MPI massive parallelization of smoothed particle hydrodynamics for strong fluid-structure interaction

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Abstract

Strong fluid-structure interaction is very common in many fields of engineering and science. However, conventional mesh-based methods have limitations in simulating such problems, especially extreme mechanics problems under explosion and impact loadings. The smoothed particle hydrodynamics (SPH) method offers inherent benefits in dealing with complex interfaces and large material deformations. In addition, we introduce MPI (Message Passing Interface) in our SPH scheme to reduce computational time in simulating time-consuming 3D engineering problems. And some optimizations are adopted to ensure the massive computation of the SPH method. To reduce memory footprint and achieve better scalability, an optimized memory management strategy is developed and a non-blocking MPI point-to-point communications scheme with parallel IO is implemented. We use several examples to demonstrate the scalability and accuracy of the present parallel SPH framework. As shown in Fig.1, the key characteristics of the dynamic failure process of complex structures subjected to extreme loadings can be well captured. In addition, there could be up to 2.04 billion particles in the present simulation. The scalability of the present massively parallel SPH program is good, which is shown in Fig.2. The program achieves maximum parallel efficiency of 97% on 10020 CPU cores.

Keywords: Smoothed particle hydrodynamics, Message passing interface, Massive high-performance computing, Memory management, Strong fluid-structure interaction

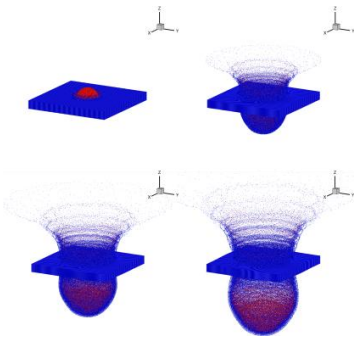

Figure 1. Oblique view of the 3D hypervelocity impact process

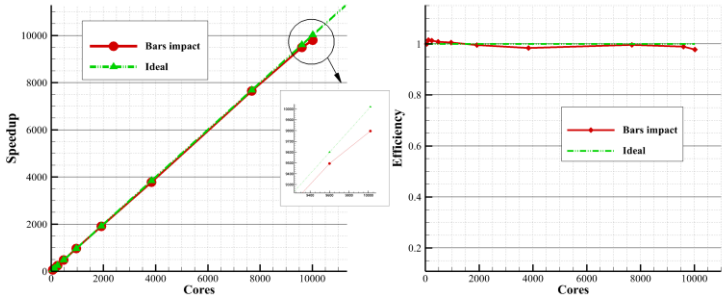

Figure 2. parallel speedup and efficiency in the scaling test (a) parallel speedup and (b) parallel efficiency.