Imposition of essential boundary condition in heat conduction problem based on Isogeometric analysis

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Abstract

One of the major concerns with Isogeometric analysis is finding an efficient approach to impose essential boundary conditions (EBCs). Non-interpolating nature of NURBS leads to the non-satisfaction of Kronecker delta property therefore, imposing EBCs is not a straightforward task. The purpose of this paper is using a two-step method to impose EBCs for improving the accuracy of solution field in transient heat flow within two-dimensional region. In the proposed approach, The EBCs are defined on Dirichlet boundary as determined temperatures and independent of time. In the first step, EBCs are built into the variational formulation weakly, choosing weight function appropriately. In the second step, with fixed condition, the system of equations is adjusted appropriately. For investigation of the proposed approach, two numerical examples have been performed. The results demonstrate significant improvement in accuracy and rate of convergence in comparison with direct imposition of essential boundary condition and finite element method.

Keywords: isogeometric, essential boundary conditions, transient heat flow

1. INTRODUCTION

Isogeometric analysis (IGA) is a recently developed computational approach that offers the possibility of integrating finite element analysis (FEA) into conventional NURBS-based Computer Aided Design (CAD) tools. The concept of the IGA in mechanic problems is pioneered by Hughes and his co-workers as a novel technique for the discretization of partial differential equations [1]. The basic idea and also the heart of the IGA are to utilize the basis functions that are able to model geometries exactly, from the CAD points of view, for numerical simulations of physical phenomena. It can be achieved by using the B-splines or Non Uniform Rational B-splines (NURBS) for the geometrical description and invoke the isoparametric concepts to define the unknown field variables. The IGA-based approaches have constantly developed and shown many great advantages on solving many different problems in a wide range of research areas such as fluid–structure interaction, shells, structural analysis and so on [2-6]. In spite of these advantages, the IGA method suffers from some deficiencies. One of the most significant drawbacks arises from imposition of essential boundary conditions. Due to the non-interpolating nature of NURBS basis functions, the properties of Kronecker Delta are not satisfied, and as a consequence, the imposition of essential boundary conditions needs special treatment. In considering this, several methods have been proposed for imposing essential boundary conditions in IGA. This issue for NURBS-based isogeometric analysis was first discussed by Hughes et al. [1]. This method is efficient for homogenous boundary conditions but it is not reliable in non-homogenous boundary conditions. Therefore, the enhancement of essential boundary conditions in IGA needs to be researched more thoroughly [1]. Wang and Xuan [7] have proposed an improved method for imposition of essential boundary conditions in IGA which is based on concepts of the mixed transformation method that was originated by Chen and Wang [8]. This method produces more accurate results and convergence rates in comparison with DM [7].

Imposing essential boundary conditions in time dependent problems is applied in IGA with Hughes et al. [4] at first. They applied direct method in structural vibrations and wave propagation problems. As mentioned above,