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THE PROCEDURE FOR TESTING THE FUNCTIONAL CHARACTERISTICS OF TANK GEARBOXES DEVELOPED ON THE BASIS OF T-72 TANKS

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Abstract: *For the purposes of installing new or overhauled tank gearboxes in domestic tanks developed on the basis of the Soviet T-72 tank, it is necessary to inspect their functionality and quality. The inspection is performed at the request of the customer from the Ministry of Defense of the Republic of Serbia, prior to the installation of the gearbox inside the vehicle. This procedure was developed parallel to the development of domestic M-84 and M-84A tanks; it is still relevant and is constantly improved on. The conditions have been defined, a test bench has been assembled and the procedure for functional testing of gearboxes has been standardized in order to verify the compliance with the requirements set in the appropriate Quality Insurance Regulation (Serb. PKP).*

Keywords: *tank, T-72, M-84, M-84A, Vihor, testing, gearboxes.*

1. INTRODUCTION

With the purchase of a license in the 1980s (construction and technical documentation) for a T-72 tank produced in the former USSR, the former Yugoslavia, and later the Republic of Serbia as its legal successor, created a field for the development of quality scientific analysis [1] and theoretical studies related to tank issues [2], and as a scientific support in the education of professional staff and for mass production of tanks for the needs of the armed forces of our country at that time (M-84 and M-84A tanks).

Among the significant technical achievements in this field is the formation of a test bench and the development of a procedure for testing the functional characteristics of gearboxes used in testing new (purchased on the market) or overhauled gearboxes for our T-72, M-84 and M-84A tanks, and for the needs of the Ministry of Defense. Gearboxes (left and right) are tested with the side gears and associated pumps, according to the predefined requirements [3-5]. The purpose of testing new, as well as overhauled gearboxes, is to check their functional characteristics. The introduction of this procedure enabled further development tests, so the significant success in this area was achieved on complex projects of the Vihor tank prototype, development of an electro-hydraulic system for semi-automatic and automatic gear transmissions, Integral power pack "IPG 1200", etc.

Although the foundations of this procedure were laid more than thirty years ago, it is constantly being improved by introducing modern measuring equipment, automatization of the certain testing phases and results recording, etc. These tests are performed in the Laboratory for Vehicle Subsystems of VTI in Kumodraž with a frequency of 4 - 5 gearboxes per year.

2. TESTING PROCEDURE

2.1. General requirements

Gearboxes with side gears and associated pumps (left and right) for T-72, M-84, M-84A and VIHOR tanks can be tested on the test bench. All these gearboxes are identical in external dimensions, with the gearboxes for the VIHOR tank having five transmission gears, while the others have seven transmission gears. With this in mind, it is necessary to install a suitable hydraulic distributor on the test bench, considering the number of gears in the gearbox.

According to [3], when testing the gearbox on the test bench, it is necessary to provide:

a) Oil pressure on the hydraulic distributor regulator

b) p=11±0.5 bar at II, III, IV, V, VI and VII transmission gear (for Vihor at II, III, IV and V gear)

c) p=17±0.5 bar at I gear and the reverse gear (RG).

d) Temperature of the oil at the gearbox outlet 100±10ºC, at the rotational speed of 2060±50 min^{-1} at the inlet of the gearbox,

e) Flow of oil for the lubrication of the gearbox of 30 to 42 l/min, while it is allowed to reduce the flow in VI and VII gears (for Vihor in IV and V gears) to 29 l/min,

f) Total oil flow in the hydro system of 70±10 l/min,

g) Pressure of the lubricant oil is $2^{+0.5}$ bar. It is allowed to increase the pressure up to 3 bar in VI and VII gears (for Vihor in IV and V gears), while at the same time the flow of the lubricating oil must be 30 to 42 l/min.

Gearbox testing is performed with the TSZp-8 oil or some other oil applicable for these gearboxes. The technological test mode starts when the oil temperature at the transmission outlet reaches 40ºC. The control test mode starts after the end of the technological mode.

Tables 1 and 2 provide the test modes and the maximum permitted power applied to drive the unloaded gearbox in relevant gears, as well as the rotation speed of the gearbox output shaft for M-84 (T-72), M-84A and Vihor tanks [3].

Table 1. Testing modalities for M-84 (T-72) and M-84A tank gearboxes

Mode	Gear transmittion	Input shaft rotation speed [rpm]	Operating time in each gear [min]	Maximum power applied to drive the transmission [kW]		Side gear output shaft rotation speed [rpm]	
				Right	Left	Tank M-84 (T-72)	Tank M-84A
1	2	3	4	5	6	7	8
Techno-logical	N-1-2-3-4-5-6-7-RG	1300±50	3	Do not control	Do not control	Do not control	Do not control
Control	N	2060±50	3	15	20	-	-
	1		3	15	20	46±5	50±5
	2		3	15	20	86±9	94±9
	3		3	15	20	108±11	118±11
	4		3	15	20	136±14	148±14
	5		3	16	22	186±19	203±19
	6		3	18	24	258±26	281±26
	7		3	18	24	378±38	412±38
	RG		3	18	24	26±3	29±3

Table 2. Testing modalities for Vihor prototype tank

Mode	Gear transmittion	Input shaft rotation speed [rpm]	Operating time in each gear [min]	Maximum power applied to drive the transmission [kW]		Side gear output shaft rotation speed [rpm]
				Right	Left	Tank Vihor
1	2	3	4	5	6	7
Techno-logical	N-1-2-3-4-5-RG	1300±50	3	Do not control	Do not control	Do not control
Control	N	2060±50	3	15	20	-
	1		3	15	20	65±6
	2		3	15	20	101±10
	3		3	15	20	168±17
	4		3	18	24	272±27
	5		3	18	24	412±41
	RG		3	18	24	44±4

The oil leakage in the transmission friction assemblies in each gear must not exceed 2 l/min, provided that per one friction assembly it must not exceed 1 l/min.

Certain transmission stages are achieved by engaging friction assemblies (couplings) in the following order:

- Neutral friction assembly F4
- I friction assemblies F3 i F4
- II friction assemblies F4 i F6
- III friction assemblies F3 i F6
- IV friction assemblies F1 i F4
- V friction assemblies F1 i F3
- VI friction assemblies F2 i F4
- VII friction assemblies F2 i F3
- Reverse gear friction assemblies F3 i F5

2.2. Test bench

The test bench is designed to enable the development and complex functional testing of gearboxes with side gears and associated pumps of the T 72, M 84, M 84A and

VIHOR tanks. Figures 1 and 2 show the test benches for testing the left and right gearboxes. The left gearbox (Figure 1) is tested with its own thrust pump, while the right (Figure 2) is tested with an auxiliary thrust pump. This auxiliary pump provides the required oil flow and pressure to control and lubricate the gearbox. Direction of rotation of the transmission input shaft, viewed from the side of the drive, when testing the left gearbox is clockwise, and when testing the right gearbox, the direction is opposite.

Test benches consist of the following components:

- propulsion groups,
- housings with adapters,
- gearshift steering mechanism,
- hydraulic installations with auxiliary pump,
- oil cooling system and
- control and measuring devices.

2.2.1. Propulsion group

The propulsion group consists of a 75 kW electric motor (1), manufactured by SEVER, with a variable flow hydraulic pump F1V.107.Ma.g - REXROTH HYDROMATIK (2) and a variable flow hydraulic motor AGV.80.Ma - REXROTH HYDROMATIK (3). These hydraulic components make it possible to achieve the desired number of rotations at the gearbox inlet.

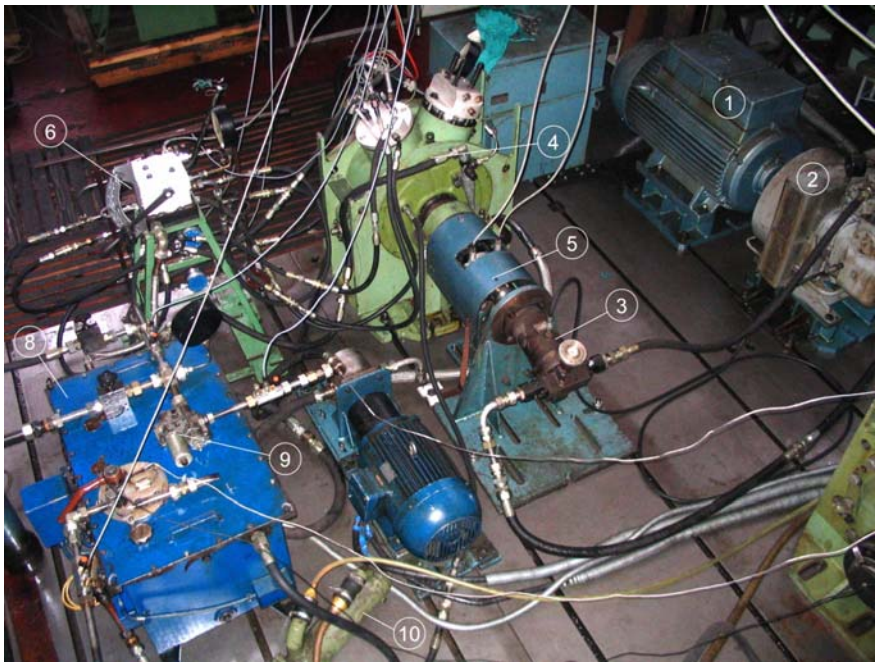

Figure 1. A test bench for the left gearbox inspection

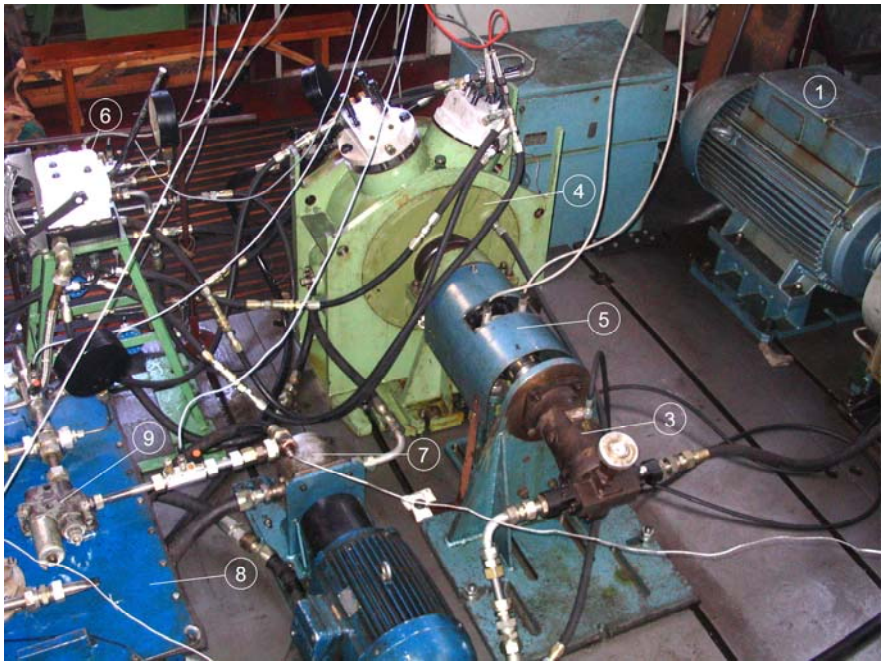

Figure 2. A test bench for the right gearbox inspection

2.2.2. Housing with adapters

Housing solution with adapters (4), enables the conducting of tests of the left and right gearbox. The adapters are used to drain the oil, which comes from the hydraulic distributor, into the appropriate friction assemblies of the gearbox, depending on the engaged transmission gear. The connection of the gearbox with the hydraulic motor is realized through the gear wheel couplings and a torsion dynamometer (5).

2.2.3. Mechanism for the gear shift control

The gearshift is controlled manually, from the command desk (6), via the lever system. The right hydraulic distributor, utilized from the serial production, is located on the command section.

2.2.4. Hydraulic installation with the auxiliary pump

The hydraulic installation consists of an auxiliary gear pump (7) with a capacity of 160 l/min, a reservoir (8) with a volume of app.120 l with a valve device (9) and a piping system. The auxiliary pump provides pressure in the steering system only when testing the right gearbox (Figure 2).

2.2.5. Oil cooling system

The heated oil from the gearbox housing, which is pumped by its own gear pump, is cooled via the cooler (10) by circulating the flowing water from the water supply network back to the reservoir.

2.2.6. Control and measuring devices

Control and measuring devices are used for control and registration of parameters, when testing gearboxes, defined in [3]. During testing on the test bench, the following parameters are measured and recorded (Figures 3 and 4):

- torque and rotational speed on the input shaft of the gearbox (Mu, nu),
- pressures in the friction assemblies of the gearbox (p1, p2, p3, p4, p5 and p6),
- oil pressure in the control system (pu)
- oil pressure in the gearbox lubrication system (pp)
- total oil flow in the hydraulic system (Qu),
- gearbox lubrication oil flow (Qp)
- oil flows (leakages) in the friction assemblies of the gearbox (Q1, Q2, Q3, Q4, Q5 i Q6),
- oil temperature at gearbox inlet (t).

In addition to the above, the parameters that could not be shown on the hydraulic diagrams are also measured (Figures 3 and 4):

- side gear output shaft rotational speed (ni),
- oil temperature at gearbox outlet (ti).

To measure the input parameters on the gearbox, on the test bench, a torsiometer from the company HBM, T30FN range 2000Nm, 3000 min^{-1} is used. The HBM MA1 sensor-inductive encoder and DV2556 preamplifier are used to generate the output speed signal. As a torque amplifier, the MD3555 amplifier is used, and for the rotational speed the N3556, as well as the digital indicator DA3418.

The pressures in the friction assemblies are measured by the pressure transmitters with measuring tapes from HBM Company P4AK and KWS 3082 amplifiers, as well as the digital indicator DA3418. The remaining pressures in the system are measured using the manometers with an elastic measuring element from HAENNI Company. To measure the flow, except for leakages, HDT RE2 turbine flow meters are used, along with the Q300 indicating instruments. For measuring the leakages, HDT, GFM-5 volumetric flow sensors with a range of up to 5 l/min are used, together with SEG1060 indicating instruments. Type J sensors and a Fluke 2190A thermometer are used to measure temperatures.

2.3. Hydraulic scheme of the test bench

Figures 3 and 4 show the hydraulic diagrams of the test bench when testing the left and right gearboxes. The labels on the figures are: EM - electric propulsion motor; HP - hydraulic pump; HM hydraulic motor; M - tested gearbox; RM - hydraulic distributor (distribution mechanism); VU - valve device; R - oil reservoir; PP - auxiliary oil pump and F1, F2, F3, F4, F5 and F6 - friction assemblies in the gearbox.

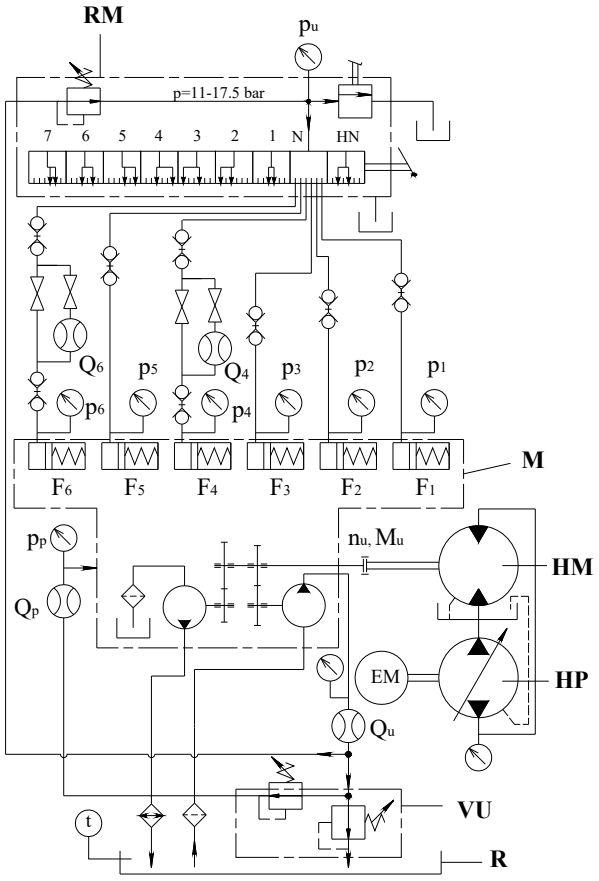

Figure 3. Hydraulic scheme of the test bench for the left gearbox inspection

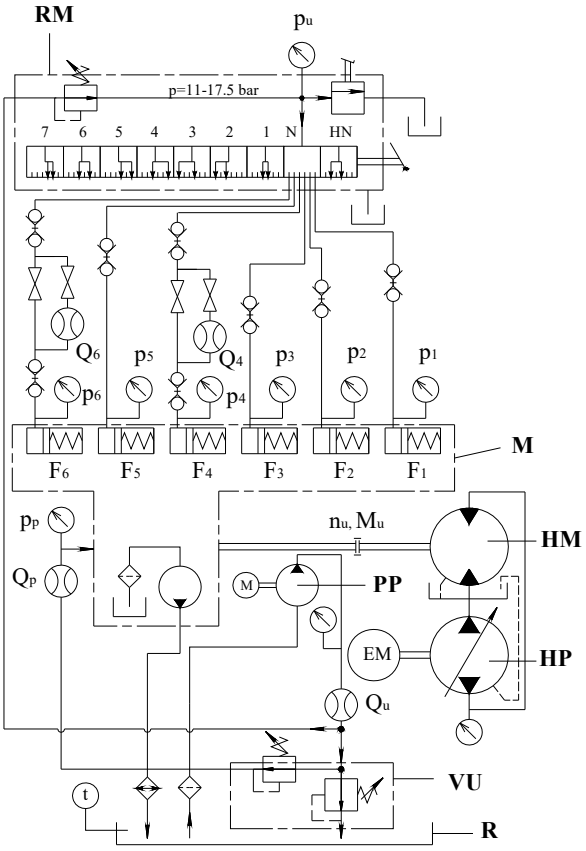

Figure 4. Hydraulic scheme of the test bench for the right gearbox inspection

2.4. Measurement of oil leakage in friction assemblies

When measuring oil leakage (losses) in the friction assemblies, it is necessary to install appropriate flow meters in the appropriate hydraulic lines, which connect the hydraulic distributor and the adapter on the gearbox housing. Since two friction assemblies are included in each transmission, two flow meters are installed for each gear. Figures 3 and 4 show the example of the measurement of the leakage in the II transmission (couplings F4 and F6 are included). The meter with pipelines and taps is given in Figure 5, and its hydraulic scheme is provided in Figure 6. As shown, the flow meters are placed in the parallel line with the main line.

Figure 5. Section of the installation with the flow meter

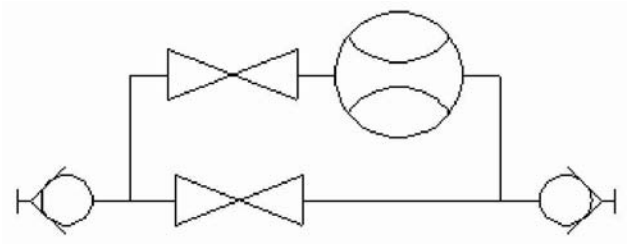

Figure 6. Hydraulic scheme of the installation with the flow meter

The assembly of the section of the installation containing the flow meter (when measuring leakages in individual gears) is done with the help of automatic couplings. Before switching on the gear, it is necessary to open the tap in the main line and close the tap in the auxiliary line (it is located in front of the flow meter). When the gear is engaged and when the measured values reach constant values (rotation speed and torque), it is necessary to open the tap in front of the flow meter, and close it in the main line. In this way, the oil flow, *i.e.* the oil leakage in the friction coupling, is directed to the auxiliary line where the flow meter is located. This procedure is repeated for each gear.

3. TESTING RESULTS

When testing the gearbox, it is necessary to provide the conditions described in the section 2.1, in relation to Tables 1 and 2. In each transmission, the parameters are measured and registered on the basis of which a conclusion can be made if the gearbox is operational. Based on the measured input rotation speed and torque, the power utilized to drive the unloaded gearbox is calculated according to the following formula:

$$P = M \cdot \omega = M \cdot n \cdot \frac{\pi}{30000} \qquad (1)$$

where:

P - Power [kW]

M – Torque [Nm]

n – rotational speed [rpm]

The measurement results are continuously recorded, while the maximum values of the power for the operation of the unloaded gearbox are obtained by calculation. By comparing the measured leaks and the calculated power values for the transmission drive with the permitted values, the quality of the transmission is determined.

4. CONCLUSION

The paper describes the original procedure of verification tests of the functional characteristics of gearboxes for tanks developed on the basis of the T-72 tank. By comparing the measured leaks and the calculated values of the power for the transmission drive in relation to the permitted values, the quality of the transmission is determined, and a decision is made whether it can be installed in the vehicle or not. The procedure can be

applied to the new and reconditioned gearboxes. Although the foundations of this procedure were laid 30 years ago, it is still relevant and is constantly being improved. The test bench, where the tests are performed, is located in the VTI's Laboratory for Vehicle Subsystems in Kumodraž, and the frequency of tests is app. 4 - 5 gearboxes per year.

The validation of the applied method is supported by the fact that during the decades-long examination of tank gearboxes according to the described procedure, the external clients have never filed any complaint.

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