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A 3D CURVE SMOOTHING METHOD PRESERVING NODES FOR THE BEAM-TO-BEAM CONTACT

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ABSTRACT

Ensuring C^1 continuity between finite elements is arguably the most important aspect of the geometry modelling in the FEM for the analysis of contact. A failure to do so results in discontinuities of the normal and tangential vector definitions, which are basic in the contact formulation. As a result, if a large relative sliding of contacting bodies occurs , the iterative solving of a non-linear contact problem encounters problems with preserving of convergence and in some cases no convergence can be achieved at all.

This effect is especially pronounced in situations where only few contact points exist. The beam-to-beam contact with the point-wise contact assumption [1] belongs to this category. Thus it is even more important in this case to provide the effective method for 3D curve smoothing.

In the previous work [2] a method was developed, which proved to be effective and resulted in a very good behaviour in large sliding cases. However its drawback was that the resulting smooth curve did not pass through the current nodes of the FE mesh. Thus in cases of a relatively large curvature of beams some inaccuracies of the geometry with respect to the real shape of the beam could be observed.

This paper deals with a method of the construction of a C^1-continuous 3D curve, which preserves the nodes, i.e. they lie on the resulting curve. The way to construct the curve is illustrated in Fig. 1.

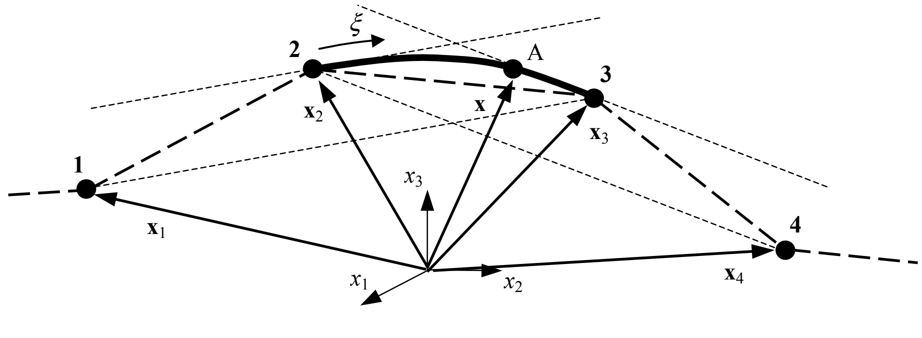

Fig. 1. The 3D curve preserving nodes

Any point A on the curve is represented by its position vector $\mathbf{x}$. Each of its three components is expressed by a Hermite polynomial

$$x_i = a_i \xi^3 + b_i \xi^2 + c_i \xi + d_i = \mathbf{a}_i \circ \boldsymbol{\xi} \, . \tag{1}$$

The boundary conditions yielding C^1-continuity between adjacent curve segments are

$$\begin{aligned} \xi = -1 \;\; &\Rightarrow \;\; x_i = x_{2i} \quad \text{and} \quad \frac{\partial x_i}{\partial \xi} = \varphi_{13i} = \frac{x_{3i} - x_{1i}}{2 l_{13}} l_{23} \;, \\ \xi = 1 \;\; &\Rightarrow \;\; x_i = x_{3i} \quad \text{and} \quad \frac{\partial x_i}{\partial \xi} = \varphi_{24i} = \frac{x_{4i} - x_{2i}}{2 l_{24}} l_{23} \;, \end{aligned} \tag{2}$$

where the components of the position vectors for four nodes involved in the construction of the smooth curve segment are denoted by

$$\mathbf{x}_1 = (x_{1i})^T \, , \quad \mathbf{x}_2 = (x_{2i})^T \, , \quad \mathbf{x}_3 = (x_{3i})^T \, , \quad \mathbf{x}_4 = (x_{4i})^T$$

and l_{jk} are the straight line distances between the nodes j and k. After basic mathematical operations the position of any point A can be expressed in terms of nodal co-ordinates

$$x_i = \boldsymbol{\xi} \circ \left\{ \frac{1}{4} \begin{bmatrix} 1 & -1 & 1 & 1 \\ 0 & 0 & -1 & 1 \\ -3 & 3 & -1 & -1 \\ 2 & 2 & 1 & -1 \end{bmatrix} \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -l_{23}/2l_{13} & 0 & l_{23}/2l_{13} & 0 \\ 0 & -l_{23}/2l_{24} & 0 & l_{23}/2l_{24} \end{bmatrix} \begin{bmatrix} x_{1i} \\ x_{2i} \\ x_{3i} \\ x_{4i} \end{bmatrix} \right\} . \tag{3}$$

It must be noted that the representation (3) is not linear in nodal co-ordinates due to the presence of lengths l_{jk} in the second submatrix. This fact must be considered in the evaluation of contact finite element matrices [2]. Unlike in typical FE approach, linearizations of variations of displacements, being in fact their second partial derivatives with respect to nodal displacements, are nonzero.

The definition (3) of the smoothed curve was embedded in the framework of the frictional beam-to-beam contact described in detail in [2, 3]. The resulting contact finite element was applied in the analysis of various schemes of contacting beams proving the efficiency of the suggested smoothing technique in the case of large sliding. The numerical results will be presented at the conference.

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