Effect of Proximity on the Thermal Rating of a Single Power Cable in Ventilated Tunnels

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Abstract

Power transmission through power cables installed in ventilated tunnels has been increasingly used worldwide and offers a complex thermal environment. These cables are placed on supports or fixed close to the tunnel walls. Established correlations currently in use have been deduced from a non-fully developed turbulent flow and the effect of the proximity to a tunnel wall is not accounted for precisely. This paper details the experimental and numerical investigations of the heat transfer from a single cable in a fully developed turbulent air flow, with emphasis on the effect of the cable spacing from the tunnel wall. Nusselt numbers have been compared for different spacing and velocities thanks to a coupled model between COMSOL Multiphysics® software and MATLAB® software, where the inverse method is used to identify heat transfer coefficients on the cable surface.

The overall heat transfer is found to be meaningfully lower than in previous studies while the same threshold value for the wall spacing is found. The local effect of the confinement is explained with the velocity profiles evolution with the confinement from numerical simulations using the open source code OpenFOAM. The velocity and wall shear stress profiles obtained for each configurations help explain the cooling derating when the cable position is beyond the threshold value of 2De (De: cable diameter).

The radiative heat exchange, assessed numerically with a radiative model in COMSOL software, is found to be up to 30% of the total heat loss which has a visible impact on the temperature profile of the tunnel wall.

To give a more precise rating of cables in ventilated tunnel, an improved cooling law for cables in tunnel taking into account the proximity of the wall has been developed from the present study and confronted to the experimental and simulated data.

Reference

[1] J.H. Neherand M.H McGrath, The Calculation of the Temperature Rise and Load Capability of Cable Systems, AIEE 1957.
[2] 60287-2-1, International Standard IEC . Electric cables – Calculation of the current rating, 2006.
[3] Cigré, The calculation of continuous ratings for forced-cooled cables, Electra 66, 1979.
[4] Cigré, Forced cooled cables – calculation of thermal transients and cyclic loads, Electra 104, 1986.
[5] Cigré , Calculation of temperatures in ventilated cable tunnels, Electra 143, 1992.
[6] Cigré , Calculation of temperatures in ventilated cable tunnels – part 2, Electra 144, 1992.
[7] B.M. Weedy and H.M El Zayyat , Heat Transfer From Cables In Tunnels Ans Shafts, IEEE-PES, 1972.
[8] G.J. Anders , Rating of cables on riser poles, in trays, in tunnels and shafts – a review, IEEE Transaction on Power Delivery, 1996.
[9] J. Pilgrim, Rating Independent Cable Circuits in Forced-Ventilated Cable Tunnels, IEEE Transactions on power Delivery, 2010.
[10] E. Dorison and G.J. Anders , Current rating of cables installed in deep or ventilated tunnels, 2011.
[11] E. Dorison, G.J. Anders and F Lesur , Ampacity Calculations for Deeply Buried Cables, IEEE Transaction on Power Delivery, 2010.
[12] A. Neale, D. Derome, B. Blocken, J. Carmeliet, CFD calculation of convective heat transfer coefficients and validation – Part 2: Turbulent flow, Annexe 41 – Kyoto, April 3nd to 5th, 2006.
[13] H.E. Dillion, A. F. Emery, R.J. Cochran , A.M. Mescher, Validation of Radiation Computations using Viewfactors and COMSOL's Hemicube Approaches, COMSOL User Conference, 2014.
[14] H. Jasak, H.G. Weller and N. Nordin , In-Cylinder CFD Simulation Using C++ Object-Oriented Toolkit, Chalmers University of Technology, 2004.
[15] S. Sadokierski, J-L Thiffeault , Heat transfer in Underground Rail Tunnels, eprint arxiv:0709.1748, 2008.
[16] B. Watel, S. Harmand, B. Desmet, Influence of Flow Velocity and Fin Spacing on the Forced Convective Heat Transfer from an Annular-Finned Tube, JSME International Journal, 1999.
[17] F. Boukrouche and al. , A Thermal Study of Power Cables Cooling in Tunnels, Eurotherm - conference paper, Kracow (Poland), 2016.

Figures used in the abstract

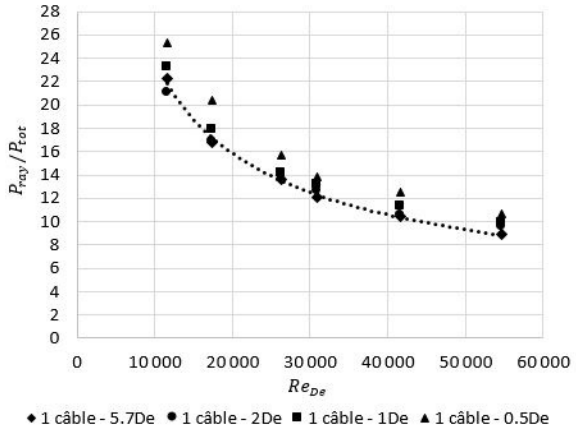

Figure 1: Radiative contribution to the heat transfer for the four wall spacing values.

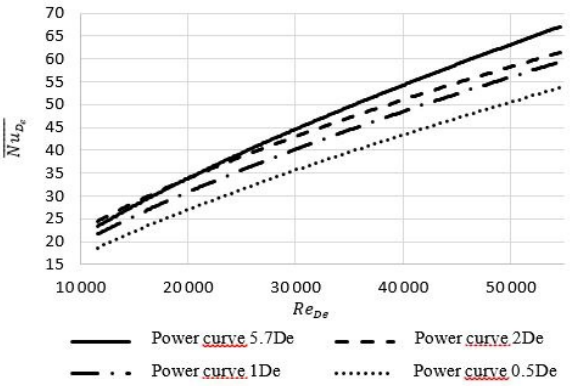

Figure 2: Mean azimuthal Nusselt number for the four wall spacing values.

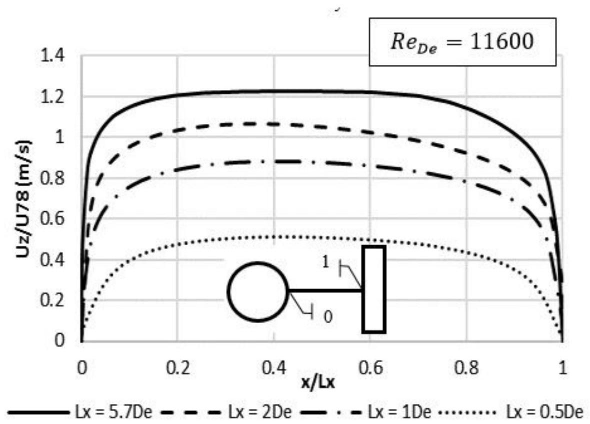

Figure 3: Velocity profiles for ReDe = 11600, scaled for the mean turbulent velocity.

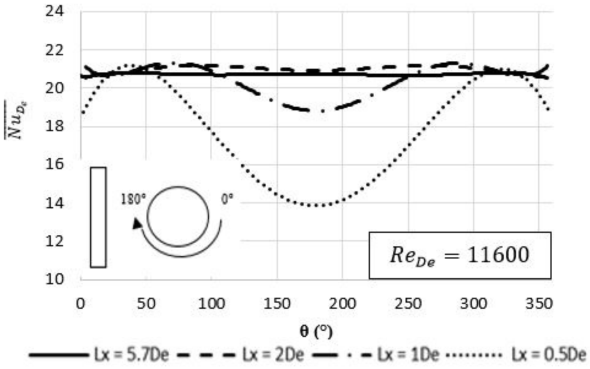

Figure 4: Local Nusselt number distributions for the four positions.