DEVELOPMENT AND VALIDATION OF THE PASSIVE ADJUSTMENT TOROIDAL HELIOSTAT (PATH)

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High solar field efficiency is an important goal for improving the cost effectiveness and practicality of point focus solar thermal systems. Simulations performed by Heliosystems have shown that very significant improvements can be made to the energy capture efficiency of solar thermal receivers by improving the concentration ratio of the solar field. These improvements are beyond the capability of conventional heliostats and a new type of heliostat is required. Heliosystems has developed the first prototypes of a new heliostat called a Passive Adjustment Toroidal Heliostat (PATH) to meet these requirements. The performance of the PATH is compared with toroidal and other conventional spherical azimuth-elevation heliostats

Simulated Performance

Ray tracing simulations have been used to simulate and compare the performance of solar fields of PATH, toroidal and conventional heliostats.

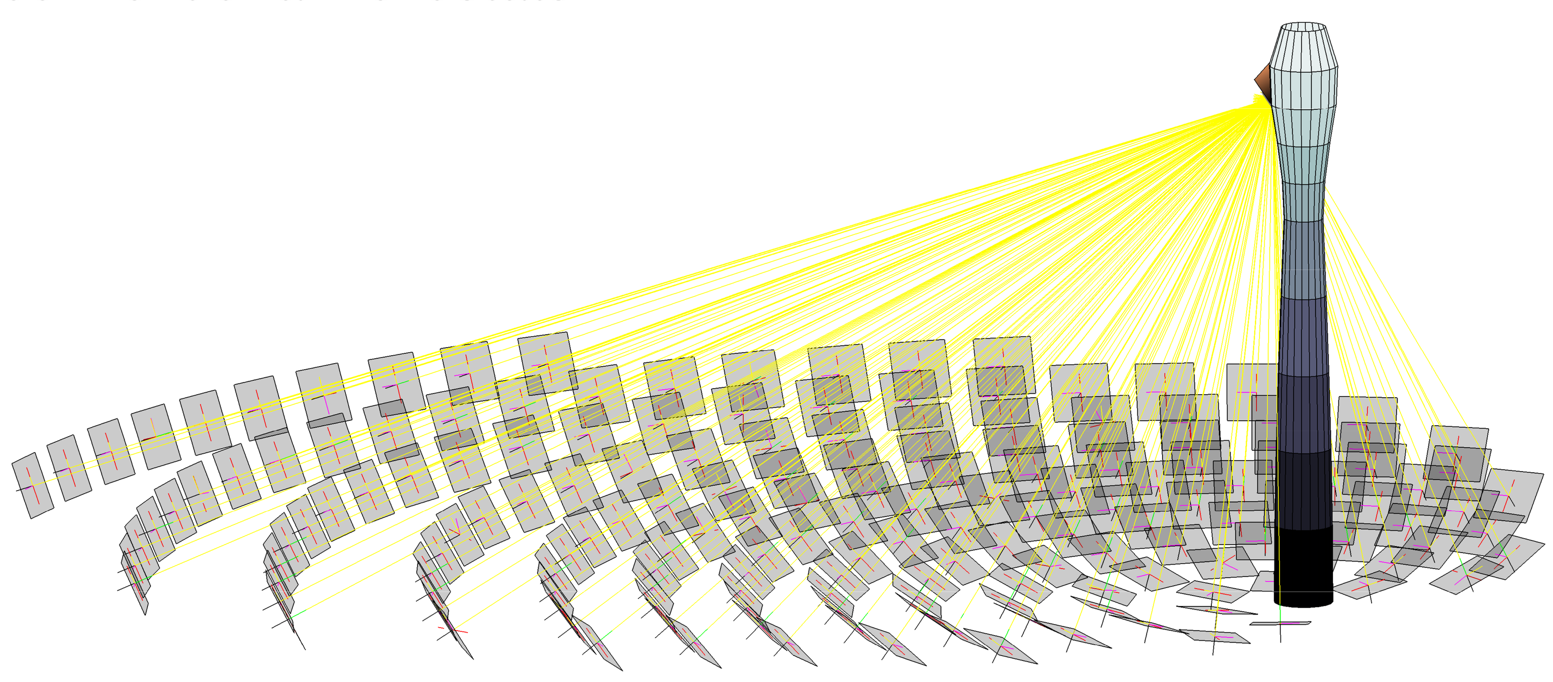

Fig.1 An optimised solar field used for comparison of the performance of different heliostats. Receiver diameter: 800mm, angled at 45° to horizontal and 23m above ground level

Yearly average energy delivery results are shown in Fig.2 for clear day DNI, and show that the PATH solar field performs 22% better than the solar field of toroidal heliostats. 40% more energy is collected from the PATH field than from the spherical heliostat field. The most substantial improvements from the PATH were in the early morning and late afternoon, when the effects of astigmatism limit the performance of the other types of heliostat. This improvement was consistent with the increase in concentration ratio over the whole day, and proportionally higher increase in the morning and afternoon.

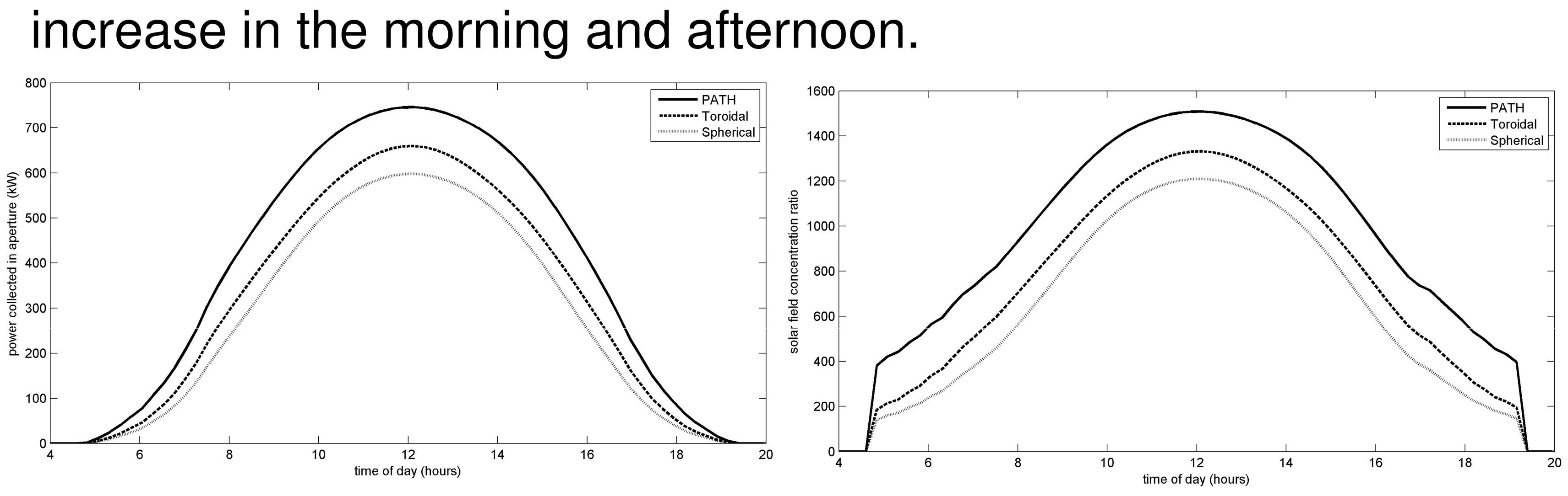

Fig.2a)Yearly average clear day power delivery into receiver aperture. b) solar field concentration ratios from PATH, toroidal and spherical heliostat fields.

The projected improvements from the PATH are such that even if the PATH cost more to produce than the other types of heliostat, it's improved efficiency could offset the higher unit cost. As many components are identical for all heliostats, it is feasible that a lower overall cost of energy could be achieved from the PATH.

The Prototype

Heliosystems developed a first generation PATH pier and mirror system to validate the concept of the passive adjustment system. The prototype featured the spinning elevation tracking mechanism characteristic of the toroidal (or target - aligned) heliostat with two independent precision slewing drives. The mirror was 3m x 3m in size and with independent static and dynamic curvature in tangential and sagittal directions. Curvature was varied as a function of gravitational loadings and elevation drive angle. Optimisation of both static and dynamic properties of the mirror were done using custom heliostat simulation tools developed by Heliosystems.

Experimental

The prototype PATH was tested against an equivalent toroidal heliostat. Both were tested at the same location, directly east of the receiver such that angle of incidence variation was very high for the day. The measurements were made by tracking the heliostat images on a white lambertian target at the position of the receiver aperture, and measuring their images throughout the day. The optical measurements were made using a calibrated camera imaging system in combination with a local pyrheliometer. Samples of the images are shown in Fig. 3.

Fig.3 Heliostat images from the toroidal heliostat (above) and the PATH heliostat (below) at angles of incidence: 47° , 26° & 15° respectively. Astigmatism is significantly reduced by the PATH heliostat, but image irregularities due to mirror surface errors are worse for this prototype.

Image measurements were compared with simulation, and the results for beam FWHMs are shown in Fig.4. The agreement with the simulation is good for the toroidal heliostat, and reasonable for the PATH mirror. Deviation from simulation for the PATH result is most likely to be due to the fact that the surface accuracy achieved for this mirror was not as good as was achieved for the toroidal mirror. Heliostat mirror surface measurements confirmed this, but quantitative results were not available at the time of writing.

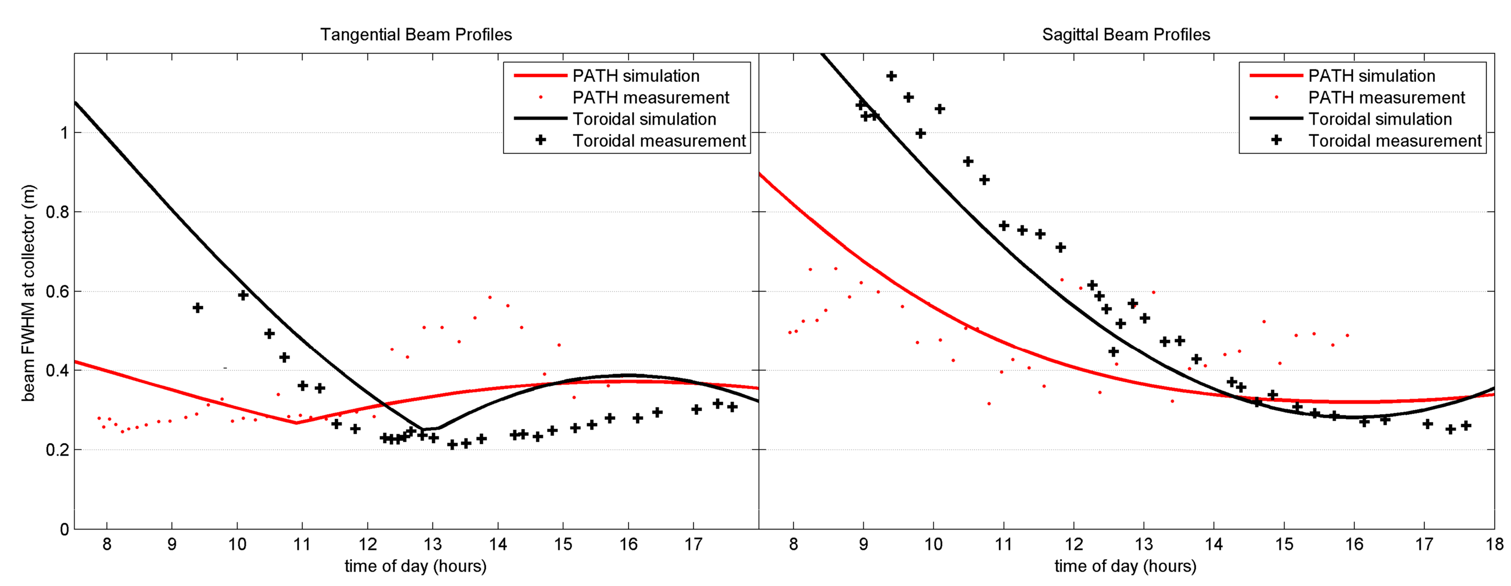

Fig.4 Comparison of beam profiles measured from heliostat prototypes and simulation results.

Conclusion

Heliosystems has developed a new type of heliostat that offers the possibility of higher solar field efficiency and lower cost of energy. Simulation results show that the PATH would deliver more power than other heliostats, especially in the morning and afternoon. Image measurements from the first prototype demonstrated that the predicted improvements are real and match the simulation. Further work is required to improve the surface accuracy of the PATH mirror, and to reduce its cost and complexity.