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UTICAJ RAZUGLJENI^ANOG SLOJA NA DINAMI^KU NOSIVOST TANJIRASTIH OPRUGA ZA SPOJNICE MOTORNIH VOZILA

IMPACT OF THE DECARBONATED LAYER ON THE DYNAMIC PERSISTENCE (DURABILITY) OF DIAPHRAGM SPRINGS OF MOTOR VEHICLES CLUTCHES

REZIME

Rad obra|uje problematiku takozvanog razugljeni~avanja povr{inskog sloja tanjirastih opruga za spopjnice motornih vozila. U odre|enim uslovima je mogu}e da jedan deo uglenika napusti povr{inski sloj metala i samim tim do|e do bitnog pogor{anja njegovih mehani~kih karakteristika. Ovim je efektom smanjena debljina nose}eg preseka opruge {to direknto uti~e na nivo napona i vek trajanja. U radu je uz analiti~ki i eksperimentalni pristup analiziran uticaj veli~ine razugleni~anog sloja na nivo napona i dinami~ku izdr`ljivost tanjirastih oruga za spojnice motornih vozila. Na osnovu dobivenih i prikazanih rezultata je mogu}e izvla~iti zaklju~ke o pa`nji koju treba posvetiti ovom fenomenu u proizvodnji, kako bi se izbegli ne`eljeni efekti.

KLU^NE RE^I: spojnica, tanjirasta opruga, razugljeni~avanje, dinami~ka izdr`livost

ABSTRACT

This paper covers the phenomenon of decarbonation of the surface of the diaphragm springs for motor vehicles clutches. In certain conditions, it is possible that one part of the carbon leaves the metal surface and, therefore, its mechanical characteristics will deteriorate. Thus, the thickness of the cross-section of the core is reduced, which has a direct impact on the level of strain and the durability of diaphragm spring,. An analytical and experimental approach is presented in this paper , in order to analyze the impact of decarbonated layer upon the level of strain and durability of diaphragm springs for motor vehicles' clutches. The shown results could be a basis to make conclusions about the care needed to avoid this phenomenon during the process of production.

KEY WORDS: clutch, diaphragm spring, decarbonation, durability

1. GENERAL REMARKS

Surface layer of metals is normally treated by thermo-chemical procedures in order to provide the needed elements (carbon C – for carbonization, nitrogen N – for nitration, and so on). The aim is to increase some characteristics of metals, such as resistance to wear, durability, etc.

These processes take place on certain temperatures and in ambient containing diffuseable element, that is able to apart in chemically active atom state.

As a result of dissociation, the diffusion elements may be separated in atom state, and, in the second stage, they will be absorbed by the metal surface. Thermo – chemical treatment is finished when diffusion process stops.

The thermo – chemical process aimed at increasing of content of carbon is named cementation. This procedure increases the surface hardness of the metal, and it becomes more resistant to wear. In the same time, the internal tough resistance remains. unchanged.

Because of the high diffusion speed , the carbon may pass a significant distance within the steel, for a short period. In case of appropriate external atmosphere, the carbon could leave the steel. This phenomenon is named decarbonation.

The high-carbon-percentage steel may be a victim of decarbonation phenomenon when treated by a certain thermal treatment (soft stoke, hardening, minting). In such conditions, it is often possible, that decarbonation from the metal surface takes place, unwanted and uncontrolled. This becomes more probable if the neighboring gasses contain higher percentage of oxidizing components (oxygen, carbon dioxide, or steam).

The allowed decarbonation zone must not be higher than 1% of the thickness.

It is necessary to mention that decarbonated zone may be enlarged as a result of incorrect thermal treatment. Such zone has direct influence on dynamic resistance of the diaphragm spring, and may cause break. Increasing of this zone appears as a result of insufficient protection of the atmosphere during its thermal treatment.

The thickness of decarbonated zone has an impact on the “thickness” of the remaining material. In this way, an unwanted process of reducing the strength of cross section takes place. The dimensions of the cross section of the spring are virtually reduced, and therefore, the strain in critical cross sections is changed.

2. Theoretical approach

In order to get an insight in the impact of the depth of the decarbonation layer on the level of strain in certain cross sections, calculation of static values has been performed according to the ALMEN-LASLO method (Fig.1).

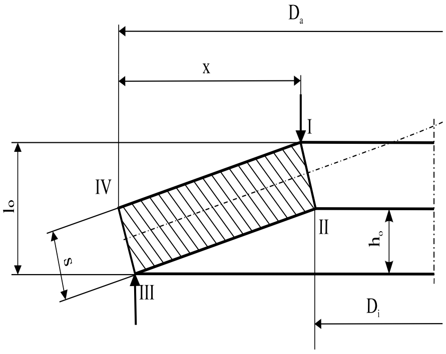

Fig.1

- The force of diaphragm spring is calculated by following equation:

$$F=\frac{4E}{1-\mu^2}\cdot\frac{s^4}{K_1\cdot D_a^2}\cdot\frac{f}{s}\left[\left(\frac{h_o}{s}-\frac{f}{s}\right)\cdot\left(\frac{h_0}{s}-\frac{f}{2\cdot s}\right)+1\right]\ldots(1)$$

- The strain level is calculated by following equations:

$$\mathbf{\sigma_I=\frac{4E}{1-\mu^2}\cdot\frac{s^2}{k_1\cdot D_a{}^2}\cdot\frac{f}{s}\cdot\left[-k_2\left(\frac{h_0}{s}-\frac{f}{2s}\right)-k_3\right]}\ \ldots(2)$$

$$\mathbf{\sigma_{II}=\frac{4E}{1-\mu^2}\cdot\frac{s^2}{k_1\cdot D_a{}^2}\cdot\frac{f}{s}\cdot\left[-k_2\left(\frac{h_0}{s}-\frac{f}{2s}\right)+k_3\right]}\ \ldots(3)$$

$$\mathbf{\sigma_{III}=\frac{4E}{1-\mu^2}\cdot\frac{s^2}{k_1\cdot D_a{}^2}\cdot\frac{1}{\delta}\cdot\frac{f}{s}\cdot\left[\left(2k_3-k_2\right)\left(\frac{h_0}{s}-\frac{f}{2s}\right)+k_3\right]}\ ..(4)$$

$$\mathbf{\sigma_{IV}=\frac{4E}{1-\mu^2}\cdot\frac{s^2}{k_1\cdot D_a{}^2}\cdot\frac{1}{\delta}\cdot\frac{f}{s}\cdot\left[\left(2k_3-k_2\right)\left(\frac{h_0}{s}-\frac{f}{2s}\right)-k_3\right]}\ldots(5)$$

$E=206000\left[N/mm^2\right]$ - module of elasticity
s [mm] - material thickness
Da [mm] - external diameter of the spring
Di [mm] - internal diameter of the spring
f [mm] - spring bend
ho [mm] - flat spring bend
$\mu=0{,}3$ - Poisson number

The coefficients k_1, k_2, 1and k_3 are calculated by following equations:

$$\mathbf{k_1=\frac{1}{\pi}\cdot\frac{\left(\frac{\delta-1}{\delta}\right)^2}{\frac{\delta+1}{\delta-1}-\frac{2}{\ln\delta}}}$$

$$\mathbf{k_2=\frac{1}{\pi}\cdot\frac{6}{\ln\delta}\cdot\left(\frac{\delta-1}{\ln\delta}-1\right)}$$

$$\mathbf{k_3=\frac{1}{\pi}\cdot\frac{6}{\ln\delta}\cdot\frac{\delta-1}{2}}$$

Where:

$$\mathbf{\delta=D_a/D_i}$$

The calculation of static strains has been performed for diaphragm spring of the car Zastava 101. The concrete dimensions are as follows:

Da=174 [mm] - external diameter

Di=134 [mm] - internal diameter

Da1=168 [mm] - external supporting diameter

Di1=134,9 [mm] - internal supporting diameter

α=11° - diaphragm spring angle

l=8 [mm] - release displacement

s=1,94 [mm] - diaphragm spring thickness

d=34,2 [mm] - release thrust bearing diameter

The results are shown in tab.1.

Table N-r. 1.

	f [mm]	F[N]	σ_I [N/mm^2]	σ_{II} [N/mm^2]	σ_{III} [N/mm^2]	σ_{IV} [N/mm^2]
f=max	5,487	1591	-1404	388,8	1117	-264
f=ho	3,888	2194	-1246	26,5	1002	22,3
f=min	2,297	2797	-884	-131,8	716,2	137

On the basis of the values shown in tab. n-r. 1, the most loaded points are I (internal upper edge), and III (external lower_edge) when the bend is minimum.

Table 2 contains the strain in the same points depending on the depth of decarbonated layer.

Table N-r. 2.

Static strain in points I and III.							
	Depth of decarbonated layer (one side).						
	0	10	20	30	40	50	60
fmax [mm]	5,478	5,494	5,51	5,525	5,54	5,555	5,57
s [mm]	1,94	1,92	1,90	1,88	1,86	1,84	1,82
Fi [N]	1591	1512	1434	1359	1285	1212,8	1142
$\boldsymbol{\sigma_{I,i} [N/mm^2]}$	-1404	-1396	-1387	-1378	-1369	-1360	-1351
$\boldsymbol{A_I = F_i / \sigma_{I,i} [mm^2]}$	1,133	1,08	1,034	0,986	0,939	0,892	0,846
$\boldsymbol{\sigma_{III,i} [N/mm^2]}$	1117	1110	1103	1096	1089	1082	1075
$\boldsymbol{A_{III} = F_i / \sigma_{III,i} [mm^2]}$	1,425	1,367	1,3	1,24	1,18	1,121	1,063

As shown in Table 2, reduction of the thickness of the diaphragm spring (as a result of the decarbonated zone) is followed by reduction of the spring force. The same occurs with the strain , and the surface of the points I and III. This phenomenon is adverse, because definite force is needed for proper functioning of the clutch. That force is obtained through adequate thermal treatment of the diaphragm spring. When the bend of the spring is maximum f=5.478 [mm], the spring force is minimum F=1591 [N], and the strain is the highest in the points I and III. When the spring force is constant, the strain is increasing as a result of reducing of the surface in points I and III. Reduction of the surface is caused by decarbonation zone in the spring. This causes breaking of the spring. This increase is shown in Table 3.

Tab. N-r. 3.

F=1591 [N]	Static strain in points I and III						
	Depth of the decarbonation zone (from one side) [μm]						
	0	10	20	30	40	50	60
$\boldsymbol{\sigma_I [N/mm^2]}$	-1400	-1470	-1540	-1610	-1690	-1780	-1880
$\boldsymbol{\sigma_{III} [N/mm^2]}$	1120	1170	1222	1282	1350	1418	1496
$\boldsymbol{\sigma_{Ii} / \sigma_{IO} [\%]}$	0	5	10	15	21	27	34
$\boldsymbol{\sigma_{IIIi} / \sigma_{IIIO} [\%]}$	0	4,5	9	14	20	26	34

3. Experiment

In order to check the validity of this knowledge, some experiments have been performed. The aim was to determine permanent dynamic durability.

Thirty five diaphragm springs (for the car Zastava 101) were produced. All of them had different depth of the decarbonation zone. After assembling in the clutch, first forces of pushing and releasing were measured. In the final stage, the springs were tested on test stand without rotation in order to determine the dynamic fatigue.

4. Results

Table n-r. 4 contains the test results.

Table N-r. 4

	N-r.of cycles	Decarb. zone **[μm]**	Decarb. zone hardness **HV**	Core hardness **HV**	Tensile strength [N/mm2]
1	20000	51	290	470	1520
2	25000	48	300	470	1520
3	30000	47	310	470	1520
4	100000	28	330	470	1520
5	100000	25	335	470	1520
6	100000	33	324	470	1520
7	100000	30	330	470	1520
8	100000	28	332	470	1520
9	100000	35	320	470	1520
10	100000	28	330	470	1520
11	100000	32	320	470	1520
12	100000	35	315	470	1520
13	200000	20	340	470	1520
14	200000	18	347	470	1520
15	200000	22	335	470	1520
16	200000	22	340	470	1520
17	200000	18	347	470	1520
18	200000	16	355	470	1520
19	200000	21	340	470	1520
20	200000	20	340	470	1520
21	300000	12	368	470	1520
22	300000	15	360	470	1520
23	300000	10	396	470	1520
24	300000	14	367	470	1520
25	300000	12	386	470	1520
26	400000	8	412	470	1520
27	400000	6	420	470	1520
28	500000	5	420	470	1520
29	>1000000	0	470	470	1520
30	>1000000	3 *	440	470	1520
31	>1000000	2 *	440	470	1520
32	>1000000	0	470	470	1520
33	>1000000	0	470	470	1520
34	>1000000	0	470	470	1520
35	>1000000	0	470	470	1520

- - decarbonated layer is scattered

5. Analysis

Following conclusions were drown as a result of proceeded calculations and tests:

- When increasing the decarbonated layer, the strain in points I and III also becomes higher. Figure 2 shows the dependence between strain and the depth of decarbonated zone in point III.

- The curve of change can be illustrated with following equation:

$$\mathbf{y = A \cdot x^2 + B \cdot x + C}$$

A=0,003214
B=0,3643
C=0,25

- As the diagram shows, when the decarbonation layer value increases up to 60 [μm] (3% for depth of y=1.94[μm]) for one side, i.e. 6% for both sides, the static strain also increases up to 34%. In case of diaphragm springs with higher thickness, this rate is decreasing if the decarbonation zone depth remains constant (this layer depth is constant for constant thermal treatment, i.e. it does not depend on the spring thickness). It can be said that the springs with smaller thickness depend more on this zone. Their static strains are increasing, which is a reason of unwanted break.

- Fig. 3 shows the influence of the decarbonated zone on the permanent dynamic durability.

- The function may be illustrated with following equation:

$$\mathbf{y = e^{B \cdot x} \cdot A}$$

A=60,44
B= -0,00526

- As the diagram shows, when the depth of decarbonated zone is higher, dynamic durability becomes lower. In the same time, if the depth of decarbonated zone becomes smaller, the dynamic durability increases. This diagram also shows that the experimental results are in line with the well known Veler's diagram of dynamic durability and the number of cycles.

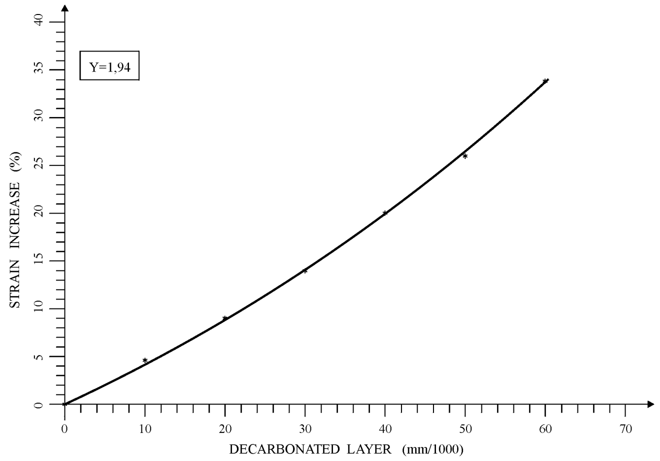

fig. 2

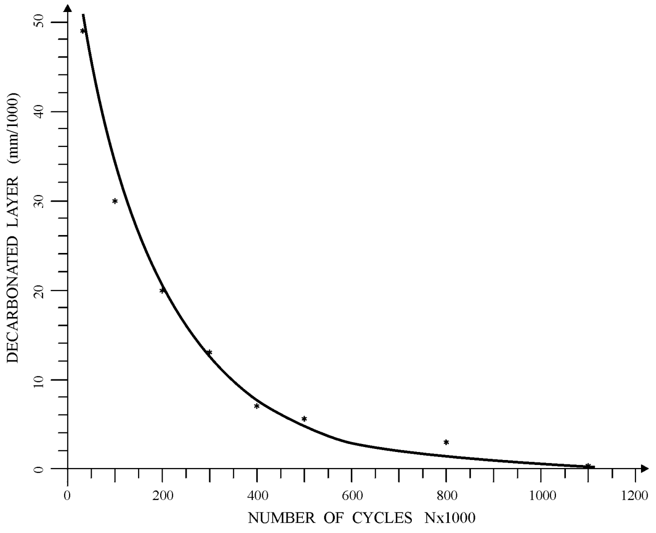

Fig. 3

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