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Efficiency comparison and performance analysis of internally-cooled liquid desiccant dehumidifiers using LiCl and $CaCl_2$ aqueous solutions

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The models of internally-cooled dehumidifiers

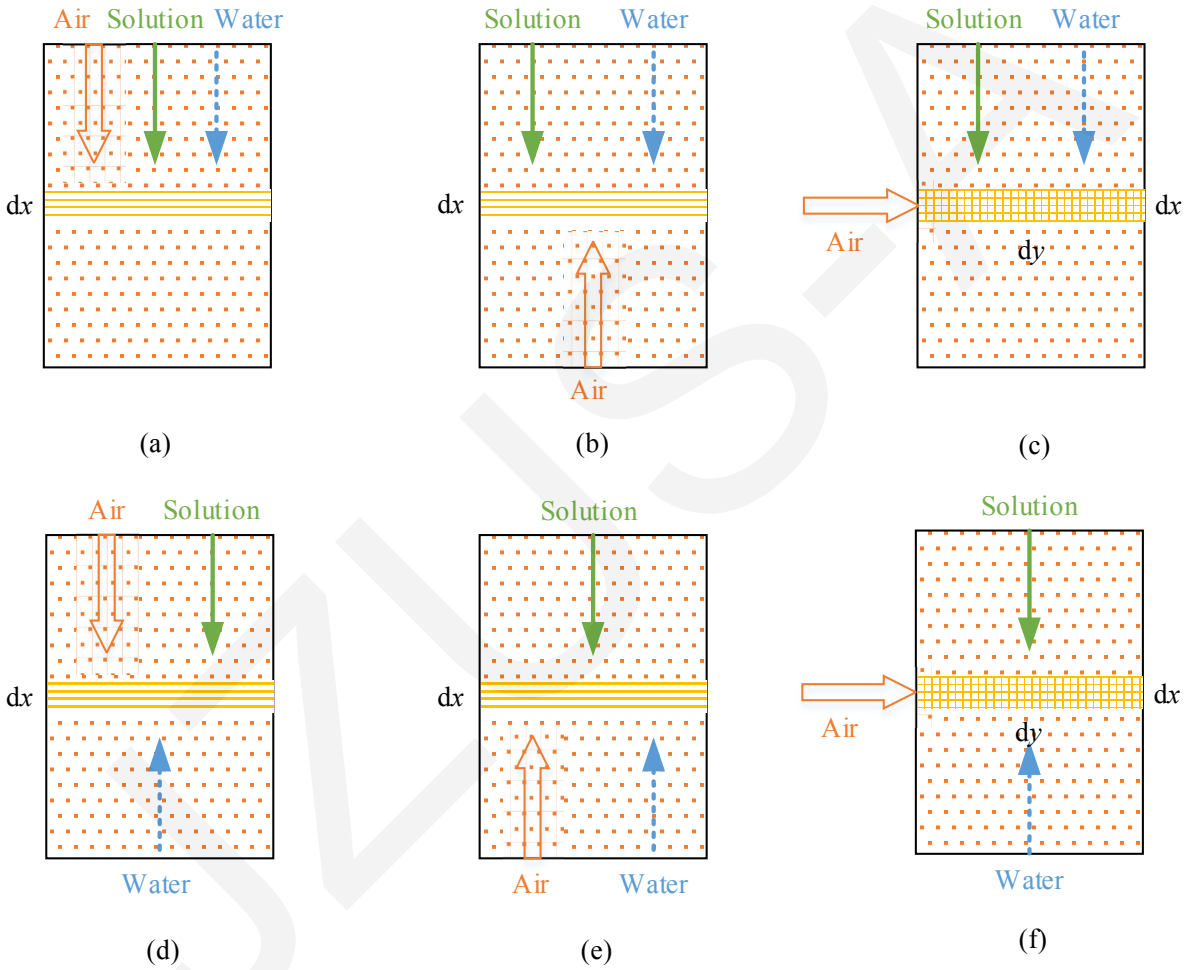


Fig. 1 Physical models of internally-cooled dehumidifiers
(a) Pa.- Ⅰ; (b) Co.- Ⅰ; (c) Cr.- Ⅰ; (d) Pa.- Ⅱ; (e) Co.- Ⅱ; (f) Cr.- Ⅱ

Mathematical models of efficiency analysis

1.Dehumidification efficiency

$$\eta_{\mathrm{D}}^{*}=\frac{\omega_{\mathrm{a,in}}-\omega_{\mathrm{a,out}}}{\omega_{\mathrm{a,in}}-\omega_{\mathrm{e,in}}^{*}},$$

$$\omega_{\mathrm{e,in}}^{*}=\mathrm{f}\left[X,\min\left(t_{\mathrm{s,in}},t_{\mathrm{w,in}}\right)\right].$$

2.Exergy efficiency

$$\eta_{\mathrm{E}}=\frac{\Delta E_{\mathrm{a}}}{\Delta E_{\mathrm{s}}+\Delta E_{\mathrm{w}}}=\frac{E_{\mathrm{a,out}}-E_{\mathrm{a,in}}}{\left(E_{\mathrm{s,in}}-E_{\mathrm{s,out}}\right)+\left(E_{\mathrm{w,in}}-E_{\mathrm{w,out}}\right)}.$$

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Performance analysis of internally-cooled liquid desiccant dehumidifiers

1.Effects of device parameters on the efficiencies of internally-cooled dehumidifiers

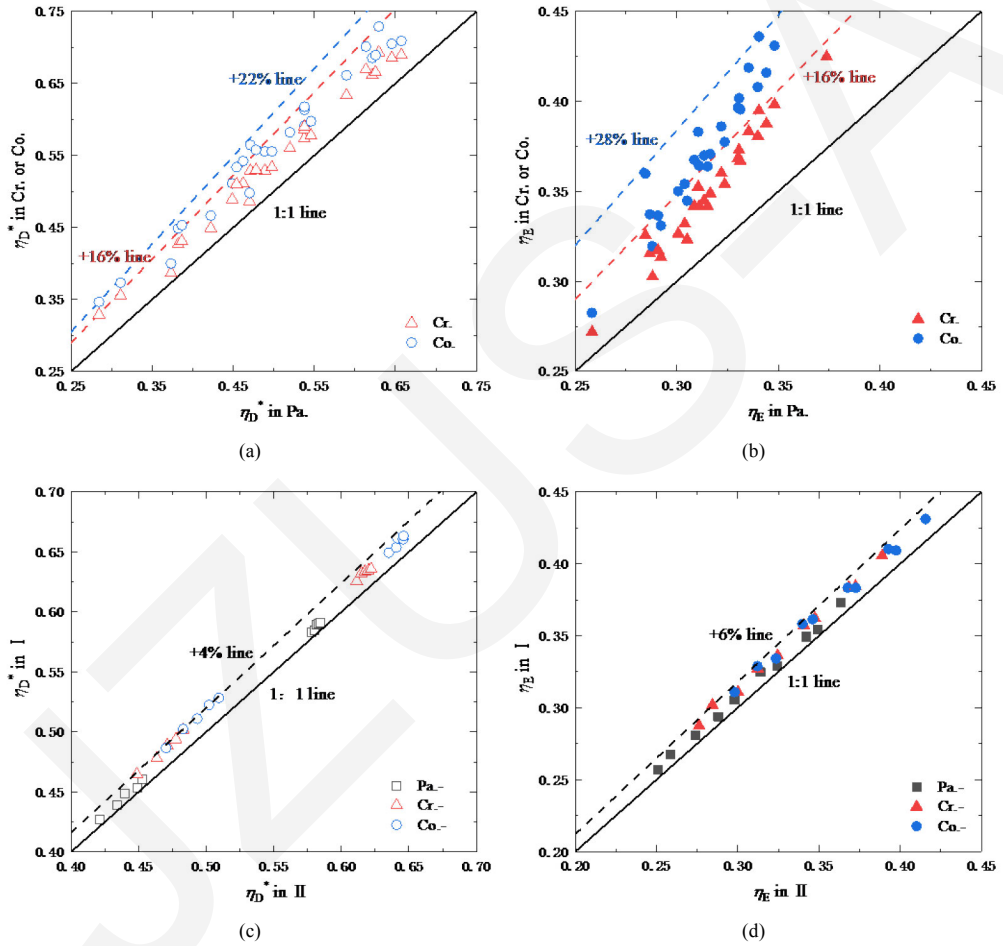


Fig. 4 Effects of flow types on the efficiencies of internally-cooled dehumidifiers
(a) Dehumidification efficiencies in parallel, cross and counter flow; (b) Exergy efficiencies in parallel, cross and counter flow; (c) Dehumidification efficiencies in Ⅰ and Ⅱ flow; (d) Exergy efficiencies in Ⅰ and Ⅱ flow

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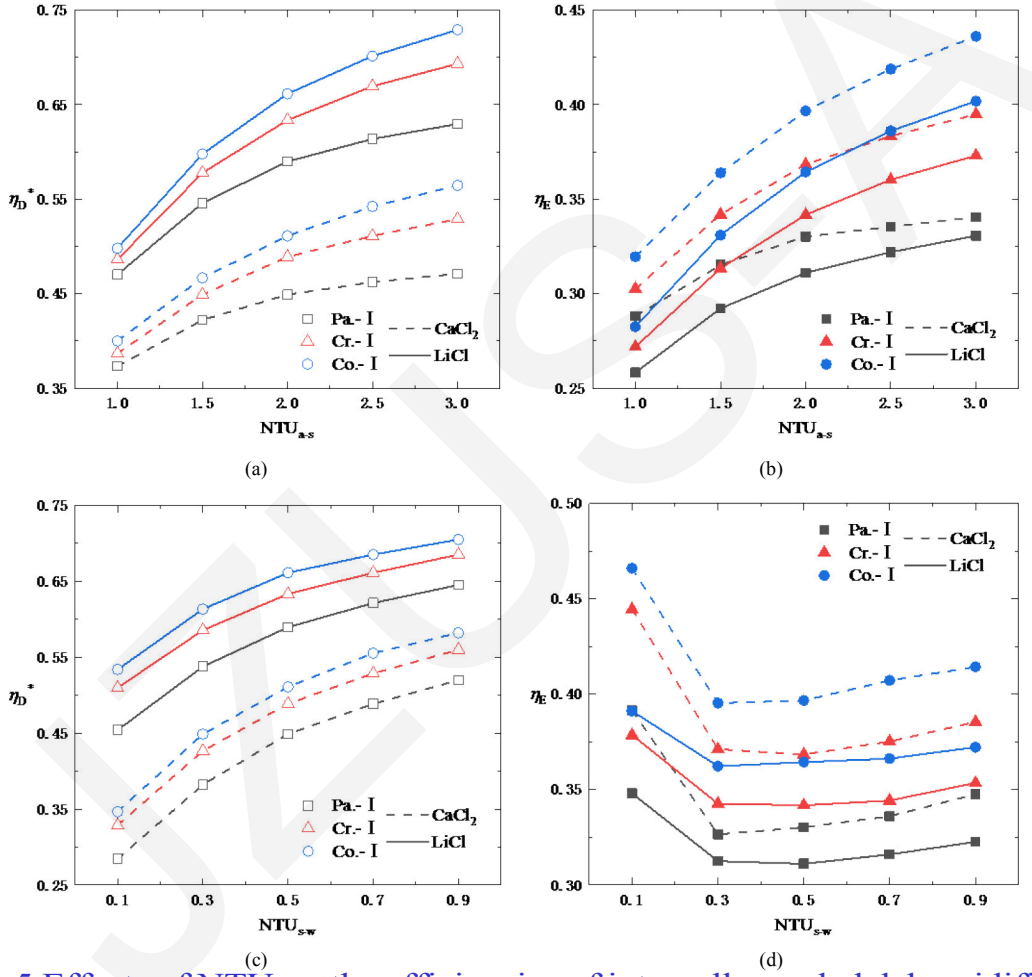
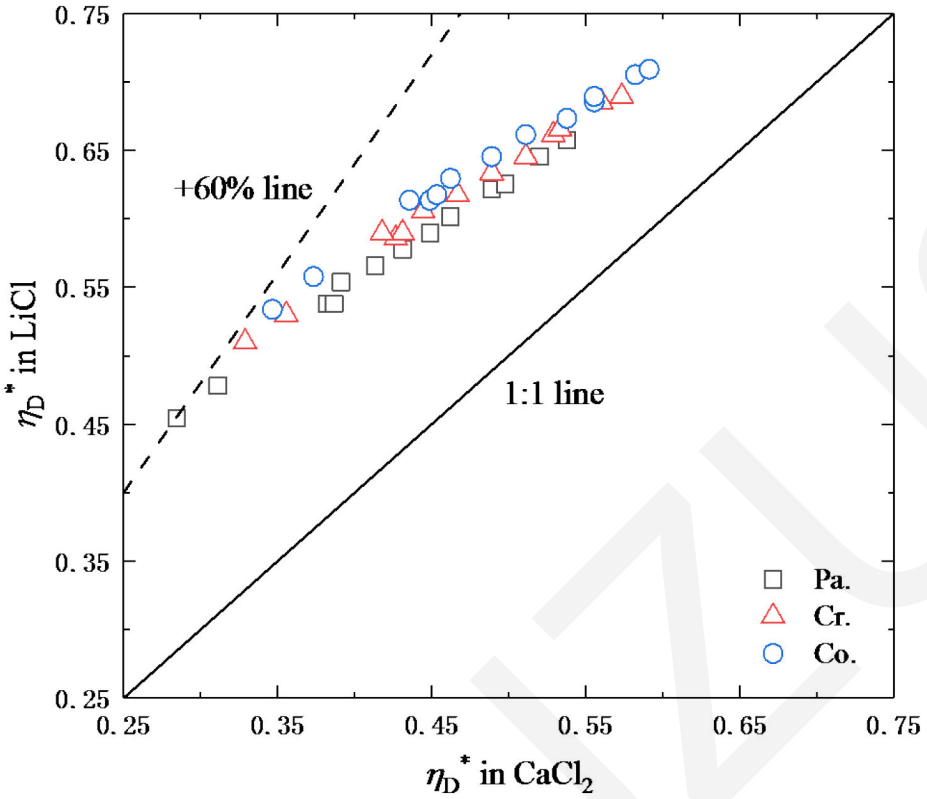


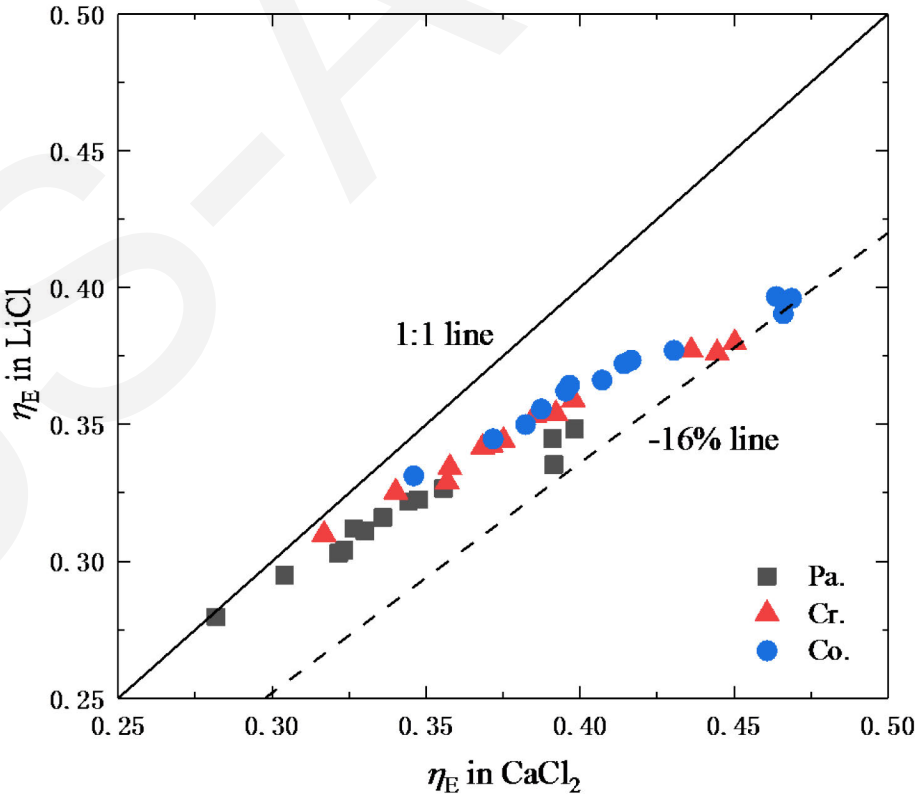
Fig. 5 Effects of NTU on the efficiencies of internally-cooled dehumidifiers
(a) Effect of NTU_{a-s} on dehumidification efficiency; (b) Effect of NTU_{a-s} on exergy efficiency; (c) Effect of NTU_{s-w} on dehumidification efficiency; (d) Effect of NTU_{s-w} on exergy efficiency

Performance analysis of internally-cooled liquid desiccant dehumidifiers

2.Effects of the fluids parameters on the efficiencies of internally-cooled dehumidifiers



(a)



(b)

Fig. 6 Effects of liquid desiccant types on the efficiencies of internally-cooled dehumidifiers
(a) Effect of liquid desiccant types on dehumidification efficiency; (b) Effect of liquid desiccant types on exergy efficiency

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Performance analysis of internally-cooled liquid desiccant dehumidifiers

2.Effects of the fluids parameters on the efficiencies of internally-cooled dehumidifiers

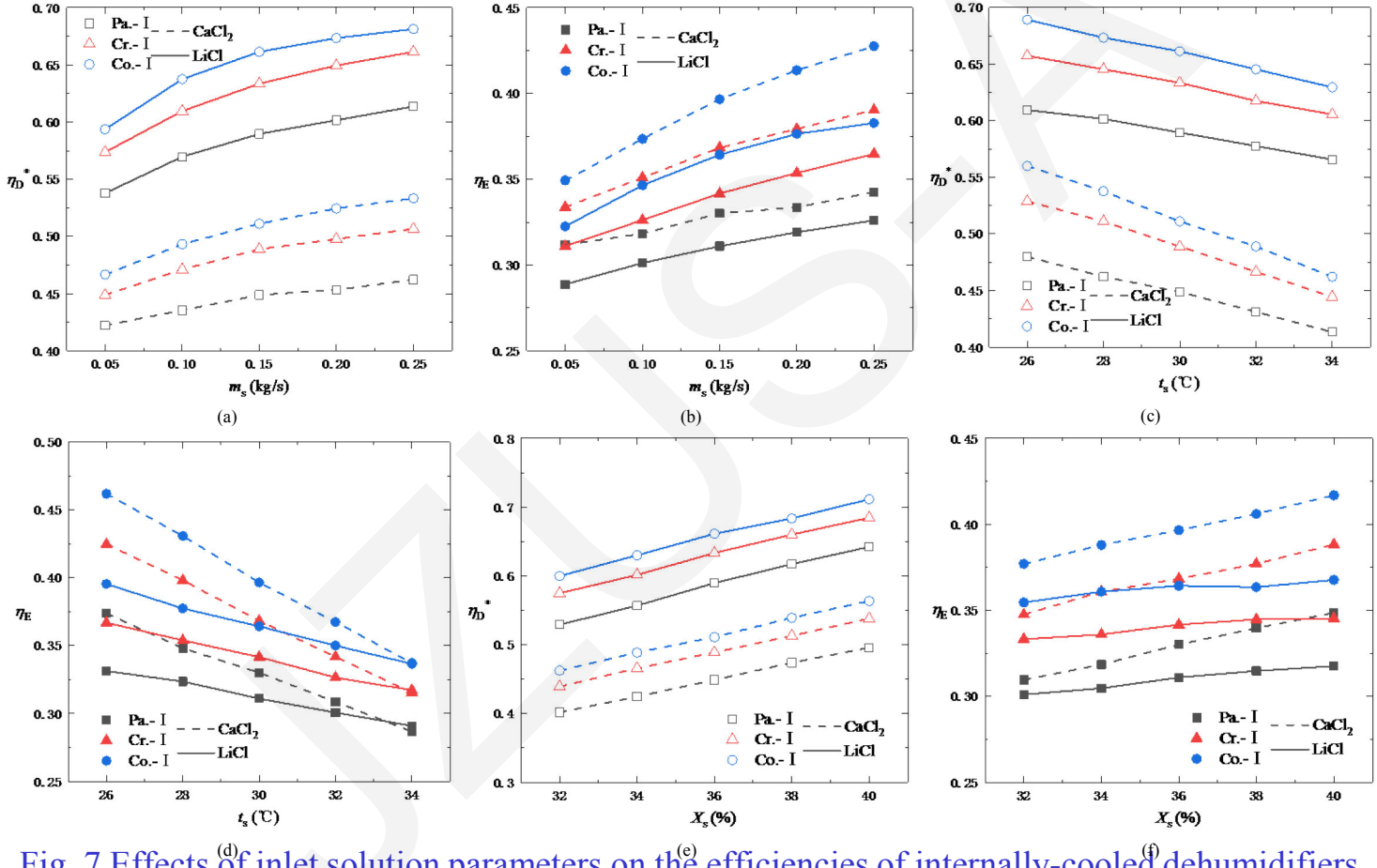


Fig. 7 Effects of inlet solution parameters on the efficiencies of internally-cooled dehumidifiers
(a) Effect of m_s on dehumidification efficiency; (b) Effect of m_s on exergy efficiency; (c) Effect of t_s on dehumidification efficiency; (d) Effect of t_s on exergy efficiency; (e) Effect of X_s on dehumidification efficiency; (f) Effect of X_s on exergy efficiency

Performance analysis of internally-cooled liquid desiccant dehumidifiers

2.Effects of the fluids parameters on the efficiencies of internally-cooled dehumidifiers

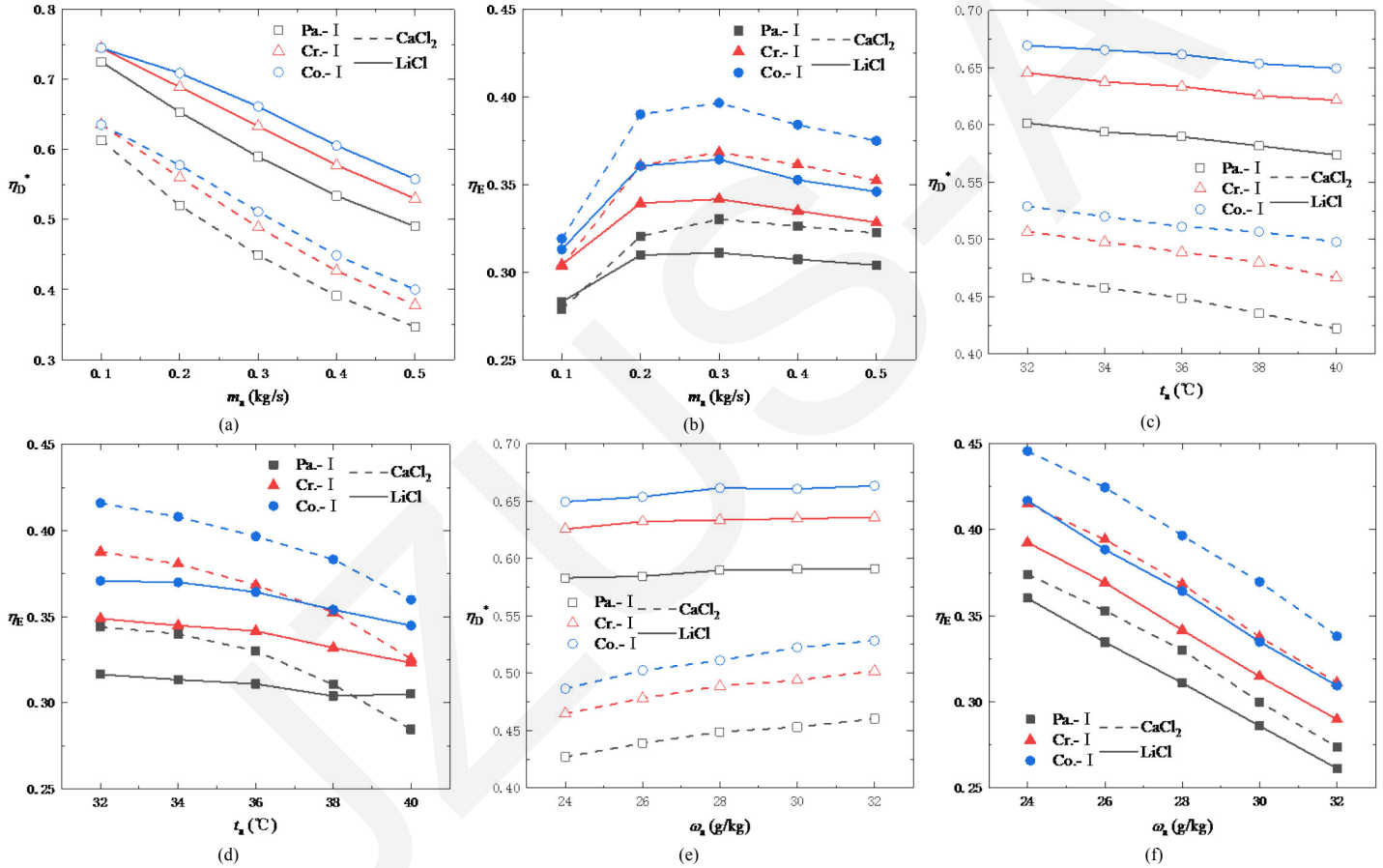


Fig. 8 Effects of inlet air parameters on the efficiencies of internally-cooled dehumidifiers
(a) Effect of m_a on dehumidification efficiency; (b) Effect of m_a on exergy efficiency; (c) Effect of t_a on dehumidification efficiency; (d) Effect of t_a on exergy efficiency; (e) Effect of ω_a on dehumidification efficiency; (f) Effect of ω_a on exergy efficiency

Performance analysis of internally-cooled liquid desiccant dehumidifiers

2.Effects of the fluids parameters on the efficiencies of internally-cooled dehumidifiers

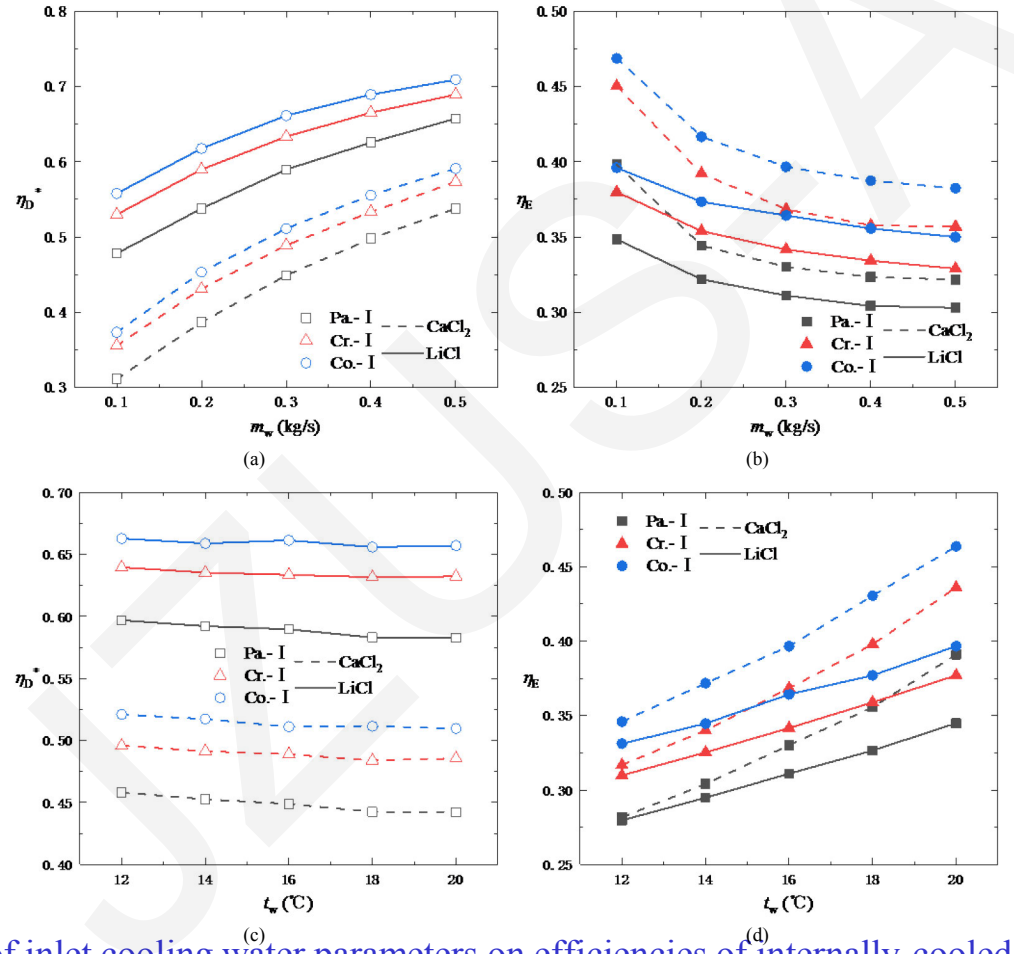


Fig.9 Effects of inlet cooling water parameters on efficiencies of internally-cooled dehumidifiers
(a) Effect of m_w on dehumidification efficiency; (b) Effect of m_w on exergy efficiency; (c) Effect of t_w on dehumidification efficiency; (d) Effect of t_w on exergy efficiency

Conclusions

(1) A novel definition of dehumidification efficiency, taking into account the cost of cooling water, is defined in this paper to avoid the possibility of the traditional one in internally-cooled dehumidifiers exceeding the range of 0 to 1 under certain conditions. The novel dehumidification efficiency, in which the inlet solution equilibrium humidity ratio is calculated according to the minimum temperature among the inlet solution and cooling water, is a better evaluation of internally-cooled dehumidifiers.

(2) Counter flow between air and solution shows the highest dehumidification efficiency and exergy efficiency, followed by cross flow, and parallel flow shows the lowest. Flow types between solution and cooling water have little effect on efficiencies, and Ⅰ flow (water flow parallel to the solution) shows an increase about of 5% compared with Ⅱ flow (water flow counter to solution).

(3)) The dehumidification efficiency of the LiCl solution is higher than that of the $CaCl_2$ solution, and can be increased by 60%, while the exergy efficiency of the LiCl solution can be reduced by 16% compared with that of the $CaCl_2$ solution.

(4) Higher $NTU_{a\text{-}s}$ should be used in the design of internally-cooled dehumidifiers. Higher solution concentration and lower inlet temperature of solution and air are recommended to achieve both superior dehumidification efficiency and exergy efficiency in internally-cooled dehumidifiers.