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Mini Review

Ultrasonic Humidifier Applications in HVAC system

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Introduction

Malaysia and Sri Lanka are facing energy crisis like several other developing countries. Cost of energy never going to decrease in near future, leading the focus toward optimization and efficiency of the systems. It has been recorded in past that cost of generating energy is much higher than the cost of improving efficiency up to certain limit. Energy usage indicate that more than 42% consumed by HVAC systems in 2010 comparing with total energy consumption in commercial buildings [1]. Buildings are constructed to provide a safe and comfortable internal environment at all variation of external conditions. The success of a building design depends on economically maintaining the desired interior conditions to some extent. Although control of inside conditions is usually caused by the active heating and cooling systems, the selection of HVAC must start with an efficient system. The main challenge of building Heating, Ventilating and Air-Conditioning industry nowadays is creating HVAC solutions that are able to provide comfortable and healthy indoor environment while consuming low energy.

Modern society people spend about 90% of their lives indoors [2] as a consequence, there is an initiation in last decade to shrink the HVAC energy consumption without compromising the thermal comfort and IAQ standards defined by ASHRAE, and increasing energy efficiency in buildings has been recognized as one of the fastest and most cost-effective way to save energy and reduce greenhouse gas emissions [3]. Madhavi et al. [4] identified that thermal comfort as a six-dimensional topological solid, having at least six parameters that give dimensions to any unique thermal condition. Two of these, activity and clothing are specific to an individual while air temperature, humidity, air velocity and radiation are the properties of the environment. Humidity level drop drastically during winter which leads to dry skin, irritated eyes, nose, and throat, nose bleeds and nasal congestion to humans [5] adding humidifier is an effective way to provide humid climate to achieve thermal comfort zone as per ASHARE 55-2010 standard. Especially in some cities in Asia RH value drops below 20%, where they forced to equip with indoor heating systems in winter [6-10] combining with indoor humidifier.

Ultrasonic humidifiers are known as energy efficient humidifier system because of its well-known very little energy usage and high-quality moisture and its better performance in close environment where required less maintenance [11]. Ultrasonic humidifier operates greater than 20kHz frequency according to the of pressure pulsation. Ultrasonic applications are classified as low and high intensity applications and high-intensity ultrasound has low frequencies from 20 to 40kHz. The ultrasonic humidifier has transducer which is a piezo electric crystal convert electronic high frequency signal into high frequency mechanical oscillations. When a piezo-electric crystal immersed in water, water tries to follow the high frequency oscillating movement of the crystal but cannot. This lead to a momentary vacuum and the cavitated water through the surface produce very fine mist, which is called ultrasonic atomization [10]. Ultrasonic humidification is an adiabatic process because evaporation happens between atomized water mist and control environment more importantly mist will be there in that closed system. Conventional bubble-type humidifier and ultrasonic atomization compared by Sung et al. [12] and concluded that better controllable humidity achieved by adjusting either the driving voltage or the heating temperature by using ultrasonic atomization.

Comparing ultrasonic humidifier with traditional steam humidification system, ultrasonic humidifier preferred due to safety, economy and convenience in indoor application [13-16]. Ultrasonic humidifier is utilized directly to the indoor environment as portable humidification system [15], or as assembled with air-conditioning systems [13,14]. In air-conditioning system, supply air either humidified in ventilation ducts by using spray or free stream flow over water pool before being force to supply into air conditioning evaporator [13]. However, portable humidifier placed in living indoor environment and humidify surrounding air directly and then send into air conditioning system for further comfort control [16].

Although humidifier have many benefits it might have a scarcity about specific minerals to aerosolize, water containing minerals may result in expulsion of "white dust." [17,18]. If children inhale the white dust, it will deposit in the lungs. This was found experiment were done on mice while exposed to few humidifiers, ultrasonic humidifier also one of the humidifiers used in the study [19,20]. Ultrasonic humidifiers efficiently aerosolize 85%-90% of dissolved minerals present in the water used to fill the humidifier

[18,21]. To verify that Sain et al. [15] used ultrasonic humidifier to fill with waters of varying mineral content and hardness and found that it can cause modes ranging between 109 and 322 nm in diameter. It is important to note that even a low TDS (75 mg/L) tap water can produce approximately three times more inhalable particles than deionized water. This indicates that consumers should be advised to use deionized or distilled water to fill ultrasonic humidifiers to reduce exposure to inhalable particles [15]. However, this lead to new research branch that, more research is need to develop low cost distillation methods to extract minerals in case of large scale industrial applications.

Similar to Air Flow Distribution (AFD), humidification and mixing between water droplet, or mist with dry air also is a vital part in HVAC systems. The spread of droplets, or mist will enhance its presence of low RH values. Under dry conditions, droplets would dry out and become fine droplet nuclei, or mist further contributing to farther airborne transmission [22,23]. While the air inlet condition changes evaporation and transmission pattern also change inside the distribution ducts and spreading to atmospheric air. This distribution combining with mist are not 'dry', may produce 'wet' sensation to humans upon contact and cause discomfort for the users. Belarbi et al. [24] found that spray can cause larger diameter droplets, if only a fraction evaporates, and remaining droplet size can cause sensation of wetness and reduce the cooling performance and effectiveness and it is a case of for RH can reach 100% according to Huang et al. [25].

Pu et al. conducted numerical simulations to study the steady state air temperature and relative humidity distributions in a ventilated room with ultrasonic humidification system installed in ventilation ducts [14]. During the indoor humidification process, water droplets and water vapor were generated by ultrasonic humidifier simultaneously [16], resulting in complex and non-uniform thermal environment (temperature and humidity). Even though, CFD is a powerful and reliable source in fluid area, research work on simulating the moisture transferring while absorbing and transferring as convection in two phase flow are limited. Water spray system was used by Suresh Kumar et al. [26,27] to study the heat and mass transfer characteristics between spraying mist bubbles and surrounding air by conducting experimental and CFD simulation. They concluded that smaller nozzle size with higher pressure are better than larger ones with smaller pressure. However, it's contradicts with energy optimization and efficiency approach and their CFD model showed ±30% and ±15% error in parallel and counter spray arrangement respectively.

However, experiments should be done and published as data set for validate simulation models, especially for CFD researchers. Because most of the CFD models were validated by using Suresh Kumar et al. [26] study and now more accurate measuring devices and real time data collecting techniques are available. Hamid et al. [28] one of them who used Suresh Kumar et al. [26] experimental data for validation and redefined the solver mathematical model and analysed impact of air inlet dry bulb temperature, humidity, air velocity, inlet water temperature, and droplet size distribution. They concluded that inlet dry-bulb air temperature has a strong effect on the amount of sensible cooling, moisture content of the inlet air influences the rate of evaporation, lower value of the inlet air velocity relative to the droplets improves the cooling performance, constant value of the inlet dry-bulb air temperature, reducing the inlet water temperature improves the performance of the system, and diameter of spray is reduced from 430 to 310 μm, the cooling performance of the system is improved by more than 110%. Later, Hamid et al. [29] covered the rest of gap left in CFD validation by analysing Grid-sensitivity analysis, Comparison of CFD results and wind-tunnel experiments, Impact of turbulence models, Impact of number of particle streams, and Impact of spray nozzle angle. Reader should note that these studies never done experimentally yet and especially there is gap for ultrasonic humidifiers will be filled by this author in future.

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