Development of Numerical Coupled Analysis Method by Air Flow Analysis and Snow Accretion Analysis

Kohei Murotani
Railway Technical Research Institute
Japan
murotani.kohei.03@rtri.or.jp

Koji Nakade
Railway Technical Research Institute
Japan
nakade.koji.27@rtri.or.jp

Yasushi Kamata
Railway Technical Research Institute
Japan
kamata.yasushi.19@rtri.or.jp

Daisuke Takahashi
Railway Technical Research Institute
Japan
takahashi.daisuke.54@rtri.or.jp

ABSTRACT

In this research, to take countermeasures against the snow accretion damage, we developed a simulator for realizing the snow accretion process as shown in the following. Firstly, air flow analysis is performed by "Airflow simulator" developed by RTRI (Railway Technical Research Institute). Secondly, the trajectory of flying snow is calculated by the equation of motion for gravity and drag using the distribution of velocity of the air flow. Thirdly, snow accretion analysis is performed by "Particle simulator" developed by RTRI. The shape modified by the snow accretion is reflected onto the boundary conditions of the air flow analysis. In this research, we show the results of the snow accretion analysis for a simple cubic shapes in order to aim at development of the snow accretion algorithm and validation, the result of the snow accretion analysis for a train bogie model is discussed.

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 areas as shown in the figure 1. When the lump of snow falls off from 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 against the snow accretion damage, we developed a simulator for realizing the snow accretion process using the "Airflow simulator" and the "Particle simulator". In this research, snow accretion analysis for a simple cubic shape is performed in order to aim at development of the snow accretion algorithm and validation, the result of the snow accretion analysis for a train bogie model is discussed.

Figure 1: Snow accretion on a train bogies [1].

2 AIRFLOW SIMULATOR

The "Airflow simulator" is developed by RTRI (Railway Technical Research Institute), to analyze 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, the Poisson equation solver by the Jacobi method and the LES model by the coherent structure Smagorisky model are adopted in order to solve the Navier-Stokes equation for incompressible fluid flow. In the parallel computing method, the orthogonal domain decomposition is adopted. The target problem size is 10 million to 100 billion grids. The "Airflow simulator" achieved 84% of parallel efficiency in the K computer.

3 PARTICLE SIMULATOR

The "Particle simulator" is developed by RTRI, to solve the tsunami analysis and so on. The "Particle simulator" is developed using the LexADV_EMPS [2-4] of a parallel computing library for the MPS method (Moving Particle Simulation). In the parallel computing method, the dynamic load balancing by ParMETIS are adopted. The target problem size is 1 million to 10 billion grids. The "Particle simulator" achieved 88% of parallel efficiency in the K computer.

4 SNOW ACCRETION ANALYSIS

In this research, as shown in the figure 2, the simulator for realizing the snow accretion process as shown in the following was developed. Firstly, air flow analysis is performed by the "Airflow simulator". Secondly, the trajectory of the flying snow is calculated by "equation of motion for gravity and drag" of

$$\frac{d\vec{U}_{snow}}{dt} = \frac{3}{4} C_d \frac{\rho_{air}}{\rho_{snow}} \frac{1}{d_{snow}} \vec{U}_r \left\| \vec{U}_r \right\| + \vec{g} \qquad (1)$$

using the distribution of velocity of the air flow. Thirdly, snow accretion analysis is performed by the "Particle simulator". The shape modified by the snow accretion is reflected onto the boundary conditions of the air flow analysis.

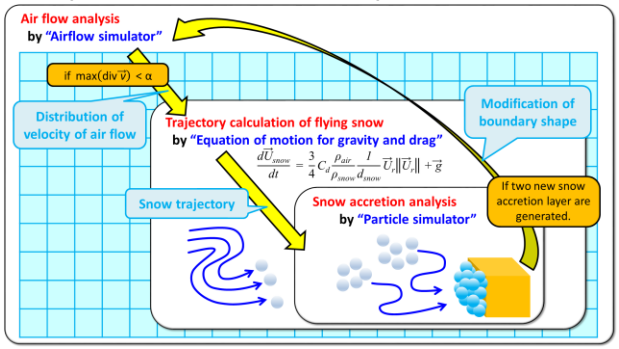


Figure 2: Coupled analysis method by air flow analysis and snow accretion analysis.

5 RESULT OF SNOW ACCRETION ANALYSIS

The figure 3 is the snow accretion analysis for a cubic shape. In the figure 3, the colour represents the velocity magnitude of the air flow, the horizontal lines represents the stream lines of the air flow, the opacity white represents the accretion snow and the transparent white represents the flying snow. In this research, the snow accretion experiment, as shown in the figure 3, was done at the snowfall wind tunnel. The figure 4 shows the result of the comparison between the analysis and the experiment. We developed the snow accretion algorithm such as realizing the snow accretion shape of the experiment.

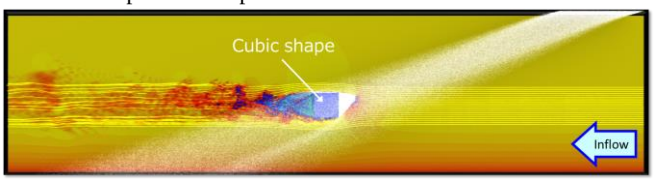
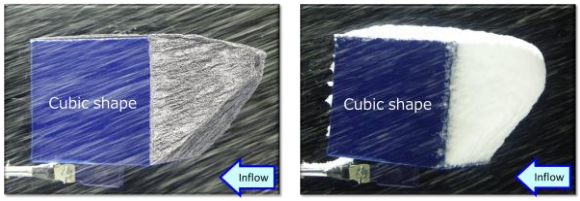


Figure 3: Snow accretion analysis for a cubic shape.



(a) Analysis (b) Experiment

Figure 4: Comparison between the analysis and the experiment.

The figure 5 shows the result of snow accretion analysis for a train bogie model and the figure 6 shows the result viewed from the bottom of the train bogie model. The snow accretion occurs at the back wall of the train bogie in the figure 6. We can confirm that a lot of accreted snow comes from the side of the train vehicle along the stream lines. Additionally, we can also confirm that the accreted snow which comes from the bottom of the bogie is less than that from the side.

Figure 5: Snow accretion analysis for a train bogie model.

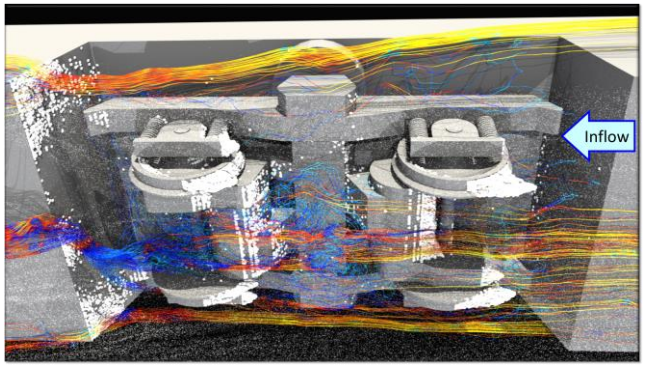


Figure 6: Snow accretion analysis viewed from the bottom of the train bogie model.

6 CONCLUSION

We have validated the results obtained from our snow accretion by comparing them with those obtained from the experiments by the use the snowfall wind tunnel. Additionally, since this snow accretion simulator is made by the distributed memory parallel calculation programing, it allows us to solve a very huge calculation model such as a whole train bogie. In the future, based on the results of the calculations of various modified train shapes, we will propose a train shape by means of which the amount of accreted snow can be reduced.

ACKNOWLEDGMENTS

In this research, we used computational resources of the K computer provided by the RIKEN Advanced Institute for Computational Science and the FX100 provided by the Nagoya university through the HPCI System Research project (Project ID: hp170067, hp180014). This work was supported by JSPS KAKENHI Grant Number 17K05152.

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