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Comparison between multiobjectif and classical algorithms for identifying damage law parameters using an inverse methodology

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ABSTRACT

In the recent literature many authors use an inverse methodology in order to determine the parameters of material behaviour laws which are becoming more and more complex. The reliability of this method is linked to the experimental results and the numeric model used. In most cases, only one experimental curve is used in order to determine the behaviour and the material damage law parameters. The aims of this work are to highlight the effect of identifying the parameters by using two curves and to determine the best optimisation system which results in the least mean square error between the experimental and the numerical curves. The material damage models used for this study are the Lemaitre [1] and the Gurson Tvergaard Needleman (GTN) [2, 3] models. These have been linked with the Ludwick hardening law:

$$R = \sigma_y + K\varepsilon_{pl}^n$$

where σ_y is the yield stress, K is the hardening modulus and n is the hardening exponent. These parameters have been defined using an experimental curve from a tensile test, but they are also included in the optimisation. These two parameters must be optimised, because if damage is considered to begin with an equivalent plastic strain equal to zero, the hardening law defined by the tensile test implicitly includes damage. The others parameters are related to the material damage law. For the Lemaitre model, the parameters to be optimised are: β and s_0. These two parameters characterise the isotropic ductile damage evolution [4]. The yield function for the Lemaitre model and the dissipation potential are:

$$\phi = \frac{\sigma_{eq}}{(1-D)} - R = 0 \quad ; \qquad \dot{D} = \left(\frac{\dot{\lambda}}{(1-D)^{\beta-1}}\right)\left(\frac{-Y}{S_0}\right)^{s_0} \dot{p}$$

where Y is the associated variable of the damage D and is defined by:

$$Y = -\frac{1}{2}(\mathbf{C}^{el} : \boldsymbol{\varepsilon}^{el}) : \boldsymbol{\varepsilon}^{el}$$

Therefore, the increment of the damage value is:

$$\dot{D} = \left(\frac{1}{(1-D)^{\beta-1}} \right) \left(\frac{D_c}{\varepsilon_R - \varepsilon_D} \right) \left[\frac{2}{3}(1+\upsilon) + 3(1-2\upsilon) \left(\frac{\sigma_H}{\sigma_{eq}} \right)^2 \right]^{s_0} \dot{p}$$

where D_c, ε_R and ε_D are the critical damage value at failure, the equivalent plastic strain at failure and the equivalent plastic strain when the damage first occurs. υ is Poisson's ratio, σ_H is the hydrostatic stress, σ_{eq} is the Von Mises equivalent stress and $\dot{p}$ is the cumulative plastic strain increment.

For the GTN model, the parameters to identify are q_1, q_2 and q_3, which are usually considered to be material parameters and s_N, f_N and ε_N, which are parameters related to void nucleation. For the GTN model, the constitutive equations are:

$$\phi = \left(\frac{\sigma_{eq}}{\sigma_y} \right)^2 + 2q_1 f \cosh\left(-\frac{3}{2} \frac{q_2 \sigma_H}{\sigma_y} \right) - \left(1 + q_3 f^2\right) = 0$$

$$A = \frac{f_N}{s_N \sqrt{2\pi}} \exp\left[-\frac{1}{2} \left(\frac{\bar{\varepsilon}_m^{pl} - \varepsilon_N}{s_N} \right)^2 \right]$$

where ϕ is the yield function, f represents the volume fraction of the voids in the material. The second equation defines a normal distribution for the nucleation strain rate, where ε_N is the mean strain value, s_N the standard deviation and f_N the volume fraction of newly nucleated voids.

In order to determine these parameters, two kinds of experimental curves will be used: a tensile test curve and a damage versus the equivalent plastic strain curve. The least mean square error is calculated for each curve. This is the error between the curves determined via numeric simulation and the experimental curves. Two optimisation strategies are investigated. In the first the objective function for the inverse methodology will be considered as the sum of the errors from the two curves and it will be optimised with a classical quasi-Newton algorithm. Secondly, a multiobjectif algorithm (a well known genetic algorithm NSGA II [5]), is used in order to optimise the error for each curve independently and the solution is presented in the form of a Pareto frontier. In that case, further possible solutions can be obtained. It is possible, by comparing the results, to see if the value of the sum function lies on the Pareto frontier at the end of the optimisation. The better optimisation strategy can then be determined.

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