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Investigations on joint interfaces using zero thickness finite elements

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ABSTRACT

An important contribution to global damping of mechanical devices is *structural damping* due to microslip effects with friction in joint interfaces. In order to investigate the mechanical behaviour in these contact interfaces numerically, a contact element in the context of Finite Element Method (FEM) is presented. The assumptions for the contacting bodies are small deformations and linear elastic material behaviour. Therefore a linear FE formulation can be used and a discretization with linear (locking free) isoparametric 8-node brick elements is chosen. An appropriate discretization of the contact area can be achieved with isoparametric 8-node zero thickness elements (zt8), Figure 1, which can be regarded as degenerated 3D continuum elements, see [1]. The suggested element is well suited for the present problem because the contact area is known and only small relative displacements occur.

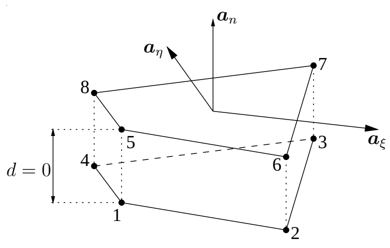

Figure 1: Zero thickness element with local coordinate system

Using a proper parametrization of the contact area, [2], it is possible to apply the element in contact interfaces lying arbitrarily in space and in interfaces discretized with distorted elements. Therefore the local coordinate system with covariant local tangential vectors $\boldsymbol{a}_\xi$, $\boldsymbol{a}_\eta$ and the normal vector $\boldsymbol{a}_n$ is introduced, as depicted in Figure 1. The interface stresses $\boldsymbol{t}$ of these elements are formulated in this local system depending on the relative displacements $\boldsymbol{g}$ between the upper and lower elementside,

$$\boldsymbol{t} = \boldsymbol{t}(\boldsymbol{g}) = t_n \boldsymbol{a}_n + t^\alpha \boldsymbol{a}_\alpha \,, \qquad \alpha \in \{\xi, \eta\} \,, \tag{1}$$

whereas this dependence is given in terms of constitutive contact laws. In normal direction linear, exponential and potential laws are implemented and in tangential direction an elastic, ideal plastic behaviour is treated within a radial return mapping algorithm. Now the virtual work in the interface element can be formulated in stresses and relative displacements and the FE discretization can be introduced. The numerical integration is done using LOBATTO rule because of stress oscillations which may appear in the interface at high stress gradients. These steps result in the vector of contact forces on element level, depending in general nonlinearly on the relative displacements. The assembly into the whole system can be done easily because of the equivalent formulation of contact- and surrounding elements. Thus the whole system behaves nonlinear because of the contact interface and therefore a solution of the vector function $\boldsymbol{k}(\boldsymbol{u}) = \boldsymbol{f}$ has to be achieved, with inner nodal forces $\boldsymbol{k}$ depending on the nodal displacements $\boldsymbol{u}$, and the external forces $\boldsymbol{f}$. The classical solution method is the NEWTON-RAPHSON algorithm where at special choices of contact parameters difficulties concerning convergence occur. A damped NEWTON-RAPHSON iteration helps but leads to slow convergence. Dynamic systems, where additionally inertia and viscous damping forces are taken into account, are solved with a NEWMARK time step integration. In order to show that the presented method works in principle, the example of a onesided clamped structure consisting of two bolted beams is considered. The viscous damping parameters are taken from measurements on a single beam and are interpreted as material parameters in order to capture material damping. The excitation of the structure is done with a step relaxation, i.e. a static load is suddenly released. The structural response of the free end of the beam in vertical direction u_{Az} is measured with a laser doppler vibrometer and compared with the simulation, see Figure 2. The constitutive contact parameters are chosen in order to fit the measurements in the time domain. A good

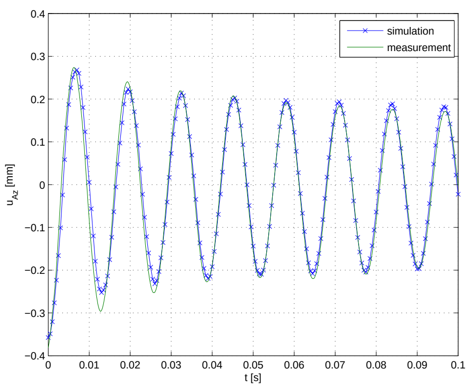

Figure 2: z-displacement of the free end after step relaxation

agreement of measurement and simulation especially regarding the frequency can be seen. Moreover one sees that in the first cycles the most energy is dissipated, which is due to friction. Especially in these dynamic systems the convergence problems in the solution of the nonlinear equations lead to long calculation times, so more efficient nonlinear solution techniques are to be tested and presented in this contribution.

REFERENCES

[1] J.-M. Hohberg. "Concrete Joints". In: *Mechanics of Geomaterial Interfaces, Amsterdam: Elsevier, Studies in Applied Mechanics.*, Vol. **42**, A.P.S. Selvadurai and M.J. Boulon (Editors), 421–446, 1995.

[2] K. Willner. *Kontinuums- und Kontaktmechanik*, Berlin: Springer, 2003.