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MODELING OF THE FRICTION AND WEAR CHARACTERISTICS OF SEMI-METALLIC FRICTION MATERIALS FOR COMMERCIAL VEHICLE DISC BRAKES

Ž. Arsenić [1]
[1] University of Belgrade, Belgrade,Serbia, zarsenic@mas.bg.ac.rs

Abstract: *The increased use of the disc brakes on commercial vehicles has provided a new challenge in the prediction of performance and wear of friction materials under different operating conditions from those of passenger car brakes, where most disc brake friction material development has taken place.*
A prerequisite for successful prediction of service life and performance is the accurate description of the effects of operating parameters on these tribological properties.
This paper presents the description of the effects of pressure, speed and temperature on the friction coefficient and wear of a semi-metallic friction material under commercial vehicle operating conditions, using a modeling technique developed at Belgrade University.
Keywords: *disc brakes; friction materials; wear.*

1. INTRODUCTION

It is necessary to perform tests on vehicles or specially designed single ended inertia dynamometer in order to adequately conduct the experimental and theoretical research in the field of friction mechanism characteristics, as well as motor vehicle applied friction materials.
However, it is well known that all those test methods are rather lengthy and expensive. This is directly related to the fact that due to the unknown, but necessary relations between friction, wear and all other factors, which determine tribological characteristics of friction complex and the brake itself, the functional characteristics under all operational conditions, i.e. under all characteristic conditions, should be assessed by the experimental research work.
The mathematical modeling method of the friction materials tribological characteristics provides efficient experiments and in effect, as well as simpler and more reliable prediction of friction materials functional characteristics. So far the scientific research work performed in this field has shown that it is possible to apply mathematical modeling of friction materials friction and wear, in a very successful way /1,2/.
However, those experiments didn't treat the possibility of friction and wear modeling application using other types of friction materials. Taking that into consideration and knowing that friction materials based on asbestos are replaced with more efficient semi-metallic friction materials, the following paper shows the possibility of friction and wear modeling application on motor vehicle disk-brakes..

2. EXPERIMENTAL RESEARCH

Experimental research was carried out using semi-metallic friction materials for the disk-brake built in a motor vehicle, using single-ended inertia dynamometer and relating computerized test equipment.
The experimental research programmed was composed of two parts:
- The first part encompassed the research of dependence between friction (μ), pressure (p), speed (v) and temperature (θ), all on order to obtain experimental data for friction coefficient that helped in creating the friction model. Within this frame-work, 140 brake applications were performed, all with different values of

influential parameters pressure (p), speed (v) and temperature (θ). The programmed of this part of the research is shown in table 1.

- The second part involved research of dependability between wear (w), pressure (p), speed (v) and temperature (θ), pressure (p), speed (v) and temperature (θ), all in order to obtain experimental data for wear that subsequently helped in creating the wear model. Six different test were carried out with the total of 1200 brake applications (200 applications per test), so that the first four tests helped in creating the wear model and the other two in checking the obtained model. The programmed of this part of the research is shown in table 2. The change in brake pad thickness was measured after each test.

Table 1

Mien Pressure (bar)	Initial speed (km/h)	Mien temperature (oC)	Coefficient of friction (-)	
			Experimental	Analytical
20	30	60	0,418	0,422
30	27	105	0,425	0,424
36	25	155	0,428	0,428
59	20	200	0,42	0,422
55	40	75	0,4	0,404
38	42	120	0,425	0,423
30	45	170	0,432	0,436
70	40	220	0,42	0,422
20	65	175	0,445	0,447
47	57	190	0,425	0,428
20	65	245	0,45	0,455
38	85	115	0,426	0,423
75	80	165	0,417	0,415
65	81	225	0,426	0,425
20	105	145	0,44	0,444

Table 2

Number of test	Mien Pressure (bar)	Initial spped (km/h)	Mien temperature (oC)	Wear for 200 application (mm)	
				Experimental	Analytical
1	20	50	175	0,258	0,261
2	20	90	200	0,705	0,697
3	60	45	150	0,435	0,432
4	60	40	270	0,462	0,465
5	40	60	95	0,425	0,422
6	20	50	175	0,262	0,261

3. MATHEMATICAL MODELING

On the basis of the previously obtained experimental results of friction coefficient and wear, a special method of mathematical modeling was conducted /1,2/, with the following results as a consequence:

a) Friction

$$\mu = 0,395 \cdot p^{-0,055} \cdot v^{0,005} \cdot \theta^{0,052} \quad (1)$$

b) Wear

$$w = 7,55 \cdot 10^{-6} \cdot p^{0,672} \cdot v^{1,573} \cdot \theta^{0,442} \quad (2)$$

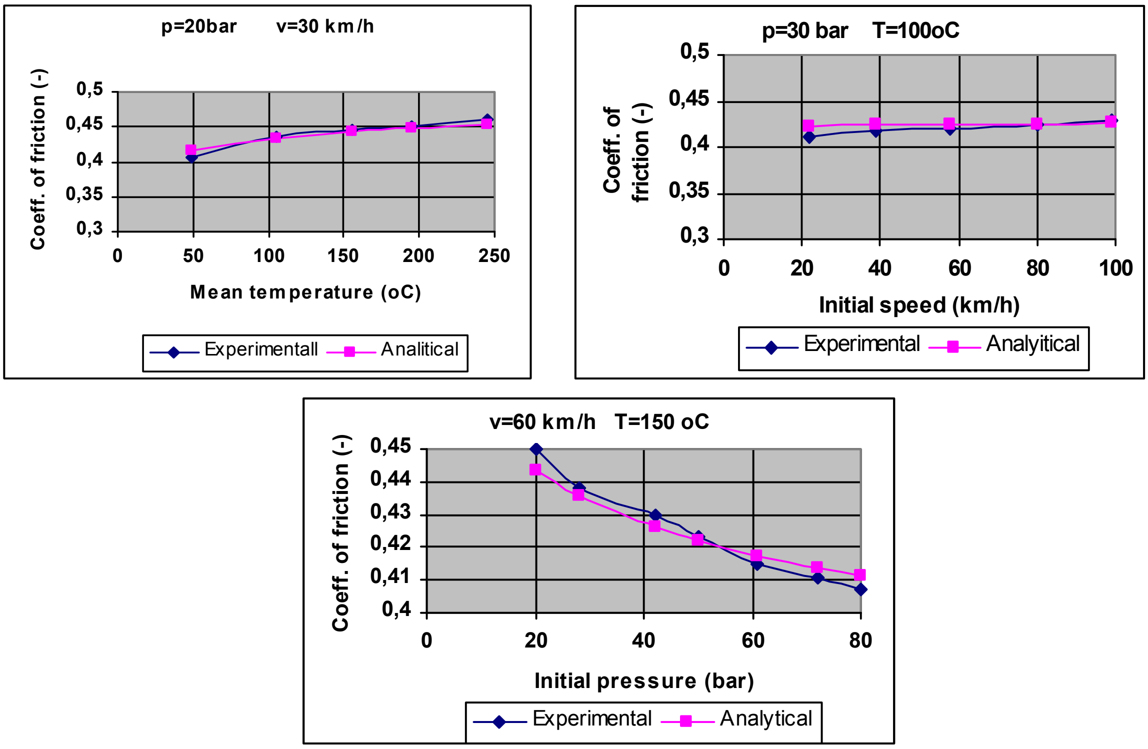

Figure 1: Diagram1

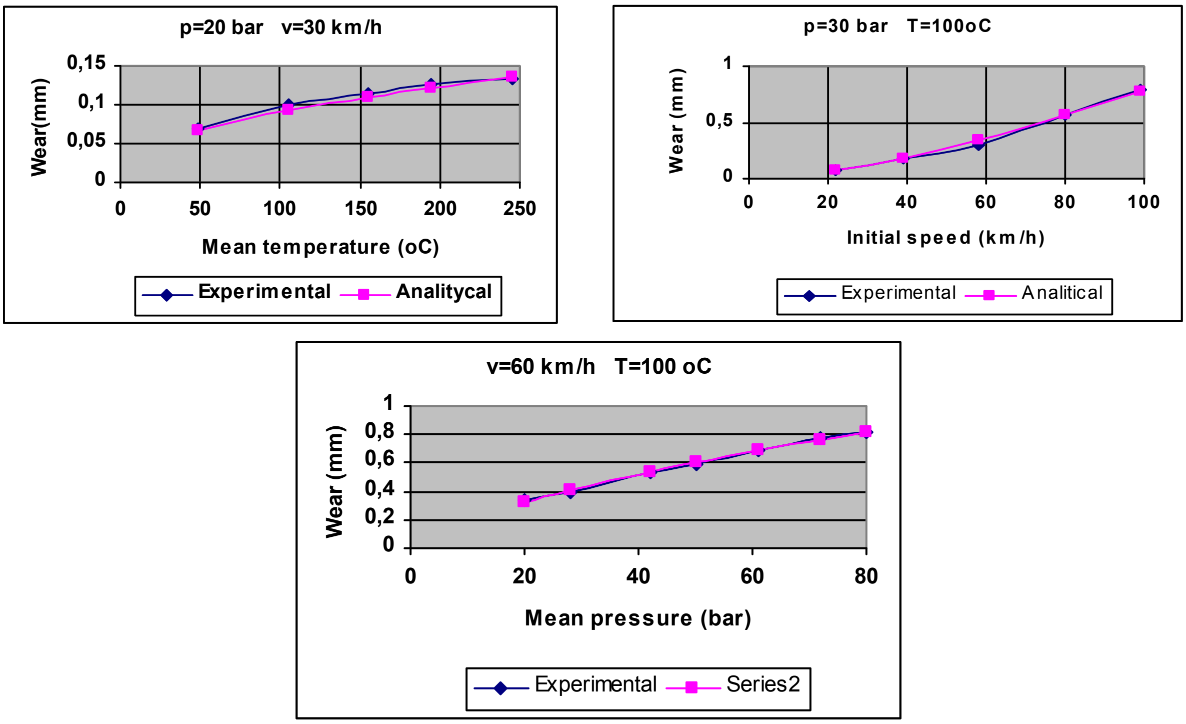

Figure 2: Diagram2

4. ANALYSIS OF EXPERIMENTAL RESULTS

Based on obtained experimental and theoretical results (using 1 and 2 model) related to friction and wear, it is possible to carry out their comparative analysis, that could show the difference magnitudes between experimental and theoretical results. Comparative analysis is presented in tables and diagrams.

In tab. 1 some of comparative analysis results are given, related to friction, obtained experimentally and theoretically. This is also illustrated using Diagram 1.

In tab. 2 comparative wear result are given, obtained experimentally and theoretically. It is, as in case of friction, illustrated on Diagram 2.
Results related to friction and wear are presented in tables and on diagrams, thus enabling following conclusion:

- The difference between experimentally obtained values of friction coefficient (exp. test on inertia dynamometer) and using the model (1) are, for an average of 140 brake applications, $\pm 6\%$ within the full range of the pressure, speed and temperature change.
- The difference between the wear values for all six tests is an average $\pm 6\%$. It is necessary to point that the 5^{th}\$$6^{th}$ test were not used in determining of the wear model.

3. CONCLUSION

Conducted research as have shown that the developed method of the mathematical friction and wear modeling is possible to apply on semi-metallic friction materials for commercial vehicles.
Thus it is possible to obtain the desired friction and wear modeling with quick and inexpensive experimental research, which, as a consequence, has multiple importances.
The developed models clearly show the character and influence of specific parameters (p, v, θ), in view of predetermining friction and wear under other, different work conditions.

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