

Advanced Ventilation Systems–Theory, Practice, Limitations and Solutions



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Abbreviations: RA: Recirculated Air; FA: Fresh Air; MV: Mixing Ventilation; DV: Displacement Ventilation; UFAD: Under Floor Air Distribution; ACV: Air Curtain Ventilation; TAC: Task Ambient Conditioning; PV: Personalized Ventilation; SV: Stratum Ventilation; IAJS: Intermittent Air Jet Strategy

Editorial

The task of HVAC systems is to offset indoor thermal load and/or ventilation load. Indoor thermal load can be offset by either convective-dominant way or radiant-dominant way. In convective dominant way, system recirculated air (RA) is thermally conditioned in term of temperature and humidity. Indoor ventilation load has to be offset by convective dominant way, in which outdoor air is filtered, thermally conditioned and thus it becomes fresh air (FA) to dilute indoor pollutants such as CO₂. FA can be supplied in different ways separately or compositely with RA, which is the main focus of this paper.

FA and RA can be well mixed and supplied together from ceiling or upper space of indoor environments, which is mixing ventilation (MV). Two typical systems are all-air system and fan coil plus FA system. Some alternatives such as active chilled beam can also be found. MV is supposed to create uniform indoor environments in term of thermal and air quality aspects. MV was most widely used system in engineering practice. Without making full use of FA, air with mediocre quality is inhaled by human occupants. To avoid energy waste, it is also unnecessary to thermally condition spaces without intensive human occupancy. For the aforementioned reasons, advanced ventilation strategies have been presented mainly after 2000, tested in laboratories and applied to engineering projects.

Displacement ventilation (DV) originated from Nordic countries, which was mainly used to industrial workshops with high

headroom's in initial stage. The concept was used to other types of buildings, design guidelines were relatively mature and successful engineering projects can be found. Air is mainly supplied from floor mounted DV cylinders at very low velocity. Thermal buoyancy, instead of supply air momentum, is the major driving force to move air upwards from floor airake. Obvious vertical temperature gradient exists. However, air duct must be extended and connected with floor mounted DV cylinders. Once FA and RA are supplied together from DV cylinders, large number of DV cylinders must be installed to keep enough supply air outlet area and low supply air velocity. For spaces with large spans, hollow pillar or raised access floor must be used as connected air duct in core zones. Under floor air distribution (UFAD) can also achieve displacement mode ventilation by reducing supply air velocity.

As a solution, Li presented the concept of vertical wall attached airflow in 2005, which is based on MV, DV and impinging jet flow. The concept was named air curtain ventilation (ACV) later [1,2]. Mixture of FA and RA is first delivered, and attaches to vertical wall or pillar surface then moves downwards due to the Coanda effect. As the air jet with high momentum approaches the floor, it impinges the corner, and then separates from the vertical wall or pillar surface and reattaches to the floor to generate air lake. Supply air velocity, and distance between vertical surface and centre of supply air diffuser were mainly studied. Compared with DV, similar temperature and velocity fields can be achieved and big supply air flowrate problem can be solved. Therefore, a lot of successful

engineering projects can be found in buildings with high space height such as city halls, metro stations, and hydro power stations along Yangtze River and Yellow River.

For indoor built environments without high and large spaces, displacement mode ventilation is not so effective and suitable. The concept of human centered design is emphasized. Task ambient conditioning (TAC) concept originated in 1990s and was developed to personalized ventilation (PV) in 2001 by Fanger [3]. PV supplies 100% FA into human breathing zones, avoids cross infections by individually controlled FA, intensifies task zone control and less intensifies ambient zone control to achieve energy efficient thermal comfort. Laboratory tests were mainly performed under temperate and cold climates. After Fanger's sabbatical leave in Singapore, PV started to be widely tested under hot and humid climates such as tropic Singapore and sub-tropic Hong Kong. To the authors' knowledge, PV is suitable for indoor spaces with fixed occupant workstations, low occupant density and high risks of cross infection. Major limitation is the extended PV air ductwork in the occupied zone and the need for a secondary background ventilation system, which hinder its practical applications. Some trials, such as ceiling mounted coaxial nozzle instead of desktop mounted PV, were performed. However, mature design guidelines are necessary and under developed.

Lin proposed stratum ventilation (SV) in 2005, which supplies air to human breathing level (1.1 m) and generated sandwich airflow field in indoor environments [4]. SV is more suitable for spaces with high occupant density such as classrooms and open offices. The ratio of task area over ambient area, as a new evaluating

index, is crucial to justify the application of SV or PV. Intermittent air jet strategy (IAJS) was presented by Sandberg recently, which is based on his previous studies regarding single row of confluent jets used in classrooms with high occupant density [5]. It is only under chamber test stage. SV can adopt the IAJS technology to increase the length of its supply air jets.

Different advanced ventilation strategies, mainly including DV, UFAD, ACV, PV, SV and IAJS were summarized in terms of their theory research, practical application, main limitations and corresponding solutions. Different advanced ventilation strategies suit different types of applications. Because of the limit in length, highly summarized contents were presented here which will be elaborated in another review paper. The purpose is to communicate with HVAC researchers, engineers, policy makers, manufacturers, etc. Discussions, comments and suggestions are the most welcome!

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