Transmitted by the expert from Germany

Informal Document No. **GRRF-58-5**
(58th GRRF, 20–23 September 2005,
agenda item 6.7.)

Proposal for a draft Supplement to the 01 series of amendments to Regulation No. 55: (Uniform provisions concerning the approval of mechanical coupling components of combinations of vehicles)

A) PROPOSAL for add-on of a further strength test procedure for coupling balls and towing brackets class A50-X – modifications in following clauses of the Regulation:

CONTENTS (page 3 of the Regulation)
Annex 7 Installation and special requirements
to insert: appendix 2 compendium of CARLOS TC test procedure

4. General requirements for mechanical coupling devices or components (page 14 of the Regulation)
to insert:
Paragraph 4.9.
For towing brackets with coupling balls class A the relevant requirements in annex 6 can be replaced by an alternative test procedure (three dimensional fatigue test procedure described in annex 6, paragraph 3.1.9 and annex 7, appendix 2.

Annex 6 (page 60 of the Regulation)
Paragraph 3. Specific testing requirements
Paragraph 3.1. Coupling balls and towing brackets
to insert:

Paragraph 3.1.9. 3-dimensional variable loading tests

Paragraph 3.1.9.1. Test facility, support, resonance control

Application of a hydropulse system with three hydraulic actuators for simultaneous introduction and control of the force components Fx (longitudinal), Fy (lateral) and Fz (vertical), see annex 7, appendix 2, fig. 1.1. Unintended moments round the coupling point have to be avoided.

a) Stiff support of the test specimen at the test bench:

In case of well defined force transfer (see annex 7, appendix 2, e.g. figure A and B), the compliance of the fitting points of the coupling device has to be less than 2 mm (for the maximum forces Fx, Fy, Fz)

In case of undefined force transfer (see annex 7, appendix 2, e.g. figure C), the compliance of the main force transfer points has to be less than 2 mm (for the maximum forces Fx, Fy, Fz), the compliance of the auxiliary fitting points has to be similar to reality (vehicle body) or the auxiliary fitting points must not be attached during the test.

Continued: paragraph 3.1.9.1. Test facility, support, resonance control

b) coupling device mounted at an original vehicle or body part:

In case of applying an original vehicle or (part of) body in white, its axles may be fixed at the test facility or the base.
Possible resonance effects have to be compensated by a suitable test facility control system and may be reduced by additional fixing of the wheel suspensions.

<u>Paragraph 3.1.9.2</u>. Test specimen

The test specimen concerned have to consist of the complete mechanical coupling device (coupling ball, ball neck, towing bracket) and all mounting parts belonging to it, which are required for attachment of the coupling device at the vehicle body.

<u>Paragraph 3.1.9.3</u>. Loading

Introduction of 3-dimensional force components Fx, Fy and Fz at the coupling ball centre. Use of standardized load sequences (variable amplitudes and correlations), calibrated for individual application by the D-value (see annex 7, appendix 2 (load modules, sequences, static support load, test frequencies, test duration, ect., factor 1,15).

<u>Paragraph 3.1.9.4</u>. Material, mechanical wear

All parts of safety-relevant mechanical coupling devices shall be made of steel or light alloy.
If the coupling ball is made of light alloy, resistance to abrasion has to be assured for the satisfaction of the Technical Control Board Service.

<u>Paragraph 3.1.9.5.</u> Failure criteria, evaluation

No cracks or fractures are allowed. The dye-penetration method of crack testing or an equivalent method shall be used to determine any cracking during or after the test.
No global plastic deformation is allowed, referenced to the middle of the ball (measurement uncertainty less 3 mm)

Continued paragraph 3.1.9.5. Failure criteria, evaluation

The test must not effect the functionality and safety of the coupling device, e.g. detaching and mounting, safe connection of the trailer, maximum permissible play.

Bolts in between the towbar must not be loose after the test.
In case of testing the coupling device mounted at an original vehicle or body part, the fixation (bolts) between towbar and vehicle body must also not be loose.

Annex 7 *(page 74 of the Regulation)*

to insert

Appendix 2 - compendium of CARLOS TC test pocedure
(CARLOS TC = CAR LOading Standard, Trailer Coupling)

3-Dimensional Variable Loading Tests for coupling devices

1. Base signals -loading modules – files and test duration

The loading modules are load-time histories of the variable force components Fx (longitudinal, channel 1), Fy (lateral, channel 2) and Fz (vertical, channel 3) with service-like correlations / phase relations.
The sample rate is constant, $\Delta t=0.005$ s
The data files are stored on CD “CARLOS TC” in RPC- and ASCII-Format (*.rpc, *.asc). CD and support are available at www.lbf.fhg.de.

For the total test apply the following module repetition sequence / frequencies:
10*(5*(10*M1+M2)+M3).

Modules	Data-file	Module duration	Repetition frequency	Total test duration
1	CTC_M1.*	630 sec	500	92 hours
2	CTC_M2.*	271 sec	50	
3	CTC_M3.*	51 sec	10	

2. Loading modules – calibration and parameters (test coupling device)

For calibration in kN multiply the base control signals with **1,15 * D-value**

Module	Max values of control signals (kN / 1.15 D)	Number of load cycles Total Test	Frequency limit (Δt=0.005 s)	Limits of load transient velocities
1	Fx: +0.90, -0.36 Fy: +0.22, -0.25 Fz: +0.41 –0.49	Fx : 2.11 E06 Fy : 1.49 E06 Fz: 2.51 E06	20 Hz	Fx: 21 (kN/1.15D) / s Fy: 7 (kN/1.15D) / s Fz: 12 (kN/1.15D) / s
2	Fx: +1.15, -1.24 Fy: +0.29, -0.35 Fz: +0.46, -0.49			
3	Fx: +1.28, -1.71 Fy: +0.41, -0.38 Fz: +0.57, -0.58			

3. Support load (static vertical load)

The variable load modules M1 - M3 do not include the static vertical support load. The permissible support load has to be added to the vertical loads Fz (channel 3, sign support load negative, see figures D1 and D2).

4. Additional requirements

The maximum force amplitudes of Fx, Fy and Fz must be reached for all modules. This is to assure by measuring during testing with maximum value memory (deviation max 5%).

The difference between the target signal and the actual signal should be minimal. The phase relation has to be kept. This is to evaluate by the comparison of the RMS value of the target signal to the RMS value of the error signal (target signal minus actual signal in time domain). The deviation in ratio (RMS error divided by RMS target) has to be less than 5%.

Continued annex 7: 3-Dimensional Variable Loading Tests for coupling devices

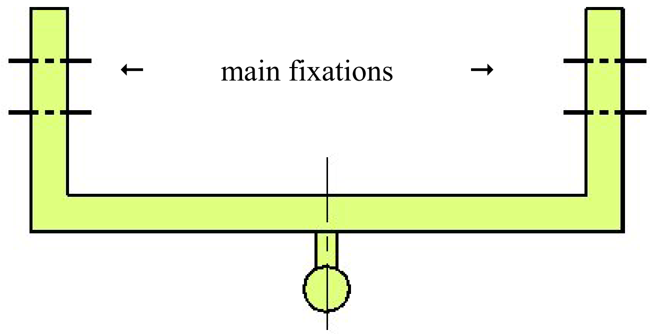
The fictive damage sum for the total test must be reached. This is to evaluate for example by online damage accumulation during the whole test and accumulation of the actual fictive damage sum for the whole test and comparison with the target value (alternative: at least 3 times during the test, e.g. at the beginning, in the middle and at the end of the test).

Requirements: S-N curve: slope k=5 endurance limit neglected, measurement uncertainty: < 3 % of max. measured value, total fictive damage sum for the whole test >= 100% of target fictive damage sum (x-, y-, z-direction) (mean load effects neglected)

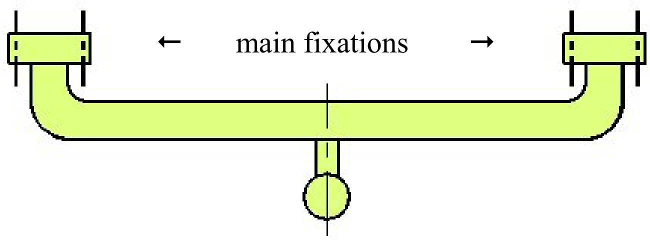
5. Trailer Coupling Fitting Variants (simplified)

Figures A, B: Statically determined, figure C: Statically undetermined

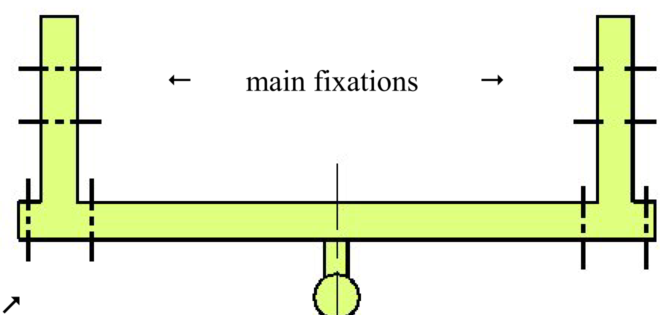
A



B



C



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supplementary fixations - undefined force transfer

CARLOS TC, Load spectra of Multiaxial Verification Tests (example)

a) definition of force directions

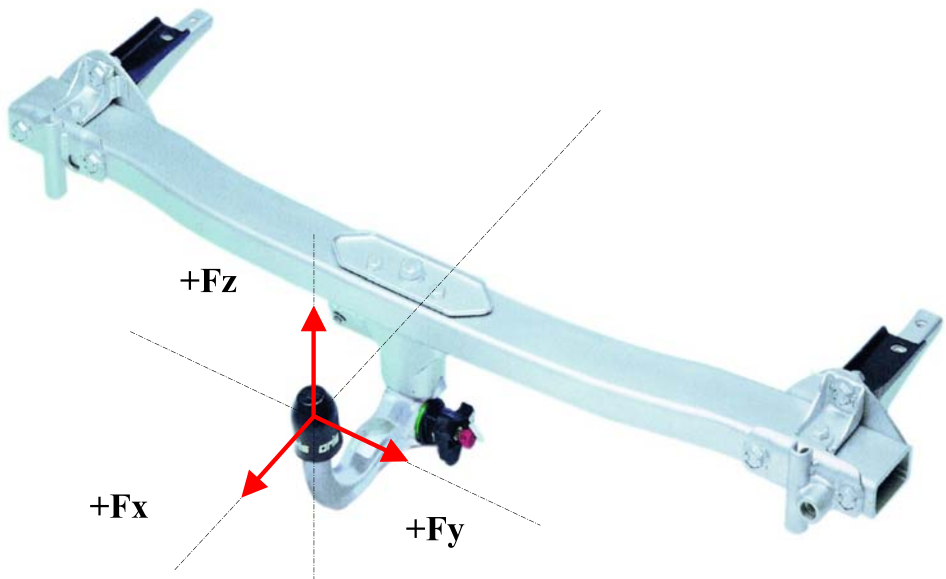
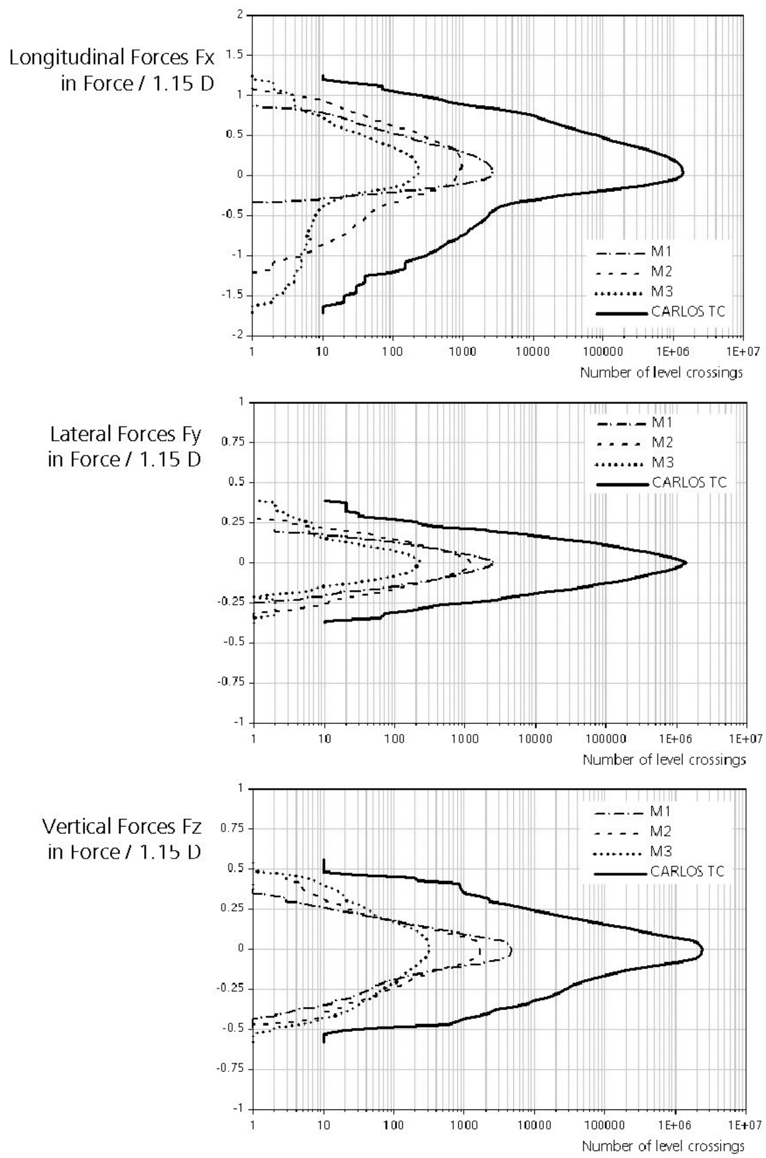


figure D1

b) **load cycle distributions**

figure D2



B) JUSTIFICATION

Standardization of Loads for the Fatigue Verification of coupling devices - towing brackets and coupling balls

This justification on hand is a summary of the conform statement of the companies and institutes mentioned below regarding the present situation of the fatigue verification of coupling devices for passenger cars. A joint venture has been started aiming at the development of standardized loads for the fatigue verification of coupling devices for passenger cars, according to the state of the art and meant for updating the existing dissatisfying legal rules.
The memorandum consists of four comments representing the view of the concerned parties:

- Technical control board (TUV)
- Car manufacturers
- Towing device manufacturers
- Fraunhofer Institute for Structural Durability (LBF) - project manager
- How to go ahead - proposal

Section 1: Mr. Knut Wartenberg, TÜV Automotive, Munich
Mr. Werner Conrads, RWTÜV Fahrzeug GmbH, Essen

The Technical control board (TÜV) is authorized by the Federal Motor Transport Authority (Kraftfahrt-Bundesamt KBA) to test vehicles, systems or technical units according representative directives and to confirm conformity of production. TÜV takes part on national and international committees to proceed in safety and technical progress and in this position TÜV observes traffic, system behaviour, fatigue, requirements and compatibility to the vehicle technique.

TÜV had participated in technically settling ECE 55-01 regulation and did contribute to the fatigue requirements. The test procedure described in paragraphs 2 and 3 of annex 6, was a compromise to simplify the execution of the tests: For example it was agreed to define a 15° test angle in plus/minus direction dependant ball position, to fix the test sample rigid at the test bench and to run the test with sinusoidal constant amplitude. The experts were of the opinion that these test parameters can assure fatigue life. Nevertheless they knew that such test does not cover the need of an optimized design respectively the best working together with the vehicle chassis and fixing points. Furthermore it became obviously that there is also a need to take into account forces/moments onto coupling devices which are created from the horizontal direction across the driving line, especially in case of detachable systems and also forces and moments created from the use of bike carriers and/or damping stabilizers.

To open the possibility to realize modern design philosophy and to give choice of materials other than steel, an alternative approach for fatigue tests is necessary.

The described alternative test procedure consists of a three dimensional test procedure where the service loads are collected and settled by randomly changing amplitudes and correlations between the force components. Service life is to assure by a representative number of test cycles.
The test can also apply coupling devices made of light alloy material.

Main reasons:

The vehicle manufacturer have to optimize the design of the rear vehicle body and thereby mounted coupling device regarding material, stiffness, permissible trailer mass, weight and crash performance.
Vehicle and towing bracket manufacturer have to shorten time to develop design and to increase performance. Rear body and coupling device are charged in the same way. Therefore it is useful to install the same test procedures for it.

The above described procedure can fulfil the need of the manufacturer and the aspects of safety and environment equally. The coupling device is to optimize; weight is to save. Safety is increased, because vehicle body and coupling device are developed, designed and tested together.

Section 2: Mr. Hartmut Klätschke, CARLOS TC project manager
Fraunhofer Institute for Structural Durability (LBF)

<u>CARLOS TC joint venture, technological background</u>

Due to the reasons mentioned in the sections 1, 3 and 4 the Fraunhofer Institute for Structural Durability (LBF) was commissioned to run a joint venture together with the car- and supplier-industry and technical control boards, aiming at the elaboration of the scientific and statistical basis for a new standard according to the state-of-the-art : CARLOS TC (CAR LOading Standard, Trailer Coupling).
The joint venture started about end of 2000, the list of participants see enclosure figure 1. Substantial service load collections and the fatigue verification philosophies have been provided by the car manufacturers, the expert knowledge of all participating persons is available for the project.

The graph in enclosure figure 2 shows (simplified) a comparison between the present fatigue verification test according to the legal regulation ECE 55-01 and the real loading environment.
The ECE 55-01 is based on a uni axial test : $2 \cdot 10^6$ load cycles with constant amplitudes $\pm 0.6\,D$ (definition see in enclosure figure 2); the force components Fx (longitudinal) and Fz (vertical) are due to sloped force direction, see the rectangular spectra in enclosure figure 2. Lateral forces are missing.

Real service loads act in all three directions with randomly changing sizes and correlations; the ranges of the highest load cycles exceed the ECE 55-01 cycles 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 enclosure figure 3. The causes are different driving and courses, special loading events, system characteristics and, last but not least, the car-manufacturer-specific verification philosophies behind it.

The statistical evaluation leads to probability-values for exceeding certain load limits – or, taken by (fictive) damage-equivalent amplitudes – to an assessment of the ECE 55-01 requirement in comparison to real service loading, see enclosure figure 4. Even treating these results of damage calculations with the utmost caution, the conclusion must be drawn that the ECE 55-01 regulation does not match the scatter range of real loading situations sufficiently – an optimal light weight design according to the state-of-the-art can not be expected in case of ECE 55-01 application. 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, ect.. Numerous publications exist on this topic; just one may be quoted here in this regard, see e.g. enclosure figure 5 [Schütz, D.; Heuler, P.: The significance of variable amplitude fatigue testing, American Society for Testing and Materials, Philadelphia, 1995].
The transfer of these findings on the situation of fatigue tests with various trailer coupling types (fixed / removable, different materials as steel, aluminum alloys, etc.) makes clear that the fatigue effects under real loading can not be properly reproduced under considerably simplified test conditions.

In the CARLOS TC joint venture the phase of loading analyses has been completed. The next steps will be the setting up of the Standard Load Spectra and the generation of corresponding multiaxial Standard Load-Time Histories. These will be, on the one hand, optimized for the shortest possible test duration and maintain, on the other hand, all fatigue-relevant properties of real service conditions. The project is planned to be finished in 2002.

Section 3: Dr. Andreas Sigwart, Ford-Werke AG Cologne, Spokesman of the Car industry members

Standardization of Loads for the Fatigue Verification of Trailer Couplings and Car Bodies

The current valid legal requirement to verify the fatigue of Trailer couplings is represented by ECE 55-01. This requirement (uni axial loading, constant amplitude) is based on available test technology used in the 1960’s. The motorcar industry uses customer-correlated loads under service conditions since the early 1980’s to verifiy the fatigue of their car bodies.

This means there is an inconsistent process to Sign-Off a Trailer Coupling by the supplier and the car body by the motorcar industry:
The supplier has to fulfil ECE 55-01 level and therefore is developing the part according to this requirement.
Most of the car industry verifies their car bodies with measured and customer correlated multiaxial loads (variable amplitudes).
Having car bodies and Trailer couplings designed to different fatigue requirements this causes usually several development loops coupled with high costs.
The motor car industry strongly recommend to add a multiaxial car load standard as an alternative to the ECE 55-01 to enable Trailer Coupling supplier **AND** car industry designing to the same principle.

Section 4: Mr. Jörg Riehle, Oris Fahrzeugteile Hans Riehle GmbH
Spokesman of the towing device manufacturer members

Testing Procedures According to the CARLOS Principle for the Approval of Mechanical Coupling Devices and Components of Combinations of Vehicles

From the viewpoint of a towing device manufacturer, in the following we would like to explain the technical relevance and the importance of the CARLOS testing procedure to be implemented into the approval mechanism of mechanical coupling devices.

Current situation
In order to provide towing equipment for new vehicles at the point of market introduction, mechanical coupling devices are typically designed and tested parallel to the vehicle’s engineering phase. The vehicle manufacturer has the responsibility to ensure the structural integrity of the fixing points of the coupling device; the towing equipment manufacturer needs to ensure all functions for the coupling device itself. Since there are no individual, legal regulations for the car manufacturer, the testing of the fixing points is performed in car manufacturer specific ways. However, almost all of them include three-dimensional load testing, either on a test bench or as a road test.
The towing device manufacturer needs to deliver a tow bar which is able to comply with this type of testing. On the other side, in order to achieve a European homologation, one-dimensional durability tests on a test bench according to ECE 55-01 are required.
Although the three-dimensional durability test (car manufacturer) much more precisely copies the real working conditions of a towing equipment, the parts have to be designed also to meet one-dimensional ECE 55-01 testing. Consequently, all types of load calculation and testing procedures have to be performed in a two-fold manner. In practice, the accordance to ECE 55-01 will be done first, afterwards the three-dimensional load testing will be performed at the car manufacturer. The difference of the two testing procedures leads to a significant number of engineering loops.

Benefits of an alternative approval method according to the CARLOS principle
With the possibility of achieving a European homologation by performing a three-dimensional durability test on a test bench at the towing equipment manufacturer's location, the difference of requirements will be reduced. Therefore, the expected number of engineering cycles will be lower, leading to a more streamlined, customer-oriented engineering process.

The number of engineering cycles can be reduced even further by allowing an approval method for ECE homologation in which the three-dimensional testing of the towing device assembled to the vehicle will be allowed. In this scenario, towing device and fitting points of the vehicle can be tested all at once. Designs of the vehicle and the tow bar can be focused on a single approval method.

It is our sincere interest to include approval methods according to the CARLOS principle into the ECE homologation proceedings. Faster development times will lead to better customer offerings with up to date equipment and shorter product life cycles.

How to go ahead - proposal

German delegation proposes to install an ad hoc group to study the details, to discuss the proposed test procedure, and to prepare a final document for (the next) GRRF meeting.

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