Efficiency factors for space heating system in buildings

Christian Brembilla

Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av filosofie doktorsexamen framläggs till offentligt försvar i N300, Naturvetarhuset, måndagen den 22 oktober, kl. 13.00
Avhandlingen kommer att förvaras på engelska.

Fakultetsopponent: Prof., Bjørn Reidar Sørensen,
UiT Norges arktiske Universitet, Tromsø, Norway
The thesis focuses on the efficiency of the space heating system. In particular, the efficiency factors measure the efficiency of thermal zone. The efficiency factors measures how the energy is used in a space heating. Efficiency factors relatively close to one mean that the energy is used "efficiently", by contrast, efficiency factors close to the zero mean that the majority of the energy is lost to the outdoor environment. This method for the appraisal of space heating performance reads as if it is apparently simple and intuitive. In reality, the efficiency factor method has several pitfalls. The thesis provides tools, insights and remarks on how to apply the efficiency factor method to space heating systems equipped with hydronic panel radiator and floor heating respectively. Models of the latter heaters together with the multilayer wall were developed and validated to understand the reliability of their predictions. The hypothesis is that the heat stored in the building thermal mass and heaters plays a role in defining the building thermal performance and as a result in the appraisal of the efficiency factors. The validation is based on the sensitivity bands of the models' predictions. The heaters were tested in in a thermostatic booth simulator. Benefits and drawbacks of each model were highlighted to increase awareness of their use in the engineering fields. The results showed how the models accounting for the heat stored performed the charging phase. In addition, results of how the multilayer wall delayed and damped down the heat wave coming from the outdoor environment were presented with the appraisal of the decrement factor and time delay of the indoor temperature. The results of the efficiency factors analysis reveal how the weather affects the efficiency of each locality situated in cold climates. Lastly how different control strategies impact on the efficiency factors of space heating and its distribution system. To conclude, this study highlights the paradoxes around the efficiency factor method. The thesis proposes how such factors have to be interpreted by researchers and scientists tackling the lack of information around this topic.

Keywords
Efficiency factors of space heating, hydronic panel radiator, hydronic floor heating, multilayer wall, numerical modelling, room control volume, decrement factor, time delay, heat conduction, heat convection, heat radiation, heat storage, thermal inertia, Euler solver, Newton-Raphson method, synthetic weather file, feedback and feed-forward control strategies, adaptive control, validation methodology, uncertainty bands, robustness of model predictions, thermostatic booth simulator, differential sensitivity analysis, transient model of panel radiator with multiple storage elements, active thermal mass, benchmark performance indicator, linear regression model, calibration through uncertainty bands, hybrid model of low-energy building: law driven + data driven, outdoor temperature compensation/heating curve, solar radiation model, finite difference method, heat equation