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IMPROVED AND EXTREME GEOMETRO-KINEMATIC PARAMETERS OF HIGH-LOADED HYPERBOLOID GEARS

Creation high-loaded hyperboloid gears with improved and extreme geometrykinematic parameters on the basis of quasi hyperboloid gearings – a perspective and effective direction in increase of technical and economic characteristics of reducers. Use of any reserves in manufacture hyperboloid gears and reducers can give and already really gives considerable economic benefit at the expense of improvement of a design, increase of labor productivity, improvement of quality, decrease in the cost price, increase of competitiveness of production.

Key words: *high-loaded hyperboloid gears; geometro-kinematic parameters; speed of teeth rolling*; *factor of specific sliding.*

Introduction. The major role in increase of technical and economic characteristics of reducers – mass production of branches of an economic complex of Ukraine – is played by the tooth gearings in many respects defining durability, reliability and competitiveness of mechanisms in which they are applied. Increasing requirements to increase in district speeds, loading and a resource, to reduction of dimensions and weights of reducers all are to a lesser degree satisfied with traditional gears which do not meet in some cases to market economy requirements on such parameters as individual capacity, accuracy, specific material – and power consumption, competitiveness. So, in the conditions of occurrence of Ukraine in the World Trade Organization mechanical drives the general machine-building and the special application, issued at the enterprises of Ukraine, are subject to updating in the shortest terms with the account of increase of their technological level, expansion of consumer properties and competitiveness improvements.

The researches directed on creation effective hyperboloid gears [1; 2; 3], possessing high loading ability and efficiency, smaller metal consumption, are actual and meet the requirements scientifically – technical progress of modern mechanical engineering. The research urgency hyperboloid gear does not decrease with the continuous tendency to increase of geared capacity [4], characteristic for modern mechanical engineering.

Creation of the gears answering high scientifically – to technical and industrial level, demands joint to consideration of all parameters of quality of projected gear, and also constructive and technological ways of their maintenance, with the account of business factors, scientifically – technical and which industrial realization – a subject of multicriterion synthesis and optimization of tooth gearings with improved and extreme geometrykinematic parameters and operational characteristics.

Research is spent within the limits of works and on the basis of the program scientifically – technical researches [5; 6].

Objects and problems. Research objective - development of the theory and increase of a technological level of spatial gears by creation high-loaded hyperboloid gears – screw and hypoid – gears with the improved and extreme quality parameters as now the most part of reducers and gears special, the general machine-building and

machine-tool constructing appointment which are offered by manufacturers of the countries of the post-Soviet territory, are the models developed, mainly, in 1960 – 1980th. They have been put in pawn in a design of numerous machine tools, cars and mechanisms and applied and to this day. However, owing to the different reasons even in new projects the mentioned gears and reducers any more do not satisfy to modern technology requirements, are noncompetitive in comparison with foreign analogues, and in most cases their application in modern manufacture is unprofitable.

In various branches national economy Ukraine and in the leading industrially developed countries of the world intensive researches are carried out in area hyperboloid (spatial) machine-tool and the worker of the gearings, directed on increase of bearing ability hyperboloid – screw, worm, spiroid and hypoid gears which in increasingly scales are made at machine-building factories of the countries of the world. So, from materials of annual international conference on mechanical transmissions (Japan, Fokuoka) it is known, that in the world: the release volume hyperboloid gears double each 5-7 years, thus in the beginning of the third millennium annual cost hyperboloid wheels has exceeded some billions US dollars.

The mentioned allows to tell, that use of any reserves in manufacture hyperboloid gears, gears and reducers can give and already really gives considerable economic benefit at the expense of improvement of a design, increase of labor productivity, improvement of quality, decrease in the cost price, increase of competitiveness of production.

The special place among spatial gears and reducers is occupied hypoid and screw cogwheels with improved (extreme) qualitative (geometrykinematic) parameters, with the containing big latent reserves of increase in their durability and improvement of operational qualities. Including, one of essential reserves is transition from bevel and cylindrical initial surfaces to quasihyperboloid to the initial surfaces least deviating from hyperboloid axoids – theoretical initial surfaces.

Thus, it is possible to assume, that quasihyperboloid gears [7] should possess the best quality parameters among spatial tooth gearings. The offer brought by us on a geometrical reserve of perfection screw, worm, spiroid and hypoid gears and transition from conic and cylindrical initial surfaces to quasihyperboloid gears has the settlement acknowledgement consisting in the following numerical comparative analysis.

To numerical research were exposed quasihyperboloid gears with Novikova gearing, gearing of type Novikova, involute gearing, quasiinvolute gearing, globoidal gearing with following parameters: $m_n = 3$ mm, $Z_1 = 13$, $Z_2 = 54$ mm, $r_1 = 26,344$ mm, $r_2 = 26,344$ mm, $a_w = 52,688$, $u_0 = 0,2407$, $\gamma = 90^0$ (orthogonal gears), $\beta_1 = 74^0 34'$, $\beta_2 = 15^0 26'$.

Results of calculation of quality parameters are reflected on fig. 1 – 11: №1 – gearing gears with Novikova gearing; №2 – gearing of type Novikova; №3 – involute gearing; №4 – quasiinvolute gearing, №5 – globoidal gearing [8, 9]. In these figures from five considered types hypoid gears only №3 possesses linear contact of teeth's, other four types of gears – dot contact. In this connection for №3 on fig. 1, 3, 5, 7, 9 the additional information including, along with a median point of a line of instant contact, as well its trailer points is placed. Let's analyze the received results.

Relative speed of teeth sliding (fig. 2 and 3). Highest "rating" on this quality parameter gear №1, the lowest - globoidal gears №5, intermediate position occupy hypoid gears №2, №3 and №4: relative speed of sliding of teeth's in gear №1 in 2,4 … 5,3 times is less, than in other four types of gears.

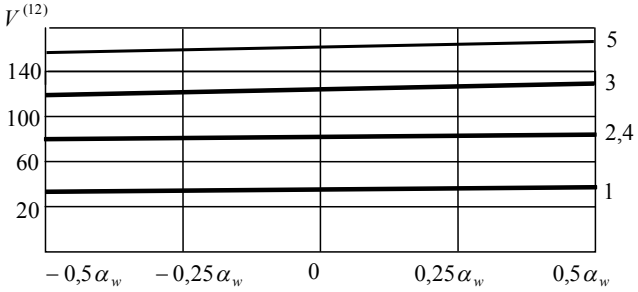

Fig. 1. Relative speed of sliding of teeth's, $V^{(12)}$ мм· с$^{-1}$ (№3 – a line from c fig. 2)

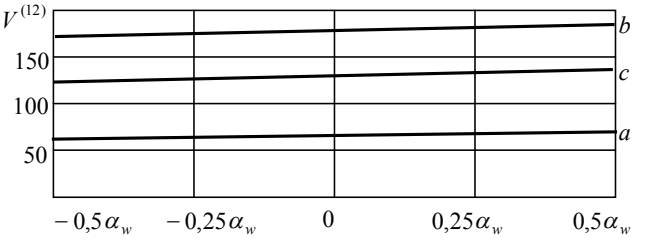

Fig. 2. Hypoid gear №3. Relative speed of sliding of teeth's: $V^{(12)}$ мм· с$^{-1}$
(a , - b in trailer, c - in median points of a line of instant contact)

Factors of teeth specific sliding (fig. 3 - 6). Highest "rating" on these quality parameter gear №1 possesses, as well as above, hypoid, the lowest – hypoid gear №5, intermediate position occupy hypoid gears №2, №3 and №4.

Total speed of teeth rolling (fig. 7 and 8). Highest "rating" on this quality parameter gear №5, the lowest - hypoid gear №4 possesses hypoid, intermediate position occupy hypoid gears №1, №2 and №3: total speed ***of rolling*** teeth's in gear №5 in 1,3 … 4,2 times more than in other four types of gears.

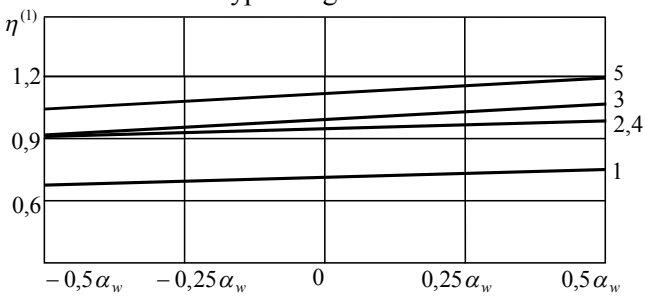

Fig. 3. Factor of specific sliding $\eta^{(1)}$ (№3 – a line from c fig. 4)

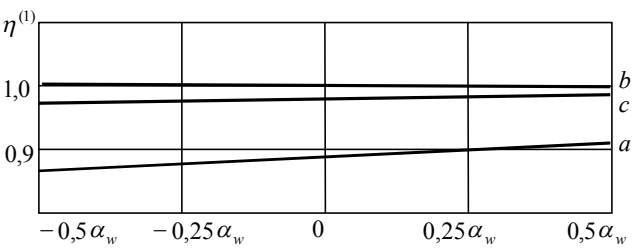

Fig. 4. Hypoid gear №3. Factor of specific $\eta^{(1)}$ sliding
(a , b - in trailer, c - in median points of a line of instant contact)

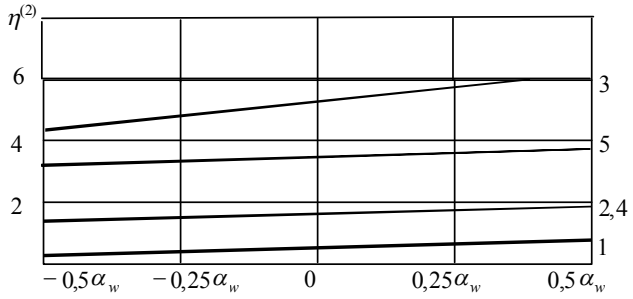

Fig. 5. Factor of specific sliding $\eta^{(2)}$ (№3 – a line from *c* fig. 4)

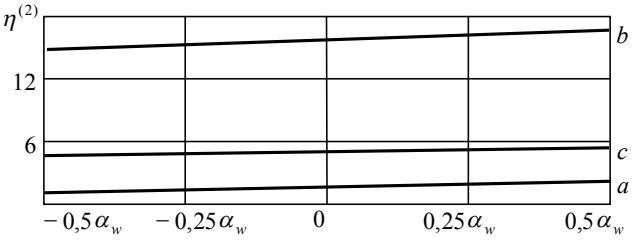

Fig. 6. Hypoid gear №3. Factor of specific sliding $\eta^{(2)}$
(*a* , *b* -in trailer, *c* - in median points of lines of instant contact)

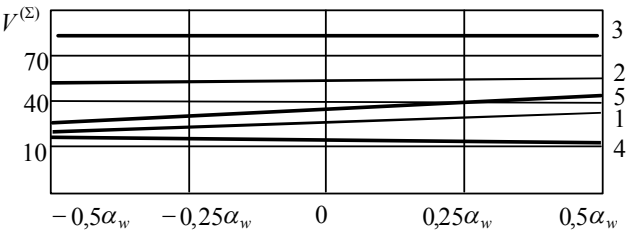

Fig. 7. Total speed of rolling teeth's, $V^{(\Sigma)}$ мм· с$^{-1}$ (№3 – a line from *c* fig. 8)

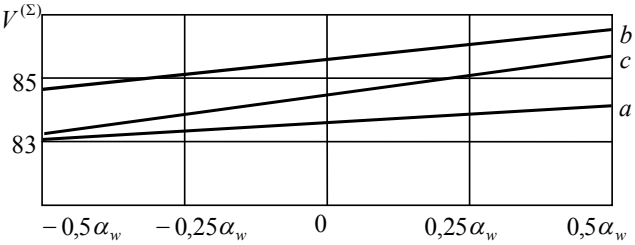

Fig. 8. Hypoid gear №3. Total speed of rolling teeth's, $V^{(\Sigma)}$ мм· с$^{-1}$
(*a* , *b* in trailer, *c* - in median points of a line of instant contact)

Factor of teeth scoring resistance. (fig. 10 and 11). Highest "rating" on this quality parameter gear №1, the lowest - hypoid gear №4 possesses, intermediate position occupy hypoid gears №2, №3 and №5: the factor of scoring resistance in gear №1 in 1,5 … 5,7 times is less than in other four types of gears.

Factor of teeth comparative intense condition (fig. 11). The area of a platform of instant contact of teeths in hypoid gear №1 in 5,5 … 9 times exceeds the area of a platform of instant contact in hypoid gear №2. This statement is fair and in relation to gears №3, №4 and №5 as the intense condition of teeths of gear №2 is elastic, under equal

conditions, is more low elastic an intense condition of teeth's of gears №3, №4 and №5.

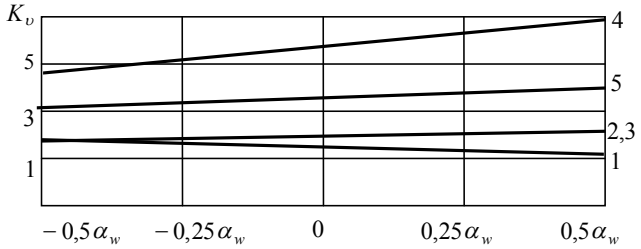

Fig 9. Factor of scoring resistance teeth's K_υ (№3 – a line from c fig. 10)

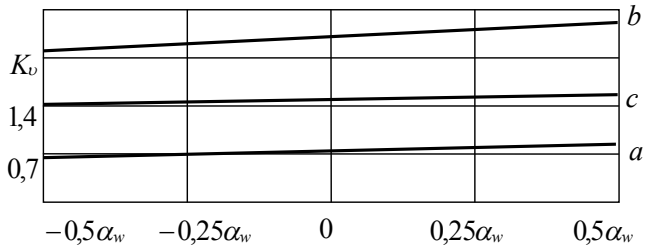

Fig. 10. Hypoid gear №3. Factor of teeth scoring resistance K_υ

(a , - b in trailer, - c in median points of a line of instant contact)

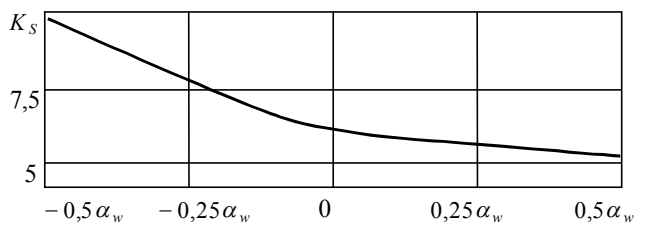

Fig. 11. Factor K_S a comparative teeth intense condition of gears №2 and №1

Conclusions. Synthesis of spatial gearings on the basis of the initial surfaces least deviating from hyperboloid axoids - a perspective direction of essential increase in durability and improvement performances screw, worm, spiroid and hypoid gears. Gearing of Novikova thus is more perspective, than involute gear.

References

1. Golubenko A. L, Medintseva J.V., Kinematics of tooth generation quasihyperboloid wheels and a problem of synthesis improved hyperboloid gears // Mashinoznavstvo. – 2007. – № 1 (115). – p. 26-29.

2. Golubenko A.L., Medintseva J.V., Nosko P.L. Geometrokinematic parameters and the basic criteria of bearing ability hyperboloid gears // Reporter of East-Ukrainian National University named after V. Dahl. – 2007. – № 2. – p. 35-40.

3. Golubenko A.L., Gribanova J.V., Kramar N.M. Gipoid of gear with extreme quality parameters: questions of synthesis, the analysis and tooth generation // Header of scientific works East-Ukrainian National University named after V. Dahl. – Lugansk, 2003. – p. 117.

4. Golubenko A.L., Medintseva J.V., Nosko P.L. Aspects and problems of synthesis and mathematically-mechanical forming teeth's quasihyperboloid wheels improved hyperboloid gears // Reporter of East-Ukrainian National University named after V. Dahl. – 2007. – № 9 (115). – p. 42-51.

5. P.M.Tkach, P.L.Nosko, O.V.Bashta, O.O Revyakina, A.O.Kornienko, O.V. Tisov, Yu.O.Tsybrii Mathematical model for formation of spur gear teeth by a hyperbolic reference

profile // Bulletin of the National Technical University "KPI". Series: Mechanical Engineering and CAD: Coll. Sciences. Ave. / Nat. tech. University of Kharkiv. polytechnics inst-t. - Kharkiv: NTU "KPI", 2018. - № 25 (1301) 2018. - p.140-148.

6. Shishov V.P., Mukhovati A.A., Nosko P.L., Fil P.V., Boyko G.A., Bashta O.V. Highly loaded globoid and spiroid worm gears // Monograph - K .: NAU, 2017. -240p.

7. Medintseva Y.V., Balitskaya T.Y., Ratov D.V. Quasihyperboloid gears – alternative traditional hyperboloid gears // Reporter of East-Ukrainian National University named after V. Dahl. – 2007. – № 3 (109), part 2. – p. 94-99.

8. Vlasenko V.N. Works TK-47 "Mechanical drives" on harmonization of national and international standards // Reporter national technical university "HPI". – 2005. – № 40. – p. 3-6.

9. Vlasenko V. N. Modern condition and prospects of development of mechanical drives the general machine-building applications with gears Novikova // Reporter national technical university "HPI". – 2007. – № 21. – p. 11-19.

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УДОСКОНАЛЕНІ І ЕКСТРЕМАЛЬНІ ГЕОМЕТРО-КІНЕМАТИЧНІ ПАРАМЕТРИ ГІПЕРБОЛОЇДНИХ КОЛІС

Створення високонавантажених гіперболоїдних передач із покращеними та екстремальними геометрикінематичними параметрами на основі квазігіперболоїдних передач - перспективний та ефективний напрямок підвищення техніко-економічних характеристик редукторів. Актуальність дослідницької гіперболоїдної передачі не зменшується при постійній тенденції до збільшення потужності, характерній для сучасного машинобудування. У світі обсяг випуску гіперболоїдних передач подвоюється кожні 5-7 років, таким чином на початку третього тисячоліття щорічна вартість гіперболоїдних коліс перевищила кілька мільярдів доларів США. Використання будь-яких резервів у виробництві гіперболоїдних передач, шестерень і редукторів може дати і вже справді дає значну економічну вигоду за рахунок вдосконалення конструкції, підвищення продуктивності праці, поліпшення якості, зниження собівартості, підвищення конкурентоспроможності виробництва. Можна припустити, що квазігіперболоїдні передачі повинні мати найкращі параметри якості серед просторових зубчастих передач. Пропозиція, щодо геометричного запасу гвинтових, черв'ячних, спіроїдних та гіпоїдних передач та переходу від конічних і циліндричних початкових поверхонь до квазігіперболоїдних коліс, має підтвердження розрахунку, що полягає у викладеному числовому порівняльному аналізі. Чисельному дослідженню підлягали квазігіперболоїдні передачі з передачею Новікова, зубчасті передачі типу Новікова, евольвентні передачі, квазіевольвентні передачі, глобоїдна передача. Синтез просторових передач на основі вихідних поверхонь, що найменше відхиляються від гіперболоїдних аксоїдів, перспективний напрямок істотного підвищення міцності та покращення показників гвинтових, черв'ячних, спіроїдних та гіпоїдних передач. Колесо Новікова, таким чином, є більш перспективним, ніж евольвентна передача.

Ключові слова: високонавантажені гіперболоїдні передачі; геометрично-кінематичні параметри; швидкість кочення зубців; коефіцієнт питомого ковзання.

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