swift

Thermal Comfort Assessment of Indoor Environments Using SWIFT

SWIFT provides all features for the assessment of thermal comfort of indoor environments. Different designs of heating and air conditioning can be judged based on standard thermal comfort indices. The general 3D capabilities of SWIFT together with the comfort enhancements enable simulations of real conditions in a fast and efficient manner.

Human Comfort
The factors that determine human comfort are numerous and complex, but by controlling certain key parameters, indoor space can be made quite comfortable. Important parameters include thermal comfort (temperature, relative humidity, thermal radiation and local air velocity), indoor air quality (air change rate and fresh air delivered to breathing zone), and acoustic quality (noise criteria or room criteria). Some parameters, such as the activity level and dress of the occupants can play an important role, however the design engineer has no control over these factors and as such average values have to be assumed.

Thermal Comfort Assessment
A number indices and standards has been published for the assessment of thermal comfort. The popular ones, PMV, PPD, DR, ADPI (definition of these indices are below), are used for SWIFT calculations.

The most general method of assessing thermal comfort employs the equations for predicted mean vote (PMV) and predicted percentage dissatisfied (PPD) produced by Fanger and defined in ISO7730. These equations are based on empirical investigations of how people react to different environments. It is well known that different people have different perceptions of climates in buildings, and that any given climate is unlikely to be considered satisfactory by all. In fact it is considered that satisfying 80% of occupants is good, therefore a PPD of less then 20% is the design target.

Both PMV and PPD provide measures of the likely response of occupants. The PMV index ranges from –3 (very cold) through 0 (thermally neutral response) to +3 (very hot). The PPD index is directly related PMV (some consider it redundant), however, from an engineering stance, it is useful to have both available. While PPD provides the information as to whether the environment is likely to be acceptable, PMV tells us what the problem is – e.g. whether it is too hot or too cold.

$PMV\ (0.303e^{-0.036M}+0.028)((M-W)-H-E_c-C_{res}-E_{res})$ Where M – metabolic rate, W – external work, H- dry heat loss, E_c – evaporation heat exchange at skin, C_{res} – respiratory convective heat exchange, E_{res} – respiratory evaporate heat exchange

$PPD = 100-95e^{-n}$ [%], where $n= 0.03353PMV^4+0.2179PMV^2$ The number of parameters used to produce these measures show the complexity of the human response to the environment. PMV and PPD include air temperature, mean radiant temperature, air velocity, vapor pressure, clothing level, metabolic rate and external work rate. Standard ISO7730 recommends $-0.5<PMV<0.5$ and PD≤10%. An additional parameter which measures draught is the Draught Risk (DR) which defines the percentage of people predicted to be bothered by a draught. Since draughts are considered by many to be extremely annoying it is important for the CFD analysis to produce some measure of it. The DR can be calculated by the following equation:
$DR = (34-t_a)^{0.62}(0.37.v.T_u+3.14)$ [%]
where

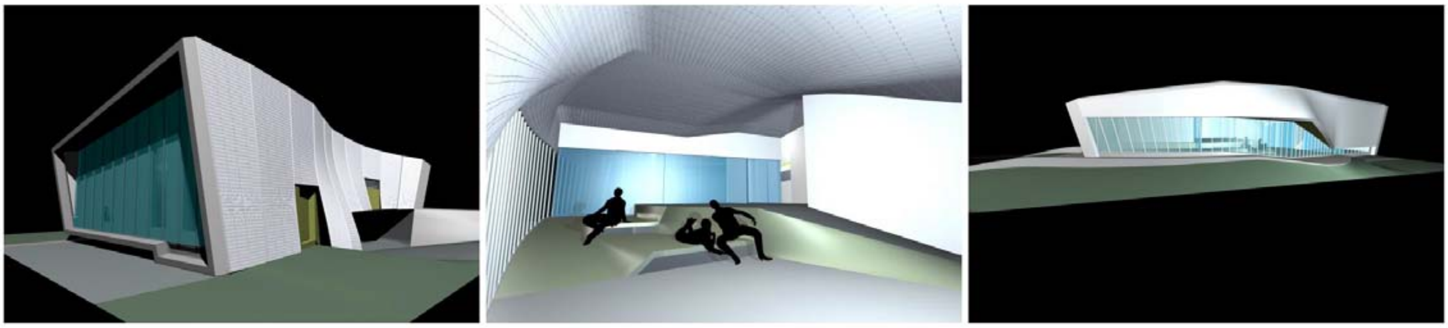

Figure 1: Family house design by Elastic

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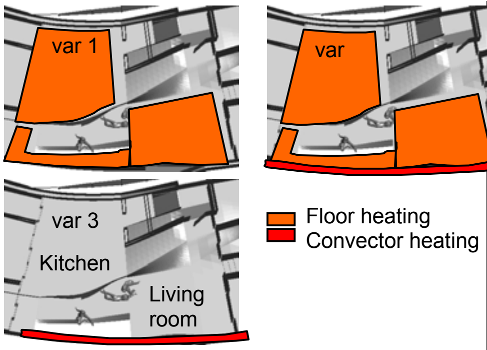

Figure 2: Boundary conditions for each heating variant

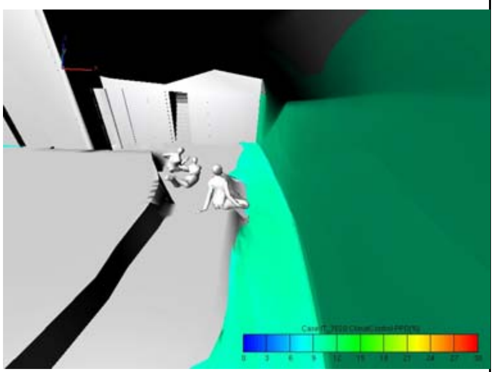

Figure 3: Isosurface of PPD 10% - floor heating

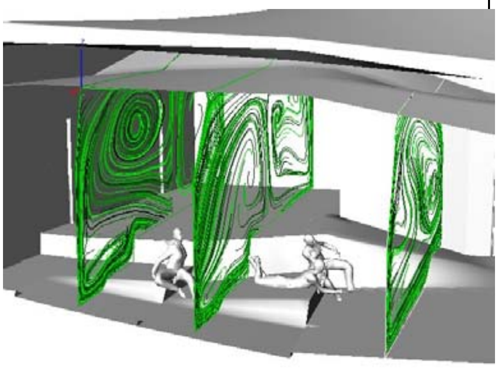

Figure 4: Streamlines – floor and convector heating

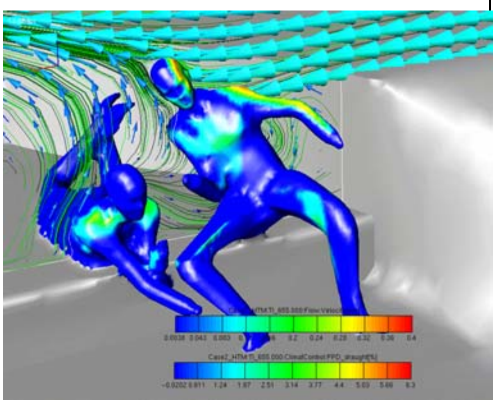

Figure 5: DR-Index - floor and convector heating

t_a and v are local air temperature and velocity, Tu local turbulence intensity.
The comfort limit for this parameter is 15%.

Another evaluation concept is called effective draft temperature T_d and Air Diffusion Performance Index (ADPI), which uses the local air temperature and velocity to determine a relative feeling of coolness and to measure the uniformity of the space in terms of the proportion of the volume within prescribed criteria.

The effective draft temperature is defined as: $Td = T_p - T_m - 7.66 (v - 0.15)$ Where T_p and v are local temperature (°C) and velocity (m/s); T_m is mean air temperature (°C)
Comfort studies have shown that the effects of temperature and velocity on comfort will be acceptable if T_d is kept between –1.7 and +1.1°C and local air velocity is lower than 0.35m/s. The Air Diffusion Performance Index (ADPI) of a space is the percentage of locations in a space in which the limits of the effective draft temperature are met. In other words an ADPI of 80% means that 80% of the locations in the space have an effective draft temperature of –1.7 to +1.1°C. Obviously, an ADPI index of 100% would be the ultimate condition, but efforts required to achieve this condition would often cost much more than the added benefit.
ASHRAE recommends an ADPI of at least 80%. ADPI less than 70% could be indicative of either localized drafts or regions of poor air circulation (or both). Poor ADPI will likely result in a space not meeting the comfort requirements of ASHRAE standard 55 (1992), in a number of locations within the space and furthermore can also result is slow system response to changing loads, as the areas of poor circulation can include the thermostat, which relies on a well mixed room to properly sense room temperatures and loads.

Application Example
The evaluation of 3 different heating concepts for a residential dwelling is described as an example for a practical SWIFT application. The room layout and the 3 heating variants – floor heating, convector heating and mixed heating - are shown in Fig. 1 and 2.

The simulations for the variant with floor heating are identifying regions of the occupying area as uncomfortable domains. The assessment by the PPD index (Fig.3) shows regions with a value of more than 10% and indicates the need for an improvement of the heating .

Heating layouts with convector or mixed floor/convector heating are significantly improving the indoor environment. A big vortex (Fig. 4) is generated in both variants with negligible areas of secondary motions. These overall vortex structure enhances the air mixture and results in a quite uniform temperature distribution. Local velocities are sufficiently low and the DR index stays well below 15% (Fig. 5).

From a fluid dynamics standpoint the convector and mixed heating can be recommend for the investigated dwelling house. The final choice will be strongly influenced by cost factors.

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