NUMERICAL ANALYSES OF MULTI – LAYERED ANISOTROPIC HIGH VISCOUS FLUID USING A PARTICLE METHOD FOR PRESS MOLDING OF CFRTP

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Introduction

Carbon Fiber Reinforced Thermo Plastic (CFRTP) is a kind of composite material made with thermoplastic resin. CFRTP is capable of being molded repeatedly, and its molding process can be completed in a sufficiently short time. To overcome the problems such as high production cost and the insufficient available quantity that conventional thermosetting resin have, establishment of the efficient mass production method of CFRTP using press molding is greatly desired.

CFRTP products are manufactured by unidirectional (UD) prepreg as a base material, and most of cases, UD prepreg has multi–layered structure. CFRTP UD prepreg sheets, however, could be seen as a high viscous material, and its non-uniform distribution of viscosity caused by aggregate of the fiber directions have the property of being anisotropic [1]. To avoid filling defect and fiber breakage, pre-evaluation of molding process utilizing numerical methods could be helpful for experimental stages; however, the existing numerical methodologies have some difficulties to treat anisotropic viscous materials.

In this study, a numerical method using meshfree particle-based discretization, which can handle multi-layered anisotropic high viscous flows of which physical properties are simulated as UD prepreg sheets, is presented. As validation of the proposal, two numerical examples are demonstrated.

An anisotropic viscosity modeling correlated with the fiber direction, numerical results, and discussions

In this study, a composite material is discretized as a particle system. Each particle has a fiber direction and the anisotropy of the viscosity is determined according to the fiber direction. The governing equations adopted in this study are as follows:

$$\frac{D\mathbf{u}}{Dt} = \mathbf{C}\nabla^2\mathbf{u} - \frac{1}{\rho}\nabla P, \tag{1}$$

$$\nabla \cdot \mathbf{u} = 0, \tag{2}$$

where $\mathbf{u}$ is the velocity, t is the time, ρ is the density, P is the pressure, and $\mathbf{C}$ is the viscosity tensor, respectively. The viscosity tensor $\mathbf{C}$ is defined as follows:

$$\mathbf{C} = (\mathbf{p} \quad \mathbf{q} \quad \mathbf{r})^{-T} \begin{pmatrix} \nu_{hor} & 0 & 0 \\ 0 & \nu_{ver} & 0 \\ 0 & 0 & \nu_{ver} \end{pmatrix} (\mathbf{p} \quad \mathbf{q} \quad \mathbf{r})^{-1}, \tag{3}$$

where $\mathbf{p}$ is the normalized fiber direction vector, $\mathbf{q}$, $\mathbf{r}$ are the normalized vectors which are vertical to $\mathbf{p}$ and perpendicular each other, ν_{hor} is the kinematic viscosity of the fiber direction, and ν_{ver} is the kinematic viscosity of the direction $\mathbf{q}$ and $\mathbf{r}$, respectively. The Standard LSMPS schemes Type-A [2]

are employed to discretize the spatial derivative operators, and arithmetic mean of **C** of each layer are adopted on the boundary particles between two layers.

Two demonstrable cases in which multi-layered materials are pressed, are analyzed to validate the proposed method. Figure 1 shows the result of an analysis in which four oblique anisotropic viscous material layers are stacked up. Each layer has a different fiber direction so that it exhibits an unyielding tendency to flow toward the direction perpendicular to the fiber direction. Figure 2 displays the result of a problem in which four rectangular cakes of anisotropic viscous material are placed on a checkered pattern with a right angle. In this case, the flow toward the direction perpendicular to the fiber direction is observed. Moreover, unphysical pressure oscillation is not found in contrast to the existing particle approaches such as the SPH methods [3] and the MPS methods [4]. These results agree with actual behavior of the pressed CFRTP composite, and they demonstrate that proposed method is promising for the press molding analysis of CFRTP composite.
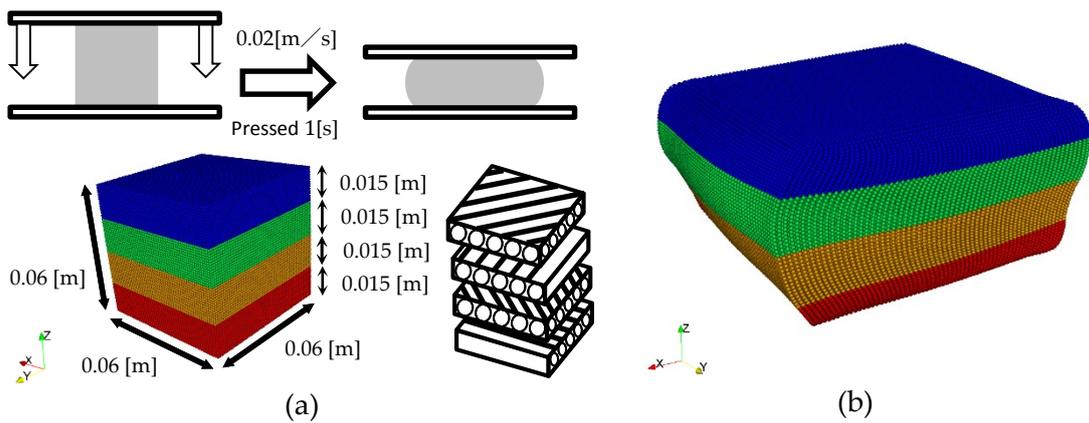

(a)

(b)

Figure 1: *Problem pressing the laminate stacked vertically; (a) Simulation condition and (b) Result.*
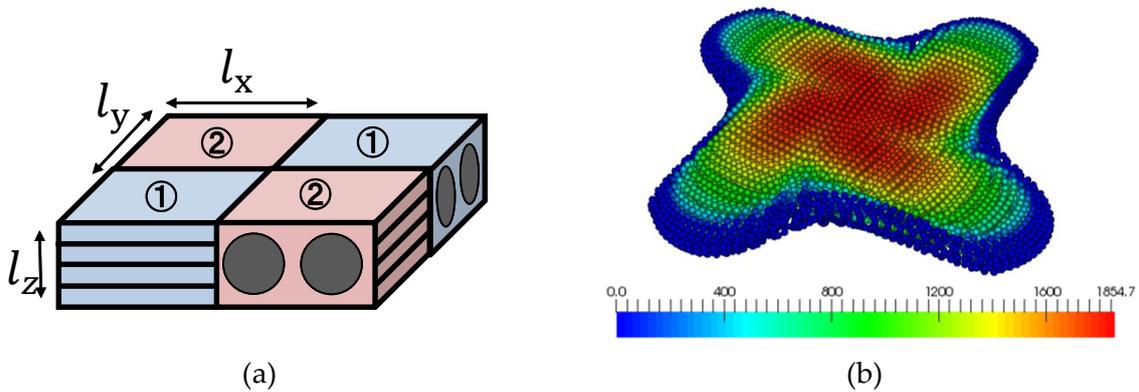

(a)

(b)

Figure 2: *Problem pressing the laminate placed on a checkered pattern; (a) Simulation condition and (b) Result.*

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