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宇宙での砂礫の溶融凝固プロセスの物理モデル構築

Physical modeling of melting-solidification process of regolith in space environment

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1. Introduction

For long-term manned lunar exploration, which has been planned for near future, human bases are essential. Due to the severe lunar environment, mechanical strength for lunar base structures is required to be at a high level, especially exterior walls. One possible structure for exterior walls has been proposed by previous study[1)], which is made of lunar regolith bound with coagulant brought from Earth. However, transporting the coagulant from Earth is costly and unsustainable. As possible methods for binding the regolith using only local resources, sintering and melting can be considered. Structures made by sintering might be not suitable for exterior walls, because of the low-strength due to the porous involved[2)]. Therefore, it is considered appropriate to manufacture building materials for the exterior wall using the melting and solidification process. For the simulation of such processes, many physical components must be considered, for instance, phase-change, heat and mass transfer in low-gravity environments. However, such physical models had not been reported in the previous studies. Therefore, this study aims to construct a new physical model of the melting-solidification process for manufacturing in space using local lunar resources by formulating a three-phase transport model.

2. Overview of model

When the computational resolution is selected as a scale of regolith particles, the computational cost must be enormous, thus, a coarse-grained model is considered to be effective. In this study, first, the conservation equation for each phase is formulated by using each phase volume fraction. Then, those equations are averaged into the mixture phase equation by summation rule. These governing equations are implemented in the open-source software, OpenFOAM.

3. Results

Validity of the proposed model was confirmed partially by simple calculations as shown in **Fig.1**, **Fig.2**. In **Fig.1**, α stands for volume fraction of each phase mixture. This calculation shows that the solid phase doesn't move without phase change, whereas liquid and gas phases move. **Fig.2** shows that the solid phase proportion change with phase change. To confirm the validity of the physical model, more verifications are needed.

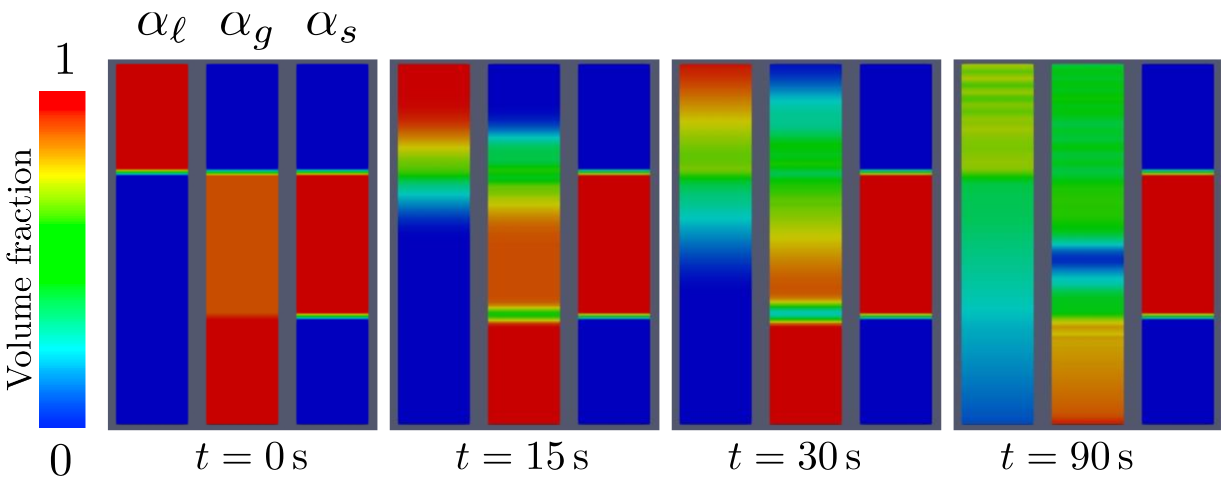

Fig.1 The verification for each phase behavior without phase change.

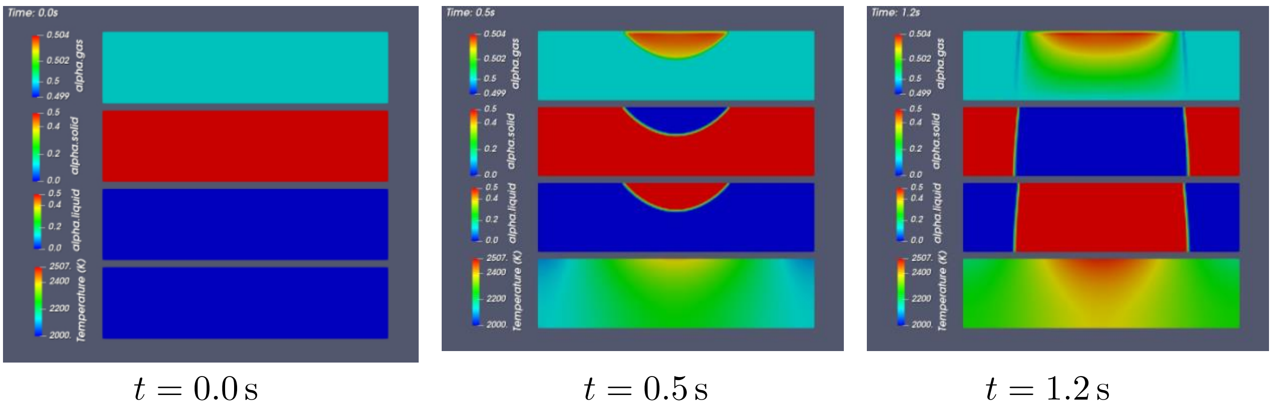

Fig.2 The verification for each phase behavior with phase change.

References

1) Foster+Partners: “Lunar Habitation” (2012).
2) Obayashi corporation, press release (2018).