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INFLUENCE OF HEATING ELEMENTS DYNAMICS ON ENERGY SAVINGS

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Dynamic heating computer simulations of one model typical living room heated alternatively by two types of heating bodies are presented in this paper. This contribution describes a numerical model of two heating elements (plate radiator and a new type of convector) showing different thermal inertia by using the TRNSYS software. The results show energy savings approximately of 10% for the new tested convector, where the thermal comfort is better in terms of reaching the required room temperature.

Keywords: *heating radiators, thermal inertia, energy savings, software TRNSYS*

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1. Introduction

Pressure to reduce the energy performance of buildings, embodied in current regulations or technical standards, forces the professional public to look for heat savings in all areas of energy management in buildings and their energy systems [10, 11]. Basic dynamic behavior of heating surfaces, or heating bodies are dealt with by a number of publications based on experiments or detailed CFD simulations [6–9]. These researches are mainly focused on basic transient phenomena and not on energy savings. Another publication presents an experimental validation of a numerical model of transient behaviour of heating surfaces by experiments [5].

Some researches dealing with energy savings achieved by the proper use of Thermostatic Valve (TRV) [2, 4] but do not treat the thermal inertia of heating bodies.

There are other publications dealing with room, radiator and TRV simulations, simplifying a thermal behaviour of a heating body to a lumped model – [1], state space and thermal resistance models – [3], but are not based on up-to-date detailed CFD simulations.

The present contribution focuses on the quantification of energy savings in the dynamic operation of heating radiators (HR) using TRSYS simulations of room and radiator thermal behaviour based on CFD simulations. This paper compares two heating bodies in a heated room under chosen dynamic operation conditions.

2. Theory of dynamic heating of buildings

In general, the need for heat output for room heating varies over time due to an influence of changing in heat losses, heat gains, and a user control. If the entire heating system is capable of responding accurately to these changes, the interior heating temperature is always exactly the required one and there is no temporary insufficient heating or overheating of the heated room. It is obvious, that every overheating is also automatically associated with a certain increased heat consumption.

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From the physical point of view, all the heating surfaces exhibit, differently, the heat inertia rate during heating up and shut-down, and thus show a certain degree of under-heating or over-heating in a room. It is obvious that the greater the thermal inertia of the heating surface is, the more significant the above mentioned phenomena are.

3. Definition of the case

The effect of hot water radiators thermal inertia was assessed by computer simulation of the thermal behavior for a typical room using the TRNSYS computer simulation code.

3.1. Specification of simulated radiators

Two different types of radiators – plate radiator [13] and a convector, [14] – of, about the same, heating output were chosen. The basic specification and comparison are shown in Table 1. It is worth noting, it is clearly seen that there a twice bigger compactness of the convector (heating output per m^3 of radiator volume).

Quantitative regulation of heating output is envisaged by a thermostatic valve for both radiators. The thermostatic valve is, for simplification, considered to be responding extremely quickly to the changing required temperature of the interior. It is assumed that we have a heating water at a constant temperature of 75 °C at the radiator inlet. These simplifications are taken to exclude the control system influence and to be considered only the influence of the radiator thermal inertia/dynamics.

3.2. Specifications of the heated room

The chosen room today is a common living room with 2 chilled walls and a window with a floor area of 20 m^2. The thermal and technical properties meet the requirements of the thermal resistance standard, and ventilation with infiltrations with a constant air exchange rate of $n = 0.5\ \text{h}^{-1}$ is considered.

3.3. Specification of boundary conditions

Simulations of 2 cases were performed – further [17].

Initially, a simplified shutdown simulation (jump-off of the heating water to the radiators) was performed to compare the maximum unwanted room overheating, due to their different heat capacity, at a constant room temperature of 20 °C.

Subsequently, a thermal behavior and heat consumption simulations were performed for the typical winter day. A sunny January day with an average outdoor air temperature of +2.2 °C in South Moravia was chosen to simulate thermal behavior. In the room the desired interior temperature was selected as shown in Table 2. The initial temperature of the room has been set to 19 °C.

The dynamics of the thermal behavior of the compared radiators were determined by the detailed non-stationary CFD simulation by their heating up and shut-down. The obtained results in this CFD simulation were used to create simplified 1D models of both OTs in the TRNSYS software. The simplified model can, among other things, distinguish thermal energy supplying by heating water to the radiator and the heating energy supplied by the radiator to the room.

4. Results and discussion

A comparison of the heat capacity of the radiators and the thermal energy delivered to the heated room during shutdown (jump off of the heating water supply) at a constant ambient temperature of 20 °C is shown in Table 3.

The obtained value of 77% is the theoretical, highest achievable heat savings when the convector is

Table 1. Specification of simulated radiators

Specification	Type	Heating output at 75/65/20 °C	Dimensions (height / length / depth)	Compactness	Connecting way
		[W]	[mm]	[kW/m^3]	
RADIK 20S CLEAN 80/90 cm	Plate radiator	1170	900/800/100	16.3	double-sided, diagonal
Tomton R1 with forced convection	Convector	1216	570/502/135	31.5	bottom connection

Table 2. Distribution of required temperature during a typical day

Activity	Sleep	Morning activity	Non occupied	Evening activity
Time [h]	21:00 – 4:00	4:00 – 6:00	6:00 – 16:00	16:00 – 21:00
Required temperature [°C]	19 °C	20 °C	17 °C	20 °C

Table 3. Heat capacity of radiators and the corresponding amount of heat delivered to the room

	Thermal capacity	Duration of the shutdown 3 000 s	Duration of the shutdown 10 000 s
	C	E	E
	[J/K]	[kWh]	[kWh]
Plate radiator	38 259.04	0.082	0.600
Convector	8 845.90	0.020	0.148
Energy saving [%]	77%	76%	75%

Table 4. Temperatures and overheating during the test day

OT	Room temperature at 0 h	Room temperature at 24:00	Room temperature real average per day	Room temperature required average per day	Average room overheating per day
	T	T	T	T	ΔT
	[°C]	[°C]	[°C]	[°C]	[K]
Plate radiator	19.00	18.69	18.74	18.33	0.41
Convector	19.00	18.24	18.55	18.33	0.21

Table 5. Heat energy balance for the test day

	Heat delivered to the radiator	Heat delivered to the room	Transmission heat losses of the room	Ventilation heat losses of the room	Solar heat gains	Room energy change per day
	E	E	E	E	E	E
	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]
Plate radiator	12.64	12.40	9.07	2.00	0.073457	1.40
Convector	11.16	11.16	8.97	1.98	0.075702	0.29
Saving [%]	11.7%	10.1%	1.2%	1.2%	3.0%	79.4%

used instead of the plate radiator during one shutdown course (theoretical). The saving will always depend on the dynamics of changes in the required heating output in the reality. The smaller the changes in reality become, the smaller the savings will be.

The results of the simulations for the typical winter day are shown in the following tables and graph. Table 4 shows both the desired and achieved temperatures and the average room overheating rate. It can be seen that a room heated by a more dynamic radiator – convector shows a more precise adherence to the desired room temperature and also a lower average unwanted overheating.

Table 5 summarizes the essential components of the room's thermal balance over the test day.

The results show that, although plate radiator has slightly lower heating output (compared to the convector), due its higher thermal inertia, it supplies more heat to the room, hence increases its overall heat loss. Because of the higher average room temperature obtained, when we are using the plate radiator, a lower degree of utilization of solar gains of the room is observed.

However, the most significant result is the heat savings of ~10% when the convector is used instead of the plate radiator.

The course of all significant variables for both heating modes of the room is shown in Fig. 1. The green areas present the heat savings using the convector, the red areas present the heat savings using the plate radiator.

5. Conclusion

The achieved results of the selected room by a more dynamic radiator (convector) show in this case:

- Lower heat loss of the room by transmission;
- Lower heat losses of the room by infiltration;
- Higher degree of utilization of solar gains of the room of ~3%;
- Lower average room overheating by ~0.2 K;
- Heat energy savings for heating ~10 %.

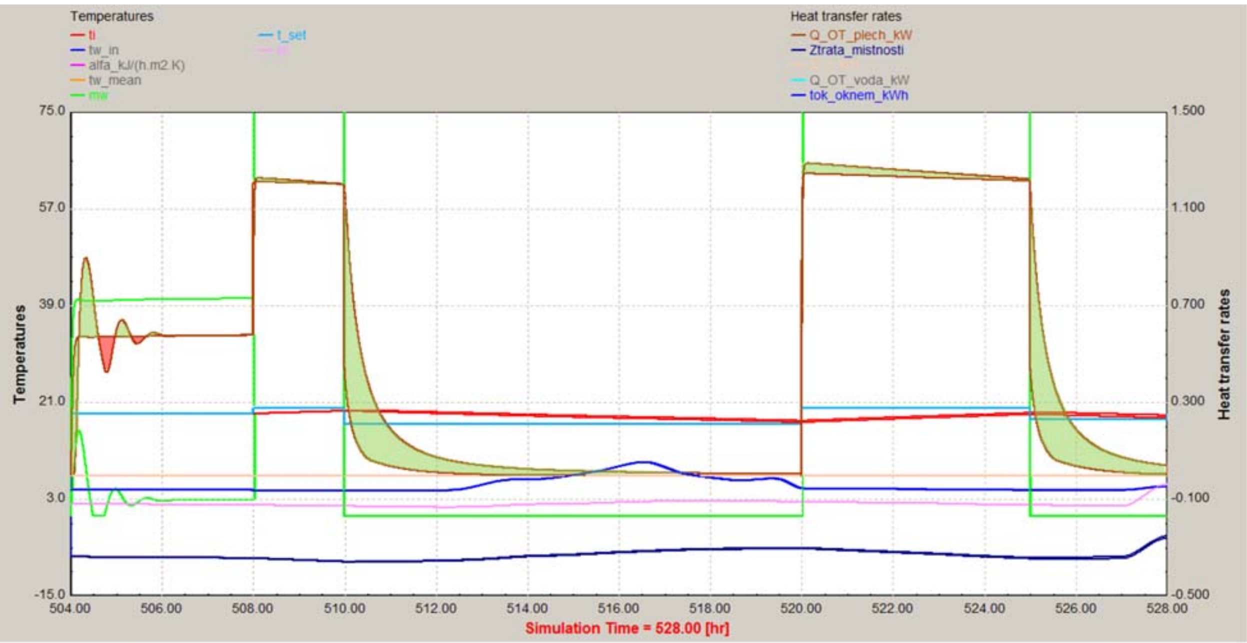

Fig. 1. The course of temperatures and heat fluxes during the test day

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References

[1] Xu, B., Fu L., Di H. (2008), Dynamic simulation of space heating systems with radiators controlled by TRVs in buildings. Energy and Buildings. Department of Building Science, School of Architecture, Tsinghua University, Beijing, 100084, China, 40(9), 1755–1764. DOI: 10.1016/j.enbuild.2008.03.004. Dostupné také z: https://www.scopus.com/inward/record.uri?eid=2-s2.0-44349156989&doi=10.1016%2fj.enbuild.2008.03.004&partnerID=40&md5=2159defe36d42e6327b356980a844201

[2] Monetti V., Fabrizio E., Filippi M. (2015), Impact of low investment strategies for space heating control: Application of thermostatic radiators valves to an old residential building: Application of thermostatic radiators valves to an old residential building. Energy and Buildings, DENERG, Politecnico di Torino, Corso Duca degli Abruzzi 24, Torino, Italy, 95, 202–210. DOI: 10.1016/j.enbuild.2015.01.001. Dostupné také z: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84939959517&doi=10.1016%2fj.enbuild.2015.01.001&partnerID=40&md5=d2c9ea09a01c881ad71a7d15a86ea403

[3] Ning B., Schiavon S., Bauman F. S. (2017), A novel classification scheme for design and control of radiant system based on thermal response time. Energy and Buildings, 137, 38–45. DOI: https://doi.org/10.1016/j.enbuild.2016.12.013. ISSN 03787788. Dostupné také z: http://www.sciencedirect.com/science/article/pii/S0378778816317583

[4] Boss B. (2015), Thermostatic radiator valves for multiunit residential buildings. HPAC Heating, Piping, AirConditioning Engineering. Danforss, Baltimore, MD, United States, 87(7), 16–20. Dostupné také z: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84939864546&partnerID=40&md5=2b1c481451fb37dc1c117f01ead926fb

[5] Thomas S., Franck P.-Y., André P. (2011), Model validation of a dynamic embedded water base surface heat emitting system for buildings. Building Simulation, 4(1), 41–48. DOI: 10.1007/s12273-011-0025-8. ISSN 19968744. Dostupné také z: http://dx.doi.org/10.1007/s12273-011-0025-8

[6] Boháč J., Bašta J. (2016), Temperature fields dynamic of panel radiators. Vytapeni, Vetrani, Instalace. ČVUT v Praze, Fakulta Strojní, Ústav Techniky Prostředí, Czech Republic, 25(1), 2–5. Dostupné také z: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84957661819&partnerID=40&md5=eec3adbf0a1321063d6573b1968541f6

[7] Bašta J., Vavřička R. (2006), Otopné plochy (I): Charakteristiky otopných těles. TZB-info [online]. 2006(2006), 1–9. ISSN 1801-4399.

[8] Jančík L., Bašta J. (2008), Setrvačnost náběhu a chladnutí otopných těles. TZB- info [online]. 2008(1), 1–3. ISSN 1801-4399.

[9] Jančík L., Bašta J. (2008), Posouzení dynamického chování otopných těles termografickou metodou. In: Jaroš, M. (Ed.). Simulace budov a technika prostředí 2008: Sborník 5. konference IBPSA-CZ. Praha: Česká technika – nakladatelství ČVUT, pp. 45–48. ISBN 978-80-254-3373-7.

[10] Petráš D. (2001), Nízkoteplotné vykurovanie a obnovitel'né zdroje energie. Bratislava: Jaga group, 271 p. ISBN 80-889-0512-5.

[11] Recknagel H., Sprenger E., Schramek E. (2001), Taschenbuch für Heizung und Klimatechnik (Handbook of Heat-

ing and Air-conditioning Technology). 70. Auf. München: Oldenbourg, 2017 s. ISBN 34-862-6450-8.

[12] Šikula O. (2011), Simulace provozních režimů otopných systémů s velkou akumulací. Vytapeni, Vetrani, Instalace. Praha, 2011(5), 12–14.

[13] Šikula O., Plášek J. (2010), Vliv nočního útlumu vytápění na roční potřebu tepla. Vytápění, větrání, instalace: odborný časopis Společnosti pro techniku prostředí. Praha: Společnost pro techniku prostředí, 19(3), 124–130. ISSN 1210-1389.

[14] Radik desková otopná tělesa. Katalog výrobce 12/2016. Korado, a.s. Česká Třebová. Dostupné z: https://www.korado.cz/produkty/radik.html

[15] Radiátor TOMTON R1. Technická specifikace. Dostupné z: http://www.tomton-radiators.com/produkt/radiator-tomton-r1/

[16] Šikula O., Charvát P., Adjlout L.; Ladjedel O. (2017), Modeling of radiators with mass flow control. In: Buildings and Environment: From Research to Application. Applied Mechanics and Materials. Switzerland: Trans Tech Publications, pp. 1–8. ISBN: 978-3-0357-1202- 5. ISSN: 1662-7482.

[17] Šikula, O., Charvát, P., Rozehnal, D. (2017), Dynamika otopných těles a jejich vliv na spotřebu tepla. In: Konference Vytápění Třeboň 2017. Novotného lávka 5, Praha 1 (ČSVTS): Společnost pro techniku prostředí, pp. 214–218. ISBN: 978-80-02-02712-6.