THE EXPERIMENTAL INSTALLATION FOR COMPREHENSIVE TESTING OF THE POWER TRANSMISSION SYSTEM ON MOTOR VEHICLES

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Abstract: *Power transmissions in motor vehicles are one of the key elements of the overall quality of the whole system and therefore special attention should be paid to this issue. In order to find the simplest solution for general purposes that fully complies with the requirements for the application on motor vehicles of the categories M and N, a test bench is designed with the configuration in the form of "closed-loop" which allows testing of virtually all elements and assemblies of the power transmission in a wide range of operating regimes and load conditions. Application of the configuration with two gearbox transmissions and a larger number of shafts and cardanshafts gives the possibility of parallel testing of various solutions in the early stages of transmission development, which significantly speeds up the process of finding the optimal solution. Implementation of the brake mechanism in the contour allows testing of differential mechanisms by changing regimes without stopping the test bench. Simple procedure enables variation of driveshaft's angles to a considerable extent, covering most of the real operating regimes. This configuration of the test bench contains all the elements of the transmission and provides quick insight into the critical points that may lead to a system failure.*

Keywords: POWER TRANSMISSION, RELIABILITY TESTING

1. Introduction

Tests of reliability in the field of power transmissions are widely used and include both specific components as assemblies (transmission, drive axle, hub drive ...), as well as individual elements that are critical in terms of lifetime (gears, bearings, shafts, cardan shafts ...).

Given the complexity of the power transmission system on vehicles as a technical system, it is quite normal to test the reliability of their assemblies and elements are used for a whole range of test installations and different methodologies. These are often simple solutions that were realized with greater or lesser use of parts and vehicle assemblies, but there is also increasing application of specially designed test benches, with a relatively high degree of universality.

The impact on the total cost of reliability testing comes from several factors. One of the most important concerns the test installation alone. It is therefore understandable the intention to create a test installation in such a manner to provide a wide application for different types of tests.

Basically, there are two methods of reliability investigations: transmission load applied by use of parasitic power or active power. In the first case the transmission is statically loaded with a certain torque, of constant or variable values, and thus the motor that drives the system loaded in such a manner, only overcomes the internal resistance (typically 20-30% of the total circulating power), while the parasitic power circulates through the system determined by the torque and speed. Such installations are usually called test benches with circulating power, or "closed contour" test benches ("4-Square-Test-System", "closed loop"). A general characteristic of the test benches with the circulation of parasitic power is their simplicity, and in particular, the relatively low cost of manufacture.

In the second case, the transmission is driven by a motor and loaded by a braking device situated on its output shaft. Thus the brake reduces total power applied on the transmission (minus the degree of efficiency), that leads to a significant increase of the direct costs of the test. These test benches are called in-line or "open contour".

The installations aimed for reliability testing of the front driving axle are somewhat more complex. In this case, it is necessary to apply on driving half-shafts not only torque but also a motion that simulates the control of front steering wheels.

2. Review of the applied solutions

The complexity of the power transmission system on vehicle requires the application of numerous methods and test installations for testing the reliability of their assemblies and components. These are often simple solutions that were realized with greater or lesser use of vehicle parts and assemblies, but there is also the increasing application of specially designed test benches, of a relatively high degree of universality.

Figure 1 shows a common base configuration of the closed loop test installation applied for testing of coupled gears, reduction gearboxes, etc. Basically, it consists of two reduction gearboxes linked with shafts, while one of them is equipped with the torque input system. The shown test bench T12-U (Tribology Department of ITeE-PIB in Radom) [3] is equipped with a control-measuring system, consisting of sensors (thermocouples, an indicator of the number of revolutions) and controllers.

Figure 1. *Test bench T12-U*

As already mentioned, this concept of means that the electric motor must overcome only the friction between gears, rolling bearings, and several smaller resistance components (seals, internal friction in oil, ..). The whole structure is very simple and compact.

Figure 2. *Test bench for testing of gearboxes (Czech Technical University in Prague)*

Figure 2 shows the " closed loop " test bench for transmission testing , which is designed for testing of the gearboxes [2] of the well-known car manufacturer Škoda *(Laboratory at Juliska at CTU in Prague)*. A special feature of the test bench is that the way the gearbox is installed fully corresponds to its position in the vehicle. Entering load in the contour, which simultaneously examines two transmissions, is performed by a mechanism with the screw wheel.

Figure 3. *Test bench for testing of the articulated shaft*

Figure 3 shows a test bench for testing of the articulated shafts [4] of the firm Blum-Novotest, Willich, Germany, which examines simultaneously four articulated half-shafts in a "closed contour" configuration. Swivel stand allows variable rotation angle for simulating real operating conditions. The test bench measures and controls the following values: speed, torque and angle of rotation; safety parameters are simultaneously monitored, such as leakage of the lubricant, the temperature of the joints, etc. In case of failure detection, test bench stops automatically. Implemented cooling system allows for the maintenance of operating regime in real conditions

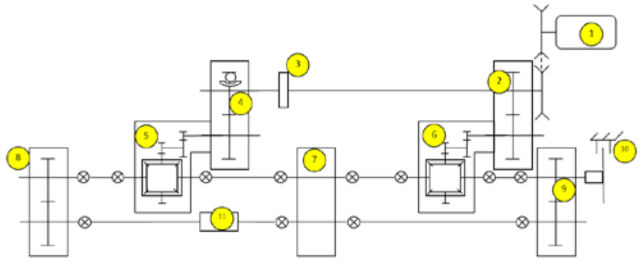
3. Description of the transmission test bench

Test bench of "closed contour" type has indisputable advantages when it comes to the necessary resources for the implementation of the test. In this case, the transmission is statically loaded with the certain torque, of constant or variable value, and the driving motor loads the system only to overcome internal resistance, while the parasitic power circulates through the system determined by the torque and rotational speed. The general characteristic of test benches with the circulation of the parasitic power is their simplicity, and in particular, the relatively low cost of manufacture [1]. It is also of great importance that the costs of tests on this type of test benches are significantly lower.

When selecting a concept of the test bench it is useful to have the possibility of realization of parallel testing of various solutions of elements and components of the transmission, and therefore the selected solution has the ability to simultaneously test at least two sets of the same type (gearbox, differential, shaft ...). Figure 4 shows the scheme of the realized test bench that meets the above criteria and allows testing of complete transmissions of passenger cars and light commercial vehicles.

Input the number of revolutions of the contour is defined by the required testing regime and is realized by setting the appropriate belt drive applied on the electric motor driving shaft. The existing solution is intended for testing the transmissions of high-speed IC engines, but the simple manipulation can easily lead to the application of the other operating regimes.

Torsional load of the closed contour is entered via a screw mechanism integrated in the gear train (Fig. 6) by use of specially designed key. The value of the torque can be read via the built-in sensor (11).



1-Driving electric motor, 2-Gearbox with its mounts, 3-Elastic coupling, 4-Gearbox with screw mechanism for entering the load, 5-Transmission 1, 6-Transmission 2, 7-Gearbox to connect articulated half-shafts of the transmission, 8 -Gearbox, 9-Gearbox, 10-Disc brake, 11-Sensors of torque and number of revolutions

Figure 4. *Scheme of the transmission test bench*

Figure 5. *Braking system of the articulated half-shafts*

When the braking mechanism is actuated (Fig. 5), which consists of a disc brake steered by a hydro pneumatic system controlled via a programmable electronic control unit , one of the articulated half-shafts on the transmission output stops and in this way activates the differential mechanism in the transmission. Operation of the control unit is monitored by speed gauge (11) on the output shaft of the transmission.

Figure 6. *Mechanism for entering torque*

The examination of the articulated drive-shafts is realized by moving the gearbox (item 9, Fig. 4) so as to change the angle of rotation for larger or smaller value, depending on the length of the shaft (eight joints).

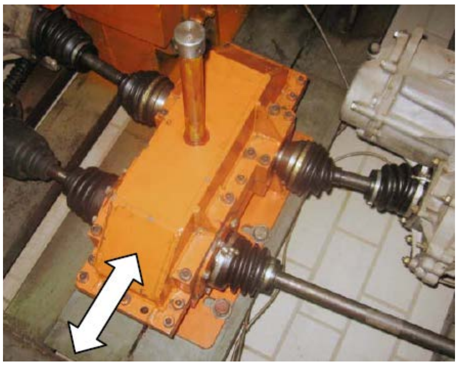


Figure 7. *Gearbox for articulated half-shafts in position for testing of joint with required angle (arrow indicates the direction of displacement)*

• Basic technical characteristics of the device

Number of test objects (transmissions)	2
Rated speed (input of the transmission)	2580 min^{-1}
Maximum torque (output of the transmission)	2000 Nm

High power electric motor (50 kW) provides continuous operating regime in a closed contour, but keeping in mind that driving power accounts for about 20-30% of the power circulating in the contour, it can be expected that the capacity of the drive group meets the requirements for the most of the transmissions of passenger cars and light commercial vehicles.

Coupled gear pairs (item 2,4,7,8,9, Fig. 4) in the gearboxes are designed for multiple higher loads in comparison with the experimental transmission for the sake of reliable operation over an extended period of time.

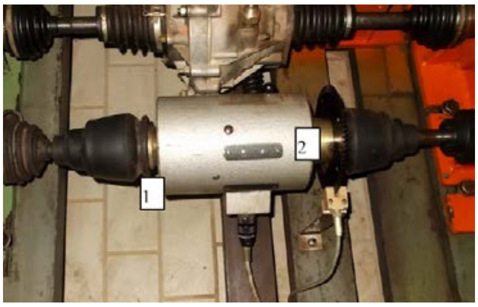


Figure 8. *Torque and speed sensors*

Measuring equipment on the test bench (Fig. 8) consists of HBM T2 torque sensor, range 0-2000 Nm, with associated HPSC amplifier bridge with the carrier frequency 5kHz (measuring counter, Figure 11), then the speed gauge at the exit of the transmission and thermo-sensor that measures transmission oil temperature (Figs. 9, 10) and are connected to the control desk so as to activate the operation break in case of exceeding the pre-set temperature.

Figure 9. *Devices for measuring and controlling the gearbox oil temperature*

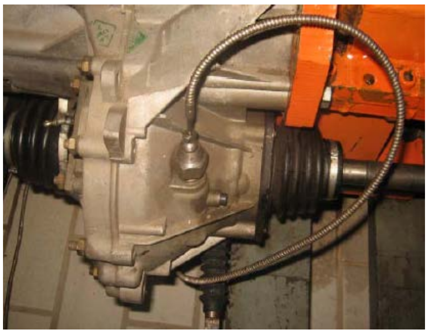


Figure 10. *Oil temperature sensor*

Complete look of the test bench for transmission in operating condition with mounted safety cover can be seen in Fig. 11. If necessary, the measuring system can be extended with the existing data acquisition system based on the AD converter. In order to maintain the temperature of transmission elements within the permissible limits, the system is supplemented with two high capacity fans.

Figure 11. *Transmission test bench with safety cover*

4. Conclusions

Application of the configuration with two gearbox transmissions and a larger number of shafts and cardanshafts gives the possibility of parallel testing of various solutions in the early stages of transmission development, which significantly speeds up the process of finding the optimal solution.

Implementation of the brake mechanism in the contour allows testing of differential mechanisms by changing regimes without stopping the test bench. Simple procedure enables variation of driveshaft's angles to a considerable extent, covering most of the real operating regimes.

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