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Working Party on Brakes and Running Gear

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Item 5 of the provisional agenda

REGULATION No. 55
(Mechanical couplings)

Proposal for draft amendments to Regulation No. 55

Submitted by the experts of the informal working group on mechanical couplings */

The text reproduced below was prepared by the experts of the informal working group on mechanical couplings in order to insert into Regulation No. 55 an alternative test procedure. The modifications to the existing text of the Regulation are marked in **bold** characters.

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*/ In accordance with the programme of work of the Inland Transport Committee for 2006-2010 (ECE/TRANS/166/Add.1, programme activity 02.4), the World Forum will develop, harmonize and update Regulations in order to enhance performance of vehicles. The present document is submitted in conformity with that mandate.

A. PROPOSAL

Annex 5, paragraph 1.4., amend to read:

"1.4. Coupling balls and towing devices shall be able to satisfy the tests given in Annex 6, paragraph 3.1. **or paragraph 3.10. according to the choice of the manufacturer. However, the requirements given in paragraphs 3.1.7. and 3.1.8. are always applicable.**"

Annex 6

Paragraph 1.3., amend to read:

"1.3. The dynamic test **(except the test according to paragraph 3.10. of this annex)** shall be performed with approximately sinusoidal load (alternating and/or pulsating) with a number of stress cycles appropriate to the material. No cracks or fractures shall occur."

Paragraph 1.5., amend to read:

"1.5. The loading assumptions in the dynamic tests are based on the horizontal force component in the longitudinal axis of the vehicle and the vertical force component. Horizontal force components transverse to the longitudinal axis of the vehicle, and moments, are not taken into account provided they are of only minor significance. **This simplification is not valid for the test procedure according to paragraph 3.10. of this annex.**

If the design ……"

Paragraph 2., amend to read:

"2. TEST PROCEDURES

In case the test procedure according to paragraph 3.10. of this annex is used, paragraphs 2.1., 2.2., 2.3. and 2.5. are not applicable."

Paragraph 3., amend to read:

"3. SPECIFIC TESTING REQUIREMENTS

In case the test procedure according to paragraph 3.10. of this annex is used, the requirements of paragraphs 3.1.1. to 3.1.6. are not applicable."

Add new paragraphs 3.10. to 3.10.4., to read:

"**3.10. Alternative endurance test for coupling balls and towing brackets with a D-value ≤ 14 kN.**

Alternatively to the test procedure described in paragraph 3.1., coupling balls and towing brackets with a D-value ≤ 14 kN can be tested under the following conditions.

3.10.1. Introduction

The endurance test described below consists of a multi-axial test with 3 load directions, with simultaneously introduced forces, defined maximum amplitudes and fatigue equivalences (load intensity values, according to the definition given below).

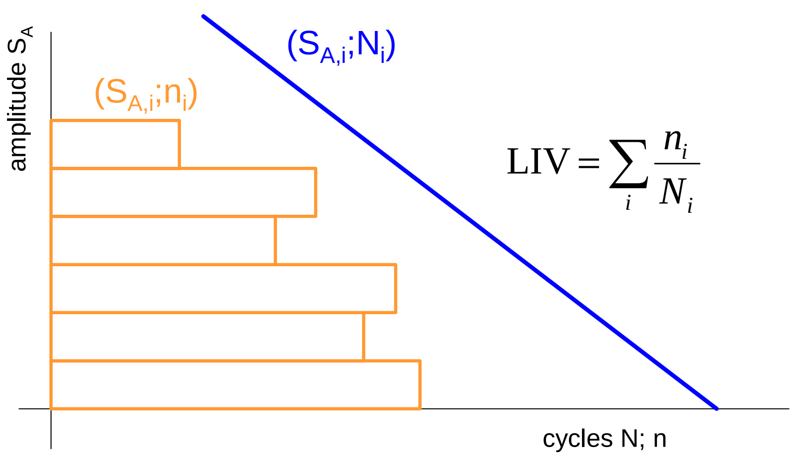
3.10.2. Test requirements

3.10.2.1. Definition of the load intensity value LIV:

The LIV is a scalar value which represents the severity of one load time history considering durability aspects (identical to damage sum). For the damage accumulation the miner elementary rule is used. For its determination, the load amplitudes and the number of repetitions of each amplitude are considered (effects of mean loads are not taken into account).

The S-N curve (Basquin curve) represents the load amplitudes versus the number of repetitions ($S_{A,i}$ vs. N_i). It has a constant slope k in a double logarithmic diagram (i.e. every amplitude /applied test force $S_{A,i}$ relates to a limited number of cycles N_i). The curve represents the theoretical fatigue limit for the analyzed structure.

The load time history is counted in a range-pair diagram of load amplitude versus number of repetitions ($S_{A,i}$ vs. n_i). The sum of the ratio n_i/N_i for all available amplitude levels $S_{A,i}$ is equal to the LIV.



3.10.2.2. Required LIVs and maximum amplitudes

The following coordinate system has to be considered:

x direction: longitudinal direction / opposite of driving direction
y direction: to the right considering the driving direction
z direction: vertical upwards

The load time history can then be expressed following the intermediate directions based on the main directions (x, y, z) considering the following equations ($\alpha = 45°$; $\alpha' = 35.2°$):

$$F_{xy}(t) = F_x(t) \cdot \cos(\alpha) + F_y(t) \cdot \sin(\alpha)$$
$$F_{xz}(t) = F_x(t) \cdot \cos(\alpha) + F_z(t) \cdot \sin(\alpha)$$
$$F_{yz}(t) = F_y(t) \cdot \cos(\alpha) + F_z(t) \cdot \sin(\alpha)$$

$$F_{xyz}(t) = F_{xy}(t) \cdot \cos(\alpha') + F_z(t) \cdot \sin(\alpha')$$
$$F_{xzy}(t) = F_{xz}(t) \cdot \cos(\alpha') - F_y(t) \cdot \sin(\alpha')$$
$$F_{yzx}(t) = F_{yz}(t) \cdot \cos(\alpha') - F_x(t) \cdot \sin(\alpha')$$

The LIVs expressed in each direction (also combined directions) are calculated respectively as the sum of the ratio n_i/N_i for all available amplitude levels defined in the adequate direction.

In order to demonstrate the minimum fatigue life of the device to be type-approved, the endurance test has to achieve at least the following LIVs:

	LIV (1 kN ≤ D ≤ 7 kN)	**LIV (7 kN < D ≤ 14 kN)**
LIVx	**0.0212**	**0.0212**
LIVy	**linear regression between: D=1 kN: 7.026 e-4; D=7 kN: 1.4052 e-4**	**1.4052 e-4**
LIVz	**1.1519 e-3**	**1.1519 e-3**
LIVxy	**linear regression between: D=1 kN: 6.2617 e-3; D=7 kN: 4.9884 e-3**	**4.9884 e-3**
LIVxz	**9.1802 e-3**	**9.1802 e-3**
LIVyz	**linear regression between: D=1 kN: 7.4988 e-4; D=7 kN: 4.2919 e-4**	**4.2919 e-4**
LIVxyz	**linear regression between: D=1 kN: 4.5456 e-3; D=7 kN: 3.9478 e-3**	**3.9478 e-3**
LIVxzy	**linear regression between: D=1 kN: 5.1977 e-3; D=7 kN: 4.3325 e-3**	**4.3325 e-3**
LIVyzx	**linear regression between: D=1 kN: 4.5204 e-3; D=7 kN: 2.9687 e-3**	**2.9687 e-3**

To derive a load time history based on above mentioned LIVs, the slope shall be k = 5 (see definition in paragraph 3.10.2.1.). The Basquin curve shall pass through the point of an amplitude S_A=0,6·D with the number of cycles N=2·10^6.

The static vertical load S (as defined in paragraph 2.11.3. of this Regulation) on the coupling device as declared by the manufacturer shall be added to the vertical loads.

During the test, the maximum amplitudes should not exceed the following values:

	longitudinal Fx [-]	lateral Fy [-]	vertical Fz [-]
Maximum	+1.3·D	+0.45·D	+0.6·D+S
Minimum	-1.75·D	-0.45·D	-0.6·D+S

3.10.3. Test conditions

The coupling device shall be mounted on a rigid test bench or on a vehicle. In the case of a 3 dimensional time history signal, it shall be applied by three actuators for simultaneous introduction and control of the force components Fx (longitudinal), Fy (lateral) and Fz (vertical). In other cases, the number and the position of the actuators may be chosen in agreement between the manufacturer and the technical services. In any case, the test installation shall be able to introduce simultaneously the necessary forces in order to fulfil the LIVs required in paragraph 3.10.2.2.

All bolts have to be tightened with the torque as specified by the manufacturer.

3.10.3.1. Coupling device mounted on stiff support:

The compliance of the fixing points of the coupling device shall not exceed 1.5 mm from the reference point of "0-Load" during the application of the maximum and minimum forces Fx, Fy, Fz and each separately applied to the coupling point.

3.10.3.2. Coupling device mounted on vehicle body or body part:

In this case the coupling device shall be mounted on the vehicle body or a body part of the vehicle type, for which the coupling device is designed. The vehicle or body part shall be fitted on a suitable rig or test bench in such a manner, that any effect of the vehicles suspension is eliminated.

The exact conditions during the test shall be declared in the relating test report. Possible resonance effects have to be compensated by a suitable test facility control system and may be reduced by additional fixing between vehicle body and test rig or modified frequency.

3.10.4. Failure criteria

In addition to the criteria given in paragraph 4.1. verified by liquid penetration verification of this Regulation, the coupling device shall be deemed to have failed the test, if:

(a) any visible plastic deformation is detected;

(b) any functionality and safety of the coupling is effected (e.g. safe connection of the trailer, maximum play);

(c) any torque loss of the bolts exceeding 30 per cent of the nominal torque measured in the closing direction;

(d) a coupling device with detachable part cannot be detached and attached for at least 3 times. For the first detachment, one impact is permitted."

B. JUSTIFICATION

It is important to underline, that the proposed procedure is an alternative procedure to be performed voluntarily instead of the actually foreseen component test. The introduction of the alternative procedure has a couple of advantages, but for "after market" provider the disadvantage of higher test costs.

The graph in Figure 1 shows a comparison between the force amplitudes applied in the present fatigue verification test according to the Regulation No. 55, 01 series of amendments and the loading used by car manufacturers to represent customer service.

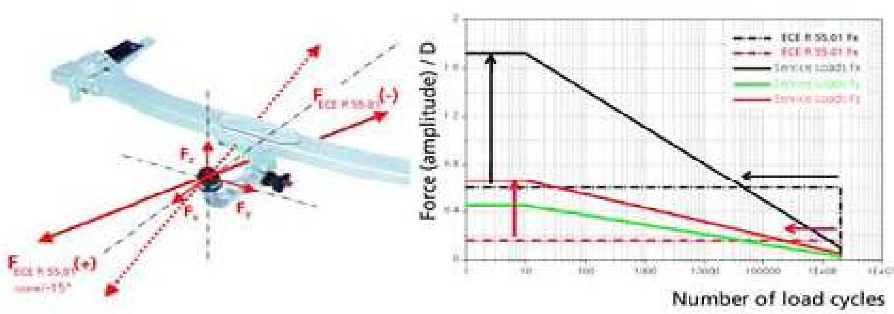


Figure 1

The procedure according to paragraph 3.1. of Annex 6 to Regulation No. 55 is an uni-axial test: 2-load cycles with constant amplitudes (definition see in Figure 1; the force components Fx (longitudinal) and Fz (vertical) are due to the chosen force direction, see the rectangular spectra in Figure 1. Lateral forces are not taken into account.

Real service loads act in all three directions with randomly changing amplitudes and correlations. The ranges of the highest load cycles exceed the load cycles defined by Regulation No. 55 significantly, the ranges of the most frequent load cycles are clearly smaller.

The service loads, measured from different car manufacturers on public roads and proving grounds with various vehicle-trailer combinations are, of course, subject to wide scatter, even scaled to the respective D-values, see Figure 2.

The causes are different driving and courses, special loading events, system characteristics and the car-manufacturer-specific verification philosophies behind it.

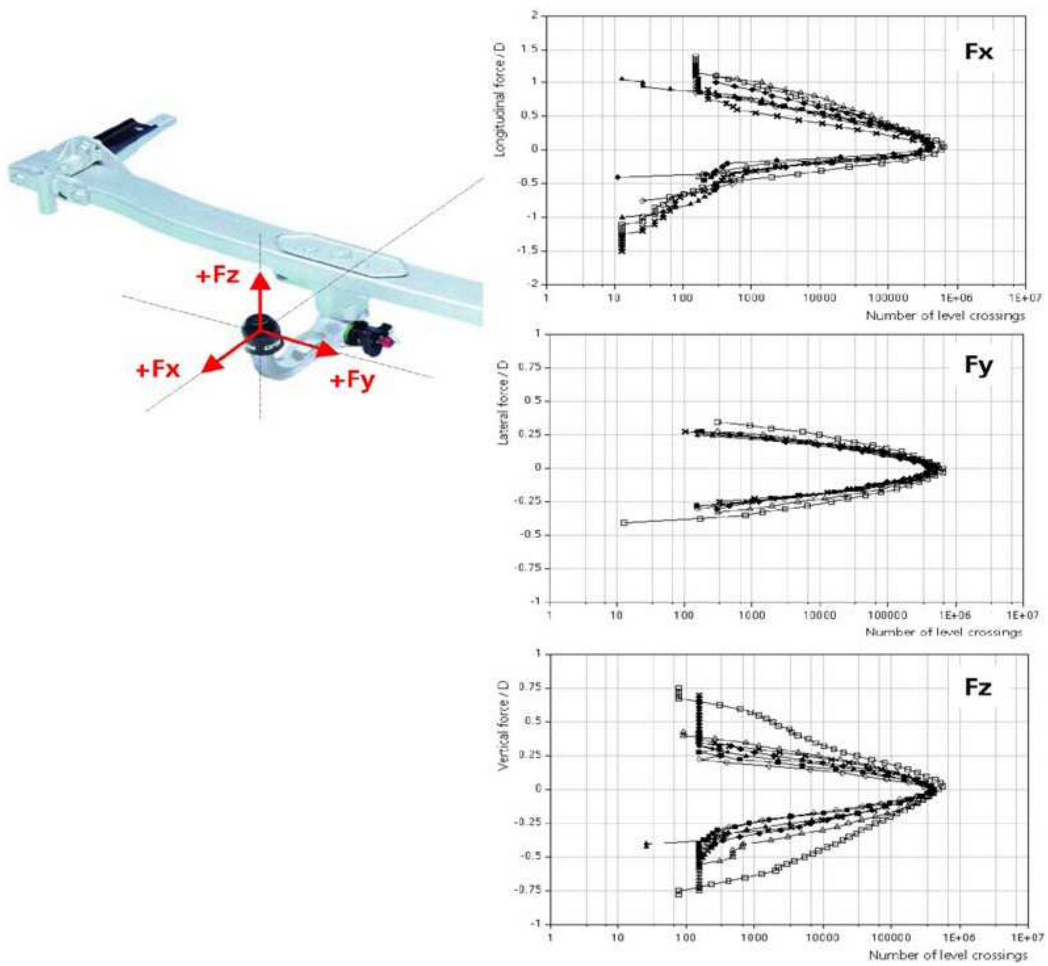


Figure 2: Evaluation of real service loads due to different car manufacturers.

The statistical evaluation leads to a probability-values for exceeding certain load limits - or taken by (fictive) load-intensity values - to an assessment of the Regulation No. 55 requirement in comparison to real service loading.

Even treating these results of relative damage estimations with the utmost caution, the conclusion shall be drawn that the rule of Regulation No. 55 does not match the scatter range of real loading situations sufficiently; an optimal light weight design according to the state-of-the-art cannot be expected in the case of application of the Regulation.

The damage-equivalent amplitudes of the 3-dimensional test load intensity orientated test procedure match the loading distributions of the car manufacturers used for verification testing with well defined probabilities of exceedance (see Figure 3).

Additionally, there are several reasons for verification tests close to reality, especially linked to individual high loads effecting changes of residual stresses, decreasing fatigue limits, changing failure sites, etc. Numerous publications exist on this topic.

One of these e.g.: [Schütz,D; Heuler,P.: The significance of variable amplitude fatigue testing, American Society for testing and Materials, Philadelphia, 1995]

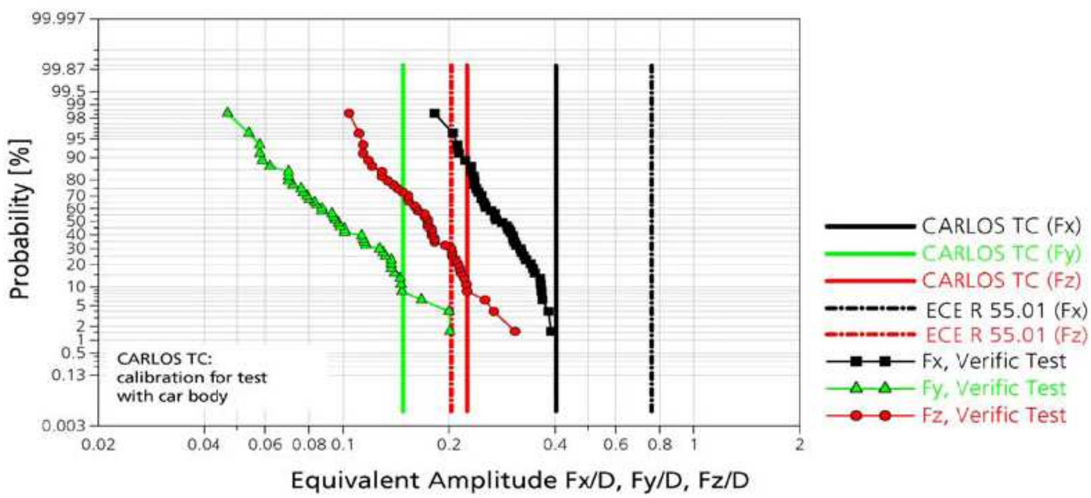


Figure 3: Comparison of equivalent amplitudes - Fatigue verification tests according to Regulation No. 55, 01 series of amendments (42 verification tests, damage sum supposed for constant amplitude = 0.3)

In the Carlos TC joint venture has been developed an adapted test procedure including force standardization and load histogram. Together with the French vehicle manufacturers, important coupling manufacturers and technical services engaged with coupling approvals, this procedure has been adapted in an important way to the different requirements.

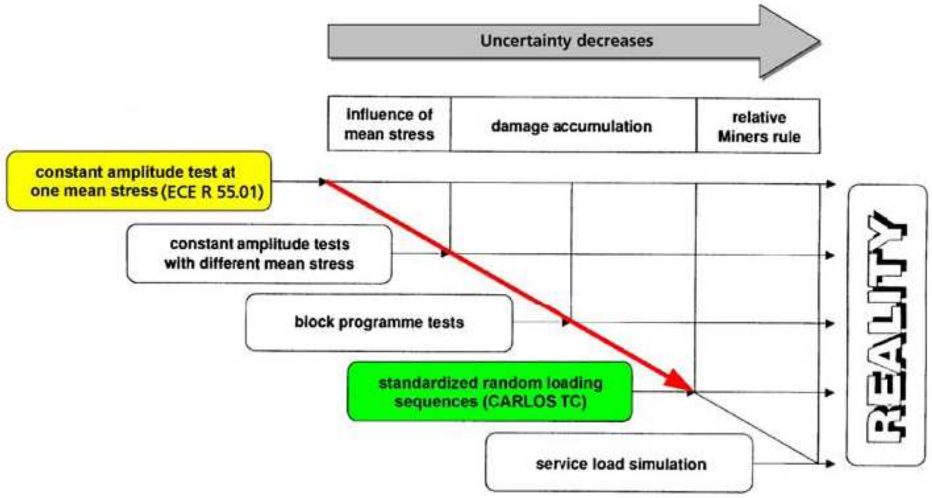


Figure 4: Relationship of certainty and different kinds of simulations

Summary:

By the alternative test procedure, reality will be approached by:

(a) increasing the maximum force amplitude,
(b) introduction of Fy as further testing direction,
(c) 3-dimensional testing with variable amplitudes and mean loads.

Approaching reality means lower necessary safety factor, lower weight and less fuel consumption.

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