EXTENSION OF A THERMAL SIMULATION MODEL FOR A TRAM AND SIMULATION WITH ON-SITE MEASUREMENT DATA

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Introduction. Nowadays, HVAC systems are state of the art in buildings and cars. To compete with private transport, public transport operators have followed the trend and started to equip local public transport vehicles (like metros and trams) with HVAC systems. HVAC systems in trams can consume up to 10% of the whole electrical energy during the vehicle life cycle [1] and about one third of the total consumed energy during operation [2].

Only dynamic simulation models, where all relevant factors are considered, enable the simulation of energy consumption and passenger comfort [3]. An (existing) thermal simulation model of a tram is extended using on-site measurement data which were collected in Vienna by a tram.

Existing Model In the existing model various environmental conditions like outdoor air, radiation of the sun, wind speed and thermal load from passengers are considered [3]. The measured indoor air temperature is compared against the given set-point value by the controller and a control signal is calculated. The supply air is conditioned according to the control signal by the HVAC unit and blown into the vehicle body. With the supply air and environmental conditions a new indoor air temperature can be calculated. Therefore, the simulation model consists of three models: *a*) a controller, *b*) an HVAC and *c*) a vehicle model. The parameters of the model were achieved from climatic wind tunnel experiments. On-site measurement data was used to extend the existing simulation model.

Model Extensions The model is extended with the effect of the doorway during station stops and the indoor air temperature set-point is recalculated. The open doors have an effect on the indoor air, because indoor air is replaced with outdoor air. Explicit measurements are not possible due to security and vandalism concerns. The correction value was estimated using particle swarm optimisation.

The temperature set-point curve is derived from EN 14750-1. Closed loop simulation results of the indoor air temperature showed significant deviations from measurement results. An explanation is, that the actual set-point is modified by a further unknown effect. Parameters of the actual set-point function are estimated with a least-squares algorithm.

Simulation MATLAB is used as simulation platform. Measurement data were provided, sampling time is 10 s. One measurement day lasts for about 20 hours. Simulation of a whole measurement day takes about 6-10 min (including pre- and post processing) on a single core processor.

[1] Struckl, W. M. *Green Line - Umweltgerechte Produktentwicklungsstrategien für Schienenfahrzeuge auf Basis der Lebenszyklusanalyse des Metrofahrzeuges Oslo*. PhD thesis, Vienna University of Technology, 2007
[2] Haller, G. and Kreitmayer, M. *Climatic wind tunnel test for higher energy efficiency*. In: Railvolution, M-Presse plus, 38 - 40
[3] Hofstädter, R. N. and Kozek M. *Holistic Thermal Simulation Model of a Tram*. Conference on Computer Modelling and Simulation, proceedings, Brno, 2011.