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EFFECT OF THE ARRANGEMENT OF THE POWERTRAIN ON THE CONFIGURATION OF TRACKED COMBAT VEHICLES

Abstract. The paper deals with the issues of the location of the powertrain and its effect on the design and configuration of tracked combat vehicles. Configuration of the powertrain, due to the dimensions and weight of the latter, have a decisive effect on basic components of combat vehicles, including those that are important for crew protection, weapons and mobility.

Keywords: powertrain, crew protection, vehicle weight, traction parameters.

1. INTRODUCTION

Configuration of a tracked combat vehicle, its weight and dimensions depend mostly on the vehicle chassis. Chassis of modern tracked combat vehicles feature a number of structural solutions and configurations [1, 3]. The selection of the chassis defining configuration depends on many factors and requirements the vehicle has to meet as a whole. The greatest effect on chassis configuration is that of the engine compartment and of the powertrain located there. Due to the large size and weight of the powertrain, its selection and orientation in the chassis determines how the vehicle is configured. Depending on the location of the engine compartment, either in the front or in the rear of the chassis, the other compartments and modules of a combat vehicle must be adapted to the adopted configuration. The powertrain may occupy up to 40% of the chassis space.

With regard to the requirements for a particular type of vehicle, and taking into account existing designs of combat vehicles, including tanks [1, 3], it should be assumed that in order to ensure the possibility of limiting the maximum weight, provide a weight margin for modernization and to maintain the vehicle as small as possible, the design of a tracked combat vehicle should be based on a chassis with the lightest and smallest powertrain.

Today, in the era of modernization of equipment of the Polish Armed Forces and in view of the lack of available domestic solutions, it is necessary to acquire or develop designs and configurations of power units for existing and new tracked combat vehicles [4, 5, 6]. Selection of a powertrain and its arrangement in the chassis are among the major issues in the design of new tracked combat vehicles and in the considerations and concepts pertaining to the modification of existing vehicles [2].

2. CONFIGURATION OF A TRACKED COMBAT VEHICLE

Requirements defined for a tracked combat vehicle, such as total weight, armament type, crew protection level, determine vehicle configuration and allow to single out units, compartments and modules. In the case of tanks these can be classified into:

- chassis;
- engine compartment;
- ammunition compartment;

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- combat / crew compartment;
- turret system;
- weapons module;
- munitions stowage module;
- under turret basket module.

Depending on the location of the engine compartment, either in the front or in the rear of the chassis, the other compartments and modules of a tank must be adapted to the adopted configuration.

2.1. Powertrain front location

In the case of front arrangement of the powertrain, the solution applied most often nowadays is based on an "L" configuration of the powertrain, where the gearbox is arranged transversely and the engine is arranged longitudinally behind the gearbox. In this configuration, despite the engine shaft axis being offset in relation to the axis of the vehicle, it is necessary to provide sufficient space for the driver, which determines the width of the vehicle.

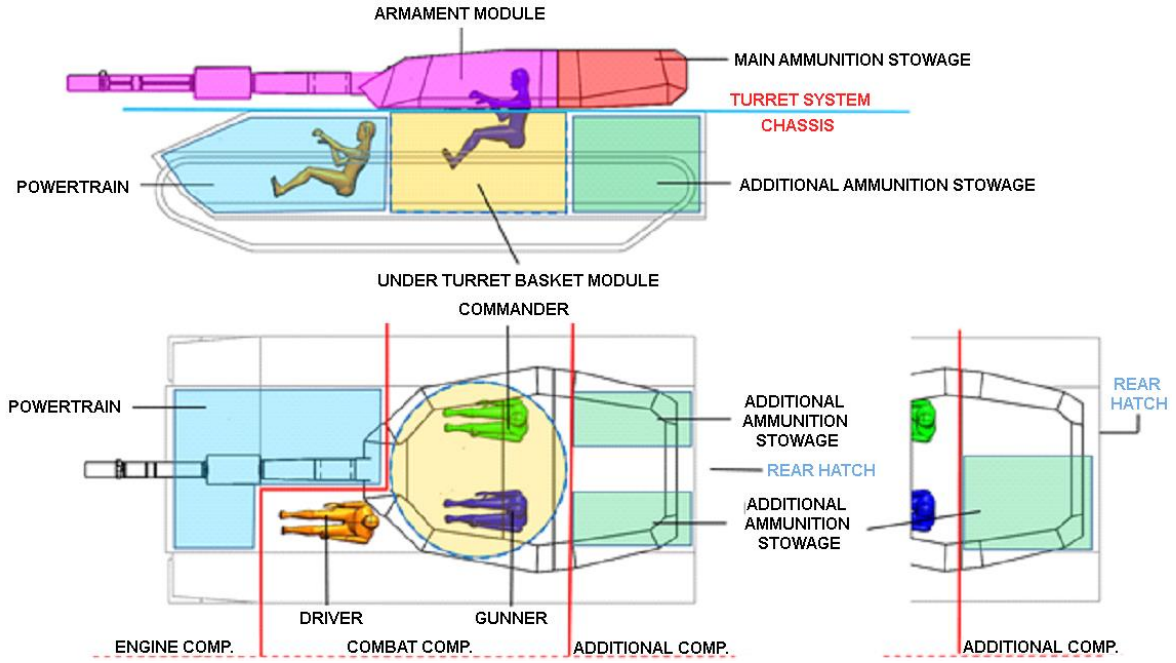

Fig. 1. General structure of a tracked combat vehicle with the engine compartment in the front

The advantages of this variant include the possibility of using an additional hatch for the crew at the rear of the chassis, allowing for safe evacuation of the crew, also in case of vehicle overturning. Placement of the powertrain at the front leaves space for a separate additional munitions stowage in the rear part of the chassis. The front arranged powertrain extends the life of the tracks, especially those made of elastomers. The disadvantages of this configuration include concentration of the weight of the powertrain in the front, which affects the traction parameters (negotiation of terrain obstacles). The driver's space is constrained. The power unit located at the front determines the shape and inclination of the front plate of

the chassis hull: decreasing the inclination of the front plate reduces the "apparent" thickness of the armour. Moreover, large surface area of air intake and exhaust is required for the power train, which necessitates providing armour on the internal walls of the engine compartment and increases the weight. The location of the power unit also imposes shifting of the turret system towards the rear of the vehicle. At the same time, the main armament, for example a cannon, must be mounted higher in order to enable gun depression, which increases the total height of the vehicle. The thermal signature of the vehicle, the main source of which is the powertrain located at the front of the vehicle, conduces to its detection and tracking under combat conditions.

Fig. 2. Thermovision camera image of a combat vehicle with the powertrain at the front

2.2. Powertrain rear location

In the case of rear arrangement of the powertrain, the solution adopted for analysis is based on a "U" configuration of the powertrain, where the engine is arranged parallel to the gearbox. This configuration provides sufficient internal space and does not reduce the space in the front of the vehicle. The other possible powertrain configuration is the "T" arrangement where the engine is positioned perpendicular to the gearbox. However, due to the weight and size, applicability of this configuration is very limited. Providing the required driver space when arranging the powertrain at the rear does not affect the width of the vehicle.

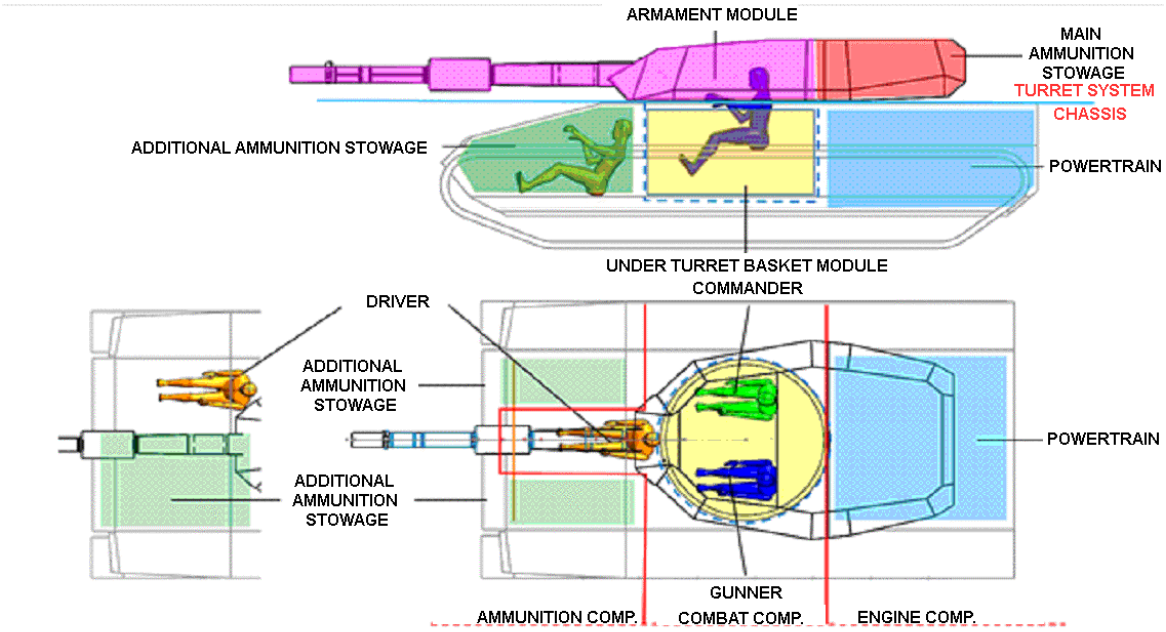

Fig. 3. General structure of a tracked combat vehicle with the engine compartment at the rear

Placing the powertrain at the rear of the vehicle improves the vehicle's traction properties in terms of negotiation of terrain obstacles. In this arrangement the driver has more space around and the driver's station does not determine the width of the vehicle. Powertrain located at the rear of the vehicle also enables reducing the height of the front part of the chassis and inclination of the front plate of the chassis hull which improves the level of ballistic protection of the crew and enables reduction of the hull weight: increasing the inclination of the front plate increases the "apparent" thickness of the armour. This location of the powertrain enables shifting of the turret system towards the front of the vehicle and reduces the limitations of gun depression. Under combat conditions, the great advantage of the rear powertrain location is the reduced thermal signature of the vehicle which makes vehicle detection and tracking more difficult. One of the disadvantages of this solution is the lack of an additional hatch for crew evacuation. Evacuation is only possible through the main hatches of the chassis and turret. Moreover, when the tracks are driven by the rear wheels, the life of the tracks, especially those made of elastomers, is compromised.

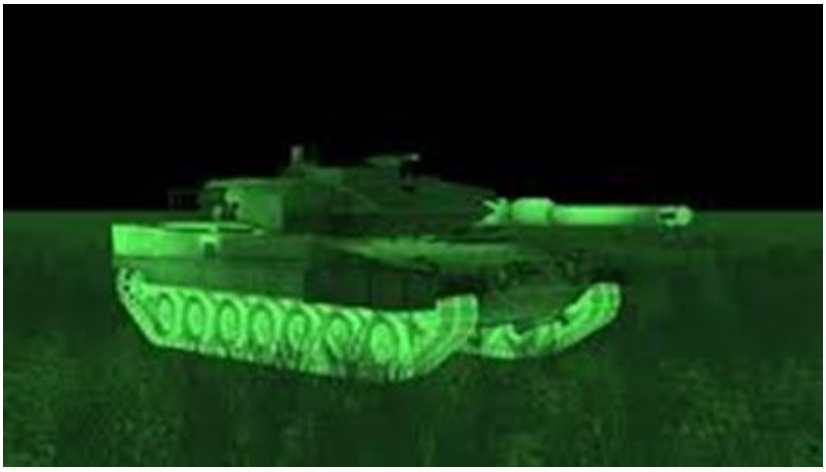

Fig. 4. Thermovision camera image of a combat vehicle with the powertrain at the rear

Effect of powertrain location in the chassis on vehicle features and parameters is presented in the table below.

Table 1. Effect of powertrain location on vehicle configuration and parameters.

Main parameters related to configuration	Powertrain location in vehicle chassis	
	front	**rear**
Use	IFV, gun-howitzer, light combat vehicles, special vehicles.	Tanks, engineering vehicles, recovery vehicles.
Applied power-pack configurations	L arrangement, right- or left-hand	T or U arrangement
Power transmission	Reduced undulation of the top run of the track and reduced number or elimination of return rolls. Extended life of drive wheels and tracks. Need to use elaborate final drives. Less load on track tensioning system.	Undulation of the top run of the track requires the use of return rolls. Shorter life of drive wheels and tracks. Possibility of using smaller coaxial final drives. More load on track tensioning system.
Arrangement of crew member stations and effect on crew	Driver station located either on the left or right side and moved towards the rear of vehicle. Limited room and field of observation for the driver. Noise and engine temperature affecting the crew compartment, especially the driver.	Driver station may be located anywhere along the entire width of the front part of vehicle hull. Much room and wide field of observation for the driver. Noise and engine temperature effect on crew compartment can be mitigated.
Ammunition arrangement in the chassis	Only in the rear, behind crew stations. Separate ammunition compartment possible.	Only in the front, beside or between crew stations. Ammunition compartment separation difficult.
Vehicle protection	Reduced, due to large surface area of powertrain cover. Need to install armoured partition of the engine compartment. Powertrain liable to damage. Vehicle can be easily immobilized by enemy.	Uniform structure enables optimization of configuration and provision of required protection. Powertrain damage less probable. Vehicle cannot be easily immobilized by enemy.
Hull	High profile of the front part of the chassis hull.	Low profile of the front part of the chassis hull.
	Shape of the front part is determined by the shape of the powertrain.	Shape of the front part can be configured as needed.
Weight and dimensions	Height and width of vehicle determined by high powertrain. Disadvantageous location of the centre of mass of the chassis in the front part of the vehicle. Increased weight of armour in the front part.	Location of the centre of mass of the chassis is balanced by the powertrain and armour of the front part of chassis.
Detection and tracking	Concentration of the thermal signature in the front part makes detection and tracking by enemy easier.	Concentration of the thermal signature in the rear part deters detection and tracking by enemy.

Turret system	Must be shifted to the rear of vehicle, limited gun depression. Uneven 360° firing parameters.	Central location on chassis possible. Even 360° firing parameters.
Hatches and crew evacuation	In addition to driver's hatch, additional hatch can be located in the rear part of chassis; escape hatch in vehicle bottom can be eliminated.	In addition to driver's hatch, additional hatch can only be located in vehicle bottom.

3. MULTIPLE-CRITERIA ANALYSIS

In order to evaluate the location of the powertrain in a tracked combat vehicle, an analysis of the features that determine powertrain configuration should be performed. Conducted analyses allow to indicate the optimal solution, but do not determine the final choice, retaining the opportunity to choose alternatives which depend on possible special requirements. Subject to arrangement of the main components and units, subject to evaluation was also the arrangement of ammunition stowage, crew evacuation possibilities, vehicle dimensions and transportability.

In order to indicate the best theoretical solution of the design and configuration of the tracked combat vehicle, a multiple-criteria analysis was carried out, including analysis of the most important features and parameters affecting vehicle configuration. The analysis is applied to an example of a theoretical tank.

Scale of the estimation of the fulfilment of criteria by a given solution:

0 – solution does not fulfil the criterion

1 – solution fulfils the criterion to small extent only

2 – solution fulfils the criterion to some extent

3 – solution fully fulfils the criterion.

Table 2. Adopted criteria and method of their evaluation.

Evaluation / Criterion		0	1	2	3
K1	Weight of main components, t	>18.5	17.5-18.5	16.5-17.5	<16.5
K2	Vehicle width, mm	>3600	3501-3600	3401-3500	<3400
K3	Transportability, mm	>3290	3201-3290	3101-3200	<3100
K4	Evacuation	1 hatch	2 hatches	3 hatches	>3 hatches
K5	Elastomer tracks	Not possible	Partly possible	Possible, with limitations	Fully possible
K6	Negotiation of obstacles	Not possible	Partly possible	Possible, with limitations	Fully possible
K7	Inclination of front plate	Angle selection not possible	Angle selection possible with limitations	Angle selection partly possible	Angle selection fully possible

K8	Driver's station	No room	Limited space and layout design not possible	Limited space and layout design fully possible	Space available and layout design fully possible
K9	Vehicle height, mm	>2700	2651-2700	2551-2650	<2550
K10	Location and protection of additional ammunition stowage in chassis	No room, layout design not possible	Limited space and layout design not possible	Limited space and layout design fully possible	Space available and layout design fully possible

Table 3. Multiple-criteria analysis of selected features of a tank as an example of a tracked combat vehicle.

Criterion of comparison	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	Weight of criterion	Powertrain location		Maximum value
												Front	Rear	
K1		0.75	1	0.5	0.75	1	1	0.75	0.75	0.75	7.50	2	3	3
K2	0.25		0.5	0.25	0.5	0.25	0.25	0.25	0.5	0.25	3	1	2	3
K3	0	0.5		0	0.25	0.25	0.25	0.25	0.25	0.25	3	0	0	3
K4	0.5	0.75	1		0.25	0.5	0.75	0.5	0.5	0.75	5.5	3	2	3
K5	0.25	0.5	0.75	0.75		0.75	0.5	0.75	0.5	0.5	5.25	3	2	3
K6	0	0.75	0.75	0.5	0.25		0.75	0.5	0.5	0.5	4.5	2	3	3
K7	0	0.75	0.75	0.25	0.5	0.25		0.75	0.5	0.5	4.25	2	3	3
K8	0.25	0.75	0.75	0.5	0.25	0.5	0.25		0.5	0.5	4.25	1	3	3
K9	0.25	0.5	0.75	0.5	0.5	0.5	0.5	0.5		0.5	4.5	2	3	3
K10	0.25	0.75	0.75	0.25	0.5	0.5	0.5	0.5	0.5		4.5	3	2	3
											Total points	94.5	111.5	135.75
											Index	70%	82%	100%

4. SUMMARY AND CONCLUSIONS

The considerations and analyzes carried out lead to a conclusion that, for tracked combat vehicles, the location of the powertrain depends on the requirements set for a given type of vehicle, and at the same time it has a decisive impact on the configuration and design of the entire vehicle. In most tank designs, the adopted solutions are based on the powertrain located in the rear part of the vehicle. In IFV type vehicles, gun-howitzers [1, 3] and wherever it is necessary to provide sufficient space for the crew or equipment, the features and adopted criteria indicate the use of a powertrain located in the front part of the vehicle. The presented manner of evaluation and verification of powertrain location solutions, along with the results of multiple-criteria analysis, can be used by research centres, e.g. in developing new projects related to tracked combat vehicles, as part of the 4th Security and Defence Contest financed by the National Centre for Research and Development in Warsaw.

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