SWEDISH STANDARDS INSTITUTE

SVENSK STANDARD
SS-EN 14067-3

Fastställd 2003-05-09
Utgåva 1

Järnvägar – Aerodynamik –
Del 3: Aerodynamik i tunnlar

Railway applications – Aerodynamics –
Part 3: Aerodynamics in tunnels

ICS 45.060.01
Språk: engelska
Publicerad: juni 2003

Europastandarden EN 14067-3:2003 gäller som svensk standard. Detta dokument innehåller den officiella engelska versionen av EN 14067-3:2003.

The European Standard EN 14067-3:2003 has the status of a Swedish Standard. This document contains the official English version of EN 14067-3:2003.

Dokumentet består av 16 sidor.

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 14067-3

April 2003

ICS 45.060.01

English version

Railway applications - Aerodynamics - Part 3: Aerodynamics in tunnels

Applications ferroviaires - Aérodynamique - Partie 3: Aérodynamique en tunnel

Bahnanwendungen - Aerodynamik - Teil 3: Aerodynamik im Tunnel

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

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EUROPÄISCHES KOMITEE FÜR NORMUNG

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Ref. No. EN 14067-3:2003 E

Contents

Foreword

This document EN 14067-3:2003 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of an identical text or by endorsement, at the latest by October 2003, and conflicting national standards shall be withdrawn at the latest by October 2003.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.

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1) in preparation

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

3 Aerodynamic resistance

The symbols used in the present standard are explained in EN 14067-1.

3.1 General

As the drag may be drastically increased in a tunnel, it is also important to deal here with this additional source of resistance.

3.2 Resistance to motion formula

In a tunnel, the same resistance to motion formula as in the open air can be used under otherwise identical conditions (straight and level track, constant speed), the only modification is the introduction of a tunnel factor T_f in the third term:

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

T_f is the ratio (≥ 1) of the tunnel drag by the open air drag. It varies during the train passage through the tunnel.

The increase of drag in a tunnel expressed by T_f depends on many factors, the blockage ratio B of the train in the tunnel is by far the most important of them. But the type of the train and its length also have to be considered, as well as, at least for short tunnels (< 2000 m), the tunnel length and the train speed.

Examples of the variation of T_f averaged over the whole passage through the tunnel, with the blockage ratio B, the train length L_{tr}, the tunnel length L_{tu}, the train speed v_{tr} and the type of train are given in Figures 1 and 2. A method to calculate the averaged tunnel factor T_f is given in prEN (wi00256128).

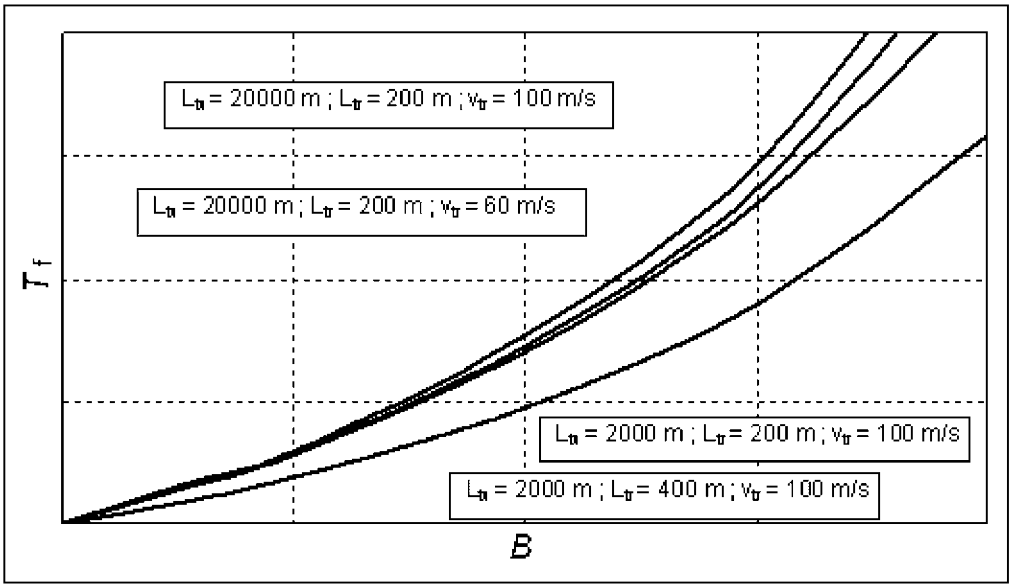

Figure 1 — Averaged tunnel factors for a high speed train

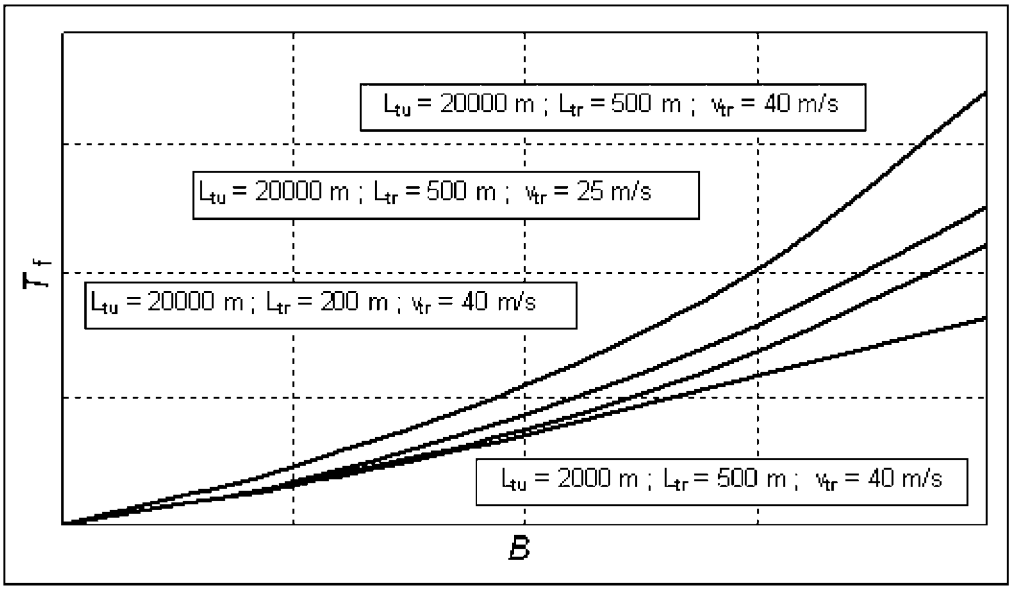

Figure 2 — Averaged tunnel factors for a freight train

4 Aerodynamic effects of a single train passing through a tunnel

4.1 General

When a train passes through a tunnel, pressure waves are generated which propagate along the tunnel approximately at sonic speed. These pressure variations will pass into the interior of the trains, unless they are pressure sealed, and may cause discomfort to train passengers. The difference of pressure between outside and inside the vehicle will produce transient loads on the structure and on other vehicle components. Vehicle design shall be undertaken considering these effects.

4.2 Pressure transients

When a train enters a tunnel, a compression wave is induced propagating along the tunnel with sonic speed (see a in Figure 3). This wave is reflected at the opposite portal as a rarefaction wave. When the rear of the train enters the tunnel, a rarefaction wave is produced again propagating along the tunnel relative to the moving air with sonic speed. This wave is reflected at the opposite tunnel end as a compression wave. These two waves are the main waves and they are always reflected at portals with opposite sense. Minor waves are caused by the passage of these waves over the train head and the train tail and so a very complex wave pattern is generated.

The superposition of waves of the same sign causes an increase of the pressure amplitude, whereas the superposition of waves with opposite sign causes a decrease of the amplitude. Depending on the location in the tunnel, the pressure histories can be very different. Further localised pressure changes are caused when the train head passes (pressure drop) and when the rear of the train passes (pressure increase).

A typical pressure history at a point in the tunnel for a train passage is shown in c in Figure 3. The pressure distribution at a point on the train looks different (see b in Figure 3).

The intensity of the head entrance wave is a typical measure for the pressure history of a train passage. The intensity of the head entrance wave is given by the formula

$$\boldsymbol{p}-\boldsymbol{p}_0=\frac{\rho v_{tr}^2}{2}\,\frac{1-\dfrac{(1-\boldsymbol{B})^2}{1+\zeta_\mathrm{h}}}{\dfrac{(1-\boldsymbol{B})^2}{1+\zeta_\mathrm{h}}+\dfrac{v_{tr}}{c}\left[1-\dfrac{(1-\boldsymbol{B})^2}{1+\zeta_\mathrm{h}}-\dfrac{\kappa v_\mathrm{tr}^2}{c^2}\left[1-\dfrac{(1-\boldsymbol{B})^2}{2(1+\zeta_\mathrm{h})}\right]\right]} \qquad (2)$$

where $\zeta_\mathrm{h}=\zeta_\mathrm{K}\boldsymbol{B}^2$ is the head loss coefficient. ζ_K depends on the shape of the head and takes the values in the range, $0 \le \zeta_K \le 8$.

For aerodynamically well shaped trains and small values of $\boldsymbol{B}$ the loss coefficient ζ_h (depending on the shape of the train head) can be neglected compared to 1. For this case the pressure increase is function of the train speed v_{tr} and the blockage ratio $\boldsymbol{B}$ only.

$$\boldsymbol{p}-\boldsymbol{p}_0\approx\frac{\rho v_\mathrm{tr}^2}{2}\,\frac{2\boldsymbol{B}}{1-2\boldsymbol{B}} \qquad (3)$$