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PREDICTION MODELS FOR RAIL TEMPERATURES VALIDATED WITH EXPERIMENTAL MEASUREMENTS

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ABSTRACT

Rail temperatures play an important role when understanding and predicting rail track instabilities. A rail temperature energy balance model was used, validated with FEA analysis, and compared with field-collected data. Both simplified and Finite Element Analysis (FEA) model are in good agreement. Compared with the collected data, the model reaches an R^2 of 0.83. Boundary conditions improvements are needed.

Keywords: Rail Temperature / Finite Element Analysis / Prediction Models

1. INTRODUCTION

Railways are structures exposed to the open weather with a high amplitude of temperature changes during the day and over the seasons. These changes lead to internal stresses, depending on the track boundary conditions. Thus, understanding the mechanism of track instability is as important as being able to predict the instability before it happens. An approach to do this forecast is by understanding the thermal behavior of a rail track during the day (Wu et al., 2010).

An energy balance model was proposed by Keslar and Zhang (2007), which takes into account the effect of solar radiation, wind speed, ambient temperature, and radiation emissions. Later on, Hong (2019) modified this model to include the variation of sun elevation and azimuth.

This paper's goal is to simulate one day of rail temperature in a track segment placed in the city of Mirandela-Portugal, using the model proposed by Hong (2019) and the FEA model with the software Ansys and comparing both results with field-collected data.

2. PREDICTION MODELS

The simplified model is described in Eq. (1), which is a non-linear first order differential equation and represents the energy balance of the rail segment. The Eq. (2) shows the convection coefficient that depends on the wind velocity. This model is solved with SciPy tools.

$$\mathrm{SR}\cdot\mathrm{SA}\cdot\mathrm{A_s}-\left[h_{conv}\cdot A_c(T_{rail}-T_{amb})+\epsilon_{res}\cdot\sigma\cdot A_r\left(T_{rail}^4-T_{amb}^4\right)\right]=\rho\cdot C\cdot V\cdot\frac{dT_{rail}}{dt} \quad (1)$$

$$h_{conv}=\begin{cases}5.6+4\cdot w_V\ ; w_v\leq 5\ ms^{-1}\\ 7.2\cdot(w_v)^{0.78}\ ; w_v>5ms^{-1}\end{cases} \quad (2)$$

The FEA model was built using the element PLANE55 – 4 nodes with temperature as degree of freedom (DOF), with linear interpolation and full gauss integration. The COMBIN39 is also used and features 2 nodes with temperature as DOF with linear interpolation and exact integration. Figure 1 shows the final model, UIC54 rail profile is used. The material properties for steel are temperature dependent and based on EN1993-1-2. The solution parameters: non-linear transient analysis, time step of 60 seconds, from 6:00 to 23:00, thus, 61200 seconds.

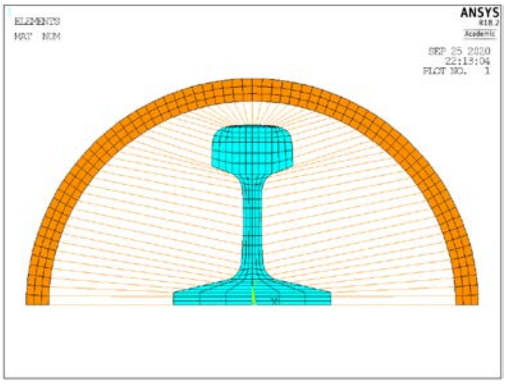

Fig. 1 - Ansys mesh.

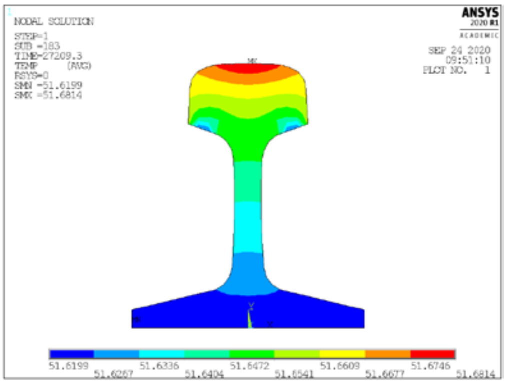

Fig. 2 - Profile results at time 13:30.

The field data used in the simulation were collected with an automatic weather station (figure 4) and thermocouples installed on the rail. The simulation uses one-day data obtained on 22/07/2020. The results are shown in figure 2 and 3.

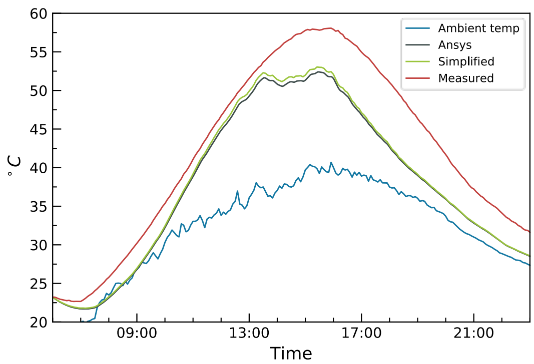

Fig. 3 - Rail temperatures.

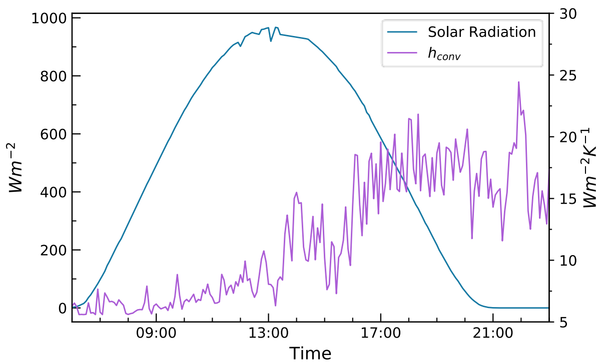

Fig. 4 - Input data.

3. CONCLUSIONS

Both simplified and FEA model are in good agreement, thus the simplified models can easily be used as a tool since it's more practical than FEA models. In comparison with measured temperature, the model performs with R^2 of 0.83, but improvements are needed, mainly on the boundary conditions.

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