Isogeometric Analysis of Arbitrarily Shaped Structures: A Numerical Approach Based on the Strong Formulation

Francesco Tornabene, Nicholas Fantuzzi* and Michele Bacciocchi

DICAM Department, School of Engineering and Architecture, University of Bologna
Viale del Risorgimento 2, 40136, Bologna, Italy
e-mail: francesco.tornabene@unibo.it, nicholas.fantuzzi@unibo.it, michele.bacciocchi@unibo.it
web page: http://software.dicam.unibo.it/diqumaspab-project

ABSTRACT

A numerical solution is sought for many engineering applications since it is not always possible to achieve analytical results. This statement is even more truthful when the reference domain of the problem under consideration is characterized by an irregular or arbitrary shape. For this purpose, several numerical approaches have been developed in the last decades to deal with these kinds of problems.

Let us consider the mechanical analysis of some structural elements, such as membranes, plates, and shells. In this regards, the most common numerical scheme to obtain a solution is given by the Finite Element (FE) method. Its basic aspect is the domain decomposition in many elements, in which the unknown field is approximated through low order polynomials. The weak form of the governing equations is typically solved. In addition, the so-called mapping technique is used to deal with arbitrarily shaped subdomains.

The main aim of this research is to present a new numerical approach which implements higher-order approximating polynomials within each discrete element. Unlike classic schemes, the present methodology is developed to solve the strong form of the fundamental equations [1]. Thus, the mathematical problem is approximated numerically by means of the Differential Quadrature (DQ) method. Arbitrarily shaped domains are accurately described using a nonlinear mapping based on NURBS curves. The employment of peculiar blending functions allows to reduce the number of elements required to approximate accurately any irregular domain [2-4]. Therefore, this approach is part of the well-known framework of Isogeometric Analysis (IGA). Due to its features, the methodology at issue is named Strong Formulation Isogeometric Analysis (SFIGA).

Several numerical applications are investigated to prove the accuracy, reliability, and stability features of the technique. In particular, this research is focused on the study of the mechanical behavior of membrane, as well as laminated composite plates and shells. This approach is validated by means of the comparison with the results available in the literature or obtained through a FE model realized by commercial codes.

REFERENCES

[1] F. Tornabene, N. Fantuzzi, F. Ubertini and E. Viola, "Strong Formulation Finite Element Method Based on Differential Quadrature: A Survey", *Applied Mechanics Review*, **67**, 020801-1-55, (2015).

[2] N. Fantuzzi and F. Tornabene, "Strong Formulation Isogeometric Analysis (SFIGA) for Laminated Composite Arbitrarily Shaped Plates", *Composites Part B Engineering*, Vol. **96**, pp. 173-203, (2016).

[3] F. Tornabene, N. Fantuzzi and M. Bacciocchi, "The GDQ Method for the Free Vibration Analysis of Arbitrarily Shaped Laminated Composite Shells Using a NURBS-Based Isogeometric Approach", *Composite Structures*, Vol. **154**, pp. 190-218, (2016).

[4] N. Fantuzzi, G. Della Puppa, F. Tornabene and M. Trautz, "Strong Formulation Isogeometric Analysis for the Vibration of Thin Membranes of General Shape", *International Journal of Mechanical Sciences*, Vol. **120**, 322-340, (2017).