

# The alternator and the ancillary components continuous drive from the gearbox

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**Abstract.** This paper considered implementation variations of the alternator and/or other units (systems) continuous mechanical drive from summing reduction unit, combined power flows from input and output gearbox valves. The three-link planetary mechanism is used in the simplest case as a reduction unit. These principals could be used in the hybrid cars transmission. The main purpose of this concept is to provide an uninterrupted power supply to the vehicle electrical onboard system from the alternator, including cases of the engine off. Describing principles could be used in transmissions of the wheel traction transport vehicles and tracked vehicles with the hybrid propulsion system. Variants of double way transmission kinematics schemes are provided. The differential characteristics of the schemes are movement and steering abilities with the inoperable internal combustion or electric engines. It worth noting that such engineering solution have extra advantages. The steering control level is increasing, electromechanical drive could replace hydrostatic steering control transmission as a more chip, reliable and technical.

## 1. Introduction

The number of an electric energy consumers and their power in transport vehicles are always increasing. The units operational integrity, which providing vehicle movement and driving control, more often depends on the on-board electrical network. The oil pump with an electric drive, the power distribution mechanism with an electromechanical drive of a control elements [1,2], the traction electrical motor as a part of the hybrid propulsion system [3,4], the hybrid power distribution mechanism [5], steering device, the electric power steering, etc. have already implemented in the automotive industry. The battery capacity without working alternator is not enough to ensure the all consumers operation. But the alternator does not work, when the engine is not running.

The alternator or the reversible electric machine is a propulsion system part of almost any modern heat engine vehicle. The traction electrical motor, which could be made as the reversible electric machine, in the parallel/series type hybrid propulsion system could have a function of an alternator and a starter. However, this solution requires using the complex reduction gearbox with an electronic control device in the transmission for the implementation of all operation modes of the propulsion system.

The operation of the alternator should be ensured for a vehicle towing, for example. Therefore, the reserve alternator driven by the driven shaft of the transforming mechanism could be used for cases of this kind. The low power alternator would provide systems for vehicle mobility in critical situations.



The alternator drive from a planetary gear set is alternative to drive from the heat engine. The planetary gear set provides summing rotation speed of the engine drive shaft and the output shaft of the reduction unit. So, we could use all control systems during the towing operation. This solution helps to solve the problem with "the bump start".

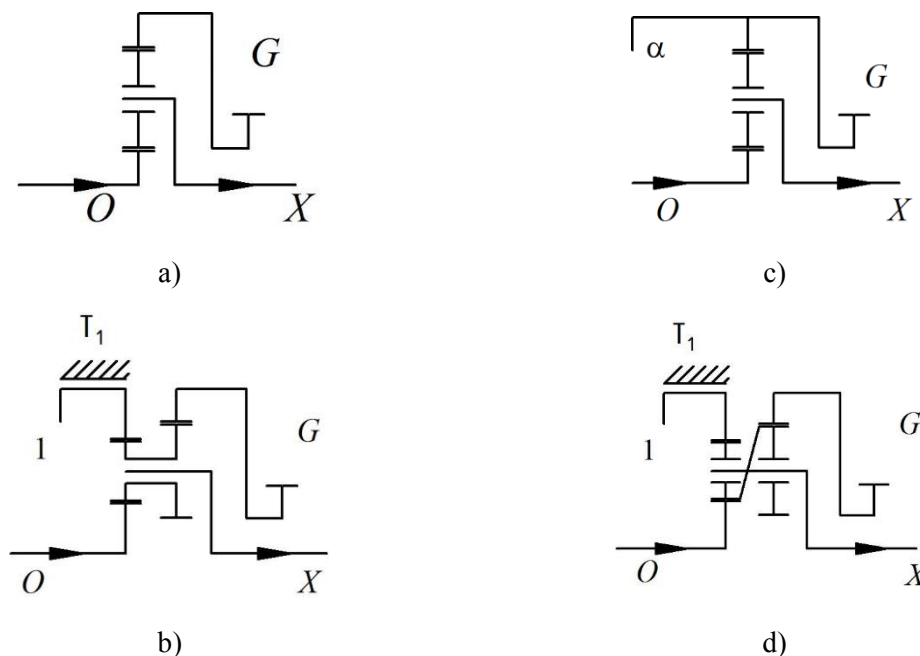
The planetary gearbox oil pump is also should be driven, when the engine is not running. Nowadays the most part of the vehicle manufacturers provide the oil pump driving from the torque converter pump wheel, which is part of the hydro mechanical transmission. The oil pump driving is indirectly provided from the heat engine output shaft. In this case it is necessary to limit the towed vehicle speed and the towing distance [6]. The towing is generally prohibited sometimes, and evacuation is recommended by spec lift or flatbed recovery truck, which is unacceptable in many cases.

## 2. Results

The principles of continuous mechanical drive Focus on the options of the electric alternator and the oil pump drive providing from the transforming mechanism. The connection with the ancillary component is carried out through the link G. The output of the link G could be from the driving or driven link of the transforming mechanism, depending on the transmission layout. The latter case options shown in Figure 1.

Figure 1, a: the plan is universal to the transforming mechanism type. The link G is an ring gear of a simple planetary gear mechanism which isn't include into the kinematic scheme of the actual transforming mechanism. The rotation speed plan of the proposed planetary gear mechanism is shown in Figure 2.

The changing of a direction of link G rotation in mechanism(when reversing) should be considered when using this plan, so it is necessary to provide a method for automatically reversing the driven alternator and pump.



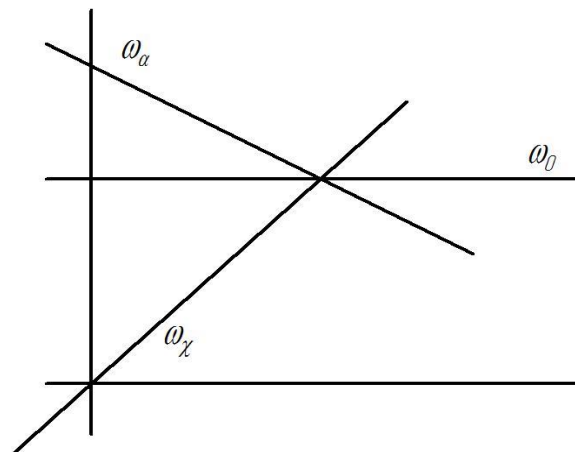
**Figure 1.** Variants of the power take-off transforming mechanism(TM) organization: O - is the driving link, X - is the driven link and G - is driving link of the alternator and / or the oil pump;  $\alpha$ - is the connecting link 1- is an arbitrary link of the planetary gearbox (special case TM) and T1- is the control element associated with an arbitrary link.

Figure 1, b: the plan for the planetary gearbox with more than 3 degrees of freedom. The link  $\alpha$  is a connecting link which isn't concerned with the gearbox controls. The enforcing conditions  $\text{sign}(\omega_\alpha) = \text{const}$  is theoretically possible.

The rotation speed of the link  $\alpha$  is  $\omega_\alpha$ . The alternator and pump aren't need in the reverse gear in these conditions. The plan involves using the one of the planetary gearbox rows. Such an approach makes it possible to reduce the transforming mechanism axial dimension in comparison with version 1, a.

Figure 1, c and 1, d: the link G is included in the complex four-link mechanism (option c - low-tech stepped satellites are used, option d - the plan with the concatenated satellites is used). The link 1 is one of planetary gearbox arbitrary main links connected to the control element T1. This simplifies the gearbox plan synthesis while retaining the other advantages of option 1, b.

It should be noted that the kinematic plans options in Figure 1 are also applicable to solve the specific task of a parallel power flow driving of the high-speed tracked machine steering mechanism [7-11]. However, in this case, attention is being given to another drive feature. It becomes possible to provide a hyperbolic law of the design turning radius changing to the vehicle speed, this relation in traditional mechanisms is linear, which limits the average vehicle speed and causes heat engine underutilization.

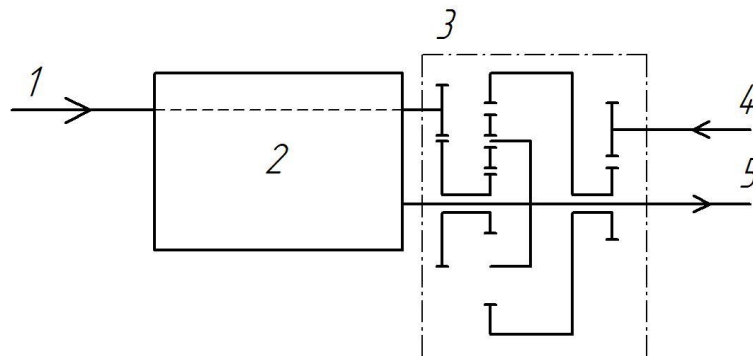


**Figure 2.** Three-link mechanism velocity diagram, performed according to the plan in Figure 1, a.

The principle shown in Figure 1, b-d, could be used in the transmission of the hybrid power plant vehicle. The traction electrical motor could be made as the reversible electric machine and discard the alternator. Refusing to use a starter isn't advisable, as it is quite compact, the transmission plan gets easier and the number of the transmission layout solutions are increasing. The connection host of heat engine and traction electrical motor engine is shown in Figure 3. It is named "parallel/series type hybrid" for the double-flows transmission with the central gearbox.

The plan of the double flows parallel/series type hybrid propulsion system for the transport vehicle with central gearbox is shown in Figure 4, a. You could see that it is used another principle in the parallel flow power distribution. The energy of the storage system 8 supply the traction electric motor for power input to parallel flow. The energy storage system is charged by the alternator 9 which is driven from the gearbox 3. Thus, the traction electric motor is a part of the tracked vehicle steering mechanism.

The double flows mechanisms are used in the tracked vehicles. The designing and the power, kinematic aspects analyzing issues are considered in the fundamental literature sources [4, 6, 8, 12]. However, the problem of the transmission use for the hybrid propulsion system isn't considered to this moment.



**Figure 3.** The transmission plane variants for the parallel/series type hybrid propulsion system of the transport vehicle with central gearbox (see the Fig.1,a): 1 – power input from the heat engine; 2 – converting mechanism (for example: gearbox); 3 – reduction gearbox; 4 – power input from the traction electric motor; 5 – power output to the final gear.

The mechanism operates as a hybrid mechanism of the power distribution [13]. The steering device friction  $C_R$  is on for the linear motion. The brake  $T_R$  is on for the power redistribution between to the turn. At the same time the control element isn't worked on the slipping mode [14], all types of turnings are provided by the traction electric motor. Two-steps reduction unit is providing size reduction of the traction electric motor. Considering transmission designing principle is applicable for high-speed tracked vehicles weighting 8-30 tons.

The plan of the double flows parallel/series type hybrid propulsion system for the transport vehicle with on-board gearboxes is shown in Fig. 4, b [15]. It commonly used for the special transport technological vehicle built on the main battle tank (military engineering vehicle, vehicle-launched bridge, vehicle to work in the radiation electrochemical reaction areas etc.).

In this scheme the central shaft should be stopped by the brake  $T_0$  to provide neutral turn. At this moment the friction  $C_0$  should be turned off. We note that in this case the traction electric motor could be used as a heat engine starter. This starting mode is recommended only for the emergency conditions as it leads to the extra power loss.

#### The operating modes

Rectilinear motion using only the heat engine. The heat engine is connecting with input shaft of the transmission and traction electric alternator main power way. The economic operating mode is preferable. There is no mechanical connection between the engine and the transmission parallel power way. The traction electric motor is connected to the parallel power way by the reduction unit P. The reduction unit transmission ratio is selected for the traction electric motor according to provide the whole range of the turning radiuses. Symmetrical spur-gear differential with two control elements (brake  $T_R$  and locking clutch  $C_R$ ) is set up in the parallel power way. During the rectilinear motion traction electric motor is turned off, the parallel power way isn't used: the brake  $T_R$  and clutch  $C_R$  are turned on (the planetary gear set is locked).

Rectilinear motion is stable. The traction electric alternator output energy is accumulated in the energy storage device. It could be used to other consumers supply connected to high-voltage network. As the traction electric motor of domestically made cars should be used next to 50% of the vehicle movement time, the traction electric alternator power could be less than traction electric motor power by 20-30%.

The turning using the heat engine and traction electric motor. The clutch  $C_R$  is turned off, brake  $T_R$  (transmission ratio of the planetary gear set D is (-1)). The traction electric motor turns on (the rotation direction is chosen by the vehicle turning direction). The same gears are selected for the both on-board

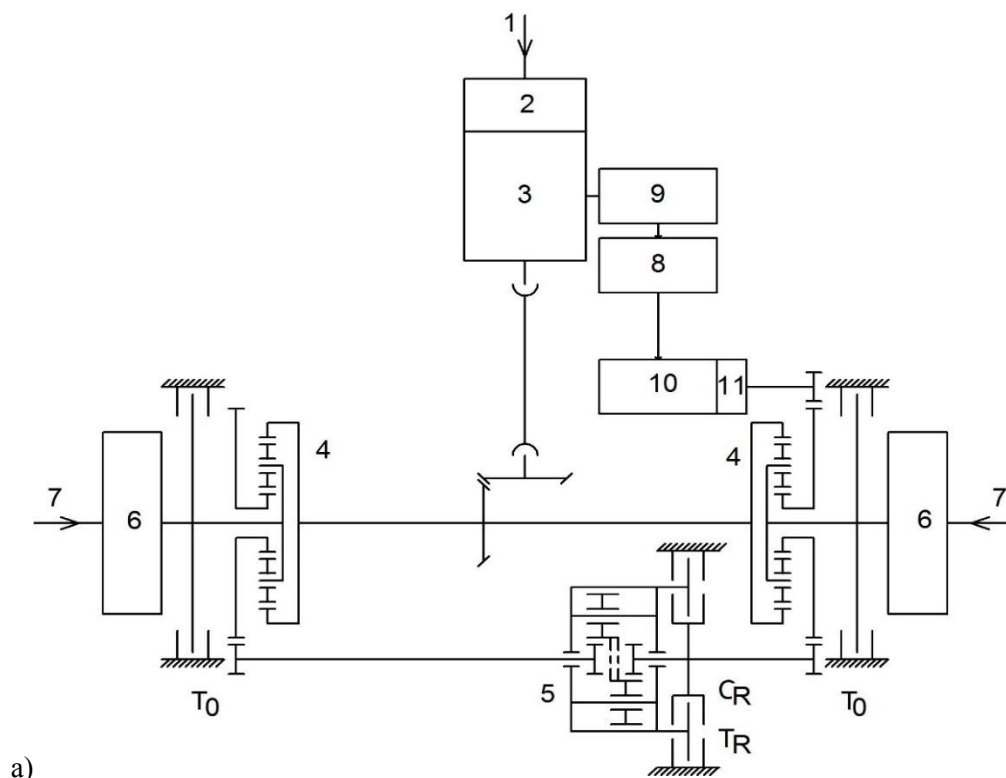
gearboxes (the using of low range gear for low speed track gearbox could be considered). According to the kinematics of the double flows steering device, the speed of the high-speed track increases and the speed of the low-speed track declines, because the boards differential connection. The traction electric motor supply is provided by energy storage device and traction electric alternator, therefore the sum wheel power could be higher than the engine power for a short time.

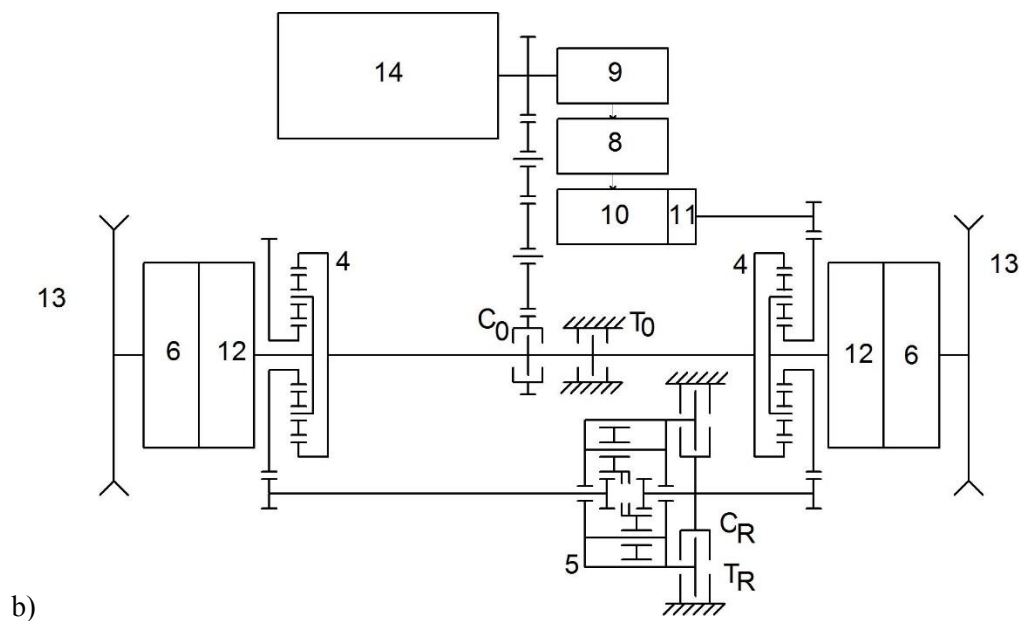
Neutral turning using only traction electric motor. The traction electric motor maximum power should be selected according to opportunities to provide this mode.

When the main power flow fails, the vehicle could use only traction electric motor for rectilinear motion when failing engine (fallback mode). In that case, the low range gear of the low speed track gearbox turns on or the output shaft stops. The minimum turning radius is equal to a half of the track width.

Rectilinear motion using heat engine and tracked electric motor (accelerated mode). In that case, the both power ways are used. The mode is applied to achieve the maximum speed. The parallel flow clutch  $C_R$  turns on.

Rectilinear motion using only tracked electric motor (fallback mode). When the main power flow fails (the main power flow shafts are stopped, for example, by the dynamic braking modes) the traction electric motor could be used to move the vehicle for a short time. The parallel power flow clutch  $C_R$  turns on. The stopping on-board brakes are used for the steering control system because the low vehicle speed. The energy storage system supplies the movement. The development of the SPBTU specialist could be implemented in such transmission design [16-18].





**Figure 4.** Kinematic diagram of double-flows transmission: a –with central gearbox; b –with on-board gearboxes; 1 –power supply from engine; 2 – coupling mechanism; 3 – gearbox; 4 – summing planetary gear set; 5 – differential with clutches  $C_R$  and  $T_R$ ; 6 – track gear reducer; 7 –power transfer to the drive wheel; 8 – energy storage device; 9 – traction electric alternator; 10 – tracked electricmotor; 11 – parallel flow reverse gear; 12 – tracked gearbox; 13 – drive wheel; 14 – internal combustion engine;  $C_0$  – central clutch;  $T_0$  –brake.

**Table 1.** Vehicle operation modes.

Operation modes	With the central gearbox		With the on-board track gear-boxes	
	Tracked electric motor	Activated control elements	Tracked electric motor	Activated control elements
Rectilinear motion using only the heat engine	Off	$T_R$ and $C_R$	Off	$T_R$ , $C_0$ and $C_R$
The turning using the heat engine and traction electric motor	Engine-on mode with a given rotation direction	$T_R$	Engine-on mode with a given rotation direction	$C_0$ and $T_R$
Neutral turning using only traction electric motor	Engine-on mode with a given rotation direction	$T_R$	Engine-on mode with a given rotation direction	$T_0$ and $T_R$
Rectilinear motion using heat engine and tracked electric motor (Accelerated mode)	Engine-on mode	$C_R$	Engine-on mode	$C_R$
Rectilinear motion using only tracked electric motor (fallback mode).	Engine-on mode	$C_R$	Engine-on mode	$C_R$

The turning using only heat engine (fallback mode). When the parallel power flow fails, tracked gearboxes or on-board stopping brakes is used to control vehicle movement. The brake  $T_R$  and the clutch  $C_R$  (sun gear of the summing planetary gear set is stopped) should be turned on in both variants of the parallel flow. The vehicle could be used for moving and fighting.

Both plans shown in Figure 4 provide the possibility to control the vehicle movement in case the traction electric motor or the vehicle electrical onboard system fails. When the transmission with central gearbox is used, the speed should be low and on-board stopping brakes should be used for steering control.

When the transmission with track gearboxes is used, low range gear or stopping brake for low speed track gearbox is turned on to provide steering control fallback mode. This principle is used in the serial Russian tanks.

All operation modes for the kinematic diagram (Figure 4) are shown in the Table 1.

### 3. Discussion

The special aspects of the drive kinematics are considered in this section. The connection between the planetary gearbox and the traction motor is carried out through the link G. The transforming mechanism in addition to the gearbox may include the hydrodynamic transmission could be included in the transforming mechanism in addition to the gearbox.

The gearbox kinematic scheme must provide all operating modes of the power plant:

- operation of the heat engine (The traction electrical motor works in alternator mode);
- multiple operation of the heat engine and traction electrical motor;
- operation of the traction electrical motor;
- neutral;
- parking.

Such principle of the connection between the gearbox and traction electrical motor allows to eliminate the use of the complex reduction gearbox that reconciles the operation of the heat engine and traction electrical motor isn't not necessary if we use describing principle.

The drive principle described above could be used in tracked transport vehicle transmission that provides the principle of a parallel/series type hybrid, the same as such wheeled vehicles transmissions with tracked electric motor as part of the power distribution mechanism [19,20,21,22]. The lubrication system pump of the planetary gearboxes, for example.

The inventive drive method is universal, and it could be used for all gearbox types. But an additional summing planetary gear set is necessary in a helical or spur gearboxes, it complicates the transmission that isn't always economically acceptable. Such function in the planetary gearbox can be performed by one of the planetary gears set with minimal complication in the construction.

### 4. Conclusion

According to the results of work, Russian patents [23-25] were obtained.

1. The possibility of organizing the alternator and / or an oil pump drive using a differential mechanism which combines the input and output links of the transforming mechanism was shown.

2. The direction changing of the leading link in such drive should be, therefore it is necessary to provide the pump or alternator reverse.

3. This principle of communication with the transforming mechanism could be use in new plan development of the implementing hybrid transmission.

### References

- [1] Ushiroda Yu, Sawase K, Takahashi N, Suzuki K and Manabe K 2003 Development of Super AYC *Technical Review* **20** 73-6
- [2] Bulyashov A H Automotive Handbook URL [http://www.irs.kit.edu/131213\\_GC\\_TorqueVectoring\\_ZF\\_Handout.pdf](http://www.irs.kit.edu/131213_GC_TorqueVectoring_ZF_Handout.pdf)

- [3] Dobretsov R Yu, Lozin A V and Semenov A G 2018 *Gibridnyj mekhanizm raspredeleniya moshchnosti v transmissii transportnoj mashiny* [The hybrid power distribution mechanism in the transport vehicle transmission] Patent RU No 2656938 [In Russian]
- [4] Wong J Y 2001 *Theory of ground vehicles* (USA: John Wiley & Sons)
- [5] Grigoryev I V, Dobretsov R Yu and Gazizov A M 2017 Puti uluchsheniya upravlyaemosti lesny'x i transportny'x gusenichny'x mashin [Ways to improve controllability of logging and transport tracked vehicles] *Vestnik Bashkirskogo gosudarstvennogo agrarnogo universiteta* **23** 97-106
- [6] Fischer R, Küçükay F, Jürgens G, Najork R and Pollak B 2015 *The Automotive Transmission Book* (Switzerland: Springer International Publishing)
- [7] Lozin A V 2016 *Dvuhpotochnaya transmissiya transportnoj mashiny s bortovym sposobom povorota* [The double-flows transmission of the transport tracked vehicles with skid steering] Patent RU No 2599855 [In Russian]
- [8] Ogorkiewicz R M 1991 *Technology of Tanks* Vol 1 (UK: Jane's)
- [9] Wang G G, Wang S H and Chen C W 1990 Design of turning control for a tracked vehicle *IEEE Control Systems Magazine* **10** 122–5
- [10] Demidov N N 2019 The drivetrain and the steering mechanism for the twin engines tracked vehicle *J. of Phys.: Conf. Ser.* **1177** 012010
- [11] Lozin A V 2018 Hyperbolic steering for tracked vehicles *Proceedings of the 4th Int. Conf. on Industrial Eng., ICIE 2018* (Cham: Springer) pp 2367-74
- [12] Shelomov V B 2013 *Teoriya dvizheniya mnogocелеvyh gusenichnyh i kolesnyh mashin. Tyagovyj raschet krivolinejnogo dvizheniya* [The theory of multi-purpose tracked and wheeled vehicles movement. Traction calculation of curvilinear motion] (Saint-Petersburg: SPbPolyTechU) [In Russian]
- [13] Didikov R A 2017 Power distribution control in perspective wheeled tractor transmission *Procedia Engineering* **206** 1735-40
- [14] Uvakina D 2018 Performance improvement of Arctic tracked vehicles *MATEC Web of Conferences* **245** 17001
- [15] Didikov R A 2018 Power distribution control in the transmission of the perspective wheeled tractor with automated Gearbox *Advances in Intelligent Systems and Computing* (Cham: Springer) 192-200
- [16] Belko V O, Glivenko D E, Emelyanov O A, Ivanov I D and Plotnikov A A 2017 Current pulse polarity effect on metallized film capacitors failure *IEEE Transactions on Plasma Science* **45** 1020-5
- [17] Belko V O and Emelyanov O A 2016 Self-healing in segmented metallized film capacitors: experimental and theoretical investigations for engineering design *J. of Applied Physics* **119** 024509
- [18] Belko V O, Petrenya Y K, Andreev A M, Kosteliov A M and Roitgarz M B 2019 Numerical simulation of discharge activity in hv rotating machine insulation *Proc. of the 2019 IEEE Conf. of Russian Young Researchers in Electrical and Electronic Eng.* (Saint-Petersburg: IEEE) pp 800-2
- [19] Dobretsov R Yu, Gubachev M, Naletov I and Vasiliev A 2018 On the way to driverless road-train: digital technologies in modeling of movement, calculation and design of a road-train with hybrid propulsion unit *SHS Web of Conf.* **44** 00030
- [20] Didikov R A 2018 Transmission of the perspective wheel tractor with automatic gearbox: management of the power distribution mechanism *Int. Review of Mechanical Eng.* **12** 790-6
- [21] Kondakov S V, Kharlapanov D V and Vansovich E I 2016 Models of the turn resistance for high – speed caterpillar vehicles *Russian Engineering Research* **36** 1-5
- [22] Bukashkin A Yu 2017 Split transmission of tractor with automatic gearbox *Procedia Engineering* **206** 1728-34



- [23] Dobretsov R Yu, Lozin A V and Semenov A G 2018 *Privod elektricheskogo generatora v sostave samohodnogo nazemnogo transportnogo sredstva* [The drive electric alternator as a part of an automotive surface vehicle] Patent RU No 265694 [In Russian]
- [24] Dobretsov R Yu, Lozin A V and Semenov A G 2018 *Bortovaya nasosnaya stanciya sistem smazki i gidravlicheskogo upravleniya nazemnogo transportnogo sredstva* [The onboard pump for lubrication and hydraulic control systems of surface vehicle] Patent RU No 2656956 [In Russian]
- [25] Izotov V Z, Pyatkov VA, Starovoytov V S and Suslov AA 1976 *Mekhanizm povorota gusenichnoj mashin* [The tracked vehicle steering device] Patent RU No 521174 [In Russian]