CHARACTERIZATION OF THE STRESS FIELDS NEAR CRACK TIP FOR COMPACT SPECIMEN FOR ELASTIC-PLASTIC MATERIALS IN PLANE STRAIN STATE DOMINATION

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1. Introduction

One of many basic specimens used in fracture mechanics is a compact specimen, designated by C(T). It appears in the ASTM standards [1],or even the norm that is still in force in Poland in the didactic or research process [2]. In 2012, Zhu and Joyce [3] presented an overview of methods for determining fracture toughness using C(T), SEN(B) and CC(T) specimens, indicating the need to consider the influence of geometric constraints in formulas approximating the equations of the J-R curves. The parameters of geometrical constraints mentioned in the paper [3] include the Q-stress (Q-parameter) defined by O'Dowd et al. and the A_2 parameter (described also as A_2 aplitude) discussed by Yang et al.. It should be remembered, however, that both parameters – Q and A_2 are determined by numerical calculations with the assumption of small deformations and displacements, which leads to obtaining singular stress distributions near the crack tip. It can be said that both parameters are a correction of the HRR solution presented in 1968 and improve the description of stress fields near the crack tip taking into account the influence of the other parts of the asymptotic solution.

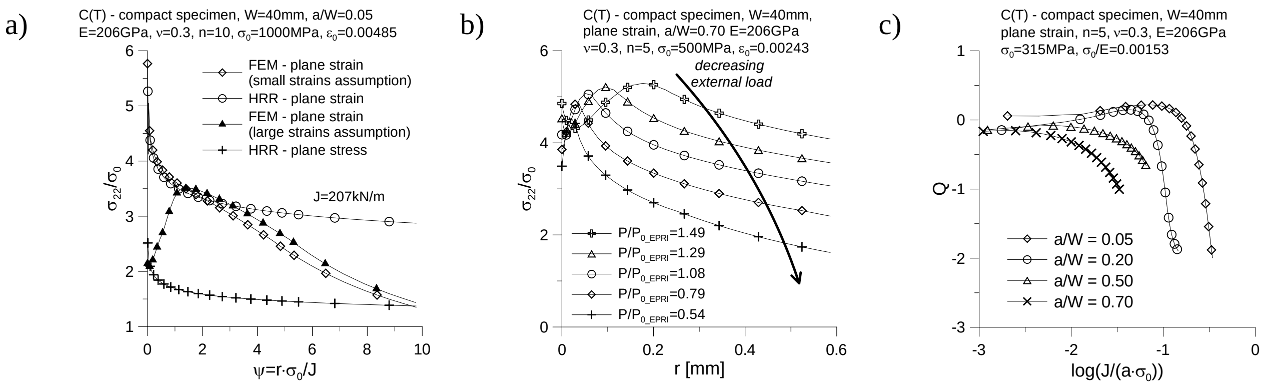

Fig. 1. a) The stress distribution near the crack tip for C(T); b) The influence of the external load on the maximum crack opening stress (normalized by yield stress) for C(T) specimens; c)The influence of the crack length on the $Q=f(\log(J/(a\cdot\sigma_0))$ trajectories for C(T) specimens.

As it is known, in the real structural element, the stresses in front of the crack tip are finite - such a distribution in numerical calculations is obtained by assuming large strains and large displacements, which in the case of stress distribution leads to reach a Maximum of the crack Opening Stress (MOS) at a specific distance from the crack tip [4] - Figure 1a. The value of this maximum as well as its position near the crack tip was used in [4] in the proposal of a modified crack criterion based on the RKR hypothesis. It should be noted that the level of MOS and their position near the crack tip depends on the material characteristics, geometry and external load (Figure 1b), which is also shown in [4]. The same applies to the Q-parameter, commonly referred to as Q-stresses (Figure 1c).

The applications of the fracture mechanics to solving practical engineering problems require knowledge of the Q-parameter or the MOS and their position in front of the fracture tip. In addition, these parameters, generally referred to as in-plane constraints, are determined by carrying out comprehensive numerical calculations, the results of which are subject to detailed analysis (postprocessing). The development of a numerical model allowing to estimate the measures of in-plane constraints is not a trivial problem, as shown in [5]. Based on previous achievements [6-9], the author of this article presents a catalog of numerical solutions and their approximations, which for compact specimens allow to estimate the values of selected measurements of in-plane constraints depending on external load, crack length or material characteristics.

2. Highlights, some results and summary

All calculations were made using the ADINA program, using the analysis schemes developed over the years. In addition to the ready solution catalog, the influence of material characteristics and the relative crack length on selected measures of in-plane constraints were discussed, also taking into account the influence of external load expressed by J-integral (which may be accepted as a crack driving force).
The numerical analysis was showed, that in the range of low external loads, it is noticed that C(T) specimens characterized by high level of in-plane constraints. The increase in the relative crack length causes an increase in the value of Q-stresses – the in-plane constraints increase. The increase in external load results in decreasing of the level of in-plane constraints expressed by Q-stress. The C(T) specimens characterized by a lower yield point, faster reach a lower level of in-plane constraints. The lower level of in-plane constraints is also characterized by C(T) specimens made of a strongly hardening material.
Based on the FEM analysis, assume large deformations, it can be noted, that the level of MOS increases with the increasing external load, and then reaches the saturation state. The weak influence of the crack length should on the level of MOS is observed. The same conclusions may be apply to the normalized position of the MOS near the crack tip. A very pronounced effect of the yield point on the level of MOS of the fracture surfaces was observed - the smaller the yield point, the greater the values of the MOS. The MOS of the fracture surfaces and their normalized position near the crack tip are clearly influenced by the degree of material hardening – the stronger material, the greater value of the MOS and the smaller the value of their normalized position relative to the crack tip.
Some details of the numerical models, the specific numerical results presented in the graphical form, their approximation using simple mathematical formulas (formulas, tables with coefficients, comparison with numerical results) and right conclusions will be presented on the conference poster on August 2018.

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