Evaluation of the Strain Energy Density value with volume free FE model

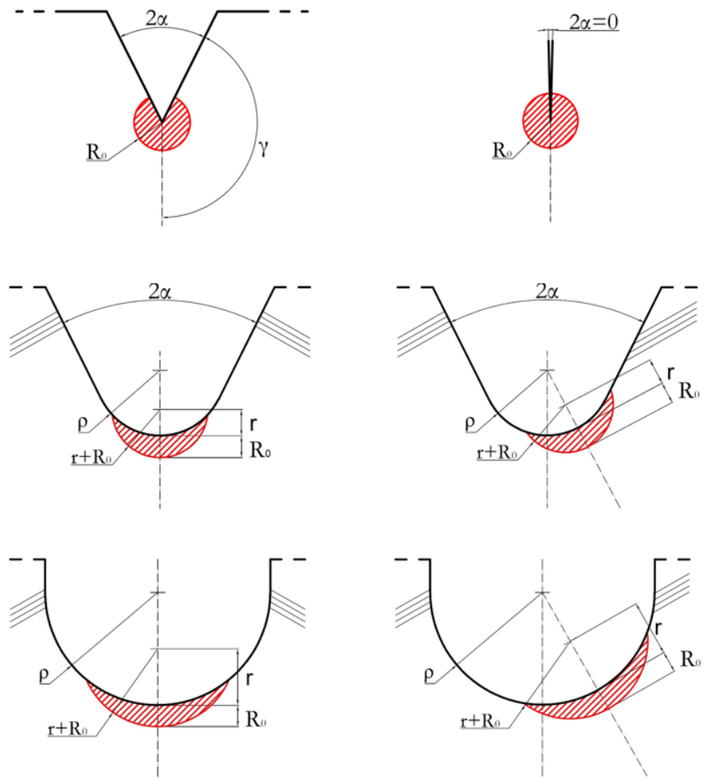
The Strain Energy Density (SED) method allows to investigate both fracture in static condition and fatigue failure.
Dealing with both pointed and blunt V- and U-notches, according to this method, the brittle fracture is assumed to occur when the local SED $\bar{W}$ averaged in a given control volume reaches a critical value.

$$\bar{W} = \bar{W}_C$$

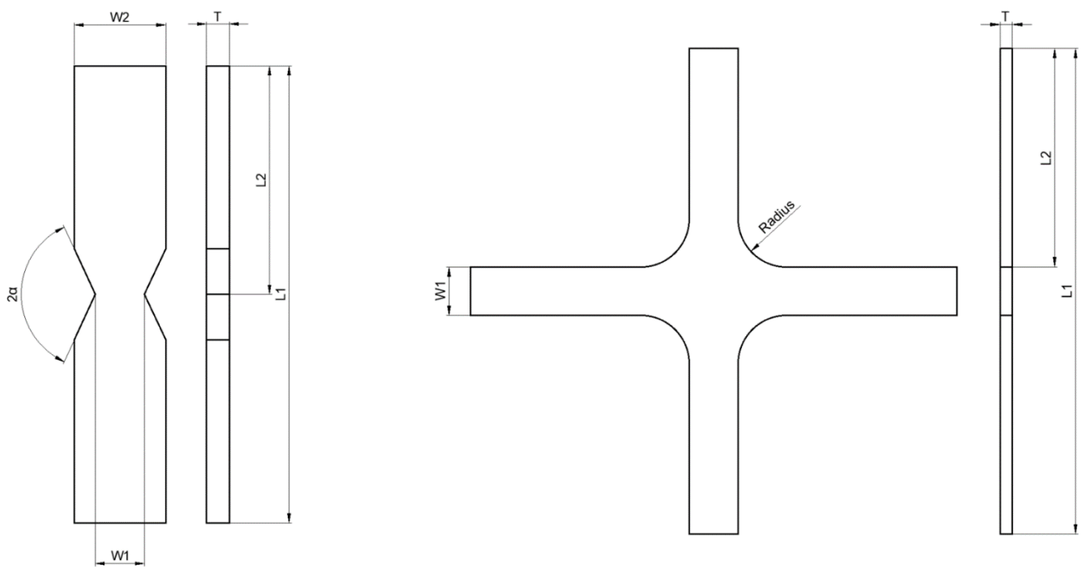
This critical value is independent of the notch opening angle and independent of the loading type.
The SED critical value can be determined , for an ideally brittle material, through the conventional ultimate tensile strength σ_t as:

$$\bar{W}_C = \frac{\sigma_t^2}{2E}$$

In order to evaluate the averaged value of the SED, a sector-shaped cylinder of radius R_0 along the notch tip line, termed ‘’control volume’’ is considered. In plane problems, the control volume becomes a circle or a circular sector.
The shape of the control volume is a function of the notch type (blunt or pointed, U- or V-shaped) while its location changes along the notch edge depending on the loading mode and, essentially, following the basic idea of the mode I dominance concept. The size of the control volume can be assessed through the components material properties.
One of the major limitations of this method, that restricts also its practical application, is the need to build in the pre-processor phase of the FE analysis the control volume.

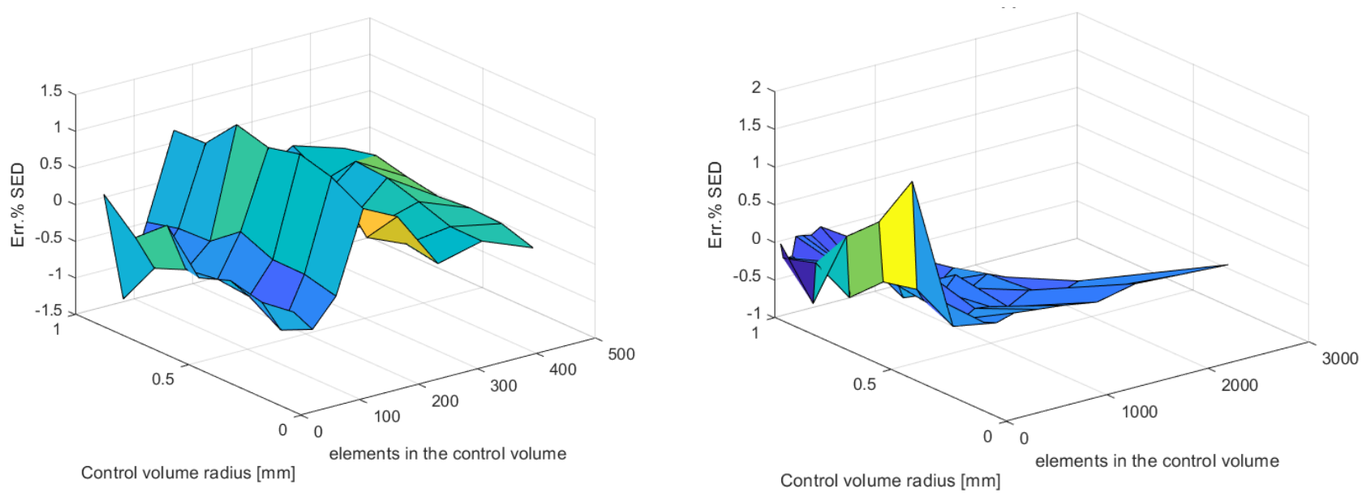


Control volume



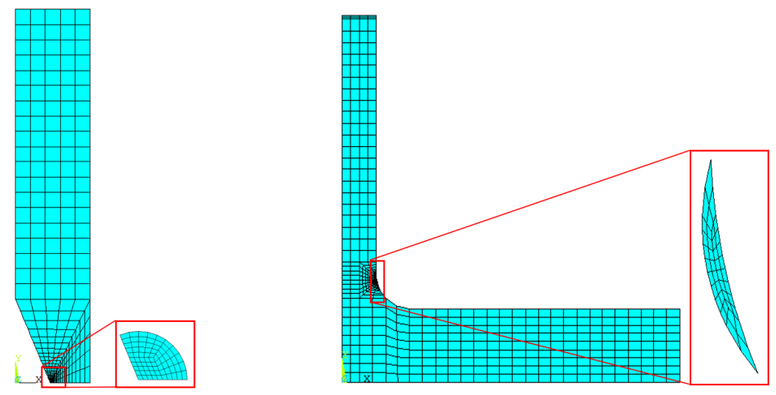
Details analysed

The SED value for the conventional FE models is acquired following the procedure exploited until now to apply the SED method, as it is clear from the control volume shown in the magnification.
As regards the control volume free models the SED value is acquired through a selection of the elements close to the notch tips using a polar coordinate system centred in the notch tip with the radius of the control volume considered for the V-notch specimen while for the other component the SED value is acquired through a selection of the elements using a polar coordinate system centred along the segment that links the point of maximum of the first principal stress and the center of the connection fillet at a distance r from the component surface.
The result of such a selection is shown both in the magnification.

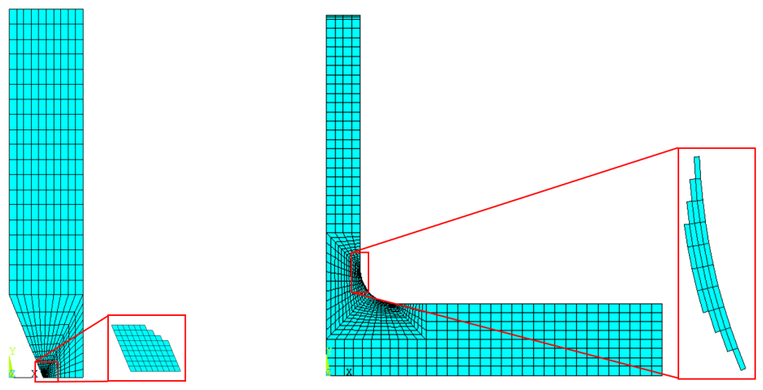


SED % error for control volume free FE models

In order to demonstrate that an acceptable evaluation of the SED value is possible also with a control volume free FE model and that its low sensibility to mesh remains however almost the same, a series of FE analysis were carried out.
The details taken into account are a V-notched specimen and a component made by two plates attached by a connection fillet.
The analysis were carried out for different geometrical configuration of the models, different mesh refinements and different control volume radius.



Conventional FE model and control volume for SED evaluation



Control volume free FE model and control volume for SED evaluation

The data acquired show that a good estimation of the SED value is possible also without the construction of the control volume in the pre-processing phase of the FE analysis. An evaluation with an error less than 1% is possible with a mesh size of 1/6 of the control volume radius for the V-notch specimen geometry for each geometry considered while for the second geometry this is possible also with a mesh size of 1/4 of the control volume radius for each geometry considered.

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