Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, November 2-3, 2006

Validation of the LILAC Code Using Backward-Facing Step Benchmark Problems

Nam-il Tak, Jongtae Kim, Won-Jae Lee
KAERI, 150 Deokjin-dong, Yuseong-gu, Daejeon 305-353, Korea, takni@kaeri.re.kr

1. Introduction

KAERI is developing a computational fluid dynamics (CFD) code, named LILAC [1], in order to analyze the thermo-fluid behaviors in high temperature gas cooled reactors. Lots of sophisticated physical models, such as turbulence, conjugated heat transfer, radiation heat transfer, etc., have been implemented in the LILAC code. However, the validation of the LILAC code has not been matured as yet, when compared with the existing commercial CFD codes. The main objective of the present study is to strengthen the reliability of the LILAC code by using conventional benchmark problems. Backward-facing step problems are selected for the benchmarks in this study. All simulation results of the LILAC code are evaluated against existing experimental data and compared with those of a commercial code CFX10 [2]. The same meshes are applied for LILAC and CFX10.

2. Backward-Facing Step Problems

The flow over a backward-facing step provides an excellent test case for the accuracy of a numerical prediction of complex flows. The geometry is simple but the flow through it contains most of the complexities such as a flow separation, reattachment, and a re-development. Therefore, it was widely used as a benchmark problem to validate numerical models [3-4]. Three different cases, i.e., two-dimensional laminar, three-dimensional laminar, and two dimensional turbulent flows, are considered in this work.

Case I: 2-D Laminar Flow over Backward-Facing Step

The experiment performed by Armaly et al.[5] is selected for the benchmark. The geometry of the test section is shown in Fig. 1. The high aspect ratio of the test section (1:36) was used for a two-dimensional flow.

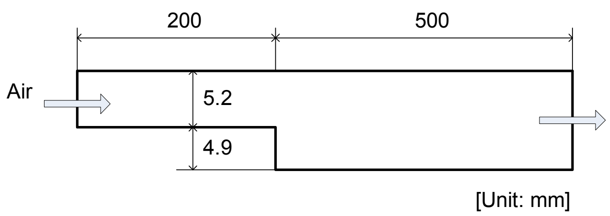

Fig. 1. The geometry of the test section of Armaly et al.'s experiment.

Fig. 2 shows the predicted u-velocity distributions by the LILAC code. In this paper, the Reynolds number (Re_D) is defined based on the inlet velocity (u_{in}) and the hydraulic diameter (D_h) of the inlet duct. As shown in Fig. 2, LILAC predicts the experiment data very well. In addition, perfect agreements can be seen between the LILAC and CFX10 results. Table 1 shows that the LILAC code has the same level of accuracy for the prediction of the reattachment length as the existing commercial codes.

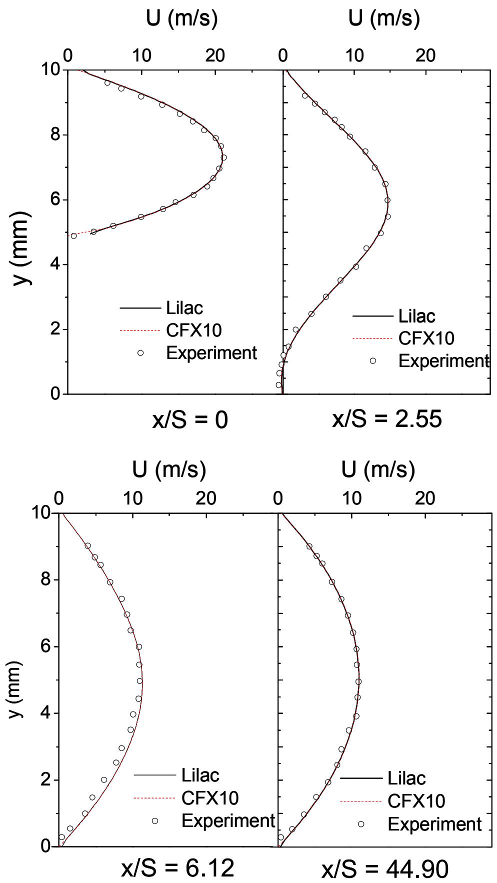

Fig. 2. The results of the LILAC simulation for Case I (Re_D=100).

Table 1. Predicted reattachment lengths for Re_D = 200

Experiment	LILAC	CFX10	FLOW-3D	FLOTRAN	FLUENT
5.0[a]	4.85	4.72	4.87[a]	4.59[a]	4.98[a]

[a]Values are taken from the reference [4].

Case II: 3-D Laminar Flow over Backward-Facing Step

A recent experiment by Armaly et al. [6] is selected for the three-dimensional benchmark case. They used a rectangular duct with an aspect ratio of 8 to examine three-dimensional effects. Fig. 3 shows the results of the LILAC simulation of their experiment at Re_D = 343. A good agreement between the LILAC prediction and the experiment is found for the u-velocity distribution. There exists some difference in the v-velocity. However, the difference between the numerical predictions and the experimental data seems to be mainly from the uncertainties of the experimental measurement. The same explanation was reported by the authors of the experiment in their study. Again, excellent agreements can be seen between the LILAC and CFX10 predictions.

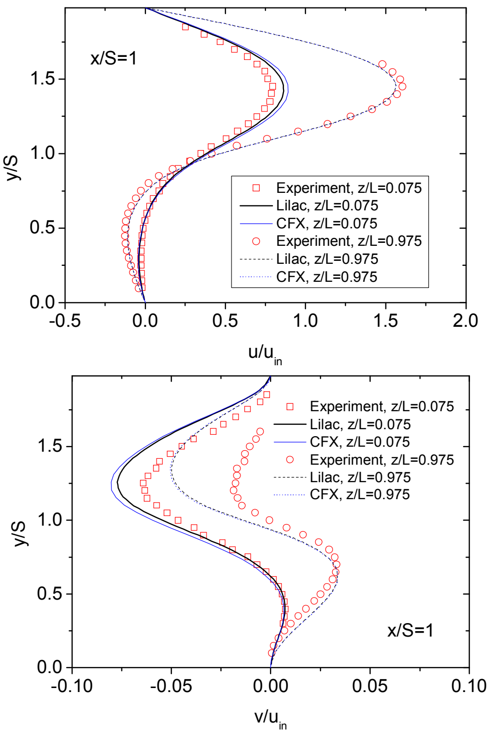

Fig. 3. The results of the LILAC simulation for Case II ($Re_D = 343$).

<u>Case III: 2-D Turbulent Flow over Backward-Facing Step</u>

In order to validate turbulence models in the LILAC code, the two-dimensional turbulent flow experiment performed by J. Kim et al. [7] is chosen for the last benchmark in this work. Fig. 4 shows the predicted u-velocity distributions by the LILAC code. Three different turbulence models are applied. A good agreement is seen between the predicted distributions and the experimental data except for the recirculation region. Fig. 5 shows the predicted reattachment lengths. It clearly shows the well-known characteristics of the each turbulence model. In particular, a better performance of the RNG k-ε and SST models is observed.

3. Conclusions

In the present study, three kinds of backward-facing step benchmark problems have been solved by the LILAC code. It covers two-dimensional laminar, three-dimensional laminar, and two-dimensional turbulent flows. In general, good agreements between the experimental and LILAC results were obtained for the selected benchmarks. Some discrepancies were found in Case II and Case III. These are not from the LILAC code but from the experimental uncertainties (Case II) and the turbulence models themselves (Case III). The comparison between the LILAC and CFX10 results show that the LILAC code is able to predict the same level of accuracy as the CFX10 code for the tested benchmarks.

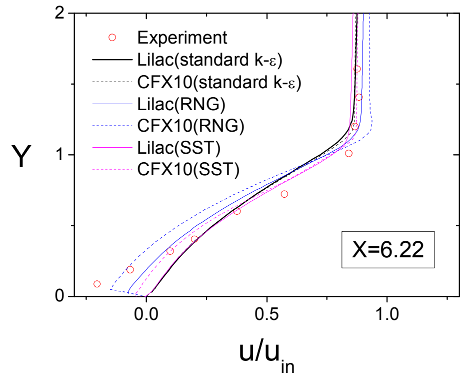

Fig. 4. The predicted u-velocity by the LILAC code and comparison, Case III (Re_D=139220).

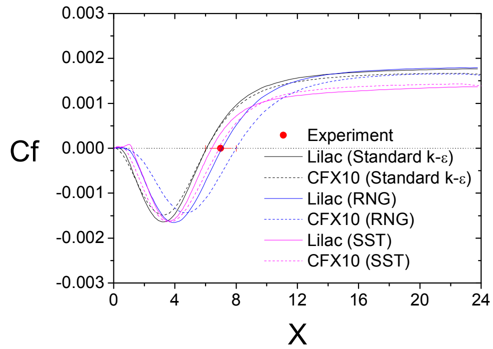

Fig. 5. The predicted frictional coefficient by the LILAC code and comparison, Case III (Re_D = 139220).

ACKNOWLEDGMENTS

This work was financially supported by the Korean Ministry of Science and Technology.

REFERENCES

[1] J. Kim et al., KAERI/TR-2126/2002, 2002.
[2] ANSYS Incorporated, CFX10 Manuals, 2005.
[3] Proc. 1980-81 AFOSR-HTTM-Standford Conference on Complex Turbulent Flows: Comparison of Computation and Experiment, Vol. I and II, 1982.
[4] C. J. Freitas, J. of Fluid Eng., Vol. 117, p. 208, 1995.
[5] B. F. Armaly et al., J. Fluid Mech., Vol. 127, p. 473, 1983.
[6] B. F. Armaly et al., Int. J. of Heat & Mass Tranfer, Vol. 46, p. 3573, 2003.
[7] J. Kim et al., J. Fluid Eng., Vol. 102, p. 302, 1980.