Appendix to “Numerical solution of the Navier-Stokes equations for the flow in a cylinder cascade”

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A1. Grid dependence studies

Extensive grid dependence tests were made to check that the results obtained on the finest grids were grid independent. In figures A1-A4 the behavior of the various flow properties such as the length of the eddy, width, maximum vorticity on body surface and drag coefficients, are compared for varying number of point in the τ direction and varying number of Chebychev collocation points. In all these figures the solid line indicates the finest grid used (with the parameters as indicated in the figure) and the various other dashed lines with symbols have grid sizes as shown in the figure key. Figures A1-A4 show clearly that the $W = 5$ results are fully resolved up to $R = 4000$. In figures A5-A8 similar results for the $W = 20$ case are presented. Clearly our results are fully resolved on the finest grids used for these gap widths. For a gap-wdith of $W = 5$ even a coarse grid with as little as 32 Chebychev points in the vertical direction is enough to obtain reasonable results.

The same is not true however for increasing gap widths. The length of the eddy appears to be the most sensitive quantity to compute accurately. In figures A9-A12, it is seen that for $W = 50$, the length of the eddy is sensitive to the number of points used, and the accuracy also depends on the Reynolds number. At least 64 points and at least $h = 1/20$ are necessary for low Reynolds number for this case. For higher Reynolds numbers ($R > 800$) the number of Chebychev points required to resolve the flow features increases. At the larger Reynolds numbers, the results for eddy length on the finest grid ($N = 100, h = 1/30$ suggest converged values especially for the eddy width, and drag.

The $W = 100$ gap width case is even harder to compute accurately for the high Reynolds numbers. Figures A13-A16 show that the only computed quantity which is grid independent is the eddy width. The length of the eddy can be accurately computed up to about $R = 700$. At a Reynolds number of 800 there is about 10% difference in the results between the 3 finest grids used. At larger Reynolds numbers the differences are much larger.

One may conclude therefore that whereas for small gap widths the flow feature can be resolved using fairly coarse grids, for larger gap widths, using a coarse mesh can cause huge differences in the overall solution properties, particularly for the length of the eddy. It was not possible to compute with even finer meshes because of computer resource limitations.

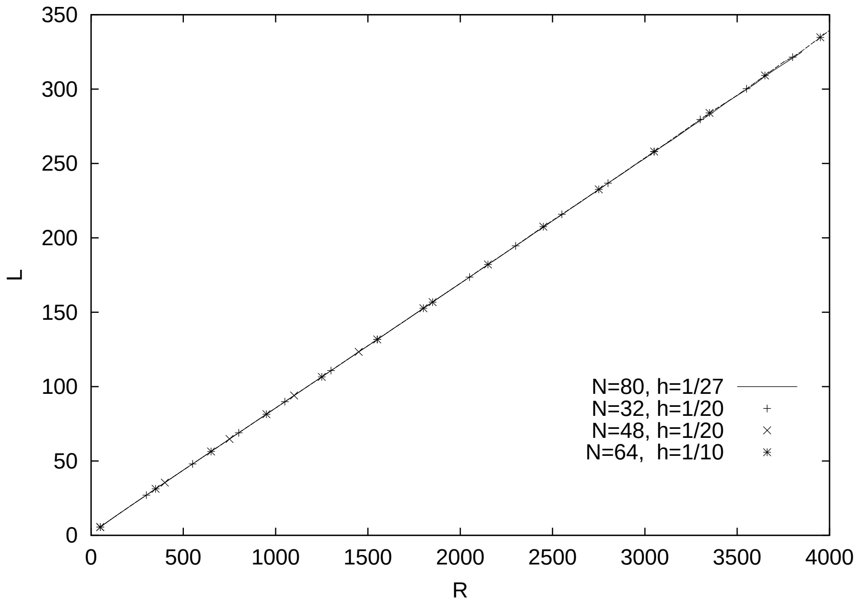

FIGURE A1. Grid dependence in the length of the eddy for $W = 5$. $N + 1$ denotes the number of Chebychev points used and h is the step length in the τ direction. The solid line is from the finest grid. The different symbols show the number of points used for other cases as indicated.

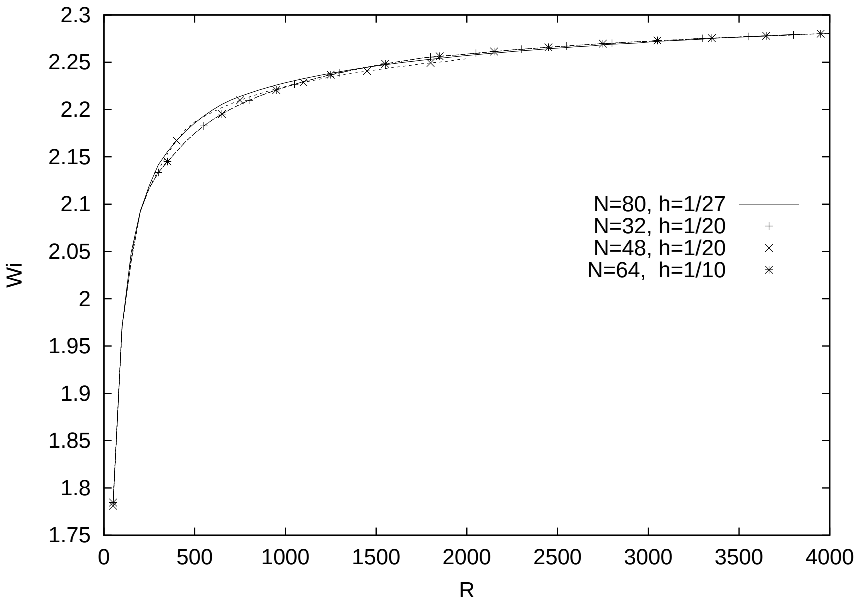

FIGURE A2. Grid dependence in the width of the eddy for $W = 5$.

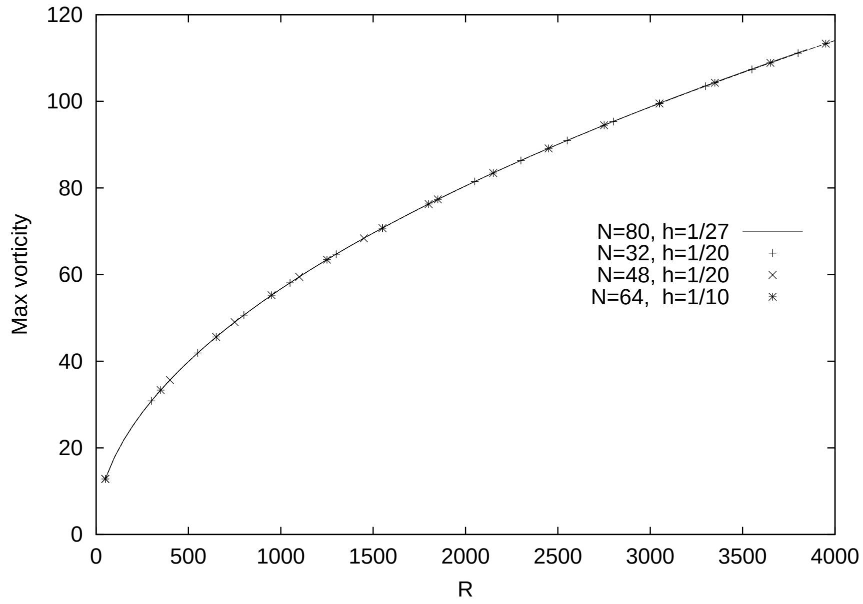

FIGURE A3. Grid dependence in the maximum vorticity on the body surface for $W = 5$.

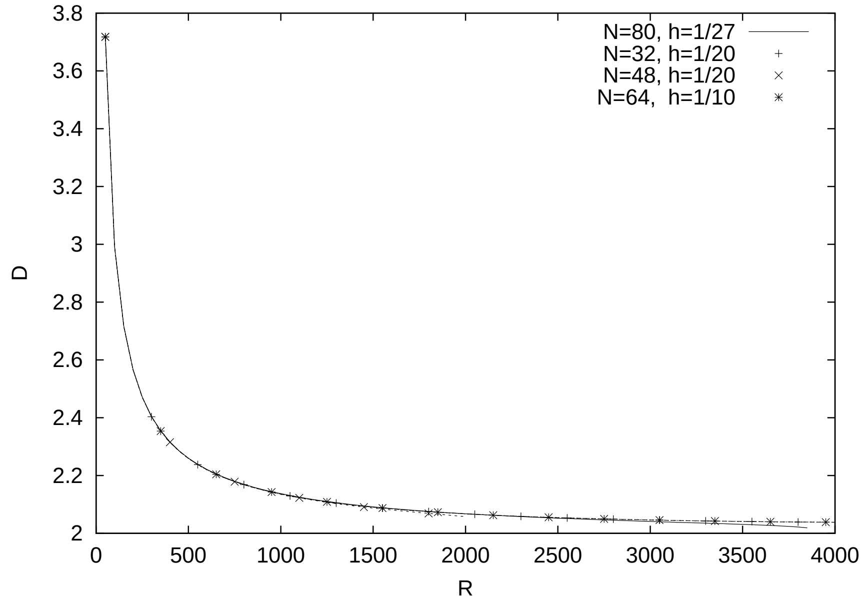

FIGURE A4. Grid dependence in the drag coefficient for $W = 5$.

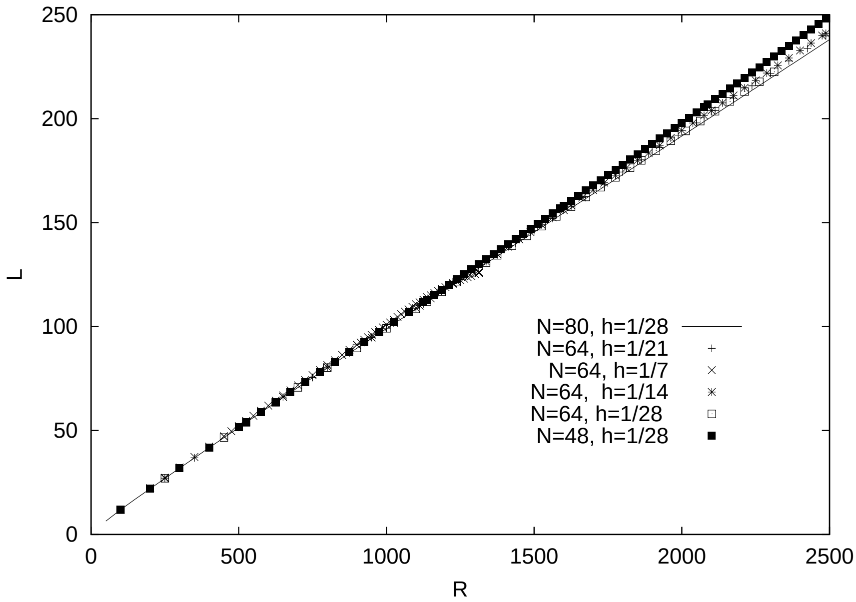

FIGURE A5. Grid dependence in the length of the eddy for $W = 20$.

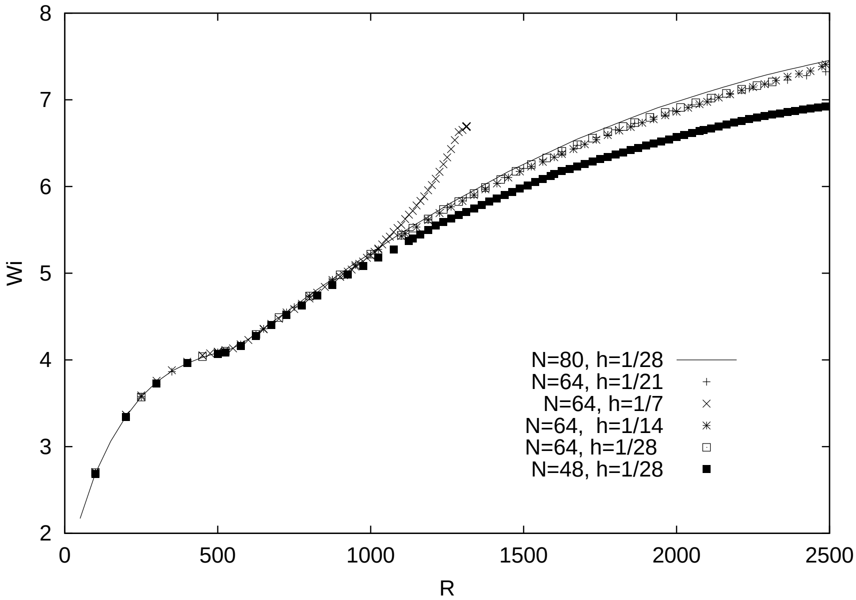

FIGURE A6. Grid dependence in the width of the eddy for $W = 20$.

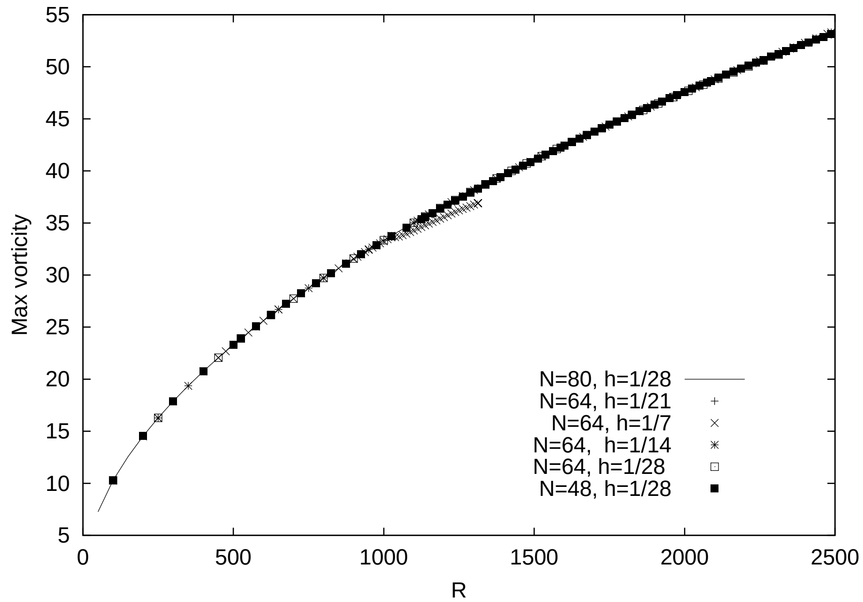

FIGURE A7. Grid dependence in the maximum vorticity on the body surface for $W = 20$.

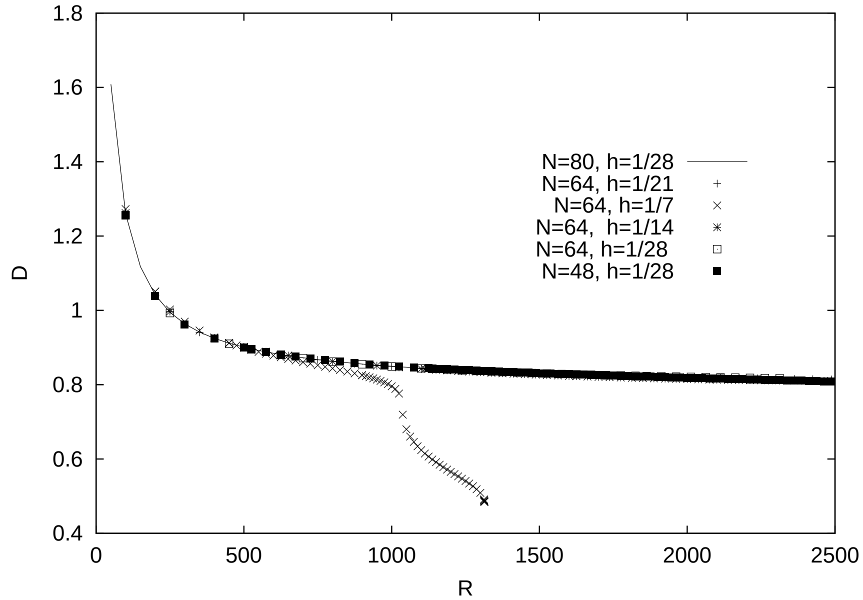

FIGURE A8. Grid dependence in the drag coefficient for $W = 20$.

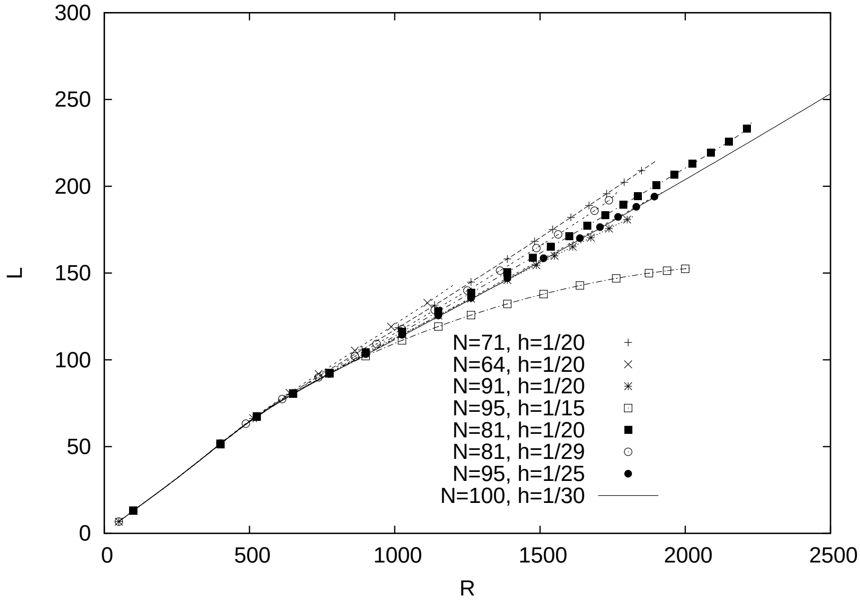

FIGURE A9. Grid dependence in the length of the eddy for $W = 50$.

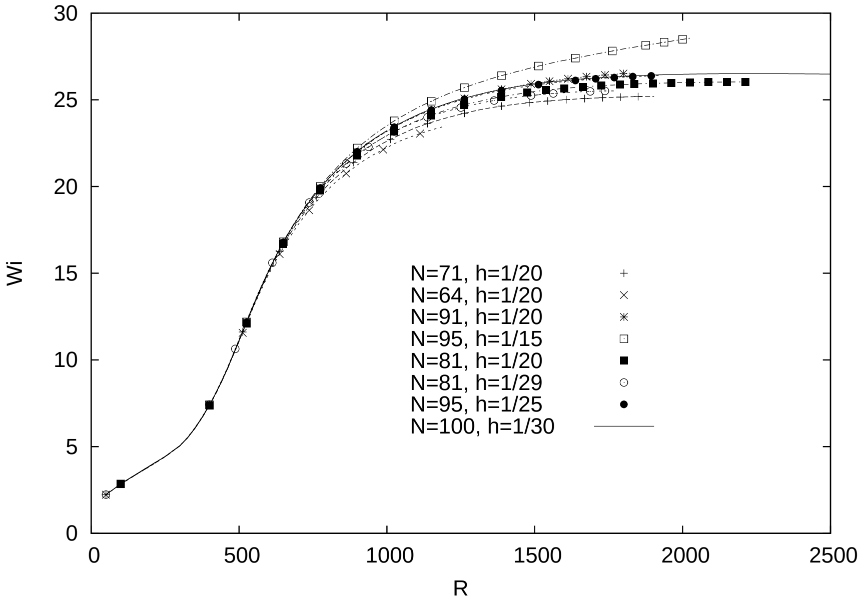

FIGURE A10. Grid dependence in the width of the eddy for $W = 50$.

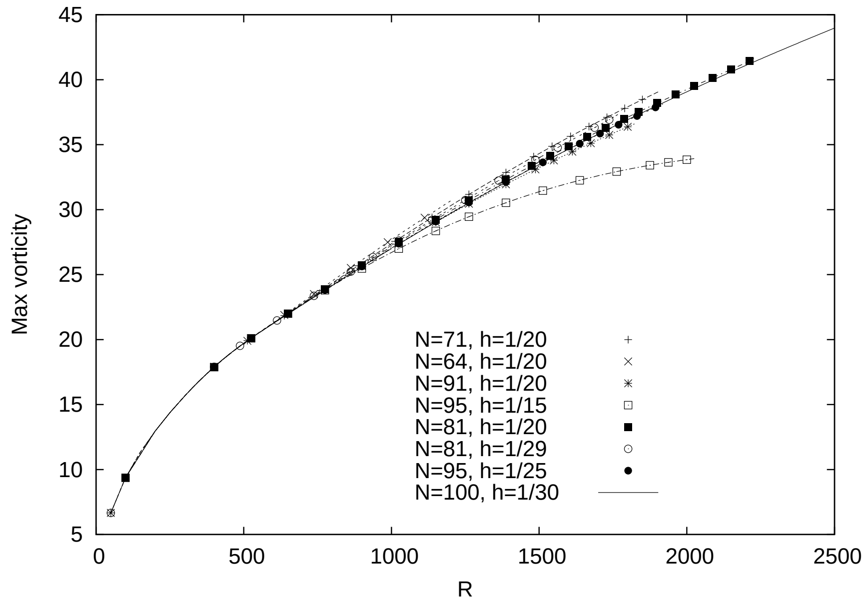

FIGURE A11. Grid dependence in the maximum vorticity for $W = 50$.

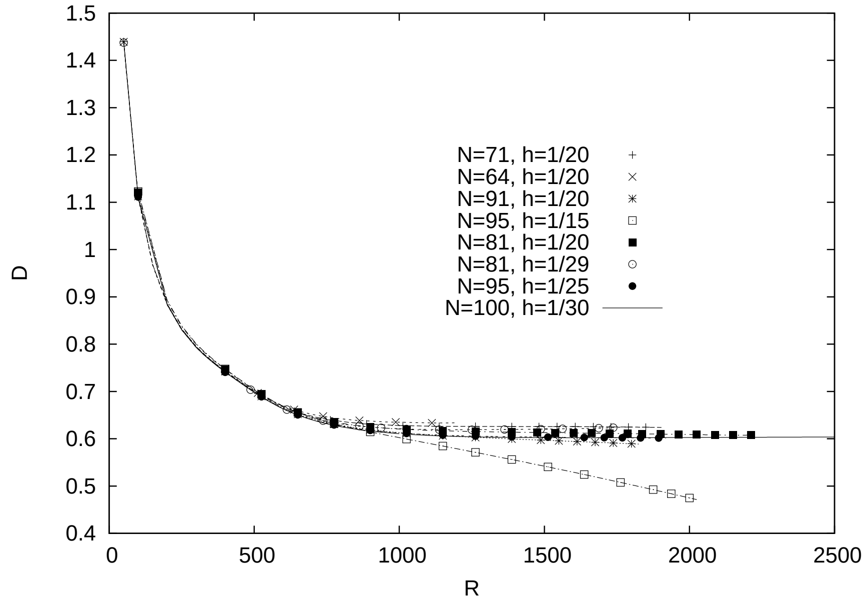

FIGURE A12. Grid dependence in the drag coefficient for $W = 50$.

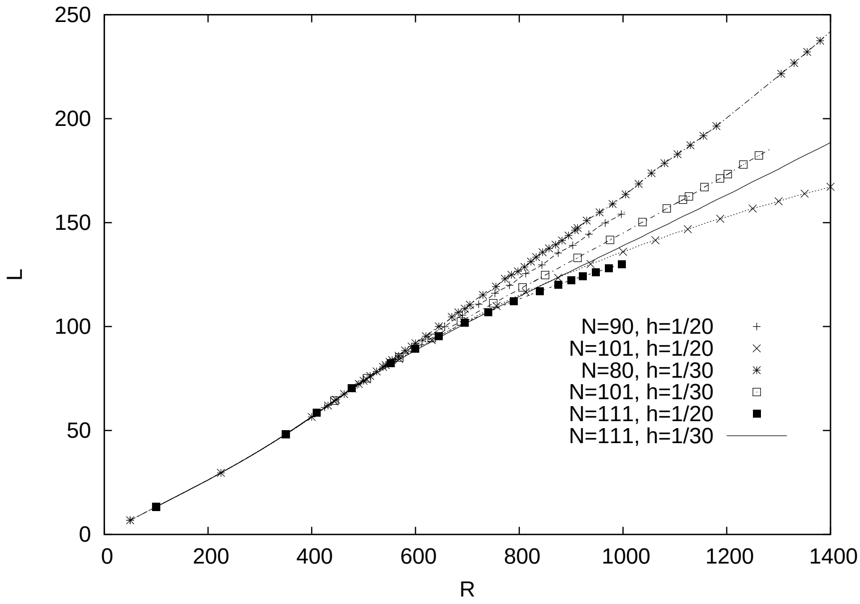

FIGURE A13. Grid dependence in the length of the eddy for $W = 100$. $N + 1$ denotes the number of Chebychev points used and h is the step length in the τ direction.

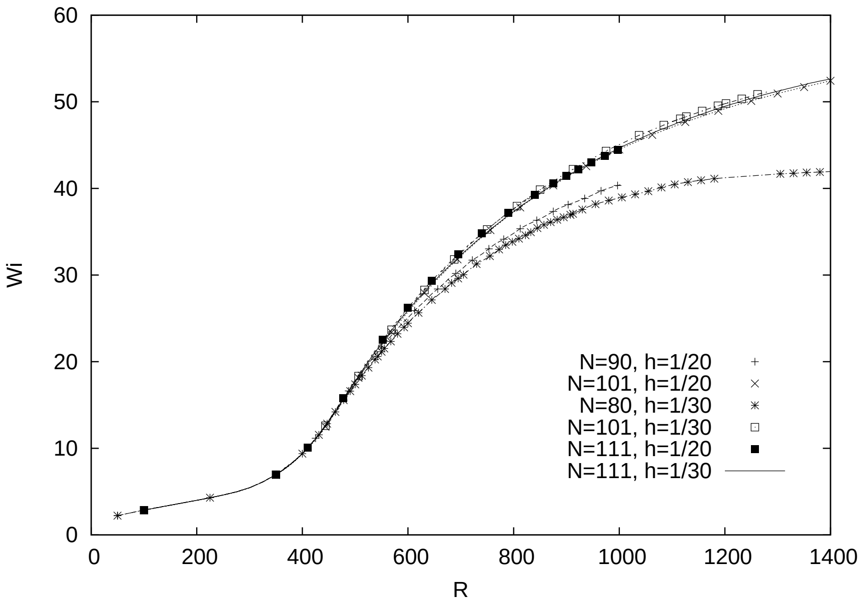

FIGURE A14. Grid dependence in the width of the eddy for $W = 100$.

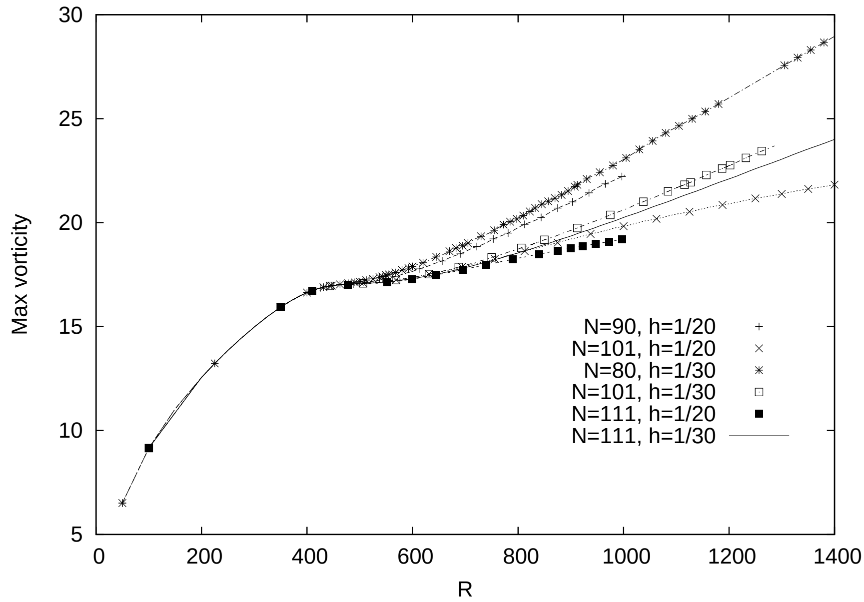

FIGURE A15. Grid dependence in the maximum vorticity on the body surface for $W = 100$.

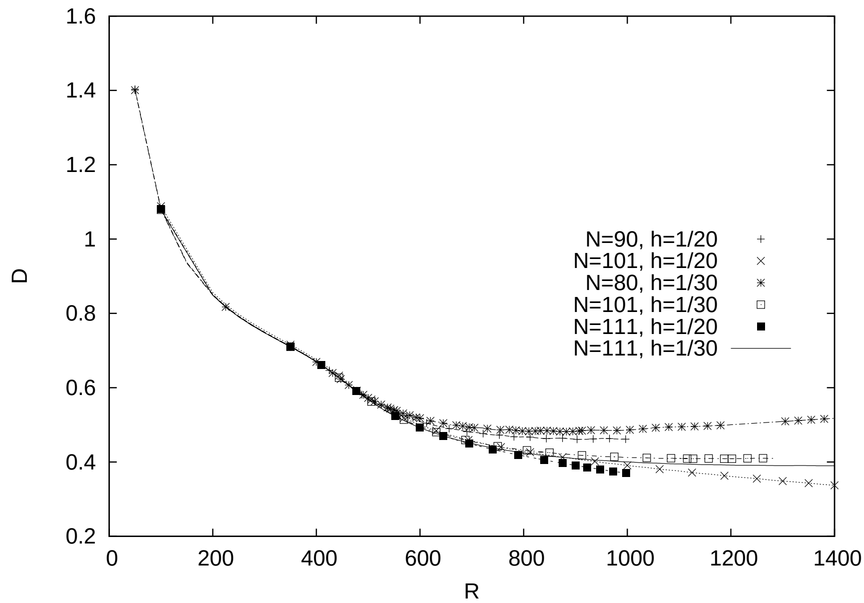

FIGURE A16. Grid dependence in the drag coefficient for $W = 100$.