ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1161762

MODERN TENDENCIES IN THE DESIGN OF AUTONOMOUS UTILITY VEHICLES

Arkadiusz Mężyk, Tomasz Czapla, Wojciech Klein
Edyta Krzystała, Grzegorz Gembalczyk

Silesian University of Technology
Department of Theoretical and Applied Mechanics
Akademicka Street 2A, 44-100 Gliwice, Poland
tel.:+48 32 237 16 46, fax: +48 32 237 28 70
e-mail: arkadiusz.mezyk@polsl.pl, tomasz.czapla@polsl.pl, wojciech.klein@polsl.pl
edyta.krzystala@polsl.pl, grzegorz.gembalczyk@polsl.pl

Damian Domagała, Olaf Dudek

Silesian University of Technology
Akademicka Street 2A, 44-100 Gliwice, Poland
tel.:+48 32 237 16 46, fax: +48 32 237 28 70
e-mail: damidom434@student.polsl.pl, dudekolaf@gmail.com

Abstract

The article discusses the role of the modern approach to the design of autonomous utility vehicles. The study has been exemplified by a currently designed multi-purpose hybrid engineer vehicle. The article covers the application of modern hybrid drive and the suspension allowing for the regulation of the tension wheel.

The drive system used in the described vehicle is a serial type. In contrast to the conventional solutions used so far in a similar vehicle, this system eliminate heavy and difficult parts to produce (e.g., gears) which allows to significant reduction of a vehicle's weight.

The suspension system is based on the classical concept - with a torsional shafts. A movable tension wheel is an innovative element, which has been used in this suspension system. When the wheel is in the lower position the area of pressure increased so the force exerted on the ground is less. This option is useful in difficult, muddy off-road conditions. The Volvo Company wants to apply similar capabilities in their prototype diggers.

In the article, the importance of the external appearance of the vehicle has been considered as well. A removable cab allows the remote control of the vehicle at any time and the same has been provided as an example of a modern solution concerning the external appearance of the vehicle.

Keywords: *autonomous vehicles, machine design, utility vehicles, hybrid drive*

1. Introduction

The current development of special vehicles for civilian purposes has resulted in the production of UNIMOG wheeled vehicle (Fig. 1 and 2), which is developed as a universal wheeled chassis for engineer vehicles since more than 60 years. The vehicle is characterized by high mobility and versatility of possible attachments. It has found its application in virtually all branches of economy and the vehicles of this type are present in many countries of the world.

The multi-purpose engineer vehicles are used also as inspection, transport and reconnaissance trucks.

The high-mobility vehicles are also manufactured with the application of tracks. Initially, the development of these constructions has been restricted by high noise levels, transport difficulties and low durability of steel tracks. In the recent times, however, advancements in the polymer tracks have been made which provides new application possibilities.

Fig.1. UNIMOG U500 Vehicle

Fig. 2. UNIMOG U20 Vehicle

The vehicles with polymer tracks are characterized by low noise levels, high durability and suitability for public roads and difficult field conditions. Low unit pressure on the ground, preventing damage to the road, is a significant quality. Light tracked vehicles are not very common in Poland. The above are used, among others, in National Parks by Forestry Service. The demand for such vehicles is, however, relatively high in e.g. the construction and energy production sectors, forestry and geodetic services, life saving and firefighting services etc.

Fig. 3. TALOS Reconnaissance Vehicle

From industrial marketing point of view, an innovative approach to the production and design of various types of appliances plays a crucial role. The introduction of new ideas, manufacturing, distribution and promotion methods, technology, entering new markets, introducing new products or any significant change of elements are the basic conditions of the long-term development of manufacturing companies. The product innovations accepted by markets grant the companies' advantage over competition and may give, sometimes, a chance to monopolize temporarily the market.

Autonomous vehicles are an example of innovative solutions introduced in the industry. While travelling to a pre-set point, the autonomous vehicle can independently route an optimal course while maintaining full safety of the vehicle and the surroundings. The correct performance of such functions is possibly due to the use of cams, safety scanners and supporting sensors. The whole vehicle is controlled by a computer connected to GPS and satellite navigation. The vehicles of this type detect all dangers and comply with traffic regulations or do not allow exceeding the vehicle potential in difficult terrain conditions. Due to their numerous advantages, autonomous vehicles constitute the future of the transport and may substitute conventional vehicles in many domains.

2. Multipurpose engineer vehicle as an example of a modern autonomous vehicle of start-up of the vehicle

The modern autonomous vehicles may be exemplified by the multipurpose engineer hybrid vehicle designed within the scientific-industrial consortium (Leader: Silesian University of Technology, OBRUM Sp. z o.o. and Industrial Research Institute for Automation and Measurements PIAP). The application of a hybrid drive with a track system using polymer tracks allows for the construction of an ecological special vehicle useful e.g. in National Parks or other areas protected against noise (such as residential districts, city districts by night etc.).

The high functionality and relatively low price indicate the possibility to reach a proper economic effect and to create a product, which fills a gap in the market. The designed engineer vehicle with a tracked chassis and a target mass of 5t shall be intended for all users travelling in difficult terrains, including construction employees, geodetic services, forest guarding services as well as firefighters, flood rescue services and technical assistance.

The vehicle shall be characterized by many modern solutions, which will enable its use in the character of:

- utility vehicle characterized by high-mobility and water and terrain obstacle surmount ability,
- technical assistance vehicle in crisis situations,
- light utility tractor ,
- snow cutter and plough carrying vehicle,
- a chassis serving as a base for special bodies,
- evacuation vehicle for personal and equipment rescue in crisis conditions,
- a vehicle for supportive engineer works (attached plough, crane, winch etc.).

Moreover, it is planned that the control system of the platform will allow for a remote control by an operator. This requires the preparation of a vehicle guidance system and enabling the interactive control by the operator.

3. Technical parameters of the platform

The preparation of assumptions requires, among others, the determination of the vehicle's intended use and functions, exploitation conditions, defining the required technical and exploitation parameters while giving consideration the binding Polish and EU standards and provisions. The assumed technical and utility parameters must be in line with proper standards concerning vehicles, resistance to environmental conditions as well as proper requirements of the OSH in the scope of exploitation and utility.

Due to the possible participation in traffic, the designed vehicle will be subject to the Euro 5 and Euro 6 pollutant emission reduction standards (in force from September the 1st 2014). In line with the standard for N2 vehicles – vehicles designed and manufactured for the transportation of loads, the total mass of which is in the 2.6-12 tons range, the emissions of diesel-powered engines shall not exceed the following values:

- Carbon dioxide 500 mg/km,
- Solid particles: 5 mg/km,
- Nitrogen oxides (NOx): 180 mg/km,
- The total mass of hydrocarbons and nitrogen oxides: 230 mg/km.

Before the design process has been commenced, the basic technical parameters of the vehicle have been initially determined. The construction assumptions presented below are, however, initial at this stage of construction and will be verified in the last stage of the investment. It has also been assumed that the demonstrative vehicle will serve factory testing and will be the basis. The initial assumed parameters of the demonstrative unit have been presented in the Tab. 1.

Tab. 1. Assumed vehicle parameters

Requirements/ parameter	Value
Base weight	3500 kg
Total weight	5000 kg
Unit pressure on ground	0.04 MPa
Dimensions:	
Length	4000 mm
Height	1300 mm
Width	2100 mm
Road clearance	380 mm
Base unit power	28 kW/t
Unit power at total weight	20 kW/t
Range/ fuel tank volume	350 km/150 l
Terrain obstacles:	
Wall	600 mm
Trench width	1500 mm
Slope climb	30°
Lateral tilt	25°
Water obstacles	500 mm
Speed in terrain	30-40 km/h
Max. speed	to 70 km/h
Turning radius	0-∞
Special equipment	plough, crane

4. Hybrid drive system

Considering the fact that in the recent years, electrical engines become much lighter than decades ago, and the reliable and effective engines using permanent magnets become more and more available – the performance of the vehicles may be improved by the application of a hybrid combustion-electric engine. The most important advantages of the hybrid drive over a mechanical drive are:

- decreased fuel consumption and thus increased range,
- minimized noise and heat emissions,
- better freedom of drive geometry configuration (not reliant upon the reduction of drive system volume),
- possible operation in silent mode due to the use of electric drive powered by batteries.

The drive system is one of the most important elements of hybrid-tracked vehicles. It is responsible for turning at any given speed of the vehicle and fluid and precise change of movement trajectory, as intended by the operator controlling the vehicle locally or remotely. The solutions applied up to now based mostly on parallel or parallel-serial hybrid drives with planetary gears and double power feed. Serial hybrid drive in which the vehicle tracks are driven by separate electric engines (brushless DC motors with permanent magnets, which ensures high power and small dimensions) powered by the power flow control system, may be an alternative and modern solution. First electric motor is mechanically connected to rotary-type internal combustion engine and is configured to produce electrical energy (works in generator mode). Such a concept has been applied in the designed multipurpose hybrid drive vehicle. This scheme of system is shown in Fig. 4.

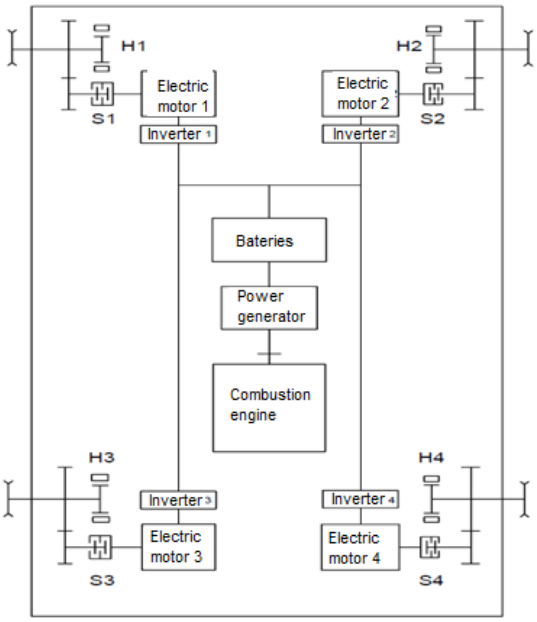


Fig. 4. Diagram of the hybrid drive concept

One of the drawbacks of the serial hybrid systems is the high price of the electric engines. These are, however, widely available and easily installed. The serial hybrid drives also involve large costs for the performance of the main gear. Moreover, the performance of the gear of that type is a very difficult project involving many tests and long waiting time for the ready product.

The advantages of the hybrid serial dive include, without any doubts, the higher efficiency of the electrical gear than in the case of mechanical or hydrokinetic gears used in parallel drives. Moreover, the serial hybrid system does not require application of a heavy main gear. A larger freedom in the layout of the components allows also for an optimal setting of the centre of gravity.

5. Suspension system

Various kind of suspension systems are applied in the existent and newly designed vehicles. These range from rigid or with control arm in case of small vehicles travelling at small speeds, independent suspensions and finally semi-active and active systems. The allowable vertical acceleration values in unmanned vehicles may be higher than in the manned vehicles due to the elimination of the safety criterion and the comfort of work.

Within the project feasibility study, conceptual analyses have been performed for various configurations of the suspension system as well as an analysis of the market in the view of availability of subassemblies necessary to complete the vehicle suspension.

The main advantages of the selected concept include:

- decreased fuel consumption and thus increased range,
- relatively small problems with drive transmission,
- proper mass of the suspension,
- known parameters of the suspension subassemblies (road wheel and drive wheel diameters length of the control arms),
- Small volume of elements in the body.

The form of the suspension, which shall be applied in the demonstrative unit, has been presented in the Fig. 5. A classic system with driving wheels in the back, four road wheels from each side and two tensioner wheels in the front part of the body has been selected. Behind the rear driving wheel, two road wheels mounted on leading control arms and two on trailing arms have been installed.

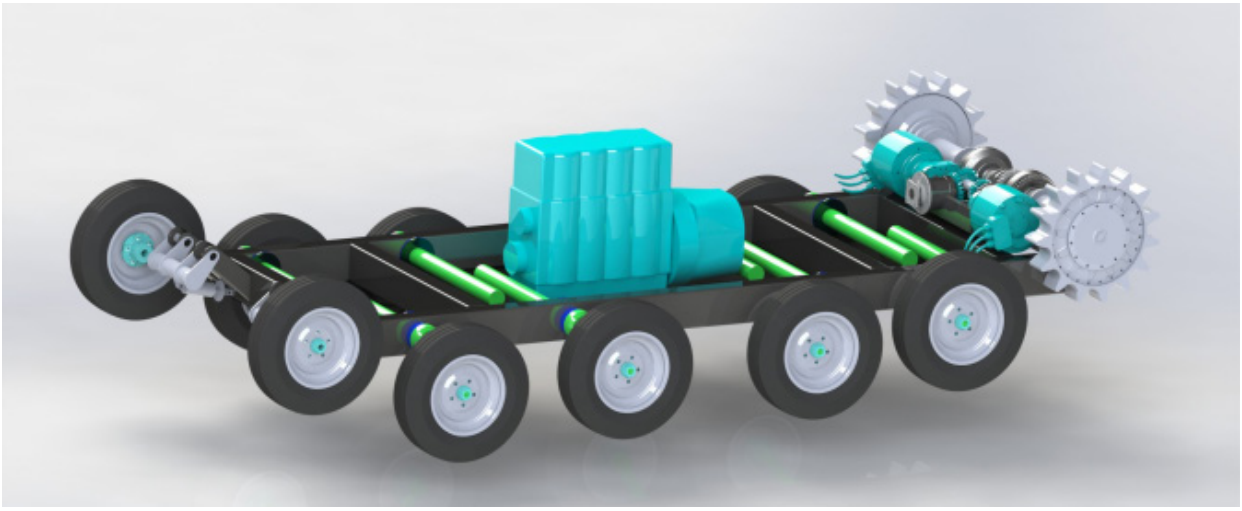
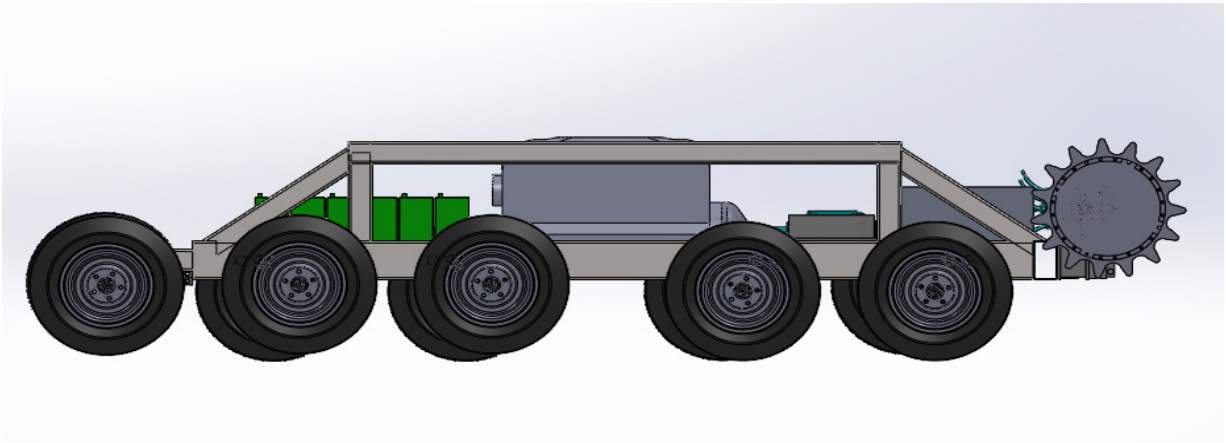


Fig. 5. The configuration of the WIPH vehicle wheels and steering system

The constructed demonstrative unit will utilize metal tracks. Use of special covers will thus be necessary in traffic. The final version of the vehicle will however be equipped with polymer composite tracks of a smaller width. To modernize the suspension in the final version of the vehicle, some modifications are planned, which will be possible to optimize after the tests performed with the technology demonstration unit. One of such innovations planned for introduction in the final construction of the vehicle is the possibility of overcoming an obstruction with the use of a vertically movable tensioner wheel. Lowering the wheel, on the other hand, helps in travelling on boggy grounds, where the distribution of pressure on a larger track surface is beneficial.

a)



b)

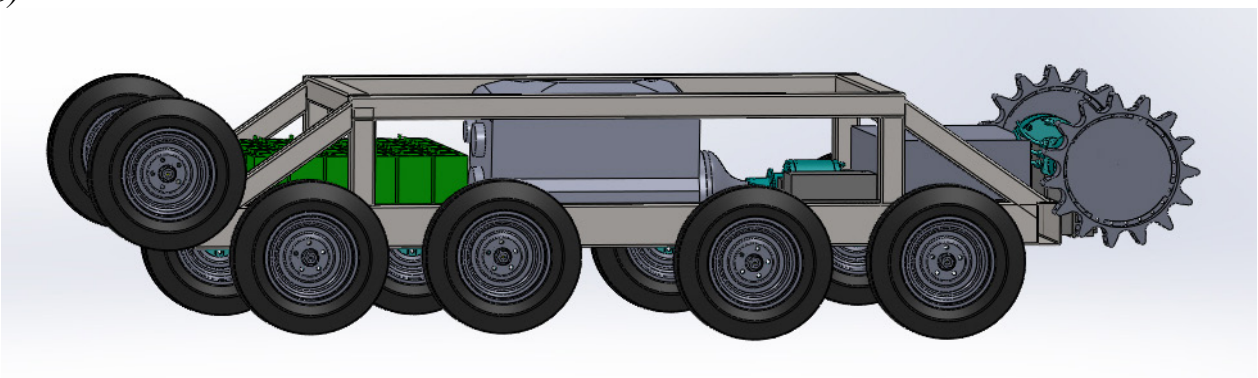


Fig. 6. Suspension configuration with a) lowered and b) raised first pair of road wheels

6. External design of the vehicle

The external appearance is a significant element of modern design. In the designed platform, the body plays a vital role in the viewpoint of appearance, as it must contain all the subassemblies and should ensure good esthetics of the entire vehicle.

To ensure optimal dimensions and proper endurance of the vehicle, the external design must be adjusted to the chassis frame. In the early phase of the project, many various concepts of the vehicle body have been proposed. One of such solutions has been presented in the Fig. 7.

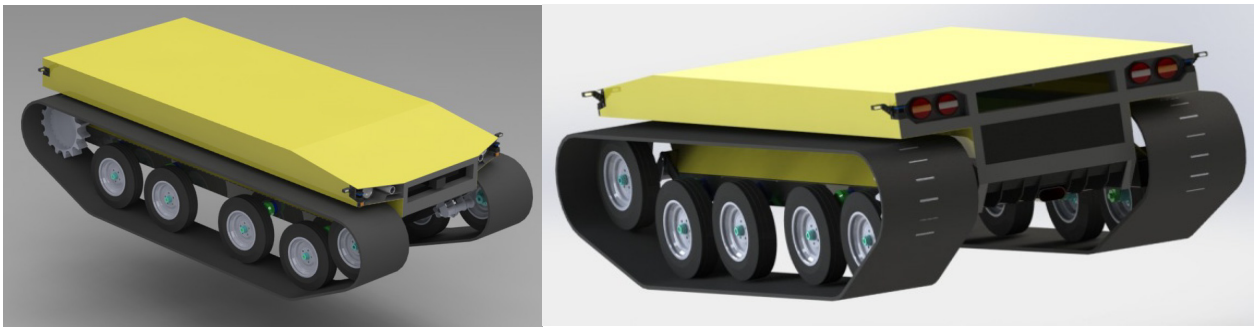


Fig. 7. Model of the WIPH vehicle model

In the design works, it has been assumed that the vehicle will be equipped with a removable cab with a control panel. Disassembling the cab will allow for remote control of the vehicle (an additional remote control panel will be a separate element).

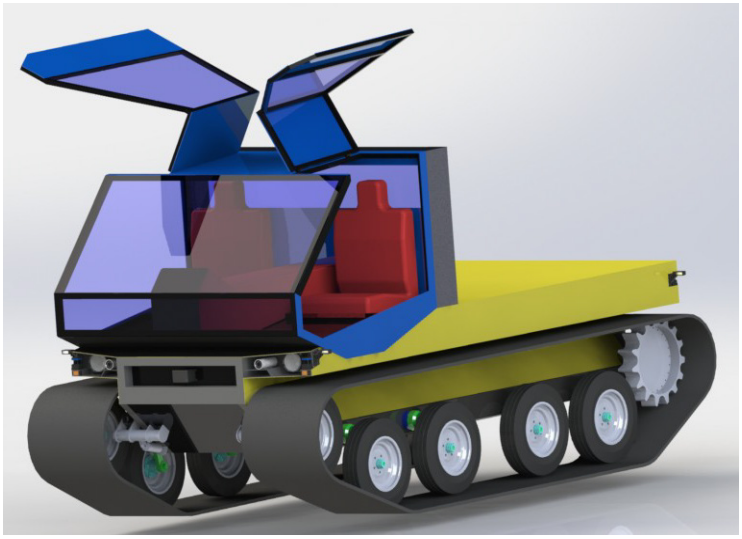


Fig. 8. The cab concept of the WIPH vehicle

The final appearance of the cab has been determined by both esthetic and practical considerations. The above concept with doors opened upwards has been rejected due to difficulties in manufacturing and the necessity to apply additional actuators

The cab, which is an additional equipment of the platform is an element which should be easily mounted and dismounted due to a large mass of the whole construction (it has been assumed that the cabin weight shall not exceed 300 kg). To ensure easy access to the battery pack in the body, the possibility to tilt the cabin without disassembling has been ensured. This has been achieved through the application of hydraulic actuators and movable front mounts. The cab frame has been constructed of rectangular profiles of sections from 30x20x2 to 60x40x3 and the internal plating is of 2 mm thickness.

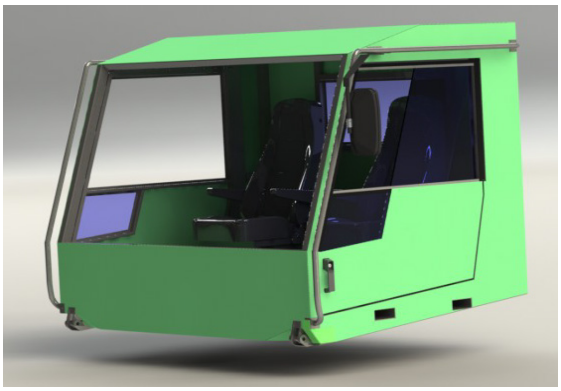


Fig. 9. Model of the WIPH vehicle cab

Additional equipment (such as plough or crane) is to be integral part of the vehicle, which requires providing space for its installation (with quick release couplings). Additionally, proper sensors allowing for autonomous movement must be installed. Directional indicators are an additional element necessary for the vehicle's use in roadworks.

7. Summary

The innovative and modern approach is essential in the design of utility vehicles. The presented multipurpose engineer vehicle is an example of innovative solutions related to the suspension and the general external appearance of the vehicle, especially the bodywork and the cab. The used hybrid serial drive system is along with a modern suspension and attractive appearance. The remote control, even in autonomous mode – using sensor signals providing information on the surroundings of the vehicle is an additional advantage.

Acknowledgement

The study within the project Contract No.PBS1/A6/15/2013 conducted within the 1st Applied Tests Contest.

References

[1] Burdziński, Z., *Teoria ruchu pojazdu gąsienicowego*, Wydawnictwo Komunikacji i Łączności, Warsaw 1972.
[2] Czapla, T., Wrona, J., *Technology Development of Military Applications of Unmanned Ground Vehicles, Vision Based Systems for UAV Applications,* Studies in Computational Intelligence, Springer, Vol. 481, pp. 293-309, 2013.
[3] Klein, W., Mężyk, A., Czapla, T., *Hybrydowy układ napędowy pojazdu gąsienicowego*, Szybkobieżne pojazdy gąsienicowe, Nr 1, pp. 61-68, 2009.
[4] Mężyk, A., Czapla, T., Klein, W., *Hybrid drive application for high-speed tracked vehicle*, Journal of KONES, Vol. 16, No. 1, pp. 341-349, Warsaw 2009.
[5] http://www.mercedes-benz.pl.