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## Thermal Engineering and Applied Science



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# Heat Transfer Enhancement in Externally Finned Tubes and Internally Finned Tubes and Annuli

Springer

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# Nomenclature

| | |
|---|---|
| $\Delta p$ | Air-side pressure drop, Pa or lbf/ft$^2$ |
| $\Delta p_f$ | Pressure drop assignable to fin area in finned tube exchanger, Pa or lbf/ft$^2$ |
| $a$ | Major diameter for rectangular tube cross section, m or ft |
| $A$ | Total heat transfer surface area (both primary and secondary, if any) on one side of a direct transfer type exchanger; total heat transfer surface area of a regenerator, m$^2$ or ft$^2$ |
| $A_c$ | Flow cross-sectional area in minimum flow area, m$^2$ or ft$^2$ |
| $A_f$ | Fin or extended surface area on one side of the exchanger, m$^2$ or ft$^2$ |
| $A_{fa}$ | Actual flow area of an internally finned tube, $A_n(1 - 2e/d_i)^2$, m$^2$ or ft$^2$ |
| $A_{fin}$ | Inter-fin flow area of an internally finned tube, $A_{fa} - A_{core}$, m$^2$ or ft$^2$ |
| $A_{fr}$ | Heat exchanger frontal area, m$^2$ or ft$^2$ |
| $A_n$ | Nominal flow area of an internally finned tube $\Pi d_i^2/4$, m$^2$ or ft$^2$ |
| AMTD | Arithmetic mean temperature difference K |
| $B$ | Minor diameter for rectangular tube cross section, m or ft |
| $D_{ab}$ | Diffusion coefficient for component a through component b, m$^2$/s |
| $D_i$ | Internal diameter, m or ft |
| $d_o$ | Outside diameter, m or ft |
| $D_{vi}$ | Volume-based tube inner diameter, m or ft |
| $e/d$ | Rib height, dimensionless |
| $f$ | Fanning friction factor $\Delta P \rho D_h/2LG^2$, dimensionless |
| $f_f$ | Friction factor of fins in Eq. 6.5 ($=2\ \Delta p \pm \rho A_c/A_j G^2$), dimensionless |
| $f_t$ | Friction factor of tubes in Eq. 6.5 ($=2\ \Delta p \pm \rho A_c/A_t G^2$), where $A = A - A_f$, dimensionless |
| $f_{tb}$ | Tube bank friction factor $= \Delta P \rho D_h/2NG^2$, dimensionless |
| $Gr$ | Grashof number $= g\beta \Delta T D_h^3/v^2$, dimensionless |
| $Gz$ | Graetz number $= \Pi d_i Re Pr/4L$, dimensionless |
| $j$ | $StPr^{2/3}$ dimensionless |
| $n_L$ | Number of louvers in airflow depth, dimensionless |
| $Nu_{Dh}$ | Nusselt number $= hD_h/k$, dimensionless |
| $p/d$ | Rib pitch, dimensionless |

| | |
|---|---|
| $p_f$ | Fin pitch, center to center spacing, m or ft |
| $p_w$ | Wave pitch of wavy fin, m or ft |
| $Re_{Dvi}$ | Reynolds number based on $D_{vi}$, $GD_{vi}/\mu$ dimensionless |
| $Re_{Dvo}$ | Reynolds number based on $D_{vo}$, $GD_{vc}/\mu$ dimensionless |
| $s$ | Spacing between two fins $= p_f - t$, m or ft |
| $S_f$ | Flow frontal area of heat exchanger, $m^2$ or $ft^2$ |
| $Sh$ | Sherwood number for mass transfer ($=K_m D_h/D_{ab}$), dimensionless |
| $St$ | Stanton number $= h/Gc_p$ dimensionless |
| $u*$ | Friction velocity $= (\tau_u/\rho)^{1/2}$, m/s or ft/s |
| $u_m$ | Fluid mean axial velocity at the minimum free flow area, m/s or ft/s |
| $V_m$ | Heat exchanger tube material volume, $m^3$ or $ft^3$ |
| $w_{fin}$ | Weight of fins in heat exchanger, kg or lbm |
| $w_s$ | Width of segmented fin (Fig. 6.20), m or ft |
| $W_{tot}$ | Weight of tubes and fins in heat exchanger, kg or lbm |
| $w_{tub}$ | Weight of tubes in heat exchanger, kg or lbm |
| $X^+$ | $x/D_h RePr$, dimensionless |
| $X_{DV}{}^+$ | $RePrD_v/L$, dimensionless |

## Greek Symbols

| | |
|---|---|
| $2\theta$ | Included angle of fin cross section normal to flow, radians, or degrees |
| $\alpha$ | Helix angle relative to tube axis radians or degrees |
| $\beta$ | Helix angle |
| $\gamma$ | Reciprocal of fin pitch, m or ft |
| $\delta$ | Liquid film thickness |
| $\Delta p$ | Pressure drop |
| $\Delta T$ | Temperature difference |
| $\varepsilon$ | Permittivity |
| $\eta_f$ | Fin efficiency or temperature effectiveness of the fin, dimensionless |
| $\eta_o$ | Surface efficiency of finned surface $= 1 - (1 - \eta_f)A_f/A$, dimensionless |
| $\mu$ | Dynamic viscosity |
| $\theta$ | Louver angle for louver fin, radians |
| $\rho$ | Density |
| $\sigma$ | Surface tension |
| $\tau_w$ | Wall shear stress, Pa or $lbf/ft^2$ |

## Subscripts

| | |
|---|---|
| ave | Average |
| deff | Effective diameter |
| ev | Evaporation |
| fd | Fully developed flow |

| | |
|---|---|
| H1 | Heat flux boundary condition |
| i | Inner |
| il | Inline tube arrangement |
| in | Inlet |
| L | Liquid |
| m | Average value over flow length |
| o | Outer |
| o | Outside (air-side) surface |
| p | Plain tube or surface |
| s | Saturated |
| st | Staggered tube arrangement |
| sub | Subcooled |
| v | Vapor |
| w | Evaluated at wall temperature |
| x | Local value |