossible to define force and deformation characteristics of helical spring hone (HSH) theoretically, including:

- variability of planes of the screw body cuts along its own geometrical axis [2];
- variability of tensions which appear in the spirals along the length of the helical spring deformed surface (HSDS) while application of force constant value [2] ;

Therefore, we made a decision to apply a combined method of research.

The combined method involves studying the interaction of the parameters that were obtained with the help of different methods, including:

- theoretical research of radial and axial spring deformations of HSDS [2];
- experimental study of forces' correlation and spring axial and radial deformations of HSDS;
- computer diagnostics of tensions that emerge in different points of the HSDS body [2];
- theoretical study of the torque effect on the spring deformation of the screw body with closed endings.

Helical deformation and the arising tangential tensions of the bodies similar to HSDS, for example, traditional springs are considered in a range of publications [3].

In this case the tangential tensions which arise in the body of the helical element in general view without differentiation of their values on every spiral were considered.

But computer diagnostics [2] showed different values of tensions which arise in the limits of every spiral of HSDS. Therefore, it would be reasonable to consider the process of arising of tensions in the body of HSDS directly in the limits of each separate spiral.

Research of the moments of torsion of a spiral of the helical spring hone

For this process it is necessary to take a number of assumptions, particularly:

- helical deformations of spiral of HSDS as a result of torque and tangential tensions arise synchronously from the two opposite sides;
- helical deformation and the torque which provides the deformation at every sequential spiral takes into account the values of these parameters that were received at the previous spiral;
- the work of the torque is defined by the square of the triangle which is placed beyond coordinate axis: torque and the angle of twist;
- the force depiction is built on the basis of the data received for HSDS with nominal diameter 12.7 мм;

- the values of the loads of HSDS and corresponding to them helical deformations, linear and angular are defined with the help of equations [4]:

$$\begin{cases} \varphi_з = \dfrac{2\pi P_Z R^2\, i\, l}{\sigma_2 I} \\ \lambda = \dfrac{2\pi R^3 i}{\sigma_2 I} \\ \Delta d = 2R\cos(\alpha - \varphi_з) \\ \lambda = 2R\sin\varphi_i \\ \varphi_i = \alpha - \varphi_з \end{cases}, \qquad (1)$$

where: φ_3 – twist angle or the lift angle of the screw line after loading;

P_z – axis force;

R – radius of the cylinder of the body of HSDS along axis line of the crossed cut;

i – number of spirals of HSDS;

σ_2 – springiness modulus of the second kind or slip modulus;

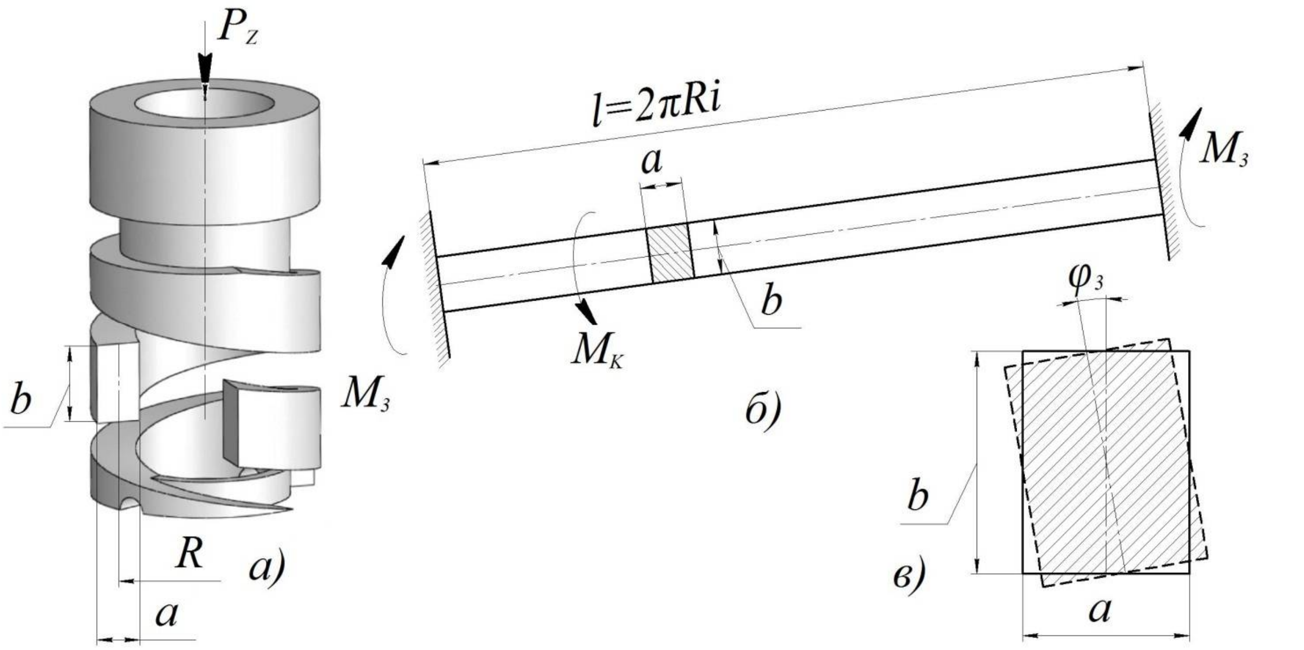
I – inertia moment, geometric characteristics of toughness while twisting;

α – lift angle of the screw line before loading;

λ – draft value of HSDS while loading;

φ_i – lift angle of the screw line of HSDS after loading.

HSDS or helical screw element is considered as a straightened rod with closed endings [27, p. 208] see Fig. 1



R – HSDS radius; P_Z – compressing force; M_3 – closing moment; $M_к$ – torque; $\varphi_з$ – angle of twisting the cut; i – number of complete spirals of HSDS; l – length of spirals;

a) HSDS; б) straightened rod; в) cut of the rod;

Fig. 1. Scheme of HSDS loading

Deformation of the ending in the case of HSDS is carried out with closed position from both sides. That is why it is unreasonable to apply classical equations of the twisting angle [4, pp.206-209]. Picture 2 shows the scheme of the action of torque loading with closed endings.

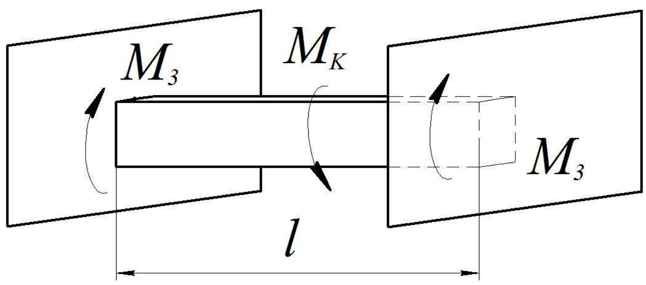


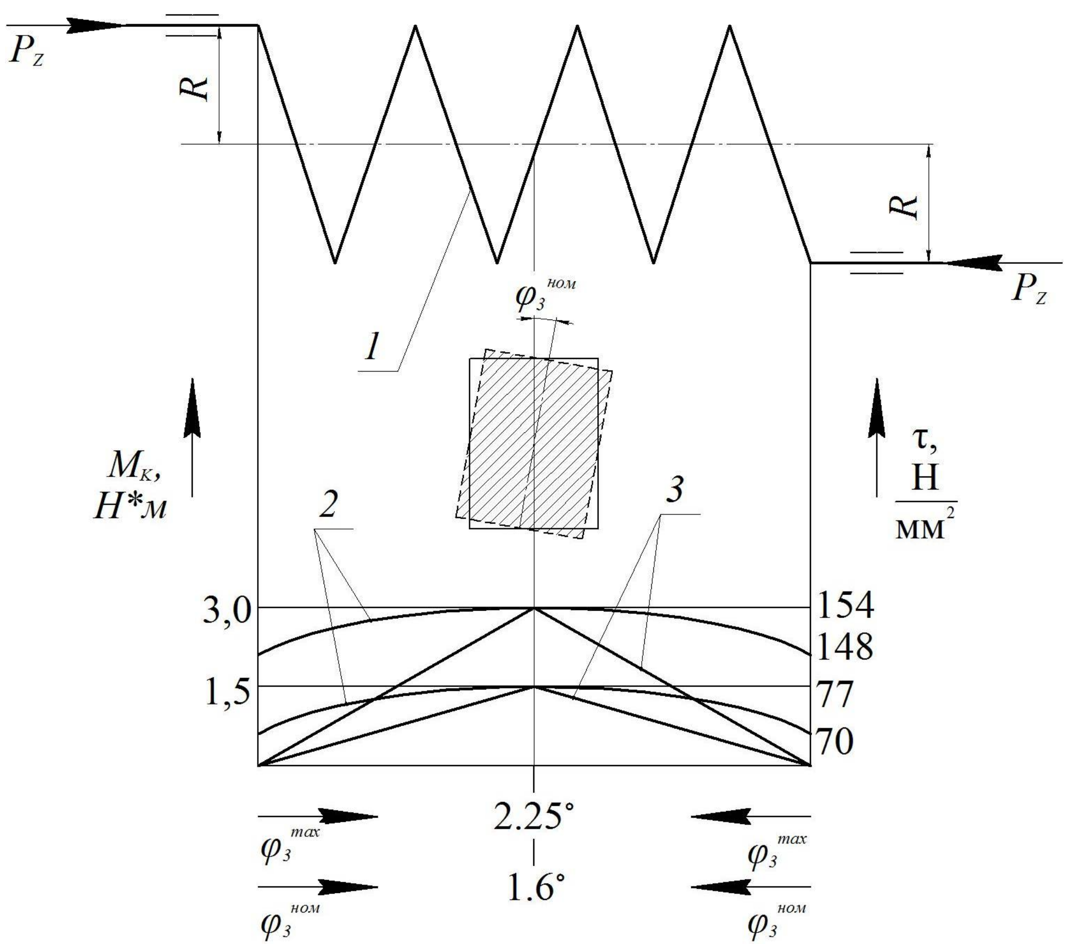
Fig. 2. The scheme of torque while loading of springy body of HSDS with closed ends

Accordingly, the twist angle φ_3 will be defined with the help of the equation:

$$\varphi_3 = \frac{0{,}5 P_z R l}{\sigma_2 * I}, \qquad (2)$$

where: l is the length of the straightened rod;
σ_2 is the springiness modulus of the second kind or slip modulus.

Taking into account the above-mentioned assumptions we can build the scheme of HSDS loading with definition with the help of computer diagnostics of the characteristics of changes of tangent tensions (Picture 3).

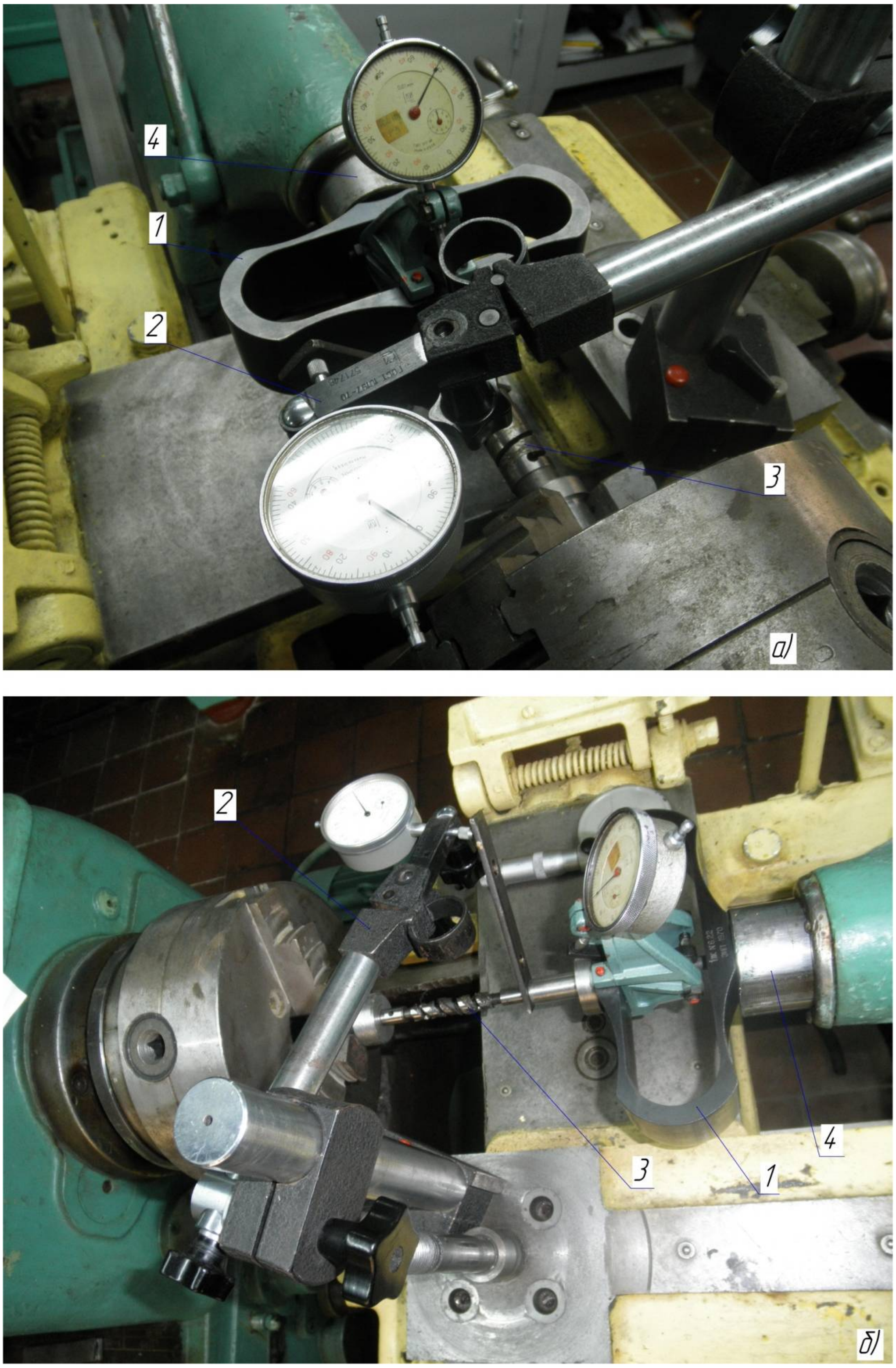


1 – HSDS; 2 – curvilinear dependence of the change of tangent tensions τ along the body of HSDS received by the method of computer diagnostics; 3 – the area of adjacent triangles which reflect the operation of the torque $M_к$.

Fig. 3. The graph of loading of HSDS

Experimental research of deformation of helical spring hone

Pilot mount for definition of the necessary strength of deformation and increase of diameter of HSDS was made after modernization of the lathe 1A616 and consists of dynamometer 1, magnetic indicator stand 2 and HSDS 3. (Picture 4).



1 – dynamometer; 2 – magnetic indicator stand; 3 – HSDS; 4 – tailstock pinole;

a) for HSDS with diameter Ø25 мм; б) for HSDS with diameter Ø12,7 мм;.

Fig. 4. Pilot mount for definition of the necessary strength of deformation and increase of diameter of HSDS

HSDS 1 is mounted into the three-jaw chuck of the lathe that has a special detent which limits axial movement. The dynamometer 1, in its turn, is mounted between HSDS 3 and the tailstock pinole 4. In order to define the axial deformation of HSDS 1 we used a special plate which is contacted with the knife of magnetic indicator stand 2.

The pilot mount works in the following way: the effort and axial movement are done due to the tailstock pinole. The value of the received axial movement is defined by the indicator which is mounted on the magnetic stand and the value of the applied force was counted by dynamometer 1 which had been calibrated before. The measurement of the received radial size was made by a micrometer.

Measurements of the external cylindrical contour of HSH were made by the reference machine (Picture 5).

а)   б)

1 – the reference machine Carl Zeiss CONTURA G2; 2 – sensor; 3 – HSH.

a) general view of the measurement area of the external cylindrical contour of HSH; б) the measurement area of the external cylindrical contour of HSH;

Fig. 5. Reference machine Carl Zeiss CONTURA

The parameter values that are controlled in the process of diagnostics are given in Table 1. We received a considerable mismatch in theoretical and experimental dependences. This is because the screw groove was made with closed ends. In other words, in case of springy deformations there is a resistance. That is why we suggested applying empirical formulas to calculate the increase of diameter and the necessary value of deformation.

Table 1

Parameters that are controlled in the process of diagnostics

№	Value of indicator of movements, мм	Value of indicator of dynamometer	Effort PZ, H	Diameter, мм
1	2	3	4	5
HSH with diameter Ø12,7 мм				
1	0	0	0	8,74
2	0,25	20	597,5	8,76
3	0,5	40	1185,9	8,80
4	0,75	61	1803,8	8,82
5	1,0	80	2362,88	8,84

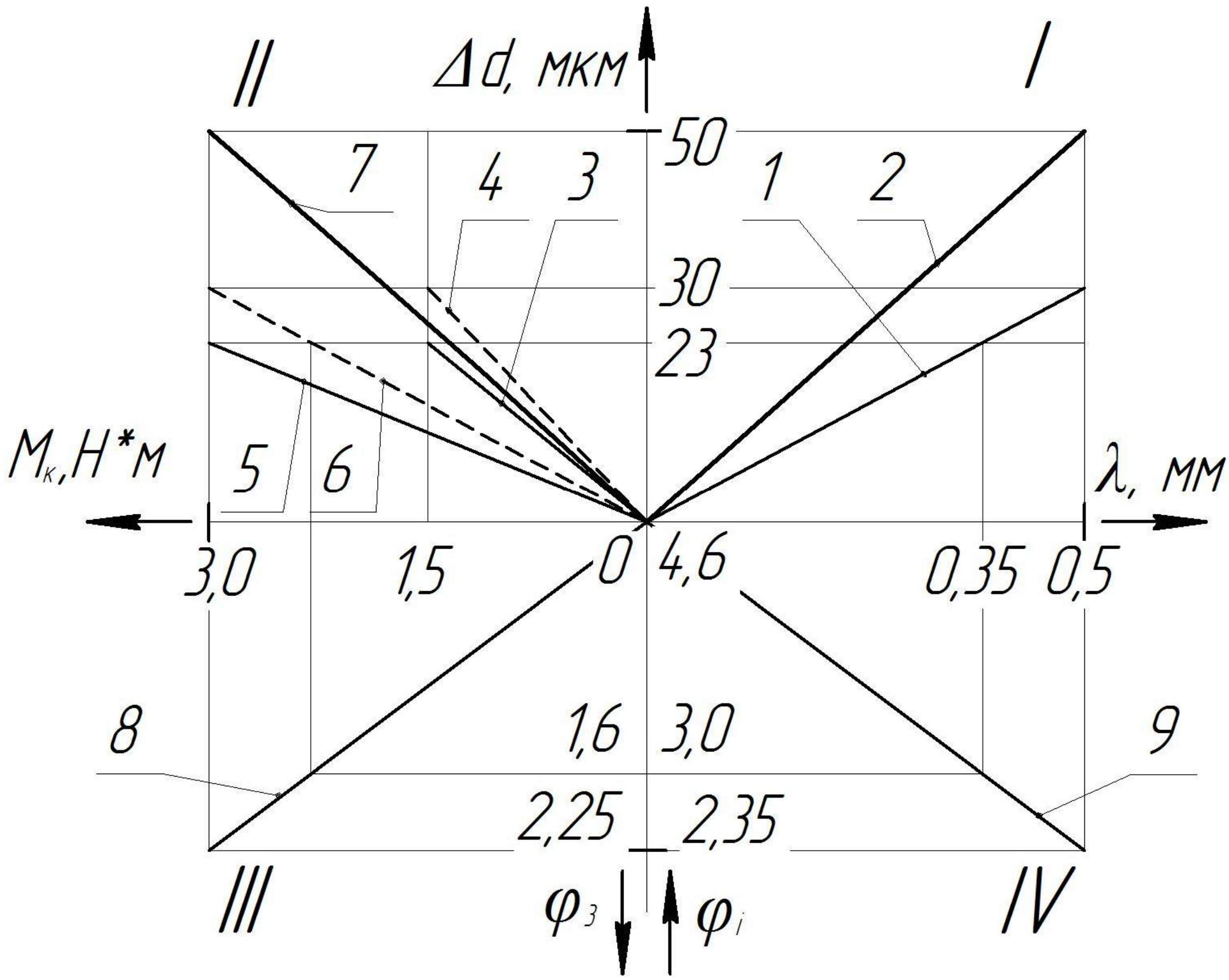
1	2	3	4	5
HSDS with diameter Ø25,0 мм				
1	0	0	0	21,17
2	0,25	20	597,5	21,18
3	0,5	38	1127,1	21,20
4	0,75	55	1627,3	21,22
5	1,0	70	2059,6	21,24

Force depiction of HSH

Force depiction of HSH is built on the basis of theoretical and experimental data shown in Picture 6.

Force depiction enables to define springy deformations which arise after corresponding loading.

The mismatch in theoretical and experimental graphs proves the difference in actual areas of the cuts of HSDS and their values which were taken into account in theoretical calculations.



I – theoretical 1 and experimental 2 dependence Δd=f(λ); II – theoretical 3,4,5,6 and experimental 7 dependences Δd=f(M_k); III – theoretical dependence 8 φ_3=f(M_k); IV – theoretical dependence 9 φ_3=f(λ);Δd – diameter increase; M_k – torque; λ – axial draft of HSDS; φ_3 – twisting angle; φ_i – alternating value of the angle of the screw line lifting;

Fig. 6. Force depiction of loads and helical spring deformations of HSDS

Conclusions

Therefore, as a result of building of force depiction we received the following conclusions.

The tension in spirals of HSDS has alternating values along its spiral with the difference between the maximum and minimum values varying from 5 to 10% depending on the degree of loading.

The angle of the spiral shape changes according to the tension and the maximum value of angle shape is obtained in the middle of the body of HSDS.

The methodology of force depiction can be applied to define performance indicators of HSDS.

Springy deformation of the spirals of HSDS does not influence the operational performance because HSH is polished with maximum deformation before exploitation.

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