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PU	Public	PU
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D4.1.2 ***Fatigue tests on full scale axles***

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Date : *30/06/2008*

Annex XX

to EN13260

1 Scope

Scope of the present annex is to describe the requirements that must be met and the procedure that must followed when having to characterize the fatigue limits of full scale axles so that results coming from different laboratories can be considered to be comparable.

The obtained fatigue limits are then used to determine permissible stresses for the design of axles according to the procedure described in EN13103 and EN13104 or as reference for the fatigue tests made to qualify new axles as required by EN13260 and E13261.

2 General specimen requirements

Specimens used for testing must be representative of normally produced axles; they can have a specific configuration to enable the test execution but the complete production process must be the same as for normally produced axles.

3 General test rig requirements

The test rig used for the test must be able to apply at the tested section a rotating bending moment with a constant stress amplitude. Typical configuration are in figure 1. During the test, the monitoring of relevant measures should ensure that the applied stress amplitudes remain constant enter a range of +-5MPa.

The main active control of the test rig can be based on : the applied load, the applied stress, the applied displacement; on this parameter a control on the error should be made in order to ensure the maximum above accepted error on the applied stress.

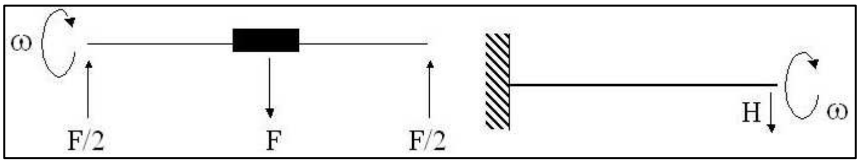

Figure 1

4 "F3 and F4" Axle wheels seats fatigue limit

4.1 Geometry

F3 refers to solid axles (without bore) and F4 to bored axles.

The dimensions of the specimens must be similar to the dimensions of normally produced axles; dimensions ranges are given in figure 2.

The actual fatigue limit of press fitted areas on the axle depends on many geometrical parameters, specially on the diameter ratio D/d: for a given applied nominal stress at the border of the seat, by increasing the diameter ratio, the actual longitudinal stress at the border of the seat decreases; so the nominal fatigue limit will also increase. Above a certain value of the diameter ratio cracks will start to appear on the body and not anymore on the seat.

To have an over all view of the fatigue limit F3 and F4 it would be appropriate to perform tests at different diameter ratios (3 should are sufficient). By interpolation of these three values and by knowing the fatigue limit of the body F1 it's possible to determine the transition D/d above which cracks will appear on the body and below on the seat. This is an important information for optimal design of axles in new materials ensuring that cracks would appear on the body instead of on the seat where it's more difficult to detect them by ultrasonic test.

R	75
r	15
S	35
D/d	In steps: 1,05 ; 1,10 ; 1,15 ; …..
d	>=140
D	=<200
Chamfer geometry	
Surf. roughness	0,8
Coupling on wheelseat	H7v6 Press fit or shrinking
f thickness of pressfitted ring	>20
t	165
q	170

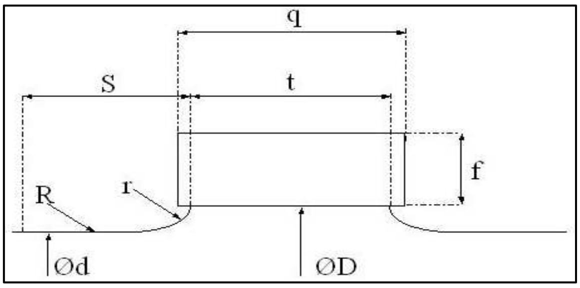

Figure 2

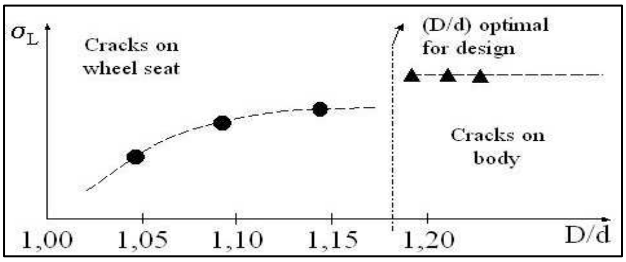

Figure 3

4.2 Verification of applied stress

Coherent to the axle calculation method, the stress to be considered is the nominal stress (σ_{nom}) at the border section of the axle wheel seat.

The stress must be determined experimentally on the tested axle by applying the axle calculation method based on the beam theory if the applied force is measured or by extrapolation of strain gauge measures on both side of the notch where the stress varies linearly.

4.3 End test condition

The result of the fatigue test will be :

- "no crack" if after 10^7 cycles and after taking off the press fitted hub, no cracks larger than 1 mm are be found by Penetrant Liquid test or Magnetic test
- "crack" if the axle cracks before 10^7 cycles or if cracks larger than 1 mm are found at the end of the test with the above methods.

4.4 Determination of the fatigue limit

If fatigue limits are to be determined at three different values of D/d, the number of axles to be tested is 5 per each value of D/d.

The stress step is 10 MPa and the stress level sequence follows the Stair Case method.

The fatigue limit to be considered is the highest stress level without cracks.

5 "F5" Axle journal fatigue limit

In the preparation of this document no information has been found that refers to previous tests performed to determine the fatigue limits of A1N and A4T steel grades that are given in the EN Standards.

In the specific case it's very difficult to reproduce in the test rig the same loading configuration; the following procedure, quite simple to be performed, is considered to be more critical than the actual case.

5.1 Geometry

The tested axle must reproduce the typical journal geometry where an internal bearing ring must be press fitted (figure 4).

It's underlined that this configuration does not correctly reproduce some particular conditions:

- The theoretical bending moment is zero at the centre of the bearing couple and increases to the applied stress limit with a high gradient; the resulting micro-sliding at the critical section should be lower than if the bending moment was constant through the bearings.
- The bearings are longitudinally compressed against the labyrinth; this should reduce the possibility for micro-sliding.

Higher micro-sliding than in reality would increase the wear damaging at the journal/bearing interface and fretting fatigue phenomena would take place earlier.

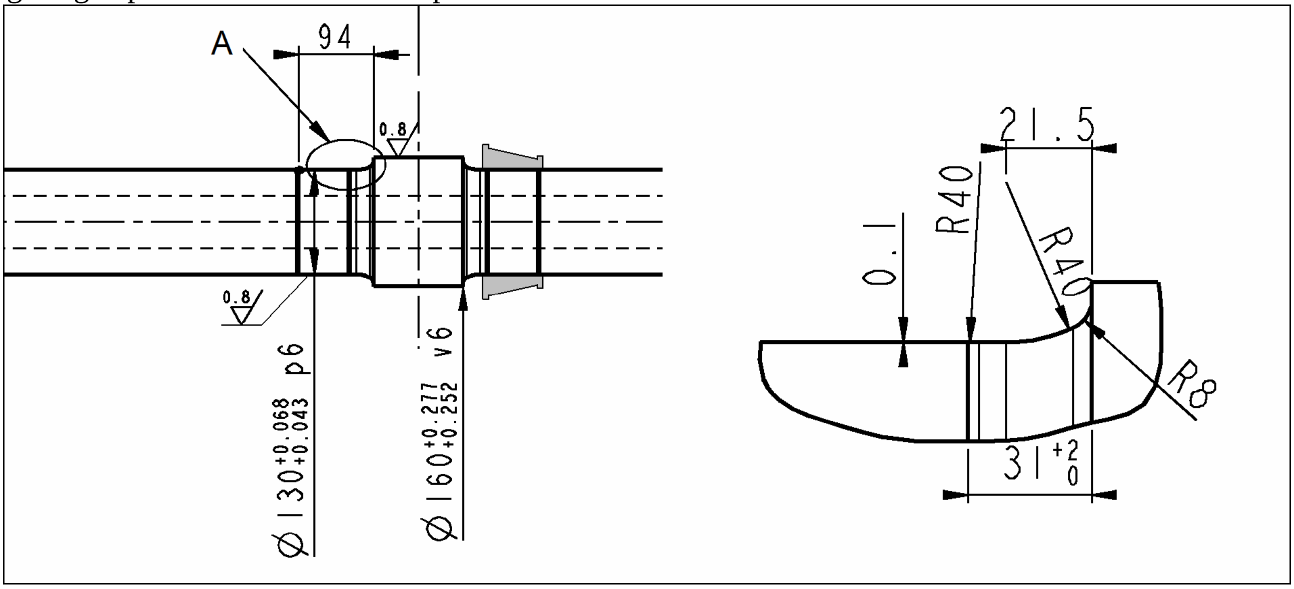

Figure 4

5.2 Verification of applied stress

The stress to be considered is the nominal stress (σ_{nom}) at the bearing/axle interface section where the nominal stress is higher.

The stress must be determined experimentally on the tested axle by applying the axle calculation method based on the beam theory if the applied force is measured or by extrapolation of strain gauge measures on both side of the notch where the stress varies linearly.

5.3 End test condition

The result of the fatigue test will be :

- "no crack" if after 10^7 cycles and after taking off the press fitted hub, no cracks larger than 1 mm are be found by Penetrant Liquid test or Magnetic test

- "crack" if the axle cracks before 10^7 cycles or if cracks larger than 1 mm are found at the end of the test with the above methods.

5.4 Determination of the fatigue limit

The statistical method applied to determine the fatigue limit is the well known Stair case method.

The number of axles to be tested should be 15 from at least 3 different batch productions.

The stress step is 10 MPa.

The fatigue limit is determined with a probability of non failure of 97,5 %.

Annex XX

to EN13261

1 Scope

Scope of the present annex is to describe the requirements that must be met and the procedure that must followed when having to characterize the fatigue limits of full scale axles so that results coming from different laboratories can be considered to be comparable.

The obtained fatigue limits are then used to determine permissible stresses for the design of axles according to the procedure described in EN13103 and EN13104 or as reference for the fatigue tests made to qualify new axles as required by EN13260 and E13261.

2 General specimen requirements

Specimens used for testing must be representative of normally produced axles; they can have a specific configuration to enable the test execution but the complete production process must be the same as for normally produced axles.

3 General test rig requirements

The test rig used for the test must be able to apply at the tested section a rotating bending moment with a constant stress amplitude. Typical configuration are in figure 1. During the test, the monitoring of relevant measures should ensure that the applied stress amplitudes remain constant enter a range of +-5MPa.

The main active control of the test rig can be based on : the applied load, the applied stress, the applied displacement; on this parameter a control on the error should be made in order to ensure the maximum above accepted error on the applied stress.

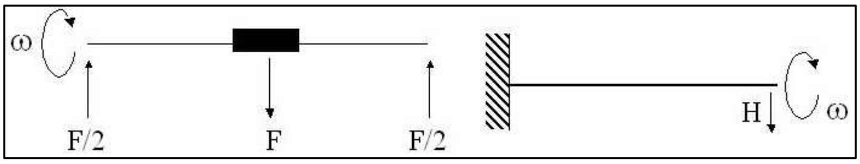

Figure 1

4 "F1" Axle body fatigue limit

4.1 Geometry

The dimensions of the specimens must be similar to the dimensions of normally produced axles; minimum dimensions are given in figure 2.

R	75
r	15
S	35
D/d	>=1,15 (1)
d	>=150 (2)
D	-3
Surf. Roughness	1,6(3)
D'/d	1,3 – 1,5 (4)

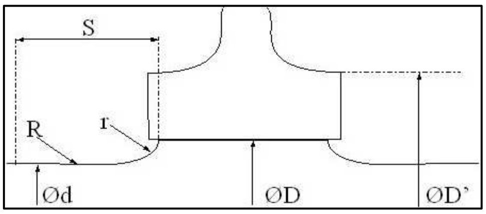

Figure 2

(1) A too small diameter ratio would give cracks in the seat; the value at witch crack will not appear on the seat but on the body depends on the axle steel fatigue resistance (the higher is the fatigue resistance F1 the higher will be this value of diameter ratio.

(2) Full scale fatigue limits are statistically lower than those obtained from small specimens due to the volume scale effect (by increasing the tested volume, the probability of having a larger defect in the material would also increase).

(3) Future possibilities of increasing the surface roughness to enable a better paint adhesion must be considered in the determination of fatigue limits.

(4) The thickness of the hub together with the seat / hub interference will determine some stress concentration at the axle body fillet base; for this reason the coupling of the diameters should be similar to typical configurations.

4.2 Verification of applied stress

Independent on the type of test rig, the applied maximum stress must be experimentally verified in terms of maximum value and longitudinal position of maximum value.
This is done with an array of strain gauges longitudinally placed at the fillet before the axle seat containing the maximum strain value (see figure 3); the distance between strain gauges should be < 4mm and the length

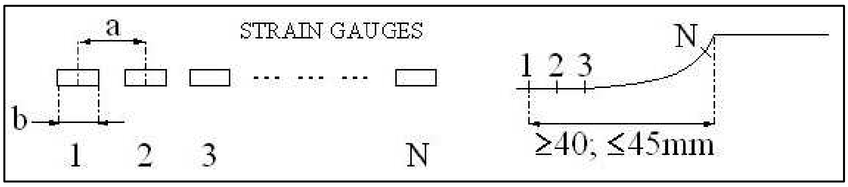

Figure 3

To be coherent with the axle calculation method (EN13103, EN13104), the stress is determined with the hypothesis that the stress state is mono-axial : $\sigma_{real}=E*\varepsilon$
For the tested axle shape, the static stress concentration factor must be determined : $k_t=(\sigma_{real})/\sigma_{nom}$
σ_{nom} is the nominal stress at the section where the real measured stress is maximum and is determined by applying the axle calculation method based on the beam theory if the applied force is measured or by extrapolation of strain gauge measures at 2 sections of the axle where the longitudinal strains vary linearly.
The fatigue limit is determined in terms of both real measured stress and nominal stress which is strictly dependent on the axle geometry (D, d, r).
It has been verified that the experimental k_t factors are greater than the values given in the EN Standard (in the case of D/d=1,15, R=75, r=15, s=35, experimental kt=1,22; the k factor given in the EN Standards is 1,02) ; as a preliminary rule (to be discussed): if real measured fatigue limit stresses are used in axle design, then experimental k_t factors (for example from Petterson) should be used considering the hypothesis that $k_t = k_f$ for typical filets used on railway axles; if nominal fatigue limit stresses are used in axle design, then k factor given in the EN Standards could be used. This would mean that the fatigue limits given in the EN Standards for A1N or A4T are nominal fatigue limits.

4.3 End test condition

The result of the fatigue test will be :
- “no crack” if after 10^7 cycles no cracks will be determined by Penetrant Liquid test or Magnetic test
- “crack” if the axle cracks before 10^7 cycles or if cracks larger than 1 mm are found at the end of the test with the above methods.

4.4 Determination of the fatigue limit

The statistical method applied to determine the fatigue limit is the well known Stair case method.
The number of axles to be tested should be 15 from at least 3 different batch productions.
The stress step is 10 MPa.
The fatigue limit is determined with a probability of non failure of 97,5 %.

5 “F2” Axle bore fatigue limit

5.1 Geometry

The axle used for the test has a notch to simulate the worst scratch left from the machining process of the bore. The notch is machined with a special tool on the external body according to the geometrical parameters given in figure 4

d	<=140
α	30°
s	1
r	0,04

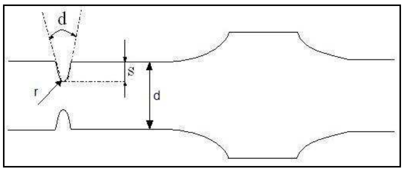

Figure 4

5.2 Verification of applied stress

The stress to be considered is the nominal stress ($\square_{nom}$) at the section where the notch is.

The stress must be determined experimentally on the tested axle by applying the axle calculation method based on the beam theory if the applied force is measured or by extrapolation of strain gauge measures on both side of the notch where the stress varies linearly.

5.3 End test condition

The result of the fatigue test will be :

- "no crack" if after 10^7 cycles no cracks will be determined by ultrasonic test
- "crack" if the axle cracks before 10^7 cycles or if cracks larger than 1 mm are found at the end of the test with the above method.

5.4 Determination of the fatigue limit

The statistical method applied to determine the fatigue limit is the well known Stair case method.

The number of axles to be tested should be 15 from at least 3 different batch productions.

The stress step is 10 MPa.

The fatigue limit is determined with a probability of non failure of 97,5 %.