Aerodynamic Screening of a Yurt-Inspired Passive Wind-Flow Collector

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Introduction

Small wind-energy systems are highly sensitive to local velocity because the available kinetic power density scales with the third power of wind speed. Passive collectors and diffuser-augmented turbines therefore try to modify the pressure field around a rotor and draw more mass flow through a useful section.

The present work investigates a yurt-inspired architectural shell as a possible passive wind-flow collector. The form is radially organised, low-profile and compatible with modular construction, but this architectural motivation does not automatically imply aerodynamic concentration.

The first design question is whether the unmodified shell can deliver an accelerated stream to turbine-relevant sections before guide vanes, rotor loading or flow-straightening elements are added.

The study is deliberately positioned as a screening stage. If the base geometry creates velocity augmentation, the next step would be turbine matching. If it does not, the correct next step is redesign of the inlet, guide surfaces and diffuser/brim elements.

The diagnostic quantity used in this stage is the velocity ratio $\alpha_i = U_i / U_\infty$ at three monitored sections: channel inlet, channel outlet and diffuser outlet.

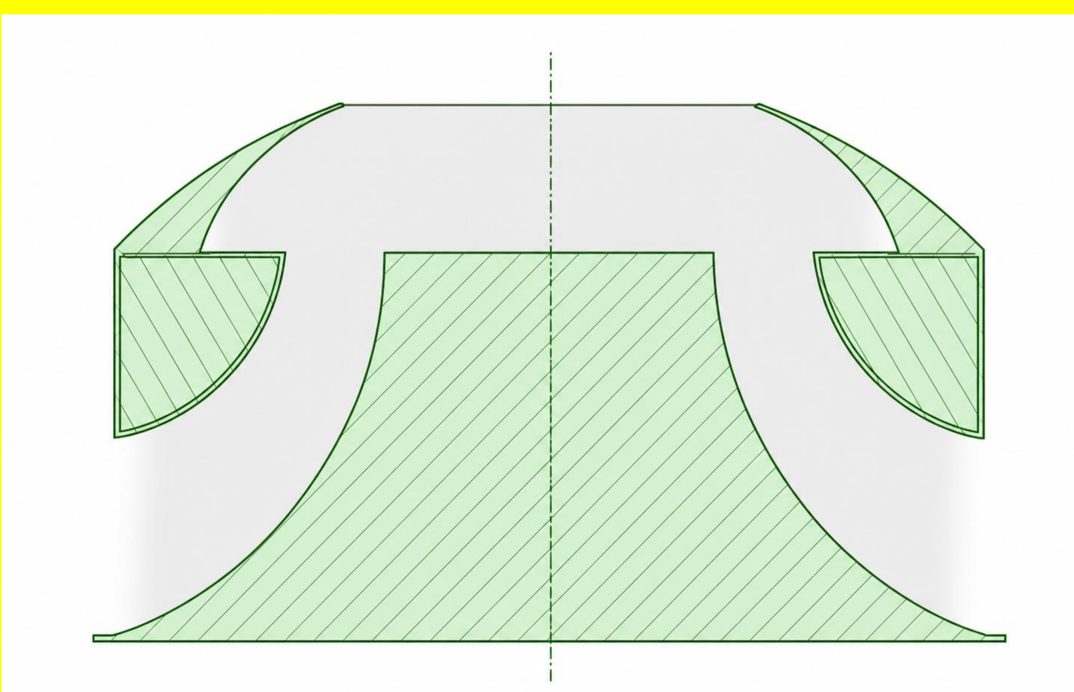

Fig. 1. Yurt-inspired collector geometry and monitored sections.

Numerical setup

Simulations were performed in Ansys Fluent using a three-dimensional steady pressure-based formulation.

The turbulence closure was the SST k–ω model. Air density was $\rho = 1.225$ kg/m³ and dynamic viscosity was $\mu = 1.7894\times10^{-5}$ kg/(m·s).

Two inlet velocities were analysed: $U_\infty = 4$ m/s and $U_\infty = 6$ m/s. The outlet was prescribed as a zero gauge-pressure outlet. Top and side boundaries were symmetry boundaries; ground and solid walls were stationary no-slip surfaces.

The same polyhedral mesh was used in both operating points and contained 597,292 cells, 3,443,899 faces and 2,594,127 nodes. No rotor, actuator disk, porous resistance or fan zone was included, so the results describe the empty collector only.

2. The monitored surfaces were selected to separate the initial entry into the channel, downstream delivery through the channel and discharge through the diffuser outlet.

3. This separation avoids a common ambiguity in architectural collector concepts: local acceleration somewhere around the body is not equivalent to useful acceleration at a turbine plane.

4. Negative mass-flow signs in Fluent were interpreted as surface-normal orientation; magnitudes were used for comparison.

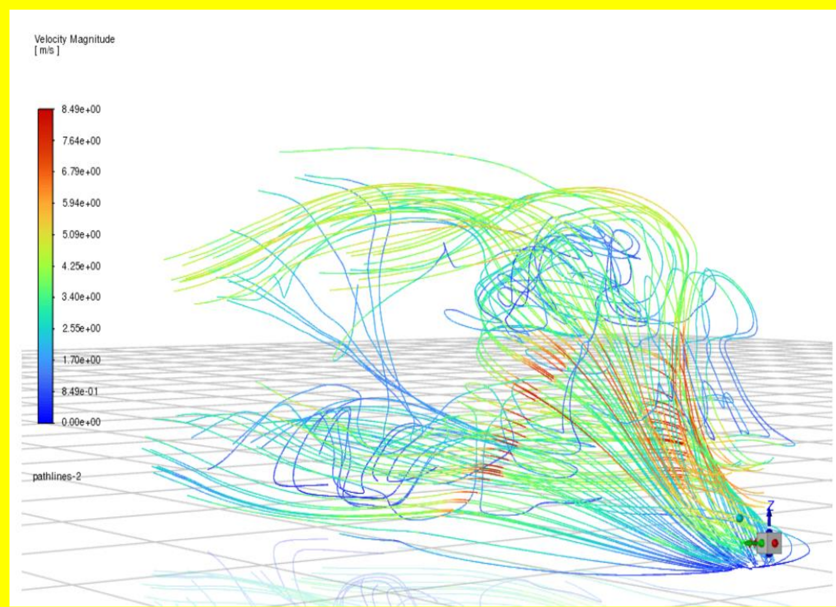

Fig. 2. Pathlines for the 6 m/s case.

Numerical model

The simulations used the SIMPLE pressure–velocity coupling scheme. Pressure was discretised with a second-order scheme; momentum, turbulent kinetic energy and specific dissipation rate were discretised with second-order upwind schemes.

The 4 m/s case was obtained from a control restart after an earlier trend-identification run. The 6 m/s case was run for 700 iterations. Velocity and turbulence residuals satisfied the selected criterion, while continuity residuals remained above 10^{-3}.

The results are therefore used as a robust qualitative screening outcome. Final quantitative claims require additional convergence, grid-independence and domain-independence checks.

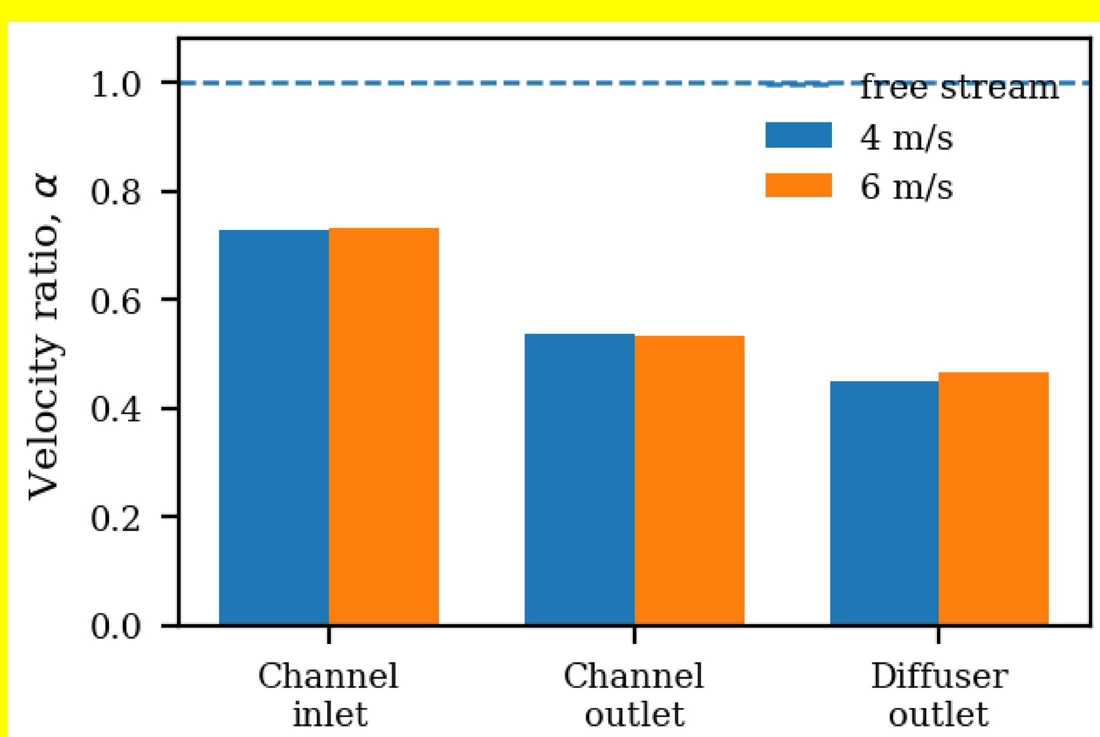

Fig. 3. Velocity ratio at monitored sections.

Results

The channel inlet was the most favourable section, but it reached only 72.8% of the free-stream velocity in the 4 m/s case and 73.1% in the 6 m/s case.

The channel outlet was approximately 53–54% of the free stream, and the diffuser outlet was approximately 45–47%. Thus none of the usable sections exhibited the acceleration expected from a flow concentrator.

The pressure response was dynamically consistent between the two velocity cases. At the channel inlet, C□ was about 0.170 at 4 m/s and 0.177 at 6 m/s. At the channel outlet, C□ was approximately −0.381 and −0.361, and at the diffuser outlet it was approximately −0.238 and −0.232.

These values indicate a repeatable downstream suction tendency, but the pressure field does not generate an accelerated stream through the intended channel and diffuser path.

Mass-flow magnitudes scaled approximately with the imposed inlet velocity, which supports the interpretation that the two operating points represent the same geometry-controlled topology rather than different flow regimes.

Pathlines explain the monitored values: much of the incident flow is redirected around the structure or involved in recirculating trajectories. Local acceleration around the shell is therefore not the same as controlled concentration through a turbine plane.

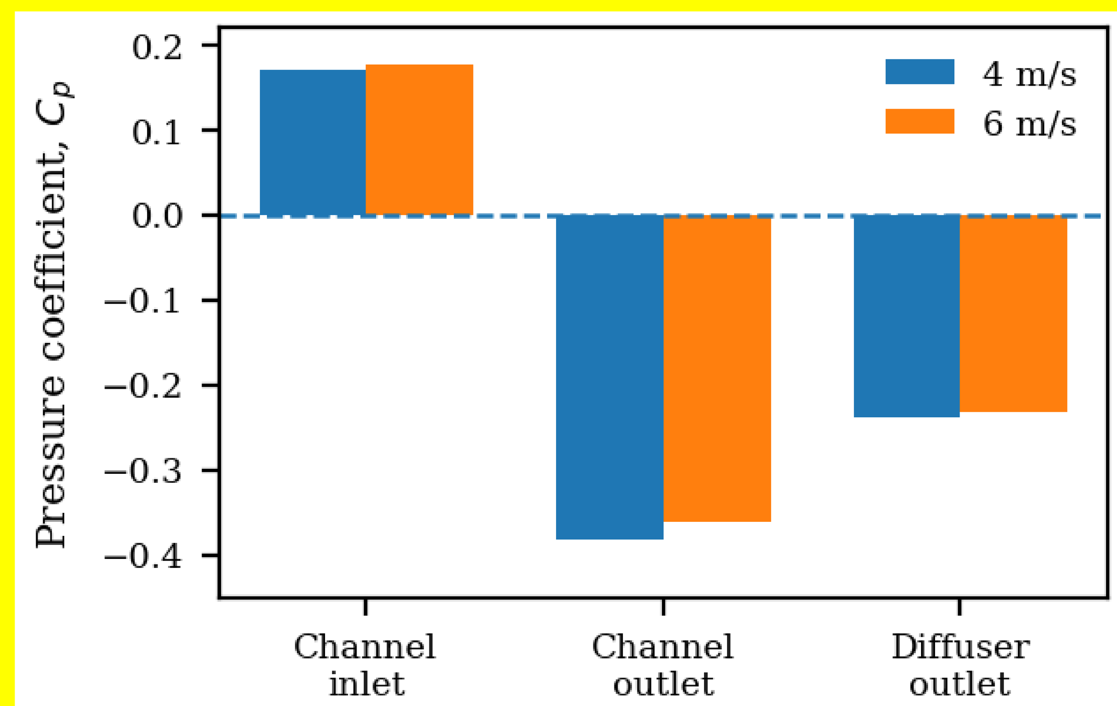

Fig. 4. Pressure coefficient at monitored surfaces.

Conclusions

The main conclusions drawn from this screening study are:

- No monitored section showed velocity augmentation; α_i remained below unity for both inlet speeds.
- The base yurt-inspired shell acts as a flow-intercepting and flow-redirecting body, not as an effective concentrator.
- Downstream suction is present, but it is not converted into useful channel acceleration.
- Future work should optimise guide vanes, inlet lips, diffuser/brim elements and aperture preservation before turbine integration is evaluated.
- The next CFD stage should include mesh and domain sensitivity, yaw-angle sweeps, rotor loading and experimental validation.

References

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