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2nd edition, February 2003

Translation

OR

Motive power units - Bogies and running gear - Bogie frame structure strength tests

Engins moteurs - Bogies et organes de roulement - Essais de résistance des structures de châssis de bogies

Triebfahrzeuge - Drehgestelle und Laufwerke - Festigkeitsprüfung an Strukturen von Drehgestellrahmen

UNION INTERNATIONALE DES CHEMINS DE FER
INTERNATIONALER EISENBAHNVERBAND
INTERNATIONAL UNION OF RAILWAYS

Leaflet to be classified in Volumes :

V - Rolling Stock

VI - Traction
VIII - Technical specifications

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The person responsible for this leaflet is named in the UIC Code

Contents

Summary

This leaflet is part of a set concerning the technical approval of motor bogies. It describes the rig tests performed to verify the ability of bogie frames to withstand in-service loads.

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1 - Introduction

This leaflet is part of a set concerning the technical approval of motor bogies which also includes *UIC Leaflet 615-0, 615-1, 515-3, 615-4 and 515-5* (see Bibliography - page 16).

It describes the rig tests performed to verify the ability of bogie frames to withstand in-service loads.

Four groups of tests are distinguished:

- **Static tests** with "exceptional" loads.

  These tests verify that there is no risk of permanent bogie deformation due to superposition of the maximum in-service loads.

- **Static tests** to simulate the main in-service loads.

  These tests verify that there is no risk of fatigue cracks due to superposition of the main in-service loads (vertical and transverse forces, effects of track twist).

- **Static tests** to simulate particular in-service loads.

  These tests verify that there is no risk of localised fatigue cracks due to repetitive stresses originating from the bogie components (motors, brakes, shock-absorbers, anti-roll bars) and from running through small-radius curves.

- **Fatigue tests**

  These tests enable the overall bogie service life to be ascertained, the safety margin to be evaluated and possible weak points not identified by the static tests to be detected. They shall, therefore, be performed after the static tests. Considering the capabilities of existing test installations, these tests can only be recommended.

The values of the forces to be applied, as quoted in this document, are not yet founded on a solid base of experience and should therefore be considered as provisional.

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2 - General conditions

It shall be verified that bogie frames used for the tests fully conform to the design drawings and have been manufactured using the same processes as during series production.

- It is recommended that the static tests be performed on the bogie incorporating its suspension and, where relevant, its traction motors.

- For practical reasons this arrangement is usually not possible for the fatigue tests; hence the test set-up for these tests shall be analysed carefully.

The test set-up shall reproduce the deformations observed in service as closely as possible. Particular attention shall be paid to the transmission of those forces that are distributed over several interconnecting elements (pivot, springs, stops, etc.).

Stresses at the points of highest stress are measured by means of strain gauges, using:

- unidirectional gauges for those places where the direction of the main stress is known,

- bi-directional gauges for those places where the two main directions are known,

- tri-directional gauges (rosettes) in all remaining cases.

The active part of the strain gauges shall not exceed 6 mm.

The locations of the gauges should only be defined by experienced personnel, using the results of finite-element analysis. If required, preliminary tests can be performed, using strain-indicating varnish or any other appropriate method.

Notation and load definitions :

n_b = number of bogies

n_e = number of wheelsets per bogie

m^+ (kg) = bogie weight

m_v (kg) = empty weight of vehicle in running order (where relevant, with fuel and water load)

Test loads for passenger-carrying vehicles, calculated in accordance with *UIC Leaflet 566* (see Bibliography - page 16) for main-line vehicles.

c_1 :
- 1 passenger of 80 kg per seat[a]
- 4 passengers per m^2 in the corridors and entrance vestibules[b]
- 300 kg per m^2 in the luggage compartments

c_2 :
- 1 passenger of 80 kg per seat[a]
- 2 passengers per m^2 in the corridors and entrance vestibules[c]
- 300 kg per m^2 in the luggage compartments

a. 70 kg for suburban-type vehicles.
b. may be increased up to 10, depending on type of service.
c. may be increased up to 4, depending on type of service

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3 - Static tests with exceptional loads

3.1 - Definition of applied loads

(See diagram in Appendix A - page 13)

- Vertical test loads per bogie (one for each sole-bar) :

$$F_{z1max}(N) = F_{z2max}(N) = \frac{1{,}4\,g}{2n_b}(m_v + c_1 - n_b m^+)$$

- Transverse test load per bogie:

$$F_{ymax} = 2\left(10^4 + \frac{(m_v + c_1)g}{3n_e n_b}\right)$$

- Warping of the bogie corresponding to 100% off-loading at the level of one of the wheels, in order to simulate the case of a derailed bogie.

NB:

1. Longitudinal forces are not simulated in the case of the test programme with exceptional loads.

2. For bogies with 3 wheelsets ($n_e = 3$), it is assumed that the centre wheelset does not participate in the transmission of transverse forces.

3. The factor 1,4 can be increased to 2 in exceptional cases, where the operating conditions are considered to be particularly severe.

3.2 - Test procedure and results to be obtained

The test is performed in two stages:

- a preliminary test, performed with loads equal to half the maximum values, to ascertain that no major problems will occur during the full-load test;

- the full-load test, which must not result in the elastic limit being exceeded at any point, or in any permanent deformation after removal of the test loads.

Inertia forces acting on the bogie are not simulated during this test. Therefore, the transverse force applied above the secondary suspension to balance the forces at the level of the wheels is generally too large. If, as a result, the elastic limit is exceeded in components located above the secondary transverse suspension, the test shall be performed again for those components only, with the transverse force reduced by half.

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4 - Static tests to simulate the main in-service loads

4.1 - Definition of applied loads

(See diagram in Appendix A - page 13)

- Vertical forces:

  Vertical forces F_{z1} and F_{z2} acting on the longitudinal sole-bars are defined in accordance with the table in point 4.2, with:

$$F_z(N) = \frac{g}{2n_b}(m_v + 1{,}2c_2 - n_b m^+)$$

- Transverse force per bogie:

$$F_y(N) = 0{,}5\ (F_z + 0{,}5\ m^+ g)$$

- Warping of the bogie corresponding to a track twist of 5 ‰ at the level of the wheels.

4.2 - Test procedure

The test set-up should allow application of the loads at the places where they occur in service while at the same time simulating the play and degrees of freedom associated with the suspensions and the bogie/body connecting elements.

The initial state (zero of the gauges) is defined as the bogie frame without traction motor.

After installation of the traction motors, the bogie frame is subjected to various load configurations, in order to simulate:

- the dynamic variations of the vertical forces due to vertical motion (bounce) of the body, represented by a percentage β of vertical forces: βF_z,

- the dynamic variations of the vertical forces due to rolling motion of the body, represented by a percentage α of vertical forces: αF_z.

In general, for normal operating conditions on European Railways:

$$\alpha = 0{,}1 \qquad \beta = 0{,}2$$

Higher values can be used if the track quality is known to be markedly inferior or if the vehicle is operated under conditions of very substantial cant deficiency.

NB : dynamic loads due to the inertia of the traction motors are addressed in point 5.

The different load configurations to be applied successively are defined in the table below:

Load case	Vertical force per solebar		Transverse force exerted on bogie
	F_{z1}	F_{z2}	
0	Installation of traction motors		0
1	F_z	F_z	0
2	$(1 + \alpha - \beta)\ F_z$	$(1 - \alpha - \beta)\ F_z$	0
3	$(1 + \alpha - \beta)\ F_z$	$(1 - \alpha - \beta)\ F_z$	$+ F_y$
4	$(1 + \alpha + \beta)\ F_z$	$(1 - \alpha + \beta)\ F_z$	0
5	$(1 + \alpha + \beta)\ F_z$	$(1 - \alpha + \beta)\ F_z$	$+ F_y$
6	$(1 - \alpha - \beta)\ F_z$	$(1 + \alpha - \beta)\ F_z$	0
7	$(1 - \alpha - \beta)\ F_z$	$(1 + \alpha - \beta)\ F_z$	$- F_y$
8	$(1 - \alpha + \beta)\ F_z$	$(1 + \alpha + \beta)\ F_z$	0
9	$(1 - \alpha + \beta)\ F_z$	$(1 + \alpha + \beta)\ F_z$	$- F_y$

After these tests, load cases n° 3, 5, 7 and 9 are repeated with superposition of the track twist.

The introduction of the track twist should not modify the sum of the vertical forces.

NB : the purpose of load cases 2, 4, 6 and 8 is only to evaluate the influence of the transverse forces.

4.3 - Results to be obtained

At each measuring point, the stresses resulting from each load case defined in point 4.2 - page 5 are recorded.

From these values, the minimal value σ_{min} and the maximal value σ_{max} are taken in order to determine:

$$\sigma_{ave} = \frac{\sigma_{min} + \sigma_{max}}{2} \quad \text{and} \quad \Delta_{\sigma} = \frac{\sigma_{max} - \sigma_{min}}{2}$$

The limiting stresses to be respected are given in the documents that correspond to the current state of knowledge, such as the Goodman-Smith diagrams given in *Appendix 6 of ERRI Report B12 RP17*.

However, in the case where a fatigue test is planned - and only in this case - it will be permissible to exceed these limit stresses by up to 20% at a limited number of measurement points, which will then be monitored with particular care during the fatigue test.

If, in the bogie components located above the secondary transverse suspension, the elastic limit is exceeded by more than 20% due to the effect of the transverse force, the test shall be repeated for those components only, with the transverse force reduced by half, as described in point 3.2 - page 4.

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5 - Static tests to simulate particular in-service loads

5.1 - Definition of applied loads

The forces simulated during these tests are mostly linked to specific design features of the bogie and to its operational use (traction, braking). Hence it is not feasible to define all tests in this leaflet exhaustively.

Nevertheless, it is possible to indicate a test procedure for standard bogies of the type currently in service on main European railways.

5.1.1 - Traction motors and transmissions

The dynamic effects due to the inertia of the motors and the transmissions are simulated by applying:

- at the mounting points on the central transom : alternating forces equal to 0,2([1]) times the weight of the motors,
- at the mounting points on the headstocks: alternating forces equal to three times the weight of the elements mounted on these headstocks.

Whether these forces are to be combined shall be examined case by case.

5.1.2 - Electrical traction/braking devices

The forces that simulate the drive forces acting on the frame are applied at the level of the axle boxes.

The forces that simulate the reaction torque of the motors are applied at the level of the supports on the bogie.

5.1.3 - Pneumatic braking devices

The forces that simulate the effects of the braking devices on the structure are applied at those locations where they normally occur (i.e. forces resulting from brake-block application on the wheels or forces resulting from brake-pad application on the brake discs).

The values to be used are those corresponding to maximum in-service braking.

5.1.4 - Shock absorbers

A force of 1,5 F_A is applied to the bogie at the location of each shock absorber (anti-yaw, vertical, transverse or longitudinal). F_A equals the value of the force that results in a fatigue load. This corresponds generally to the force generated by the shock absorber at its rated speed.

1. Value probably too low, to be defined more accurately later.

5.1.5 - Anti-roll bars

If the anti-roll bars cannot be installed during the tests defined in point 4 - page 5 (in the case of bogies with pneumatic secondary suspension, for instance) a special test shall be performed by connecting the bars to a transverse structure on the test rig and inclining the latter first towards one side and then towards the other over an angle corresponding to the usual in-service values (approx. 20 milliradians).

5.1.6 - Longitudinal forces

The longitudinal forces are due to the yawing motion and to the forces on the wheelsets when running through small-radius curves.

For conventional bogies with non-steering wheelsets, the value of this force is typically:

$$F_x = 0{,}1\left(F_z + \frac{m^+}{2}g\right)$$

NB : the F_x forces can be applied using either the test rig, the other wheelset, or the bogie frame as a bearing point.

5.2 - Test procedure

In all cases, a vertical load F_z is first applied on each longitudinal frame member. The values of the vertical reaction at the level of the four wheels (Q_{11}, Q_{12}, Q_{21} and Q_{22}) are recorded.

The forces mentioned in the preceding paragraphs are then applied, first in one direction then in the other, while verifying that the sum of the reaction forces ($Q_{11} + Q_{12} + Q_{21} + Q_{22}$) remains constant.

In this manner, three values are obtained at each strain measurement point, from which the smallest and largest value are taken in order to determine σ_{ave} and $\Delta\sigma$.

5.3 - Results to be obtained

For each of these tests, two cases shall be considered:

- for those points where the tests simulating the main in-service loads show only the presence of very low stresses, it will be sufficient to verify that the stresses due to the specific loads are below the limiting values,

- for those points where the tests defined in point 4 - page 5 have shown the existence of significant stresses, the obtained stresses shall be superimposed and it shall be verified that the limiting values are not exceeded.

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6 - Fatigue tests

6.1 - Test conditions

The fatigue tests are performed:

- on the complete bogie frame when it is possible to apply the test forces without removing the drive system (traction motors and gear trains), or
- after removal of the drive system, but only if the latter does not contribute to the stiffness of the frame.

6.2 - Definition of applied loads

- Vertical forces (per solebar):
  - static components:

    $F_{zs1} = F_{zs2} = F_z$ (same value as in point 4.1 - page 5)

  - quasi-static components (simulation of roll in curves):

    $F_{zq1} = - F_{zq2} = \pm \alpha . F_z$ (see point 4.1)

  - dynamic components (simulation of bounce of the body):

    $F_{zd1} = F_{zd2} = \pm \beta . F_z$ (see point 4.1)

- Transverse forces (per bogie):
  - quasi-static components:

    $F_{yq} = \pm 0,25 . (F_z + 0,5m^+ . g)$

  - dynamic components:

    $F_{yd} = \pm 0,25 . (F_z + 0,5m^+ . g)$

- Warping of the bogie frame when the bogie plus its suspension is subjected to a track twist of 5 ‰.

6.3 - Test procedure

The tests are performed in a test set-up that allows the application and distribution of the forces exactly at the same places where they act in service, while at the same time simulating correctly the play and the degrees of freedom associated with the suspensions and the bogie/body connecting elements.

6.3.1 - Quasi-static and dynamic loads

The tests consist of alternating quasi-static and dynamic load sequences that represent running through right and left curves.

If the static tests defined in point 4 - page 5 have shown that the track twist only induced stresses in limited zones of the bogie where the stresses caused by the vertical and transverse force are minor, the fatigue test, in a first stage, can be carried out with only vertical and transverse forces.

In this case, the vertical and transverse quasi-static and dynamic forces vary with time as shown in the diagrams in Appendix B - page 14.

In each sequence corresponding to a curve to the right or to the left, the number of dynamic cycles, vertically and transversely, is normally 20.

In the case where the bogie is to be used on lines with many curves, this number can be reduced to 10, or even less if the line has an exceptional number of curves.

The dynamic variations of the vertical and transverse forces shall be of the same frequency and in phase, as shown in the diagrams.

The tests shall consist of as many sequences simulating curves to the right as to the left.

The test is performed in three steps, corresponding to increasing levels of applied loads, as shown in Appendix C - page 15.

- The first load step consists of a total number of dynamic cycles of 6×10^6.
- The second load step consists of 2×10^6 cycles, with the static forces unchanged and the quasi-static and dynamic forces multiplied by 1,2.
- The third load step consists of 2×10^6 cycles, and is performed as the second, but with the factor 1,2 replaced by 1,4.

6.3.2 - Track twist loads

10^6 alternating track twist loads are to applied in all:

6×10^5 for the first load step of the diagram in Appendix C and 2×10^5 for each of the other two, during which the track-twist amplitudes are multiplied by 1,2 and 1,4 respectively.

To define these tests, the results of the static tests and the capabilities of the existing test installations shall be taken into account:

- if the static test shows that the bogie frame is not affected by the track twist (for instance in the case of bogies with low torsional stiffness, or bogies with articulated frame) the track-twist simulation test is not necessary;
- if the static tests in point 4 - page 5 have shown that the effects of the track twist loads are clearly different from those resulting from the vertical and transverse forces (for instance because the stresses occur in different zones) the track-twist simulation cycles can be applied separately from the other loads.

If neither of the above conditions are met, the test rig shall be adapted in order to apply the vertical and transverse forces and the track-twist loads simultaneously.

6.4 - Results to be obtained

- No cracks shall be found after the first two load steps. This is to be confirmed by a non-destructive inspection (magnetic particle or dye penetration test) performed after $4x10^6$ cycles, at the end of both the first and second load steps.

  During the third load step, the occurrence of very small cracks is acceptable as long as they would not require immediate repairs if they occurred in service.

  In this case it is advised to request the manufacturer to modify the bogie design locally in order to increase its strength, without a new test being necessary.

- The evolution of the stresses at the places of highest stress found during the static test shall be monitored with strain gauges during the fatigue test, and in particular where stresses exceeding the limiting stress have been tolerated in accordance with point 4.3 - page 6.

- For the components located above the secondary suspension, it will not be necessary to take into account any cracks occurring at places found to be overloaded during the static test because of the excessive value of the transverse force.

- Before performing fatigue tests on the bogie itself, it is advised to fatigue-test the connecting elements (flexible articulations, for instance) to determine their service life, and to avoid any incidents during the complete bogie-frame tests.

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7 - Estimation of fatigue strength

If the fatigue test cannot be performed, it is recommended to replace it by the following estimation procedure:

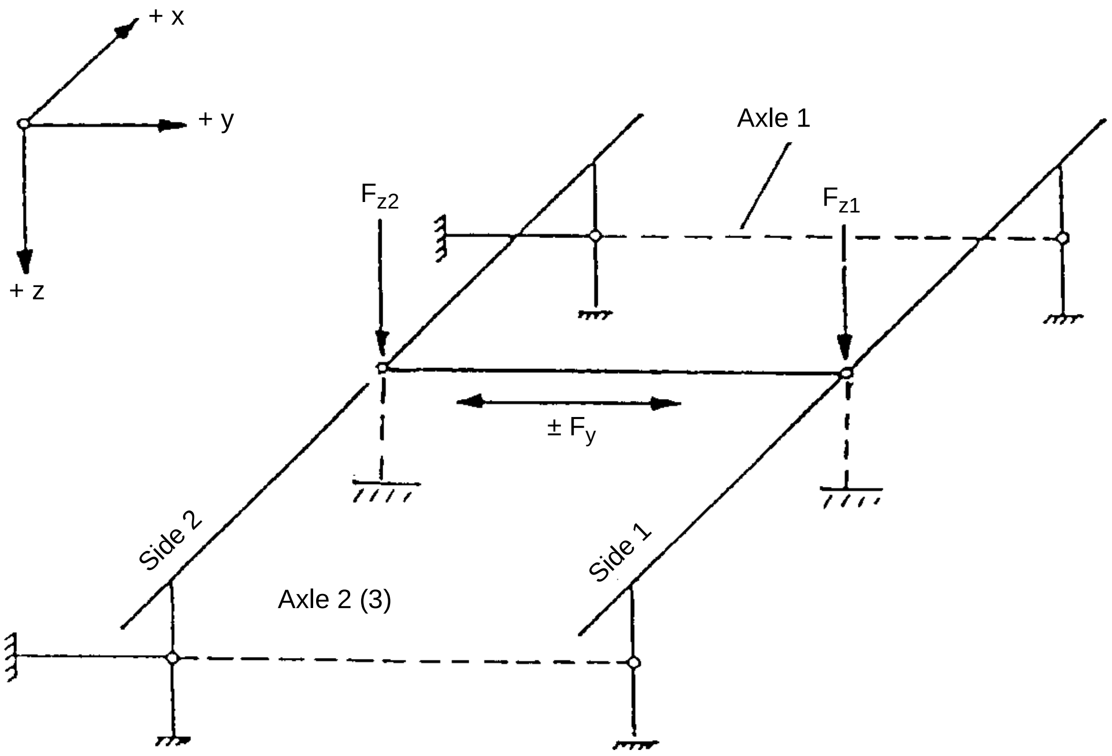
After performing the static tests, the bogie is tested operationally under representative in-service track and speed conditions.

The stresses are measured at the critical points found during the static tests.

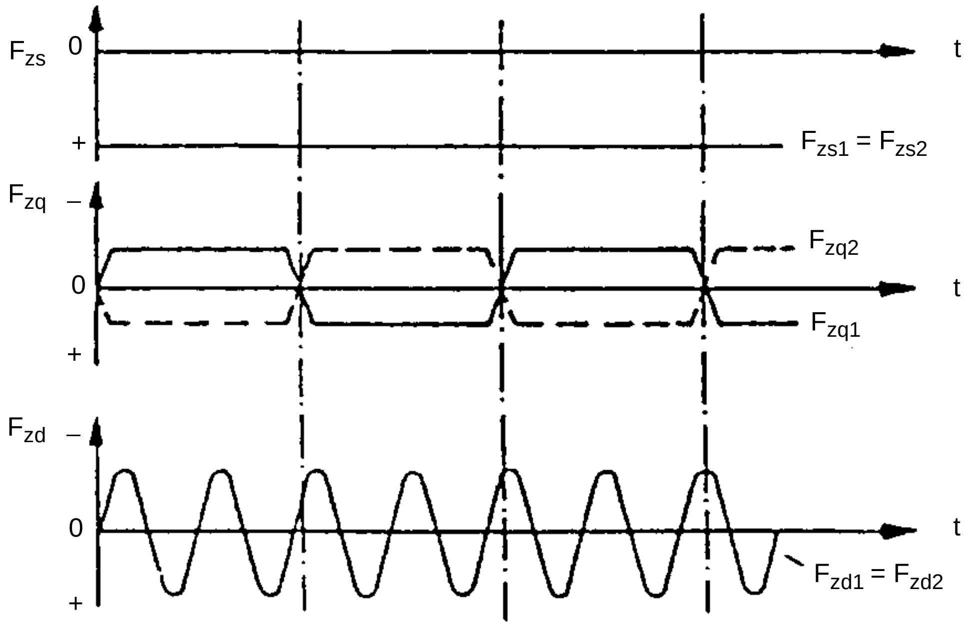
The probability of the occurrence of cracks in the bogie shall be estimated according to an appropriate national or international method.

These methods are not yet standardised

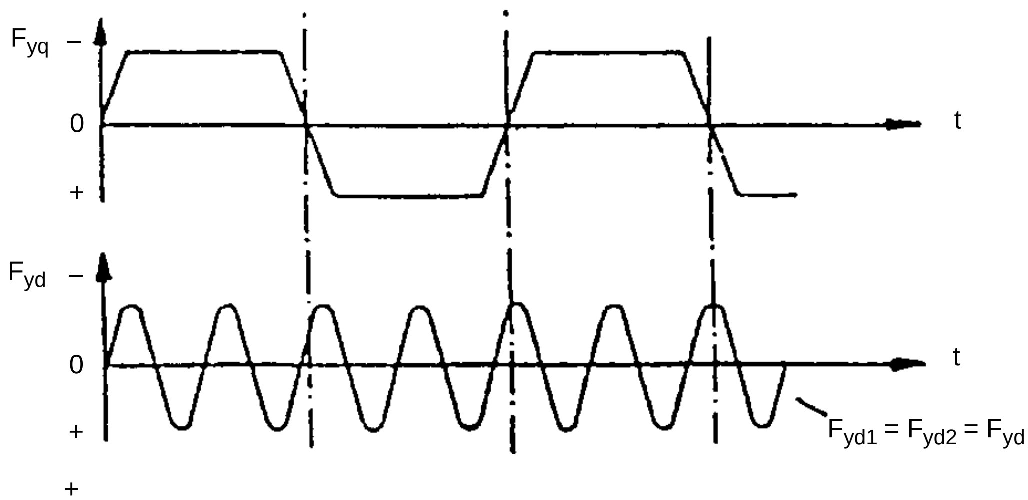
Appendix A - Diagram showing the forces applied during static testing



Appendix B - Diagram showing the forces applied during fatigue testing in relation to time

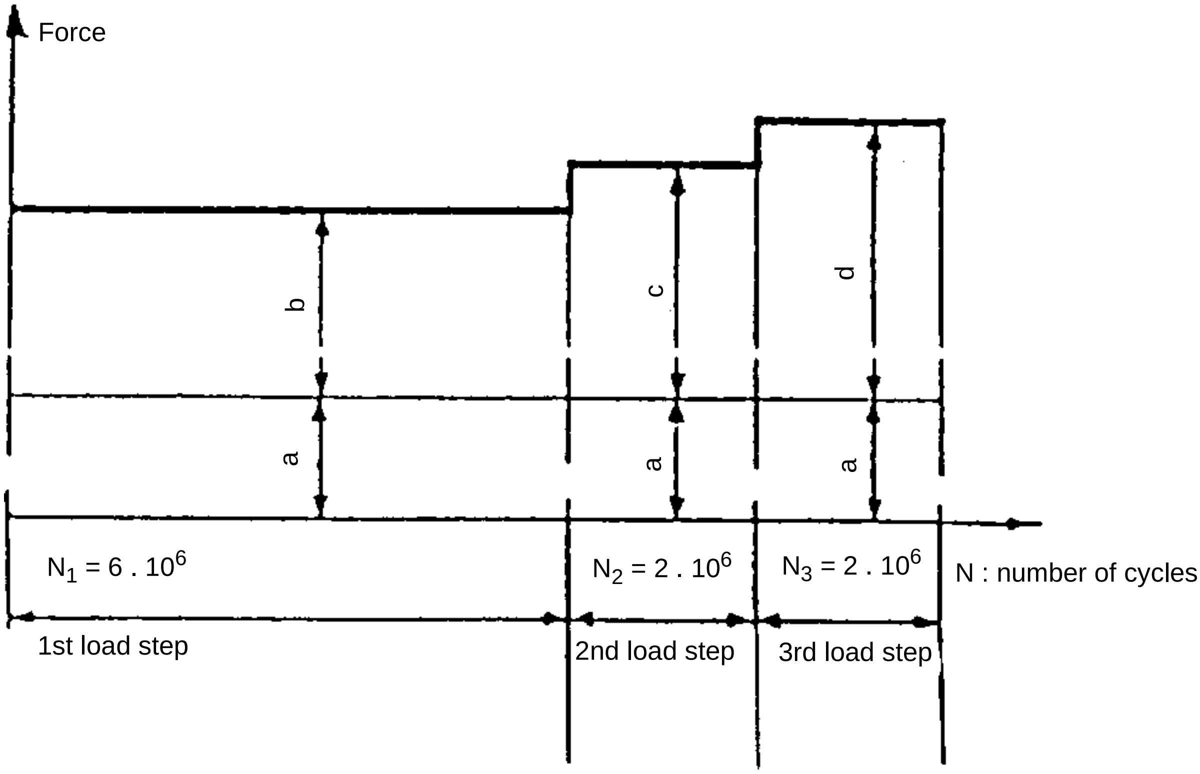


Forces exerted in the z direction



Forces exerted in the y direction

Appendix C - Definition of fatigue test steps



a = (static) vertical

b = 1 (quasi-static + dynamic), vertical and transverse

c = 1,2 (quasi-static + dynamic), vertical and transverse

d = 1,4 (quasi-static + dynamic), vertical and transverse

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Leaflet 515-3: Rolling stock - Bogies - Running gear - Axle design calculation method, 1st edition of 1.7.94

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2. Minutes of meetings

International Union of Railways
Traction and Rolling Stock Committee (Question 5/A/7 - Item 2.2 - Requirements of motor bogies), May 1993

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