THE DISCRETE STRAIN GAP (DSG) METHOD AND ITS APPLICATION TO SHELL ELEMENTS

F. Koschnick[a], M. Bischoff[a] and K.-U. Bletzinger[a]

[a]Chair of Structural Analysis
Technische Universität München
Munich, Germany
{koschnick; bischoff; kub}@bv.tum.de

The Discrete Strain Gap (DSG) method provides a general concept for modeling locking-free structural finite element. It can be used to treat all kind of geometrical locking effects, namely in-plane shear, transverse shear and membrane locking, and can be applied to both triangles and quadrilaterals of arbitrary polynomial order. Therefore the DSG-method represents a uniform theoretical framework for the development of locking-free finite elements.

Originally proposed by Bletzinger et al. [1] as the Discrete *Shear* Gap Method to avoid transverse shear locking in shells it has been extended successfully to treat membrane locking in curved Timoshenko-beams [2]. Due to the aspired generality of the DSG-method further developments have been made regarding its application to shell elements. In this context the problem of membrane locking in shell elements is treated by the straightforward extension of the existing method. In a further step the DSG method is used to avoid the remaining 'geometrical' locking phenomenon i.e. in-plane shear locking.

The Discrete Strain Gap Method is derived from standard Galerkin formulation and therefore utilizes only nodal displacement and rotational degrees of freedom. It can be classified as a 'B-bar' method because it results in a modification of the strain displacement operator B.
The initial idea of the DSG method is the computation of so-called Discrete Strain Gaps at the element nodes and their interpolation across the element domain. These Strain Gaps are obtained by integration of the corresponding kinematic equations for in-plane shear, transverse shear and membrane strains, respectively.
Using the discrete shear gaps to determine the related strain field effectively eliminates parasitic strains and thus avoids locking. The whole procedure of integration and interpolation can be done analytically in advance, and thus introduces no additional numerical effort compared to a standard displacement formulation. There is also a close relationship to the Assumed Natural Strain (ANS) Method.
Like in the case of ANS elements, sensitivity to mesh distortions and oscillations of the transverse shear forces can be overcome by the use of stabilization techniques [3]. Using only one-point integration, especially the three-node DSG-element shows an excellent performance and seems to be particularly attractive for large scale computations with a lot of time steps, e.g. when using explicit codes.
As the Discrete *Shear* Gap method has already been applied successfully to formulate non-linear general shell elements it is expected that the corresponding generalization of the principal idea presented in this paper to non-linear shells is straightforward.

References

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