ON THE BEHAVIOR OF THE INNER PEAK IN TURBULENT PIPE FLOW

Franziska König[1], El-Sayed Zanoun [2], Lothar Jehring [1] & Christoph Egbers [1]
[1]*Department of Aerodynamics and Fluid Mechanics, Brandenburg University of Technology, Cottbus, Germany*
[2]*Department of Mechanical Engineering, American University Cairo, Cairo, Egypt*

Abstract The scaling behavior of mean and fluctuating velocities is a highly discussed field in pipe flow turbulence [1, 2]. This discussion will be supported through experimental results from the CoLaPipe, which show in some cases qualitatively the same behavior. Nevertheless, the "absolute" value of the inner peak is further unclear, because of the differences between the experiments, *Superpipe* and CoLaPipe. This claims for more intensive investigations combining natural and artificial transition cases.

INTRODUCTION

During the last decade different conclusions regarding the near-wall scaling of the streamwise turbulence intensity were drawn [1, 2]. On one side a Reynolds number independent behavior of the streamwise variance was reported [1], and on the other side an increase in the amplitude of the inner-scaled peak with increasing Reynolds number (up to $R^+ = 3000$) was stated [2]. Especially, in the case of high Reynolds number pipe flow ($R^+ \leq 3000$), where only experimental data from Princeton University/ONR Superpipe are available, some doubts arise and further experimental results are necessary. To support the actual discussion on the scaling behavior of the mean and fluctuating velocities within turbulent pipe flow, we introduce the CoLaPipe and represent some experimental results for $R^+ \geq 3000$.

COLAPIPE - COTTBUS LARGE PIPE TEST FACILITY

A new pipe test facility for investigations on high Reynolds number pipe flow turbulence ($Re_m \leq 1.5 \times 10^6$) was setup. Figure 1 depicts the closed-return design of the CoLaPipe with two available test sections providing a length-to-diameter ratio of $L/D = 148$ and $L/D = 79$.

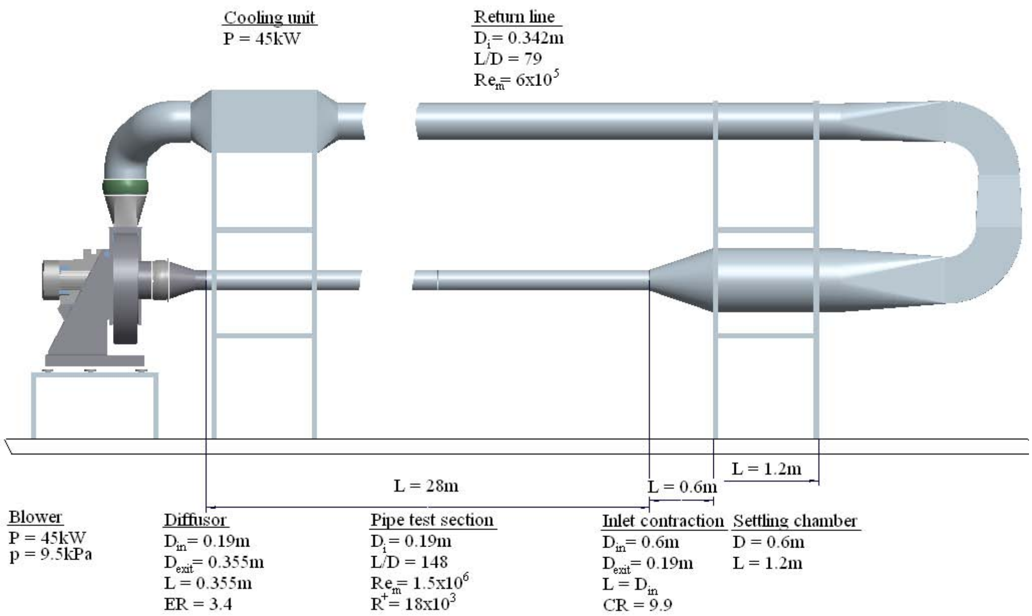

Figure 1. Experimental setup of the CoLaPipe showing all wind tunnel components.

MEASUREMENT TECHNIQUES

For measurements of the mean and fluctuating flow properties we applied the common hot-wire anemometry (HWA). Single HWA-sensors with $D_w = 5\mu m$ and $l_w = 1250\mu m$ are used together with an IFA300 HWA System from *TSI*. The data are sampled with a frequency of $10kHz$ over a time period of $26.2sec$. Additionally, the pipe test section is equipped with static pressure holes of $D_i = 0.5mm$ to evaluate the wall friction velocity u_τ independently from mean velocity measurements. The measurement data are statistically verified and carefully obtained to minimize measurement errors.

RESULTS

The following figure shows some first results regarding the inner scaled turbulence fluctuations for different Kármán numbers R^+.

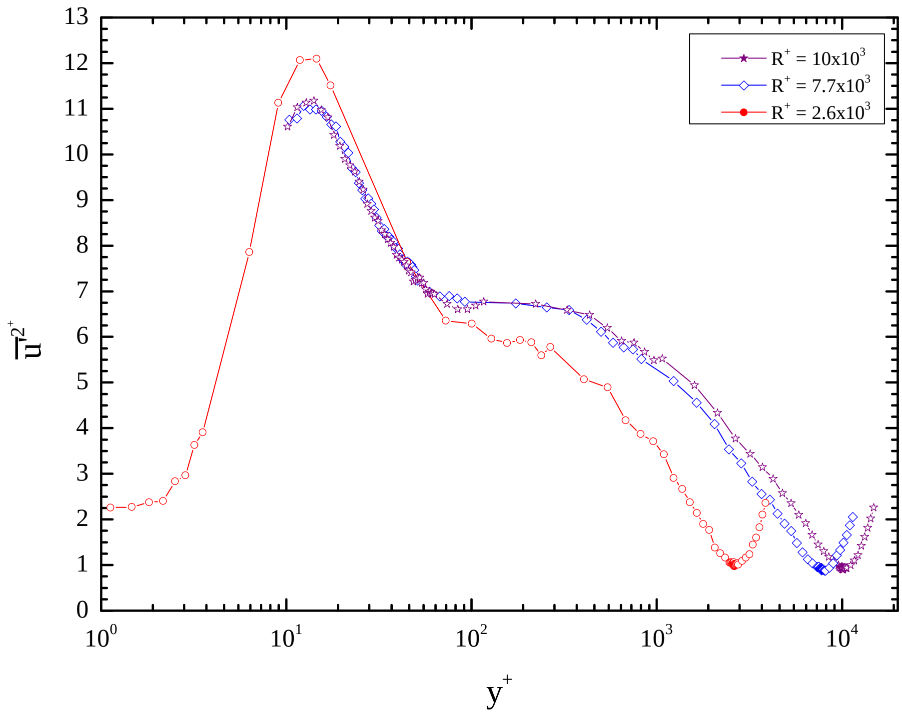

Figure 2. Inner scaled turbulence fluctuations for $R^+ = 2.6 \times 10^3$, $R^+ = 7.7 \times 10^3$ and $R^+ = 10 \times 10^3$.

Figure 2 shows the collapse of the fluctuating velocity profiles for $R^+ = 7.7 \times 10^3$ and $R^+ = 10 \times 10^3$, respectively, in the vicinity of the wall. This behavior supports the view communicated by [1] even for higher R^+. Whereas the dataset of the lower Kármán number behaves slightly different resulting in a higher amplitude.
An interesting fact is the difference in the presented values for the inner peak of the fluctuating velocity in contrast to the value reported by [1], which can be caused by:

- artificial transition in contrast to undisturbed boundary conditions during the *Superpipe* experiments,
- different estimation of u_τ and therewith uncertainties, and
- spatial filtering effects.

CONCLUSION AND OUTLOOK

These results show clearly the necessity of further experiments regarding the scaling behavior of the fluctuating velocity, especially in the case of high Reynolds number pipe flow turbulence. Additionally, a deeper discussion on natural and artificial transition scenarios will be presented as well as different measuring positions along the pipe test section. Spatial filtering effects and their correction are also a part of the presented results.

References

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[2] R. Örlü and P. H. Alfredsson. Comment of the scaling of the near-wall streamwise variance peak in turbulent pipe flow. *Experiments in Fluids* **54**: 1431, 2013