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# NUMERICAL SIMULATION OF TURBULENT CHANNEL FLOW WITH WALL SYNTHETIC BOUNDARY CONDITIONS

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*Abstract* We use POD-based synthetic wall boundary conditions to mimic the flow at a height $y+ \sim 50$ within the wall region of a turbulent channel flow. Two different estimation methods (full reconstruction and phase reconstruction) are used to build a boundary condition from the knowledge of the instantaneous flow above that height. The numerical simulation is then carried out in a reduced domain, which excludes the wall region below that height. Turbulent statistics and one-point velocity spectra of the simulation are compared with those of a full domain. A slight overestimation of the small-scale content in the center of the channel is observed for the phase reconstruction method.

## PREVIOUS RESULTS

In previous work [2] we have examined how POD-based synthetic conditions could be generated in order to bypass the simulation of the wall region, which requires a very high resolution and therefore constitutes a severe limitation on the Reynolds numbers that can be reached for wall-bounded flows. The basic assumption is that the second-order statistics of the flow are known, which means that the POD eigenfunctions and eigenvalues are known over the full domain. The boundary condition consists of a planar velocity field which is made up of the superposition of POD spatial eigenfunctions whose amplitude needs to be estimated. In Podvin and Fraigneau (JoT 2011 [2] ), two different methods were examined to reconstruct the amplitude. The first method was to integrate a system of low-order differential equations for the amplitudes (Podvin, PoF 2009 [1]). The second method was to use the flow in the simulation domain (i.e above the boundary plane) to obtain an estimate for the amplitude of the POD modes. Both methods were tested and were found to result in some statistical agreement with a full channel simulation at a low Reynolds number. However the adaptation height required to observe the statistical agreement was smaller in the second case, which led us to study this case in more detail. In EFMC 9, we showed results at higher Reynolds numbers for two different, threshold-based, estimation methods. In the first estimation method, the full coefficient was estimated from the simulation. In the second estimation method, only the phase was estimated from the simulation. Statistical agreement was observed for the mean profile and the turbulent intensities. In the present paper, we extend the analysis to small scales and use one-point spectral analysis to carry out a comparison between the reduced and the full simulations.

## NEW RESULTS

Two Reynolds numbers $R = 295$ and $R = 590$, based on the friction velocity and channel half-height, were considered. The Reynolds stress is well reproduced by both methods, as can be seen in figure 1. An adjustable parameter in the estimation method is the threshold $t$, which determines which POD structures are included in the estimation. Several values of the threshold were considered in order to test the robustness of the procedure. Detailed spectral analysis in figure 2 confirms that the estimation is relatively independent of the exact value of the threshold, which indicates some robustness of the procedure. The agreement between the reduced simulations and the reference case is good over the height of the channel. However, the phase estimation method results in a slight overestimation of the small-scale energy content of the velocity fied in the core region.

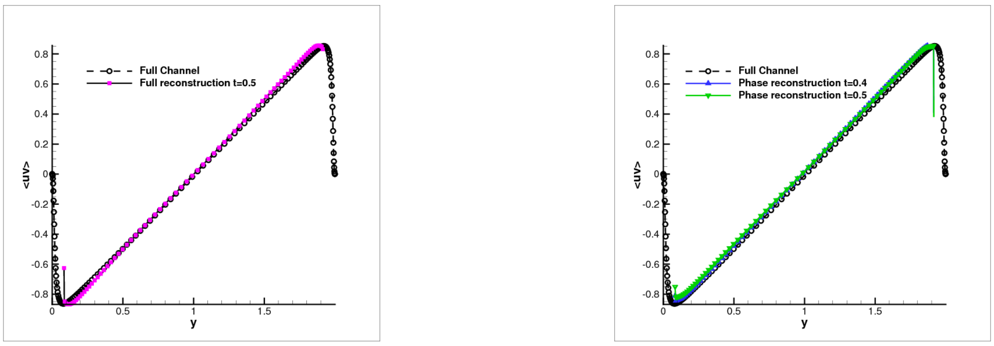


**Figure 1.** Reynolds stress at $R = 590$ left: full reconstruction method; right: phase reconstruction method


**Figure 2.** One-dimensional streamwise velocity spectra at $R = 295$ on three different planes (boundary plane $y+ = 50$, $y+ = 148$, channel center $y+ = 295$); left: full reconstruction method; right: phase reconstruction method

## References


[1] B. Podvin. A POD-based model for the wall layer of a turbulent channel flow. *Physics of Fluids*, **21**(1):015111, 2009.

[2] B. Podvin and Y. Fraigneau. Synthetic wall boundary conditions for the direct numerical simulation of wall-bounded turbulence. *Journal of Turbulence*, 2011,12, 1-26.