VARIABLE ZONAL MULTIPOINT ANALYSIS IN ENCLOSURE WITH TURBULENT TRANSPORT PROPERTIES IN ADVANCED THERMAL ENERGY REDUCTION TECHNIQUE

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ABSTRACT

Many recently developed energy-reducing strategies with respect to heat loads in residential interiors included in simulation programs possess extensive capabilities in handling these loads (gains or sinks) for each zone – spatial unit designed for maintaining moist air thermodynamics there [1], [2]. We have taken up procedure, which was primarily dedicated to the influence of the sensor positions of a room model [3]. In the study were proposed some important hints regarding the most desirable sensor locations, which in turns enables to set up mathematical model of the room accurate enough to be usable testing tool for room controllers (thermostatic control). Up to this point was our methodology analogous [4]: with the model components, yielding local values of heat transfer coefficients (radiative and convective) on room-faced wall surfaces, an assessment was made about heat load and (vertical) temperature profile out from handful checkpoints. The proposed technique retrieves a portion of desired (local) air velocities PS and draft risk PD (Fig.2), [3], while solving Navier-Stokes equations (NSE) at meridian – surface cross cut area of occupied space in two-dimensional (2D) analysis and turns them immediately as input variables into three-level-decision control algorithm in order to reduce spatial heating (cooling) energy.

Summarising the results, time-consuming numerical calculation of NSE does not retrieve data ‘on-time’, such as turbulence intensity and indoor air velocity components in 2D-calculations over the meridian cross-area within the occupied space, Fig.3, both needed in either empirical or theoretical models (PMV, PPD) with sufficient accuracy. Rather, including them into controller’s input signals can contribute in reducing heating loads. This would happen, when for inst. convective heat transfer occurs along adjacent air layers onto colder wall surfaces (outside walls) in contrary to buoyancy force. Managing slower their movement means certain boost in thermal resistance and overall U-value, eventually. Therefore, purported goal of operative switching of guarded qualities throughout occupied space to a zone singled out from the occupied space could still benefit for heating energy reduction.

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The ability to adjust thermal comfort parameters, air velocity and air temperature – in a ventilated/heated space could involve statistical parameters that include human thermal sensation acquired through (occupants') voting. Such empirical value on the vote-basis may represent desired value across of occupants' possible differences. In control level, PS, or a PI-controller (P-proportional, S-sum part) output seeks to maintain desired value of effective temperature T_e (pink area in Fig.1) [1] with quadratic criterion $\min \; I = \sum_{k=0}^{\infty} e^2(k)$ where $e(k) = w(k) - y(k)$, $k = j.\Delta\tau$, j=0,1,2…, while keeping the secondary thermal comfort parameter – either PD or PS - in a bay area IV, Fig. 1, graphically marked with error band around targeted floating value.

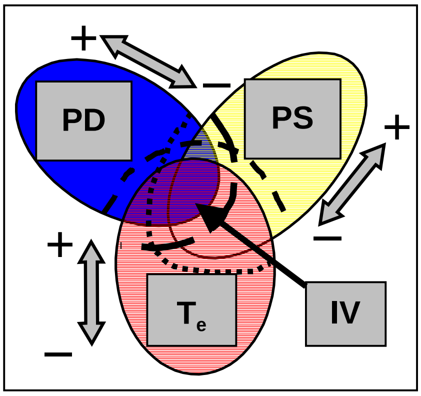

Fig.1 Thermal comfort area (indicated in cross-section as IV) represents desired states of progressive controlling of turbulence intensity (PD-index) and desired local air velocity (PS-index) chosen under given indoor thermal environment (T_e – effective temperature). In joint areas are indicated also respective error bands (dashed lines).

The PD index – a blue zone in Fig.1 - is evaluated as a steady function PD = f(τ = 18 p.m.; h = 1.1m), h - distance above floor level, for laminar flow range (air turbulence ~ 0 %) according to conventional formula ($v(\xi,\psi,\tau)$ - local mean air velocity [m/s]):

$$PD(\xi,\psi,\tau) = PD\left[T_a(\xi,\psi,\tau), v(\xi,\psi,\tau), Tu(\xi,\psi,\tau)\right] \qquad (\%) \qquad (1)$$

where turbulence intensity value Tu in Eq.(1) becomes approximated by

$$Tu(\xi,\psi,\tau) \equiv {100\, v_{SD}(\xi,\psi,\tau)} \big/ {v(\xi,\psi,\tau)} \qquad (\%) \qquad (2)$$

in order to describe how fluctuating the air velocity is ($v_{SD}(\xi,\psi,\tau)$ - standard deviation of air velocity [m/s]). Both variables are calculated in the immediate occupant(s) position, therefore draught rating (%) can be reliable. Tu value in Eq.(1) becomes Detailed the turbulence intensity map, with any approximation equation is needed only by occupant(s) closest environment. Because the Tu value is included in both considered parameters, namely PS and PD indices, only one (index) may be requested [2], [3], however, the other parameter – PS area – in Fig.1 provides yet another options for the controller – to set air velocity v as result from actual air temperature Ta.

As time-varying qualities determine the PD-index, Eq.(1), boundary conditions supplied to CFD model must be treated accordingly [4]: Fig.2 shows block scheme, in which are processed both CFD-velocity field calculation mentioned above and the thermal comfort parameter: PD-index (resp. PS-index) as final outcome. We employed a flexible tool at Matlab environment Simulink in order to proceed with the air velocity vector calculation (input block [v,t] on the left in Fig.2).

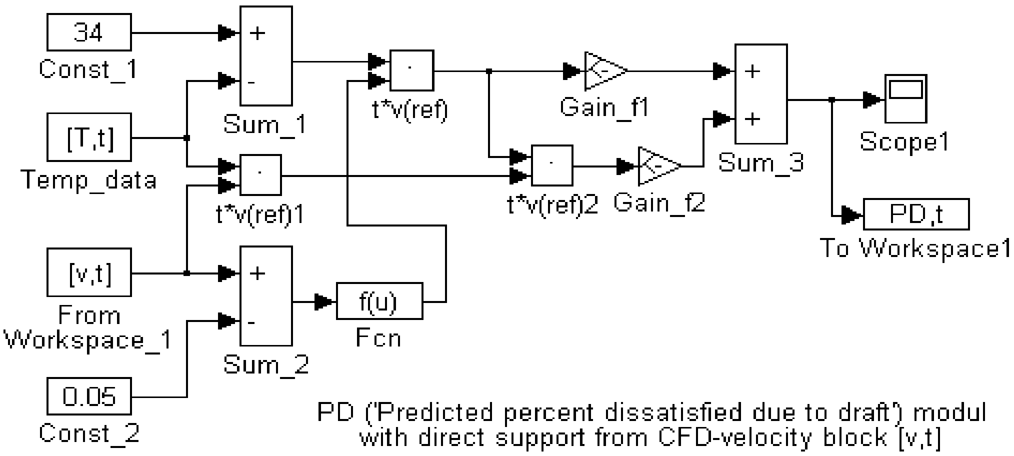

Fig.2 Block-diagram of PD -index evaluation with direct inputs of CFD -vector outcomes.

Adjustable air velocity represented by yellow *PS-index area* at Fig.1 requires known values in the immediate vicinity of occupant(s). That is possible by calculating them from velocity profiles obtained in both horizontal, as well as vertical directions (Fig.3) and to retrieve the maximal velocity magnitude in form of $|\vec{\mathbf{u}}(\xi,\chi)| = \sqrt{\mathrm{u}(\xi,\chi)^2 + \mathrm{v}(\xi,\chi)^2}$ there.

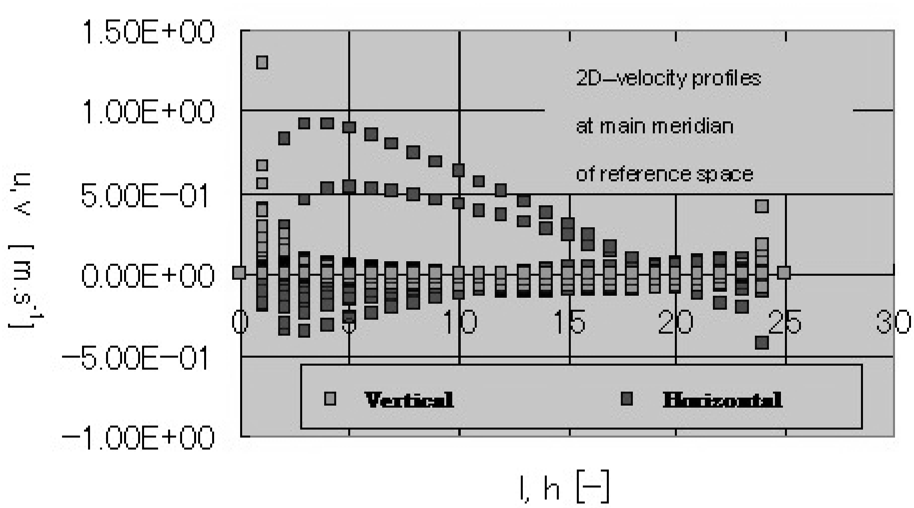

Fig.3 Indoor air velocity profiles in investigated space's main meridian cross-cut induced by thermal buoyancy. 2D-velocity field of air movement; ACH = 2.0.

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