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भारतीय मानक **मसौदा**

स्वचल वाहन — वाहन गत्यात्मक परीक्षण पद्धतियाँ
भाग 4 सवारी आराम मापन

Draft *Indian Standard*

AUTOMOTIVE VEHICLES — VEHICLE DYNAMICS TEST METHODS
PART 4 RIDE COMFORT MEASUREMENTS

ICS 43.020

Automotive Braking Systems, Vehicle Testing, Steering and performance Evaluation Sectional Committee, TED 04	**Last date for receipt of comments is 20/08/2024**

FOREWORD

(Formal clauses will be added later)

The dynamic behavior of a road vehicle is a most important part of vehicle safety as outlined in IS 17128 (Part 2). Ride comfort is another focused parameter in vehicle evaluation in automotive development works. Comfortable ride for driver and passenger is essential for a Vehicle for travel satisfaction. Ride comfort mainly associated with Vibrations, which will be uncomfortable to passenger and driver. Road vehicles have all directional vibrations in real word. There are many sources of vibrations in any road vehicles which includes of rotating parts, reciprocating parts of the vehicle, Road induced vibrations transferred thru tyre to passenger. To simplify the Ride comfort and scope, this standard is added mainly on development for ride comfort focus thru vertical inputs and associated vibrations.

There are literatures available on human body comfort vibration boundary limits, w.r.t. exposure time. Lot of research papers defines the limits and its exposure time as comfort criteria. These literatures on can be used to understand the comfort boundaries and developmental limits for the vehicle. This standard does not cover those.

Dynamics standard has been published in five parts. While Part 4 of this standard covers Ride comfort measurement method.

The composition of the Committee responsible for the formulation of this standard will be added later in Annex B.

Draft *Indian Standard*

AUTOMOTIVE VEHICLES — VEHICLE DYNAMICS TEST METHODS
PART 4 RIDE COMFORT MEASUREMENTS

1 SCOPE

1.1 These Indian standard covers evaluations and measurement of vibrations mainly dominated by vertical direction which is primary cause for Comfort development in vehicle. This also covers the vehicle parameters which are mainly developed for Ride comfort.

Note
This standard provides guidelines for various parameters and test methods used to evaluate vibrations associated with ride comfort & not for any regulatory requirements.

2 REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS/ISO	*Title*
IS 17128 (Part 1) : 2019	Automotive Vehicles — Vehicle Dynamics Test Methods Part 1 general test conditions
IS 17128 (Part 2) : 2019	Automotive Vehicles — Vehicle Dynamics Test Methods Part 2 — Steady-State Test Procedure for Vehicle Stability and Controllability — Open-Loop and Closed Loop Test
IS 17128 (Part 3) : 2021	Automotive Vehicles — Vehicle Dynamics Measurements Test Procedure Part-3 — Transient Response Test Procedure Open Loop And Closed Loop Test
Doc: TED 04 (25917) Part-5: XXXX	Automotive Vehicles — Vehicle Dynamics Measurements Test Procedure Part 5 Subjective Evaluation -Vehicle Ride, Handling, steering (*under development*)
ISO 2631-1: 1997	Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration Part 1 General requirements

3 TERMS AND DEFINITIONS

For the purpose of this standard following term and definition used

3.1 Ride Test Track

Specifically Developed various Road surfaces for Ride comfort evaluation as test track with controlled environment. These surfaces can generate various frequency inputs to Vehicle.

3.2 Normal Road Surface

Normal Road used by driver during intended use of Vehicle. There are different road surfaces vehicle encounters during normal intended usage, like Normal Paved Road, Rough Roads (damaged, partial paved), Countryside Roads (Different quality of Road surface), Off-Road (not paved, partially Paved), Various type of Paved surfaces like concrete, Tar etc.

3.3 Primary Ride

Primary ride is the vibratory characteristic of a sprung mass associated with the principal stiffnesses of tyres occurred while driving on a wavy road. Its frequency ranges up to about 6 Hz, which includes some frequency band inducing motion sickness. The specific range is wholly dependent on the size of a vehicle. In general, the primary ride is principally represented by *body bounce*. But it may be specifically categorized into several zones of frequency ranges.

3.4 Secondary Ride

Secondary ride is the vibratory characteristic of un-sprung masses supported with the principal stiffnesses of tyres generated while driving a rough road. Its frequency ranges from about 6 to 25 Hz. Its range is also dependent on the size of a vehicle.

3.5 Impact Ride

Impact ride is wholly determined by an impact shock due to the enveloping characteristic of a tyre while driving over various impact objects. In general, it is called *impact harshness*. Its frequency usually ranges above 25 Hz. The impact ride does not include the local vibratory characteristic of tyre components, which produce higher-frequency vibrations belonging to an NVH scope which are mainly above 100Hz. In reality, a driver’s subjective assessment on the impact ride is also influenced by audible high frequencies in addition to tactical low frequencies.

3.6 Pitch Movement

Vehicle movements about lateral Y-Axis of the vehicle. These are low frequency vibrations, gets generated due to front and Rear suspension vertical motion not in same phase.

4 PARAMETERS INFLUENCING THE RIDE VIBRATION FREQUENCY AND AMPLITUDE AND PERCEPTION

Normally following parameters influence the ride comfort of the vehicle. There are many other parameters which can impact but with minor influence

4.1 Vehicle parameter

a) Vehicle Total Mass, Sprung Mass, Un-sprung Mass;
b) Mass distribution at all four wheels at Kerb and Loaded condition;
c) Vehicle CG Location;
d) Wheelbase, Track width;
e) Suspension system:
    1) Type of Suspension system
    2) Suspension kinematic and Compliances characterization
    3) Suspension Breakaway force (friction and Hysteresis)
    4) Shock absorber damping characterization,
    5) Active OR semi active damping characterization if such system available in vehicle.
    6) Active, Semi active suspension system characterization if provided in Vehicle.

f) Seating systems;
g) Bending and Torsional stiffness of Platform, Body, Vehicle;
h) Tyre Stiffness and damping properties;

4.2 Other then the Vehicle Parameters

a) Various Road surfaces like smooth road, Rough road, Paved type of surface i.e. Tar, concrete etc;
b) Speed of the vehicle on different road surfaces;

c) Speed breakers profile;
d) Wind direction; and
e) Road surface wet, dry surface etc.

5 Measurement parameters and Equipment's

Following parameters can be measured which is helpful to analyze the ride comfort and further analysis for development work.

5.1 Vehicle parameter and normally used instruments:

a) Suspension Travel: K&C Test Rig
b) Spring Ratio front and Rear: K&C test rig.
c) Wheel stiffness and hysteresis: K&C Test Rig
d) Tyre Stiffness and Damping: Tyre Parameter Measurement Rigs/equipment.
e) CG measurement: CG measurement platform
f) Wheelbase, Track width: Length measuring device contact/non-contact type can be used
g) Accelerometers (primary vertical direction)
h) LVDT/non-contact type optical sensors to measure the travel
j) Length measurement device to locate the accelerometer at intended positions on the vehicle.
k) Vehicle weight and all four wheels weight
m) Tyre pressure: Gauge
n) Wheel alignment measuring equipment.
p) Suspension natural frequency and Damped frequency, K&C Test Rig or calculated from suspension system parameter.

5.2 Parameters During the test drive:

a) Vehicle Speed: non-contact type sensors, GPS sensors;
b) Vertical accelerations of sprung and un-sprung mass;
c) Accelerations measurement: Sensors or equivalent devices on Driver and passenger locations to measure the vibration;
d) Pitch Frequency, Gyroscope, Navigation sensors, LVDT, accelerometers;
e) Lateral acceleration (Ay)
f) Yaw velocity (optional); and
g) Suspension Travel (LVDTs)

Note
It is advised to measure the vehicle parameters as mentioned in para 5.1 and record during the development of Ride comfort.

6 INSTRUMENTATION OF THE VEHICLE

6.1 Locations of various sensors for measurement during test drive to be used to measure the responses as listed in **5.2**. Below is the general guideline, however Development engineer can decide any other or more locations based on Vehicle under development.

6.2 Accelerometers: can be installed at CG, Passenger location at seat & back, floor, axle center on all four wheels (unsprang and sprung mass suspension attachments point on body, floor, seat rail), LVDT- Install the LVDT to measure the travel of sprung mass w.r.t. un-sprung mass. LVDT can be installed between front axle and Platform/Chassis.

7 TESTING AND DATA RECORDING

7.1 Test Track Drive

For the purpose of vehicle characterization, Test track surfaces can be used. For this purpose, specific Ride tracks available which can generate various discomfort vibration frequencies while driving on those surfaces. During the development phase of various set ups, vehicle speed to be maintained same by expert driver so results are meaningful for improvement direction and repeatability of results. On test Track drive source of vibrations are constant for repeatability, as track surfaces are maintained.

Note

1. Test tracks drive is very useful during the vehicle development process to identify the developmental work for comfort targets. Vehicle parameters i.e. Wheel Base, Track width, CG height, suspension system characterization can generate different output when driven at different speeds. For repeatability it is advisable to compare the data of same speeds on specific test tracks. Maintain the speed within +/-1 kmph for less than 100 kmph and +/- 2 kmph for more than 100 kmph. Caution-Vehicle to be driven based on Track limit or safe speed of the vehicle whichever is lower.

2. It is recommended to drive the vehicle of same side (Left/right/Centre) of track to get repeatability

7.2 Normal Road Drive

It is not preferred to do ride developments work on normal public road. If required, then drive to be as per intended use of the vehicle as normal customer as per Road rules. Initial and post development vehicle can be driven capture the preliminary and final data for comfort criteria. There can be practical difficulty in real world that road surfaces may not remain same, as time to time road surfaces deteriorates OR improved surfaces paved. In such case similar road surfaces can be identified to have correlation of comfort before and after development.

Vibrations inputs from real drive surfaces will have wide range of frequencies combination exposure to passenger. Separations and filtration of relevant comfort frequencies needed during data analysis which are relevant to comfort.

Caution-Vehicle to be driven based on speed limit of Road or safe speed of the vehicle whichever is lower. It is recommended not to do the ride comfort developmental trails on Public Road.

7.3 Test Runs for data capturing

Test runs can be done to capture the data. Process of data capturing can be followed for Test Tracks and Real Road drive. Run vehicle at various speeds and record the data and accelerations levels. Check the repeatability of test data for number of runs. Typically, standard practice is to have 3 repeatable runs within the acceptable variation. Data collections to be done on dry surface condition.

7.3.1 Vehicle with Driver Only

7.3.2 With intended loads. Care needs to be taken for loading. It is recommended to use manikin at intended passenger positions representing the Human Body mass distribution i.e. CG, Interia, Load distribution on seat and floor. Other way is to drive the vehicle with passenger at intended position. Also, it is advisable to use vehicle boot for loads as per real/intended usage.

7.3.3 With Fully loaded Vehicle, with intended passengers and boot load.

Note

Maintain appropriate Fuel in fuel tank, as weight of fuel can change certain inertia properties. It is advisable to maintain same level of fuel during various developmental trials OR use 90% fuel tank filled. This can be decided based on vehicle intended usage in real world.

8 EVALUATION AND ANALYSIS

The ride quality evaluation system consists of Capturing the data from various sensors mounted in vehicle with real time thru Multi Channel data acquisition system, as all data needs same time scale to anaylse. Data can be plotted in Time Domain and Frequency Domain to analyze. For this Frequency and time domain based compatible data analysis Software can be used to plot the various data. Data can be plotted with required signal conditioning by filtering the noise (unrelated data) data.

Data can be plotted for various test track runs, various speeds, specific event maneuvers (speed breakers, pot holes etc) to analyze.

Based on time based and frequency-based plots graphs with overlapping of targeted Comfort boundary limits.

Further these data with co-relations based on a) Vehicle characterization data measured thru K&C, Damping, Tyre properties b) Other data captured like Suspension Travel, unsprung mass frequency/Velocity, to be used to analyze the cause of dis-comfort frequencies. Based on this analysis comfort improvement parameters can be identified to improve the Ride comfort.

Annex A can be referred for the representative Graphs for comparative analysis.

While data capturing and analysis, crash factor events to be identified and separated from data analysis, as it may give different levels of accelerations values which will not truly represent the relative analysis.

Note

Certain change to in Vehicle system characterization to improve the Ride comfort, can impact the vehicle Transient behavior (refer IS 17128 (Part 3) and IS 17128 (Part 4)). Hence it is recommended to check the Vehicle transient Behavior as outlined in IS 17128 (Part 3) and Subjective Assessment as outlined in Doc. TED 04 (XXXX) (Part 5).

ANNEX A
(*Clause* **8**)

REPRESENTATIVE GRAPHS ON GENERAL DATA

A-1 Data Acquisition

Measure the human contact point accelerations at different human contact locations such as seat, floor etc. (in X, Y & Z directions), then the measured test data to be analyzed to calculate statistical values for each run like Maximum, Minimum, Range, Root Mean Square (RMS) and Standard Deviation. then the measured data is further processed as per ISO 2631-1 with weighted filters and respective factors.

The Directional RMS values are then calculated by applying respective weighing filters as per ISO 2631-1. Here, RMS before applying weighting filters are denoted as Unweighted RMS and Filtered RMS are denoted as Weighted RMS.

A-2 Ride analysis done as per ISO 2631-1 & Point RMS are calculated as

For Seat:

$$RMS\ (Point\ Vibration\ Total\ Value) = \sqrt{(X^2 + Y^2 + Z^2)}$$

For Seat Back

$$RMS\ (Point\ Vibration\ Total\ Value) = \sqrt{((0.8 \times X)^2 + (0.5 \times Y)^2 + (0.4 \times Z)^2)}$$

For Floor

$$RMS\ (Point\ Vibration\ Total\ Value) = \sqrt{((0.25 \times X)^2 + (0.25 \times Y)^2 + (0.4 \times Z)^2)}$$

In case of measurement of rotational vibrations at seat location, the overall vibration total value analysis can be carried using the respective frequency weighting filters and the multiplying factors as per the ISO 2631-1. Below are the diffract directional for supporting seat surface in meters per radian (m/rad) are as,

Rotational acceleration about X- axis with k = 0.63 m/rad

Rotational acceleration about Y- axis with k = 0.4 m/rad

Rotational acceleration about Z- axis with k = 0.2 m/rad

where k is multiplying factor

A-3 Overall RMS for Driver and Passenger seat are then calculated as below

Overall RMS is calculated as below:

$$Overall\ RMS\ (g) = \sqrt{((\ Seat\ point\ RMS)^2 + (\ Seat\ Back\ point\ RMS)^2 + (\ Floor\ Point\ RMS)^2)}$$

For Driver Seat

$$Driver\ location\ RMS\ (g) = \sqrt{((\ Driver\ Seat\ point\ RMS)^2 + (\ Driver\ Seat\ Back\ point\ RMS)^2 + (\ Driver\ Floor\ Point\ RMS)^2)}$$

For Passenger Seat

$$Pass\ location\ RMS\ (g) = \sqrt{((\ Pass\ Seat\ point\ RMS)^2 + (\ Pass\ Seat\ Back\ point\ RMS)^2 + (\ Pass\ Floor\ Point\ RMS)^2)}$$

The representative graphs for comparative studies can be plotted with average weighted resultant / point RMS along with its Overall weighted RMS for various tracks/roads at various speeds as:

a) Driver seat surface, Driver back, Driver floor, Overall Driver seat RMS.
b) Middle seat surface, Middle seat back, Middle floor, Overall Middle seat RMS.
c) Last seat surface, Last seat back, Last floor, Overall Last seat RMS.

1) Overall RMS for Driver Location (*see* Fig. 1)

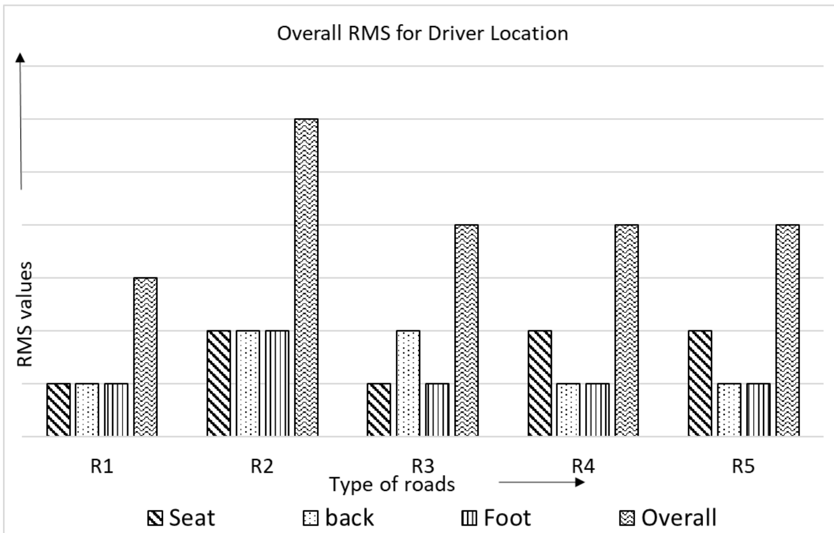

FIG. 1 OVERALL RMS FOR DRIVER LOCATION

2) Overall RMS for Mid Row for Passenger Location (*see* Fig. 2)

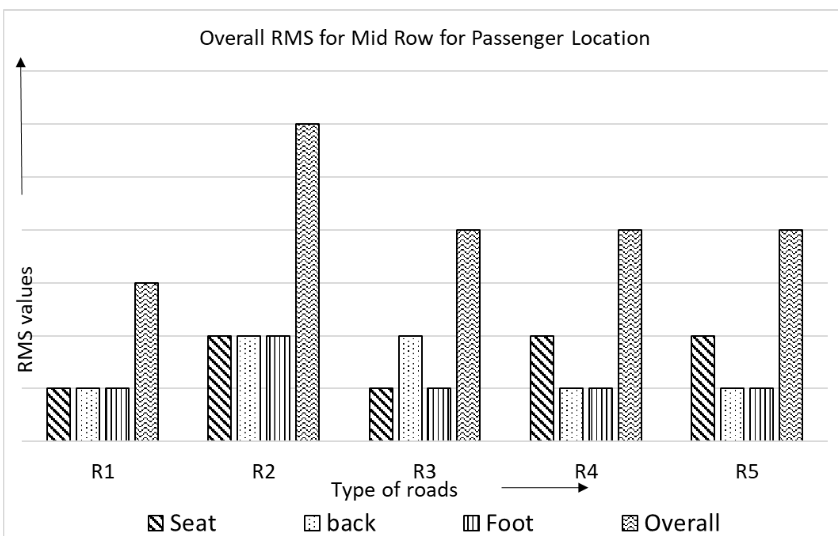

FIG. 2 OVERALL RMS FOR MID ROW FOR PASSENGER LOCATION

3) Overall RMS for Last Row for Passenger Location (*see* Fig. 3)

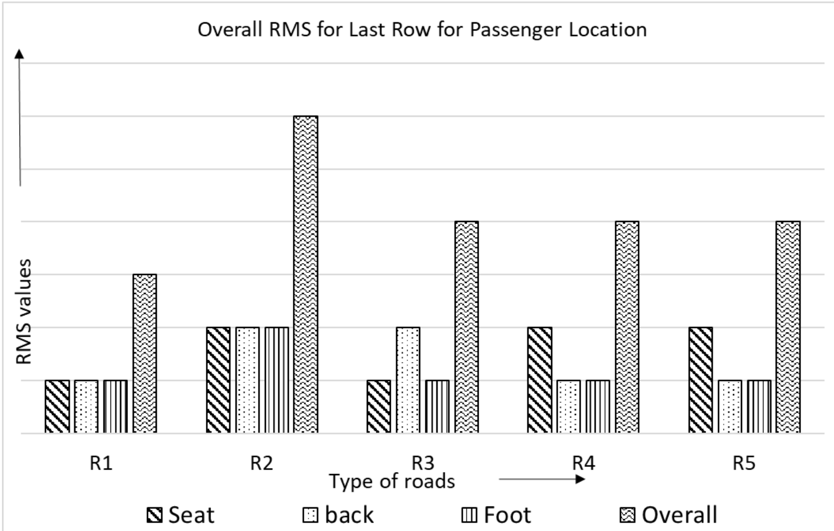

FIG. 3 OVERALL RMS FOR LAST ROW FOR PASSENGER LOCATION

ANNEX B

(*Foreword*)

COMMITTEE COMPOSITION
WILL BE ADDED LATER