SLOVENSKI STANDARD

SIST EN 14067-4:2006

01-marec-2006

Železniške naprave – Aerodinamika – 4. del: Zahteve in preskusni postopki pri aerodinamiki na odprti progi

Railway applications - Aerodynamics - Part 4: Requirements and test procedures for aerodynamics on open track

Bahnanwendungen - Aerodynamik - Teil 4: Anforderungen und Prüfverfahren für Aerodynamik auf offener Strecke

Applications ferroviaires - Aérodynamique - Partie 4 : Exigences et procédures d'essai pur l'aérodynamique a l'air libre

Ta slovenski standard je istoveten z: EN 14067-4:2005

ICS:

45.060.01

SIST EN 14067-4:2006 **en**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 14067-4

November 2005

ICS 45.060.01

English Version

Railway applications - Aerodynamics - Part 4: Requirements and test procedures for aerodynamics on open track

Applications ferroviaires - Aérodynamique - Partie 4 : Exigences et procédures d'essai pour l'aérodynamique à l'air libre

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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Ref. No. EN 14067-4:2005: E

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Foreword

This European Standard (EN 14067-4:2005) has been prepared by Technical Committee CEN/TC 256 "*Railway Applications*", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2006, and conflicting national standards shall be withdrawn at the latest by May 2006.

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 96/48/EC.

For relationship with EU Directive, see informative Annex ZA, which is an integral part of this European Standard.

This European Standard is part of the series "*Railway applications – Aerodynamics*" which consists of the following parts:

— *Part 1: Symbols and units*

— *Part 2: Aerodynamics on open track*

— *Part 3: Aerodynamics in tunnels*

— *Part 4: Requirements and test procedures for aerodynamics on open track*

— *Part 5: Requirements and test procedures for aerodynamics in tunnels*

— *Part 6: Cross wind effects on railway operation*

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

Trains running on open track generate aerodynamic loads on objects and persons they pass. If trains are being passed by other trains, trains are also subject to aerodynamic loading themselves. The aerodynamic loading caused by a train passing an object or a person near the track, or when two trains pass each other, depends mainly on the following parameters:

— running speed of the train(s);

— distance between the object and the train(s);

— geometry of the train(s);

— geometry of the object;

— ambient wind effects.

Trains running on open track have to overcome a resistance to motion.

1 Scope

This European Standard applies to train-induced aerodynamic loading on open track caused by:

— trains passing a permanent or temporary structure;

— trains passing a person who is alongside the track;

— two trains passing each other.

This European Standard applies to open air structures of any length and closed structures of a length less than 20 m enveloping the tracks. For closed structures enveloping the tracks that are longer than 20 m prEN 14067-5 applies.

For effects caused by cross winds, the aerodynamic phenomena are described in prEN 14067-6.

In addition, this European Standard applies to the resistance of motion for trains in open air.

2 Normative references

The following referenced documents are indispensable for the application of this European Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 14067-1:2003, *Railway applications — Aerodynamics — Part 1: Symbols and units*

EN 14067-2, *Railway applications — Aerodynamics — Part 2: Aerodynamics on open track*

ISO 8756, *Air quality — Handling of temperature, pressure and humidity data*

3 Terms, definitions, symbols and abbreviations

For the purposes of this European Standard, the terms, definitions, symbols and abbreviations given in EN 14067-1:2003 apply. Additional terms, definitions, symbols and abbreviations are explained in the text.

4 Resistance to motion

4.1 General

For a train travelling at constant speed in open air and zero wind conditions on straight and level track, the following equation relates the train's resistance to motion R_1 to the train speed v_{tr}:

$$\mathrm{R}_1 = C_1 + C_2 \mathrm{v}_{tr} + C_3 \mathrm{v}_{tr}^2 \tag{1}$$

where

$C_1 + C_2 v_{tr}$ denotes both the mechanical resistance and the air momentum drag due to cooling air for the locomotives and the air conditioning of the trailer cars;

$C_3 v_{tr}^2$ denotes the aerodynamic resistance due to pressure drag and skin friction drag.

4.2 Assessment by predictive formulae

There are no agreed formulae available.

4.3 Assessment by numerical simulations

There are no agreed methods available.

4.4 Assessment by reduced-scale tests

There are no agreed methods available.

4.5 Assessment by full-scale tests

4.5.1 General remarks and application

For complete train sets, the most prominent approach to assess resistance to motion by full-scale tests is to carry out coasting tests.

A coasting test allows a determination of the speed dependent terms of R_1. For the C_1 term, a special test is needed, the most reliable being to haul the train at very low speed. The basic principle of a coasting test is to run the train up to a certain speed and then cease the tractive effort and all sources of magnetic resistance (e.g. insulated gate bipolar transistor – IGBT) before entering a test section. Instantaneous train speed and position are measured along the testing section. A recording of the train acceleration may also be needed depending on the method used. From this information, it is possible to estimate R_1 by fitting a theoretical curve to the experimental deceleration data. The major advantage of this methodology is that no measurement of the tractive effort is needed.

There are two different post-test data treatments commonly used to obtain the resistance to motion of a train from a coasting test:

— the regression method and

— the speed history identification method.

The following subclauses deal with the hauling test requirements, the coasting test requirements and the post-test data treatment.

4.5.2 Requirements for train hauling procedure

A train hauling test consists of pulling the train at constant speed using a windlass. This test should be undertaken on a straight and level test section, for which the quality of both the geometry and the rail surface has to be as good as possible.

C_1 is determined via the mean tractive effort over a time interval for which the windlass speed is constant. In order to prevent the influence of speed dependent terms, the windlass speed has to be approximately 1 m/s.

The ambient wind speed shall be monitored and less than 2 m/s. Thus, the hauling test may be performed in a tunnel in order to minimize any wind influence.

Due to the effects of adhesion, coupling looseness, etc., the breakaway phase has to be avoided. The train mass shall be known with an accuracy of ± 2 % for mass correction purposes and the train axle-boxes shall be at the train operational temperature.

The uncertainty in C_1 determined from this test shall be lower than 10 %.

4.5.3 Requirements for coasting test procedure

If the regression method is to be used, the coasting test shall be performed on test sections which are as close as possible to ideal, i.e. straight and level. The equivalent grade resistance, taking into account both gradients and curves, shall be as low as possible compared to the resistance to motion. The previous requirement is not needed for the speed history identification post-test data treatments where grade and curve influence is taken into account in the post-test data treatments. For both post-test data treatments, it has to be ensured that the train under investigation can run at its maximum speed on the selected test section. Moreover, the detailed characteristics of the test section (slopes and curve radii) have to be known precisely. If these characteristics are not easily available, an alternative method is to measure all three components of the acceleration by a dedicated accelerometer. Meteorological information, i.e. ambient wind speed, air pressure, humidity and temperature, ideally shall be measured either on the test section or on the train exterior. It is essential that the location of the train relative to the track gradient, curve changes and meteorological station are known. For example, a start and stop mark, readable by the train, may be used to determine the train's entrance and exit from the test section.

The train composition and mass, ideally in normal operational order, should be the same for each test. If not, the differences need to be taken into account when post-processing the data. The mass of the test train as well as the k factor accounting for the energy stored in the rotating masses shall be known with an accuracy of within ± 2 %. The k factor can be determined by coasting the train uphill with slow initial speed until the train comes to a stop. Axle-boxes shall be at their normal operational temperature. Furthermore, all cooling equipment shall have a well-defined and time-stable state, so as not to introduce bias into the measurements. The train shall be equipped with a velocity sensor, an odometer allowing train speed measurement with an accuracy of the greater of ± 1 % or ± 1 km/h.

Coasting tests ideally should be performed from the maximum train speed $v_{tr,max}$ to zero. It is permissible to limit the test to the following speed range: [$v_{tr,max}$; $v_{tr,max}/3$]. This reduced speed range may be achieved either in a single run or in a number of separate runs. If the latter approach is adopted, the train speed on entry into the test section should be varied in a stepwise manner, e.g. by steps of $v_{tr,max}/20$ over the speed range [$v_{tr,max}$; $v_{tr,max}$ /3]. The relevant train measurements, i.e. speed, acceleration, etc., shall be recorded at a minimum sampling rate of 10 Hz. External events such as passing trains, tunnels, bridges or switches and crossings have to be carefully recorded by time and position. The data measured when passing these features should normally be excluded from the post-test data analysis. For the regression method, a minimum of three runs over the whole speed range is recommended, to assess the repeatability of the results and for the statistical analysis needed during the later analysis. For the speed history identification method, at least three runs should be performed from $v_{tr,max}$ to $v_{tr,max}/3$.

The main principle when analysing coasting test data is to respect the fundamental principle of dynamics:

$$km\gamma = \sum R_{\mathrm{i}} = -\left(R_1 + R_2\right) \tag{2}$$

where

k accounting for the energy stored in rotating masses;

m is the train mass;

γ is the train acceleration measured during the coasting test;

$\sum R_{\mathrm{i}}$ is the sum of all the resistances to motion.

The train acceleration γ can be measured directly during coasting tests or by calculating the derivative of speed between two time or track intervals. For the regression method, data affected by gradient changes shall be excluded from analysis. For both methodologies, data affected by switching off the tractive effort shall be excluded from analysis. Data acquired during the coasting test, e.g. train speed, acceleration, etc. should be low pass filtered. If the test section includes curves or slopes, the corresponding curving and grade resistances shall be taken into account as a part of the total resistance to motion. The equivalent curving and grade resistance is given by the following formula:

$$R_2 = m \cdot g\left(i + \frac{800}{r}\right) \quad (3)$$

where

- g is the acceleration due to gravity;
- m is the train mass;
- i is the gradient of the track in 0,1%;
- r is the curve radius in m ($800/r$ = 0 for a straight track).

For each coasting test run, corrections shall be made for any differences in test train mass and meteorological conditions.

For the regression method, the resistance to motion is expressed in terms of the train speed using equations (1) to (3). An estimate of the coefficients C_1, C_2, and C_3 can be deduced by fitting a calculated curve to the measured data. In order to obtain a more stable result, the C_1 coefficient shall be fixed to the mass corrected value derived from the train hauling test. The C_2 value may also be fixed using an assessment of the air momentum loss or a more sophisticated approach. It is important to define a statistic which measures the goodness of fit of the calculated curve. For the regression method, this indicator can be the regression coefficient. When using the regression method, it is necessary to ensure a uniform weighting of data when fitting the theoretical curve.

The speed history identification method is iterative and is based on the calculation of the coasting time t as a function of the train speed v_{tr}, using estimated resistance formulae. The parameters in the resistance formulae are adjusted until a good agreement between the calculated and the measured $v_{tr} \sim t$ diagrams is reached. A quality indicator has to be defined, i.e. the mean value of differences between calculated and measured speed on the full coasting test. The integral of $k\, m\, d\, v_{tr} / R_1$ which gives the coasting time between two speed values is calculated numerically. At each speed step, all the parameters affecting the resistance are adjusted so that a perfect simulation of the train run is made.

The mean values for R_1 and its standard deviations should be reported.