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# Fracture assessment of U-notches under three point bending by means of local energy density

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ABSTRACT

The main purpose of the paper is twofold. First, to provide a new set of experimental results on fracture of U-notched samples, made of two different materials; second, to apply a fracture criterion based on the strain energy density (SED) averaged over a control volume to assess the fracture load of blunt-notched components under three point bending. Two different materials are considered in the tests: a composite material (Al–15%SiC) tested at room temperature and a steel with a ferritic–pearlitic structure tested at −40 °C. All samples are weakened by U-notches characterized by different values of notch root radius and notch depth. The theoretical loads to failure as determined according to the SED criterion are compared with the experimental data from more than 40 static tests and with a SED-based scatter band recently reported in the literature for a number of materials exhibiting a brittle behaviour under static loads.



## 1. Introduction

In asserting structural safety it is very important to evaluate the loading capacity of notched components, where stress concentrations can lead to catastrophic failure or to a shortening of the fatigue life of the structure. The analysis of stress fields in the vicinity of notched components and the search for failure criteria applicable in such cases are both topics of active research [1–4].

Fracture behaviour of notched samples loaded under mode I has been the subject of extensive research during the last years considering mainly brittle or quasi-brittle materials [5–8]. The main criteria are widely reviewed in Ref. [9].

Dealing with the failures from sharp and blunt notched specimens, the Cohesive Zone Model (CZM) criterion has been widely used and refined considering the influence of different softening curve for the material [10–15]. In parallel, a criterion based on the strain energy density (SED) has been developed [16–18] and applied to a large bulk of experimental data [19–23].

Recently the SED criterion and the CZM have been applied also to analyse failure from notched components loaded in mixed mode (I + II) for brittle or quasi-brittle materials. Theoretical findings have been supported by an extensive experimental activity enlarging the scarce available data under prevalent mode II loading of blunt U-notches and V sharp notches [19–23]. Dealing with mixed-mode loading some different failure criteria have been proposed for V-notches and for U-notches [24–27] showing a different degree of accuracy with respect to experimental results while in Ref. [28] a large synthesis of the main important brittle fracture criteria for elements with V-shaped notches has been carried out.

The main purpose of this paper is to provide a new set of experimental results on static fracture of U-notched samples made of a composite material (Al–15%SiC) tested at room temperature and steel with a ferritic–pearlitic structure tested at −40 °C. The tests are carried out under bending loading by means of a three-point-bending configuration. In addition, after a brief review of the SED-based criterion [16,17] the averaged value of the elastic strain energy over a crescent shape volume has been applied to the new set of experimental results and has shown a sound capability for fracture load assessments. Finally a comparison with a SED-based scatter band recently reported in the literature [29,30] for different materials and based on local SED has been carried out.

## 2. Theoretical background

With the aim of clarifying the base of the final synthesis carried out in this paper, this section summarises the analytical frame of SED approach dealing with blunt notches.

### 2.1. Stress distributions due to U- and V-notches

With reference to the polar coordinate system shown in Fig. 1, with the origin located at point O, mode I stress distribution ahead of a V-notch tip is given by the following expressions [31]:

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