SLOVENSKI STANDARD
SIST EN 14067-2:2004

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Železniške naprave – Aerodinamika – 2. del: Aerodinamika na odprti progi

Railway applications - Aerodynamics - Part 2: Aerodynamics on open track

Bahnanwendungen - Aerodynamik - Teil 2: Aerodynamik auf offener Strecke

Applications ferroviaires - Aérodynamique - Partie 2: Aérodynamique a l'air libre

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ICS:

45.060.01	Železniška vozila na splošno	Railway rolling stock in general

SIST EN 14067-2:2004 **en**

EUROPEAN STANDARD
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English version

Railway applications - Aerodynamics - Part 2: Aerodynamics on open track

Applications ferroviaires - Aérodynamique - Partie 2: Aérodynamique à l'air libre

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This European Standard was approved by CEN on 2 January 2003.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

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Contents

Foreword

This document EN 14067-2:2003 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of an identical text or by endorsement, at the latest by October 2003, and conflicting national standards shall be withdrawn at the latest by October 2003.

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[1)]
- Part 5: Requirements and test procedures for aerodynamics in tunnels[1)]

This document includes a Bibliography.

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

1 Scope

This European Standard describes physical phenomena of railway-specific aerodynamics and gives recommendations for the documentation of tests.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 12663:2000, *Railway applications — Structural requirements of railway vehicle bodies.*

[1)] in preparation

3 Aerodynamic resistance

3.1 General

Locomotive manufacturers need to know the resistance to motion of trains to install the optimum power in their locomotives. Railway companies need it to calculate their time schedules and their energy needs, as well as to determine the type and/or number of locomotives that are necessary for a particular train consist, and to assist in equipment purchase decisions.

Although the drag of trains is normally the main component of their resistance to motion, it is difficult to dissociate from the other components, so that in this part non-aerodynamic terms will have to be considered too.

The resistance to motion is expressed in a standard formula which is applicable to all types of trains. Moreover, the methods of measurement used to obtain the resistance to motion of a train leading to a corresponding formula are defined and explained in prEN (WI 00256127).

3.2 Resistance to motion formula

For straight and level track, zero wind conditions, in open air and at constant speed, the running resistance is:

$$R = C_1 + C_2 v_{\mathrm{tr}} + C_3 v_{\mathrm{tr}}^2 \qquad (1)$$

where C_1, C_2, C_3 are constants for a particular train, and the last two terms are the aerodynamic components.
Although this formula only takes into account the first three terms of a mathematical series with which the total resistance should be represented, experience has shown that the higher terms may be neglected, while sound physical explanations can be given for these remaining terms.

C_1 is the rolling mechanical resistance. It is a linear function of the mass of the train.

$C_2 v_{\mathrm{tr}}$ represents mainly the air momentum losses due to cooling air for the locomotives and the air conditioning of the trailer cars. $C_2 = Q\rho$ where Q is the total air volume flow for forced ventilation.

The third term embodies train external pressure drag and skin friction drag.

$$C_3 = C_{\mathrm{x}} \; S_{\mathrm{tr}} \; \frac{\rho}{2} \qquad (2)$$

C_X is divided into three terms:

$$C_x = C_{\mathrm{x}1} + C_{\mathrm{x}2} + C_{\mathrm{x}3} \qquad (3)$$

where $C_{\mathrm{X}1}$ is the drag coefficient of the leading vehicle, $C_{\mathrm{X}3}$ is the drag coefficient of the tail vehicle, and $C_{\mathrm{X}2}$ is the coefficient of the train drag without the leading and tail vehicle drag and depends on train length.

Ambient wind can substantially alter aerodynamic drag (see prEN (WI 00256127)). The influence of tunnels is dealt with in EN 14067-3 and prEN (WI 00256128).

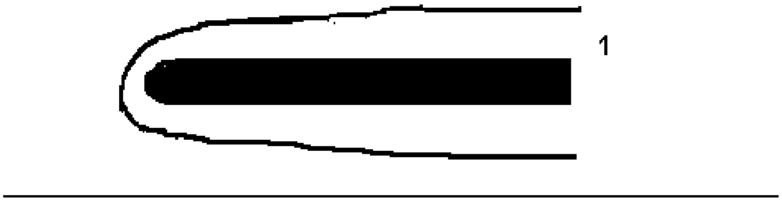
4 Aerodynamic effects of a train on persons and installations near the track

4.1 General

A moving train causes an unsteady flow field with varying pressures and flow velocities. These pressure and flow velocity transients have effects on persons, objects and buildings at the track side.

4.2 Flow field

The extent of disturbed air alongside a train moving in the open-air depends on the wind conditions as shown in Figure 1 and Figure 2.



Key

1 Disturbed field

Figure 1 — Field disturbed by train in still air

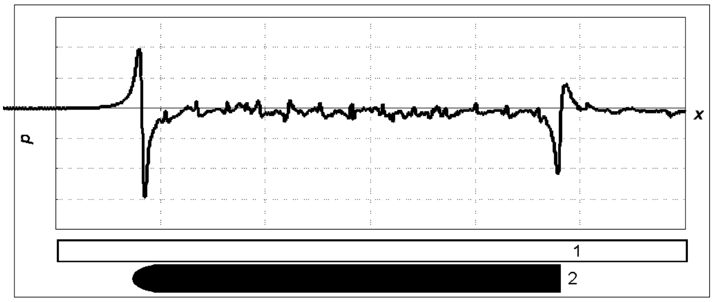
Key

1 Disturbed field
2 Ambient wind

Figure 2 — Field disturbed by train in cross-wind

4.3 Pressure changes on a wall

The pressure field on a wall parallel to the moving train in the open air is shown in Figure 3.



Key

1 Wall
2 Train

Figure 3 — Instantaneous pressure distribution on a vertical wall caused by train passing

The pressure field sweeps along with the train, and therefore at a stationary point at the side of the track, the pressure p will change with time as the train passes by in a similar way to the variation with position along the length of the train.

The most severe variation of pressure is usually caused by the passage of the train head and is of the form shown in Figure 4.

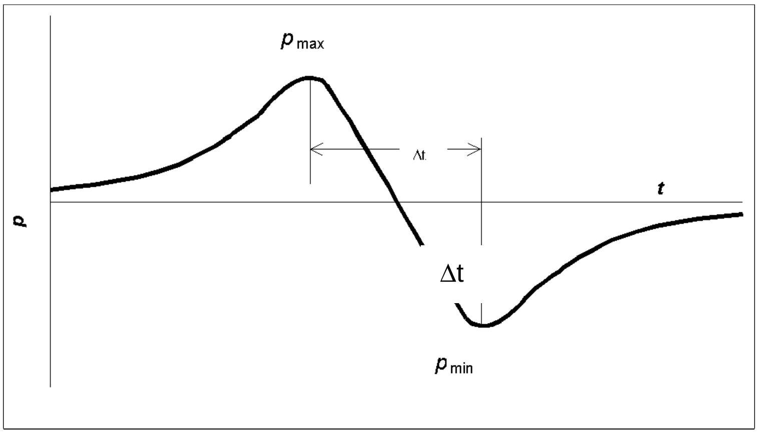


Figure 4 — Train head passing pressure pulse

As the train passes, the static pressure at the wall rises to a positive peak and drops rapidly to a negative peak. The most important parameter is the amplitude or more specifically the peak-to-peak pressure of the pressure pulse. It is related to the nose shape and is generally less for a longer smooth shape than for a bluff sharp-edged shape. The time between the pressure peaks Δt can be related to the time for the length L_n of the train nose to pass.

$$\Delta t \approx \frac{L_\mathrm{n}}{v_\mathrm{tr}} \qquad (4)$$

A lower amplitude pulse occurs as the rear of the train passes, but the order of the pressure change is reversed such that the negative peak precedes the positive peak.

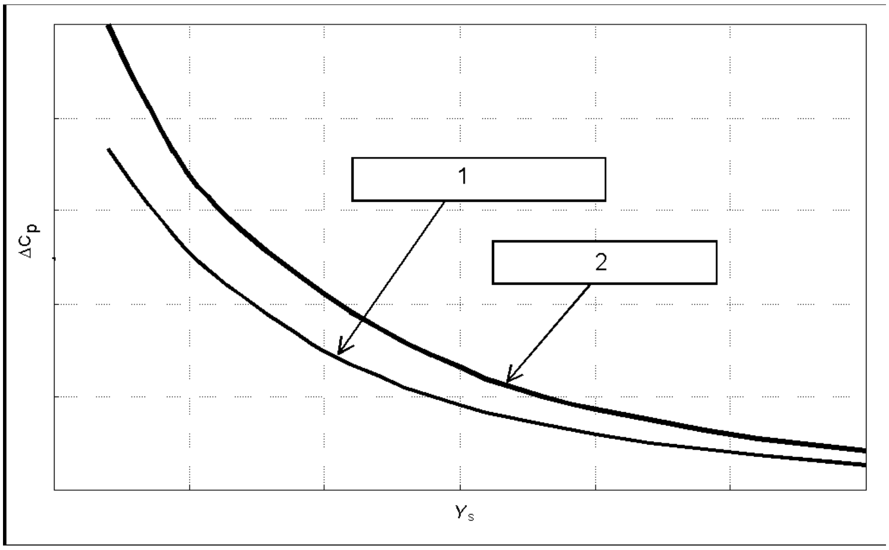
The amplitude of the pressure pulse is approximately proportional to the square of the speed of the train.

A non-dimensional pressure coefficient ΔC_p is defined by

$$\Delta C_\mathrm{p} = \frac{2\left(p_\mathrm{max} - p_\mathrm{min}\right)}{\rho v_\mathrm{tr}^2} \qquad (5)$$

The strength of ΔC_p for a particular train depends on the height of the wall, the height of the measuring point and the distance of the wall from the train side, where ΔC_p decreases with increasing distance. ΔC_p is a fundamental aerodynamic property of a particular train.

An example is given in Figure 5.



International limits do not exist for ΔC_p.

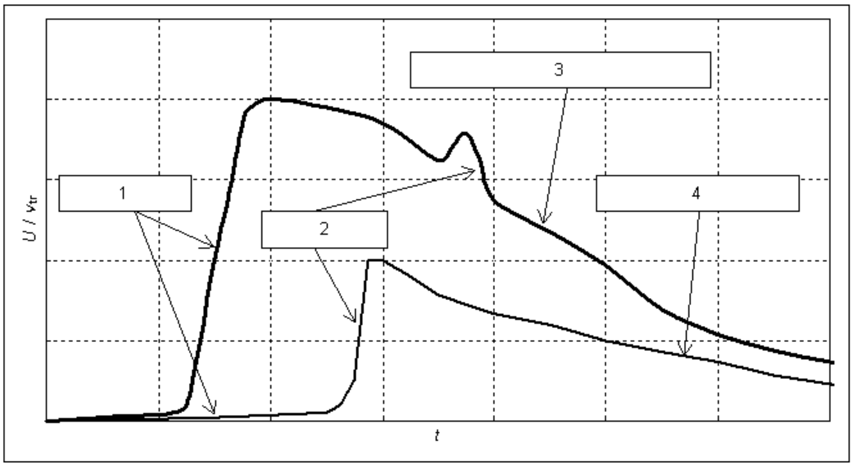
Key

1 Slender nosed trains
2 Bluff nosed trains

Figure 5 — Typical variation of pressure coefficient ΔC_p with lateral distance Y_s of the wall

4.4 Air velocities caused by train passing

Figure 6 shows typical velocity-plots for a conventional passenger train and a high speed train.



Key

1 Head Passage
2 Tail Passage
3 Conventional Passenger Train
4 High Speed Train

Figure 6 — Measured air velocities caused by passing trains

For a conventional passenger train the main disturbances start with the train head passing phase. For a high speed train these disturbances sometimes only start when the train has already passed and the peaks are normally lower due to the aerodynamic quality of this train. One important characteristic of the train is the maximum value of U, produced as it passes by.

U is dependent on lateral distance, height and speed of the train as well as on the aerodynamic quality of the train.

In crosswinds, the effects of the train's slipstream are increased on the lee side.

4.5 Forces on objects and people

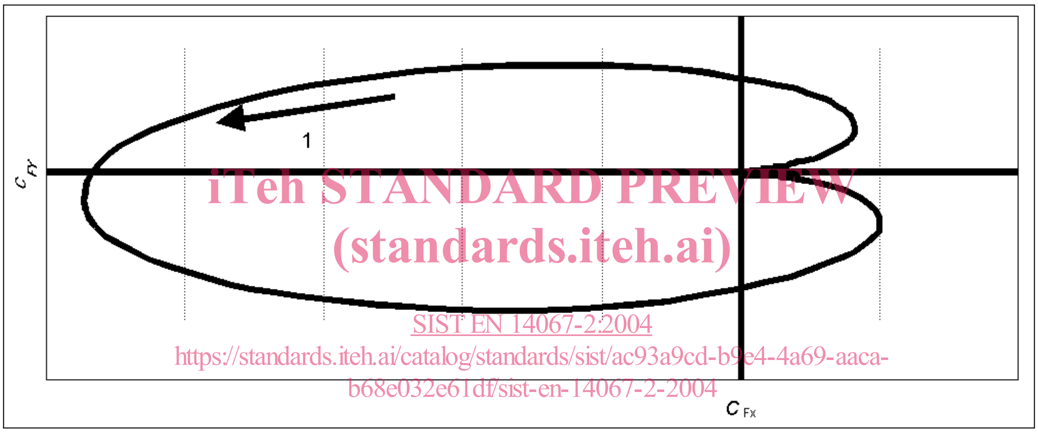
Forces on objects and people are caused by pressures and air flows. Magnitudes and directions of these forces change during the passage of a train.

Figure 7 shows the instantaneous force coefficients C_{Fx} and C_{Fy} during the passage of the head of a train.

The non-dimensional force coefficient C_{F} is defined by

$$F = C_{\mathrm{F}}\ S\ \frac{\rho\ v_{\mathrm{tr}}^2}{2} \qquad (6)$$

where F is the maximum value of the force during the passage and S a characteristic area of the object.



Key

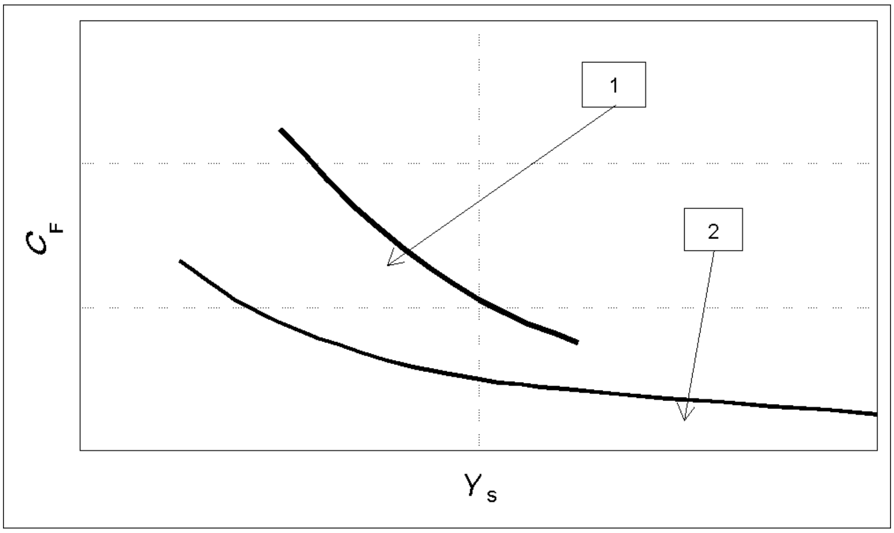
1 Increasing time

Figure 7 — Typical instantaneous force coefficients C_{Fx} and C_{Fy} for a circular cylinder at the track side

C_{F} values depend on

- the size and shape of the object,
- the distance between the object concerned to the side of the train,
- the size and shape of the train.

An example for a cylindrical object is given in Figure 8.



Key

1 Conventional Passenger Train

2 High Speed Train

Figure 8 — Typical force coefficient C_F for a circular cylinder at the track side

5 Aerodynamic effects of crossing trains in the open air

5.1 General

When a moving train passes another, a pressure pulse is generated on the side of the other train primarily by the train nose and secondarily by the train tail. This pressure transient produces a response in the structure of the train, such as a buffeting of loose doors and windows.

The train structure and subsidiary components shall be designed in such a way that they are able to take these effects in account (see EN 12663:2000, 4.6.5).

5.2 Pressure changes on the side of a train

The pressure transients on a train side caused by a passing train are similar to the pressure changes on a vertical wall parallel to the track. The most severe variation of pressure is usually caused by the passage of the train head and a lower amplitude pulse usually occurs as the rear of the train passes.

But since the train is moving, the pressure excursions will be felt quicker in proportion to their relative speed. The time between the pressure peaks (see Figure 4) can be related to the time taken for the length of the train nose to pass.

$$\Delta t \approx \frac{L_{\mathrm{n}}}{v_{\mathrm{tr},1} + v_{\mathrm{tr},2}} \qquad (7)$$

The characteristic quantity is again the pressure coefficient ΔC_{p} which is defined by

$$\Delta C_{\mathrm{p}} = \frac{2\left(p_{\max} - p_{\min}\right)}{\rho v_{\mathrm{tr}}^2} \qquad (8)$$

The pressure pulse is referred to the dynamic pressure of the passing train $\frac{\rho v_{\mathrm{tr}}^2}{2}$, because it is mainly influenced by the speed of the passing train. ΔC_{p} felt on the passing side of the observing train reduces with increasing track interval in a similar way to that for a vertical wall. An example is given in Figure 5.