National Institute of Technology Rourkela

Synopsis Seminar

Seminar Title	: Experimental study of thermal and frictional characteristics of solar air heater using impinging jets with modified absorber and jet plates
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Venue	: Seminar Hall (Mechanical Engineering Department)
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Abstract : The depletion of fossil fuel and their impact on the environment due to continual usage for our ever-increasing power needs has forced us to look pro-actively towards other renewable forms of clean energy like wind, solar, ocean energy, etc. Amongst all renewable sources of energy, solar energy is abundantly available throughout the world and can meet the energy needs of our planet if appropriately harnessed. Solar thermal collectors are used to collect solar thermal energy, and then it is transferred to the fluid. The fluid may be air, water, oil, etc. depending on the application. Many researchers are working towards performance enhancement of solar thermal collectors. This study concentrates on solar air heater with impinging jets incorporated with modifications to absorber and jet plate to improve its efficiency. Five objectives were chosen and completed. For the first objective, an experimental setup of an impinging jet solar air heater (IJSAH) was developed to study its thermal and frictional characteristics. Six cases were analysed with the jet holes spanning different lengths across the jet plate. For cases 1 and 2, jet holes spanned 100% and 80% of the length of the jet plate while having jet diameter equal to 3 mm. For cases 3,4, and 5, jet holes were drilled up to 100%, 80%, and 60% of the whole length and the diameter was increased to 6 mm. For case 6, jet holes were drilled up to 100% while keeping jet diameter equal to 9 mm. For each case, variation in Nusselt number, friction factor and temperature rise of the fluid was evaluated for Reynolds number in the range 4913 to 13103. The efficiency and thermo-hydraulic performance factor with each case were compared. It was concluded that IJSAH with reduced length of drilled section (case 5) developed similar performance to IJSAH having completely perforated jet plate (case 1) while developing significantly lower friction factor. *The temperature rise of the fluid and the friction factor developed for case 5 were around 10% and 40% lower than case 1, respectively.*

In the second objective, the thermal performance of impinging jet solar air heater (IJSAH) was improved by using wire mesh of three different sizes. The variation of Nusselt number (Nu), friction factor (f), thermo-hydraulic performance parameter (THPP), and effective efficiency were evaluated for varying Re. Maximum Nu was developed for case 3 and equalled 109.86, which was 7.3% and 246% higher than a smooth IJSAH and flat plate solar air heater (FPSAH), respectively. The minimum friction factor attained equated to 0.0314 for case 2 at Re = 13103. Maximum THPP attained by the setup equalled 1.78 for case 4, having Dj = 6 mm. The THPP attained by case 4 across the range of Re was on an average 9.15% higher when compared to smooth IJSAH with Dj = 3mm. Additionally, the system achieved maximum &etaeff of 0.53695 at Re = 4913 for case 4. Finally, it was recommended to use a wire mesh having a mesh size equal to 38.1 × 38.1 mm with Dj = 6 mm for optimum performance. For the third objective, an experimental study was conducted to analyse the thermal and frictional attributes of an IJSAH with an absorber plate having stepped transverse ribs with varying pitch and size. Two ribs of dimension 2×4 cm (R1) and 4×6 cm (R2) were tested. The pitch (p) between ribs was 2, 4, and 8 cm, with Re varying from 4913 to 13103. The jet hole diameter (Dj) considered were 3, 6 and 9 mm. The maximum Nu with the recommended R1 rib having p = 4 cm and Dj = 3 and 6 mm equalled 128.784 and 104.5004 at Re = 13103, respectively, which was 31.22 and 21.76% higher than that generated by smooth IJSAH. The friction factor (f) generated by the ribbed IJSAH having Dj = 6 mm and p = 4 cm was 57.08% lower than ribbed IJSAH with Dj = 3 mm. The peak thermohydraulic performance parameter (THPP) achieved was for R1 rib with p = 4 cm and Dj = 6 mm and equalled 1.75, which was 19.49% higher than smooth IJSAH. The R1 rib with p = 4 cm at Re = 11465 demonstrated better thermal characteristics based on detailed investigation. For the fourth objective, an experimental study on the effect of shortening of jet plate perforation length on the thermal and frictional performance of an impinging jet solar air heater with ribs (RIJSAH) was conducted. The jet span length was shortened to 80% and 60% of the total length, while the Dj considered were 3, 6, and 9 mm. There was an increase in the Nusselt number with a decrease in jet span length (JSL) for Dj = 6 mm. It was found that, at Re = 11465, the Nu developed by ribbed IJSAH with Dj = 6 mm and JSL = 60% was only 5.06% less than that developed by RIJSAH with Dj = 3 mm while suffering a friction factor 24.13% less than that generated by the latter. The THPP attained generally decreased with a decrease in JSL, but at higher Re, the THPP attained by RIJSAH wit Dj = 6 mm and 60% JSL was higher than that achieved by RIJSAH with Dj = 6 mm and 80% JSL. There was a clea decrease in temperature difference between the fluid and the absorber plate with a decrease in JSL, which enhanced the thermal performance of the system. In conclusion, it is recommended that RIJSAH be fabricated with Dj = 6 mm and 60% JSL to achieve well-optimized thermal performance.

The thermal and frictional attributes of RIJSAH having a jet plate modified with protruded circular nozzles (PCN)) was estimated. The protruded nozzle inside diameter considered were 3, 6 and 8 mm, while the thickness of these nozzles were kept constant at 2 mm. Subsequently, the performance of PCN IJSAH with reduced span of jet plate was a studied. The jet plate span length (JSL) was modified from 100% (L=1400 mm) to 80% (1120 mm) and then 60% (840 mm). For Dj = 3 mm, the Nu attained by PCN IJSAH with and without ribs were approximately the same and, as such, was not useful. For Dj = 6 mm, the average Nu attained by PCN IJSAH with ribs was 3.9% higher than that

attained by PCN IJSAH without ribs. Any decrease in JSL resulted in an increase in Nu attained. The average *Nu* attained by PCN RIJSAH with Dj = 6 mm and 60% JSL was 29.72% higher than that achieved by PCN RIJSAH with 100% JSL while generative lower friction factor. The peak THPP attained by PCN IJSAH with ribs having Dj = 8 and 6 mm was equivalent to 1.78, and 1.84, respectively, while the peak THPP attained by PCN IJSAH with ribs having Dj = 3 mm equalled 1.43 mm at *Re*=11465. The THPP improved upon shortening of JSL. The average THPP attained by PCN RIJSAH with Dj = 6 mm and 60% JSL was 2.79% higher than B1, whereas THPP attained by PCN RIJSAH with Dj = 6 mm and 80% JSL was 8.78% higher than A1. It was further seen that there was an approximate increasing trend in thermal efficiency with rising Re. It was concluded that PCN RIJSAH with reduced span of jet plate length developed better thermal performance relative to the friction factor generated.