Creating a controlled recirculation air vortex in the VoCoRec solar receiver to reduce convection losses

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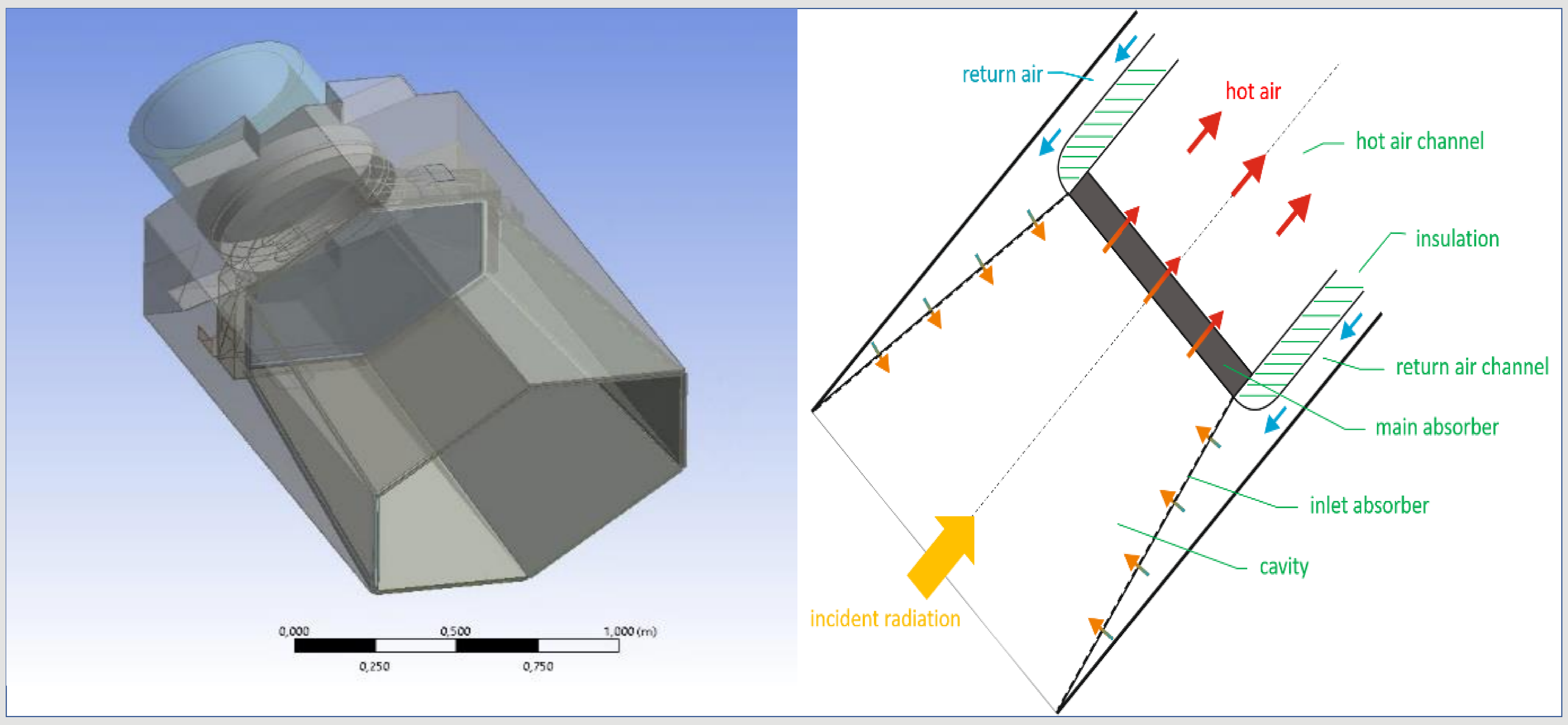
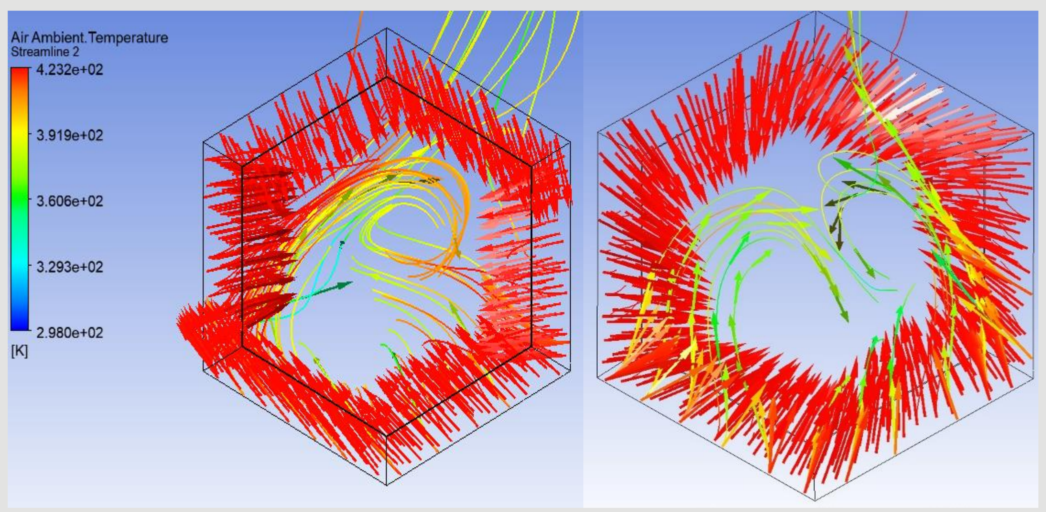


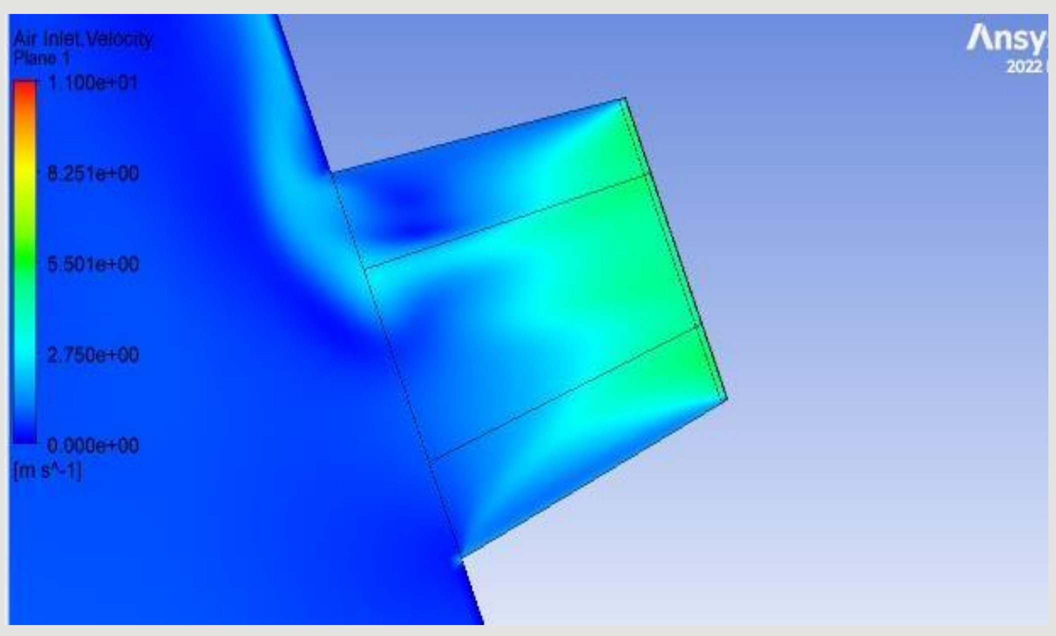
Introduktion

The efficiency of air-type solar towers influences the minimal cost of electricity/heat produced by them, which limits their use despite the widespread use of many forms of concentrated sun power plants. Nonetheless, the temperature potential of this kind of concentrated plant is the highest. To improve the efficiency of an air-type solar tower, a technique for reducing convective energy losses with return air is therefore suggested. In order to increase a cavity receiver's thermal efficiency, a little-known concept called. Using the VoCoRec design as an example, cases are shown where the vortex increases and decreases the thermal efficiency of the receiver. The concept of Air Return Ratio (ARR) is used to determine the convective losses in a solar collector. This coefficient indicates the convective losses of the receiver due to buoyancy forces and has a direct proportional dependence on the convective efficiency coefficients of the receiver. The VoCoRec receiver, which incorporates the directional vortex inside the receiver, increased the air return coefficient by 4% (at the same air mass flow rate). The dependence of the air return coefficient on different angles of the air outlet to the absorber plane, including in the radial direction, was also investigated. Increasing the angle of inclination of the air outlet to the main absorber increases the air return coefficient in all cases, but also increases the aerodynamic drag of the receiver (pressure drop).

Results

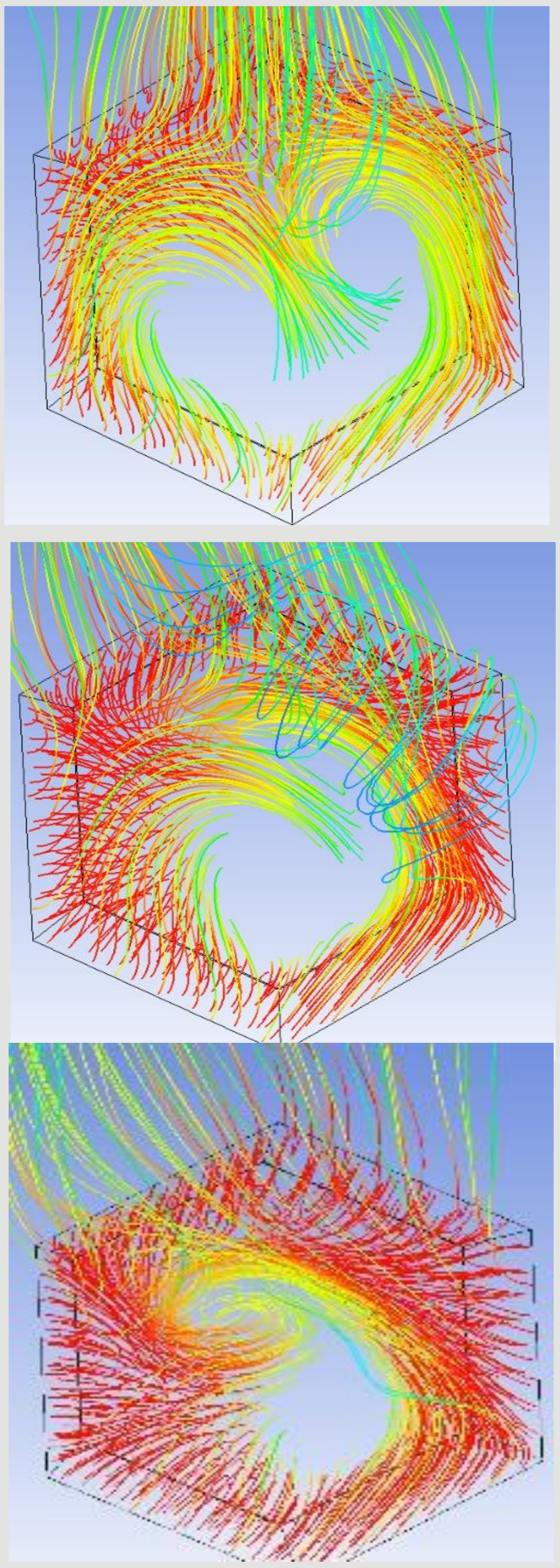
The direction of the velocity vector perpendicular to the outlet plane was chosen as the basic option. The creation of the vortex was considered in two ways: the slope of the air outlet velocity from the outlet absorber along each geometric plane (left), and the centred displaced flow given by the cylindrical coordinates of the air outlet velocity through the second absorber (right)

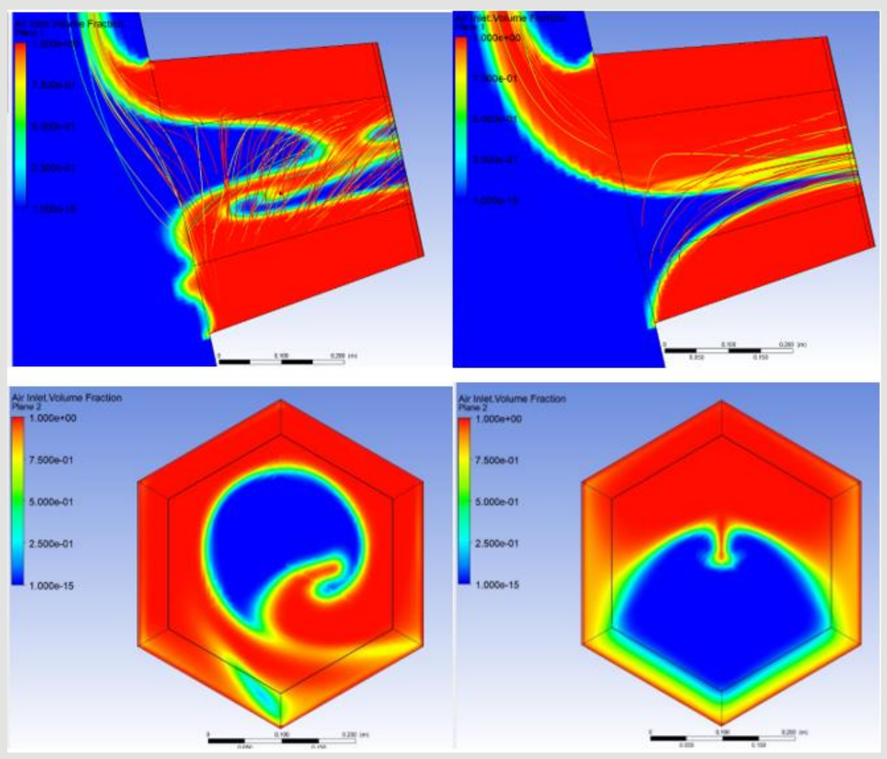




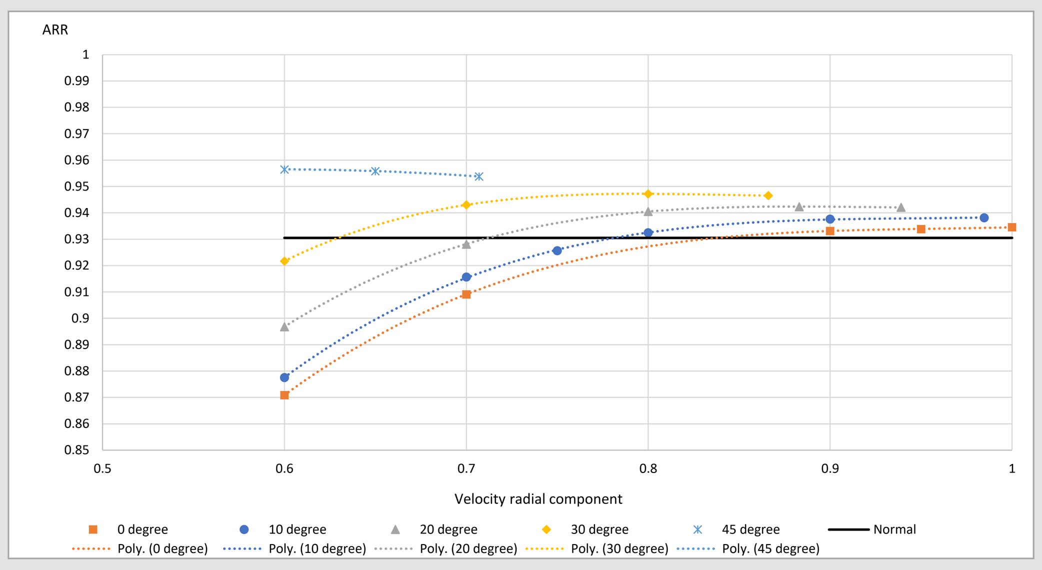
Speed distribution in VoCoRec Large type receiver with mass Flow 5.04 [kg/s], ARR=0.87

Comparison of return air current lines for VoCoRec Large M_1=1.2 kg/s, M_2=2.43 kg/s, M_3=5.04 kg/s

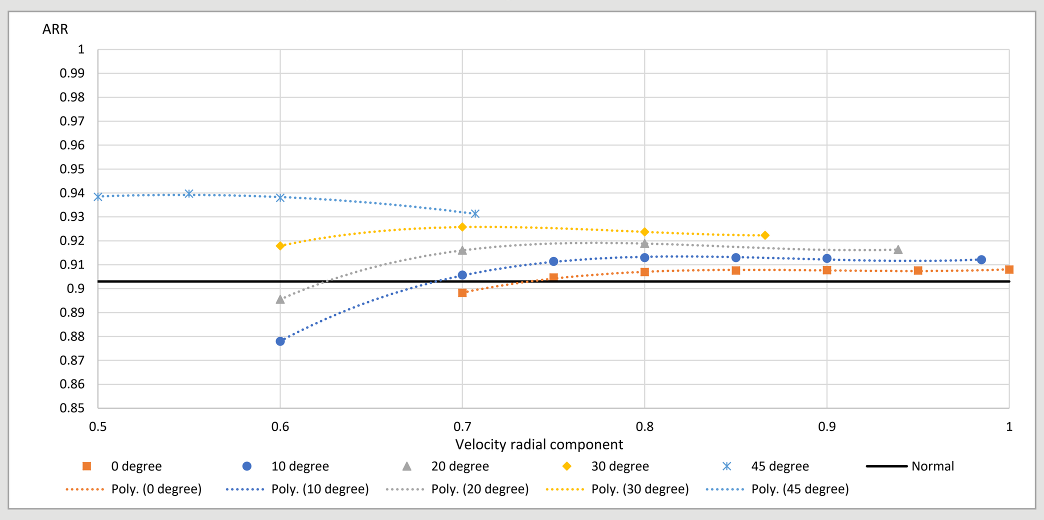




Figures bellow show the dependence ARR for different velocity components in a small size VoCoRec for different mass flow rates. The solid black line shows the ARR value for the normal velocity distribution of the outlet flow from the outlet absorber (absorber type - grid). The smaller the radial component of the velocity, the larger the tangential component (i.e., the angle of the vortex flow).
As the angle of inclination of the air from the outlet absorber increases (increasing the absolute value of the axial velocity component) to the main absorber, the ARR will increase as the air is directed deeper into the receiver.
It is expected that the optimal feed angle depends on the geometry of the receiver, namely the ratio of its depth to the diameter of the main absorber. For the geometry under consideration, this ratio is 380/350. The distance between the center of the main absorber and the far point on the receiver aperture is 424 mm, with an angle of inclination of this curve to the receiver symmetry axis of 32 degrees.



Dependence ARR for different velocity components in VoCoRec small size for m=0,21 kg/s



Dependence ARR for different velocity components in VoCoRec small size for m=0,162 kg/s

Conclusions

It was found that the creation of an adjustable outlet air vortex can increase the air return ratio in a VoCoRec receiver. For a VoCoRec receiver with a small planned geometry, an increase in ARR of 4 % was obtained at the nominal mass air flow rate

The primary conclusions that came from the computer modeling and computations were as follows:

There exists an optimal flow out angle of return air that depends on the receiver's geometry and mass flow (fig.11, fig.12);
- increasing the angle of inclination (axial velocity component) of the air from outlet absorber in the direction of the main absorber increases the ARR, but the effect from vortex decreases;
- as the mass velocity decreases, the effect of uniform flow distribution from the vortex decreases;
- for large unit of VoCoRec with the mass flow rate of 2.43 kg/s and the value of the tangential velocity component of 0.5 (radial component = 0) the ARR increases by only 0.95%.

Generally speaking, creating a vortex inside the hollow receiver's plane can decrease convection losses with air while simultaneously stabilizing the flow, which in theory raises the absorber's resistance to outside wind. The creation and improvement of this research include examining the impact of the swirling flow inside the hollow receiver on counteracting variations in the receiver's efficiency at various external wind directions and speeds. The investigation of non-design conditions of the cavity receiver with a vortex and the impact of surrounding wind on the vortex's stability are the main areas of future research.

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