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# Appendix A

The SAH thermal performance has been studied for a constant grooves pitch, as the Reynolds number, *Re* and groove relative height ratio, $\frac{e_r}{H}$ , are the most influencing parameters. Therefore, the functional relationship of Nu is written as:

$$Nu = f\left(Re, \frac{e_r}{H}\right) \tag{1}$$

To develop the bridge between *Nu* and *Re*, the variations has been obtained in logarithmic form for *Re* in the range 11000-15000 is obtained in Fig. A.1. The relationship among $ln\,(Nu)$verses $ln\,(Re)$are of the following form:

$$Nu = A_o\ Re^n \tag{2}$$

where $n = 0.7815$The expression for *Nu* in Eq. 2 obtained from appropriate data points of SAH having curved flow channel integrated with quarter-circle ribs. The R-square method was used to fit the data is shown in Fig. A.1.

$A_o$ in the above Eq. 2, depends on another roughness parameter i.e., $\frac{e_r}{H}$. The functional relationship among $ln(A_o)$ and $ln\left(\frac{e_r}{H}\right)$ was obtained in the form given in Eq. 3. The deviation in the trend among data points is shown in Fig. A.2. The expression of Nusselt number, Nu obtained using all data points in the final form given below,

$$Nu \;=\; B_0 Re^{0.78} ln\left(\frac{e_r}{H}\right)^{6.85} exp\left[0.82\left\{ln\left(\frac{e_r}{H}\right)\right\}^3 + 4.12\left\{ln\left(\frac{e_r}{H}\right)\right\}^2\right] \tag{3}$$

Where coefficient $B_o = 1.2$.

Note that the correlation is valid for quarter-circle ribs having relative height ratio, $0.125 \leq \frac{e_r}{H} \leq 0.225$, for constant ribs pitch of 50 mm.

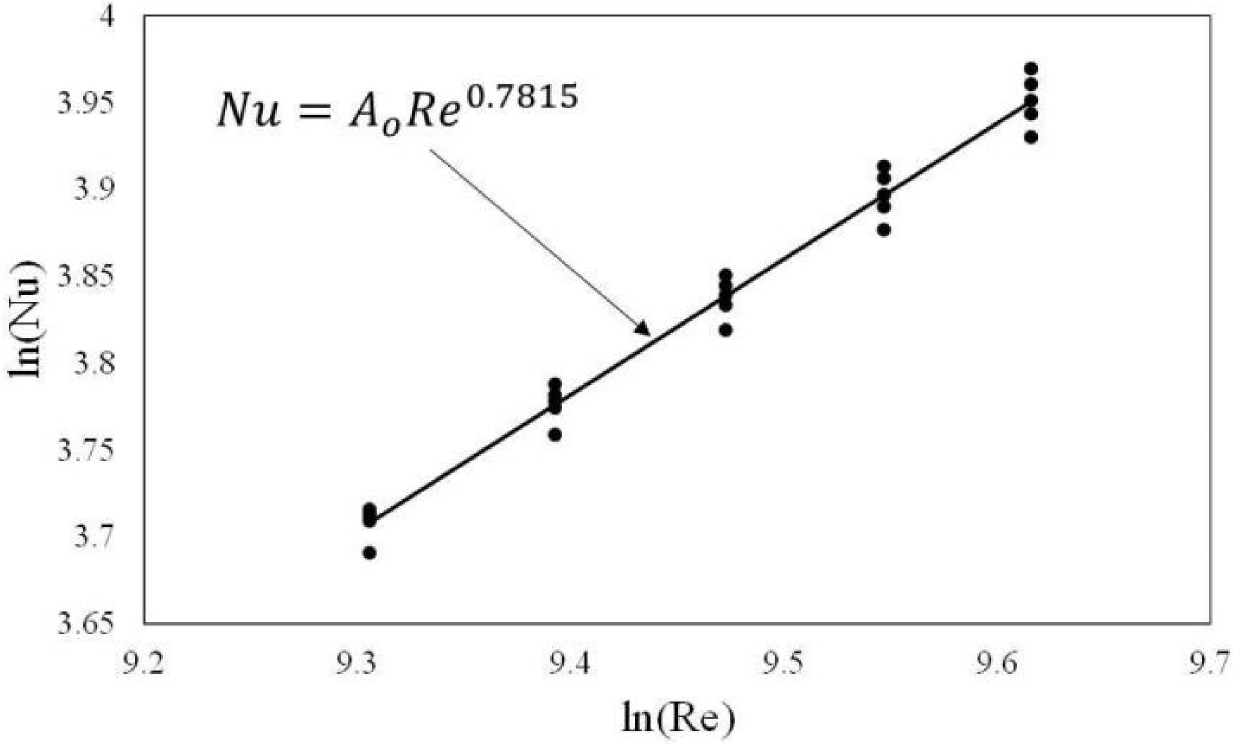


Figure A.1: Trend variation of ln(Nu) versus ln(Re) for SAH having curved design equipped with quarter-circle ribs.

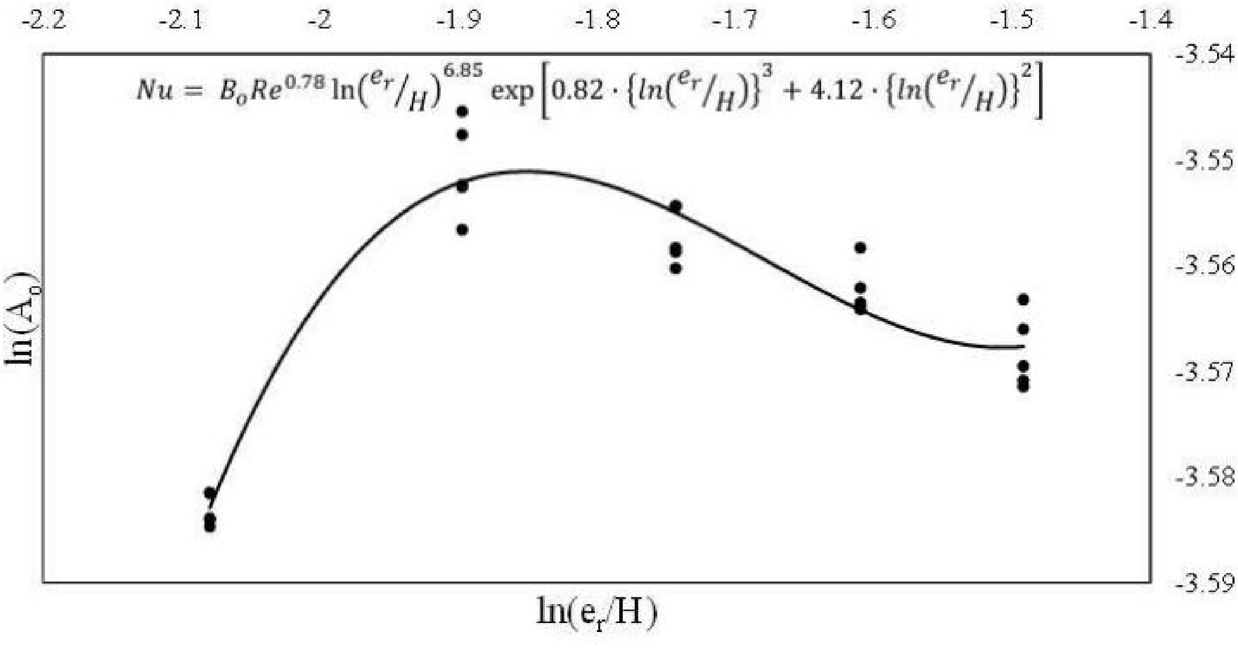


Figure A.2: Variation of $ln(A_o)$vs. $ln\left(\frac{e_r}{H}\right)$.

# Appendix B

In order to estimate the values of performance parmeters of present studies, the data of mass flow average air outlet temperature $(T_o)$,surface average absorber plate temperature $\left(T_p\right)$,and pressure drop across the duct are collected from the numerical simulations. The average bulk mean temperature $(T_{bm})$ of working fluid flowing through the SAH is defined as:

$$T_{bm} = \frac{(T_o + T_i)}{2} \tag{4}$$

Total useful heat gains of working fluid is determined by applying 1st law of thermodynamics.

For parallel DPSAH

$$Q_u = \dot{m}_l C_p (T_{lo} - T_i) + \dot{m}_u C_p (T_{uo} - T_i) \tag{5}$$

For counter DPSAH or single-pass SAH

$$Q_u = \dot{m} C_p (T_o - T_i) \tag{6}$$

Where, $\dot{m} = m_l \dot{+} \dot{m}_u$

As fluid flow over the absorber surface the velocity boundary layer changes in the flow direction. Consequently, local heat transfer coefficient varies along the absorber surface and is given as:

$$h_x = \frac{q_s^{''}}{\left(T_{surface,x} - T_{bulk,x}\right)} \tag{7}$$

The total convection heat transfer rate $(Q_u)$ is the integral of the surface heat flux $\left(q_s^{''}\right)$ over the whole absorber surface area $(A_{eff})$:

$$Q_u = \int_0^{A_{eff}} q_s^{''} dA_s \tag{8}$$

Thus the average heat transfer coefficient can be calculated as:

$$h = \left[\frac{Q}{A_{eff}(T_p - T_m)}\right] \tag{9}$$

Which is also related to $h_x$ by

$$h = \frac{1}{A_{eff}} \int_0^{A_{eff}} h_x dA_s \tag{10}$$

Local Nusselt number $Nu_x$

$$Nu_x = \frac{h_x D_h}{k} \tag{11}$$

Average Nusselt number is represented as

$$Nu = \frac{h D_h}{k} \tag{12}$$

where $D_h$ is characteristic diameter of SAH, which is defined as :

$$D_h = \frac{4A_{cross}}{P} \tag{13}$$

Darcy friction factor is determined by using Darcy-Weisbach equation as:

$$f = \frac{2\Delta P D_h}{\rho L U^2} \tag{14}$$

Thermal effectiveness of SAH is determined as:

$$\varepsilon = \left(\frac{T_0 - T_i}{T_p - T_i}\right) \tag{15}$$

Temperature factor of SAH is calculated as:

$$TF = \left(\frac{T_0 - T_i}{I}\right) \tag{16}$$

Thermal hydraulic efficiency of solar air heater is determined as:

$$\eta_{the} = \frac{Q_u - P_{fan}}{I A_{eff}} \tag{17}$$

# Brief Bio-Data of the Author

Mr. Amit Kumar is a Ph.D candidate in the Department of Mechanical Engineering at IIT (BHU) Varanasi. He has completed B.Tech in the Mechanical Engineering from Bhagalpur College of Engineering(B.C.E), Bhagalpur, Aryabhatta Knowledge University (AKU), Patna. His current areas of research are solar-thermal systems, heat transfer and fluid flow, modelling and simulation (CFD analysis), thermal energy storage.

**LIST OF PUBLICATIONS**

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1. **A. Kumar**, A.P. Singh, Akshayveer, O.P.Singh. Performance characteristics of a new curved double-pass counter flow solar air heater. **Energy** 239(2022) 121886 (IF-7.147).

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1. **A. Kumar**, A.P. Singh, Akshayveer, O.P.Singh. Novel designs of single pass solar air heater with conversing and diverging channel. **International Journal of Heat and Mass Transfer**, 2022.

2. **A. Kumar**, Akshayveer, A.P. Singh, O.P.Singh. Strategies to enhanced the performance of double-flow curved solar air heater using phase change material. **Energy Conversion and Management**, 2022.

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