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The main directions of improving technical level of gear pumps of agricultural machines

The paper presents ways to improve the design of gear pumps and hydraulic drives of modern agricultural machines. The main trends in the increase of technical level of gear pumps are: increase of pressure of hydraulic fluid which is developed by the pump, increase of specific useful capacity, volume efficiency, relief of bearings and decrease of pulsation of instant feed and noise level.
gear pump, hydraulic drive, hydraulic machine

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Основные направления повышения технического уровня шестеренных насосов сельскохозяйственной техники

В процессе исследований было установлено, что основными направлениями усовершенствования шестеренного насоса являются: повышение давления рабочей жидкости; повышение удельного рабочего объема и мощности; повышение коэффициента подачи; снижение пульсации мгновенной подачи и давления; снижение шума в процессе работы насоса. Предложены основные направления дальнейшего развития шестеренных насосов сельскохозяйственной техники, позволяющие при минимальных затратах, существенно повысить технический уровень шестеренных насосов сельскохозяйственной техники.
шестеренный насос, гидропривод, гидромашина

In modern agricultural machines the fluid power drive is increasingly being used replacing mechanical, hydrodynamic and, in some designs, the electromechanical drives [1-4].

While creating modern hydraulic systems designed for high pressure, piston pumps are preferred. However, piston hydraulic machines have a number of significant disadvantages that makes us looking for alternative fluid power machines which work according to different principles.

These fluid power machines include gear pumps (GP). Due to the simplicity of design, reliability and unpretentiousness in operation this type of pumps is widely used. In some branches of engineering GP is dominant. For example, in the domestic tractor mounted systems of agricultural and industrial application with drawbar category from 6 to 150 kN only gear-type pumps are used.

Ukraine is a major producer of GP on the territory of former Soviet Union. The leading Ukrainian enterprise producing gear pumps is a public joint stock company "Hydrosila." The production volume of gear pumps produced by Kirovograd PJSC "Hydrosila" is more than 10 ... 12% of the world production.

Problem description. One of the most important directions in the development of hydraulic machines is to increase the pressure of the hydraulic fluid.

Research has shown that the cost of manufacturing of hydraulic units with equal capacity and with increasing pressure up to 30,0...40,0 MPa is reduced [5]. Transition to higher pressure in hydraulic units lets reduce their mass and dimension, as well as reduce the influence of the gas-air component of the hydraulic fluid. T.M. Bashta in his work [6] notes that the increase in pressure in the hydraulic system of the aircraft from 21,0 MPa to 28,0 MPa reduces the mass of the elements of the hydraulic system by 12 ... 16%.

A promising trend in the development of hydraulic systems is the use of adjusting pumps and hydraulic motors in hydraulic drives. A widespread expansion of adjusting pumps and hydraulic motors has been caused by the aspiration of designers to improve the degree of efficiency of hydraulic systems and hydraulic drives, to provide energy saving in the production process and realize the possibilities of electro-hydro automated systems for the "non-human" technology and remote control.

Objective of research. Object of research are the processes happening in the gear pump.

Research results. The need to reduce the size and steel intensity of hydraulic systems and hydraulic drives with the increase of their power efficiency is also a strategic direction in the development of hydraulic systems and hydraulic drives.

From the above-mentioned we may state that the main trends in further development of hydraulic systems and hydraulic drives is to increase the operating pressure, the degree of elements' control and increase of specific power density.

As the research results show [13] it is possible to increase the pressure generated by the GP by reducing the clearances in the conested parts. However, this involves the improvement of the accuracy of production, which requires the acquisition of the precise and expensive equipment.

One of the solutions to the problem is the selective collection of parts of the pump while it is assembled which corresponds to the effect of improving the accuracy of the manufacture of parts one class up. However, this method is appropriate only in individual and small batch production and is associated with significant organizational changes in production process.

The second option is a constructive solution to increase the hydraulic resistance in each pairing or eliminating clearances in these pairings, for example, the transition to a single part. For example, replacing the individually manufactured bushings for coupled bushings eliminates the clearance at the joints of bushings. Also, as an example of a constructive solution of the pump assembly problem is refusal of the bushings in general and transition to the formation of bearings in the housing and the cover of the GP. Under this scheme "Hydrosila" company produces pumps GP-M and «Master». This example illustrates the elimination of undesirable clearances in principle.

In our latest developments we propose the design of the GP which eliminates the face plate pairing of a driven gear, and, as we know the proportion of leakage on the face plate clearances of the GP is 70 ... 80% of the total leakage.

The increase of specific useful capacity still remains important which allows increasing basic specific indicators of a GP, in particular, the power density per weight unit and volume of the GP. The solutions to this problem are described in [14 - 18]. These papers show the results of the research to increase the rate of use of the volume of spur gear rings.

The rate of use of the volume of spur gear rings of serial GP does not exceed $K_{V_0} = 0{,}30$. The proposed design of the pump, subject to certain limitations imposed by the manufacturer $K_{V_0} = 0{,}3323$ [14 -18]. Optimum rate of use of the volume of spur gear rings without limitations of the producer reaches $K_{V_0} = 0{,}417$, in some cases higher. The next task is to develop the pump with $K_{V_0} = 1{,}0$. Currently the problem has been solved at theoretical level. There is continued research allowing realization of this idea in the design of the GP.

The next stage of development of the design of the GP is the development of ways for hydraulic relief of pump bearings.

The power pressure of hydraulic fluid on the spur gear rings, the force of which is perceived by pins and bearings of the pumping unit, leads to an increase in diameter and length of bearings, which significantly reduces the design excellence and technical level of the GP. Currently, this problem is solved by the use of new materials of sliding bearings with extra load. Due to the use of metal-flourine-bedded bearings we were able to reduce the length of bearings in 1,5...1,7. But the length of the bearings 2,0...2,5 heigher than spur gear rings which define the volume of the working chamber of the GP.

Functional analysis of the GP showed that one of the reserves for increasing the technical level of the GP is to increase its specific characteristics, particularly feeding. This can be achieved by reducing the dimensions of the GP and by reducing the length and diameter of the bearings.

The solution of this important scientific problem lies in the plane of transition from flat to the development of three-dimensional model of the pumping unit of the GP, including not only pur gear rings, the parameters of which depend on the volume of the working chamber of GP but bearings as well, the volume of which in the total volume of the pumping unit 2,0...2,5 higher than the spur gear rings.

One of the most common ways to reduce the load on bearings of the GP is the use of the scheme, in which the hydraulic unloading of bearings produced by increasing the high-pressure zone. Further increase in the high pressure zone will allow reducing the length of the bearings and thus, the GP in general. But to increase the high-pressure zone we have to use gear with a larger number of teeth, which reduces the rate of use of volume of spur gear rings of GP. It follows that there exists an optimal number of gear teeth, which provides the minimum dimensions of the bearings.

In other words, it is possible to find the optimum parameters of the toothing for which the dimensions of the pumping unit, and thus the GP, will be minimal for the given design conditions.

As the optimization criterion it is proposed to apply the rate of use volume of pumping unit, which is the ratio of the form

$$K_{КУ} = \frac{\mathrm{V}_0\left(D_e, D_i\left(d_z, z\right), b\left(\left[p\right]\right), z\right)}{\mathrm{V}_{\text{КУ}}\left(d_z\left(\left[p\right]\right), D_e, b\left(\left[p\right]\right), \mathrm{l}_z\left(\left[p\right]\right)\right)}, \tag{1}$$

where V_0 - the working volume of the GP, m^3;

D_i - diameter of the gear teeth basins, m;

d_z - diameter of the pins, m;

z - the number of teeth of gears;

b - the width of the spur gear ring, m;

$\mathrm{V}_{\text{КУ}}$ - the volume used by pumping unit of GP, m^3;

l_z - pin length, m;

$\left[p\right]$ - load capacity of bearings for a given sliding speed, Pa.

The volume used by the pumping unit of the GP can be easily calculated according to the dependence

$$\mathrm{V}_{\text{КУ}} = 2\cdot\left[0{,}25\,D_e^2\cdot\left(b\left(\left[p\right]\right)+2\cdot l_z\left(\left[p\right]\right)\right)\right]. \tag{2}$$

Determination of working volume of GP under normal conditions presents no particular difficulties [14-19]. However, in the case illustrated by the dependence (1) – it is a difficult task that requires additional theoretical research. This is due to the fact that the parameters in the corresponding calculation formulas are themselves dependent variables, in particular the parameters of sliding bearings of GP.

The most important research aimed at improving the technical level of GP is to increase the feeding rate. To achieve this goal we developed new physical-mathematical and mathematical models of internal leaks in the GP. Until now, there was no method of calculating internal leaks of fluid in the calculation of the GP, which are still determined experimentally [19]. At this moment the research has been done and the results are presented in publications [20-23]. The data obtained in the research can and should be used in the calculation of the volume of internal leaks through the gaps in the joints of the GP, as well as in the development of measures aimed at increasing the pressure which is generated by the GP.

However, theoretical developments of the GP, despite their long history, are far from to be perfect. One of the directions of further development of the theory of internal leaks is to determine the relationship of volumes of internal leaks and flow rate of the hydraulic fluid in the sliding bearings of the GP.

Recent years, the work is done to reduce pulsation while instantaneous feeding of hydraulic fluid in the GP. The obtained results of theoretical research in this direction eliminated some inaccuracies of existing physical-mathematical and mathematical models and theories [28]. The developed during theoretical studies new physical and mathematical and mathematical models suggest that the geometric pulsation of instantaneous feeding and pressure during operation of the GP can be significantly reduced. These findings were fully confirmed and extended by theoretical and experimental studies of this phenomenon [28].

One of the major unexplored areas in the working process of the GP is the process of increasing the pressure of the hydraulic fluid. It is believed that the process of pressure increase occurs during the angle rotation pitch of the gear. This is a complex process depending on many factors, notably the frequency of rotational of gears, as well as circumferential, radially-directed end faces and the end faces of leaks in the transition zone.

One of the insufficiently studied trends in the theory of GP is the process of absorption. This is due to the fact that modern gear pumps have high overall and volume efficiency. Rotation speed does not exceed 60 s^{-1} and does not affect the quality of the filling chambers of the GP. By increasing the rotation speed of the drive it is possible to increase all specific indicators of GP, many of which are proportional to the speed. Consequently, the development of future designs of the GP should consider the possibility of increasing the rotation speed and pay attention to the study of the process of absorption of the hydraulic fluid.

The problem of increasing the coefficient of feeding of the GP has not been fully investigated. Still remains unsolved the mechanism of the process of compression and decompression of the hydraulic fluid in the cut-off plane of the GP. The authors of monograph [12] are concerned with a serious problem of loss of potential energy of the pressurized hydraulic fluid, which is transferred from the cut-off plane into the suction chamber. Solving this problem will increase the volume and the overall efficiency of the GP.

An important issue is the problem of regulating the feeding in GP. At present, there is a successful experience of the GP design with regulated feeding [24-27]. In case of successful solution of a number of problems and the main of which is the increase of the coefficient of regulation, it is possible to get the GP with adjustable feedrate which by its cost will be considerably cheaper than the existing designs of regulated volume gear pumps – guided-vane and axial piston pumps.

The most important area of research is the study of the dynamic characteristics of not only the GP but also other types of the regulated volume pumps. At the moment a fast increase in the expansion of production processes demands accuracy and speed regulation which creates the need to develop new methods of calculation and design of hydraulic drives and hydro-

automatics. To perform the calculations it is necessary to study the dynamic characteristics of the hydraulic drive elements.
Increasing load and speed in modern machines is accompanied by increasing noise level. Gear pumps are no exception in this regard. Measures to reduce noise in gear pumps that are described in technical literature are, as a rule, a recommendation, and a really effective way to reduce noise has not been currently developed. Consequently, the task of improving the noise performance should also be considered relevant.

It should also be noted that the energy aspect of GP operating process has not been studied in details, in particular processes connected with the loss of energy for heating the hydraulic fluid, as well as factors affecting the mechanical efficiency.

Conclusions. When designing the hydraulic drives of agricultural equipment to hydraulic machine it is appropriate to use gear pumps, which have a number of important advantages in comparison with other types of pumps. The principles by which gear pumps operate allow positioning them as pumps with a great potential. The article outlined the main ways of further improving the design of gear pumps in the direction of increasing their technical level. The main directions of improvement of the GP are: increasing pressure of hydraulic fluid generated by the pump; specific working volume and capacity; rate of feeding; unloading of bearings; instant reduction of pulsation flow and pressure, and reduced noise during operation of the pump.

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Основні напрямки підвищення технічного рівня шестеренних насосів сільськогосподарської техніки

Метою роботи було, ґрунтуючись на досвіді проектування шестеренних насосів, визначити основні напрямки розвитку їх конструкцій для подальшого підвищення технічного рівня сільськогосподарської техніки.

В процесі досліджень застосовувався критичний аналіз досвіду теоретичних, експериментальних і конструкторських розробок шестеренних насосів сільськогосподарської техніки.

Було встановлено, що основними напрямками удосконалення шестеренного насоса є наступні: підвищення тиску робочої рідини, що розвивається насосом, - за рахунок підвищення внутрішнього гідравлічного опору в конструкції шестеренного насоса; підвищення питомого робочого об'єму і потужності - шляхом оптимізації параметрів зубчатого зачеплення і усього вузла, що качає, вцілому, а також за рахунок розвантаження підшипників насоса, що дозволить зменшити габарити, як вузла, що качає, так і насоса вцілому; підвищення коефіцієнта подачі - за рахунок підвищення внутрішнього гідроопору, а також підвищення частоти обертання насоса; зниження пульсації миттєвої подачі і тиску – за рахунок встановлення того, що пульсація подачі і тиску не є неминучим недоліком, пов'язаним з конструктивними особливостями шестеренного насоса, що визначило подальший розвиток конструкції насоса в цьому напрямку шляхом усунення причин виникнення пульсації; зниження шуму в процесі роботи насоса – комплексне багатовимірне завдання, вирішення якого приведе не лише до усунення шуму, але і до істотного підвищення технічного рівня шестеренних насосів сільськогосподарської техніки.

Таким чином, були запропоновані основні напрямки подальшого розвитку шестеренних насосів сільськогосподарської техніки, що дозволяють при мінімальних витратах, в рамках традиційних конструкторських схем істотно підвищити технічний рівень шестеренних насосів сільськогосподарської техніки.
шестеренний насос, гідропривід, гідромашина

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Вплив на навколишнє середовище автобусів БАЗ-22154 під час експлуатації на різних видах палива

Обґрунтована актуальність проблеми екологічної небезпеки автомобільного транспорту та представлена порівняльна оцінка використання бензину і газового палива на прикладі автобусів БАЗ-22154 в міських умовах.
автомобільний транспорт, забруднення повітря, екологічна небезпека

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Влияние на окружающую среду автобусов БАЗ-22154 во время эксплуатации на разных видах топлива

В данной работе обоснована актуальность проблемы экологической опасности автомобильного транспорта и представлена сравнительная оценка использования бензина и газового топлива на примере автобусов БАЗ-22154 в городских условиях.
автомобильный транспорт, загрязнение воздуха, экологическая опасность

Постановка проблеми. В сучасних умовах автомобільний транспорт стає найбільш значним джерелом забруднення атмосферного повітря, особливо великих міст. Автомобільний транспорт, поглинаючи настільки необхідний для протікання життя кисень, разом з тим інтенсивно забруднює повітряне середовище токсичними