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EXTENDABLE REMOTE CONTROLLED PORTABLE BARRIER FOR STOPPING VEHICLES BY CONTROLLED TIRE DEFLATION

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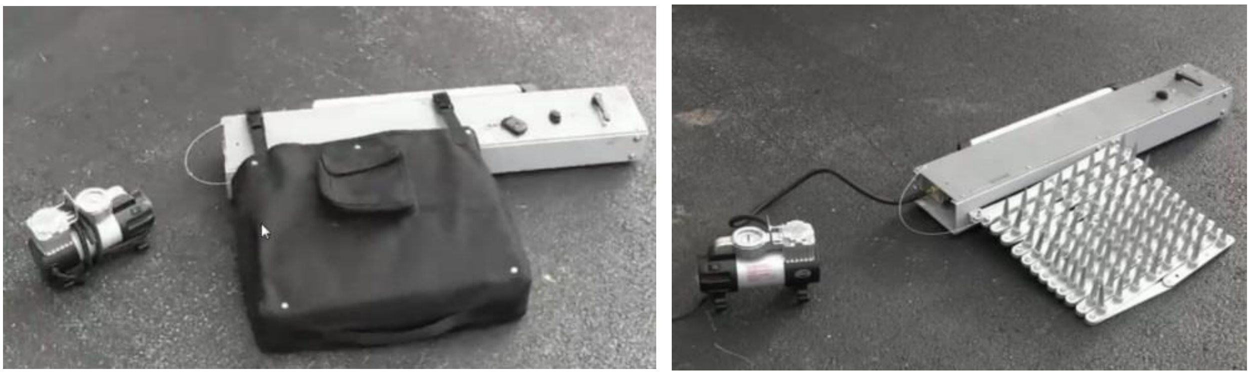
Abstract: *The article presents equipment for efficient and safe stopping of vehicles with tires, by rapidly expanding a barrier with removable spikes on the transverse direction of the road on which the target vehicle moves, thus causing controlled puncturing and deflation of at least one of its tires, on crossing the barrier. Afterwards, the barrier is quickly retracted to clear the road and allow access for the vehicles of the intervention crews to the target vehicle. The equipment is provided with mechanical and electrical safety elements which prevent accidental extension of the barrier. The phenomenon of tire explosion is avoided by a special construction of the spikes, provided with controlled air outlet holes.*

Keywords*: Barriers, spikes, extendable barriers, controlled tire deflation*

1. Introduction

The National Strategy for Research, Development and Innovation 2014 – 2020 [1] stipulates that "Social security is based on the development of technologies, products, research capabilities and systems for local and regional security, protection of critical infrastructures and services, "intelligence'', cyber security, internal and citizen security, emergency management and management of security crises, as well as for fighting terrorism, cross-border threats, organized crime, illegal trafficking, and all this has as a background the development of a security culture "; the Strategy supports "increasing the role of science in society. To this end, research and innovation meet the actual needs of the economic environment and the public sector, especially the one to increase the quality of the services offered (such as the health or safety of citizens) ".
In the rapid intervention actions of the gendarmerie, police and army crews aiming to stop target vehicles, worldwide, portable equipment such as extendable spiked barrier is used; they pierce through the tires and produce controlled deflation, causing the vehicle to slow down and stop. Other solutions practiced are the bollards which are visible on the surface but other parts of them are buried 1-2 meters beneath the ground, with a solid foundation. Near them control systems, compressed air systems or hydraulic systems are installed to lift and lower them; they also require control cables, backup generators, monitoring systems, human protection. Such arrangements are expensive and have a permanent character; usually airports, embassies and other military targets are protected in this manner. For example, a post of 0.8 meters requires a foundation of 1.2 meters, as well as all the control piping, and the posts must be installed every meter. Barriers need a similar space beneath the ground and a solid foundation, depending on the retraction mode (electric, hydraulic, pneumatic). Installing them for temporary public events is practically impossible.
The presented equipment contributes to the increase of the operability of the intervention crews involved in public order and security missions, by developing specific modern and efficient equipment, creating optimal training conditions for the crew to accommodate with them and assimilate the operational procedures, resulting in implementing a high performance management of emergency situations.
Worldwide there are all kinds of systems for restricting access or forcibly stopping cars, generally at fixed points that require excavation and assembly work. This type of extendable / retractable spiked barrier does not require such work, and it is easy to install and use.
Interests in the field of this type of equipment date from 1986, when the American company Phoenix International Ltd produced the extendable / retractable ramp with puncturing spikes and manual operation, called MagnumSpike™ [2].

Other companies with activity in the field are: Dyna Systems, Stinger Spike [3] and Federal Signal Stinger (USA) [4], Gold Deer (China), Trakya (Turkey).
DynaSpike system patented in the United States (Fig. 1) consists of the extendable / retractable platform hinged scissors-type, equipped with tire puncturing elements (spikes), pneumatic extension / retraction system, compressor for compressed air supply, electronic remote control system, protection cover of the extendable platform.



a. b.

Fig. 1. DynaSpike system patented in the United States [3]

At national level, the issue of producing a piece of equipment of type extendable / retractable spiked barrier, usable in public order and security missions, is raised for the first time.

2. The solution presented

The equipment presented is a novelty at the national level, as this product was not in the attention of the R&D entities or the productive industrial units, nor has it been manufactured so far in Romania.
In the presented version, the product “Extendable, remote controlled portable barrier for stopping vehicles by controlled tire deflation” is similar in purpose and principle of operation with the system DynaSpike, but it is based on own solutions regarding the actuation, shape and attachment of the spikes, the safety elements, etc.

Fig. 2. Extendable, remote controlled portable barrier for stopping vehicles by controlled tire deflation

The equipment is structured on three subassemblies:

1. Electro-pneumatic drive system
2. Extendable / retractable platform
3. Electronic control system

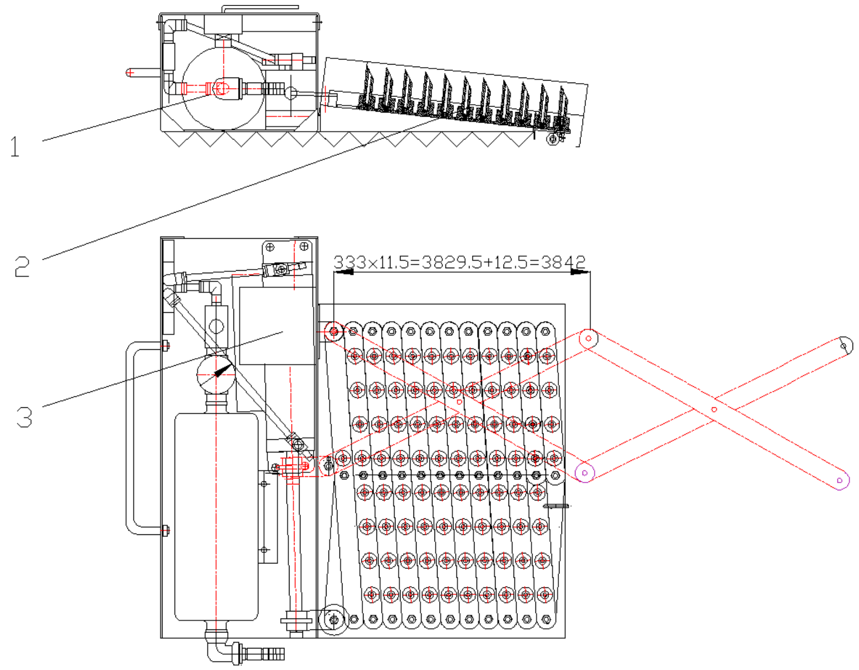


Fig. 3. Structure of the equipment type extendable, remote controlled portable barrier for stopping vehicles by controlled tire deflation

2.1 The electro-pneumatic drive system for extension / retraction includes the accumulator, the double acting pneumatic actuator, the safety valve, the solenoid valve, fast air discharge devices and loading valve [5]. The operating principle is shown in the pneumatic diagram in figure 4: valve (1) allows the accumulator (2) to be charged with compressed air at the pressure of 10 bar, registered on the pressure gauge (3). The safety tap valve (4) allows air supply to the solenoid valve (5) which drives the cylinder (7) to which one of the branches of the hinged bars of the extendable platform is connected. At maximum extension, the platform covers at least one traffic lane (3.5 m).

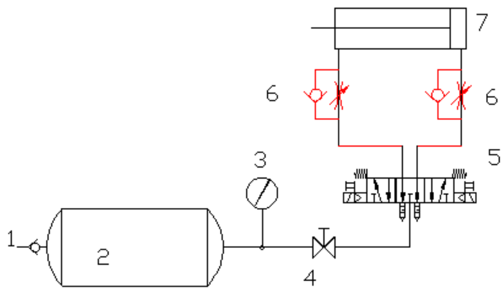


Fig. 4. Pneumatic diagram of extendable barrier [6]
1-valve; 2-compressed air tank; 3-pressure gauge; 4-safety tap valve; 5-solenoid valve; 6-throttles; 7-pneumatic cylinder

The pneumatic accumulator, initially charged at a pressure of 10 bar, stores enough air to perform a complete platform extension / retraction work cycle [7].

The double acting pneumatic actuator has the liner fastened to the housing and the rod - at the free end of one of the bars of the first deformable parallelogram. The rod stroke is correlated with the extension of the platform.
The solenoid valve, connected to the electric accumulator by an on / off safety button, provides pressurized air supply to the piston / rod chambers of the actuator, for the purpose of extension / retraction of the platform.
A safety valve type lever ball tap valve is mounted between the pneumatic accumulator and the solenoid valve on the pressure circuit to avoid accidental operation of the equipment.

2.2 The extendable platform

The hinged bars of the platform are made of spring steel, which gives them resistance and elasticity, avoiding the occurrence of remanent deformations at the impact with the tires of the target vehicle. On the upper bars of the parallelograms the penetrating spike bearing seats are arranged (8 on each bar, a total of 84 pieces). The free ends of the first deformable parallelogram are connected to the equipment housing - one, and to the pneumatic actuator rod – the other.

Fig. 5. Extendable platform

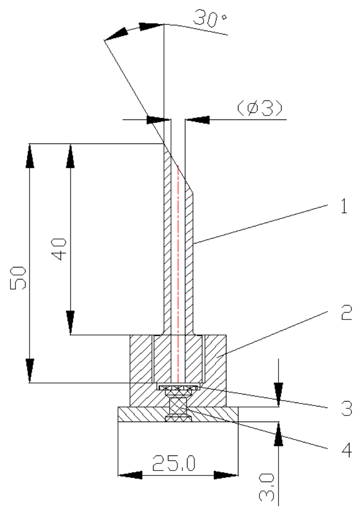


Fig. 6. Spike – spike bearing assembly

Inside the spike bearing seat (2) (Fig. 6) a neodymium magnet Ø 8x1 (3) is bonded; it has a power of about 410 g and keeps the spike (1) in position during transport and extending of the platform; when piercing occurs it is released without dragging the platform. The spike bearing seats (2) are fastened with bolts (4) to the hinged bars.

2.3 The electrical system provides the following functionalities:
Actuation of the electro-pneumatic directional control valve;

- Radio actuation, from a maximum distance of 200 m, of the electromagnets of the electro-pneumatic valve;
- Operation of the electrical system outdoors, at ambient temperatures in the range -20°C…+50°C.

The power supply of the electrical system is provided by an accumulator, which ensures a voltage of 12Vdc, at a capacity of 7Ah, type sealed accumulator with control valve (Valve Regulated Lead Acid – VRLA or Sealed Lead Acid – SLA) which can work in any position, since the electrolyte is of type gel absorbed in a porous material.
The radio actuation and operation of the electro-pneumatic directional control valves is provided by a radio control kit consisting of a receiver unit with two-channel antenna and a remote control with 2 buttons. The control outputs of the coils of the directional control valves are on the relay, with the possibility of programming each output for monostable or bistable type operation [8].
The components of the electrical installation, pneumatic installation and remote control system are located inside the equipment housing.

3. Sizing of the system [9]

The Fc force in the pneumatic cylinder rod breaks down into two forces: F_h force, which acts in the direction of the longitudinal axis of the platform, and F_b force, which acts in the direction of the bars (Fig. 7).

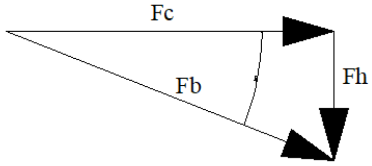


Fig. 7. Fc force in the pneumatic cylinder rod

F_h force, which is the useful force in the extension / retraction of the platform, is given by the equation:

$$F_h=F_c \cdot tg\alpha \tag{1}$$

where α is the angle formed by the bar with the housing, and it varies from the value of 4^0 for the retracted position (the bars completely folded) to the value of 62^0 for the extended barrier position.
The friction force required to extend the barrier, $F_{h\mu}$, is given by the equation:

$$F_{h\mu}=\mu \cdot G_b \tag{2}$$

where μ is coefficient of friction between steel and asphalt, and G_b is barrier weight (set consisting of bars, screws, washers, nuts, spikes and spike bearing seats).

$$G_b=m \cdot g \tag{3}$$

where m is mass of the barrier components, [kg], and g - gravitational acceleration, [m/s^2].
The friction force is determined by the equation:

$$F_{h\mu}=\mu \cdot m \cdot g=0.6 \cdot 10.575 \cdot 9.81=62.25\ N=6.225\ daN \tag{4}$$

1 [N]=1[kg·m/s^2]
Pneumatic cylinder with 50 mm piston diameter for 10 bar working pressure develops an axial force as calculated by (5)

$$F_c=p \cdot A=10 \cdot \pi \cdot d^2/4=10 \cdot 3.14 \cdot 5^2/4=196.25\ daN \tag{5}$$

The force required to start the action of extending the barrier is:

$$F_h=F_c \cdot tg\alpha=196.25 \cdot tg4^0=196.25 \cdot 0.0699=13.71\ daN \tag{6}$$

$$F_h=13.71 > F_{h\mu}=6.225 \text{ daN} \quad (7)$$

The point of articulation of the first parallelogram to the equipment housing can be placed in a favorable position to extend the barrier; the angle α has a decisive role in terms of the value of the useful force F_h.
For example, for an angle of 6^0, thought as acceptable when building the platform, the value of the useful force is 20.6 daN.
Capable force for a 50 mm cylinder:

$$F = p \cdot A = 10 \cdot \frac{\pi \cdot d^2}{4} = 10 \cdot \frac{\pi \cdot 5^2}{4} = 196.25\, daN \quad (8)$$

The air accumulator (compressed air tank)
For a 200 mm stroke, the volume of air required to drive the cylinder is:

$$V = A \cdot c = \frac{\pi \cdot d^2}{4} \cdot c = \frac{\pi \cdot 5^2}{4} \cdot 20 = 392.5\, cm^3 \quad (9)$$

4. Experimental results

The equipment (Fig. 8) was tested under real operating conditions, and the results were at the level of expectations.

Fig. 8. Equipment subjected to operational testing

At each passing of the car over the extendable remote controlled portable barrier for stopping vehicles by controlled tire deflation at least two tires were pierced through by at least 3 spikes (Fig. 9). Tire deflation was controlled through the holes in the spikes, and no danger of accident was noticed, either for the driver or for the car. On the other hand, penetration of the tires forced slowing down the speed of the car and stopping the car.

Fig. 9. Sequences from operational tests and the effect of using the extendable barrier

Fig. 9. Sequences from operational tests and the effect of using the extendable barrier (continuation)

The system has demonstrated its role and efficiency of use in emergency situations.

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