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SELECTED ASPECTS OF THE CONSTRUCTION OF ARMOURED BANK VEHICLES OF NEW GENERATION

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Abstract

The high degree of persons and property security risk, especially during cash value transport increases the demand for Cash/valuables-in-transit (CVIT) vehicles. These vehicles are, in addition to the transport of valuables, which include money, goods made of silver, gold, platinum, may also carry documents containing classified information important for the security of the State. It is noticeable tendency to increase safety requirements for use of these vehicles. The new Regulation of the Minister of Internal Affairs and Administration respecting "the requirements to be met to protect the monetary value stored and transported by businesses and other agencies" of 7 September 2010 (Dz.U. 2010.0166.1128) introduces three groups of CVIT vehicles: type A, type B and type C. The most strict, but also providing the highest levels of security are requirements for CVIT vehicles type A. This article refers to some problems concerning the design of these vehicles. The article presents regulations and standards referring to the CVIT vehicles obligatory in Poland. There are presented the uppermost technical requirements for new generation of CVIT vehicles. There are also proposed the attack protection performance classes and ratings for quality assessment of these vehicles, including the energy ratio. Some of the issues of construction and armour in relation to the use of the series cargo truck bodies and chassis for building the CVIT vehicles are discussed. There are discussed the operation and application of an innovatory auxiliary drive unit and some electronic systems.

Keywords: *transport, armoured vehicles, bank vehicles, electrical requirements, electric standards*

1. Legal acts and normative documents

The basic and detailed legislative issues concerning the armoured bank vehicles defined as vehicles designed for the transportation of monetary instruments have been covered by:

- Act on the protection of persons and property, dated 22 August 1997 (Dz. U. of 1997, No. 114, item 740, with later amendments);
- Act on the conformity surveillance system, dated 30 August 2002 (Dz. U. of 2010, No. 138, item 935, with later amendments);
- Regulation of the Minister of Internal Affairs and Administration on the requirements to be met by the protection of monetary instruments stored and transported by entrepreneurs and other organizational units, dated 7 September 2010 (Dz. U. of 2010, No. 166, item 1128).

The requirements for the armoured bank vehicles as special vehicles to be approved as roadworthy (type-approval requirements) have been laid down in the following documents:

- Directive 2007/46/EC of the European Parliament and of the Council of 5 September 2007 establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles (OJ L 263, 9.10.2007, with later amendments),
- Traffic Law Act, dated 20 June 1997 (consolidated text: Dz. U. of 2012, No. 1137, item 1448),
- Regulation of the Minister of Transport, Construction and Maritime Economy on the type approval of motor vehicles and their trailers, and of their accessories or components, dated 25 March, 2013 (Dz. U. of 2013, No. 60, item 407).

According to the current regulation of the Minister of Internal Affairs and Administration on

"The requirements to be met to protect the value of cash held and transported by entrepreneurs and other agencies" dated 7 September 2010 (Dz.U. 2010.0166.1128) there are introduced three types of armoured bank vehicles: type A, type B and type C. The highest demands are specified for the armoured bank vehicles type A. This type of armoured bank vehicles provides a high level of guards and transported values safety, but this is the level required by the regulations for the general public. Specific solutions that allow increasing the safety level above provided for armoured bank vehicles type A, will be discussed later in this article. The object of consideration will be the armoured bank vehicles type A.

2. Technical requirements

The technical requirements for cash-carrying motor vehicles have been based on the legal acts described in the preceding section and they either have the form of annexes to the said legal acts or have been issued as separate documents (technical specifications).

The new Regulation of the Minister of Internal Affairs and Administration of 7 September 2010 has introduced a number of changes to the technical requirements laid down in the previous Regulation of the Minister of Internal Affairs and Administration dated 14 October 1998. An analysis of these changes has been presented in paper [4].

In the current Regulation of the Minister of Internal Affairs and Administration, all the vehicles designed for the transportation of monetary instruments have been classified as armoured bank vehicles of category A, B, or C, depending on their design and technical protection means adopted.

A new vehicle category has also been introduced, which covers the escorting vehicles for guards, additionally protecting the transportation of monetary instruments valued at a large number of units of account. The most stringent requirements related to the protection of transportation of monetary instruments apply to the A category armoured bank vehicle.

The technical requirements for the other cash-carrying vehicles (armoured bank vehicles of category B or C), especially with regard to the armour, are less stringent; however, such vehicles are allowed for the transportation of monetary instruments valued at far less units of account.

Certification tests of cash-carrying vehicles are carried out at the Automotive Industry Institute (PIMOT) in accordance with PIMOT Technical Specifications WT/107/PIMOT/10, which provide a more detailed description of the requirements set out in the Regulations of the Minister of Internal Affairs and Administration.

3. Classification of armoured bank vehicles of new generation

The technical requirements for A category armoured bank vehicles as laid down in the Regulation of the Minister of Internal Affairs and Administration of 7 September 2010 provide grounds for the certification of such vehicles; an assumption should be made at the same time that the said requirements should be considered the necessary minimum.

Based on 13 year experience of the authors of this paper in the testing of such vehicles and on the observed market trends towards the evaluation of the so-called "armoured bank vehicles of *new generation*", some toughened requirements for such vehicles, having an impact on the protection of the guarding crew and the property transported, have been proposed below.

Five *anti-assault protection classes for armoured bank vehicles of new generation* have been proposed for the vehicle construction, depending on the *anti-assault protection degree* in case of an assault or attack:

- Class A1 – standard,
- Class A2 – standard plus,
- Class A3 – professional,
- Class A4 – professional plus,
- Class A5 – extra.

The anti-assault protection degree reflects the *vehicle armour resistance* and *departure effectiveness*. The armoured bank vehicles of new generation should be characterized by raised *armour resistance* to the following factors in comparison with that of the current A category armoured bank vehicle:

a) Fire with 7.62×39 BZ calibre bullets from a distance of 30 m,
b) Grenade explosion,
c) Antipersonnel mine explosion,
d) Explosion of an improvised explosive device (IED).

The *departure effectiveness* should manifest itself in the technical capability of the armoured bank vehicle to leave the scene of the event with the use of the basic propulsion system or an auxiliary propulsion system (APS).

Class A1 – covers the armoured bank vehicles that merely meet the requirements of the current Regulation of the Minister of Internal Affairs and Administration of 7 September 2010.
Class A2 – covers the armoured bank vehicles having the armour resistance to a) and b) above, provided with armour as required for class A1 and additional armour for the crew compartment.
Class A3 – covers the armoured bank vehicles having the armour resistance to a), b) and d) above, provided with armour as required for class A2 and additional armour for the engine.
Class A4 – covers the armoured bank vehicles having the armour resistance to a), c) and d) above, provided with armour as required for class A3 and additional armour for the under-carriage components.
Class A5 – covers the armoured bank vehicles having the armour resistance to a), b), c) and d) above, provided with armour as required for class A4 and additional armour for the undercarriage and cargo compartment.

An APS may be optionally applied to an armoured bank vehicle of any of the above classes, with the difference that additional armour for the engine is not required in such a case for classes A3 and A4.

4. Suggested armoured bank vehicle evaluation indicators

Manufacturers' offers concerning armoured bank vehicles as well as literature descriptions of such vehicles do not provide a possibility of making objective comparisons. There are some known indicators that are helpful in evaluating motor trucks and they may also be utilized to evaluate the quality of armoured bank vehicles. Based on an analysis of such indicators and of the disparate features that are exclusively specific for armoured bank vehicles, the authors have proposed the following indicators to be used for the evaluation of A category armoured bank vehicles:

1) Vehicle energy index (W_e),
2) Vehicle armour index (protection class) (W_o),
3) Cargo compartment index (W_l),
4) Vehicle power capacity index (W_m),
5) Ride comfort index (W_k),
6) Passive safety index (W_b),
7) Performance index (W_r),
8) Overall (integrated) armoured bank vehicle evaluation index (W).

The overall (integrated) armoured bank vehicle evaluation index is calculated from all the partial indices described above, with weights for particular indices $k_1 ... k_7$ within the range 0.5 ... 2.5 having been taken into account. This overall index is determined as a weighted average. Based on the general equation defining the weighted average:

$$W = \frac{\sum_{x=1}^{n} W_x \cdot k_x}{\sum_{x=1}^{n} k_x} \cdot \tag{1}$$

The armoured bank vehicle evaluation index is determined from the following equation:

$$W = \frac{W_e \cdot k_e + W_o \cdot k_o + W_l \cdot k_l + W_m \cdot k_m + W_k \cdot k_k + W_b \cdot k_b + W_r \cdot k_r}{k_e + k_o + k_l + k_m + k_k + k_b + k_r}. \quad (2)$$

5. Selected vehicle construction and armour issues

Vehicle operation conditions

a) Operation in any season and at any time of the day or night, in all the weather conditions occurring in the Polish climatic zone (ambient temperature range from 30°C to +50°C, air dustiness up to 1.0 g/m^3 for a 5 h period, wind speed up to 20 m/s, rainfall intensity up to 180 mm/h for 5 min, air humidity up to 98% at a temperature of +25°C.
b) Vehicle operation on surfaced and unsurfaced roads, in areas from those being hard to reach to urban areas with high-density buildings.
c) Parking in the open.
d) Servicing and maintenance in the territory of Poland at service stations authorized by the manufacturer.

Hazards

a) Fire from firearms and from explosive devices situated below the undercarriage.
b) Direct attacks with dangerous objects.
c) Attempts to immobilize the vehicle (tyre puncture, fuel tank puncture, pouring of paint over the windscreen), arson, overturning, and other actions dangerous to the vehicle crew.

Engine and fuel feed system

Pursuant to requirements of the Regulation of the Minister of Internal Affairs and Administration, the engine compartment of an A category armoured bank vehicle shall be provided with an automatic fire-extinguishing system and a fuel tank made in a way that would prevent explosion. No gas fuelling system shall be allowed.

The construction of an armoured bank vehicle that must be capable to leave the scene of an assault after a blast of an explosive device under the vehicle requires that the vehicle shall be provided with armour protecting at least the engine with its components and accessories. This may be accomplished by installing one large armour plate or by shielding individual components. The armour must definitely protect engine sump, fuel pipes, fuel filter, and engine control system (electric wiring).

The engine should ensure high vehicle dynamics at low gears (at low speeds) for the vehicle to be capable to rush away from the scene of the event as quickly as possible. The vehicle should be capable of accelerating from 0 to 50 km/h within not more than 12 s.

If an APS is applied as an option, the armour protecting the engine and its components and accessories should not be required.

Cooling system

In consequence of the requirement that an armoured bank vehicle must be capable to leave the scene of an assault after the blast of an explosive device under the vehicle, the cooling system must also be protected from damage. The radiator, pipes, hoses, and fan should be armoured for mechanical damage to these parts to be prevented. If the shielding of hoses is impracticable, hoses with raised resistance to puncture may be used.

If an APS is applied as an option, the armour protecting the engine cooling system should not be required.

Power transmission system

The gear ratios of the power transmission system of an armoured bank vehicle should enable

dynamic acceleration of the vehicle at low gears. The selection of the base vehicle should be preceded by an analysis of transmission gear ratios at low gears and the final drive ratio. The version with the highest overall gear ratios at low gears should be chosen.

Steering system

The armouring of the base vehicle when converting it into an armoured bank vehicle that would meet the toughened requirements will most likely cause the front axle load to exceed the acceptable limit. Such a situation will result in the necessity to subject the vehicle steering system to type-approval tests for conformity with UN ECE Regulation No. 79.01.

The increased front axle load may result in reduced tendency of the steering system to self-centre. The vehicle with no such a tendency cannot be approved as roadworthy. This behaviour should be verified when testing the vehicle for conformity with UN ECE Regulation No. 79.01.

Braking system

The armouring of the vehicle will cause an increase in the gross vehicle mass. This may result in a necessity to repeat the procedure of type approval of the braking system according to UN ECE Regulation No. 13. Any electronic stability control system (ESC or ESP) approved with the base vehicle will function in a different way in the vehicle whose mass and location of the centre of mass will differ from those of the base vehicle. Therefore, special attention should be paid to the testing of this system.

The braking system is protected against mechanical damage (caused by explosion) by the shielding of brake pipes; as regards hoses, reinforced hoses (e.g. provided with additional braid) should be used.

The braking system should make it possible for the vehicle to be safely stopped in any conditions. The friction pairs, i.e. brake pads and discs or brake linings and drums, should be made of top quality materials, resistant to high temperatures. Therefore, the brakes to be approved must be subjected to additional hot performance tests apart from the standard type-approval tests.

Road wheels

Pursuant to requirements of the Regulation of the Minister of Internal Affairs and Administration, the road wheels of an A category armoured bank vehicle shall be provided with solid inserts or be made to another design that, when punctured, would make it possible for the vehicle drive to be continued for at least 15 km with a speed of 50±5 km/h.

Vehicle armour and protective layers

Pursuant to Regulation of the Minister of Internal Affairs and Administration of 7 September 2010, where the requirements to be met by vehicles of this type have been set out, all the walls and glass panels of the crew compartment should be in conformity with the FB 5 protection class while for the vehicle floor and roof, the specifications of the FB 4 protection class should be met. Among the vehicle components situated below the vehicle floor, only the fuel tank is subject to protection.

In the armoured bank vehicles manufactured until now, an armour steel plate capable to withstand steel-cored bullet fire from an AK 47 rifle (7.62 mm calibre) is used in most cases as the protective layer. Due to the necessity of using heavy steel shields, the base vehicle must have at least 4.3 tons load capacity. Actually, vehicles of 5 tons load capacity are predominantly used for this purpose. For the vehicles with the steel protective layers having been installed, the axle load is close to, or sometimes exceeds, the maximum acceptable limit, which directly translates to a hazard to the traffic safety and reduced vehicle durability. The armour constitutes permanent additional load for the vehicle structure.

For an armoured bank vehicle to be comprehensively protected, its undercarriage (with under-carriage systems and components) must be additionally protected from the impact of a pressure wave generated by the blast of an explosive device (e.g. IED) and coming from below the vehicle

as well as from possible splinters or rebounds, especially in the part where vehicle engine, steering, braking, and suspension system components, and crew compartment are situated.

The possibility of rushing away from the scene of an assault is considered the most effective method of protection of the vehicle, its crew, and the cargo transported.

6. Auxiliary propulsion system (APS)

The APS provides a possibility for the armoured bank vehicle in emergency to leave the scene of the event as quickly as possible e.g. after the blast of an explosive device (e.g. IED) or a grenade, in case of a failure of the main propulsion system powered or driven by an internal combustion engine. The capability of fast departure from the place where the vehicle was attacked is one of the innovative features of the new vehicle construction in this project, distinguishing the vehicle from the solutions adopted previously. The minimum range of the APS operation has been assumed as 15 km, in accordance with that required by the Regulation of the Minister of Internal Affairs and Administration for a vehicle with a tyre having been shot.

Both of these events, i.e. explosion and tyre destruction, are very likely to occur together at an assault. For constructional reasons, the APS mass and dimensions cannot be too big because this would impair vehicle functionality. At the vehicle departure, speed assumed (50 to 60 km/h), the APS power capacity could be reduced in comparison with the power rating of the main propulsion system. The APS applied consisted of four DC motors of 4 × 14 kW power capacity and a belt transmission. The arrangement of APS components in the vehicle has been schematically presented in Fig. 1.

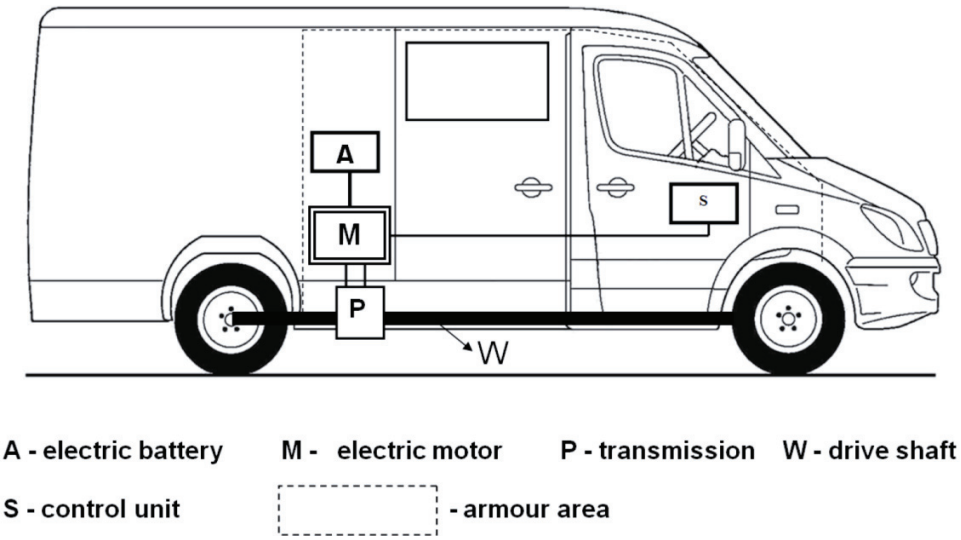

Fig. 1. Arrangement of APS components

This arrangement of APS components is advantageous in constructional terms, especially due to the favourable distribution of masses.

The placement of an APS inside the armoured space only slightly reduces the functionality of this compartment. On the other hand, the vehicle engine protection degree may be lowered when an APS is applied and this will favourably affect the loading of the front suspension of the vehicle, especially if the armoured bank vehicle is made by conversion of a typical utility vehicle.

Three constructional options of the APS to be applied in the armoured bank vehicle were considered:

1) Electrically driven,
2) Driven by an internal combustion (IC) engine,
3) Pneumatically driven.

The option with an electric motor was selected. The electric APS includes the following devices and systems: electric motor (M), power control unit (S), electric battery (A), transmission joints (P1) and (P2), speed control unit (Z), on/off switching unit (ZW), and wiring and installation hardware.

In case of failure of the main IC engine of the vehicle, the vehicle propulsion function is taken over by the electric motor (M) cooperating with the additional transmission (P) and the on/off switching unit (ZW). The electric motor is powered from the battery (A) and controlled by the power control unit (S).

Having switched on the system circuits, the driver controls the motor (M) and vehicle speed with the speed control unit (Z). The vehicle may move both forwards and rearwards. The direction of motor (M) rotation and, thus, of the vehicle motion may be changed with the use of the on/off switching unit (ZW).

The vehicle can move until the energy stored in the battery runs out. The energy reserve should be sufficient for the vehicle to travel a distance of 15 km at the nominal power output of the motor (M).

7. System for recording the parameters of motion and the alarming statuses

A system for recording the parameters of motion and the alarming statuses of an armoured bank vehicle, built in accordance with PIMOT patent application P 360807, is recommended for use in such vehicles.

The system for recording the parameters of motion and the alarming statuses, covered by the invention and presented here, intended for special vehicles i.e. armoured bank vehicles in this case, is characterized by the fact that it comprises modern electronic assemblies and elements of large-scale integration, including satellite-based vehicle location system (GPS), system reacting to accelerations and decelerations typical of a vehicle during a collision and to the generation of an alarm when any dangerous vehicle status or hazard to vehicle crew is detected.

Some parameters selected from among those entered in the main recorder are additionally saved in a non-volatile memory of a reserve recorder, which may be very useful in the case of destruction of the main recorder in result of an assault or road collision.

Thanks to a possibility of fast data transmission from the recorder to a laptop, the time histories of the parameters recorded may be checked at any time. This in turn makes it possible to operate the transport facility, i.e. an armoured bank vehicle in this case, in an effective way with ensuring high safety level.

8. Power supply system for external lights

In result of switching on the vehicle lighting system, signalling system, or auxiliary equipment, voltage fluctuations may occur in the electrical system of the armoured bank vehicle. For the system voltage to be kept on a constant level, the application of a power supply system developed at PIMOT and covered by patent application No. P38124 is proposed.

The essence of the system built in accordance with the invention lies in the fact that it comprises voltage stabilizer, emergency power supply unit, and vehicle lighting monitoring systems, with the external lighting (headlights) being powered and controlled from the vehicle electrical system via the on/off switching unit.

The on/off switching unit is connected with the emergency power supply unit and a signalling panel, which indicates the statuses of normal operation or failure of the headlights. The signalling panel is then connected with external lighting (headlights) circuits through the vehicle lighting monitoring systems. On the other hand, the emergency power supply unit is connected with external power supply circuits, voltage stabilizer control circuits, and the signalling panel.

In normal operating conditions, the external vehicle lighting system is supplied with power from the vehicle electrical system through the voltage stabilizer, thanks to which the vehicle lamps provide light of high quality characteristics.

In case of failure of the vehicle electrical system or the voltage stabilizer, which may happen e.g. in result of a road collision or an accident, the lighting circuits are powered from the emergency power supply unit.

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