Acoustic simulation using lattice Boltzmann method by multi-GPU parallel computing

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1 INTRODUCTION

In recent years, various methods such as the FDTD method and the finite element method have been used for acoustic analysis, and they have become indispensable techniques in architectural design and so on. The lattice Boltzmann method (LBM) is one of the analysis methods used in acoustic analysis. The LBM can be applied to acoustic analysis by using the acoustic time scale, which deal with the fast phenomenon of moving virtual particles[1]. In addition, since the LBM uses an orthogonal lattice, it is compatible with the immersed boundary method, which is used for complex or moving boundary. When performing acoustic analysis while taking into account the wave nature of sound, the resolution must be high, and a large computational domain must be prepared for this purpose. Therefore, in this study, we are using multiple GPUs on a supercomputer for parallel computation.

2 LATTICE BOLTZMANN METHOD

When the lattice Boltzmann method is used for acoustic analysis, the speed of sound is equal to the speed at which the virtual particle moves to the neighboring lattice point, since the acoustic time scale is used. Therefore, the speed of sound is $1/\sqrt{3}$ in the lattice Boltzmann method, and is used as the basis for standardization in this paper. In general, although there is no major difference from using the diffusion time scale, there is a bit change in the value of the Strouhal number and other factors, so this point should be noted.

3 IMMERSED BOUNDARY METHOD

When used in acoustic analysis methods, the immersed boundary method can be used as a vibration boundary in addition to moving and complex boundaries. In the immersed boundary method, we have a value that is the ideal velocity of the fluid on the boundary, and by changing that value appropriately to match the angular velocity of the sound wave, we can implement a vibrating boundary[2].

4 CALCULATION TIME BY MULTI-GPU PARALLEL COMPUTING

In this study, we use an acoustic analysis method that combines the lattice Boltzmann method and the immersed boundary method, as we have shown above. The problem with using parallel computing here is the unbalance of the computational domains within each GPU. The calculation of the immersed boundary method should be performed within the divided area when the whole analysis area is divided evenly. In this case, different number of operations

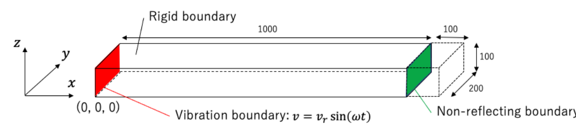

Figure 1: Acoustical tube generated by using immersed boundary method.

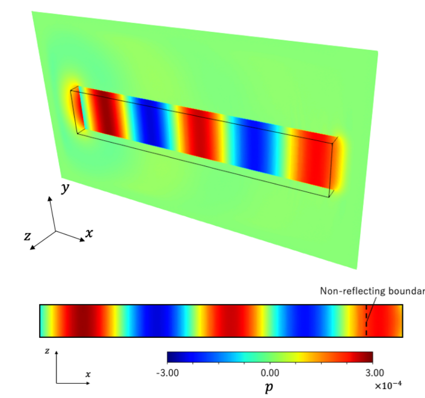

Figure 2: The acoustic pressure contour at the t = 1750.

are performed for the analysis domain that includes the immersed boundary and the analysis domain that does not include the immersed boundary, resulting in an imbalance of the calculation speed. When the analysis is done in 2D, this difference does not have much effect, however when the calculation is done in 3D, the number of points on the boundary increases and the difference becomes non-negligible. For example, Fig. 1, 2 shows the benchmark problem for an acoustic tube using the immersed boundary method. When analyzing the rectangular object in Fig. 1 in analysis domain $1400 \times 800 \times 800$, the calculation time divided by the x-axis was reduced by about 7% compared to the calculation time divided by the z-axis. In this poster, we will discuss the calculation speed of the immersed boundary method depending on the division method of the analysis domain.

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