18th International Conference
ENGINEERING MECHANICS 2012
Svratka, Czech Republic, May 14 – 17, 2012

pp. 158–159
Paper #188

MODELING OF FRESH CONCRETE FLOW USING XFEM

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Abstract: *Modeling of fresh concrete flow is interesting problem from both theoretical and practical point of view and its application to self compacting concrete casting simulations is a subject of active research with important practical aspects. Practical importance is especially in application to self compacting concrete, which is highly actual. It is usually modeled in eulerian description of motion as a problem of two immiscible fluids (concrete as a Bingham fluid and air as a newtonian fluid). Due to different physical properties of these fluids, there are discontinuities of velocity and pressure fields at the interface. In this paper, the eXtended Finite Element Method (XFEM) is used allowing the standard FE approximation space with tailor made functions across the interface to resolve the discontinuities.*

Keywords: ***Flow, concrete, XFEM, Bingham model, level set***

1. Introduction

This paper deals with eXtended Finite Element Method (XFEM) and its implementation in flow problems. Especially, it is focused on its application to fresh concrete flow. In the present work, Eulerian formulation is used. Modeling of fresh concrete flow is in context of Eulerian formulation typically done using so called two immiscible fluids concept (as a free surface flow), first proposed in (Chessa and Belytschko (2003)). For example, in the case of fresh concrete flow, one fluid represents concrete and the other one represents air. Since both fluids are immiscible, the interface between them can be always captured. In FEM context, Volume Of Fluid (see Gopala and Van Wachem (2008)) and Level set Method (Sethian (1999), Osher and Fedkiw (2003)) are proper choices. Since the flow is modeled using XFEM, the Level Set Method is used in this work. Extended Finite Element Method enriching the standard continuous approximation of velocity and pressure fields by discontinuous enrichment functions along the interface is then used to discrete governing equations.

2. Governing equations

As was mentioned before, problem is described by Navier-Stokes equations. In this work, only flow in 2D is considered. Unknown fields are then $\boldsymbol{u}$ and p. Constitutive law for air can be considered as one-parameter (viscosity μ) Newtonian fluid. Two parameter (yield stress τ_0 and plastic viscosity μ_{pl}) Bingham model is used for description of concrete flow.

3. Description of the interface

Interface between both fluids is described by level-set method(Sethian (1999). In Level-set method, interface is represented as a zero level set of some scalar function ϕ.Here, ϕ has been chosen as a signed distance function. Since the interface is changing in time, level-set representation has to be updated at each time step. Motion of the interface is governed by level-set transport equation. Motion of the interface is governed by level-set transport equation.

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4. Spatial dicretization and XFEM

Since both fluids in our model have different physical properties (density and viscosity), there are discontinuities in velocity and pressure fields along the interface. Strong discontinuity is present when there is a jump in a function. Weak discontinuity arises, when there is a jump in derivative of the function. Treatment of discontinuities is very easy and natural using XFEM. The main idea behind XFEM is to enrich approximation space with tailored global (defined in whole domain) functions which can describe discontinuities present in solution. Choice of these functions depends on solved problem and on our a priori knowledge of solution. Modeling of fresh concrete flow is a two fluid problem without the surface tension. Therefore, both velocity and pressure fields are enriched by ”abs-enrichment” function. Stabilized weak formulation of governing equations can be found in (Tezduyar and Osawa (2000)).

5. Temporal discretization and solution scheme

After spatial discretization, we have system of non-linear ordinary differential (in time) equations, which can be found in (Tezduyar and Osawa (2000)), or (Patzák and Bittnar (2009)).

6. Numerical example

For the purpose of validating our model, simple 2-D plane-stress problem was chosen. Simple Cantilever beam with ratio of the sides 4 / 1 with four weakened inclusions was chosen as a geometry. Material of Cantilever is linear elastic with Young modulus $E = 3 \cdot 10^4 MPa$, weakened holes have Young modulus $E = 0.1MPa$. Poisson ratio is equal to 0.3. Since there are different material properties, so-called ”abs enrichment” was used, because of weak discontinuity in displacement (or strong discontinuity in strains and stresses). Constant continuous load with intensity 1 kN/m is prescribed on the top surface of the beam.

7. Conclusions

In this paper, we prepared numerical model for fresh concrete casting. The problem is modeled as flow of a two immiscible homogeneous fluids with different physical properties. The concrete is considered as two-parametric Bingham fluid, the air is modeled as a standard Newtonian fluid. The interface between both fluids is descrideb in sense of level-set method. Extended finite element method is then used for description of discontinuities in velocity and pressure fields across the interface. Since there is no surface tension in this problem, presenting discontinuity is only weak and therefore, so-called ”abs enrichment” is used. As a benchmark test for validating implementation, simple 2-D plane-stress problem was chosen.

Acknowledgments

This work was supported by the Grant Agency of the Czech Technical University in Prague, grants No. SGS12/026/OHK1/1T/11 and New Industrial Technologies for Tailor-made Concrete Structures at Mass Customised Prices TailorCrete, . 7E10055.

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