Numerical simulation of metal removal in laser drilling using symmetric smooth particle hydrodynamics

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\begin{abstract}
A simple numerical model is proposed for predicting the penetration depth of metal laser drilling. A simplified 2D axisymmetric model for transient metal laser drilling is introduced. Strong-form of Symmetric Smoothed Particle Hydrodynamics (SSPH) method is used to harness its significant reduction in computational time. The 2D axisymmetric domain is discretized, then SSPH formulation is used to obtain shape functions. Collocation method is used to discretize governing and boundary conditions equations to construct the global stiffness matrix. Laser beam is assumed to be continuous wave with Gaussian distribution. MATLAB code is constructed for numerical simulation, and the results are compared with published work. A good agreement is shown, and thus the proposed numerical model is found to be computationally efficient and accurate standalone platform for predicting the penetration depth of metal laser drilling process. © 2017 Elsevier Inc. All rights reserved.
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1. Introduction

Numerical simulation has been extensively used for solving problems in engineering and science. Grid/mesh-based numerical methods have been commonly used as an essential tool in many fields such as computational fluid dynamics (CFD) and computational solid mechanics (CSM). Finite difference method was heavily used for solving the governing partial differential equations for simple geometries. Moreover, finite volume method (FVM) and finite element method (FEM) succeeded in handling complex problems in both fields of fluid flow and solid mechanics. Generally speaking, mesh-based approach relies on discretizing the physical domain into finite number of elements with fixed number of nodes. Although mesh-based numerical methods are well established tools for the analysis of advanced problem in both fluid and solid mechanics, there are some difficulties that limit their applicability in, for example, high deformation and free surface problems.

Massive computational load and continuous re-meshing are associated with handling such problems, yet the results may not be accurate enough.

Consequently, the need for numerical approach to handle such problems with minimum computational load and accurate enough results has been rapidly investigated and pursued. Accordingly, meshfree methods have been introduced to handle such problems by discretizing the whole physical domain into a finite number of particles instead of cells/nodes as in mesh-based methods. Each particle has physical meaning and carry physical properties such as mass, velocity and temp. The solution at each particle can be approximated using a weight/kernel function centered at the particle of interest. This kernel function allows only a set of the particle neighbors lying within the prescribed kernel radius of support to contribute to the field variable at the particle of interest [1–3].

One of the oldest and most well-known meshfree methods is Smoothed Particle Hydrodynamics (SPH). SPH was developed in 1977 for handling the astrophysics problems [4]. Later, it was the great tool for dealing with ballistics, volcanology and oceanography [5]. The development in meshfree methods area has been rapidly increasing year after year, thus many meshfree methods were developed such as element-free Galerkin (EFG) and reproducing kernel particle method (RKPM) that depend on deriving the