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An Analysis Relation Among the Main Parameters in the Spraying Water Room of Air Conditioning Systems

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ABSTRACT

The way in conducting air with spraying water is now in common use in air conditioning systems of textile mills, but the relation among some parameters to be designed is not clear. This paper analyses the process and gives out the calculating formula of the main parameters in the spraying water room dependent on the heat and mass transfer, two-phase flow and energy equations.

In the formula, each parameter to be selected in designing shows evidently its effect to the efficiency of heat and mass transfer. Through contrasting with experiments, the calculating results are satisfactory. Using the formula, the structure of the spraying water room is also rationally improved if the quantity of air flow to be conducted is enlarged.

L'ANALYSE DES RELATIONS ENTRE LES PRINCIPAUX PARAMETRES DANS LA CHAMBRE DE JET D'EAU DU SYSTEME DE L'AIR CONDITIONNE

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RESUME

Le conditionnement d'air au moyen du jet d'eau s'employe largement dans les usines textiles, pourtant, les relations entre les principaux paramètres dans la chambre à jet d'eau ne sont pas manifestes au cours des études. Le texte présent analyse le processus de l'air traité par le jet d'eau et, suivant la nature de la transmission de chaleur et l'équation de l'énergie, donne la formule des relations des principaux paramètres dans la chambre à jet d'eau.

Dans la formule, chaque paramètre se révèle clairement influent sur l'efficacité de la chaleur pendant le traitement par le jet d'eau. La comparaison des résultats des calculs avec ceux des essais donne les résultats satisfaisants. Si on veut augmenter le volume d'air à traiter dans la chambre à jet d'eau, on peut employer cette formule qui constribuera à améliorer d'une façon rationnelle la structure de la chambre et les paramètres initiaux.

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SYMBOLS

Q	heat transfer
Cp	constant-pressure specific heat of air
T	temperature
R	latent heat per unit mass of water
D	containing water vapour in per unit mass of dry air
t	time
F	total surface area of drops
α	heat transfer coefficient
σ	moisture-transfer coefficient
X	length of spraying water room
L	average diameter of drops
Y	containing water in per unit mass of air
Nu	Nusselt number
Re	Reynolds number
A	difference ratio of specific enthalpy or temperature
M	mass
N	number of drops
Z	density
S	cross section area
V	velocity
P	pressure
H	specific enthalpy
W	mass flow
Ro	thermal conductivity of air
Ps	pressure of spraying water in spraying head
U	ratio between water and air, Ww/Wg

SUBSCRIPTS

g	air
w	water
b	saturation point on drop surface
a	mean value

INTRODUCTION

The process of conducting air with spraying water is in common use in air conditioning systems of textile mills to keep certain temperature and relative humidity in shops, but the parameters; quantity of spraying water, water temperature, air flow velocity, average diameter of drops, structure sizes of spraying water rooms and so on, are chosen through tests and experience formula. The optimum condition is not easy to be reached in motion, design and adjusting, which consume more energy. This paper analyses the process and gives out the calculating formula of main parameters in the spraying water room. In the formula, each parameter shows evidently its effect to the efficiency of the heat and mass transfer. Through contrasting with experiments, the calculating results are satisfactory.

INFERENCE OF THE CACULATING FORMULA

According to heat and mass transfer equation, air flow in a differential length of the spraying water room, shown in Fig. 1, gives out the heat transfer

$$dQ = \left[Cp(T-Tb) + R(D-Db)\right] \cdot \sigma \cdot dF \cdot dt \qquad (1)$$

where $\sigma = \frac{\alpha}{Cp}$ $\qquad dt = \frac{dX}{Vg}$

If the average diameter of drops is L, the number of drops is N, the containing water is dMw and the mass of air is dMg in dX, the ratio between the mass of water and the mass of air is

$$Y = \frac{dMw}{dMg} \qquad (2)$$

where $dMw = \frac{\pi}{6} \cdot L^3 \cdot Zw \cdot N$

$dMg = Zg \cdot S \cdot dX$

The surface area of drops

$$dF = N \cdot \pi \cdot L^2$$
$$= \frac{6Zg \cdot Y \cdot S \cdot dX}{L \cdot Zw} \qquad (3)$$

Substituting (3) into (1), we obtain

$$dQ = \frac{6 \cdot \alpha \cdot S \cdot Y \cdot Zg}{Cp \cdot L \cdot Zw}\left[Cp(T-Tb) + R(D-Db)\right] \cdot dX \cdot dt \qquad (4)$$

Because the process of the heat and mass transfer between water and air in the spraying water room is isobaric, the quantity of heat, is obsorbed by the air crossing the differential length, is the enthalpy increase of air, or the energy equation

$$-dQ = dH \cdot dMg$$
$$= Wg(Cp \cdot dT + R \cdot dD) \cdot dt \qquad (5)$$

Put (4) and (5) together, we obtain

$$dX = \frac{-Cp \cdot L \cdot Zw \cdot Wg}{6 \cdot Y \cdot S \cdot \alpha \cdot Zg} \quad \frac{Cp \cdot dT + R \cdot dD}{Cp(T-Tb)+R(D-Db)} \qquad (6)$$

where $\alpha = \frac{Ro}{L} \cdot Nu$ $\qquad Wg = S \cdot Vg \cdot Zg$

If the Tb and the Db are mean values, or the mean value of the specific enthalpy of water, we integrate (6)

$$Xo = \frac{Cp \cdot L \cdot Vg \cdot Zw}{6 \cdot Nu \cdot Y \cdot Ro} \cdot \ln \frac{Hg_1 - Hwa}{Hg_2 - Hwa} \qquad (7)$$

The formula will become the limit, o/o, when the process is iso-enthalpy because of $Hg_1 = Hg_2 = Hwa$. In order to infer the formula of the iso-enthalpy process, the condition of the iso-enthalpy is in use and the infering process is same as above. The only differece is that the heat transfer of the heat transfer equation is the quantity of heat obsorbed by the dry air, not air. The heat transfer and energy equations become

$$dQ = \alpha(T-Tb) \cdot dF \cdot dt$$
$$-dQ = Wg \cdot Cp \cdot dT \cdot dt$$

According to the infering process as above

$$Xo = \frac{Cp \cdot L^2 \cdot Vg \cdot Zw}{6 \cdot Nu \cdot Y \cdot Ro} \cdot \ln \frac{Tg_1 - Tb}{Tg_2 - Tb} \qquad (8)$$

Contrasting (7) with (8), it is well known that $(Hg_1-Hwa)/(Hg_2-Hwa)$ and $(Tg_1-Tb)/(Tg_2-Tb)$ are similarly the efficiency of the heat and mass exchange, which is decided by the difference ratio between the starting and final states in the designing process of air conditioning on the H-D chart, then (8) and (7) merge into a general formula

$$Xo = \frac{Cp\cdot L^2\cdot Vg\cdot Zw}{6\cdot Nu\cdot Y\cdot Ro}\cdot \ln A \qquad (9)$$

This is the calculating formula of the heat and mass transfer in spraying water rooms, which shows evidently the relation among the efficiency of heat and mass transfer A, the length of spraying water rooms Xo, the velocity of air flow Vg, the average diameter of drops L, the Nusselt number Nu, and the containing water in per unit mass of air Y.

The average diameter of drops, the Nusselt number and the containing water in per unit mass of air must be known when culculating. The average diameter is dependent on your way in spraying water and conditions. The Nusselt number is dependent on

$$Nu = 2 + 0.386(Pr\cdot Re)^{0.5} \qquad (10)$$

The containing water in per unit mass of air is dependent on the distribution of drops in the spraying water room, which is calculated by the two-phase flow.

CALCULATING EXAMPLE

The data measured in Second Cotton Mill, Beijing, China

	Vs: $\frac{m}{s}$	Ps: $\frac{Kg}{cm^2}$	U	Tw_1	Tw_2	Hwa	Hg_1	Hg_2	Xo
Js: China	6.00	2.50	0.60	18.1	20.8	13.3	17.7	15.0	1.84
Luwa:Swiss	5.99	2.60	0.66	14.9	18.9	11.1	17.5	13.2	1.80
Luwa:Swiss	6.56	2.60	0.51	14.6	18.8	11.0	18.9	14.6	1.90

The average diameter is 0.25mm when the $Ps=2.5Kg/cm^2$ because the drops collide with one another that we measured. Through culculating with computator, the moving locus of drops is on Fig.2 and the velocity difference between the drops and the air flow is less than 1 m/s when the X is greater than 0.2m, then Nu=2.1. The Y is calculated by

$$Y = U\cdot \frac{Vg}{Vw}$$

The results is

$$Xo_1 = 1.883m \ ; \ Xo_2 = 1.7968m \ ; \ Xo_3 = 1.948m$$

The Xo is the effective distance between the bafflers of water and the centre of the spray head. It is satisfactory to real conditions.

CONCLUSION

The formula (9) is suitable for the designing process in the spraying water room of air conditioning and the calculating results is satisfactory with experiments, in which the relation among the main parameters can be found.

If we want to increase the quantity of air flow in a air conditioning system but the structure of the system and the parameters of air flow are not changed, the formula (9) is changed

$$L \cdot \frac{V_g}{Y} = L' \cdot \frac{V'_g}{Y'}$$

The purpose can be reached by increasing the quantity of spraying water and decreasing the average diameter of drops, or increasing Y to Y' and decreasing L to L'. The formula above provides also the way in improving old system of air conditioning and the relation among parameters adjusted in motion.

Improving the spraying efficiency, or decreasing L, is the best way to save energy and increase the efficiency of heat and mass transfer in spraying water rooms through the formula (9). And the efficiency of removing dust is not reduced.

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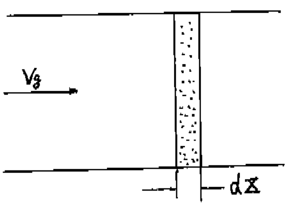

Fig. 1 The differential length in the spraying water room.

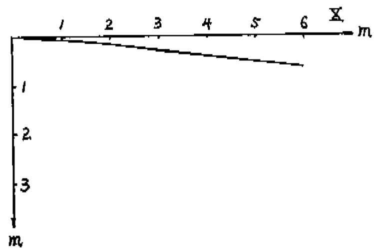

Fig. 2 The moving locus of the water drop.

V_g=7 m/s Vwo=0 L=0.25mm