Numerical Investigation into the Influence of Scale Shape on the Hydrodynamics of Fish Scale Arrays

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ABSTRACT

Aerodynamic drag is a problem that persists in many industries but has a particularly profound impact on energy consumption in the transportation sector. Naturally occurring surfaces have been optimized over thousands of years to handle the aerodynamic or hydrodynamic drag they experience. An understanding of these optimized features and underlying mechanisms would assist researchers and engineers to adapt these features in practical applications to reduce drag. One interesting feature that has received recent attention is the surface structure of fish scales. While these scales form an armor layer for fish, they also introduce a unique topography that interacts with the surrounding environment. Recent research has found that these fish scale arrays play an important role in delaying the transition from laminar to turbulent flow. However, studies have largely focused on studying the influence of a specific scale size and shape, yet research in the field of surface characterization has found that the scale size and shape can vary significantly between species and in different body sections of an individual fish. Given that the purpose of these scale variations is not well understood, there exists a need to study the influence of scale shape on the flow behaviour over these scale arrays. Knowledge of the role these variations play in modifying the flow structure can be used to enhance the design of structured surfaces which target drag reduction in practical engineering applications.

Three scale geometries (Circular, Diamond, Flat Back) were identified that align with the general characteristics of different scale shapes. The near wall flow behaviour over each array was simulated in a laminar boundary layer using ANSYS Fluent. The model was validated using experimental data collected over the circular scale array in a water channel. Results were compared in relation to variations in scale shape and modifications to the oncoming flow.

The results revealed evidence of streamwise velocity streaks which vary in size and shape based on the scale geometry. Variations in the extent of the flow recirculation region and the patterns observed in the spanwise velocity component are also found to be influenced by scale shape. Changes in the inlet flow conditions resulted in similar patterns with different magnitudes. Ultimately, this analysis strives to explore the influence of scale shape and provide a deeper understanding of how scale shape can affect the hydrodynamic performance of fish scale arrays.

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