Heat transfer characteristics of staggered inclined discrete ribs with combined gap arrangement

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Abstract. Artificial roughnesses in the form of ribs are an advantageous technique to increase solar air heaters' warmth efficiency. This research work presents new roughness utilized in a roughened channel and assesses the effective efficiency for a gap of inclined discrete rib with staggered connection geometry. The present new roughness geometry has parameters such as roughness pitch of rib of 8.0, attack angle of 75°, gap positions are varied between 0.3 & 0.1 – 0.3 & 0.4, aspect proportion of 8.0, rib height of 0.045 and rib gap width of 1.0. The Reynolds number range of 3000-14000. The maximum improvement coefficient of friction (f) and Nusselt Number (Nu) is achieved as 3.43 and 3.03 respectively, compared to the smooth channel. For the combined gap position of 0.3 & 0.3, a higher THP is achieved.

1. Introduction

Solar air heaters (SAHs) are fully utilized as a sunlight-based authority in light of its immediate arrangements and reduced action and bolster costs. SAHs are easily performed because of their low thermal efficiency limit between the absorber plate and working fluid, e.g. air. A strong system for enhancing the heat transfer between the roughened plate and the working fluid is the use of artificial geometry on the absorber roughened surface. The roughness component removes the warm boundarylayer and increases the temperature. As it may be, it likewise expands the friction losses from the blower or fan bringing about extended pumping impact requirements. Turbulence in the region of the absorber surface to isolate the laminar sub-layer must be created in order to minimize pumping energy and friction loss. As a result of utilizing artificial geometry in SAH, several investigations [1-3] were conducted to increase the path on the edge of the turbine. Lau S C et al. [1] they have seen that there is more turbulence in the rib wall, due to the flow required through inclined ribs square channel continuously about the transverse rib trade and the support of alternating current. A part of leading researchers is Lau S C et al [1, 2], Han J C et al. [3], Han J C et al. [4], Cho H H et al. [5] and Cho H H et al., [6]. For the improvement of heat transfer, they utilized inclined ribs rough geometry. Aharwal K R et al. [7] have experimentally investigated the impact on heat transfer and friction factors quality utilizing inclined discrete ribs on a square duct of SAH. They have seen that the highest value of the Nusselt numbers at the rib pitch of 8 for the angle of 60°. Aharwal K R et al. [8] investigated the rough surface geometry in the form of inclined ribs with gaps to improve the heat transfers from the roughened duct of the SAH. They have seen that the most extreme THP values are obtained as gap positions of 0.25 and gap widths of 1.0. From the literature survey above, it shows that discretizing the ribs by creating gaps in inclined ribs accelerates the flow through the gap and increases local friction, resulting in increased heat transfer from the working fluid's heat transfer layer. Most of the ribs were discretized in the past studies by establishing the gap in a straight line arrangement. In any case, no investigation has yet been done for inclined ribs, in which the inclined ribs are formed as shown in the proposed roughness geometry, gap in the conjugative ribs have not yet been examined in a zig-zag arrangement In the form of proposed in the previous investigations unpleasantness was visible in geometry [1, 2, 4, 5, 6, 7 and 8]. This test was attempted to choose the right region to improve the capacitance to improve the coefficient from the absorbing plate of the SAH of different gap arrangements. In this analysis, the position and dimensions of the gap will be calculated when inclined ribs are discretized for an order to improve performance on non-discretizing ribs.

2. Experimental test details

The experimental setup has appeared in Figure 1, as indicated by Duffy J A et al. [9]. It is fitted with a rectangular duct test area section, melting area, flow rate, around a pipe with orifice plate for the blower and electric power motor measurements. For voltage and electric current control, a variable is used to supply the warm transitions to the roughened duct. In order to measure the current and voltage provided to the heater, the voltmeter and ammeter are used. Input, output, and plate-temperatures are measured by using thermocouple wires. A data logger to record information is used to maintain a constant temperature. The pressure falls of the roughened duct are evaluated by the U- tube digital manometer. There are estimated pressure decreases along with the roughened plate by a pressure meter.

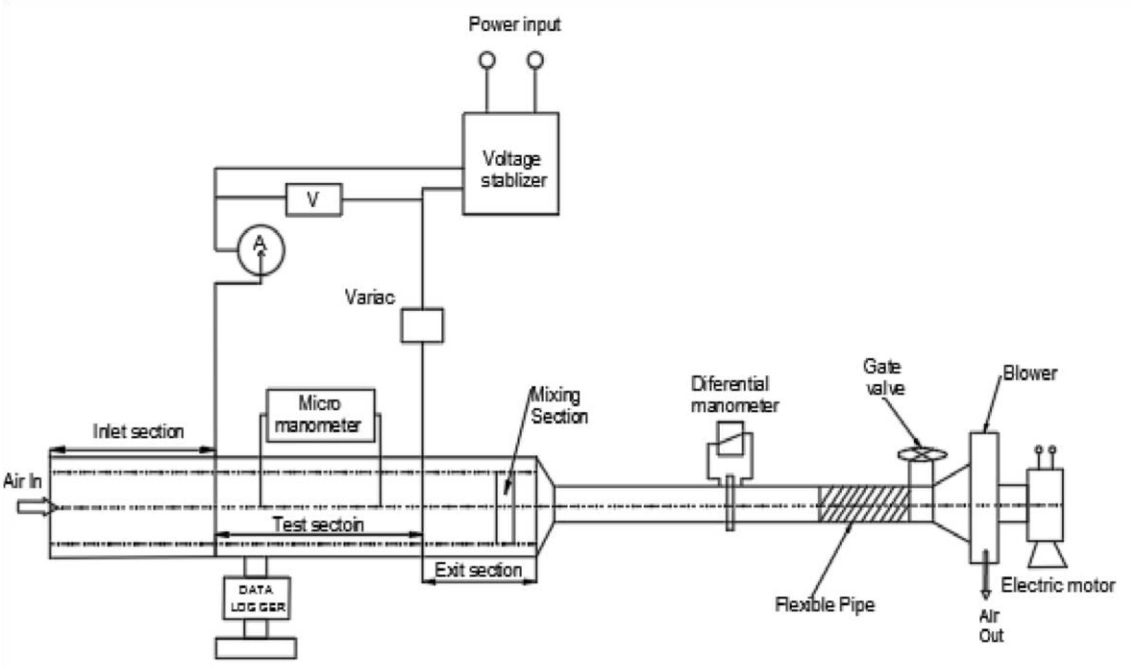


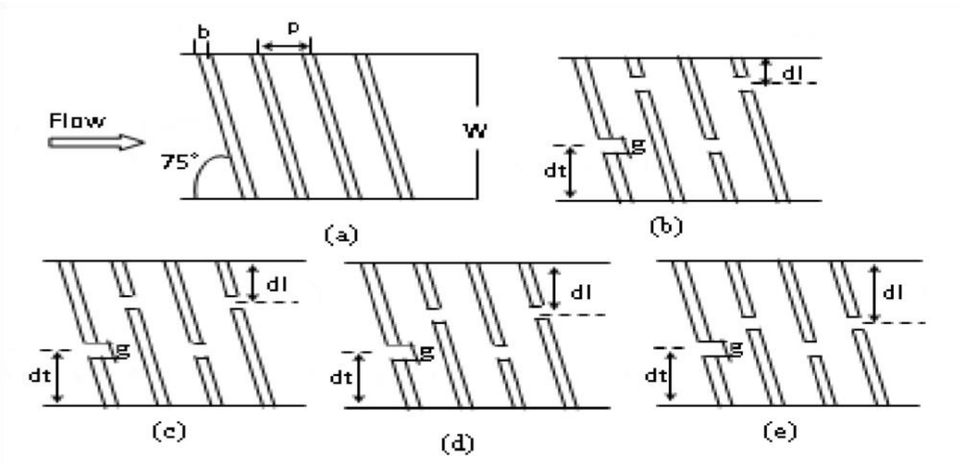
Figure 1. Experimental test program.

Table 1. Displays the parameter values for this geometry of roughness:

S. No.	Rib Parameters	Parameter Values
1.	Reynolds Number (Re)	3000 - 14000
2.	Rib pitch (P/e)	8.0
3.	Rib height (e/D_h)	0.045
4.	Attack angle (α)	75□
5.	Aspect ratio (W/H)	8.0
6.	Gap width (g/e)	1.0
7.	Combination of gap positions (dt/W and dl/W)	0.3 & 0.1 to 0.3 & 0.4

3. Rib elements and parameter values

The rib roughness parameter for investigation of new proposed rib geometry to be unique to the staggered type inclined discrete ribs has appeared in Table 1. The pitch and attack angle values have been selected respectively at 8.0 and 75°, taking into account the masterly value of these parameters, as described in the literature work, Aharwal K R et al.[7, 8]. The range of the "Re" and "e/D_h" has been picked given the necessity of the SAH, Saini J S [10]. Figure 2 (a -e) shows the schematic structure of the roughened duct.



(a) Without Gap Flow	(b) dt/W and dl/W = 0.3 and 0.1 (c) dt/W and dl/W = 0.3 and 0.2	(d) dt/W and dl/W = 0.3 and 0.3 (e) dt/W and dl/W = 0.3 and 0.4

Figure 2 (a-e). Displays the discretization of the ribs as a gap at angle 75 ° inclined ribs at various gap positions.

4. Data reductions

The roughened plate surface temperature, air input temperature, and air outlet temperature was determined according to steady-state requirements. Calculation of the useful energy gain as heat, convection coefficient, and friction coefficient function Heat transfer and friction coefficient function parameters measured are the following:

Heat transfer rate:

$$Q_u = m \times C_p \times (T_o - T_i) \quad (1)$$

Heat transfer coefficient:

$$h = Q_u/A_p \times (T_o - T_i) \quad (2)$$

Nusselt number:

$$Nu_r = (h \times D_h)/ \ (3)$$

Friction factor:

$$_r = \left[2 \times (\Delta P)_d \times D_h/\left(4 \times \rho \times L_f \times V^2\right)\right] \quad (4)$$

5. Validity test set-up

The correlation between the Nusselt number (heat move coefficient) and the grinding factor chosen through an analysis conducted on a smooth tube was achieved through the Dittus Boelter condition for the "Nu" and modified Blasius condition for "*f*" was done through. These theoretical terms are given below:

$$ {}_{s} = 0.085 \times Re^{-0.25} \quad (5) $$

$$ Nu_s = 0.023 \times Re^{0.8} \times Pr^{0.4} \quad (6) $$

A comparison between the test and evaluation value of the "Nu" and "*f*" is displayed in Figures 3 and 4, respectively. It is seen that the estimations of the "Nu" and "*f*" for the smooth surface channel acquired by the test are like the properties assessed by condition (5) and condition (6), individually. As a consequence of the experimental value of the "Nu" and "*f*", the validity of the test is assured.

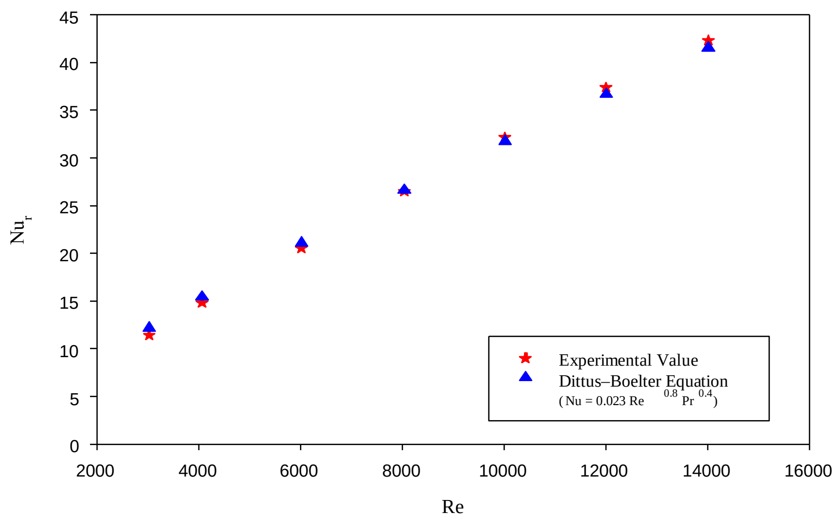


Figure 3. Comparisons of experimental value and predicted value of the "Nu" for the smooth duct.

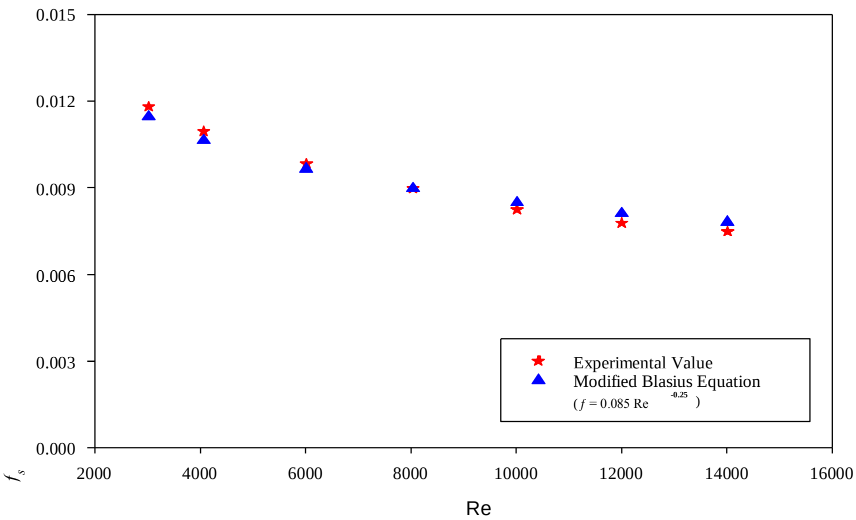


Figure 4. Comparisons of experimental value and predicted value of the "*f*" for the smooth duct.

6. Results and discussions

6.1. Effects of Reynolds number

Figure 5 displays changes in the “Re” as well as the “Nu” that show different gap conditions for fixed values of the attack angle, the rib width and the pitch of the rib. It is found that the value of the “Nu” increases, together with the “Re”, for all ruggedness systems. The highest values of the “Nu” are found for gap positions of 0.3 & 0.3 and their lowest values of 0.3 & 0.1. To see that without artificial unpleasantness regime (smooth surfaces), when the effect of rib artificial stiffness on heat rise is compared to the proportion of the “Nu” of unpleasantness rough surface and the “Nu” ratio of smooth surface (Nu_r/Nu_s) for the different value of the unpleasantness parameter as the Re” is demonstrate in Figure 6. Based on this Figure, in general, for every “Re”, the value of the proportion “Nu” is higher than the ribs no gap for the artificially roughened arrangement in conjugative inclined ribs, as gaps. Due to turbulence due to rib roughness, There's a big gap between them smooth duct and roughened duct test data. The rib roughness geometry splits the laminar sub-layer which facilitates heat transfer, creating turbulence. At least the “Re”, the distance between the rough duct and smooth duct is less, but the highest value of the “Re” is worth noting. It's observed that the scope of the “Nu” proportion is found to be 3.03 times respectively, compared to the smooth duct. For the “Nu” proportions, it could be found that the proposed “Re” range has shifted from 1.35 to 3.03 times. The highest values of the “Nu” proportion are found for gap positions of 0.3 & 0.3 and their lowest values of 0.3 & 0.1. This might be an immediate after-effect of the manner by which the gap position places of 0.3 & 0.3 is making more nearby turbulence than the other gap position.

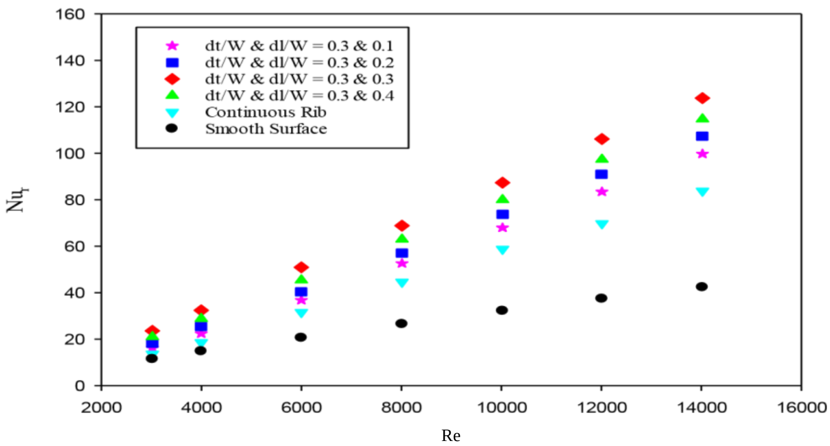


Figure 5. Displays “Nu” and “Re” variation in a various gap positions.

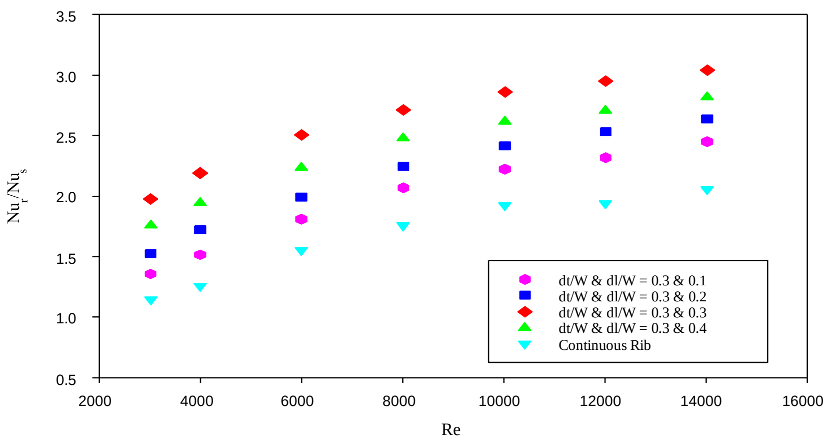


Figure 6. Displays “Nu” proportion and “Re” variation in a various gap positions.

Figure 7 displays changes in the “Re” as well as the “*f*” that show different gap conditions for fixed values of the attack angle, the rib width and the pitch of the rib. It is found that the value of the “*f*” decreases, together with the increase in “Re”, for all ruggedness systems. The highest values of the “*f*” are found for gap positions of 0.3 & 0.3 and their lowest values of 0.3 & 0.1. The highest “*f*” due to acceleration of flow and dispersion due to the geometry proposed to be unique staggered roughened duct has the most impressive “*f*” due to greater diffusion of flux and flux. Figure 8 demonstrates the changes of “*f*” proportions (*f*r/*f*s) alongside the Reynolds number as different gap positions. It's observed that the scope of the “*f*” proportion is found to be 3.43 times respectively, compared to the smooth duct. For the “*f*” proportions, it could be found that the proposed “Re” range has shifted from 2.29 to 3.43 times. The highest values of the “*f*” proportion are found for gap positions of 0.3 & 0.3 and their lowest values of 0.3 & 0.1.

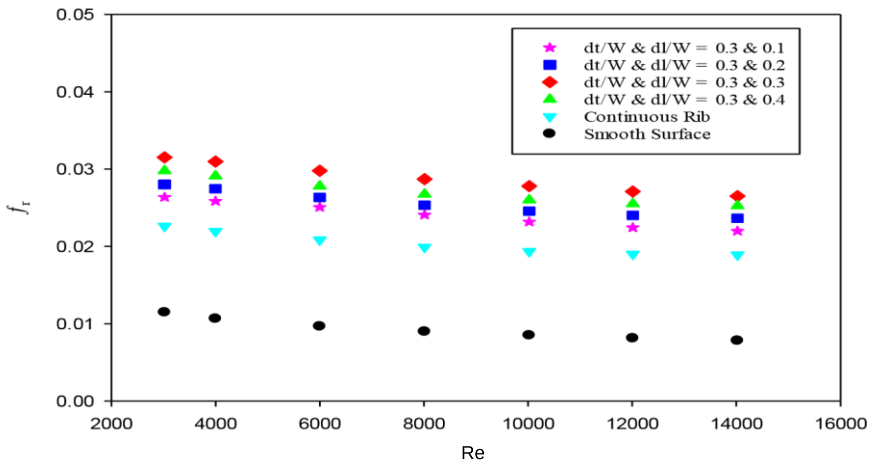


Figure 7. Displays “*f*” and “Re” variation in a various gap positions.

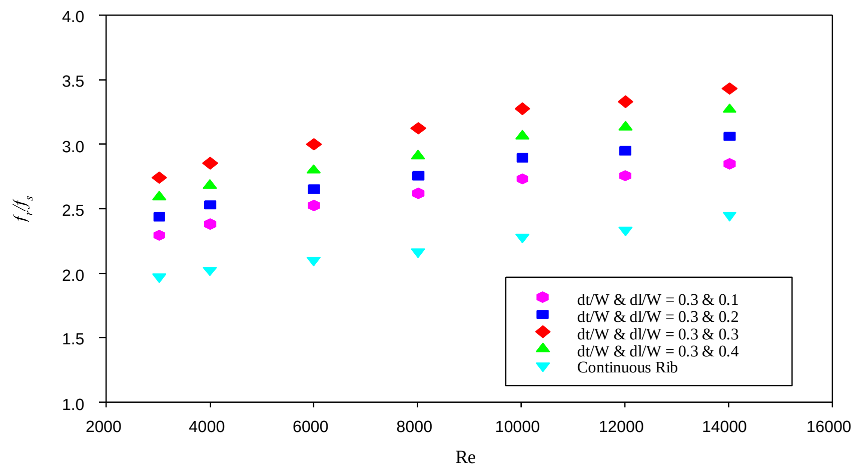


Figure 8. Displays “*f*” proportion and “Re” variation in a various gap positions.

6.2. Thermo-hydraulic performance

The “THP”, Lewis M J [11] offered THP parameters known as the “η”, efficiency parameters, which are necessary for same pumping capacity, which evaluates the improvement, as an analyzed along the smooth surface duct in the warmth move of the roughened surface duct and is defined as:

$$\eta = (Nu_r/Nu_s)/(f_r/f_s)^{1/3} \tag{7}$$

A quality of this parameter, more than unity, guarantees the reliability of using the new system and can be used to see the output of the number of action arrangements to choose the best. The value for thoroughness geometry tested in this study is shown in Figure 9. It is observed that the range of the “THP” parameter is 2.01 times compared to the smooth duct, respectively. In comparison to and without ribs under close conditions, the value of parameter is generally higher for roughened duct. It is commonly seen that the “THPP” for the proposed range of the “Re” has been changed from 1.02 to 2.01 times. Most astounding value of the “THPP” is found for gap positions of 0.3 & 0.3 and their lowest values of 0.3 & 0.1 for all values of “Re”.

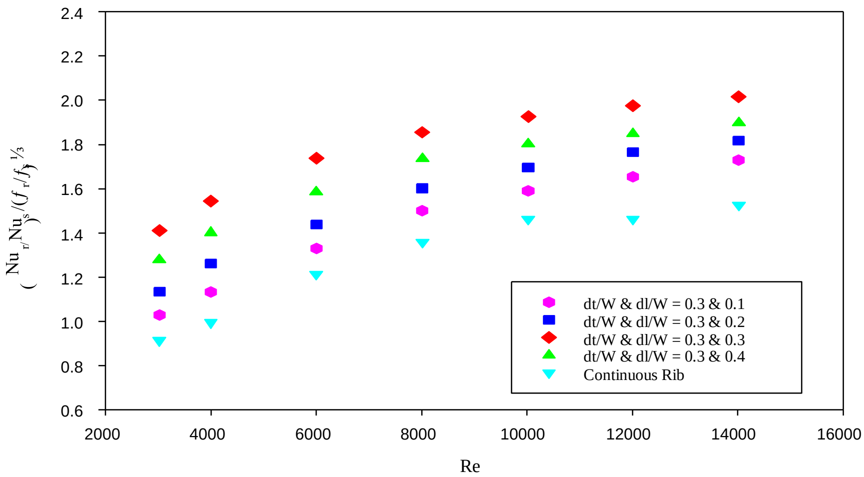


Figure 9. Displays “THP” and “Re” variation in a various gap positions.

7. Conclusions

The following findings of this study can be found below:

(i) The “Nu” demonstrates expanding patterns along expanding “Re”. Most noteworthy enhancement in “Nu” is found that an angle of attack at 75° with the combinations of gap position of 0.3 & 0.3 comparison to other gap positions.
(ii) The “*f*” demonstrates diminishing patterns along expanding “Re”. Most elevated improvement in “*f*” is found that an angle of attack at 75° with the combinations of gap position of 0.3 & 0.3 comparison to other gap positions.
(iii) The “THP” parameter shows expanding patterns with expanding “Re”. Most elevated enhancement in THP parameters is found that an angle of attack at 75° with the combinations of gap position of 0.3 & 0.3 comparison to other gap positions.

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