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TRACKED VEHICLE TOWING SYSTEM

Abstract. The paper presents an additional towing system designed for a light tracked vehicle. Reference is made to the rules of towing vehicles in road traffic and towing of special purpose vehicles, including tracked vehicles. The design of the towing system, its installation on the vehicle and strength calculations are presented.

Keywords: tracked vehicle, towing, towing system, catch, towline.

1. INTRODUCTION

The concept of vehicle towing has been known for a long time, particularly with regard to road traffic. What is towing? Towing is the act of pulling by a motor vehicle another motor vehicle, which in the given circumstances is unable to move on its own. The towed vehicle can be connected by means of a soft tow (tow rope) or a rigid tow. In the case of vehicles approved for road traffic, the rules of towing are regulated by the Traffic Code and Article 3.1 of the "Law on Road Traffic".

2. TOWING A TRACKED VEHICLE

However, the regulations mentioned above are not applied to the towing of vehicles of military units subordinate to the Ministry of National Defence and the Ministry of the Interior and Administration. Towing a tracked vehicle is considerably more difficult because of the design of such a vehicle. During towing the track largely impedes the movement and manoeuvring of the vehicle, especially during turns, since it does not allow for easy manoeuvrability. A common practice is to remove the tracks before towing.

To enable towing a tracked vehicle, in the first place the side transmissions have to be disconnected from the main transmission. This may be done by disconnecting the shaft that links the side transmission to the gearbox or, in modern gearboxes, by releasing a lever in the transmission.

We can distinguish the following methods of towing tracked vehicles:

- by lifting the front part of the vehicle with a crane and towing it by pulling;
- mounting the towing hooks crosswise enabling thereby turning of the towed vehicle;
- towing with the use of a rigid towbar;
- towing with the use of special equipment, such as the one described in this paper;
- hauling a tracked vehicle by means of a specialized vehicle with low loader trailer.

Currently, in the case of a vehicle breakdown, an on-site repair is made by quick replacement of the module which was damaged. Fig. 1 shows replacement of a drive module

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in an Abrams vehicle. This is sometimes impossible under field conditions, and then a vehicle towing system or a specialized recovery vehicle is necessary. Fig. 2 shows a Polish armoured recovery vehicle WZT-3.

Fig. 1. Replacement of the drive unit in an ABRAMS vehicle

Fig. 2. WZT3 ARV

3. TOWING SYSTEM CONCEPT

The problem described in this paper is the towing of a light tracked vehicle weighing about 5 tonnes. The tracked vehicle discussed here is a multirole engineering platform with a hybrid drive (codename WIPH). Bottom view of its hull is shown in Fig. 4. The platform structure (technology demonstrator) is undergoing numerous tests and field trials. It was therefore advisable to provide the chassis of the WIPH platform with additional equipment - towing system for quick recovery and hauling the vehicle to a workshop in the event of failure, without the need to use any specialized equipment.

Towing an engineering platform with a hybrid drive must be done with the drive system running - with switched main contactors (to connect the inverters of electric motors with batteries) and with the control system operating in torque adjustment mode and with the circuit on-board power supply switched on. When towing the WIPH vehicle, electric motors with permanent magnets generate electricity which must be dissipated. Inverters cannot do this, and energy must therefore be transmitted to batteries. In addition, the parking brake, controlled by an independent hydraulic system in the chassis, must be disengaged.

The main problem with the installation of the towing system in the chassis was the frame structure of the hull. This structure hinders both the mounting, as well usage of the towing system. It was therefore necessary to make use of the vehicle architecture to maximum possible extent without affecting the structure of the hull and its internal equipment. There was also another requirement: quick mounting of the towing system onto the vehicle. The towing system must also meet defined strength requirements. This is discussed in the further part of this paper.

Developing the concept, however, included some minor alterations in the hull body. The towing system is mounted onto a beam at the bottom of the vehicle body (Figs. 3 and 4). The bracket (Fig. 3) was shaped in such a way as to minimize the forces acting on the framework of the towing system. Fig. 3 shows the structure of the towing system, and Fig. 4 shows the manner of mounting the system on the hull of the WIPH vehicle.

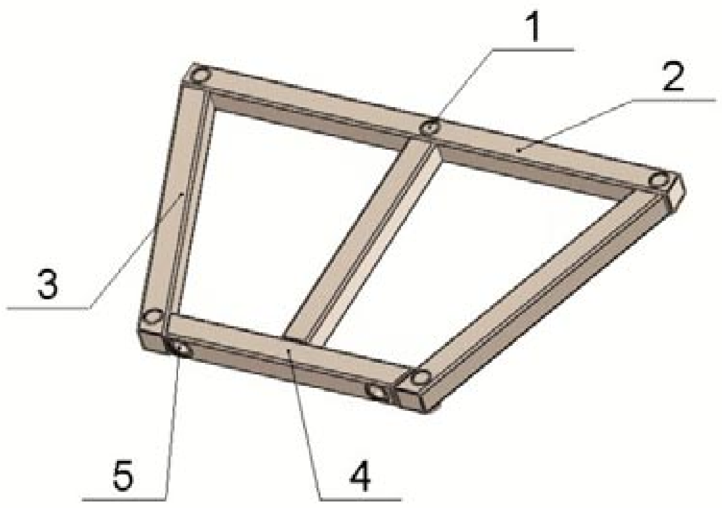


Fig. 3. Structure of the towing system
1- mounting pin, 2- rear beam, 3 - supporting beam, 4 - front beam,
5 - eyebolt

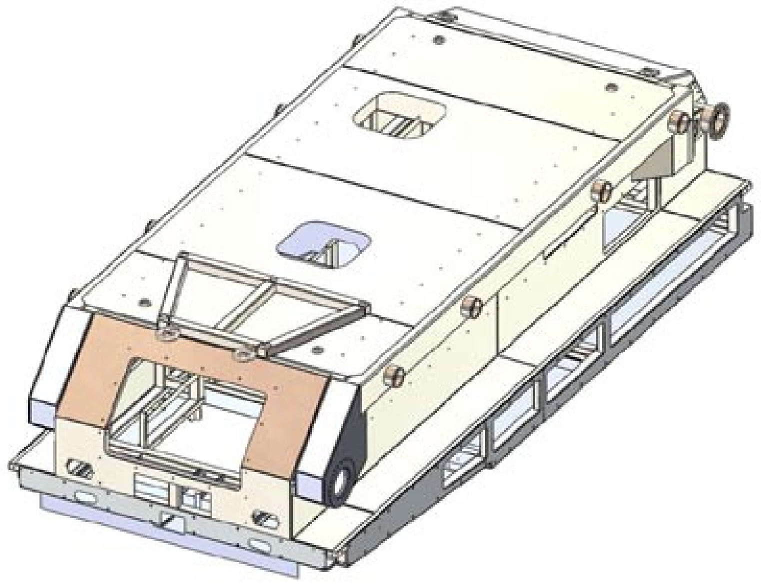


Fig. 4. Towing system mounted onto the vehicle body

4. STRENGTH CALCULATIONS

The designed structure of the towing system was subjected to strength analysis using the finite elements method within the elastic range. In the simulation made in the analysis the vehicle's traction system was locked, which is a situation wherein towing generates the highest load. The force acting on the system in this case was determined using formula (1) -

which results from the pull force (Pu) required for towing the vehicle. The force is determined from rolling resistance of the towed vehicle and weight of the vehicle.

$$Pu = (fo \cdot mp \cdot g) + (mp \cdot g) \cdot s \quad (1)$$

The following vehicle parameters are adopted for calculations:

Table 1. Vehicle parameters

Weight of vehicle	5200 kg
Rolling resistance coefficient – dry sand	0.3
Safety factor	1.5

$$Pu = (0{,}3 \cdot 5.200 \cdot 9{,}81) + (5.200 \cdot 9{,}81 \cdot cos30^{o}) \cdot 1{,}5 = 91.790 \text{ (N)} \quad (2)$$

The value taken for static calculations was 100,000 N.

Static analysis was done be means of SOLIDWORKS SIMULATION software, using the SI (MKS) system of units. Material properties are important in analyses made with the use of the finite elements method. Material data were taken from the SOLIDWORKS library. Reaction forces arising during towing were applied to the contact area on the towing hooks at the angle of towline axis action. The surface areas upon which the force acted was created so that its size corresponded to the diameter of the cable that engird the eye of the eyebolt (Fig. 3). Vectors of the acting forces are shown below (Fig. 5).

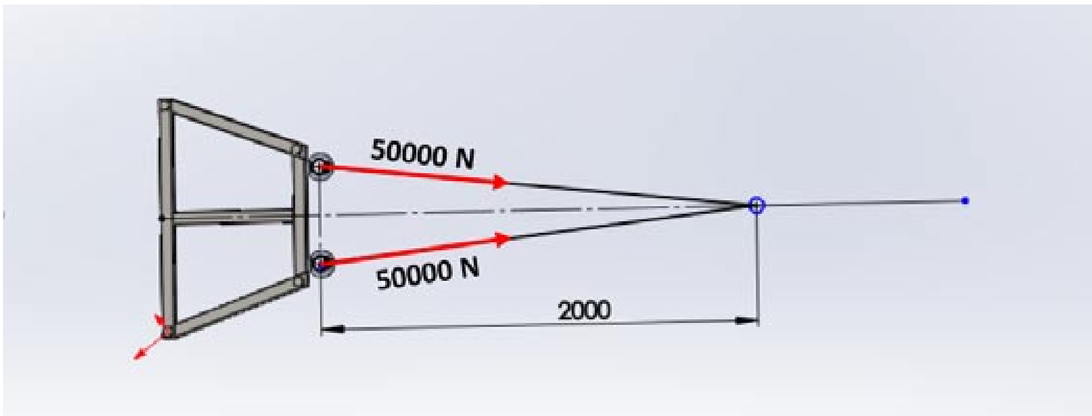
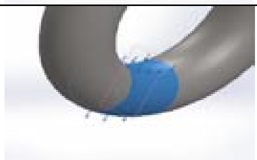


Fig. 5. Towing system mounted onto the vehicle body

The described conditions are presented in the table below.

Table 2. Loads acting on the hooks of the towing system

Load	Visual representation	Details
Force 1		The value of force in the coordinate system associated with the plane of force fixing: 50000,---,--- (N)
Force 2		The value of force in the coordinate system associated with the plane of force fixing: 50000,---,--- (N)

The towing system (adopted for calculations) is fastened by means of four pins welded to the main frame of the vehicle. The calculation model was restrained by means of pins deprived of all degrees of freedom: fixed restraint. In order to verify the correctness of the fastening, resultant forces acting in the restraints were checked. The reaction forces in the fastening points in the calculation model are close to the force of load, which is shown in the table below.

Table 3. Value of load forces

Directions of forces	x	y	z	Resultant
Values of reaction forces	-4.2	78730.3	-606881.2	99401.6
Moments of force	0	0	0	0

It may therefore be concluded that the created CAD model of the system studied is correct, and the analysis can be continued. The next step of the analysis was creating a mesh of finite elements discretizing the model into elements of defined size. As the size of the element analyzed was not large and discretization time would not be long, a high quality mesh was adopted. Such mesh provides better element discretization and reduces the probability of creating degenerated elements. Due to the size and form of the model, a solid mesh was used, and therefore the four node elements of the SOLID type. Table 4 lists some parameters of the finite elements mesh.

Table 4. Parameters of the finite elements mesh

Size of finite element	12 mm
Tolerance	0.64 mm
Number of nodes	82251
Number of finite elements	43311
Maximum aspect ratio	55.5

As shown in Fig. 6 stresses arise mainly in the front part of the structure. The rear pins do not transfer streeses produced by the load. It may therefore be concluded that they have no effect on the strength of the structure. Maximum stress has exceeded the yield point. To find out the size of the area where stress has exceeded the yield point (315 MPa), isochromatic lines intersection was applied. Isochromatic lines intersection enables determining whether the stresses that exceed the yield point affect the strength of a structure.

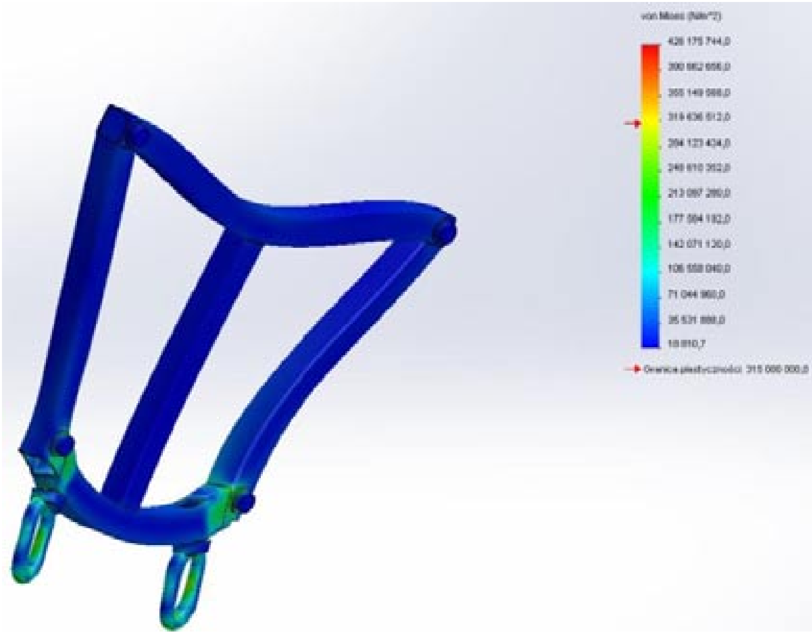


Fig. 6. Stress diagram of the towing system

Analysis of the stresses occurring in the rear part of the structure indicates that the addition of another mounting pin will not result in the weakening of the structure. In effect the final design of the towing system included five mounting pins (see Fig. 4).

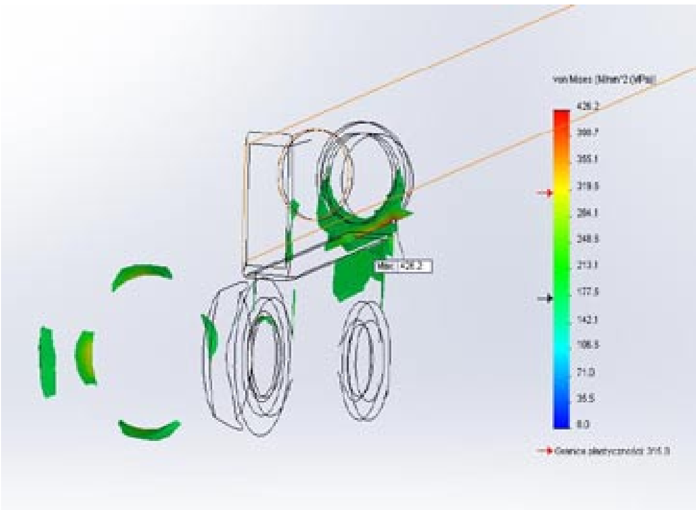


Fig. 7. Diagram of stresses of the towing system where yield point has been exceeded

Fig. 7 shows the areas where the yield point has been exceeded. Areas where the yield point has been exceeded result from mesh degeneration and do not affect the strength of the structure. After analyzing stress in the structure, displacements caused by acting forces were examined.

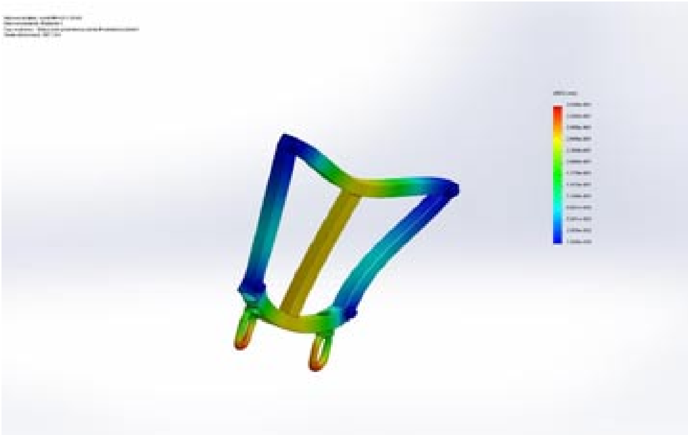


Fig. 8. Displacements

Maximum displacements in the structure are no greater than 1 mm. The figure also shows that displacement was affected by this part of the structure that had no large effect on the transfer of stresses in the system.

5. SUMMARY

The towing system of the designed structure is to form additional equipment for the WIPH multirole engineering vehicle with hybrid drive. It will be used at a later stage of development, mainly during field tests of the technology demonstrator, as a safeguard in the event of breakdown. It will enable towing the vehicle to a workshop to eliminate failure without the need to use any specialized equipment.

The developed solution is in line with the initial assumptions and meets the necessary strength requirements confirmed by the calculations performed. Installation of the towing system is also uncomplicated, its fabrication requires only the use of readily available construction materials (steel profiles, fasteners).

6. REFERENCES

[1] Burdziński Z. Teoria ruchu pojazdu gąsienicowego. Wydawnictwa Komunikacji i Łączności, 1972.

[2] Chodkowski, A. W. Badania modelowe pojazdów gąsienicowych i kołowych. Wydawnictwa Komunikacji i Łączności, 1982.

[3] Dajniak H. Ciągniki: teoria ruchu i konstruowania: podręcznik akademicki. Wydawnictwa Komunikacji i Łączności, 1985.

[4] Drexler, Z. Kodeks drogowy: Ustawa Prawo o ruchu drogowym, tabela mandatów, punkty karne, co robić w razie stłuczki, pierwsza pomoc, policjant kieruje ruchem, znaki drogowe. Agora, 2009.

[5] Mężyk A., Skowron K.: Rozwój układów przeniesienia napędów w pojazdach gąsienicowych. Szybkobieżne Pojazdy Gąsienicowe. (31, No. 3/2012. ISSN 0860-8369). OBRUM sp. z o.o., Gliwice, September 2012.

[6] Mężyk A., Klein W., Skowron K., Grabania M.Ł.: Pojazd gąsienicowy z napędem hybrydowym. Szybkobieżne Pojazdy Gąsienicowe (380 No. 3/2015 (pp. 65-94). ISSN 0860-8369. OBRUM sp. z o.o., Gliwice, September 2015.

[7] Act of 20 June 1997. Law on Road Traffic (Dz. U. No. 98, item 60, No. 123, item 779 and No. 160, item 1086 and of 1998. No. 106, item 668 and No. 133, item 872).

[8] http://www.tanks-encyclopedia.com/coldwar/US/M48_Patton.phpAccessed - 02.02.2016].

[9] http://pl.uzbrojenie.wikia.com/wiki/MIDAccessed - 02.02.2016].

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