The relevance of the use of an intelligent mechanism in the drive of modern agricultural machines

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Abstract. The article analyzes theoretical and experimental studies of intelligent mechanism designs, considers the advantages of using intelligent mechanisms for agricultural machines in comparison with traditional structural schemes. The principle of operation of an intelligent mechanism presented in the form of two differential drives for agricultural machines is considered. Planetary mechanisms of this type are systems with two or more degrees of freedom in terms of the number of structural connections, therefore, with one leading link, the movement of their driven links is determined by additional external links that may have different physical origins. The paper presents a description and also considers the main advantages of using the developed kinematic scheme of an intelligent mechanism for agricultural machines, which allows for automatic regulation in a wide range of movement speed depending on the load on the working body, the weight of grain on the conveyor belt, the type of soil on which the agricultural machine moves, etc., overload protection, increased productivity due to full engine load. The proposed intelligent mechanism for agricultural machines allows the distribution of torque from a single engine, and there is also no need to install a set of sensors and a control unit.

1 Introduction

Intelligent (self–adjusting) mechanisms are control systems that provide compensation for parametric, signaling, functional or structural uncertainties of the control object due to automatic adjustment during the operational functioning of the system [1].

Works in the direction of the development of intelligent mechanisms presented in the form of a drive based on two conical differential mechanisms were started by scientists Alabuzhev P.M., Alimov O.D., Vodyanik G.M., Drovnikov A.N., Kuznetsov V.E., Lysyansky V.A., Pershin V.A.[2], Lemeshko M.A., Karandeev Yu.E. and by others. Also engaged in the study of such mechanisms are Hinikadze T.A. (Study of the compliance of the characteristics of the adaptive hydraulic drive module with the technological parameters

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of machines), Kaimova G.T. (Synthesis of an automatic adaptive gear variator), Volkov R.Yu. (Analysis of some circuit solutions of adaptive machines for loading and drilling operations), Zgonnik I.P. [3], Pashovkin I.V. (Analysis of hydraulic drives of drilling systems with self-adaptation) and others. Patents for inventions in this field have A.N. Drovnikov (Earthmoving machine for soil development) Khadeev R.G. [4], Darda I.V. (Adaptive hydraulic drive system of the feed mechanism of the cleaning combine), Kruglov S.P. [5] and others. In these works, the two-differential drive is mainly used in drilling rigs.

2 Materials and Methods

The peculiarity of the operation of such a drive and its advantages over others are:
- the possibility of distributing power and torque from the engine shaft to three power take-off shafts (Figure 1);
- the ability to adapt the torque depending on the load conditions on the power take-off shafts;
- the ability to smoothly change the torque by setting certain torque values on one of the power take-off shafts forming the reference torque;
- ensuring optimal power circulation between the working bodies and their drives.

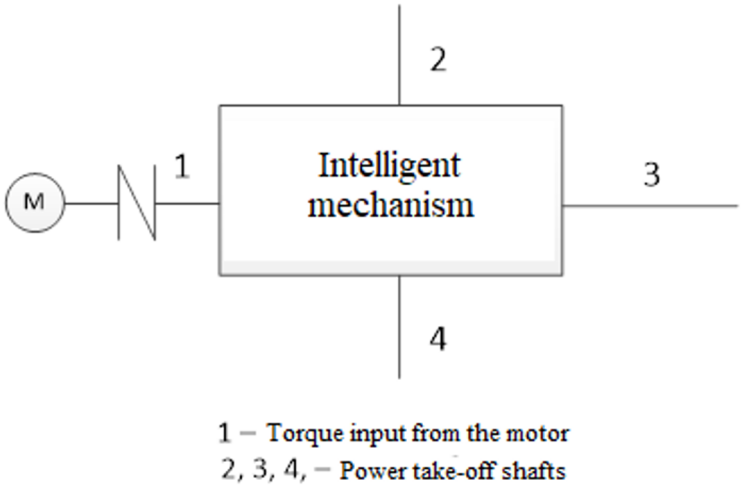

Fig. 1. Diagram of inputs/outputs to the intelligent mechanism

Based on the above works, it is possible to formulate a general principle of operation of the drive of the two differential mechanism.

The motor M transmits rotation through the driver 1 of the first conical differential DF1 (Figure 2) to the solar wheel 2 and the gear wheel 3, which is respectively connected to the gear wheel 4 of the second conical differential DF2 so that the latter have different rotation.

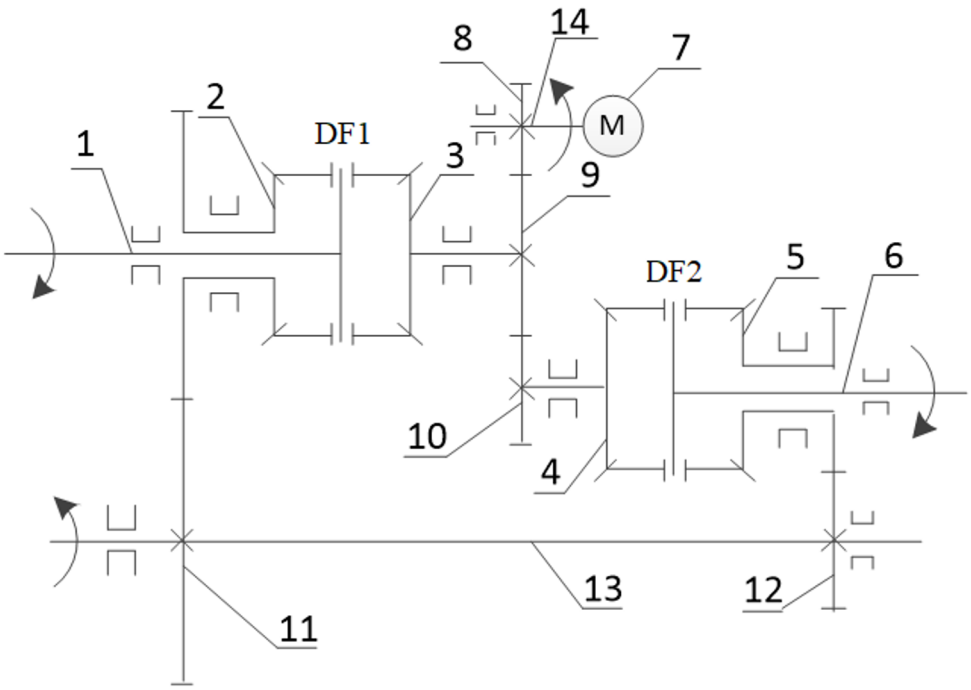

Fig. 2. Kinematic diagram of an intelligent mechanism consisting of two conical differential mechanisms

The direction of rotation of the driver 6 corresponds to the speed difference of the gear wheel 4 and the solar wheel 5. The expansion of the range of self–regulation is provided by the introduction into the kinematic scheme of the reference torque from the load motor 7, connected through the gear 8, with the gear wheels DF1 and DF2 - respectively 3 and 4 through the gears and 10. Solar wheels 2 and 5, respectively, DF1 and DF2, connected to gears 11 and 12 rigidly sitting on the shaft 13, which transmits rotation to the working body.

The mechanism works as follows. When the engine is turned on, all elements of the two differential drive rotate. As the load on the shaft 13 increases, the rotation speed of the solar wheels 2 and 5 decreases. In this regard, the rotation speed of the gear wheel 3 and the associated gear 9 increases. The gear 9 is connected to the gears 8 and 10. The rotation speed of the shaft 14 and the gear wheel 4 also increases. Since the rotation speed of the solar wheel 5 has decreased, and the rotation speed of the gear wheel 4 has increased, the rotation speed of the driver 6 decreases.

When the load on the shaft 13 decreases, the rotation speed of the solar wheels 2 and 5 increases. In this regard, the rotation speed of gears 3 and 4, as well as the gears 9 and 10 associated with them, decreases. Considering that in a conical differential, the angular velocity of rotation of the gears and the driver are related by the ratio:

$$\omega_2 = 2\omega_0 - \omega_1$$

where ω_0 is the angular velocity of rotation of the driver;

ω_1 is the angular velocity of rotation of the solar wheel;

ω_2 is the angular speed of rotation of the gear wheel.

Since the angular speed of rotation of the gears and the driver remains constant, the speed of rotation of the driver 6 increases.

With a significant increase in the load on the shaft 13 to its complete stop, the solar wheels 2 and 5 also stop. In this regard, the rotation speed of the gears 3 and 9, the shaft 14 and the gear 4 increases significantly. Since the difference in angular velocities of the solar wheels 4 and 5 becomes negative, the direction of rotation of the driver 6 changes.

3 Results and Discussion

The developed intelligent mechanism, represented by two differentials, in the drive of an agricultural machine, is devoid of the disadvantages that exist in modern agricultural machines [6]. The diagram of an agricultural machine with an intelligent mechanism is shown in Figure 3.

Unlike modern agricultural machines that have several engines (an internal combustion engine, three hydraulic motors and two electric motors), the main advantage of the developed intelligent mechanism will be the ability to automatically adjust the power and torque on:

– the drive shaft of the agricultural machine 13 (figure 3), which will lead to a change in the speed of the translational movement of the machine;

– the drive shaft of the attachments 25 (Figure 3), for example, when using an agricultural machine for harvesting grain, power and torque will be transmitted to the drive of the header and conveyor belt.

– the shaft of the fan drive 8, designed to remove straw, floor and other waste particles from the combine harvester.

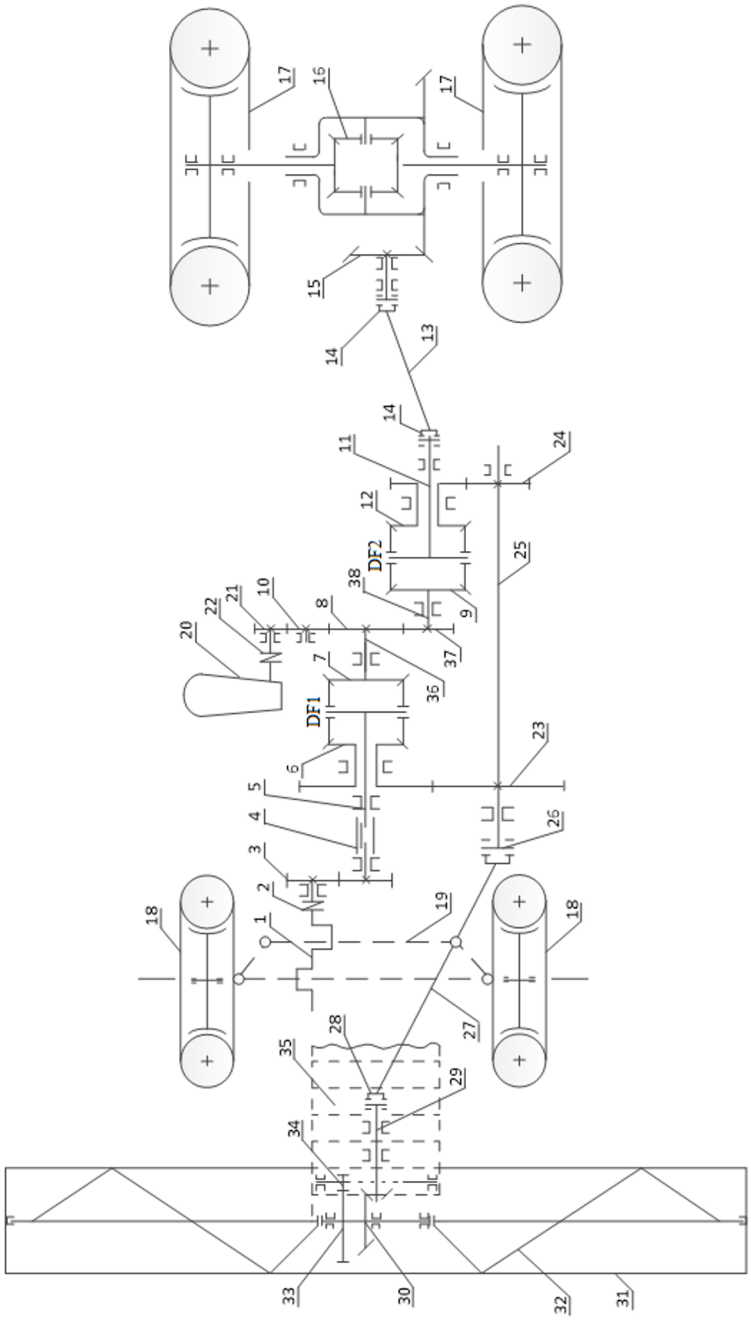

Fig. 3. Agricultural machine with intelligent mechanism

In modern agricultural machines, in addition to internal combustion engines, there are additionally electric motors, hydraulic motors that transmit rotation to the working body (for example, a reel), a conveyor belt, etc. There are none in the proposed scheme of the agricultural machine. Also, to automate the operation of a modern agricultural combine, it is required: a control unit, various sensors to control the load on the working organ, the weight of grain on the conveyor belt, etc. In an agricultural machine with the proposed

intelligent mechanism, adaptation to changing working conditions occurs due to the mechanical operation of two differential drives, as a result of which there is no need for the above mechanisms [7-13].

Figure 3 shows a diagram of the intelligent mechanism of an agricultural machine. The device consists of an engine 1 that transmits power and torque through the clutch 2 and gearbox gears 3 to the shaft 4. From the shaft 4, power and torque are transmitted through a spline connection to the driver 5 of the first bevel differential (DF1), the solar wheel 6 and the gear wheel 7. The gear wheel 7 is connected through the spline connections of the shaft 36 to the gear 8 and through the gear 37 connected by a spline connection to the shaft 38, power and torque are transmitted to the gear wheel 9 of the second conical differential (DF2) so that the latter have different rotation [14-21].

The direction of rotation of the driver 11 corresponds to the speed difference of the solar wheels 9 and 12. Further, the rotation of the driver 11 is transmitted through the driveshaft 13 with couplings 14 to the main gear 15, and then through the inter-wheel conical differential 16 to the driving wheels 17. When driving, the driving wheels 17 engage the front swivel wheels 18, connected by a controlled steering trapezoid 19.

The expansion of the ranges of rational self-regulation of the operating modes of an agricultural machine is ensured by the introduction of a centrifugal supercharger 20 into the kinematic chain, which is connected to the gears 7 and 9 by means of gears 8, 10, 21 and a clutch 22.

Mounted working equipment (reel 31 with cutting blades 32, conveyor belt 35) is connected to solar wheels 6 and 12, through gears 23, 24 and with the help of shaft 25 and coupling 26 transmits rotation to shaft 27, from which the gear 30 rotates through the coupling 28 and shaft 29. The gear 30 rotates the reel 31 with cutting blades 32. The gear 30 is mounted on the same shaft with the gear 33, from which the rotation is transmitted to the drive shaft 34 of the conveyor belt 35.

4 Conclusion

This design allows for automatic regulation in a wide range of the feed rate of the agricultural machine depending on the load on the shaft of the working body, overload protection, increased productivity due to the full load of the engine, the loads on the shaft of which are stabilized regardless of the operating conditions of the agricultural machine.

In the proposed variant, there is no control unit that collects, processes and outputs a result on changing the operating mode of an agricultural machine, a set of sensors that collect information about the operation of the machine, which includes data on the fullness of the side with grain, temperature, grain weight on the transport belt, vegetation in the field, etc. [22-27]. The proposed intelligent mechanism is more economical because its design lacks the above-mentioned controls, there is no need to develop special software for their operation, and there is also no need to spend electricity on their operation.

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