

PD ISO/TR 16250:2013



BSI Standards Publication

Road vehicles — Objective rating metrics for dynamic systems

bsi.

...making excellence a habit.™

National foreword

This Published Document is the UK implementation of ISO/TR 16250:2013.

The UK participation in its preparation was entrusted to Technical Committee AUE/15, Safety related to vehicles.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2013. Published by BSI Standards Limited 2013

ISBN 978 0 580 73294 2

ICS 43.020; 43.180

Compliance with a British Standard cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 July 2013.

Amendments issued since publication

| Date | Text affected |
|------|---------------|
|------|---------------|

TECHNICAL REPORT

PD ISO/TR 16250:2013

ISO/TR 16250

First edition
2013-07-15

Road vehicles — Objective rating metrics for dynamic systems

*Véhicules routiers — Mesures pour l'évaluation objective des
systèmes dynamiques*



Reference number
ISO/TR 16250:2013(E)

© ISO 2013



COPYRIGHT PROTECTED DOCUMENT

© ISO 2013

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

| | |
|--|-----------|
| Foreword | iv |
| Introduction | v |
| 1 Scope | 1 |
| 2 Terms and definitions | 1 |
| 3 Symbols and abbreviated terms | 1 |
| 3.1 General abbreviated terms..... | 1 |
| 3.2 General symbols and subscripts..... | 2 |
| 3.3 CORA..... | 2 |
| 3.4 EARTH and EEARTH..... | 3 |
| 3.5 Model reliability metric..... | 4 |
| 3.6 Bayesian confidence metric..... | 5 |
| 3.7 Overall ISO rating..... | 5 |
| 4 General requirements to the data | 5 |
| 5 CORA metric | 6 |
| 5.1 Corridor rating..... | 6 |
| 5.2 Cross-correlation rating..... | 8 |
| 5.3 Step-by-step procedure..... | 10 |
| 6 EARTH metric | 11 |
| 6.1 EARTH phase score..... | 12 |
| 6.2 EARTH magnitude score..... | 13 |
| 6.3 EARTH slope score..... | 14 |
| 6.4 Overall EARTH score..... | 15 |
| 6.5 Step-by-step procedure..... | 15 |
| 7 Model reliability metric | 16 |
| 8 Bayesian confidence metric | 16 |
| 9 ISO metric | 18 |
| 9.1 CORA corridor method..... | 18 |
| 9.2 EEARTH method..... | 18 |
| 9.3 Calculation of the overall ISO rating..... | 23 |
| 9.4 Meaning of the objective rating score..... | 24 |
| 10 Pre-processing of the data | 24 |
| 10.1 Sampling rate..... | 25 |
| 10.2 Filtering..... | 25 |
| 10.3 Interval of evaluation..... | 25 |
| 11 Limitations | 26 |
| 11.1 Type of signals..... | 26 |
| 11.2 Metrics validation..... | 26 |
| 11.3 Meaning of the results..... | 26 |
| 11.4 Multiple responses..... | 27 |
| Annex A (informative) Child restraint example | 28 |
| Annex B (informative) Sled test example | 46 |
| Annex C (informative) Case studies | 51 |
| Bibliography | 65 |

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received. www.iso.org/patents

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 10, *Impact test procedures*, and SC 12, *Passive safety crash protection systems*.

Introduction

Computer-Aided Engineering (CAE) has become a vital tool for product development in the automobile industry. Various computer programs and models are developed to simulate dynamic systems. To maximize the use of these models, their validity and predictive capabilities need to be assessed quantitatively. Model validation is the process of comparing CAE model outputs with test measurements in order to assess the validity or predictive capabilities of the CAE model for its intended usage. The fundamental concepts and terminology of model validation have been established mainly by standard committees including the United States Department of Energy (DOE),^[6] the American Institute of Aeronautics and Astronautics (AIAA),^[1] the Defense Modeling and Simulation Office (DMSO) of the US Department of Defense (DOD),^[5] the American Society of Mechanical Engineers Standards Committee (ASME) on verification and validation of Computational Solid Mechanics,^[2] Computational Fluid Dynamics and Heat Transfer,^[3] and various other professional societies.^{[4][22][23]}

One of the critical tasks to achieve quantitative assessment of models is to develop a validation metric that has the desirable metric properties to quantify the discrepancy between functional or time history responses from both physical test and simulation result of a dynamic system.^{[7][19][20]} Developing quantitative model validation methods has attracted considerable researchers' interest in recent years.^{[12][13][14][18][20][21][26][28][29][32]} However, the primary consideration in the selection of an effective metric should be based on the application requirements. In general, the validation metric is a quantitative measurement of the degree of agreement between the physical test and simulation result.

In this Technical Report, four state-of-the-art objective rating metrics are investigated and they are: CORrelation and Analysis (CORA) metric,^{[10][30][31]} Error Assessment of Response Time Histories (EARTH) metric,^{[28][34]} model reliability metric,^{[18][27][35]} and Bayesian confidence metric.^{[14][16][36]} Multiple dynamic system examples for both tests and CAE models are used to show their advantages and limitations. Further enhancements of the CORA corridor rating and the development of an Enhanced Error Assessment of Response Time Histories (EEARTH) metric are proposed to improve the robustness of these metrics. A new combined objective rating metric is developed to standardize the calculation of the correlation between two time history signals of dynamic systems. Multiple vehicle safety case studies are used to demonstrate the effectiveness and usefulness of the proposed metric for an ISO Technical Report.

Road vehicles — Objective rating metrics for dynamic systems

1 Scope

This Technical Report specifies a method to calculate the level of correlation between two non-ambiguous signals. The focus of the methods described in this Technical Report is on the comparison of time-history signals or functional responses obtained in all kinds of tests of the passive safety of vehicles and the corresponding numerical simulations. It is validated with signals of various kinds of physical loads such as forces, moments, accelerations, velocities, and displacements. However, other applications might be possible too, but are not in the scope of this Technical Report.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1

filtering

smoothing of signals by using standardized algorithms

2.2

goodness or level of correlation

similarity of two signals

2.3

interval of evaluation

time domain that is used to calculate the correlation between two signals

2.4

rating

rating score

calculated value that represents a certain level of correlation (objective rating)

2.5

sampling rate

recording frequency of a signal

2.6

time sample

pair values (e.g. time and amplitude) of a recorded signal

2.7

time-history signal

physical value recorded in a time domain; those signals are non-ambiguous

3 Symbols and abbreviated terms

3.1 General abbreviated terms

CAE Computer-Aided Engineering

CORA CORrelation and Analysis

DTW Dynamic Time Warping