A numerical method for simulating gas–liquid–solid three-phase flows based on the moving particle semi-implicit (MPS) approach was developed in this study. Computational instability often occurs in multiphase flow simulations if the deformations of the free surfaces between different phases are large, among other reasons. To avoid this instability, this paper proposes an improved coupling procedure between different phases in which the physical quantities of particles in different phases are calculated independently. We performed numerical tests on two illustrative problems: a dam-break problem and a solid-sphere impingement problem. The former problem is a gas–liquid two-phase problem, and the latter is a gas–liquid–solid three-phase problem. The computational results agree reasonably well with the experimental results. Thus, we confirmed that the proposed MPS method reproduces the interaction between different phases without inducing numerical instability.