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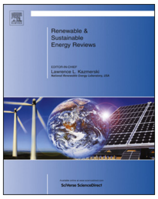

# Review of development of artificial roughness in solar air heater and performance evaluation of different orientations for double arc rib roughness

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## ABSTRACT

Concept of artificial roughness on plain surface is an important technique to enhance heat transfer rate of air flowing in solar air heater. Over the years different rib geometries have been designed to investigate heat transfer and friction characteristics of solar air heater. In this paper an attempt is made to review development of different rib geometries employed for creating artificial roughness. Heat transfer and friction factor correlations developed by various investigators are presented. Performance evaluation for different orientations of double arc rib roughness is presented.

## Contents

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## 1. Introduction

Energy plays vital role in world wide economic progress and provides impetus to industrialization. Depletion of non-renewable energy sources in near future has given way to development of renewable energy sources. Solar energy is freely available and is a clean energy source. A useful way to utilize solar energy is to convert it into thermal energy for heating purpose by using solar collectors. Solar collectors absorb incident solar radiation and convert it to useful heat for heating water or air. Solar air heaters are simple in design and most widely used collection devices. Application of solar air heater is space heating and crop drying. Thermal efficiency of solar air heater is low because of thermal resistance between absorber plate and moving air. Many techniques have been used to increase efficiency of solar air heater. Over the years researchers have used artificial roughness and corrugated absorber plate to increase efficiency of solar air heater. In this paper attempt is made to review the development of artificial roughness technique sequentially and thermo-hydraulic evaluation of double arc shaped rib roughness in different orientations is presented.

## 2. Concept of artificial roughness

Efficiency of flat plate solar air heater is low because of low convective heat transfer coefficient between absorber plate and flowing air. Higher thermal resistance increases absorber plate temperature leading to greater heat losses to environment. Low value of heat transfer coefficient is due to the presence of laminar sub-layer that is broken by providing artificial roughness on heat transferring surface [1]. Efforts for enhancing heat transfer have been directed towards artificially destroying laminar sub-layer. Artificial roughness creates turbulence near wall and breaks laminar sub-layer. However artificial roughness results in high frictional losses leading to more power requirement for fluid flow. Hence turbulence has to be created in a region very close to heat transferring surface. Core fluid flow should not be unduly disturbed to limit pumping power requirement. This is achieved by keeping height of roughness element small in comparison to duct dimensions [2]. Important parameters that characterize roughness element are roughness element height ($e$) and pitch ($p$). These are expressed in terms of dimensionless parameters such as relative roughness height ($e/D_h$) and relative roughness pitch ($p/e$).

## 3. Development of artificial roughness in solar air heater

### 3.1. Transverse ribs

### 3.1.1. Transverse continuous ribs

Prasad and Mullick [3] were the first to apply small diameter wire as roughness in solar air heater. The parameters for study were relative roughness height as 0.019 and relative roughness pitch as 12.7. They reported application of protruding wires led to improvement in plate efficiency factor from 0.63 to 0.72.

Prasad and Saini [4] used small diameter wire as roughness in solar air heater. They investigated effect of relative roughness height and relative roughness pitch on heat transfer and friction factor. Range for relative roughness height was 0.020–0.033 and for relative roughness pitch was 10–20. Maximum value of Nusselt number and friction factor were reported as 2.38 and 4.25 respectively for relative roughness pitch of 10. The roughness used is shown in Fig. 1.

Gupta et al. [5] utilized transverse wires in solar air heater for transitionally rough flow regime. Range of parameters were relative roughness height as 0.018–0.052, aspect ratio ($W/H$) as 6.8–11.5, relative roughness pitch as 10 and Reynolds number varied from 3000–18000. They reported that for transitionally rough flow regime Stanton number increases with increase in Reynolds number and Stanton number achieved maximum value for Reynolds number of 12,000.

Verma and Prasad [6] did outdoor experimental study using transverse wire roughness. Parameters for study were relative roughness height as 0.01–0.03, relative roughness pitch as 10–40, roughness Reynolds number as 8–42 and Reynolds number varied from 5000 to 20,000. They reported optimal thermo-hydraulic performance of 71% corresponded to roughness Reynolds number of 24.

### 3.1.2. Transverse broken ribs

Sahu and Bhagoria [7] investigated transverse broken ribs as shown in Fig. 2. Investigation was carried for Reynolds number as 3000–12000, roughness pitch as 10–30 mm, rib height as 1.5 mm

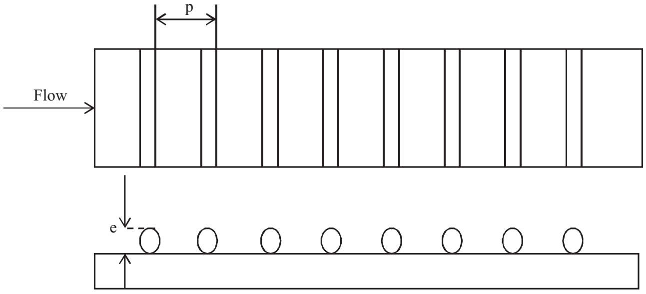

**Fig. 1.** Transverse small diameter wire.

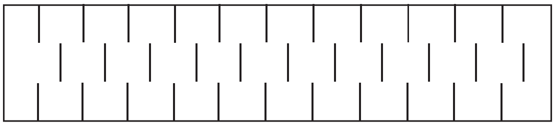

**Fig. 2.** Transverse broken ribs.