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Convective heat loss investigation from a coupled parabolic dish receiver system

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1. INTRODUCTION

Among all concentrating solar power (CSP) techniques, parabolic dishes are the most efficient system due to their higher concentration ratio and temperatures achieved inside the cavity receivers. Due to installation in the open terrine, the system efficiency is affected by the heat loss from the receivers [1]. Heat losses from the receiver occur by convection, conduction and radiation. As a result of complex velocity and temperature filed around the receiver, determination of convective heat loss is much more complicated among all these heat transfer modes [2].

All the studies reviewed so far, however, indicate that there is a significant lack of work on the impact of parabolic dishes on wind flow and heat loss at the receiver [2]. Numerous studies, highlighted in review of the field by Wu et al. [2], have examined the convection heat loss by treating the receiver as an isolated entity. . This decoupling provides a simplified regime that would be accurate for no wind condition and for certain tilt angles (θ). However, the presence of the dish structure in the flow field have a significant effect on the heat loss, particularly mixed and forced convection [3, 4]. This work is aimed to investigate the convective heat losses from the receiver in the presence of the dish structure in the flow field.

2. APPROACH

In this study, numerical investigation was performed at different operating inclinations of the parabolic dish system (PDS) with constant cavity wall temperature. An existing 20 m^2 dish with a frustum shaped receiver positioned at a focal distance of 1.84 m was selected to perform computational fluid dynamics (CFD) using Shear Stress Transport (SST) two-equation eddy-viscosity turbulence model. The fluid properties were derived as a function of temperature with the assumption that the pressure does not change significantly in the flow domain. The major focused parameters were the wind velocity (V) and the dish tilt angle (θ). The value of wind velocity were changed from 0m/s (natural convection case) to 20 m/s (forced convection case), while the tilt angles were changed from 90° to -90° degree.

3. RESULTS

In the case of zero wind velocity, the natural convection heat losses were in good agreement with the previous studies [5-7]. The heat loss form the receiver showed the dependency on the tilt angle. Maximum and minimum heat losses were found at 90° tilt angle (cavity facing horizontally sideway) and 0° tilt angle (cavity facing vertically downward).

After introducing the air flow into the system, the heat loss from receiver displayed different behaviour on different operating conditions. Most of the time, the receiver was shielded, provided by the dish structure, from free stream flow. As a result the local velocities were found to be very less than the free stream velocities. At low velocities near the receiver, the air flow provided an air curtain near the mouth of receiver. The generated air curtain supressed the convective heat loss and, as a result, the heat loss was found to lesser than the natural convection (no-wind condition).

Figure 1 showed that the heat loss was found to be lesser than the natural convection (no-wind condition) at most of the angles except between tilt angles between +/-30° and 0°. In these working conditions, the receiver was out of the wake region of dish and directly exposed to free stream wind resulting a higher heat loss. The variation at zero degree tilt angle was not plotted as it increased very rapidly up to 112 times the natural convection heat loss at 20 m/s. Compared to the case having no dish in flow, the presence of dish structure can reduce the heat loss up to 40% at higher speed [4].

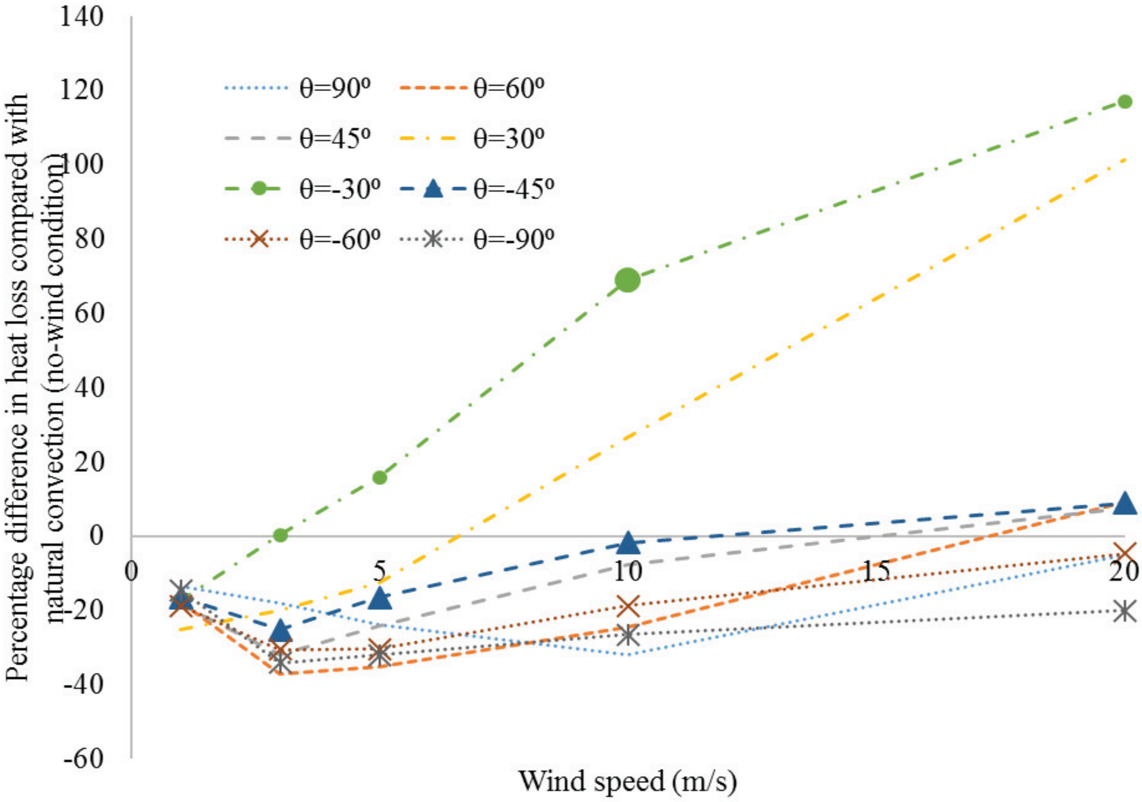

Figure 1: Comparison of convective heat losses with natural convection heat loss (no-wind condition)

4. CONCLUSIONS

The results indicated the significant reduction in the heat losses from the cavity receive due to the presence of dish structure in the flow field at different operating conditions. The local velocities near the receiver affected due to the dish and subsequently heat loss reduced. Also, at different working conditions, a critical velocity (less than 5m/s) was observed to distinguish between natural convection and mixed convection heat loss.

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