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THE INFLUENCE OF THE TECHNOLOGICAL PARAMETERS OF THERMAL ASSEMBLING ON THE QUALITY OF CONNECTIONS WITH THE INTERFERENCE SHAFT-WHEEL IS TOOTHED

In the article are given the results of studies on the selection of the technological parameters of assembling with the interference of connections shaft-wheel in the absence the keys toothed with the use of heating the wheel of the toothed, low-temperature cooling of shaft and combined thermal method during the combination in parallel of heating the wheel of the toothed and low-temperature cooling of shaft.

Keywords: *connection with the interference, thermal composition, rear axle shaft is toothed.*

In different transfers wide application found the cylindrical connections shaft- wheel toothed, connected with the use of key landings and which work with the diverse forms of operating loads. However, key connections in design and technological sense are imperfect, and also they lead to an increase in the metal content of composite articles. In a number of cases they use during assembling of shafts with the wheels toothed couplings with the interference and the keys. In this case for guaranteeing the operational strength the interference can be basic or auxiliary construction-engineering element. In one case major portion of the load is received by landing, and key roofing to additionally guarantees strength of connection, in the second case the interference fit is used for the partial unloading of key and centering of components. The key and interference fit together do not work in also the time with the reversible load. For guaranteeing their joint operation key must be established on the thrusts in both grooves, and this creates the specific technological difficulties and leads to the additional economic expenditures [1, 2].

By the most universal and expedient connection of shaft with the wheel toothed *in the absence the keys* connection with the interference, whose assembling is accomplished by different thermal methods [2, 3]. These connections transfer the significant both constants by the value and the direction torques and cyclically changed on the value and the sign. In these cases the guarantee of the increased operational strength of interference fits is very important. Different standard forms of microrelief and topology of its putting on the shafts for this purpose are used. However, in a number of cases these methods do not nevertheless satisfy the requirements of operational reliability. Therefore it is very important to develop new in the forms of microrelief and its topology, which would consider form and nature of operating loads, the technological parameters of the realization of the technology of assembling with the temporarily formed thermal clearance.

Objects and the methods of the studies

As the subjects of a study serve the *in the absence the keys* connections shaft-wheel is toothed, connected with the interference by thermal methods. For the solution of the problems presented were used the fundamental theoretical positions of the technology of machine building, theory of plasticity, elasticity and thermal conductivity, methods of the optimization, probability theory, mathematical statistics and the method of the final elements [MFE], regression analysis, computer programming.

Formulation of the problem

The establishment of the values of the technological assembly-line parameters with the combined thermal method of assembling the *in the absence the keys* landings of the connections shaft- wheel is toothed, which will ensure an improvement in the quality of the composite full-scale articles, which work on the twisting. In this case was provided for the application in the zone of contact of the connections of the persistent regular microrelief, applied to the shafts in parallel to the axis of connection, also, with different parameters of the area of putting (topology) [4, 5].

Results of studies and their consideration

Comparative studies according to the evaluation of the influence of the technological assembly-line parameters the stress-strained state and strength of *in the absence the keys* cylindrical connections with the interference are examined per the carrying assembly unit shaft- wheel the toothed cylindrical. The diameter of landing is accepted equal to 52 mm, the length of landing 50 mm, the outside diameter of the gear of 180 mm. Roughness of the contact surface of the components of R_a=0,8 – 1,25 mkm. Calculated assembly-line interference was preliminarily calculated and accepted equal to 0,080 – 0,110 mm. Material of the wheels of toothed steel of 40X, shaft steel of 40XH2. In this case the influence on the quality indicators of the connections of the height of persistent regular microrelief and area of its putting on the shaft was examined. Taking into account that shaft- wheel toothed in the process of operation they undergo twisting, it was accepted to bring microrelief to the shaft in parallel to the axis of connection. For the formation of connections with the interference the necessary values of the temperature of thermal influence for the mating parts, which make it possible to accomplish assembling with the thermal temporarily formed assembly-line clearance, were calculated.

At the very beginning were carried out the experimental-design studies of the *in the absence the keys* connections with the interference, which it was intended to form different thermal methods. Then in terms of the obtained computed values of temperature were executed the experimental-design studies *the stress-strained state* of the connection of the wheel of toothed with the shaft also of expenditures of energy with the use of a method of final elements. At the very beginning were carried out the experimental-design studies *the stress-strained state* of the *in the absence the keys* connections with the interference, which it was intended to form different thermal methods. The partition of the wheel of toothed and shaft into the finite-element models, approximating full-scale articles, was carried out for this. The results are represented in fig. 1 – 3.

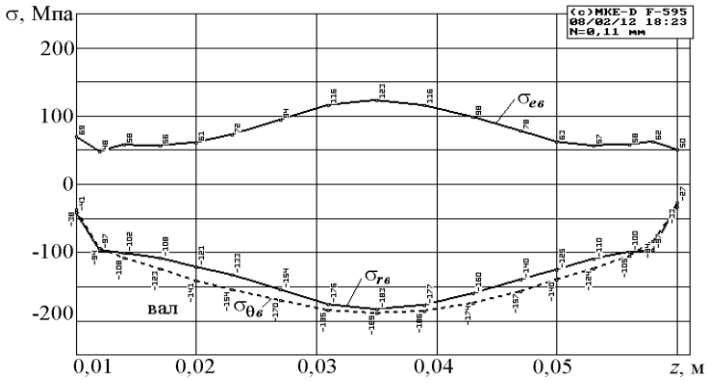

Fig. 1. **Distribution of equivalent $\sigma_{ев}$, circumferential $\sigma_{\theta в}$ and radial $\sigma_{гв}$ stresses in the shaft after assembling of connections by thermal method with the interference 0,11 mm**

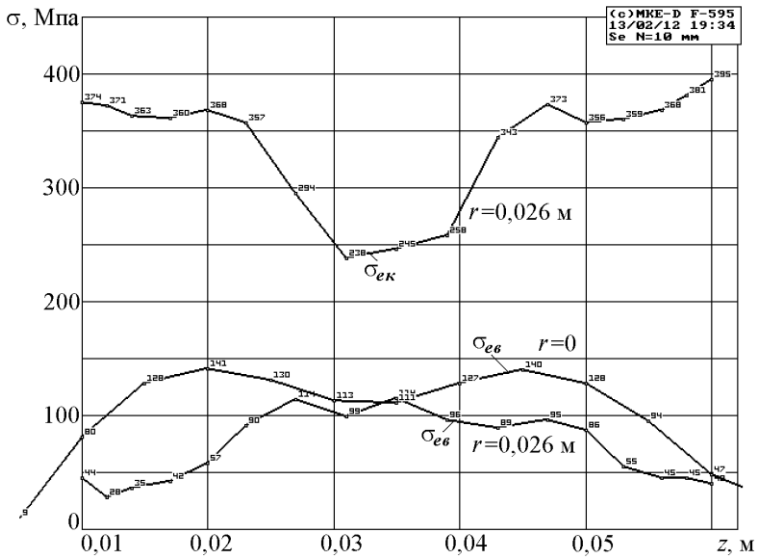

Fig. 2. **Distribution of the equivalent stresses $\sigma_{ек}$ in the contact zone in the wheel toothed and $\sigma_{ев}$ in the shaft on a radius of 0,026 m and along the rotational axis in a radius of 0 m after their assembling by thermal method with the interference 0,11 mm and with the regular microrelief with the height of $R_в$=0,04 of mm (with its putting on the length of landing $L_в$ =10 mm).**

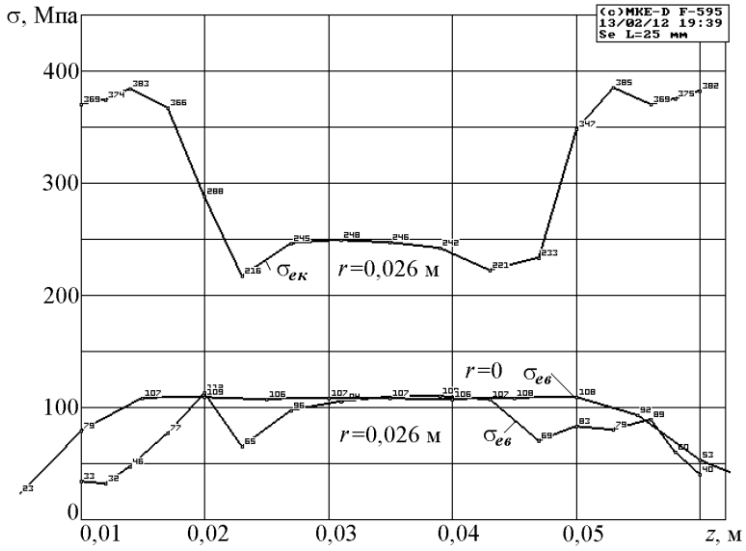

Fig. 3. **Distribution of equivalent stresses in the contact zone in the wheel toothed and in the shaft on a radius of 0,026 m and along the rotational axis in a radius of 0 m after their assembling by thermal method with the interference 0,11 mm and with the regular microrelief with the height of $R_в$=0,04 of mm (with the topology of putting on the length of landing $L_в$ =25 mm).**

In Fig. 1 is shown the distribution of stresses in the shaft after assembling of connections by thermal methods with the interference 0,11 mm and temperature balance. It is established that an increase in the interference leads to the increase *the stress-strained state.* The temperature of initial contact during the assembling by thermal methods, necessary for the realization of the assigned interference, as showed studies, after the temperature balance of components and final formation of connection does not have an effect on a change in the value of stresses. In this case radial stresses in the contact zone for the shaft and the wheel are identical.

These results confirm theoretical data of the studies of the authors [6, 7], which show, that the value of stresses in the contact zone depends on the value of interference (contact pressure), design parameters of connections and physicomechanical properties of materials. With the recommended thermal cycles with the temperature distribution in the wheel and the shaft respectively in the interval 100…40°C и –163…–103°C with an increase in altitude $R_в$ regular microrelief in the interval $R_в$=0,008…0,04 мм, *the stress-strained state* connections it is lowered on 26,61% in the wheel toothed and on 34,21% in the shaft. With the thermal cycles with the temperature distribution in the wheel and the shaft respectively in the interval 100…40°C и –163…–103°C with an increase in the area of putting regular microrelief on the length of the landing $L_в$ (fig.1–3) in the interval 10 …50 mm *the stress-strained state* it is lowered in the wheel toothed to 51,34% and the shaft by 39,02%.

It should be noted that the use of local heating of the wheel of toothed (nave and rim) and cooling of the landing part of the shaft they make it possible to decrease on 37 – 46% of expenditure of energy.

The executed results of the experimental-design studies *the stress-strained state* made it possible to conduct assembling the experimental full-scale wheels of toothed with the shafts, studies of static strength for the twisting and with the cyclic tests of a number of reducers. Are given below the results of studies of assembly units the shaft – toothed wheel of reducers Ц2У–З15Н with the fit diameter of 110 mm, the length of the landing part of 110 mm. Material of shafts – steel of 40ХН2МА, wheels of toothed steel of 40Х ГОСТ 4543–71.

For conducting of studies 3 groups of models of 5 connections in each were manufactured. The finishing treatment of the landing surfaces of shafts was performed by grinding with the roughness of R_a =1,25 mkm, and wheels by boring R_a=2,5 mkm. The hardness of shafts HB 282-290, wheels HB 254 – 266. The measurement of landing surfaces was conducted by standard procedure.

The deviation of geometric form de pulley blocks they did not exceed oval shape 0,025 mm, conicity 0,02 mm. After the measurements of actual sizes of components and staffing on the interference (1 group of 0,100-0,140 mm, 2 and 3– of group 0, 040-0,080 mm), on the shafts of 3 of group made smooth persistent microrelief in parallel to the axis of connection with a height of $R_в$=0,04 of mm. Then conducted assembling with preheating of naves and cooling the shafts with the distribution in them of temperatures respectively in interval of 100…40°C and –163…–103°C.

Besides tests with the assigned load of one direction, about conducted also the tests with the alternating load. In 3–5 min. after endurance of connection in the flow 10 min. under the assigned load, was applied the same load of opposite sign. Then of a 5-fold change in the direction of twisting, the connection after remaining under the load in the flow 3 of hours. If the connection it transferred the assigned loads, the length of connection decreased, grinding off the nave of external member, and tests were repeated.

Their decompression was produced after the twisting of connections. Processing data of experiments was conducted by standard procedure.

The strength tests of the carrying units of reducers under the influence of torque were conducted as follows. At first was performed the calculation of landings, which showed that the required by technical specifications load of 11,2 kNm with the nonreversible work even of 8,3 kNm can be provide ford with it is reversible without the installation key with the assembly conditions of shafts with the wheels by toothed with method [KTSS] and with the use of persistent regular microrelief.

As a result studies it is established:

– connections with the interferences 0,04 – 0,08 mm ensure the transfer of torque 17,2 – 22,6 kNm. With an increase on loadings occurred the turning of mating parts;

– connections with the interferences 0,10 – 0,14 mm ensured feather the dacha of reversible pulsating load 26,8 – 29,2 kNm and of not the reversible pulsating load 33,6 – 35,2 kNm during 3 of hours. After these tests the length of connection was reduced to 80 mm and repeated entire cycle of loads without the disturbance of the integrity of connections. The turning of components with the length of connection 80 mm it occurred went with the loads 36,4 – 42,6 kNm;

– connections with the interference 0,04 – 0,08 mm and the rolling of regular persistent microrelief in parallel to the axis of connection ensured the transfer of reversible pulsating load 26,8 – 29,2 kNm and with nonreversible with that pulsating of the load 33,6 – 35,2 kNm during 3 of hours with the length of connection 110 – 80 mm. The turning of components with the length of connection 80 mm went with the loads 38, 4 – 46,0 kNm.

As a result the full-scale tests of the carrying units of reducers under the influence of torque it is established, that koeffitsitnt of friction (cohesion), determined according to the tests of laboratory models are completely reliable data and can be used for calculating the bearing capacity of landings on the thrusts, which work in the conditions of the action of torque.

Conclusions

The results of the executed experimental studies made it possible to establish that to the quality of connections with the interference of shaft with the wheel toothed during their assembling by the combined thermal method of the assembling essential influence render the interrelation of the temperature of heating and of cooling the mating parts before the assembling, the parameters of regular microrelief and the topology of its fulfillment on the contact surface of shaft. In this case:

– the combined thermal method of assembling makes it possible to interconnected reduce simultaneously the temperature of heating one component and low-temperature cooling of another, due to this to decrease *the stress-strained state* of the components before the assembling and in a number of specific cases to decrease the power consumption, to create specific conditions for introducing the microrelief, thereby to obtain the maximum density of the contact zone and the strength of landings.

– are established with the combined thermal method of assembling rational temperatures of heating and cooling the components during assembling of connections with the interference. It is confirmed, during assembling of connections with the assigned assembly-line interference after the levelling off of their temperature *the stress-strained state* during the interconnected combination of reduction in temperatures of heating and cooling it remains constant.

– the application of the recommended regimes of uneven heating and cooling with the temperature distribution in the wheel toothed and the shaft respectively in interval of 100…40^{o}C and –163…

–103^{o}C with an increase in altitude of persistent regular microrelief in the range from 0,008 to 0,04 mm, *the stress-strained state* of connections is reduced. In this case equivalent stresses decrease by 26,61% in the wheel toothed and by 34,21% in the shaft.

– the application of the recommended regimes of the uneven heating of the wheel of toothed in the range of temperatures 100…40^{o}C and coolings of shaft down to temperatures –163…–103^{o}C and increase in the

area of putting the regular microrelief lengthwise of landing from 10 to 50 mm ensure a decrease *the stress-strained state* in the wheel toothed to 49,36% and the shaft to 39,02%.

– the use of uneven heating of nave and sheave of toothed and cooling of the landing part of the shaft respectively in the range of temperatures 100…40°C and –163…–103°C, 80…20°C и 186…

–126°C make it possible to descend on 37 – 46% of expenditure of energy.

– calculated contact pressure and radial stresses are reduced with an increase in the depth of the penetration of regular microrelief and area of its putting on the shaft. It is confirmed that the maximum permissible height of microrelief during assembling of the components of those prepared from steels must not exceed 0, 5 from the value of minimum assembly-line interference.

– an increase in the area of putting persistent regular microrelief on the shaft during the assembling by the combined thermal method of the assembling ensures redistribution and reduction in the stresses in the contact zone.

– the full-scale tests of reducers confirmed the results of theoretical-analytical and experimental-design studies, that makes it possible to recommend the combined thermal method of assembling, persistent regular microrelief and topology of its putting on the shaft for guaranteeing the increased strength characteristics of connections the shaft- wheel their toothed with simultaneous decrease *the stress-strained state* expenditures.

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Вплив технологічних параметрів термічного складання на якість з'єднань з натягом вал-колесо зубчасте

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У статті наведені результати досліджень на вибір технологічних параметрів складання з натягом безшпонкових з'єднань вал-колесо зубчасте з використанням нагрівання колеса зубчастого, низькотемпературного охолодження вала та комбінованого термічного способу при поєднанні паралельного нагрівання колеса зубчастого та низькотемпературного охолодження вала.

Ключові слова: з'єднання з натягом, термічне складання, вал-колесо зубчасте.

Влияние технологических параметров термической сборки на качество соединений с натягом вал-колесо зубчатое

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В статье приведены результаты исследований по выбору технологических параметров сборки с натягом безшпоночных соединений вал-колесо зубчатое с использованием нагрева колеса зубчатого, низкотемпературного охлаждения вала и комбинированного термического способа при сочетании параллельно нагрева колеса зубчатого и низкотемпературного охлаждения вала.

Ключевые слова: соединение с натягом, термическое составление, вал-колесо зубчатое.