INTEGRITY-RELIABILITY-FAILURE

IN ENGINEERING, MATERIALS, MANUFACTURING AND BIOMECHANICS

Proceedings IRF2025
8th International Conference on on Integrity-Reliability-Failure
Porto 15-18 July 2025

Editors

J.F. Silva Gomes
Shaker A. Meguid

FEUP-2025

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(2025)

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PREFACE

IRF2025 is the eighth international gathering of a prestigious series of Integrity-Reliability-Failure conferences coordinated by the International Scientific Committee on Mechanics and Materials in Design. This series of conferences started in 1999 and they are wholly devoted to advances in assessing the integrity, reliability and failure of engineering systems, materials, manufacturing and biomechanics. IRF2025 is jointly sponsored by the University of Porto, the University of Toronto and the Portuguese Society of Experimental Mechanics. The conference attracted over 160 contributions, with 148 accepted submissions involving 454 authors from 27 different countries.

The conference themes, which address novel and advanced topics on Integrity, Reliability and Failure, focused on Theory, Experiments and Applications in Engineering, including Composite and Advanced Materials, Fatigue and Fracture Mechanics, Structural Dynamics, Mechanical Design and Prototyping, Civil Engineering Applications, Biomechanical Applications, Energy and Thermo-Fluid Systems, and Industrial Engineering, among other topics.

We believe that the meeting and these proceedings offered our delegates an excellent opportunity for the discussion and dissemination of their recent work in assessing the integrity, reliability and failure of engineering structures, components and systems. They fostered research that integrates mechanics and materials in the design process, and promoted exchange of ideas and international co-operation among scientists and engineers in this important field of engineering.

We are particularly indebted to the authors and special guests for their contributions. Each of the 138 approved papers offers an opportunity for thorough discussions with the authors and the scientific community. Particularly, we acknowledge the excellent contributions of the participants, their innovative ideas and research directions, the novel modelling and simulation techniques, and the invaluable critical comments. We also take this opportunity to thank the members of the International Scientific Committee and the reviewers for their time and helpful suggestions, the symposia organizers for their efforts and valuable contributions to the success of conference and this publication, and the local organizing committee for an absolutely superb organization of this "*virtual*" meeting. To all of them, we offer our deepest gratitude.

Porto/Portugal, July 2025

J.F. Silva Gomes and Shaker A. Meguid
(Conference Co-Chairs and Editors)

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CONTENTS

LIST OF TOPICS AND SYMPOSIA

LIST OF MAIN TOPICS

LIST OF SYMPOSIA

Proceedings IRF2025: 8th International Conference on Integrity-Reliability-Failure
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SENSITIVITY ANALYSIS OF A RAILWAY TEMPERATURE PREDICTION MODEL

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ABSTRACT

Rail temperature prediction plays a crucial role in ensuring railway safety, as extreme temperatures can cause local buckling and track instability. This study conducts a reliability-based sensitivity analysis of a previously developed prediction model using MATLAB and UQLab. Two analyses were performed: a global sensitivity analysis considering all parameters as random variables and a Data-Driven Sensitivity Analysis incorporating measured data for key variables to refine the model and enhance its practical applicability. Results indicate that uncertainties in convection and solar absorption are the most influential parameters affecting the response statistics of the rail temperature predictions. Future work will focus on refining parameter distributions and conducting Monte Carlo simulations to improve model accuracy and assess its reliability in unmeasured conditions.

Keywords: Railway, prediction model, temperature, sensitivity analysis.

INTRODUCTION

Rail temperatures play an important role in a railway track mechanical behaviour. High temperatures can lead to track buckling, whereas low temperatures can cause fragile rupture. Railways are structures exposed to open weather conditions with a high amplitude of temperature changes during the day and over the seasons. Thus, prediction models have been developed to predict these temperatures and predict instabilities before they happen (Wu et al., 2010). This study conducts a reliability-based sensitivity analysis of a previously developed prediction model to identify the evaluate the influence of parameter uncertainties on rail temperature predictions. The prediction model was implemented in MATLAB, and the UQLab toolbox was utilized to perform the analysis (Marelli et al., 2022).

METHODS

The model is described in Equation (1) and uses an energy balance to model the temperature of the rail (T_r) and takes into consideration other parameters such as solar radiation (SR), convection coefficient (h_{conv}) and other geometric considerations (Piloto et al., 2022; Zhang et al., 2008). Two main sensitivity analyses are presented. First considering all parameters of the model as random variables and second excluding parameters when measured data is available. In both cases, parameters are modelled with uniform distributions within a given range. In this paper, we are using mainly Sobol Indices (SI) to measure the sensitivity of the prediction model.

$$SR \cdot \alpha_s A_s - \left[h_{conv} A_c (T_r - T_{air}) + \epsilon_{res} \sigma A_r \left(T_r^4 - T_{sky}^4\right)\right] = \rho C V \frac{dT_r}{dt} \quad (1)$$

For the second analysis, field measured data (Piloto et al., 2022) of solar radiation, ambient temperature (T_{amb}) and convection coefficient by using Equation (2) are used, thus not

modelling them with a probability distribution. Additionally, in the first analysis, single step solutions of the model are used by UQLab to calculate the Sobol indexes, whereas on the second analysis, the solutions account for an entire day of measurements.

$$h_{conv} = \begin{cases} 5.6 + 4 \cdot w_s; w_s \leq 5m/s \\ 7.2 \cdot (w_s)^{0.78}; w_s > 5m/s \end{cases} \quad (2)$$

RESULTS AND CONCLUSIONS

The results of the first analysis (Figure 1a) show a strong dependency on the ambient temperature (T_{amb}), followed by the convection coefficient (h_{conv}) and the profile area subject to convection (A_c), indicating that that the predominant energy exchange type is via convection, since all these parameters form the convection part of the model. Since these parameters can easily be determined by measuring them, it is possible to remove most of the input random parameters from the analysis to further investigate the other predominant terms of the model, which is discussed in the second analysis. The second analysis (Figure 1b) indicates that the parameters with higher influence are: the area subject to the incoming solar radiation (A_s), followed by the area subject to convection (A_c). These results demonstrate that the most influential energy exchange methods might be convection and solar energy absorption. In addition, the latter might also support the efforts to better model the A_s parameter, not only as a probability distribution but with a deterministic approach as discussed in other studies (Hong et al., 2019; Piloto et al., 2022).

The next steps include refining statistical distributions for key parameters and conducting Monte Carlo simulations with them and comparing with measured data, to estimate how well the model behaves when extrapolating or modelling not-measured environment data.

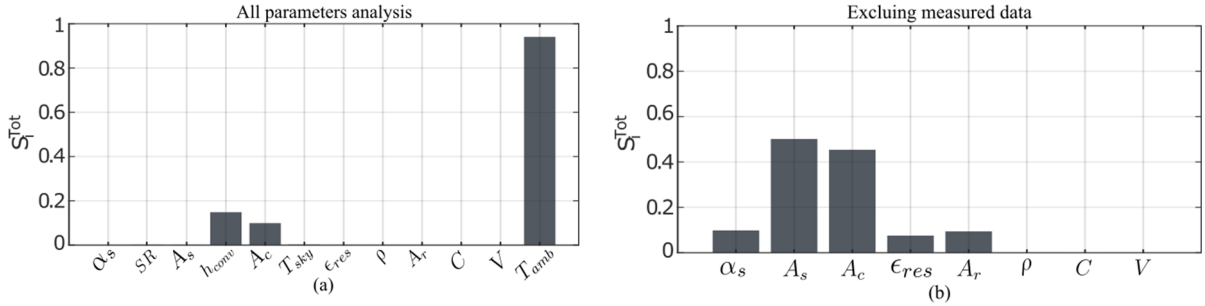

Fig. 1 - Total Sobol indices for different analysis.

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CERTIFICATE

This is to certify that **Paulo Piloto**, from IPB (Portugal), has attended and contributed to the **8th International Conference on Integrity-Reliability-Failure (IRF2025)**, which took place in Porto/ Portugal, from 15 to 18 July 2025.

Porto, 18th July 2025

Professor J.F. Silva Gomes
(IRF2025 conference Co-Chair)