ARMOURED VEHICLES BRAKES TESTS

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Abstract

Armoured vehicles are nowadays important part of modern army's equipment. Reliability of armoured vehicles is a key feature in safety of transported staff and goods. Due to high mass of these vehicles there is a real problem with optimal brake systems which should be efficient enough in order to maintain as short as possible braking distance and have acceptable manufacturing and maintenance costs. Except for military use, there is a large market for armoured vehicles civilian use by rich or influential persons, security companies and banks. Civilian use of the armoured vehicles generates problems of moving on public roads with all restrictions for brake systems which are required by law.

Brakes verification is a difficult and time consuming process due to many circumstances which must be taken into account during tests. Brake tests should be done on many levels including laboratory tests made on samples, laboratory tests made on fully assembled brakes and finally tests made with use of fully prepared vehicle both in laboratory and in real life conditions. Following work will show selected issues of such test path, which was made by Institute of Aviation Landing Gear Department.

Keywords: *transport, road transport, simulation, armoured vehicles, brakes, brake pads*

1. Introduction

Use of the armoured vehicles by armies is as old as moving vehicles themselves. In ancient times there was a horse wagon armoured with hardwood or metal plates to ensure safety of soldiers inside it. When self driven ground vehicles were invented many of the designs contained armour for the military use. In XIX century armoured trains were in common use by the armies of the world but they were limited to areas with presence of the railway tracks. True use of the armoured vehicles on the battlefields emerged when car was invented and developed in degree which allowed making heavy armoured car move in satisfactory way. Armoured vehicles (cars) were made in the same time as tanks and most common difference between them is weight and armament. Armoured vehicles are lighter and faster than tanks so they can operate in wider spectrum of conditions. Most use of such vehicles is to provide safe transportation during army redeployment or reconnaissance missions.

In modern warfare, especially during latest Afghanistan and Iraq missions, mobility of the armed forces is the key to combat success. These missions are also testing grounds in order to improve every aspect of the vehicle.

Below there is a short description of the Polish armoured vehicle used in current missions:

Dzik (Fig. 1.) is a 4.5-ton Polish-made multi-purpose infantry mobility vehicle. Produced by the AMZ works in Kutno, it is designed for serving both the patrol and intervention roles, as well as an armoured personnel carrier for use by various peace-keeping and policing forces. Its armour provides defence against 7.62 mm bullets. The Dzik-3 also boasts bulletproof windows, puncture-proof tires and smoke launchers.

The Dzik cars are powered by a turbodiesel engine that produces 146 hp (107 kW) with a 2,797 cm^3 displacement.

Fig. 1. Dzik armoured car overview

Institute of Aviation Landing Gear Department (IoA LG Dept.) is a specialist in the field of aircraft landing gear in general including shock absorbers and brakes. Landing Gear Department laboratory is capable of undertaking complete tests to confirm FAR, EASA, MIL, AP, CS standards of helicopters and airplanes with take-off mass up to 20 000 kg (44 000 lb).

Our equipment:

- 10 ton drop test, 3 ton drop test machine with drum,
- 40 ton/ 20 ton (vertical and/or side load) press,
- 5 ton drop test machine for functional/fatigue tests of complete L/G,
- wheel runner for fatigue tests of wheels,
- MTS AERO 90 - system for fatigue tests.

IoA LG dept. design activity is accomplished through use of CAD system SOLID EDGE which is fully compatible with Unigraphics. For stress and strain analysis MSC NASTRAN/PATRAN is used.

This knowledge enabled us to take the challenge in redesigning brakes for the one of the armoured vehicles which had not sufficient braking system for military use. Insufficiency manifested in too large wear of the brake pads and not enough braking power.

IoA LG Dept. made its work in few stages:

- Laboratory tests of existing brake,
- Preliminary tests with various brake pads,
- Tests with selected brake pads material,
- Design and tests of the new brake.

2. Laboratory tests of existing brake

Tests of the existing brake were made using calculations made in IoA LG Dept. in order to set up correct test parameters.

Tab. 1. Brake test parameters (E_{brake} – energy absorbed by the brake)

Nº.	Parameter	Unit	Test conditions for reference vehicle speed 60 [km/h]	100 [km/h]
1	n_b	rpm	273	455
2		rps	4.55	7.58
3	ω_b	1/s	28.58	47.65
4	V_{real}	m/s	20	33.35
5		km/h	72	120
6	A	m/s^2	6.7	6.7
7	T	s	2.99	4.97
8	S	m	30	83
9	F_{brake}	N	10298	10298
10	M_{brake}	Nm	5149	5149
11	$Q_{support}$	daN	1965	1965
12	I_b	kgm^2	843	843
13	E_{brake}	J	344178	955994

Tests were made with use of 3T drop test machine equipped with drum for brake testing (Fig. 2).

Fig. 2. Drop test machine used in brake testing

49 tests were made in this configuration. TEXTAR BZ 005 brake pads were used. Exemplary test results graph is shown below (Fig. 3).

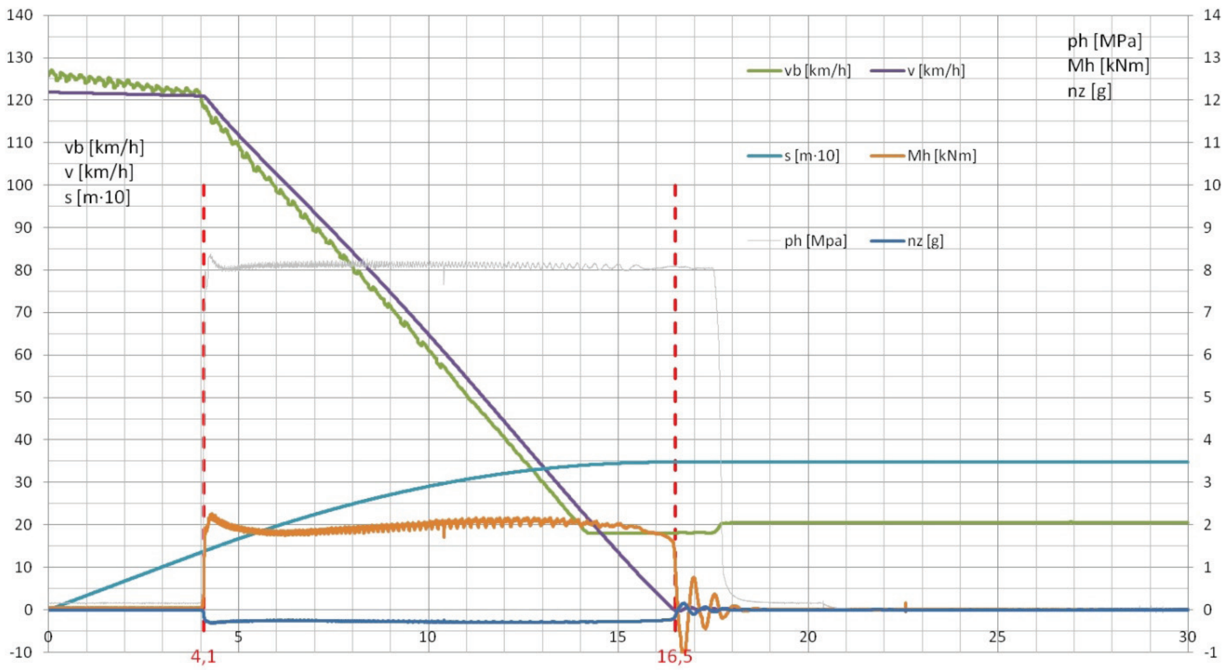

Fig. 3. Example of the original brake test results

Linear acceleration to pressure inside the brake ratio was (average) -0.0370. Such parameter is set up for easy compare between tests with other brake pads or/and brake configurations.

3. Preliminary tests with various brake pads material

Preliminary tests were made in order to check the best brake pads material for new brake. Tests were made in the same conditions of both testing hardware and software for easy results comparison. Four brake pads were taken to the tests, all of them are commercially available brake pads for high-performance use. Below there is a table with results (Tab. 2):

Tab. 2. Results obtained during tests of various brake pads

Parameter	Brake pads material			
	2000/EBC	4000/EBC	5000/EBC	Textar T30311 (7024)FF
μ_D	0.386	0.40	0.38	0.36
α	0.788	0.71	0.68	0.765
wear of brake pad in 1 braking	26.6	21.67	15.15	91.7
wear of disc brake in 1 braking	1.75	0.75	1.38	4.38

Cast iron disc brake type D1309 (EBC Brakes) was used.

As a result of the tests 4000/EBC (Fig. 4.) was chosen for further tests due to its little wear and friction coefficient thermal stability.

Fig. 4. 4000/EBC brake pads chosen for further brake testing

4. Tests of existing brake with changed brake pads

Test was performed in the same manner as previous ones. It proved that change of brake pads increase brake efficiency. Unfortunately it wasn't enough in order to meet the requested requirements. Linear acceleration to pressure inside the brake ratio was (average) -0.0382.

36 tests were made in this configuration. 4000/EBC brake pads were used. Exemplary test results graph is shown below (Fig. 5.).

Conclusion for this test was made that there is need to redesign brake in order to achieve desired brake efficiency.

5. Design and tests of the new brake

According to test results and numerical analysis done by LG dept staff the best solution to achieve desired parameters was to redesign brake in order to obtain higher braking moment. Design modifications were created in order to use commonly available braking pads materials which were tested in IoA LG Dept. as an alternative to brake pads used in original brake.

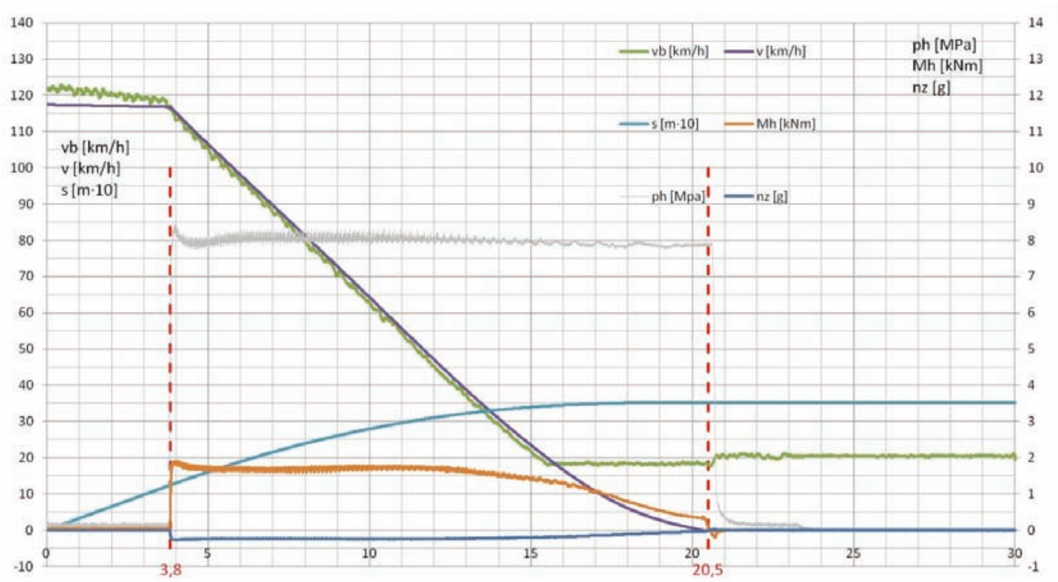

Fig. 5. 4000/EBC brake pads chosen for further brake testing

Main requirements for new brake:

- durability,
- cost of manufacturing,
- functionality,
- easy installation,
- tightness,
- interchange ability,
- corrosion resistance.

Design was made entirely by engineers of IoA LG Dept.

New version of armoured vehicles' brake can generate higher braking moment because of use 3 pistons instead of 2 as it was in original brake. New brake was designed not only to meet energy requirements; it was also design as direct replacement of the old one without any alteration in current car structure (Fig. 6).

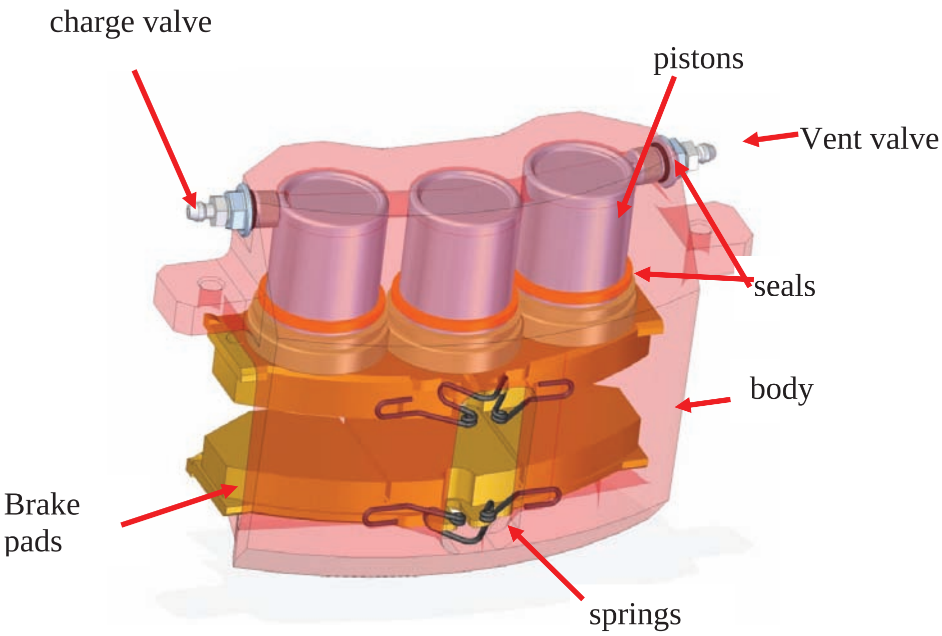

Fig. 6. 3D model of 3 piston brake

Three piston brake was tested (Fig. 7.) in the same way as older one using the same test and measurement infrastructure. This approach ensured testing staff that obtained results are fully comparable with previous ones.

Fig. 7. 3 piston brake mounted to the test stand

46 tests were made in this configuration. 4000/EBC brake pads were used. Exemplary test results graph is shown below (Fig. 8). Linear acceleration to pressure inside the brake ratio was (average) -0.0507.

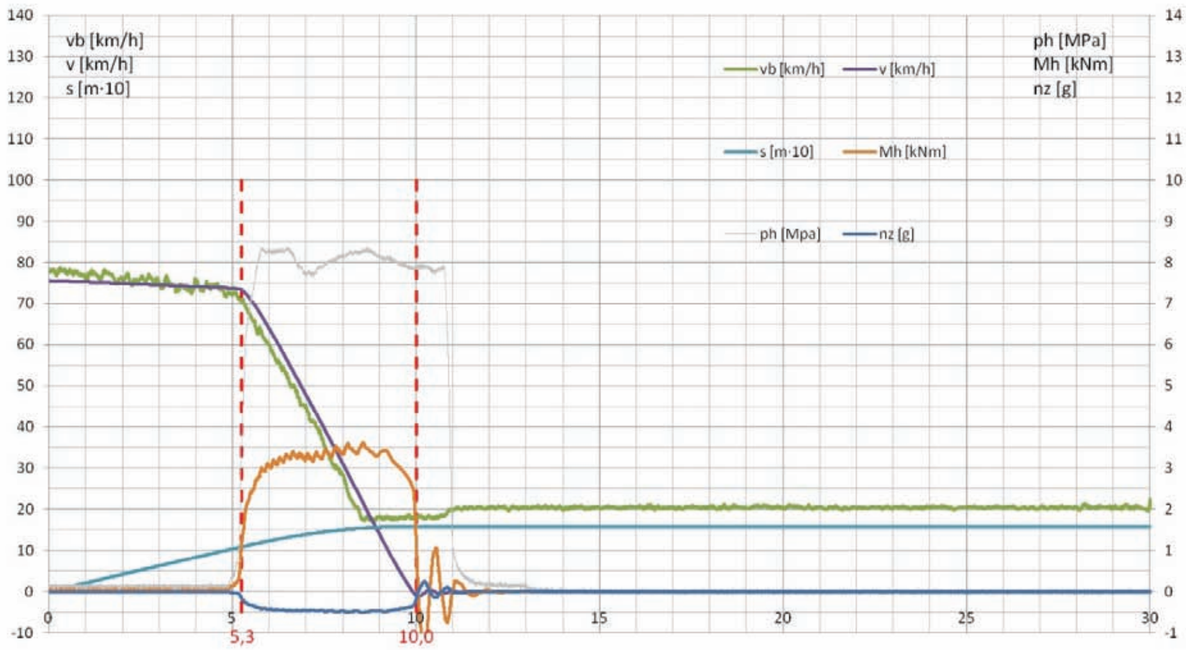

Fig. 8. Example of 3 piston brake test results.

5. Summary

All of the performed tests confirmed that new brake is more efficient than old one. This proved design assumptions made by LG dept. engineers.

Obtained test results were used in order to check if design is correct and as base for more testing using real car in real environment. Results prove better performance (Tab. 1) of the three piston brake by 31% comparing to original two piston brake (2E/3E ratio). As a base for the comparison ratio linear acceleration to release pressure was taken.

Tab. 2. Results obtained during tests of various brake pads

Average	2 piston (original brake)	3 piston (EBC4000)
	[2T]	[3E]
acceleration/pressure	0.038735631	-0.050734012

Thank to laboratory tests it was possible to make assumptions for optimization of the brake in efficient and not costly way comparing to trial method often used in this field. Test results and new design has to be proven during registered exploitation but such tests have to be made by company which produces armoured vehicles.

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