Study on the lifetime of metalic helical springs used for the suspensions of road and railway vehicles

AURELIA TĂNĂSOIU
ION COPACI
STELIAN OLARU
BOGDAN TĂNĂSOIU
Faculty of Engineering
"Aurel Vlaicu" University from Arad University
str. Elena Drăgoi, nr. 2, 310330, Arad,
ROMANIA
ioncopaci@gmail.com

Abstract: - The paper presents an experimental study on the metalic elastic element, helical spring with bar diameter of 24,4 mm, under fatigue testing, for the purpose of establishing its lifetime and consequently its reliability.

The load collective that was adopted and the number of cycles pertain to the conditions imposed by international norms.

We have presented the Wohler load and fatigue resistance curves contained in UIC report ERRI B12 Rp60.

Thus we have determined theoretically and experimentally, the lifetime as a component of the reliability of the studied metalic elastic elements, with the corresponding conclusions.

Keywords: fatigue resistance, lifetime, Wohler curves.

1 Introduction

The paper presents an experimental study on the metalic elastic element, helical spring with bar diameter of 24,4 mm. The studies conducted include fatigue testing, relative deformation, stress and lifetime determinations [1], [2], [4], [5], [6].

In order to verify the fabrication technology and the thermal and mechanical treatments applied, a set of springs was put under fatigue testing in order to determine the causes of breaks during use. The objective was to design springs which have a fatigue resistance (4000000 cycles in 3 regimes) that meets the requirements which ensure an optimal reliability, in accordance with international norms.

The set of springs has the mechanical characteristics which show a flow limit of 1489-1551 N/mm^2 (compared to the min. 1370-1670 N/mm^2 prescribed) and values of the elongation at breaking of 10,8-12,8% (compared to 6% admissible). The initial diameters of the bars are 24,33 – 24,34 mm which comply with the prescribed interval (24,4±0,1 mm). The material from which the springs were made was 50CrV4 according to DIN 17221.

2 Fatigue testing

Fatigue tests were conducted using the regimes indicated in table 1 and figures 1-3.

Table 1.

Regime	Min. Force [kN]	Avg. Force [kN]	Max. Force [kN]	ΔF [kN]	No. of cycles
1	14,090	23,938	33,786	19,696	2x10^6
2	13,754	24,681	35,607	21,853	1x10^6
3	12,796	24,969	37,141	24,345	1x10^6

The results of the fatigue testing conducted on an appropriate experimental stand were the following:

Table 2.

Spring no.	No. of cycles applied	Observations
1	1040000	Break during 1st regime
2	1128000	Break during 1st regime
3	3354000	Break during 3rd regime
4	1249000	Break during 1st regime

A large dispersion of the results is observed, together with the fact that the 4 million cycles limit, considered as necessary for good resistance during use, was not reached.

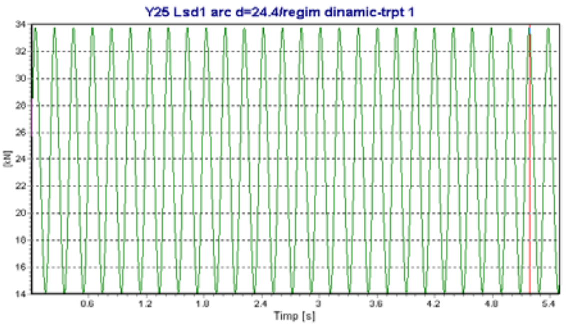

Figure 1.

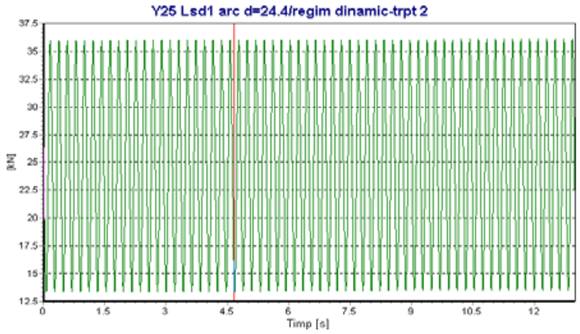

Figure 2.

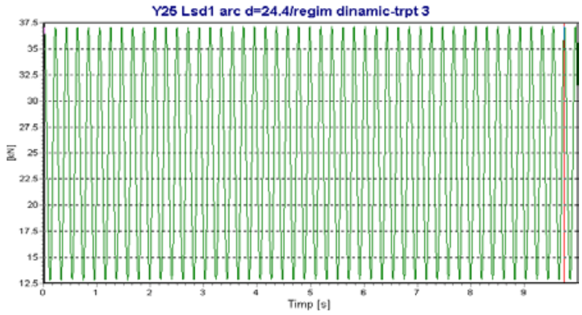

Figure 3.

3 Determining the relative deformations and the stresses

The middle section of the springs was used to determine the relative deformations, using resistive tensometric transducers type În 6/120RY11-HBM, transducters type 0 ^{o}/45 ^{o}/90^{o}. A transductor was placed on the interior and one on the exterior, according to the placement scheme in figure 4 [2], [3].

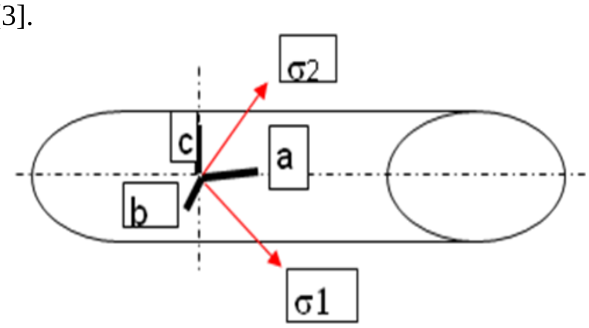

Figure 4.

Applying the forces according to the values in table 1, for the 3 testing regimes, the experimental results were obtained, results which are presented in tables 3 and 4.

In the tables, the following adnotations were used:

F – applied force ;

a, b and c – relative deformations on the three directions considered;

σ_1 , σ_2 – stresses on the principal direction 1 and 2;

α – angle from the reference direction a;

σ_{ech} –Von Mises equivalent stress.

4. Determination of the lifetime

The lifetime was determined using the Wöhler curves established by the ERRI B12 committee in report Rp60 of the UIC. The logarithmic equation of the curves is:

$$\log N_i = \log a - m \log \Delta\sigma_i$$

where Ni – number of cycles at breaking;

a, m – coeficients;

$\Delta\sigma_i$ – value of the stress applied at breaking.

For each category of notch the Wöhler curves were determined experimentally, see figure 5, which establish the admissible fatigue stress σ_{-1}.

The values of the coefficients *a* and *m* for each case are given in table 5 [7].

Table 5.

Concentration Class	Log a		Fatigue stress [N/mm^2]
	m=3	m=5	
160	12,901	17,036	117
140	12,751	16,786	104
125	12,601	16,536	93
112	12,451	16,286	83
100	12,301	16,036	74
90	12,151	15,786	66
80	12,000	15,536	59
71	11,951	15,286	52
63	11,701	15,036	46
56	11,551	14,786	41
50	11,401	14,536	37
45	11,251	14,256	33
40	11,101	14,036	29
36	11,001	13,386	26

Table 3.

Interior								
	F [kN]	a [μm/m]	b [μm/m]	c [μm/m]	σ_1 [N/mm^2]	σ_2 [N/mm^2]	α [°]	σ_{ech} [N/mm^2]
Regime 1	33.790	-705.00	-3885.50	388.50	550.38	-643.52	40.83	1034.99
	14.090	-419.59	-1655.00	171.20	210.50	-283.60	39.54	429.46
Regime 2	35.607	-712.74	-4153.70	422.45	598.82	-684.25	40.97	1112.00
	13.754	-394.16	-1502.20	155.96	188.41	-258.51	39.38	388.63
Regime 3	37.141	-759.65	-4276.60	429.67	609.76	-706.87	40.89	1141.26
	12.796	-358.50	-1399.60	148.88	178.23	-239.92	39.46	363.44

Table 4.

Exterior								
	F [kN]	a [μm/m]	b [μm/m]	c [μm/m]	σ_1 [N/mm^2]	σ_2 [N/mm^2]	α [°]	σ_{ech} [N/mm^2]
Regime 1	33.790	85.40	-1908.40	-15.50	318.34	-297.76	-44.26	533.66
	14.090	61.11	-706.50	45.85	136.17	-104.70	-44.71	209.19
Regime 2	35.607	87.85	-2063.90	-19.38	342.66	-322.51	-44.27	576.14
	13.754	56.43	-626.10	59.97	125.56	-91.31	44.93	188.60
Regime 3	37.141	89.32	-2127.30	-21.77	352.50	-332.62	-44.27	593.42
	12.796	48.40	-585.90	59.66	117.31	-85.51	44.75	176.36

Given the applied cycles for each case, the lifetime was established, in number of cycles, according to the dynamic excedent $\Delta\sigma_i = \sigma_a$. The obtained results are listed in table 6. For the lifetime computation, the curve with concentration class 160 and admissible fatigue stress 117 [N/mm^2] was used.

Table 6.

Regime no.		σ_a [N/mm^2]	Lifetime [no. of cycles]
1	interior	169,940	1622232
	exterior	91,085	10535603
2	interior	205,205	921374
	exterior	108,540	6226307
3	interior	215,765	792605
	exterior	117,545	4895910

It is observed that that the highest stresses appear at the interior fibre where the estimated lifetime is close to the requirements. There are large differences between the estimated lifetime for the interior fibre and the exterior one due to the large differences in relative deformations and stresses obtained experimentally. The estimation of the lifetime using the Wohler curves give results that are very close to the number of cycles demanded from each regime in order to ensure a good resistance in use.

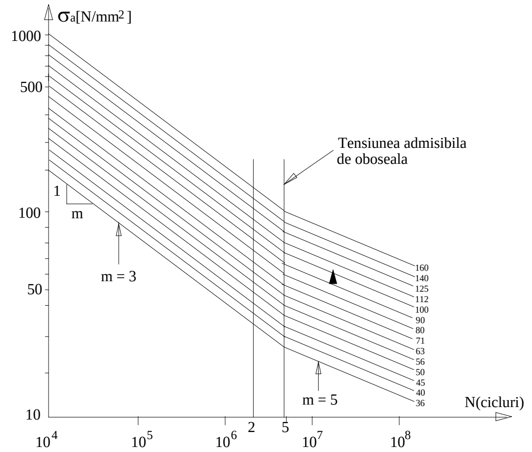

Figure 5.

5 Conclusions

The conclusions of the study are the following :

1. Estimating the lifetime by using the Wohler curves and the static determinations of the relative deformations can lead to eloquent conclusions in experimental research. The obtained results can be

conclusive enough to offer elements of considerable trust for a further design improvement.

2. In any case, fatigue testing are in order to establish definitively the use of an elastic element in regarding its resistance in use, due to the fact that there can arise imperfections and errors during manufacturing, or during the thermal or mechanical treatment.

REFERENCES

[1] Copaci I. ș.a. – “*Rezistenţa la solicitări variabile care apar în exploatarea vehiculelor feroviare*”, Ed. MIRTON Timişoara, 2005.

[2] Copaci I. ş.a. - "*Asupra solicitărilor variabile şi de şoc ce apar în exploatare la boghiul Y25 - Lsdi de 22,5 t/osie*", Conferinţa de dinamica maşinilor - CDM 2005, Braşov, 2005

[3] Copaci I., Tănăsoiu A., Olaru S. - "*Asupra rezistenţei la solicitări statice a boghiului Y25-Lsdi CU 25 t/osie*", Simpozionul Naţional de Material Rulant de Cale Ferată, Universitatea Politehnica din Bucureşti, Facultatea de Transporturi, 2004

[4] Copaci I., Tănăsoiu B. – ”*Durata de viață a elementelor elastice metalice, arcuri elicoidale, folosite la suspensia vehiculelor feroviare*”, Sesiunea de comunicări științifice cu participare internațională ”Cercetare științifică și educație în forțele aeriene”, AFASES 2008, 16-17 mai 2008, Brașov, ISBN 978-973-8415-56-0.

[5] Sebeşan, I. ; Copaci I.- ”*Teoria sistemelor elastice la vehiculele feroviare*”, Editura Matrix, București, 2008

[6] Tănăsoiu A., Tănăsoiu B. – ”*Asupra rezistenței și fiabilității arcurilor metalice elicoidale Ø24,4mm și Ø31mm utilizate la suspensia boghiurilor Y25 Lsdi ce echipează vagoanele de marfă*”, Sesiunea de comunicări științifice cu participare internațională ”Cercetare științifică și educație în forțele aeriene”, AFASES 2008, 16-17 mai 2008, Brașov, ISBN 978-973-8415-56-0.

[7] ***** ERRI B12 RP60 - „*Test to demonstrate the strength of railway vehicles*”, Utrecht, 1995.