Influence of the clutch engagement/disengagement to the friction lining lifetime in exploitation and laboratory conditions

Danev, Darko and Kjosevski, Milan and Simeonov, Simeon (2013) *Influence of the clutch engagement/disengagement to the friction lining lifetime in exploitation and laboratory conditions.* In: 24th JUMV International Automotive Conference Science and Motorvehicles, 23 - 24 April, 2013, Belgrade. (In Press)

Influence of the clutch engagement/disengagement to the friction lining lifetime in exploitation and laboratory conditions

Abstract: In most motor vehicles the transfer of torque from engine to the transmission is done through friction clutch. The process of clutch engagementis characterized with intensive sliding between the friction surfaces until angular speeds of the drive and the driven parts become equal. The sliding work depends on the workload at engagement process that directly reflects on friction lining wear intensity and thus on its lifetime. Intensive exploitation and laboratory testing are needed to optimize the engagement process characteristics with tendency most of tests to be conducted in laboratory.

Key words: friction clutch, lining, number of engagements, lifetime, tribological indicators, specific wear.

0. Introduction

Friction lining quality is expressed through tribological parameters. They are related to the stability and value of the friction coefficient, specific pressure and increased temperature between friction pairs, depending on the specific sliding work in friction connection, as on specific lining wear which should be minimal. Tribological parameters depend on lining material substances and the technology of their production.

Specific sliding work in friction connection presents ratio between the sliding work that is achieved in the clutch engagement process and total lining friction surface.

Specific wear presents ratio between lining worn-out volume and total sliding work at clutch engagement process.

Clutch engagement/disengagement frequency when vehicle starts moving and gear changes depending on operating conditions is a measure for workload which directly affects the lifetime length of clutch lining.

1. Research topics

Friction lining lifetime significantly depends on operating conditions which are expressed throughtotal cumulative sliding work as a resultof clutch engagement number in certain traffic and exploitation conditions.

Complex processes that take place during clutch engagement process, the strong dependence of performance and lifetime on operation regime and friction surface characteristics highlight the need of continuous research and development activities mainly based on conduction of appropriate tests. From obvious reasons (time, cost, durability, etc.) constantly, it is endeavored most of the tests to be carried out in laboratory conditions [3], [5], [6].

Although laboratory test methodologies are continually improved and in certain cases even standardized [4], structure differences in the individual clutches especially related friction material composition, leave this issue constantly open.

Starting from the statement above, the aim of the research is to show the process of establishing interdependence of friction lining wear and clutch engagement number in specific traffic and road conditions. Taking laboratory testing advantages, the aim is also to develop such procedures which can be the basis for forecasting its lifetime.

2. Research methodology

Testing methodology includes the studying of available experiences from the literature and published articles, as well as lining manufacturer information's for the subject, performing theoretical analyses of influential factors on clutch lifetime, conducting experimental and laboratory tests, analysis of findings and determination of conclusions.

3. Study of the subject matter

3.1. Factors with directly influence on lining lifetime

Factors with direct influence on friction lining lifetime can be divided in the following groups:

1. Exploitation factors affecting through clutch engagement number in specific traffic and road conditions.
2. Constructive exploitation factors which are resulting from the specific sliding work of friction connection in the process of its engagement.
3. Structural factors that are resulting from specific wear of frictional lining.

3.2. Number of clutch inclusions

Clutch engagement number per kilometer in different road and traffic conditionswith different vehicle loading directly affects at the frictional lining lifetime length. Based on the preliminary conducted tests [1], clutch engagement number depends on exploitation conditions per 100 km passed road and ranges between 30 and 700.

a) According to the performed tests and evaluations it is determined that the clutch engagement number when the vehicle starts moving for passed distance of 100 km city driving is from 350 to 700, for regional road driving 40-80, for national road driving 20-40 and for highway driving up to 5 engagements.
b) According to the performed tests and evaluations it is determined that the clutch engagement number for gear change from the lowest to the highest for passed distance of 100 km is up to 500 for city driving, for regional road driving up to 140, for national road driving up to 50 and for highway up to 33.
c) The equivalent clutch engagement number when the vehicle starts to the equivalent kilometer can be calculated according to expression 1.

$$\mathbf{n} = \frac{\mathbf{a_g \cdot n_{srg} + a_r \cdot n_{srr} + a_m \cdot n_{srm} + a_a \cdot n_{sra}}}{\mathbf{a_g + a_r + a_m + a_a}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where:

-$\mathbf{a_g, a_r, a_m, a_a}$ are percentage share of individual sections of road in equivalent kilometer
-$\mathbf{n_{srg}, n_{srr}, n_{srm}, n_{sra}}$ are average number of vehicle starts.

3.3. Specific slippage work in the clutch inclusion process

The specific slippage work based on the given definition in the introduction is calculated as the ratio shown in the expression 2.

$$\mathbf{a} = \frac{\mathbf{A_r}}{\mathbf{F_{vk}}}\left[\mathbf{J/cm^2}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

-$\mathbf{A_r[J]}$ - slippage work during clutch engagement;
-$\mathbf{F_{vk}\left[cm^2\right]}$ - total friction surface.

Specific slippage work value of the clutch is calculated as the sum of the specific slippage work when starting off and sum of change in the higher gears, which amounts (10-20)% of the value of the specific starting off work.

Based on the aforementioned, the specific work - $a_k$which is generated on the lining per kilometer can be calculated according to expression 3.

$a_k = n_p \cdot a_{sr} + n_s \cdot a_{sr}(0{,}1 \div 0{,}2)\left[\mathbf{J/cm^2 \cdot km}\right]$ ....(3)

Where:

$\mathbf{a_{sr}}\left[\mathbf{J/cm^2}\right]$ -is average specific clutch workload;

$\mathbf{n_p}\left[\mathbf{vkl/km}\right]$ -is number of starting offson 1[km];

$\mathbf{n_s}\left[\mathbf{vkl/km}\right]$ -is number of gear changes on 1[km];

The average specific clutch slippage work is determined as sum of two parts using the expression 4.

$\mathbf{a_{sr} = 0{,}8a_1 + 0{,}2a_2}\left[\mathbf{J/cm^2}\right]$............................ (4)

Where:

a_1 – is specific slippage work for normal working conditions and amounts $a_1 = (40 \div 60)\ \left[J/cm^2\right]$

a_2 - is specific slippage work for heavy working conditions and amounts $a_2 = (80 \div 110)\ \left[J/cm^2\right]$

3.4. Specific lining wear

According to the definition given in the introduction to determine the specific lining wear value the expression 5 can be used.

$\vartheta = \frac{\Delta b \cdot F}{A_{vk}}\left[\mathbf{cm^3 / 10MJ}\right]$................................ (5)

$\mathbf{\Delta b}[\mathbf{cm}]$ - lining wear;

$\mathbf{F}\left[\mathbf{cm^2}\right]$ - lining surface;

$\mathbf{A_{vk}}[\mathbf{10MJ}]$- total work achieved in the slippage process.

4. Lining wear test

4.1 Exploitation tests

a) To assess the lining wear according to road conditions real exploitation tests are performed on three identical vehicles (busses) equipped with identical friction lining with diameter of ⌀350/⌀195mm and thickness 3.5 mm and lining material quality T_1.
b) Road sections in which tests are performed by its structure reduced by equivalent km contain:

- Road section type 1 represents real exploitation per equivalent road drivingwhich is consist of 20% city driving, 30% regional road driving, 30%national road driving and 20% highway driving.
- Road section type 2 consists of 100% city driving and
- Road section type 3 consists of 10% city driving and 90% highway driving.

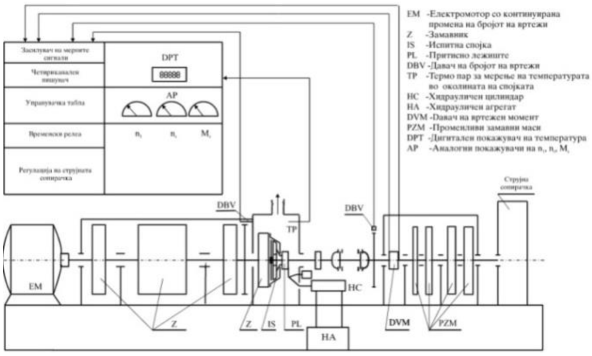
Each vehicle has passed from 12000 to 13000 km after which the linings are disassembled and lining thickness measurement is conducted in relation to the initial thickness.
c) Based on the data from point 3.2 a) and b) and using the values for *a*and *n* given in point 4.1 (as an example), clutch engagement number for vehicle starting off according to expression (1) amounts: for road section type 1 n_1=0.9, for road section type 2 n_1=5; for road section type 3 n_1=0.52.
With the same approach under expression 1 clutch engagement number for change between gears per equivalent kilometer is: for road section type 1 n_2=1.75, for road section type 2 n_2=6; for road section type 3 n_2=0.52.

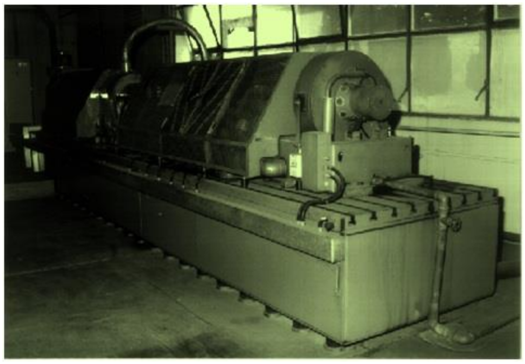
According to measurement performed the wear in those regimes is: exploitation regime type 1 Δb=0.06 cm, exploitation regime type 2Δb=0.26cm and exploitation regime type 3 Δb=0.03cm

4.2Laboratory determination of specific clutch wear

On the basis of calculated values for the clutch engagement number per equivalent kilometer for road sections type 1, type 2 and type 3on test bench with flywheels (figure 1), in laboratory conditions are performed tests on 3 linings with quality T_1, T_2, T_3. The loads (a_1 for normal working conditions and a_2 for heavy working conditions) generated in laboratory conditions on test bench are determined by the values of point 3.3 and by the opportunities for combining of test bench flywheels. The specific values for generated specific sliding loads a_1 and$a_2$in testing process are given in table 1 and in the notes below.

Based on the laboratory tests and the results obtained from full lining wear the lining lifetime (L) is determined about the load regimes type 1, type 2 and type 3 with lining quality T_1, T_2 and T_3.





a b

Figure 1

Table 1

Road type	Type 1			Type 2			Type 3		
lining	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
b[cm]	**0,3**	**0,3**	**0,3**	**0,3**	**0,3**	**0,3**	**0,3**	**0,3**	**0,3**
n_p[vk/km]	**0,9**	**0,9**	**0,9**	**5**	**5**	**5**	**0,52**	**0,52**	**0,52**
n_s[vk/km]	**1,75**	**1,75**	**1,75**	**6**	**6**	**6**	**0,73**	**0,73**	**0,73**
a_1[J/cm^2]	**46,5**	**46,5**	**46,5**	**46,5**	**46,5**	**46,5**	**46,5**	**46,5**	**46,5**
a_2[J/cm^2]	**107,3**	**107,3**	**107,3**	**107,3**	**107,3**	**107,3**	**107,3**	**107,3**	**107,3**
a_{sr}[J/cm^2]	**61,2**	**61,2**	**61,2**	**61,2**	**61,2**	**61,2**	**61,2**	**61,2**	**61,2**
a_k[J/cm^2]	**76,5**	**76,5**	**76,5**	**379**	**379**	**379**	**31,97**	**31,97**	**31,97**
υ_1[cm^3/10MJ]	**0,36**	**0,6**	**0,46**	**0,36**	**0,6**	**0,46**	**0,36**	**0,6**	**0,46**
υ_2 [cm^3/10MJ]	**1,16**	**1,41**	**0,82**	**1,16**	**1,41**	**0,82**	**1,16**	**1,41**	**0,82**
υ_k[cm^3/10MJ]	**0,52**	**0,762**	**0,532**	**0,52**	**0,762**	**0,532**	**0,52**	**0,762**	**0,532**
$L = \frac{b}{a_k \cdot \upsilon_{sr}} 10^7 [km]$	**75400**	**51400**	**73700**	**15200**	**10400**	**14800**	**180000**	**123000**	**176000**

b[cm]-available thickness of lining wear
n_p[vk/km]-number of starting offs per 1[km];
n_s[vk/km]–number of gear changes per 1[km];
a_1[J/cm^2]–specific sliding work for normal working conditions;
a_2[J/cm^2]-specific sliding work for heavy working conditions;
a_{sr}[J/cm^2]–average specific clutch sliding work;
a_k[J/cm^2]-specific clutch sliding workper 1[km];
υ_1[cm^3/10MJ]–specific lining wear at**a_1;**
υ_2 [cm^3/10MJ]- specific lining wear at**a_2;**
υ_k[cm^3/10MJ]–average lining wear;
L [km] -lining lifetime in [km].

Notes:

- The testing is done on frictional lining with dimensions Ø350/ Ø 195 /3,5 mm
- Specific sliding work a_1 is realized on test bench with material moment of inertia J_1=4.42 [kgm^2] and specific sliding work $a_2$is realized with J_2=10.22 [kgm^2] at initial angle speed ω_0=167.47 [1/s].
- T_1, T_2 and T_3 – different lining qualities from different manufactures.

5. Result analysis

5.1 Based on the date from Table 1 and using the theory of linear lining wear in function of sliding work [2], can be determined the equivalent lining wear with T_1quality for conditionally passed 12000 to 13000 km in laboratory conditions. This means that if lining wear of 3 mm is needed L=75400 km road section type 1, L=15200 km road section type 2 and L=180000 km road section type 3, then for proportional passed equivalent road section of 12000 km whereas would be for road section type 1 Δb=0.48 mm, for road section type 2 Δb=2.37 mm and for road section type 3 Δb=0.2 mm. Comparing these values with the values in point 4.1 where wear value in real conditions are: for road section type 1 Δb=0.6mm, for road section type 2 Δb=2.6 mm and for road section type 3 Δb=0.3 mmcan be concluded their full match. From the above mentioned follows that the loads generated on test bench are in accordance with clutch loads achieved in real working conditions.

5.2Based on performed result comparisons from exploitation and laboratory tests can be concluded that the shown laboratory procedure is valid and can be used as a method for determining the lining lifetime depending on exploitation conditions.In addition should be noted that data about clutch engagement number when starting of vehicle and at gear change are variable which depend on the vehicle development, traffic regulation, road infrastructure and load regime that should certainly be taken into account in terms of their assessment before their use.

6. Conclusion

From the carried out exploitation and laboratory tests on friction clutch lining wear can be concluded that the presented procedure for establishing interdependence of lining wear on clutch engagement number in both regimes gives good results which allows laboratory testing to serve as basis for determination of its lifetime.

7. Literature

1. D. Danev, “Research of the working loads on the friction clutch of the passenger cars”, PhD thesis, (in Serbian), Belgrade 1978.
2. S. Simeonov. Influence of friction linings components and structure on heavy vehicles friction clutches performances. PhD Thesis. Skopje, 1999 (in Macedonian).
3. Ivanović, V., Hoić, M., Deur, J., Herold, Z. et al., "Design of Test Rigs for a Dry Dual Clutch and its Electromechanical Actuator," SAE Int. J. Passeng. Cars - Mech. Syst. 5(1):612-620, 2012, doi:10.4271/2012-01-0807
4. William C, Orthwein “Clutches and Brakes, Design and Selection” (Chapter 14. Engineering Standards for Clutches and Brakes), CRC Press 2004, Print ISBN: 978-0-8247-4876-0, eBook ISBN: 978-0-203-02623-6
5. EnsarDogruyol “Design and Development of a Clutch Test Adaptor for a Rotary Tribometer” Masters’s thesis, Luleå University of Technology, Department of Engineering Science and Mathematics, 2010
6. AgusmianPartogiOmpusunggu, Steve Vandenplas, Paul Sas and Hendrik Van Brussel “Health Assessment and Prognostics of Automotive Clutches”, European Conference of the Prognostics and Health Management Society, Dresden, Germany 3-5 July 2012