Integrated computational materials modelling framework for investigating the process-structure-property linkage of the lunar metal welding with internal defects

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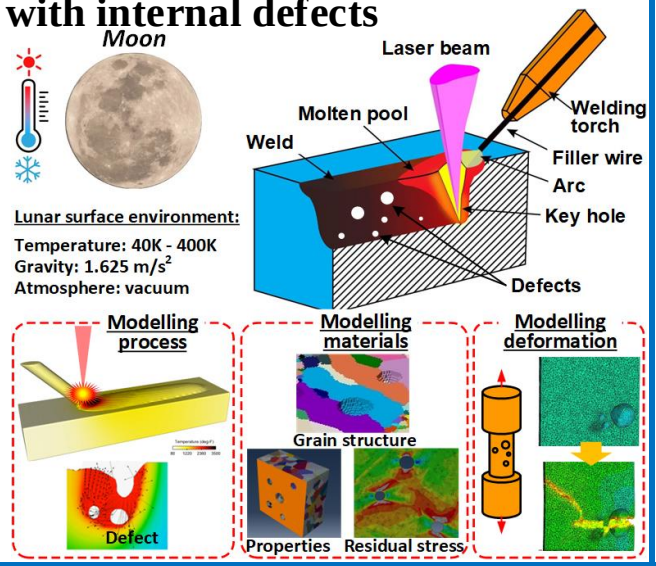

Research Objectives

An integrated computational materials modelling framework will be accomplished in this project to simulate the formation mechanism of lunar welding defect, the influence of defects on the grains, residual stress, material properties, ductile crack, and deformation under various loadings on the Moon.

Comparing to the state-of-art, the innovations include: 1) The modelling research is focused on welding defect, since the defect is widely considered as the source of fracture and welding joint failure. 2) Multi-physics mode is established to study the linkage of process-structure-property for lunar welding. 3) A systematic experimental validation includes in-space experiment and on-ground experiment. 4) A mechanistic data-driven model to optimize the lunar welding parameters to avoid defects.

This project will start from TRL 2. At the end of this project, the projected TRL will be TRL 3.

Approach

1) A multi-physics model will be established to simulate the laser welding process under Moon/Earth environments, internal defects, grains, residual stress, and heterogeneous materials properties in the welding joint. The defect evolution and ductile crack under various external loads will also be simulated.
2) The modelling framework involves thermal-fluid model, grain evolution model, CPFEM, thermal-mechanical model, and solid mechanics.
3) The modelling results will be validated by in-space experiments and on-ground experiment.
4) A mechanistic data-driven model will be established by integrating the multi-physical modelling data to predict the lunar welding defects and optimize the welding parameters.

Potential Impact

Beyond the proposed effort, the integrated computational materials model can be potentially developed for more space exploration needs:

1) The proposed model can be developed to fit various in-space conditions, like welding on Moon, Mars, or International Space Station.
2) The proposed welding model can be developed to simulate the in-space wire arc additive manufacturing (WAAM), which has the potential to fabricate or repair the large-scale spacecraft for the space exploitations.
3) The proposed model can be further developed to simulate the in-space fused deposition modelling (FDM). FDM has been proved as a feasible 3D printing process to print the non-metallic parts under in-space conditions.