# Verified Wind Tunnels for Everyone

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- Title: Numerical analysis of a mini wind tunnel and experimental investigation of the mini wind tunnel utilizing a portable, three-axis load/balance measurement system
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Wind tunnels have been around for many years, but there has always been a large problem with them. Wind tunnels that researchers use are typically the size of an entire room, which makes them expensive, hard to install, and not accessible to everyone. This paper shows how to create an inexpensive wind tunnel that is small enough to move by yourself and can record useful quantitative data. Most wind tunnels are research-grade wind tunnels that are the size of a room and are very difficult to obtain. While small desk toy wind tunnels are cheap and common, you can't measure anything with them. The wind tunnel they are making may be small and low-speed, but it can produce quantitative data, so the possibilities for growth and curiosity are vast. More people can now do experiments, ask questions, work with, and learn from this smaller-scale wind tunnel that can give you real, verifiable values.

To verify a wind tunnel, you need to record some kind of data and set up the system similar to other papers. They measured the lift and drag forces in the experimental model by placing an airfoil on sticks on a rolling platform with load cells so that they could measure the forces, as we can see in Figure 1. In this study, the big change they were testing was the size of the wind tunnel. In their experiment, they used the same NACA2412 airfoil and recorded the same values on graphs to plot their data on graphs from other papers. We can see in Figure 2 what that looks like. The only difference was that the Reynolds number was much smaller.

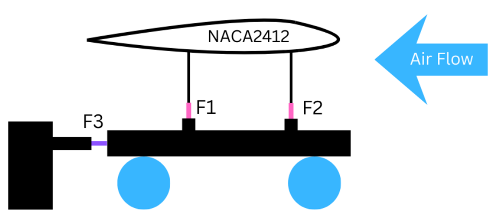


FIG. 1: This is a simplified model of the experimental setup. The pink and purple blocks represent the load cells. F1 and F2 represent lift forces and F3 represents the drag force from the NACA2421 Airfoil [1].

The Reynolds number is the ratio between the inertia forces and the viscous forces. In the more basic explanation, when the Reynolds number is low, the flow is laminar, and when it is high, the flow is turbulent. The small wind tunnel made it difficult to obtain high-speed laminar flow, which is why the Reynolds number was much lower than

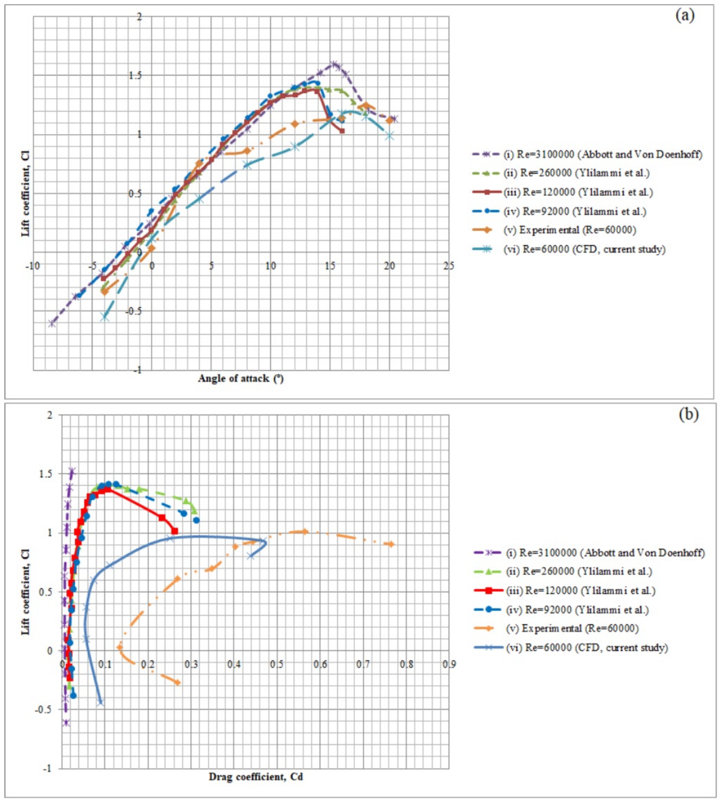


FIG. 2: Graphs that show the CFD (blue) and experimental (orange) data compared to other papers that are at much higher Reynolds numbers. [1].

in other papers. To calculate the Reynolds number of the system, they input the dimensions of the wind tunnel and the flow rate of the fan into a Computational Fluid Dynamics (CFD) model. They also ran the entire experiment in the CFD model and compared their results to the experimental results. Once they have collected all of the data, it is time to crunch some numbers and see where this wind tunnel stands. The CFD turbulence model is based on the experimental drag and lift coefficients. The mesh was chosen based on where the CFD model stopped changing the drag and lift forces as the elements in the mesh increased. As for the experimental model, the Reynolds number was simply not large enough. This is a small wind tunnel, and it is hard to get fast-flowing laminar air, which is the main restriction with this model. The experimental data from the low attack angles were much more accurate because the lift coefficient in low Reynolds numbers was not affected as much, so the data were very accurate up to about a 4-degree angle of attack. You may think this is restrictive, but I think this wind tunnel just didn't ask the right questions. It is exciting to know that there is a low-cost wind tunnel that is verified for low Reynolds number testing. You just have to come up with the right questions, and it can be a great learning tool.

[1] E. Kara and K. Öztürk, Numerical analysis of a mini wind tunnel and experimental investigation of the mini wind tunnel utilizing a portable, three-axis load/balance measurement system, Gümüşhane Üniversitesi Fen Bilimleri Dergisi **14**, 623 (2024).