# DECAY OF TURBULENCE AT HIGH REYNOLDS NUMBERS

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*Abstract* Using the unique capabilities of the Variable Density Turbulence Tunnel at the Max Planck Institute for Dynamics and Self-Organization, we investigated virtually homogeneous and isotropic grid turbulence over a wide range of Reynolds numbers, $Re = UM/\nu$, between $10^4$ and $5 \cdot 10^6$. The choice of pressurizable Sulfur Hexafluoride as a working gas makes it possible to reach extremely high Reynolds numbers without changing boundary conditions. Indeed, the Reynolds number we reached were higher than any previous classical grid wind-tunnel experiment. In this talk, we focus on the fundamental question of how fast turbulent energy decays once it has been created, and show that the Reynolds number plays no important role in setting the decay rate if it is high enough.

## THE VARIABLE DENSITY TURBULENCE TUNNEL

The Variable Density Turbulence Tunnel[2] is a pressurizable wind tunnel that can use both air and sulfur-hexafluoride as working gases. By setting the pressure of the gas to anywhere between 0.5 and 15 bar it is possible to set the Reynolds number, $Re = UM/\nu$, to values between $10^4$ and $5 \cdot 10^6$. Changing the pressure changes the kinematic viscosity, $\nu$. Here $U$ is the mean speed of the flow, $M$ the mesh spacing of the turbulence-producing classical grid. All the physical boundary conditions like grid size and shape, as well as the mean speed of the flow, remained constant throughout the experiments used in this study in order to focus solely on Reynolds number effects. To measure the rate of decay, we used a linear traverse to position hot wire probes of different distances downstream of the grid. Among the probes we used were the NSTAPs (nano-scaled thermal anemometry probes) developed at Princeton University [1], which are able to resolve all scales of the turbulent motion. We measured decay rates at about 40 different Reynolds numbers to get precise information about it's effect on the decay rate.

**Figure 1.** The Variable Density Turbulence at the Max Planck Institute for Dynamics and Self-Organization.

**Decay of turbulence**

One of the unsolved problems in turbulence is the answer to the question of how fast turbulent energy decays in time. Common consensus is that the decay of turbulent kinetic energy can be modeled with a power law function with an exponent between 1.1[4] and 1.4[3]. A more precise understanding of this decay exponent, especially concerning it's dependence on boundary conditions, is still lacking. There are strong hints that this decay exponent could exhibit a Reynolds number dependence[5], possibly leading to a fully self-similar decay with an decay exponent of 1 at extremely high Reynolds numbers.

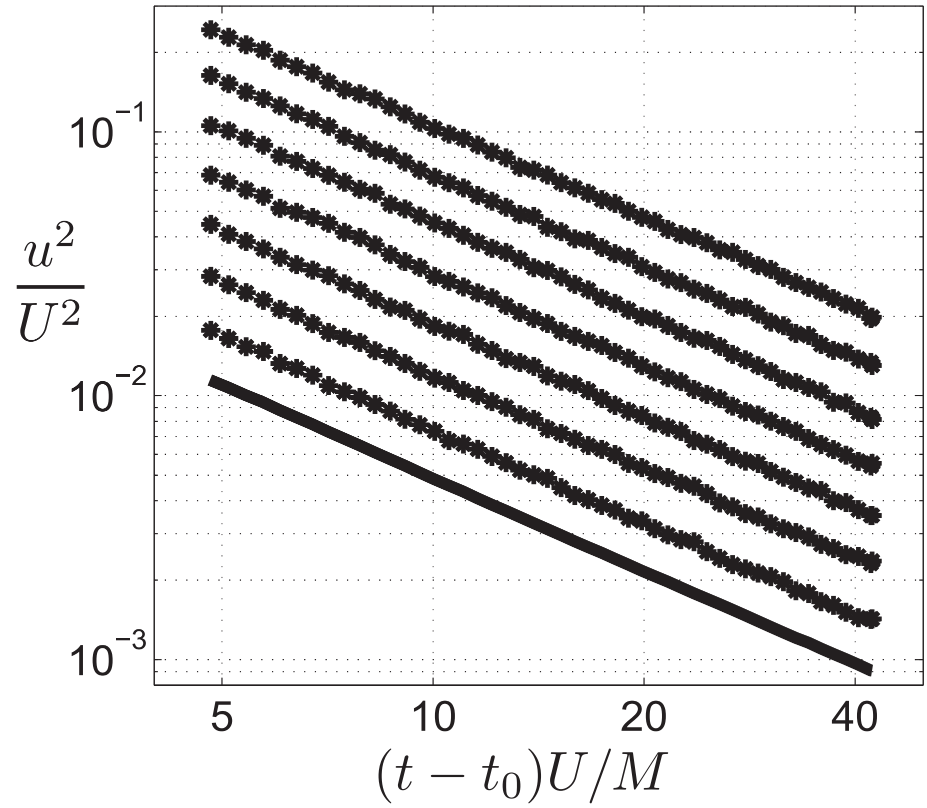


**Figure 2.** The decay of turbulent kinetic energy as a function of time for a wide range of Reynolds number between $Re = 2.6 \cdot 10^4$ and $Re_M = 4.8 \cdot 10^6$ (the curves are shifted vertically for better visibility). Here $U$ is the mean speed, $M$ the mesh spacing and $t_0$ the so-called virtual origin offset of time. The Reynolds number has virtually no effect on the shape of the decay curves.[7]

In our experiments we found that the rate of decay did not depend on the Reynolds number and to to be consistent with Saffman's prediction [6]. The consistency with Saffman's prediction can be shown not to depend on the choice of the virtual origin, and an independent method of checking Saffman's predictions will be presented in this talk.

**References**


[1] S. C. C. Bailey, G. J. Kunkel, M. Hultmark, M. Vallikivi, J. P. Hill, K. A. Meyer, C. Tsay, C. B. Arnold, and A. J. Smits. Turbulence measurements using a nanoscale thermal anemometry probe. *Journal of Fluid Mechanics*, **663**:160–179, 11 2010.

[2] E. Bodenschatz, G. P. Bewley, H. Nobach, M. Sinhuber, and H. Xu. Variable density turbulence tunnel facility. *Review of Scientific Instruments*, **85**(9):–, 2014.

[3] G. Comte-Bellot and S. Corrsin. The use of a contraction to improve the isotropy of grid-generated turbulence. *Journal of Fluid Mechanics*, **25**:657–682, 8 1966.

[4] P.-Å. Krogstad and P. A. Davidson. Is grid turbulence saffman turbulence? *Journal of Fluid Mechanics*, **642**:373–394, 1 2010.

[5] T. Kurian and J. H. M. Fransson. Grid-generated turbulence resvisited. *Fluid Dyn. Res.*, **41**:021403, 2009.

[6] P. G. Saffman. Note on decay of homogeneous turbulence. *Physics of Fluids (1958-1988)*, **10**(6), 1967.

[7] M. Sinhuber, E. Bodenschatz, and G. P. Bewley. On the decay of turbulence at high reynolds numbers. *PRL, accepted*, 2015.