TECHNICAL EVALUATION OF APC CHASSIS

Tadeusz Dziubak, Tadeusz Wysocki

Military University of Technology, Faculty of Mechanical Engineering
Institute of Motor Vehicles and Transportation
Gen. S. Kaliskiego 2, 00-908 Warsaw, Poland
tel.: +48 22 6839571, fax: +48 22 6837602
e-mail: tdziubak@wat.edu.pl, tadeusz.wysocki@wat.edu.pl

Dariusz Wozniak

Technical University of Koszalin
Faculty of Mechanical Engineering
Raclawicka 15-17, 75-620 Koszalin, Poland
tel.: +48 94 3478335, fax: +48 94 3478200
e-mail: dariuswozniak@wp.pl

Abstract

Success during combat on the modern battlefield is determined by numerous conditions. One of those conditions is a quick and unexpected (for the red force) transport of troops. Modern APCs (armoured personnel carrier) have similar terrain capability. Level of APCs adjustment to movement in a hard terrain conditions is the function of numerous indicators of its construction including e.g. correction of, usually specific, conditions for technical solutions of suspension or engine.

It is possible to acquire global numerical indicator of APC utility evaluation, basing on e.g. evaluation of the terrain mobility. Such indicator is the objective way to estimate the level of fulfilling the technical specification of subject subgroup for tactical – technical specification by the APC construction.

In the article is presented the proposal of methodical utility evaluation for modern APC chassis, which is based on account of proposed numerical indicators. Using the set indicators, we've provided comparison of directed and global evaluation of AMV Patria, towards other modern APCs. In the paper formulas of these indicators are described.

The results of evaluation are presented on charts as well ensample types of terrain trials are shown on pictures.

Keywords: *armoured personnel carrier, operational appreciation, mobility property*

1. Introduction

The constantly growing number of advantages and constant usefulness of wheeled armoured personnel carriers (APC) still decide on their well-established popularity among users all over the world, which can be proved by their wide application during various military operations, including peacekeeping/stabilization missions under the aegis of the UN or NATO. Modernizing or improving some of the technical parameters in vehicles of this type, especially the ability to handle different kinds of terrain, has significantly influenced the possibility of spreading their application possibilities on the contemporary battle field.

Analyzing the literature concerning the topic under consideration, one can encounter objective or subjective opinions of users about the quality of various APCs. Often, these opinions are quite contradictory and that is why they should be verified and analyzed from the perspective of applying changes, or from the perspective of complete rejections. Therefore, there is a need to formulate a qualitative methodology of construction assessment, directly and objectively allowing determining which of the assessed transporters can be characterized as having a better, more widely understood quality of construction.

The available literature, presenting general information on the topic discussed in the following work, is mentioned in the references [1-13, 15, 16-22]. References [11-14] concern strictly the topic of this case study.

2. Indicators of operational APC construction assessment

The case study for indicatory operational APC construction assessment for a contemporary APC has to be based on the analysis of its tactical-technical characteristics [12,13]. On the basis of these characteristics, the numeral indicators for assessment can be formulated. These indicators, as non-dimensional values, can be freely associated with one another, thus creating a general assessment indicator, e.g. assessment of tactical mobility [14]. Depending on the quantity of data available, a global construction assessment can be made, as well as partial assessment (so-called directed assessment). An example of directed assessment can be the assessment of APC ability e.g. to deal with typical terrain obstacles or the assessment of the vehicle's mobility and maneuverability.
Making a comparative assessment of chose APC constructions may involve the following stages:

- determining the set of the assessed transporters,
- list of construction parameters,
- formulating directed indicators for construction assessment,
- assigning the global indicator for construction assessment.

For the construction assessment to be more useful and direct, one should aim at not letting the directed constructions indicators be non-dimensional values, having the numbers in the <(0; 1)> class. The better construction is the construction of the transporter which has the construction assessment indicators which are nearer to 1.

It is worth to divide the assessments into groups and assign them to appropriate groups of tactical-technical requirements [11].

In this paper, whilst formulating the quantitative construction assessment indicators for the construction assessment of a few APCs, some parameters of their tactical-technical characteristics which were provided by the manufacturer have been used. The directed and global construction assessment indicators have been given using simple mathematical dependences which have been standardized so that they can have values in the (<0; 1>) class.

This work does not concern the complex assessment of APC transporters, but constitutes certain, directed mainly to widely understood chassis, an attempt towards assessing their construction. In order to make a complex assessment of APC, additional sets of assessment indicators have to be given, e.g.:

- reliability and construction durability,
- armament and resistibility to enemy action.

Objective APC construction assessment has been carried out on a limited scale due to obstructions or incomplete access to tactical-technical characteristics of some transporters. According to the authors, such assessment should evaluate and be expanded as newer technical information is acquired.

3. Directed and global operational APC chassis assessment

APC Rosomak is the polish version of the wheeled APC transporter Patria AMV 8x8, produced in Finland. The vehicle has a module construction and, as the user's opinions indicate, ideal driving properties. Module constructions allows its direct equipment configuration with respect to the purpose, e.g. medical vehicle, workshop, mortar carrier. This enables the vehicle to be broadly applied in the contemporary battlefield.

Taking into consideration the editorial requirements, only some of the values of chosen partial W_{PPW}, $W_{MŁ}$, W_{BN}, and W_{KP} indicators and the global W_{GK} indicator have been given. The have been calculated and set for the construction assessment proposed before for the following APCs: VBCI 8x8 (France), Piranha IV 8x8 (Switzerland), AMV 8x8 (Finland), Ryś 8x8 (Poland), Piranha III 8x8 (Switzerland) and Pandur II 8x8 (Austria).

Some mathematical models and the physical sense of the indicators of directed and global assessment have been presented in the following points of the work.

The general W_{PPW} indicator of dealing with water obstacles assessment

The W_{PPW} indicator determines the APC's ability to handle water obstacles by swimming across them or by wading.

$$W_{PPW} = (W_{GB} + W_{VP})/2, \quad (1)$$

where:
W_{GB} – wading depth indicator,
W_{VP} – speed level indicator for vehicle swimming.

The W_{GB} indicator describes the depth of the covered wading.

$$W_{GB} = \frac{h_{BRD}}{h_{KTO}}, \quad (2)$$

where:
h_{BRD} – maximal APC wading depth[m],
h_{KTO} – APC height [m].

The W_{VP} indicator describes the range of maximal swimming speed in forward and backward movement.

$$W_{VP} = \frac{V_{WPMAX}}{V_{PMAX}}, \quad (3)$$

where:
V_{WPMAX} – maximal APC backward swimming speed [km/h],
V_{PMAX} – maximal APC forward swimming speed [km/h].

An example of a picture from APC terrain trials in Malaysia is given in Fig. 1.

Fig. 1. Handling a water obstacle

APC Mass range $W_{MŁ}$ assessment indicator

The $W_{MŁ}$ indicator describes the possibility of loading an APC, e.g. with additional armour or higher-caliber armament. This is a very important indicator, especially for the Rosomak APC exploited in Afghanistan.

$$W_{MŁ} = \frac{m_{Ł}}{m_{MAX}}, \tag{4}$$

where:

$m_{Ł}$ – the difference in APC masses between the battle version and the basic version [t],

m_{MAX} – APC mass in the battle version [t].

Global W_{GK} construction indicator

The W_{GK} characterizes the APC construction in the analyzed scope and is the arithmetical average of the following partial indicators.

$$W_{GK} = (W_{PPW} + W_{MŁ} + W_{BN} + W_{KP})/4, \tag{5}$$

Quantitative construction assessment of contemporary wheeled transporters allows getting an answer to the question which of the analyzed APCs is the better/the best vehicle in the assessment. The global W_{GK} indicator value, being its arithmetical average, is an objective general assessment which is influenced by the partial assessments.

Below in table one, the construction assessment indicators have been given. They concern the following vehicles: VBCI 8x8 (France), Boxer 8x8 (Germany), Piranha IV 8x8 (Switzerland), AMV 8x8 (Finland), Ryś 8x8 (Poland), Pandur II 8x8 (Austria) and Piranha III 8x8 (Switzerland).

Tab. 1. Guided and global evaluation of APC construction

Vehicle / Indicators	VBCI (France)	Boxer 8x8 (Germany)	Piranha IV 8x8 (Switzerland)	AMV 8x8 (Finland)	Ryś 8x8 (Poland)	Pandur II 8x8 (Austria)	Piranha III 8x8 (Switzerland)
W_{PPW}	0.67	0.63	0.68	0.65	0.72	0.67	0.69
$W_{MŁ}$	0.38	0.24	0.40	0.42	0.27	0.29	0.27
W_{BN}	0.54	0.53	0.53	0.53	0.54	0.56	0.54
W_{KP}	0.49	0.51	0.47	0.47	0.44	0.48	0.50
W_{GK}	0.52	0.48	0.52	0.52	0.49	0.50	0.50

Whilst making a directed assessment, it is often necessary to separately compare the abilities of the APCs to handle terrain obstacles. It is one of the most important properties of a contemporary APC on the battlefield.

The W_{PT} indicator of assessing handling terrain obstacles

$$W_{PT} = (W_{PION} + W_{POP} + W_{PP})/3, \tag{6}$$

where:

W_{PION} – indicator of negotiating a h_{PION} height sidewall,

W_{POP} – indicator of negotiating a ditch,

W_{PP} – indicator of transversal clearance.

W_{PION} – indicator of negotiating an obstacle/a sidewall W_{PION}

The maximal height of a negotiated terrain obstacle depends not only on the wheel properties but also on the APC's clearance. Enlarging the r_K radius positively influence negotiating projections, thresholds or ditches.

This indicator determines a vehicle's ability to negotiate a terrain obstacle like a sidewall.

$$W_{PION} = \left(\frac{h_{PION}}{d_K} + \frac{h_{PION}}{h}\right)/2, \tag{7}$$

where:

d_K – APC wheel diameter [m], where $d_K = 0.97 \cdot r_N + r_N$ (r_N - nominal wheel radius),

h_{PION} – maximal terrain obstacle which an APC can negotiate [m],

h – APC transversal clearance [m].

Pictures from these types of terrain trials with the usage of the Rosomak APC have been illustrated below in fig. 2 – negotiating a sidewall by the vehicle's axle II and in Fig. 3 – an outline and clearance of a front wheel.

Fig. 2. Negotiating a sidewall by axle II

Fig. 3. Front wheel – axle I

W_{POP} ditch negotiating indicator

In vehicles with more than three wheel axles, the width of the negotiated ditch depends on the L_{MIN} distance between the first wheel axle and the next axle, usually the one behind the vehicle's centre of mass.

The W_{POP} indicator describes the vehicle's ability to negotiate a typical terrain obstacle like a ditch. Examples of terrain trials with the Rosomak APC are given in Fig. 4 – negotiating a ditch and a sidewall and in Fig. 5. – negotiating a ditch.

$$W_{POP} = 1 - \frac{L_{MIN}}{L_{RÓW}}, \tag{8}$$

where:

L_{MIN} – wheelbase (usually) of the first wheel axles in an APC [m],

$L_{RÓW}$ – maximal ditch width, which is negotiated by the APC [m].

Fig. 4. Negotiating a narrow ditch and a sidewall

Fig. 5. Negotiating a wide ditch

Transversal clearance W_{PP} indicator

The W_{PP} indicator assesses the construction of the transversal clearance value.

$$W_{PP} = \frac{h}{d_K}\,, \tag{9}$$

where:
h – APC transversal clearance [m],
d_K – APC wheel diameter [m], where $d_K = 0.97 \cdot r_N + r_N$ (r_N - nominal wheel radius).

Below in Table 2, the values for construction assessment have been given for the following APCs: VBCI 8x8 (France), Piranha IV 8x8 (Switzerland), AMV 8x8 (Finland), Ryś 8x8 (Poland), Piranha III 8x8 (Switzerland), Pandur II 8x8 (Austria).

Tab. 2. Defeating field obstacles index value W_{PT}

Vehicle	Parameters					Indicator			
	d_K [m]	h_{PION} [m]	h [m]	L_{MIN} [m]	$L_{RÓW}$ [m]	W_{PION}	W_{POP}	W_{PP}	W_{PT}
VBCI (France)	1.26	0.7	no data	no data	2.0	no data	no data	no data	no data
Boxer (Germany)	1.32	0.8	no data	1.55	2.0	no data	0.77	no data	no data
Piranha IV (Switzerland)	1.16	0.7	no data	no data	2.0	no data	no data	no data	no data
AMV (Finland)	1.24	0.7	0.430	1.45	2.0	0.59	0.27	0.34	0.40
Ryś (Poland)	1.14	0.4	0.400	1.30	2.0	0.67	0.35	0.34	0.45
Pandur II (Austria)	1.08	0.5	0.454	1.40	2.2	0.68	0.36	0.41	0.48
Piranha III (Switzerland)	1.12	0.6	0.475	1.22	2.0	0.66	0.39	0.42	0.49

In the available publications, it is hard to find the results of the quantitative wide global APC construction assessment. For the needs of obtaining such assessment, the wide global scale of construction assessment has been given, which is presented below in the form of such a defined W_{GK} indicator.

Global W_{GK} construction indicator

$$W_{GK} = \left(W_{ZD} + W_{PPW} + W_{PJ} + W_{SE} + W_{MŁ} + W_{BN} + W_{UN} + W_{KP}\right)/8\,, \tag{10}$$

where:
W_{ZD} – general indicator of terrain abilities assessment,
W_{PPW} – general indicator of negotiating water obstacles assessment,
W_{PJ} – general indicator of driving speed assessment,
W_{SE} – indicator of APC self-evacuation ability,
$W_{MŁ}$ – indicator of APC mass spread,

W_{BN} – general indicator of chassis block assessment,
W_{UN} – general indicator of power transmission system assessment,
W_{KP} – general indicator of vehicle steer ability assessment.

The collective results of the mentioned indicators are presented in Table 3.

Tab. 3. Global index value of construction (wide range) W_{GK}

Vehicle / Indicators	VBCI (France)	Boxer 8x8 (Germany)	Piranha IV 8x8 (Switzerland)	AMV 8x8 (Finland)	Ryś 8x8 (Poland)	Pandur II 8x8 (Austria)	Piranha III 8x8 (Switzerland)
W_{ZD}	no data	no data	no data	0.42	0.45	0.52	0.47
W_{PPW}	0.67	0.63	0.68	0.65	0.72	0.67	0.69
W_{PJ}	no data	no data	no data	0.54	no data	0.54	0.55
W_{SE}	no data	no data	no data	0.62	0.56	0.55	0.67
$W_{MŁ}$	0.38	0.24	0.40	0.42	0.27	0.29	0.27
W_{BN}	0.54	0.53	0.53	0.53	0.54	0.56	0.54
W_{UN}	no data	no data	no data	0.62	no data	0.61	0.70
W_{KP}	0.49	0.51	0.47	0.47	0.44	0.48	0.50
W_{GK}	no data	no data	no data	0.534	no data	0.528	0.548

From the results cited above, it turns out that the highest W_{GK} = 0.548 general construction assessment goes to the Piranha III 8x8 APC. Second is the AMV Patria (Rosomak) APC with W_{GK} = 0.534, and the third place is for the Pandur II 8x8 APC (W_{GK} = 0.528). The results are collectively presented as a diagram in Fig. 6.

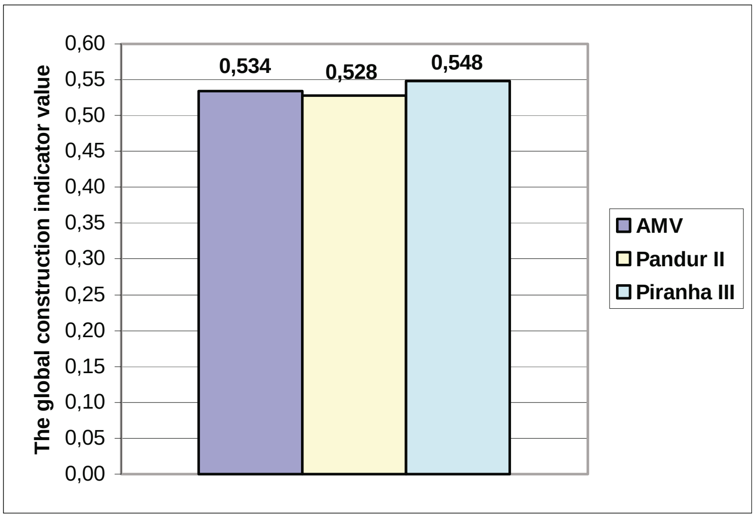

Fig. 6. Global index value of construction (wide range) W_{GK}

It is known that the standard deviation (S_{WGK}) characterizes the average value span for partial indicators from the medium W_{GK} value.

$$S_{WGK} = \sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n} \left(W_i - W_{GK}\right)^2} \tag{12}$$

where:
S_{WGK} – standard W_{GK} indicator deviation,
n – number of indicators (n = 8),

W_i – individual indicator values,
W_{GK} – global APC construction indicator.

The total S_{WGK} individually calculated indicators, for example for the Patria APC, have been presented as a diagram in Fig. 7.

The smallest standard deviation value for the global W_{GK} construction indicator, which informs about the continuity of construction perfectness of all the vehicle's systems, is achieved by the AMV Patria 8x8 APC - S_{WGK} = 0.085, then it is the second best for Pandur II 8x8 APC (S_{WGK} = 0.104), and the third place foes to the Piranha II 8x8 APC (S_{WGK} = 0.134).

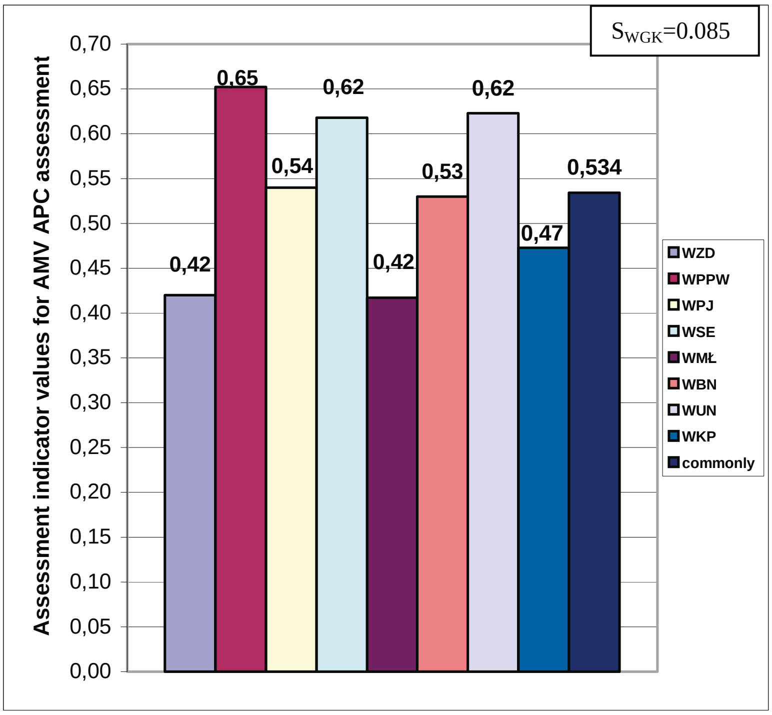

Fig. 7. Individual index value for KTO AMV Patria

4. Recapitulation

The analysis and assessment of APCs has been carried out on a limited basis due to difficult access to full tactical-technical characteristics for the assessed APCs, despite the attempts made by the authors.

Due to the assessment of the above-mentioned APCs, slight differences in the global construction assessment indicators can be seen. On the basis of this, one can assume that the presented APCs are mature products with respect to their constructions, designed especially for military users and meet their high expectations.

All of the assessed APCs have achieved a similar global chassis block W_{BN} value. This means that thanks to the actions undertaken by the constructors, these vehicles can be characterized by high transportation adaptability and good profiles, which enable them to be easily camouflaged on the contemporary battlefield.

Visible differences in the value of the global indicators are often a result of the construction of the particular systems in the analyzed APCs, as it is with the general mass $W_{MŁ}$ indicator. Three outstanding transporters (concerning assessment) are: the AMV, the VBCI and the Piranha IV APCs which are hydro pneumatic vehicles with high safety and driving comfort and have the possibility to adjust clearance height to the current terrain conditions, but as well allowing to achieve a high mass scale.

References

[1] Abbott, P., *Arming light APCs*, Military Technology (MT) 8/2001.
[2] Barnat, W., Cypko, E., Radzimierski M., *The armed transporter BTR 70*, NTW 4/1999.
[3] Bazela, R., *Contemporary battle vehicles*, The Army-Technology-Defense Report (RWTO), 9/2004.
[4] Bodin, A., Falk, A., *Military Vehicles*, *Charme's University of Technology Göteborg*, Sweden, 2003.
[5] Fuglewicz, S., *The wheeled APC – meanders of choice*, NTW 9/2001.
[6] Hanel, D., *The operational-technical requirements for APCs*, NTW 8/2001.
[7] Hołdanowicz, G., *The APC gains speed*, RWTO 5/2004.
[8] Hołdanowicz, G., *The beginning of Rosomak verification*, RWTO 7/2004.
[9] Kałwa, H., Papliński, K., *The wheeled 8x8 Rosomak APC*, 9th International IPMiT Symposium "Vehicles 2005", 2005.
[10] Kiński, A., *Ryś – the SKOT descendant*, NTW 9/2001.
[11] Micewicz, P., (edited by Wysocki T.), *The requirements given to contemporary APCs*, 23rd KNW WAT Seminar, Warsaw, 2004.
[12] Micewicz, P., (edited by Wysocki T.), *Tactical-technical assessment of the wheeled APC*, 24th KNW WAT Seminar, Warsaw, 2005.
[13] Micewicz P., (edited by Wysocki T.), *The analysis of tactical-technical properties of wheeled Rosomak and Ryś APCs*, 24th KNW WAT Seminar, Warsaw, 2005.
[14] Micewicz, P., (edited by Wysocki T.), *The assessment of contemporary wheeled APC construction*, WAT, Warsaw, 2006.
[15] Nita, M., *The Fuchs APC*, NTW 8/1997.
[16] Nita, M., *AMX – 10RC*, NTW 06/2001.
[17] Pietrzak, W., *AMV Patria for Poland*, WPTiL 3/2003.
[18] Potocki, J., *The wheeled Ryś APC*, NTW 4/2004.
[19] Ryba, Z., *The French infantry VBCI APC*, WPTiL 5/2001.
[20] Ryba, Z., *The French VAB*, WPTiL 2/2002.
[21] Simiński, P., *Contemporary wheeled APCs–developmental tendencies*, 9th International IMPiT Symposium "Vehicles 2005",2005.
[22] Użycki, D., *GTK/MRAV/PWV – the wheeled APC of a new generation*, NTW 5/2001.