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Comparison of Turbulence Models Using Overset and Sliding Meshes in Fluent ANSYS

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Abstract: This research presents a comparison of the performance of an H-Darrieus turbine with the NACA 4415 asymmetric airfoil in terms of different CFD configurations. Several turbulence models were used and evaluated using two mesh assembly methods: sliding mesh and overset using ANSYS Fluent®. The turbulence models used include the SST k-ω, k-ε realizable, and k-ε standard models. The results indicate that the overset mesh method reduces simulation time, and while the performance differences between the two methods are not substantial, the overset method offers improved control and quality in element distribution, ensuring more accurate flow predictions and mesh management.

Keywords: Overset, Sliding mesh, NACA 4415, H-Darrieus, Turbulence Models, ANSYS Fluent.

Introduction

Accurate simulation of hydrokinetic turbines is crucial for their design and optimization, particularly within the context of renewable energy. Computational Fluid Dynamics (CFD) has emerged as a powerful tool for analyzing the complex flow structures and aerodynamic forces acting on these turbines. This research aims to numerically compare the performance of sliding mesh and overset mesh techniques in Fluent for modeling the rotation of a H-Darrieus hydrokinetic turbine.

The H-Darrieus turbine, a type of vertical axis turbine, is characterized by curved blades that rotate around a central axis. This unique blade design, along with its rotational movement, presents significant challenges for accurately capturing flow physics in numerical simulations (Seel et al., 2023). Advanced numerical techniques, such as the overset mesh, also known as the chimera grid method, allow the modeling of moving and rotating components within a flow domain using overlapping mesh regions (Gorle et al., 2016). In contrast, the sliding mesh approach uses a sliding interface between stationary and rotating regions to simulate the turbine blade rotation (Bahrami et al., 2014; Farahani et al., 2010; Nabhani et al., 2024). Recent studies have examined these numerical approaches in vertical turbines with varying results. For example, the work of (Mejia et al., 2021; Yadav et al., 2019) compared sliding mesh and overset techniques in turbine modeling, showing how the accuracy of the simulations depends on both the turbulence models used and the choice of meshing technique (Ye et al., 2024). On the other hand, more recent research has evaluated the computational efficiency of both methods, concluding that the sliding mesh offers lower computational cost and shorter simulation times, without significantly compromising accuracy, especially when symmetric meshes are achieved (Duraisamy & Lakshminarayan, 2014; Robin et al., 2023).

Selecting the correct turbulence model is critical for accurately predicting the flow behavior around the H-Darrieus turbine. Common models used in simulating wind and hydrokinetic turbines include SST k-ω, k-ε Realizable, and k-ε Standard. The SST k-ω model combines the strengths of the k-ω model near walls with the k-ε model for far-field turbulence, improving accuracy in capturing flow separation and adverse pressure gradients (Wu et al., 2010). Meanwhile, the k-ε Realizable model has shown reliable performance in modeling flows around rotating devices, making it another viable option for turbine simulations devices (Farahani et al., 2010).

Research Aim and Research Questions

The aim of this study is to investigate the performance of different turbulence models in simulating the behavior of an H-Darrieus turbine using ANSYS Fluent®, and to compare the efficiency and accuracy of two mesh assembly methods: sliding mesh and overset. The research seeks to determine the impact of these methods on simulation time, computational cost, and accuracy in modeling hydrokinetic turbines.

Objectives of the study:

1. Analyze the influence of SST k-ω, k-ε realizable, and k-ε standard turbulence models at the performance prediction of an H-Darrieus turbine using ANSYS Fluent®.
2. Compare the sliding mesh and overset methods in terms of simulation time and computational efficiency.
3. Evaluate the accuracy of both mesh methods in capturing key flow characteristics and moment coefficients of the turbine.

Research Results

Table 1 compares the performance of an H-Darrieus turbine using two meshing methods (sliding mesh and overset) and three turbulence models (SST- k-ω, *k*- ε Realizable and *k*- ε Standard) in terms of maximum, minimum, average momentum, and simulation time. The results show that the sliding mesh is less efficient in terms of simulation time, since it achieves higher maximum moments and shorter times compared to the overset mesh. In particular, the SST-K-ω model stands out for offering the highest maximum moment (400,914) and high average (71,154) with a short simulation time (6:36), making it the most efficient option in terms of accuracy and computational cost. In contrast, the K- ε Realizable model has the lowest performance in both methods, with lower maximum moments and longer simulation times, making it less favorable. The *K- ε* Standard model, although intermediate in accuracy, excels in speed on the sliding mesh (6:03), but is slower on the overset mesh. Overall, the sliding mesh emerges as the most efficient option when symmetric meshes can be generated, while the SST-K-ω model offers the best balance between accuracy and simulation time.

Table 1

Comparison of methods vs. generated moment

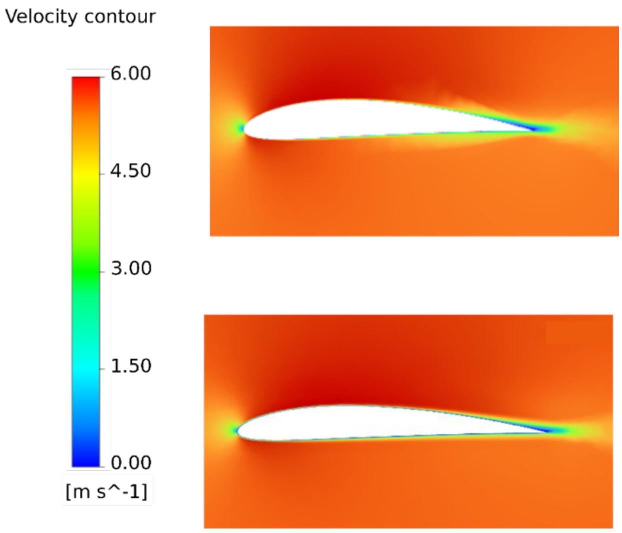
Mesh assembly method	Turbulence model	Maximum moment (Nm)	Minimum momento (Nm)	Average (Nm)	Time (h:m)
Malla deslizante	SST- k-ω	400,914	-45,059	71,154	6:36
	K- ε Realizable	372,739	-54,621	59,582	7:55
	k- ε Standard	383,918	-55,423	62,332	6:03
Overset	SST- k-ω	388,887	-43,955	69,020	6:36
	K- ε Realizable	357,829	-51,754	57,973	7:55
	k- ε Standard	376,240	-52,097	61,086	6:03

Source: authors own development

Figure 1 illustrates the velocity contour for meshes with sliding mesh and overset mesh using the SST k-ω turbulence model. In this figure, it is observed how each mesh captures the boundary layer effects differently. The overset mesh demonstrates a better resolution of the boundary layer near the turbine blades, leading to more accurate predictions of flow separation and recirculation (Duraisamy & Lakshminarayan, 2014). The sliding mesh, while computationally efficient, still provides reasonable results but tends to underestimate the boundary layer thickness, which can affect the accuracy of friction loss calculations (Bahrami et al., 2014; Mejia et al., 2021). The ability of the SST k-ω model to adapt between the k-ω formulation near walls and the k-ε model in free-stream regions is what makes it particularly suitable for such flow simulations (Wu et al., 2010). This figure underscores the importance of selecting an appropriate meshing method when simulating turbulent flows in hydrokinetic turbines.

Figure 1

Velocity contour of sliding mesh and overset with SST k-ω turbulence model.



Source: authors own development

Conclusions

This study highlights the importance of selecting the appropriate meshing method and turbulence model when simulating the performance of H-Darrieus hydrokinetic turbines. The overset method proved to be more efficient in terms of simulation time, while achieving a higher peak performance than the sliding mesh method. Among the turbulence models evaluated, the SST-k-ω and *k- ε* Standard models produced the best results in terms of peak and average moments. These results suggest that the overlapping mesh method, combined with these specific turbulence models, can significantly improve the accuracy and efficiency of the simulations, and provide valuable information for optimizing the design and operation of H-Darrieus turbines in renewable energy applications.

As future work, it is necessary to evaluate the power coefficient curve and determine how the turbulence models affect the turbine performance, including more parameters in each type of mesh.

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