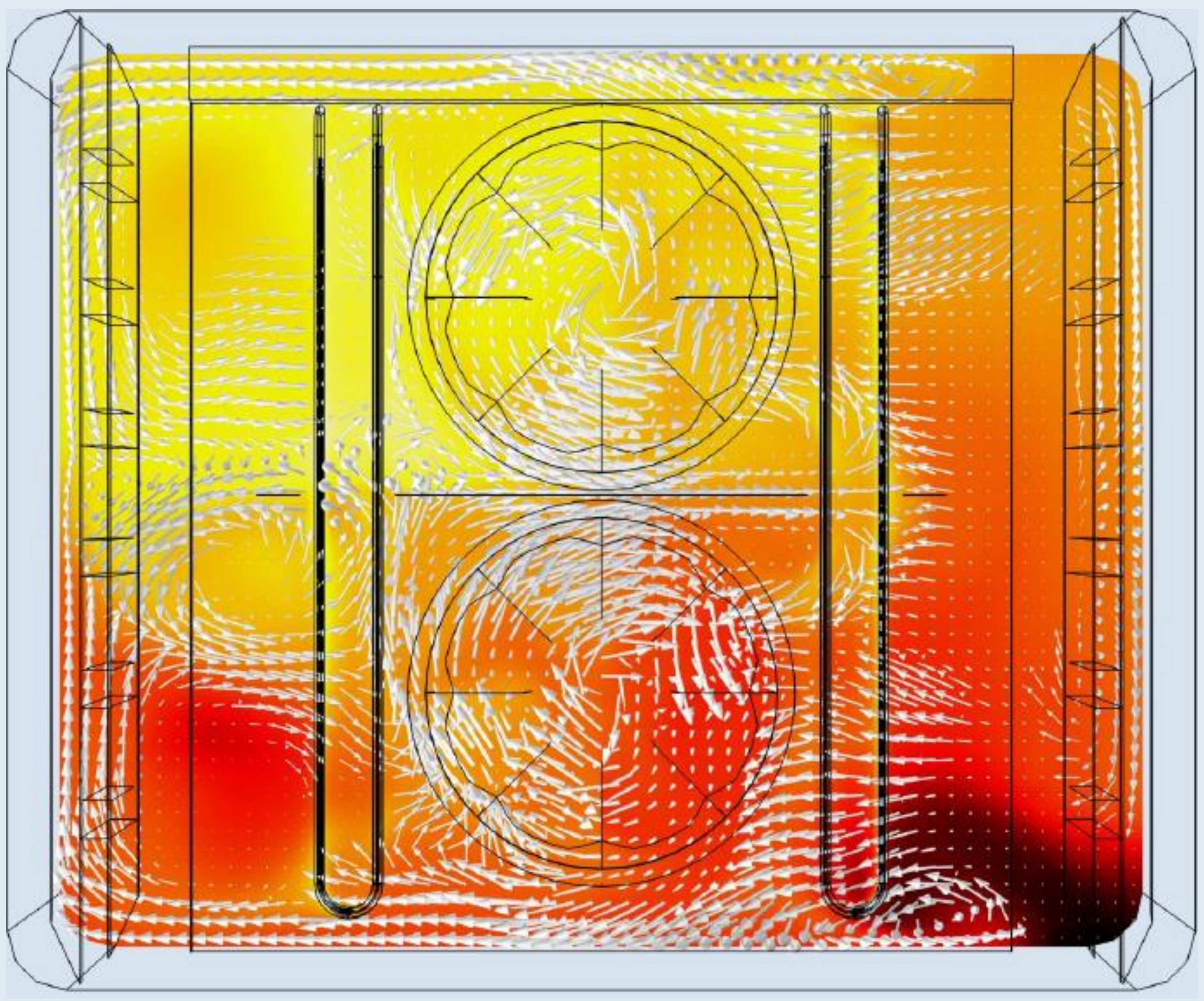

Fluid Dynamic Modeling in Oven Chambers: Balancing Accuracy and Computational Efficiency

The current study has investigated different model strategies to assess the air flow inside an oven, assessing accuracy and computational cost

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Abstract

This study focuses on comparing various fluid dynamic models for analyzing airflows within the cooking chamber of an oven. The comparison is conducted in three steps. First, a study of the fan directly connected to a test tube in suction mode, discharging radially into free space. Second, a comprehensive simulation of the fan within the actual application, i.e., the oven. Third, a similar analysis to the second step but with the velocity profile imposed, derived from the initial study. The data were analyzed and the discrepancies between the results were verified by comparing the histograms of the resulting velocity fields corresponding to the trays. This comparison showed a reasonable matching between the comprehensive simulation and the imposed velocity profile analysis. Thus, while the comprehensive approach is necessary for extremely accurate simulations, the velocity profile approach offers a sufficiently valid alternative that significantly reduces computational time, making it an efficient technique for faster estimations.

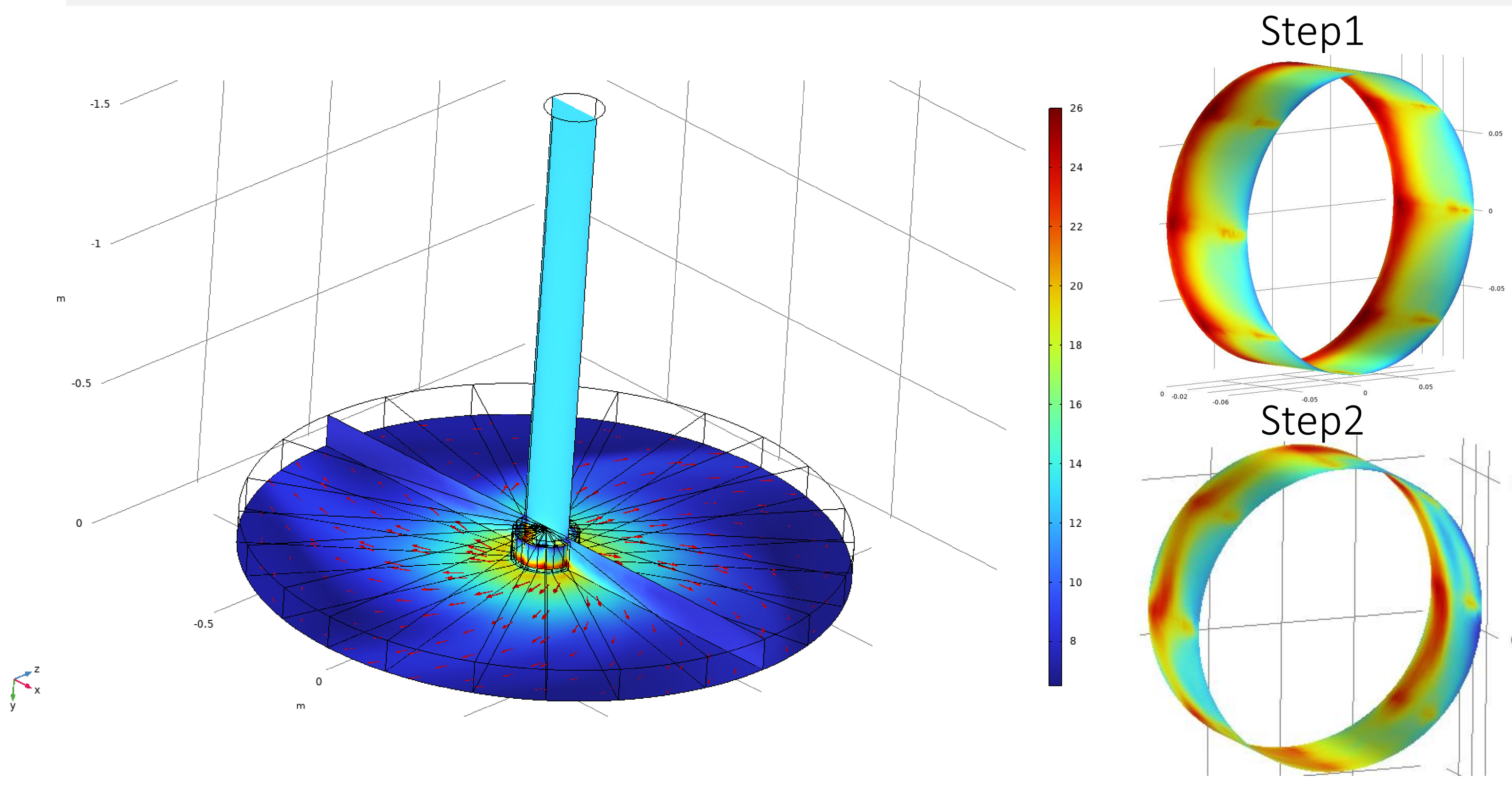

FIGURE 1. Left, model with the rotor connected to an air supplying pipe (step 1). Right, computed velocity profiles for the simplified model on the left with the full model in the oven.

Methodology

Step 1
Simplified domain fan (pipe and fan) + frozen rotor.
Low computational cost and possibility of performing experimental verification.

Step 2
Oven 0611 + frozen rotor + heat transfer.
Complex geometry of a real fan

Step 3
Oven 0611 + import speed profiles step 1 + thermal transfer.
reduction in computational cost (compared to step 2) thanks to the absence of the "rotating" fan.

Results

The numerical model has been validated through comparison of the behavior of the fan connected to a supplying pipe with experimental data (step 1). The average deviation of the velocity distribution in the trays between the full model (step 2) and the hybrid model (step 3) is equal to 4.57%. Qualitatively, the velocity profiles for the different simulations performed are comparable. Overall, the accuracy to assessing the cooking is quite high even with the simplification adopted in step 3, and therefore the full model should be adopted only for specific cases like fan design.

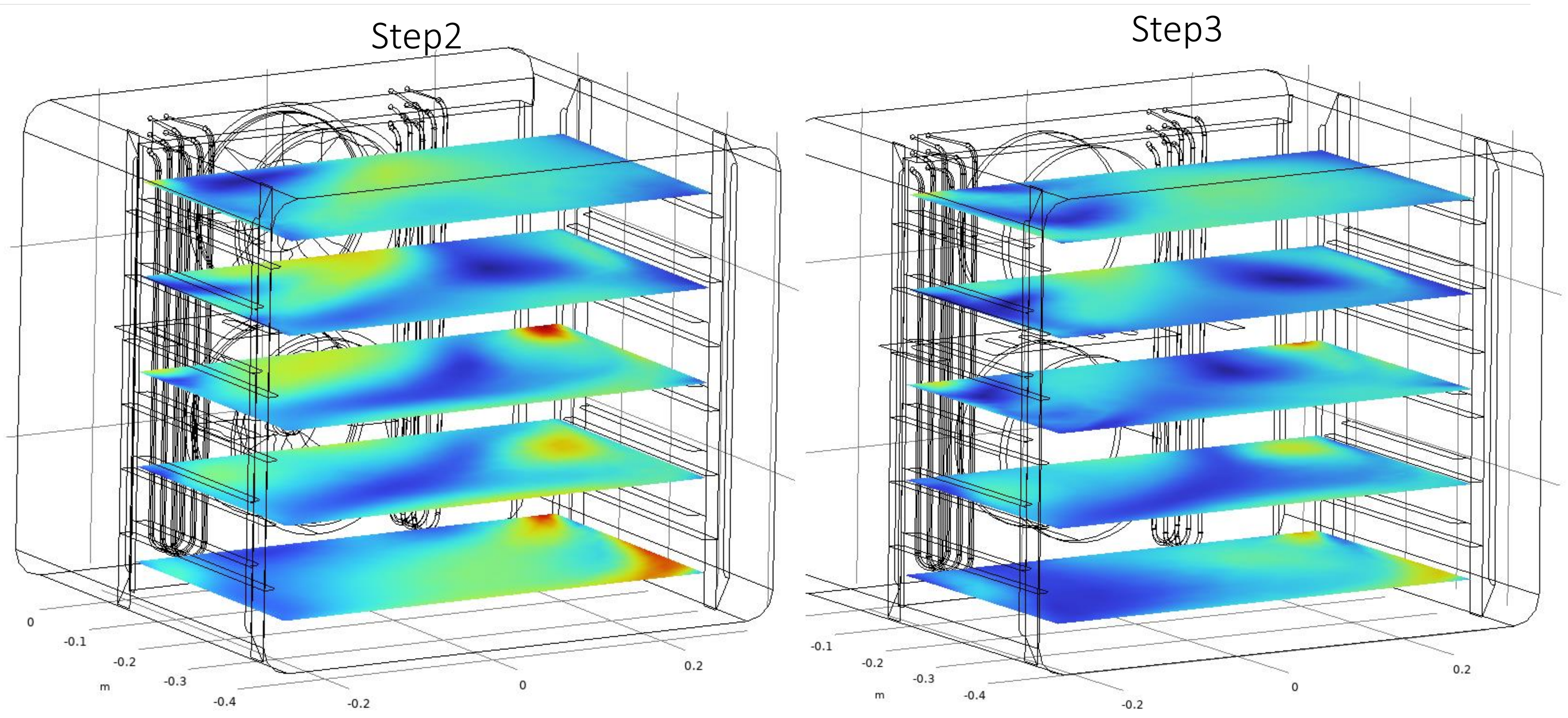

FIGURE 2. Left, velocity field over different tray levels for the model in step2. Right, the same velocity field computed in step3 with the impressed velocity profile derived from step1.

REFERENCES

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