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AN EXPERIMENTAL ANALYSIS ABOUT THE FRACTURE OF THE WHEELSET-AXLES OF THE 5100 KW ELECTRIC LOCOMOTIVE

Abstract:
The paper is focused on some experimental analysis performed in the Testing Materials Laboratory belonging to I.C.M. Resita regarding the appearance of cracks in the wheelset-axles of the 5100 kW electric locomotives. Chemical, traction, bending dynamic and torsion tests are performed for different wheelset-axles, different rolling distances and different working conditions which for the “stick-slip” phenomenon occurred.

Keywords:
locomotive, wheelset-axles, mechanical test, crack, stick-slip

INTRODUCTION

The proper against skating device of the C.F.R. 5100 kW electric locomotives is not very efficient when a high level difference has to be raised. As an example, when a heavy train is trailed on an important level difference (as it is the Brasov – Predeal railway route), some important oscillations of the wheelset-axles appeared. The main reason is that for difficult traction conditions, the adherence limit is exceeded. The driving torque on the wheels is divided into non-equal parts, so the “stick-slip” phenomenon of the wheelset-axles is present, which mean an alternate torsion and slip state. Because of the elastic assembling of the wheels on the axles, the whole ensemble will oscillate with a proper frequency.

When the phenomenon takes place in the framework of the micro-sliding domain [1],[2] which means in the framework of a perfect adherence, the oscillation are of a high amplitude. The possible consequences is the appearance of a high state of stress in the wheelset-axles. But the final and the most dangerous consequence is represented by the fracture of the wheelset-axles ensemble [3]. This is the reason why the analysis of the wheel set-axles became obviously necessary [4]. It means both a mechanical,chemical analysis and an experimental non-destructive analysis, in order to detect possible crack initiating locations in the volume of the wheelset-axles.

LABORATORY EXPERIMENTAL ANALYSIS

During the time and according to railway administration regulations, the experimental analysis often avoids the appearance of the wheelset-axles fractures. The main studied wheelset-axles types are presented in table 1.

Tabel 1.

Nr.	Locomotive type	Number of wheelset on the locomotive	Rolling distance [km]
1	060-EA-006	2	306.000
2	060-EA-040	2	481.000
3	060-EA-012	2	476.000
4	060-EA-024	6	391.000

Especially for the wheelset-axles number 3 and 4, some detailed chemical, mechanical and metallographic researches were performed, but the conclusion were drawn for all four investigated cases.

Chemical analysis

The chemical analysis of the wheelset-axle materials conduce to the partition of the chemical elements presented in table 2.

Table 2.

Wheelset nr.	C[%]	Mn[%]	Si[%]	Cr[%]	Ni[%]
3	0,32	0,47	0,24	1,49	1,59
4	0,33	0,52	0,27	1,49	1,62
Wheelset nr.	**Mo[%]**	**P[%]**	**S[%]**	**Cu[%]**	
3	0,40	0,011	0,010	0,08	
4	0,26	0,011	0,010	0,08	

When compare the above mentioned concentrations with the imposed chemical element concentration of the wheelset-axles belonging to 7350 HP electric locomotive, it is observed that the values are placed into the accepted range by the wheelset-axles producers.
The content of 0.40% Mo on the wheelset-axles number 3, in comparison with 0.30% Mo prescribed content, will not present a non-favourable factor.

Traction test

The standardized traction specimen are in accordance with now-days regulations (it presents a 16 mm diameter on the calibrate circular parts). Tests were performed on an universal (traction-compression) testing machine.
The results are presented in the framework of table 3.

Table 3.

Wheel set-axles number	Number of specimen	Yield point [MPa]	Ultimate strength [MPa]	Proportional necking [%]
1	1	730	900	17,50
2	1	700	880	18,75

DYNAMIC BENDING TEST

The dynamic bending test specimens were manufactured both longitudinally and cross-section directionally. It means that a double number of specimens were tested, and results are presented in table 4.

Table 4.

Wheelset-axles number	Number of the specimen	Longitudinal toughness [MPa m]	Transversal toughness [MPa m]
3	1	775	425
3	2	750	337,5
3	3	800	462,5
3	4	675	462,5
3	Average	750	422
4	1	1000	500
4	2	775	450
4	3	1050	512,5
4	4	875	525
4	Average	925	497

Torsion test

The torsion loading represents the main loading which produces the stick-slip phenomenon. The obtained results, presented in table 5, are in accordance with the official prescriptions and regulations of the Railway Romanian Authority (A.F.E.R.)

Table 5.

Torsion torque [Nm]	Diameter of the specimen [mm]	Yield point [MPa]	Shearing ultimate strength [MPa]
940	20	598,7	783,4
980	20	624,2	770,7
960	20	611,4	777
920	20	586	764,3
920	20	586	764,3
910	20	579,6	757,9

CONCLUSION

- *The aspect of the cross-section fracture zone represents the main juridical factor when a wheelset-axles accident takes place. The shiny zone parts (figure 1) represent the fatigue area inside where the cracks grow in time.*

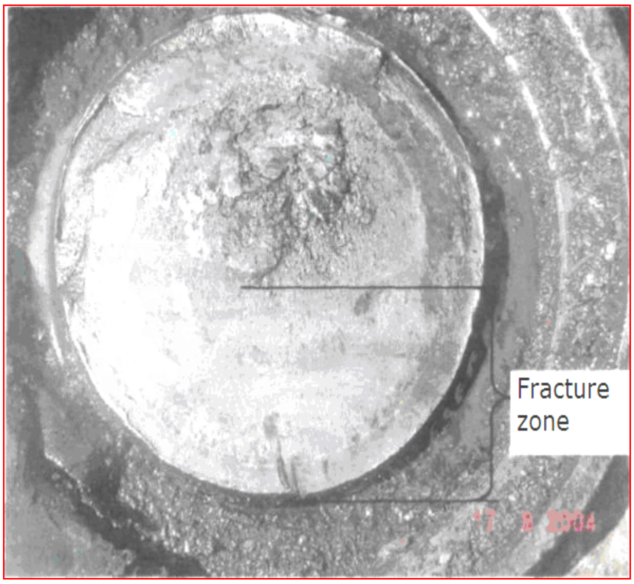

Figure 1. The aspect of the fracture zone in the body of the wheelset

Figure 2. The aspect of the fracture zone in the extremity of the wheelset (lubrication boxes)

- *For the wheelset-axles nr.1, the aspect of the crack propagation is represented as two single independent cracks growing on the free wheel.*
- *For the wheelset-axles nr.2, the crack is developed in a continuous circular direction.*
- *For the wheelset-axles nr.3, the orientation of the crack is similar, but through the cross-section of the free wheel.*
- *For the wheelset-axles nr.4, the crack is located under the gear wheel. These are the most dangerous types of cracks. It may be detected only by an ultrasound control. The ultrasonic crack detection is usually performed by using an a lightweight, compact and handy-portable flaw detector designed for use on large workpieces and in high-resolution measurements. The complementary equipment consist in a mobile push-cart on the rail and three touching heads (a normal one and two bending touching heads). The equipment (figure 3) is able to detect fatigue cracks in the rail head, horizontal cracks in the rail head and in the transient area between the rail head and the rail core as well cracks which are initiated from the holes.*

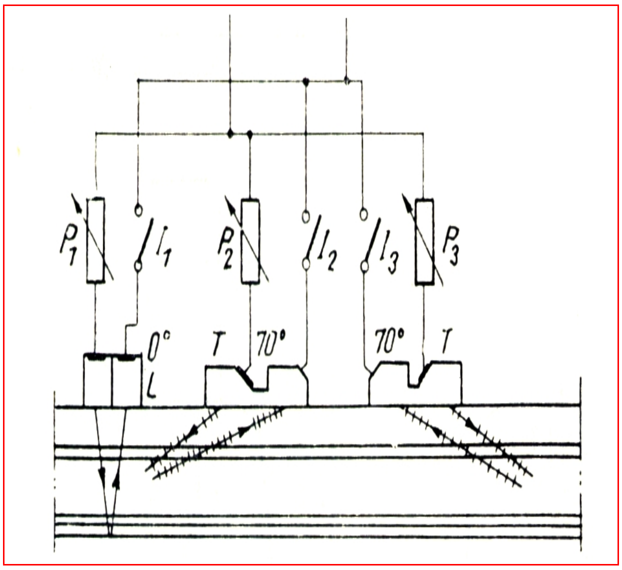

Figure 3. The mobile ultrasonic detection push-cart with three touching heads

The rail profile generates disturbed responses which have to be separated from the faults responses. Anyway, the experimental procedure is able to conduce to: the detection of the location of the cracks, the crack critical length and orientation. It may be calculated: the stress intensity coefficient at the top of the crack, the propagation rate, the estimated life-time of the *wheelset for different locations and lengths of the detected cracks.*

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