Abstract: The article also tackles topics related to dynamic testing of vehicles equipped with massive wheel inserts. The subject matter was taken due to the modernization of the Polish Armed Forces. The majority of vehicles obtained for the army are equipped with wheels with massive inserts. With the introduction of this solution to the army, there was a need to check the correctness of the operation of wheels with massive inserts. The Military Vehicles Research Laboratory of the Institute of Armoured and Automotive Technology developed a research method, which the authors presented in the following article. Dynamic testing is carried out in a practical way by unsealing the tire. The results of dynamic tests carried out on a selected military special vehicle equipped with wheels with massive inserts, which allow the vehicle to move after the tire is unsealed, were also presented. This condition can be caused by various situations, such as: passing the vehicle through the spike strip or the shooting through the tire. Special vehicles, both military and police, are highly vulnerable to the above events and must be able to evacuate from the place of danger even in the case of an unsealed tire.

Keywords: run-flat, dynamic tests, massive insoles

1. INTRODUCTION

The article also tackles topics related to dynamic testing of vehicles equipped with massive wheel inserts. Special vehicles, in particular vehicles intended for use in the police force and army, must have the ability to evacuate from the place of risk even in case of tire unsealing caused by shooting or passing through a spike strip (fig. 1). In the Military Institute of Armoured and Automotive Technology there were conducted dynamic tests of the steering and stability of Military vehicles equipped with tires with an insert in the situation of driving without air simulating a shot to the wheel and tests using directional explosive devices (fig. 2) The research was also maintaining steerability of the police car fitted with run-flat tires in case of puncturing them, for example, by running over a spike strip.
The modernization of the vehicles of the Polish Armed Forces (SZ RP) has been carried out on a large scale, taking into account the need to equip vehicles with wheels with massive inserts [2, 3, 9, 12]. In the case of unsealed tires, many features of the vehicle and the tires themselves change, among others: characteristics of tires, steering and stability of the vehicle [1, 4 -8, 10-11, 18-20]. Changes of these features have a significant impact on driving safety. The view of the wheel with the massive insert and the insert itself is shown in fig. 3.

2. RESEARCH PROBLEM AND RESEARCH METHOD

Due to the numerous needs of testing vehicles equipped with wheels with massive inserts. The Military Institute of Armoured and Automotive Technology as part of the Vehicle Research Laboratory accredited the test method for vehicles equipped with wheels with inserts.
and run-flat wheels. The tests examined the vehicle's ability to manoeuvre with reduced tire pressure and the ability to overcome a specific distance. On this basis, the research group is able to verify the correct choice of inserts for the tested vehicle. Dynamic tests are carried out on the tarmac for safety reasons. During the tests, the following parameters are monitored and recorded, such as: vehicle speed, angular velocities, acceleration of the track, tire temperature.

The monitoring and registration of these parameters in the tests carried out in WITPiS use the inertial-satellite RT 3002 system (fig. 4–5), which is easy to assemble and does not require interference in the construction of the vehicle. The measurement accuracy of the RT 3002 inertial-satellite system position is ± 2 cm (using the base station). The system also allows the monitoring and registration of these parameters in three axes of the vehicle. The RT 3002 system registers the traverse, speed and acceleration on the vehicle during the measurement. The thermal condition of the tire is monitored using a thermal imaging camera both while driving and immediately after stopping the vehicle.

![Fig. 4. RT3002 inertial-satellite system - assembly in the vehicle](image)

More sophisticated ductility tests are carried out using the robot controlling the SR 60, which works with RT 3002. SR 60 allows you to perform repetitive tests that allow you to accurately track the dependence between the given extortion and the reaction of the vehicle [17]. Unfortunately, due to the method of assembly in the car’s cabin, it is not possible to apply the device to every vehicle.
Dynamic tests have one significant disadvantage being the destructive tests, after these tests vehicle tires are usually unsuitable for further exploitation (figs. 7-8).

3. RESULTS

3.1. DYNAMIC TESTS

The presented tests were carried out on an armoured two-axle vehicle. Prior to the steerability study, left tire in the I axle of the vehicle was selected where the pressure was lowered to the value of atmospheric pressure. In simulation conditions of the tire unsealing, the manoeuvrability of the vehicle was checked (multiple left and right turning manoeuvres, turning
and driving around the circle). During the test, the vehicle was moving at a speed of about 25 km/h. After testing the steering and stability and movement, a durability test was carried out over a distance of 50 km, simulating that the rear left tire was unsealed. The test was carried out on a dry and flat surface, which was the tarmac of the airport, at a speed of up to 50 km/h. During the test, multiple left and right turn manoeuvres were made.

### 3.2. TEST RESULTS

On the basis of the conducted research, the possibility of manoeuvring the vehicle, with the simulated unsealing of the left tire of the axle wheel, it was found that the vehicle is able to perform manoeuvres of turns, turning and driving in a circle.

Based on the conducted test of the vehicle on a distance of 50 km, with the unsealed tire it was found that the vehicle is able to overcome such a distance, at a speed of up to 50 km/h with the simulated unsealing of the left tire of the axle II wheel.

During the trials, the maximum temperature of the tire recorded with a thermal camera during runs was 77.5 °C and 96.4 °C at the moment of stopping the vehicle, after performing the run over a distance of 50 km.

![Fig. 9. View of vehicle wheels after unsealing [21]](image)

![Fig. 10. View the temperature distribution of the thermal imaging camera of the tire during the drive and immediately after the vehicle has been stopped [21]](image)
Fig. 11. Inside view of the wheel tire of axle II on the left side after removal of the insert (after performing the 50 km run with reduced pressure) [21]

Fig. 12. View of the insert after the tests [21]

4. CONCLUSIONS AND SUMMARY

Dynamic tests are an important stage of qualifying tests of military vehicles due to their specific purpose. Run-flat inserts are an important part of the vehicle and allow the evacuation of the vehicle at a reduced pressure in the tires, which can be caused by shooting the tires and passing through the spike strip.

Research confirms the usability of run-flat inserts in combat conditions. On the basis of the tests, the range of the vehicle, the safe speed of the vehicle after the shot through the tire are determined and its maneuverability determined.
Badania dynamiczne pojazdów wyposażonych w koła z wkładkami masywowymi

Streszczenie: W artykule podjęto też tematykę związaną z badaniami dynamicznymi pojazdów wyposażonych koła z wkładkami masywowymi. Podjęta tematyka została podjęta ze względu na modernizacje Sił Zbrojnych RP. Większość pojazdów pozyskiwanych do wojska jest wyposażonych w koła z wkładkami masywowymi. Wraz
z wprowadzaniem tego rozwiązania do wojska powstała potrzeba sprawdzania poprawności działania kół z wkładkami masywowymi. Laboratorium Badań Pojazdów Wojskowego Instytutu Techniki Pancernej i Samochodowej opracowało metodę badawczą, którą autorzy przedstawili w poniższym artykule. Badania dynamiczne przeprowadza się w sposób praktyczny poprzez rozszerzanie opony. Zaprezentowano również wyniki badań dynamicznych przeprowadzonych na wybranym wojskowym pojazdzie specjalnym wyposażonym w koła z wkładkami masywowymi, które umożliwiają poruszanie się pojazdu po rozszerzaniu opony. Taki stan może być spowodowany różnymi sytuacjami takimi jak: przejazd pojazdu przez kolczatkę lub przestrzenienie opony. Pojazdy specjalne zarówno wojskowe jak i policyjne są w dużym stopniu narażone na powyższe zdarzenia i muszą posiadać zdolność do ewakuacji z miejsca zagrożenia nawet w przypadku rozszerzalnej opony.

Słowa kluczowe: run-flat, badania dynamiczne, wkładki masywowe