Comments on “A generalized lattice Boltzmann method for three-dimensional incompressible fluid flow simulation” by Rahmati and Ashrafizaadeh

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Abstract

In the present work we'll present some comments concerning the paper entitled ‘A generalized lattice Boltzmann method for three-dimensional incompressible fluid flow simulation’ published in Journal of Applied Fluid Mechanics (JAFM), vol. 2(1), pp. 71-96 (2009) by Ahmad Reza Rahmati and Mahmud Ashrafizaa. The comments are related to the numerical parameters influencing the accuracy of the presented results such in particular the computed Nusselt number.

Keywords: Lattice Boltzmann method, numerical simulation, grid independence test, benchmark solution, accuracy.

1. Introduction

Authors of “A generalized lattice Boltzmann method for simulation of three-dimensional incompressible fluid flow” by Rahmati and Ashrafizaadeh (RA) [1] have developed a three-dimensional numerical model based on the MRT lattice Boltzmann scheme for incompressible fluid flow (IGLB). RA applied the finite differencing technique to discretize and solve the energy equation, so that an hybrid thermal lattice Boltzmann model (HTIGLB) is used to solve thermally driven problems. Several three-dimensional test cases are used to validate the proposed model, namely the cubic cavity flow, the backward-facing step flow and the double shear flow for isothermal flow and natural convection flow in a side-wall heated cubic cavity and from discrete heat source on the bottom wall of horizontal enclosure. In this paper, some comments on the computational parameters and the computed results will be highlighted and discussed, followed by a conclusion and list of references.

2. Parameters and results

The authors carried out grid independence tests and have chosen these grid sizes to argue that this gave very accurate results without comparison to any reference results. Moreover, the rest of
the predictions involved a more critical condition, such as the Reynolds and Rayleigh numbers being greater many times than that used in the grid independence range. Thus, it is extremely difficult to rely on the grid size that resulted from the grid independence test at such conditions. This certainly will lead to wrong results as will be discussed in the following section.

3. Discussion

In page 76, RA state they will compare IGLB model (that’s of concern to the work) results to those of IBGKLK which is a particular case of the multi-speeds IGLB; so to what serve the comparison between CBGKKL and IBGKLK? To our opinion, we see that adds nothing of significance to the model of concern, IGLB. In fact, data in Tab. 3 for Re=400 and those in Tabs. 1&2 are different. Concerning Tab. 3, RA claim that “These findings…simulation.”, this is false. Such a conclusion does not be declared before comparing results of the finer grid (81³) to a well chosen reference results: We may have grid independency without achieving satisfactory accuracy, e.g. case of first-order discretization in space and time in FD, FV or FE methods based solvers.

In fact, to prove ours comments we look to results of Tab. 4. RA compare their results for the vortex centre locations to those of Ku et al. [2] ones for the same Reynolds numbers used in the grid independency test. However, the relative error in the computed main-vortex-centre z-location is 2% for Re=100, 3.67% for Re=400 and 6.4% for Re=1000; and the relative error in the computed transversal-vortex-centre y-location is 0% for Re=100, 3.43% for Re=400 and 7.19% for Re=1000. Such a results show that first, the relative error increases by increasing the Re number (although it is in the tested range) and second, the relative error magnitude is somewhat large to not allow stating on good accuracy. It can be concluded that this grid size is inappropriate and can lead to wrong results.

For Figs. 22&23, the mesh size 81³ was tested to be sufficient for Re≤1000, so it should not be used for Re four times larger (4000), which certainly will produce inaccurate results.

In page 78 (Tab. 5), the relative error in the computed recirculation zone length by comparison to Chiang et al. [3] results in a deviation of 1.997% for IBGKLK and 1.735% for the IGLB model, so a difference of 0.272% ! between the two schemes; this does not allow saying to the rigor “the IGLB model is more accurate than the IBGKLK one” as authors argued, but rather of the same order of accuracy or -to the limit- agree a little bit better with the reference results; we also recommend using more results from literature.

Additionally, in page 79 (Tab. 7) RA claim “our results agree well ... slightly underestimates...”, this joins exactly ours comments on results of Tabs. 3&4. In Tab. 7 one can easily remark that even for Ra=10⁴ the computed Nusselt number is not -to the rigor- in sufficient accuracy (3.855% of relative error); additionally for Ra>10⁴, the relative discrepancy in the computed Nusselt number is 9.154% for Ra= 10⁵ and 15.623% for Ra=10⁶, which -numerically speaking- may alter the computational efficiency of the under-validation model. The grid independence test should (i) cover all the range of the dimensionless numbers (Re, Ra …) that will be investigated, (ii) in the same problem and (iii) compare results of finer grid to well chosen former findings. Apart from this, results are certainly of wrongness. However, if finer grid will produce more CPU time for low dimensionless numbers, it is recommended to perform a test by range (see Tab. 1&2 in reference [4]). Besides, validation of new numerical schemes, models or codes in challenging areas (such as for LB method) should be based on several references (benchmark), because a particular reference can, itself, present a deviation from literature results of good confidence.

Page 85, Tab. 6: generally, spatial convergence for a numerical code does not imply getting accurate results until comparing to literature findings, as argued the authors: “this indicates that …can give very accurate results”. Even if we assume for accurate results, we should not exceed the larger value of tested parameter (here Ra=10⁴); this puts cantilevered the results of Figs. 37 & 38.
where RA use a Rayleigh number even 100 times larger than that used in grid independence test range.

Finally, (i) RA state in section 4.1 that the results of IGLB model will be compared to the IBGKLB ones, but this is often omitted. The presence of IBGKLB results may highlight the relevance of the developed IGLB model. (ii) Commenting Tab. 5 in page 78, RA alluded to what they does not perform a rigorously comparison due to the different ratio S/H magnitude, which does not allow targeting of the deviation origin. (iii) The model IBGKLB that RA used sometimes is a hybrid model where energy equation is solved by Finite Differencing. (iv) RA solved the energy equation by Finite Differencing without justifying such a choice. Is it for stability purpose, preserving computational cost. Why do not use for the thermal field a 3D passive scalar model extension of the D2Q4 one which has proven high performance. Another thermal LB alternative may also be the “simplified thermal internal energy distribution model”, which has been used successfully in 2D/3D thermal flows [5-8], with uniform and non-uniform mesh even with curved boundaries [8-10], with D3Q15 or D3Q19 lattices [8,11] and that has proven very small compressibility effects [5], high accuracy and preserved the computational cost.

4. Conclusion

To sum up, the present paper aims to give an in-depth discussion on the numerical methodology used in the study of Rahmati and Ashrafizadeh [1] in order to perform a rigorous prediction of heat and fluid flow characteristics by help of the developed 19-bits IGLB model. We propose that authors conduct a grid independence test on the most critical condition of each studied problem in order to remove the grid size effect on the computed results. We recommend, additionally, that authors perform a benchmark solution including several confident literature findings.

Conflict of Interest

The authors declare that they have no competing interests. These comments have not sought to undermine the importance of the work by Rahmati and Ashrafizadeh (2009), the significance of their contribution to the field is rewarding and fully appreciated.

Editor note: The editor contacted the authors of the original article, commented in this short communication, on 08/08/2013 to inform them about the comments proposed herein. However, no response from the authors was received. Therefore, the comments are published here without reply from the authors of the original paper.

References


