PARAMETER IDENTIFICATION IN DYNAMIC CRACK PROPAGATION

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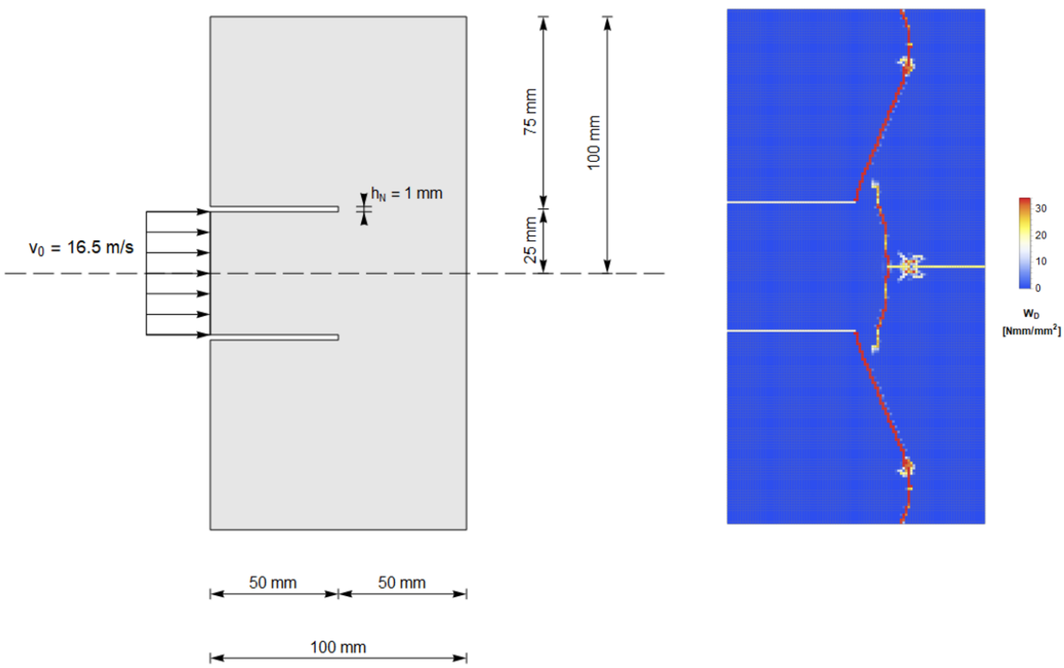
Introduction

The subject of our research work is the identification of unknown parameters in a numerical model, that enables simulation of crack propagation in a structural element subjected to dynamic loads. In order to describe a crack formation and opening in quasi brittle 2d solid we use the embedded strong discontinuity method ([1]). It provides mesh-independent solution since the fracture dissipation energy is associated with the discontinuity and does not depend on the finite element size. Usually, we do not possess all the necessary data available to carry out the numerical simulation of an experiment. Therefore, the stochastic Bayesian inverse method ([4]) is applied to identify the input parameters, that can not be measured directly – such as the fracture energy which dissipates when cracks propagate through the model domain.



(a) (b)

Figure 1: Kalthoff's test: (a) Geometry and boundary conditions. (b) Specific dissipated fracture energy at the end of simulation with the embedded discontinuity quadrilaterals Q6 (see [5]).

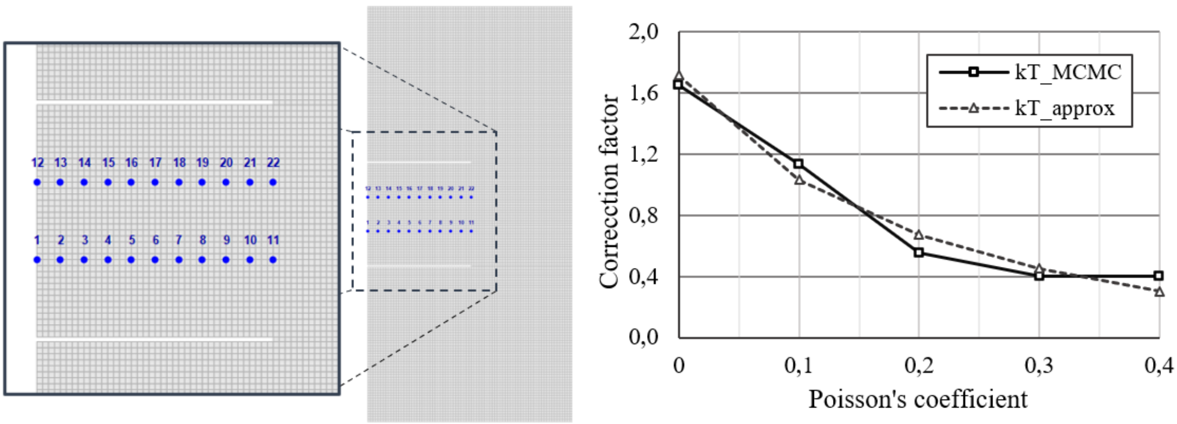
Representative example

The Kalthoff's test on a high-strength steel plate with two notches from [2] is chosen as the representative example of fracture dynamics. Fig. 1(a) illustrates geometry and boundary conditions of the specimen. Fig. 1(b) shows the field of dissipated fracture energy at the end of a deterministic simulation, where the crack path is composed of three lines: two lines propagates from each notch and one horizontal line starts at right side of the plate and bifurcates into two branches.

Lattice model calibration

In this work we use two different finite element models for modeling crack propagation with embedded strong discontinuity: the lattice element from [3] and the quadrilateral Q6 element from [5]. The lattice model is a discrete model of continuum, therefore the stiffness matrix of a lattice element has to be calibrated at first, such that the pressure and shear waves in lattice model have the same velocity as in the elastic solid model. For this purpose we introduce correction factors for longitudinal k_L, transversal k_T and rotational stiffness k_R of a lattice element.

The stochastic method Markov Chain Monte Carlo (MCMC) is employed for the identification of three correction factors, that are set to be random variables with the uniform distribution $U(0.1,\ 5)$. In this procedure, the Kalthoff's test is modified such that the imposed constant velocity of $v_0 = 16.5$ m/s is replaced with the distributed horizontal load $q_F = q_F(\lambda) = \lambda q_{F,0}$, where $q_{F,0} = 4.08 \times 10^6$ N/m. The material parameters are: Young's modulus $E = 190$ GPa and Poisson's coefficient $\nu = 0.3$. The measurements are displacements in 22 assimilation points presented in Fig. 2(a). The true measurement is generated from the deterministic simulation with the Q6 finite elements. The response of the lattice model is replaced with the generalized PCE model degree of 12, where the regression is used for computing the corresponding polynomial coefficients.



(a) (b)

Figure 2: Kalthoff's test: (a) Position of 22 assimilation points. (b) The diagram shows the shear correction factor k_T in a lattice finite element for various Poisson's coefficients ν. The curve $k_{T,MCMC}$ presents the posterior mean values of the factor k_T obtained by the identification procedure with the MCMC method. The line $k_{T,approx}$ illustrates the eq. (1).

The diagram in Fig. 2(b) collects the results for the correction factor $k_{T,MCMC}$ obtained with the stochastic analysis. The MCMC method is applied for different values of Poisson's coefficient ν. One can see that the factor $k_{T,MCMC}$ decreases towards 0.4 for higher Poisson's coefficient ν. In other words, when $\nu > 0.15$, the elastic stiffness of a lattice element in shear direction should be reduced, otherwise it should be increased. Based on the results, an approximation function for the correction factor of transversal elastic stiffness in lattice elements is proposed:

$$k_{T,approx} = \frac{1.2 - 1.5\nu}{0.7 + 3.2\nu} \tag{1}$$

We note, that the proposed approximation in eq. (1) is valid only for the considered numerical model. The generality of the approximation (1) has to be further investigated.

This research work shows that the Bayesian inverse method can be a very effective tool for determination of the unknown parameters (e.g. correction factors) that can not be expressed explicitly from the equilibrium equations due to the complexity of the relation between the finite element model response and the input parameters – as is the case for the lattice model.

Acknowledgements

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