Numerical Simulation of Snow Accretion by Airflow Simulator and Particle Simulator

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ABSTRACT

In this research, to take countermeasures for the snow accretion damage, we developed a simulator of realizing the snow accretion process in the following steps. Firstly, air flow analysis is performed by "Airflow simulator" developed by RTRI (Railway Technical Research Institute). Secondly, trajectory of flying snow is calculated by Basset-Boussinesq-Oseen equation using distributed of velocity of air flow. Thirdly, snow accretion analysis is performed by "Particle simulator" developed by RTRI. The shape modified by snow accretion is reflected onto the boundary conditions of the air flow analysis. In this year, snow accretion analysis for simple cubic shapes is performed in order to aim at system development and validation.

CCS CONCEPTS

• **Computing methodologies → Massively parallel and high-performance simulations.**

KEYWORDS

Snow accretion analysis, Air flow analysis, Interaction between snow accretion and air flow, Finite difference method, Particle Method

1 INTRODUCTION

Snow accretion is generated on the bogies of running trains in snowy area as shown in the figure 1. When the lump of snow falls off the bogies, it might damage ground facilities on tracks, vehicles, and houses along railway line. To prevent such damage, snow accretion on the bogies is removed by human power at stations. Though snowy area often suffer from the snow accretion damage, the snow accretion mechanism is still not clear. To take countermeasures for the snow accretion damage, we developed a simulator of realizing the snow accretion process using "Airflow simulator" and "Particle simulator". In this year, snow accretion analysis for simple columnar forms is performed in order to aim at system development and validation.

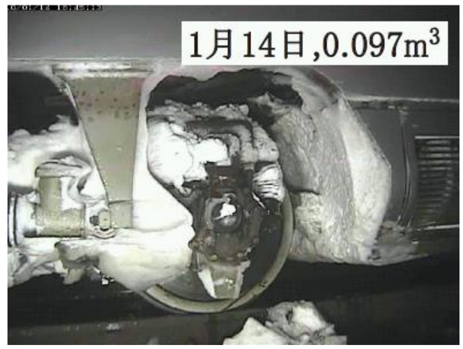

Figure 1: Snow Accretion on Train Bogies [1].

2 AIRFLOW SIMULATOR

The "Airflow simulator" is developing by RTRI (Railway Technical Research Institute), to solve the cross wind for the vehicles, air flow below the vehicle floor and so on. In the "Airflow simulator", the finite difference method for nonuniform grid, the fractional step method, the 2nd-order central difference, the 3rd-order Adams-Bashforth methods, Poisson equation solver by Jacobi method and LES model by coherent structure Smagorisky model are adopted in order to solve Navier-Stokes equation for incompressible fluid flow. In the parallel computing method, the orthogonal domain decomposition is adopted. Target problem size is 10 million to 100 billion grids. The "Airflow simulator" achieved 84% of parallel efficiency in the K computer as shown in the figure 2.

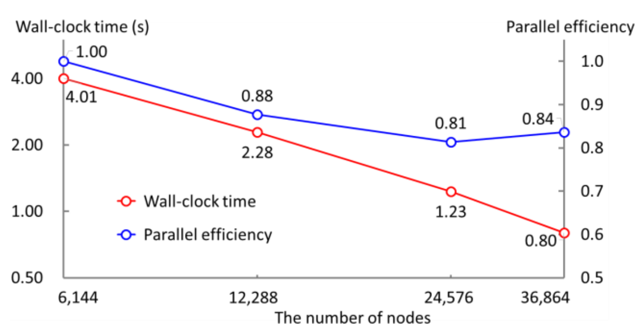

Figure 2: Strong scaling of 100 billion grids by K computer.

3 PARTICLE SIMULATOR

The “Particle simulator” is developing by RTRI, to solve the tsunami analysis and so on. The “Particle simulator” is developed using the LexADV_EMPS [2-6] of parallel computing library for MPS method (Moving Particle Simulation). In the parallel computing method, the dynamic load balancing by ParMETIS are adopted. Target problem size is 1 million to 10 billion grids. The “Particle simulator” achieved 88% of parallel efficiency in the K computer as shown in the figure 3.

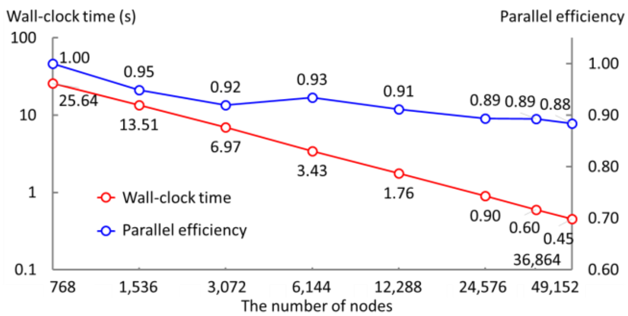

Figure 3: Strong scaling of 10 billion particles by K computer.

4 NUMERICAL SIMULATION OF SNOW ACCRETION

As shown in the figure 4, the simulator of realizing the snow accretion process in the following steps was developed. Firstly, air flow analysis is performed by “Airflow simulator”. Secondly, trajectory of flying snow is calculated by “Basset-Boussinesq-Oseen equation of

$$\frac{d\vec{U}_w}{dt} = \frac{3}{4} C_d \frac{\rho_f}{\rho_w} \frac{1}{d_w} \vec{U}_r \left| \vec{U}_r \right| + \vec{g} \tag{1}$$

using distributed of velocity of air flow. Thirdly, snow accretion analysis is performed by “Particle simulator”. The shape modified by snow accretion is reflected onto the boundary conditions of the air flow analysis. In this year, snow accretion analysis for simple cubic shaps is performed in order to aim at system development and validation as shown in the figure 5.

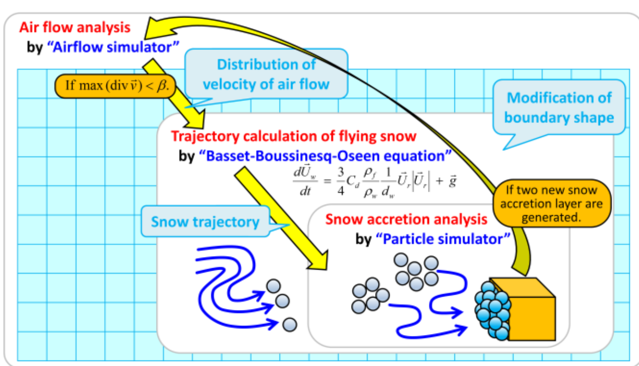

Figure 4: Numerical simulation of snow accretion.

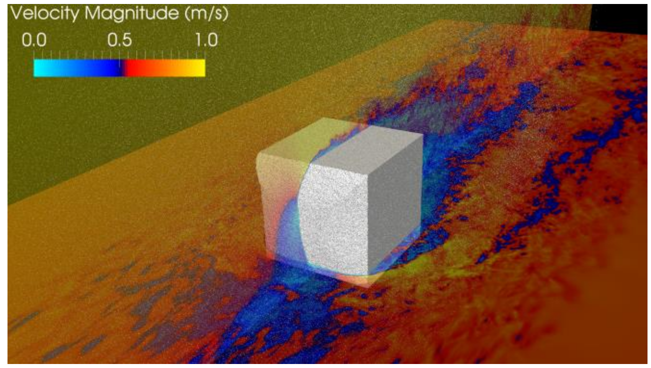

Figure 5: Result of the numerical simulation of snow accretion for the cubic shape.

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