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Force method conception using transfer matrix to apply to multiphase flow by one-by-one corresponding Particle-Cartesian cell (*P*/*CC*) model

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The objective of this study is to develop a force method for application in the multiphase flow by the one-by-one corresponding Particle-Cartesian cell model, which is previously proposed in [1].
Displacements and forces continue at the surfaces between phases, whereas strains discontinue. Meanwhile, the proposed force method is applicable for continuum mechanics and differs from the conventional method for the framework, and it is referred to as Continua-work in this study. In this study, two types of schemes are presented: the first is as follows, and second is built using the so-called separation parameter method.

The state vector: {displacement, stresses}: $\{\boldsymbol{U},\nabla\boldsymbol{F}\}$ continues and the strains represented by $\{\nabla\boldsymbol{U}\}$ discontinue in general to satisfy the week solution of the virtual work according to the FEM conception. One of the proposed force methods uses incomplete three-fold third-order element, consisting of parameter vector: $\{\boldsymbol{U},\nabla\boldsymbol{F}\}_k$ on the vertex node *k*. Therefore, the element function is represented by parameter vector: $\{\boldsymbol{U},\nabla\boldsymbol{F},\nabla\nabla\boldsymbol{F},^{\cdots}\}_0$ on the local origin. The strains are represented by $\{\nabla\boldsymbol{F}/\nu\}$ of the transfer matrix, where ν is kinetic viscosity.

The transfer matrix, also known as the reduction matrix, can represent state vector $\{\boldsymbol{U},\nabla\boldsymbol{F}\}_b$ on *b* by state vector $\{\boldsymbol{U},\nabla\boldsymbol{F}\}_a$ on *a*, even though a rigid member (rigidity $G = \infty$) is included. This is because the forces are transferred, and they continue at the boundary. In beam theory, it exists as a strong solution; however, for continua, it exists only week solutions.

The simultaneous equation is constructed by the virtual work principle. Cauchy-Riemann equations defined in two dimensions must be satisfied as necessary conditions for a robust scheme because the strain and stress represented by $\{\nabla\boldsymbol{U},\nabla\boldsymbol{F}\}$ have four components (freedom). In the same way in three dimensions, as constraint conditions, so-called conjugate variables concept has been proposed.

Accordingly, the equilibrium equation represented by $\{\boldsymbol{U}\}_k$ and$\{\nabla\boldsymbol{F}\}_k$ for multiphase flow represented with different ν has been obtained. In addition, another scheme is explained in the full paper.

REFERENCES

[1] Imamura, J. *A one-by-one corresponding Particle/Cartesian cell* (*P/CC*) *model to apply to multiphase flow problems triggered by surface tension such as large, scaled water disaster*, COMPSAFE2020, Kobe/Japan, (2020)