SMaRT

Sand **M**itigation **a**round **R**ailway **T**racks

a H2020 / MSCA / ITN / European Industrial Doctorate project

Doctoral Dissertation

Doctoral Program in Civil and Environmental Engineering

Computational Wind Engineering Simulations for the Design of Sand Mitigation Measures around Railway Tracks

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Abstract

The engineering interest about the windblown sand has been significantly growing in the last years. The large ongoing infrastructure projects in deserts require robust, cost-effective and high-performance solutions. This PhD Thesis deals with the application of the general Computational Wind Engineering design approach to developing new, innovative Sand Mitigation Measure (SMM) employed to protect desert railways. The Thesis is developed within the H2020-MSCA-ITN-2016 *"Sand Mitigation along Railway Tracks"* (SMaRT) European project under the Grant Agreement No 721798.

The scientifically-based problem setting, design framework and the quantitative assessment of the sand mitigation measures are, at the present time, not sufficiently developed in the literature. The Thesis, at first, introduces an exhaustive problem setting in the form of the innovative classification of the problems sand is causing around railways, analogously to equivalent actions in civil engineering. Sand Serviceability Limit States involve railway partial loss of capacity and passenger discomfort. Conversely, Sand Ultimate Limit States involve service interruption and passenger's unsafe conditions. Additionally, the new classification of sand mitigation measures is introduced, based on their relative position to the railway infrastructure and their working principle. Source-Path-Receiver categorization follows. The classifications are introduced to provide an orienting framework for the research and design activities within the Thesis.

Two innovative sand mitigation measures are developed. At first, the Path SMM called *Shield for Sand* is optimized in the sense of minimizing the cost-to performance ratio with the Gradient-based and Genetic algorithm models. Additionally, an innovative Receiver SMM, called *Sand Blower* is designed from scratch. For the design, a deeper insight into the aerodynamic behaviour of unmitigated railway systems is necessary. Therefore, a detailed numerical sensitivity analysis is carried out by varying the geometric parameters of the railway substructure, comprising of ballast and embankment. Moreover, typical conventional and nonconventional superstructure systems are tested. In particular, standard rails, tubular tracks, humped sleepers, and humped slab are considered. From the mentioned, humped sleepers applied on the gentlest ballast and embankment show the most promising results. In the light of this, the *Sand Blower* has been designed, applied to that railway system.

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Marko Horvat

Curriculum Vitae

Education

2017–2021 **PhD in Civil and Environmental Engineering**, *Politecnico di Torino*, European Industrial Doctorate under MSCA within SMaRT European project.

2015–2016 **Master of Mechanical Engineering**, *University of Zagreb: Faculty of Mechanical Engineering and Naval Engineering*, Summa Cum Laude, Orientation: Process and Power Engineering.

2011–2015 **Bachelor of Mechanical Engineering**, *University of Zagreb: Faculty of Mechanical Engineering and Naval Engineering*, Magna Cum Laude, Orientation: Process and Power Engineering.

Research project

PhD programme Horizon2020 / Marie Skłodowska Curie Actions / Innovative Training Network / European Industrial Doctorate. Project: *Sand Mitigation around Railway Track* (SMaRT, www.smart-eid.eu) under grant agreement No 721798.

The research for the thesis has been done within SMaRT, an interdisciplinary and intersectoral European research programme addressing Sand Mitigation around Railway Tracks in arid regions worldwide. The interdisciplinary problem between Engineering, Computational Fluid Dynamics (CFD) and Geomorphology has been tackled by experts in the fields under the consortium of Politecnico di Torino, Optiflow Company and University of Oxford.
My specific research activities revolved around the application of CFD to environmental issues induced by wind-blown sand and its deposition around civil infrastructures across deserts. I gained deep general knowledge of the CFD approach, i.e. modelling complex 3D geometries, generation of high quality meshes around them, choosing suitable mathematical models and numerical schemes, running simulations on High Performance Computing utilities, post-processing and visualizing results. The industrial progress has been achieved in close collaboration with the industry, especially during my stay at Optiflow, consulting company in CFD. Besides that, I was able to visit and experience the working environments of large Companies acting as Industrial Partner Organizations of the SMaRT project: Hitachi Rail STS, Astaldi and Reco Salcef Group.

Awards

from 09/2020	5 month scholarship at Politecnico di Torino as a Postdoc researcher.
2017–2020	3 year scholarship awarded by Marie Skłodowska-Curie Action for a European Industrial Doctorate. Title of the project: Sand Mitigation along Railway Tracks. Employer: Politecnico di Torino.
2016	Rector's Award for application of biomimicry on wind turbine blades using CFD.
2016	Ekonerg award for excellence during Master's studies.
2016	University of Zagreb scholarship for excellence during Master's studies.

Publications and Conferences

1.) L. Bruno, M. Horvat, L. Raffaele (2018). Windblown Sand along Railway Infrastructures: A Review of Challenges and Mitigation Measures, *Journal of Wind Engineering and Industrial Aerodynamics*, `https://doi.org/10.1016/j.jweia.2018.04.021`

2.) M. Horvat, L. Bruno, S. Khris, L. Raffaele (2020). Aerodynamic shape optimization of barriers for windblown sand mitigation using CFD analysis, *Journal of Wind Engineering and Industrial Aerodynamics*, `https://doi.org/10.1016/j.jweia.2019.104058`

3.) M. Horvat, L. Bruno, S. Khris (2021). CWE study of wind flow around railways: Effects of embankment and track system on sand sedimentation, *Journal of Wind Engineering and Industrial Aerodynamics*, `https://doi.org/10.1016/j.jweia.2020.104476`

4.) M. Horvat, Computational wind engineering simulations for design and performance assessment of sand mitigation measures, PhD Session during the online conference of the Italian Association for Wind Engineering, September 7th, 2020