BRITTLE FRACTURE IN CHARPY IMPACT TEST

INFLUENCE OF MATERIAL PARAMETERS

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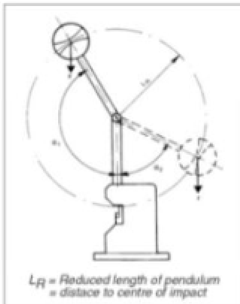
1 INTRODUCTION

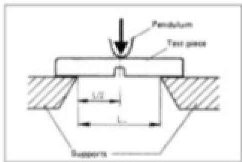
Goal of this work is to analyze the conditions under which fractures and crack propagate in materials. It relies on the theory of fracture mechanics. It has many important applications, especially in the industry field, in which built mechanical components often have flaws. The probability of the failure of the material during its operation must be assessed. To that end, engineers do a damage tolerance analysis.

The Charpy impact test is commonly used to study fractures. Its functioning is quite simple: a striker is dropped and hits a notched tensile, the difference between the final and initial heights correspond to the energy dissipated in the specimen to create a fracture.

In this work, Finite Element Element simulations of this experiment are done to analyze the influence of some parameters of the material on its resistance to fracture.



Impact strength



2 PRELIMINARY FINITE ELEMENT MODEL

We present here a FEM model of the Charpy specimen.

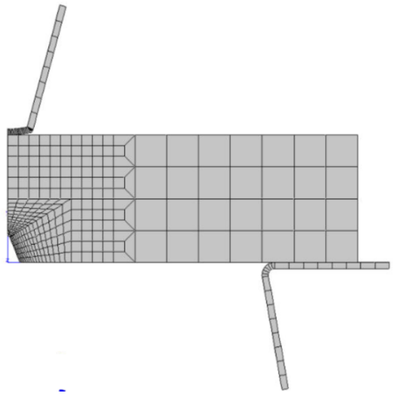
It has an isotropic elastic behavior under low strain or stress, with a Young Modulus $E = 208\text{GPa}$ which is standard for steel. It then has a isotropic non linear plastic behavior ruled by: $\sigma = R_0 + Q(1 - \exp^{-bp})$ where p is the cumulative plastic deformation $p = \int_{t=0}^{t=t*} \varepsilon_p(t)dt$.

To model the transition in plastic regime, the *Von Mises* criterion is used. It relies on the *Von Mises* equivalent stress:

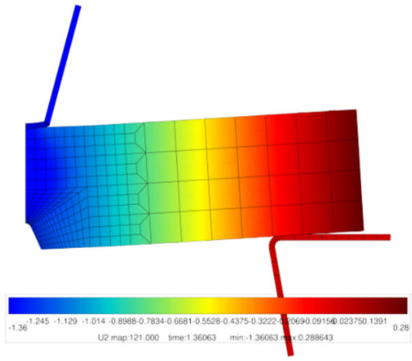
$$\sigma_{eq} = \sqrt{\frac{1}{2}\left((\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right)} \tag{1}$$

Lastly, we use the Beremin model to predict the evolution of the crack. Concerning the boundary conditions, anvils on which the specimen lies are immobile, the striker has a prescribed vertical downward movement at constant speed $\dot{u}_2 = -1\text{mm.s}^{-1}$. The ligament, ie the nodes in the vertical plane cutting the specimen in half, are also immobile along the horizontal axis. While this assumption is not physically justified, it is useful to shrink the problem size to only the right half of all aforementioned objects, because the problem can be considered symmetric along the ligament.

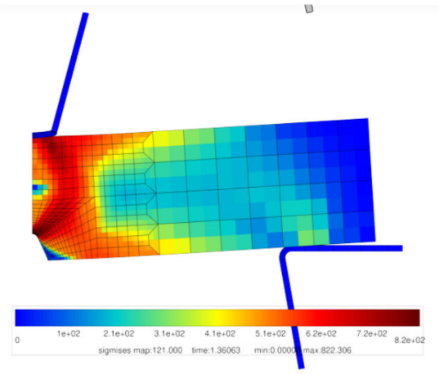
The first simulation returned an error during the last iterations.



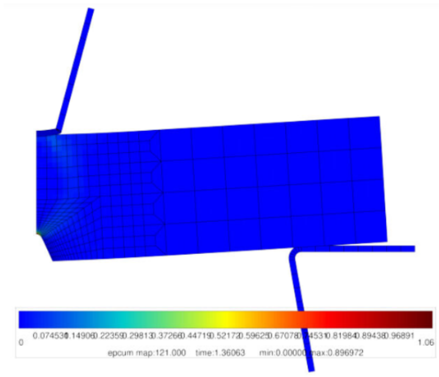
(a) Initial mesh



(b) Vertical displacement



(c) *Von Mises* stress



(d) cumulative plastic deformation

Figure 1: Results of experiment 1

We observe a concentration of high *Von Mises* stress around the notch and near the striker, $\sigma_{eq} > 700\text{MPa}$, and also a bit of plastic deformation. A possible explanation of the error could be a lacking mesh precision around those zones and also near the anvils where it reaches $\sim 310\text{MPa}$.

3 LOCAL MESH REFINEMENT

Thanks to this analysis, we choose a finer mesh in those areas :

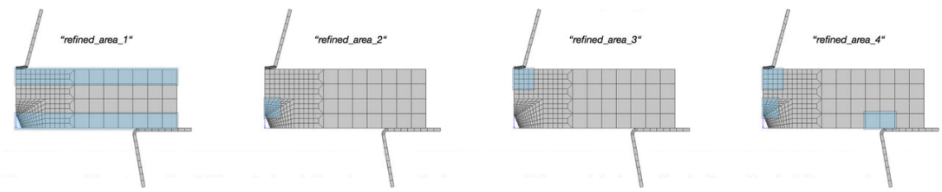
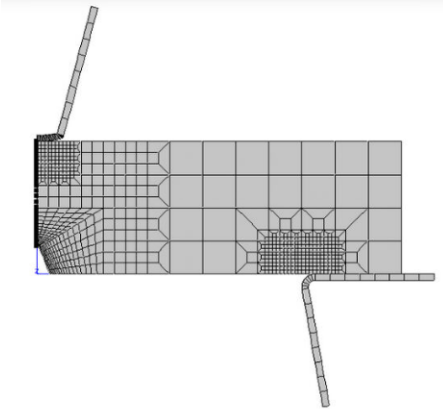


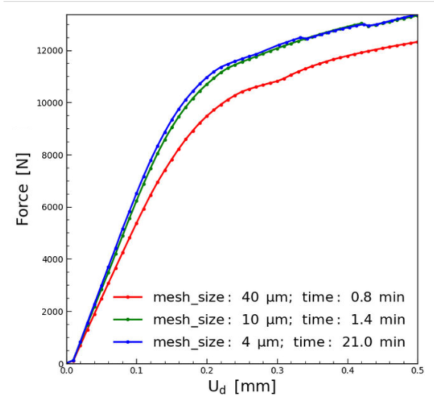
Figure 2: Propositions of mesh refinement.

The 4-th mesh fulfills our desires of refinement, so we select it. In order to select the size of the smallest mesh elements, we rerun the previous experiment with $40\mu m, 10\mu m, 4\mu m$:

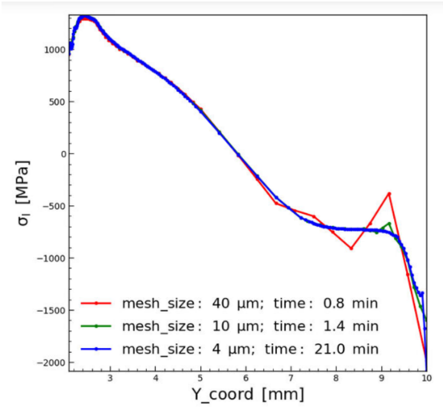
With these finer mesh, the previous simulation now converges. Results on Figures 3b and 3c quite differ between $40\mu m$ and the 2 smaller sizes, meaning we gain some model accuracy with refinement. However, $10\mu m$ and $4\mu m$ have similar



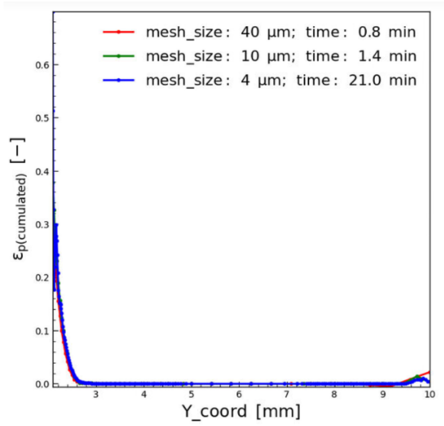
(a) Refined mesh



(b) Relation force on striker - displacement



(c) Relation first principal stress - y coordinate



(d) Relation cumulative plastic deformation - y coordinate

Figure 3: Comparison of mesh refinements

results for our precision, but the 10µm simulation was 15 times faster, therefore it is more interesting for us to choose it instead of the smallest size. We see again on Figures 3c and 3d the concentration of stress and plastic deformation near the notch ie in the low y zones.

4 GEOMETRIC PARAMETER SENSITIVITY

Now that we have a more adapted mesh and converging simulations, we wish to assess the dependency of the geometry of the Charpy specimen in its probability of failure. Numerical simulation is here useful to run multiple Charpy tests, that in reality are hard to set up. The considered parameters are the notch radius N_R, the height H and half of the width H_W:

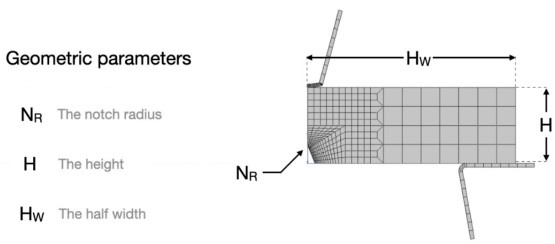
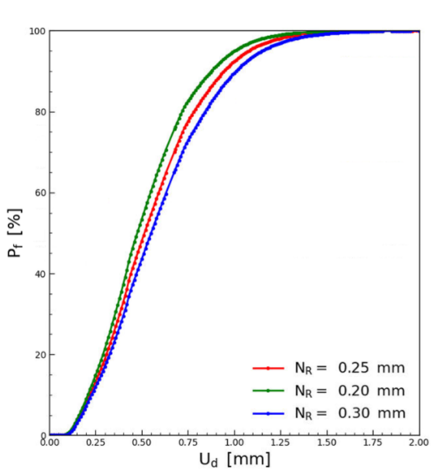
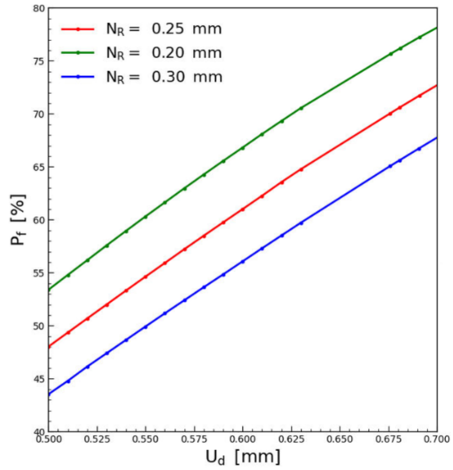


Figure 4: Considered geometric parameters.

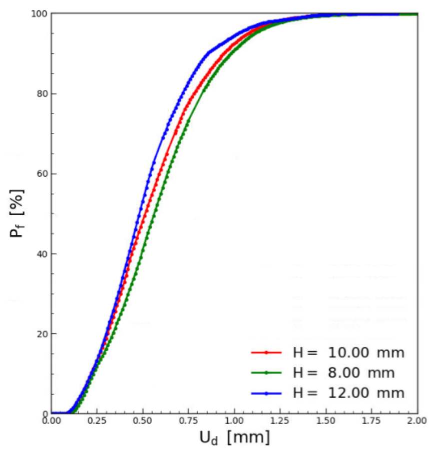
The strategy is here to run 3 simulations for each parameter, in each of them we add a certain variation of the parameter: −20%, 0% and +20%, while keeping every other at its default value.



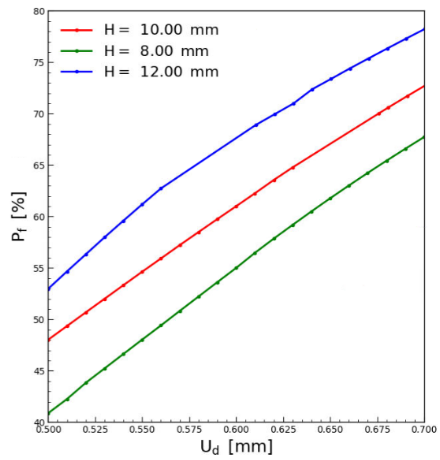
(a) Probability of failure for various N_R



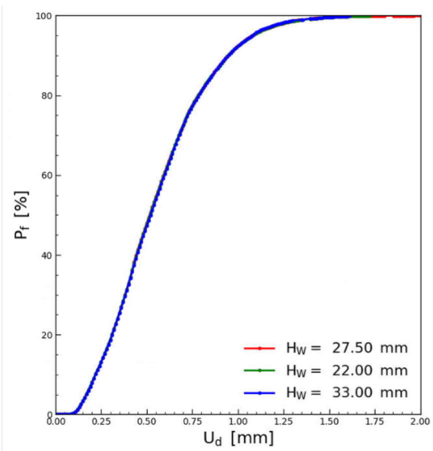
(b) Zoom



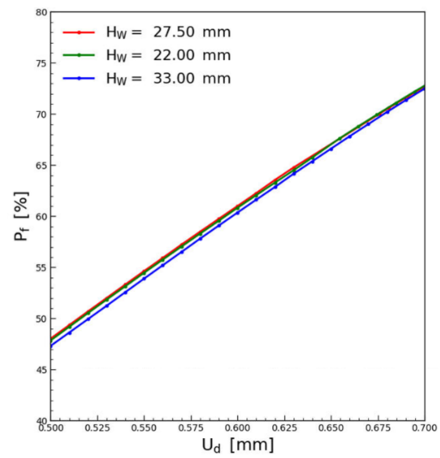
(c) Probability of failure for various H



(d) Zoom



(e) Probability of failure for various H_W



(f) Zoom

Figure 5: Probability of failure with respect to the striker displacement for various values of N_r, H and H_W.

On Figure 5, we see that the probability of failure curve has a similar shape for each parameter. The plots of the right column are zooms on the zones of highest variance between curves, with $U_d \in [0.5\text{mm}, 0.7\text{mm}]$. H_W has the lowest probability of failure

5 METHODS

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5.1 Paragraphs

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5.2 Math

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$$\cos^3\theta = \frac{1}{4}\cos\theta + \frac{3}{4}\cos 3\theta \tag{2}$$

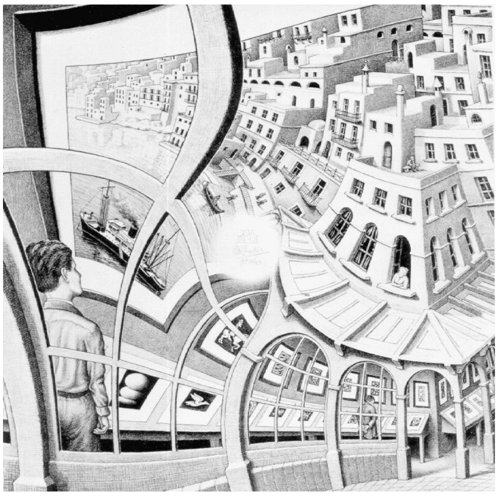

Figure 6: An example of a floating figure (a reproduction from the *Gallery of prints*, M. Escher, from http://www.mcescher.com/).

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Definition 1 (Gauss)**.** To a mathematician it is obvious that $\int_{-\infty}^{+\infty} e^{-x^2}\,dx = \sqrt{\pi}$.

Theorem 1 (Pythagoras)**.** *The square of the hypotenuse (the side opposite the right angle) is equal to the sum of the squares of the other two sides.*

Proof. We have that $\log(1)^2 = 2\log(1)$. But we also have that $\log(-1)^2 = \log(1) = 0$. Then $2\log(-1) = 0$, from which the proof. □

6 RESULTS AND DISCUSSION

Reference to Figure 6.

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6.1 Subsection

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6.1.1 Subsubsection

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WORD Definition

CONCEPT Explanation

IDEA Text

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6.1.2 Table

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Table 1: Table of Grades

Name		
First name	Last Name	Grade
John	Doe	7.5
Richard	Miles	2

Reference to Table 1.

6.2 Figure Composed of Subfigures

Reference the figure composed of multiple subfigures as Figure 7 on the following page. Reference one of the subfigures as Figure 7b on the next page.

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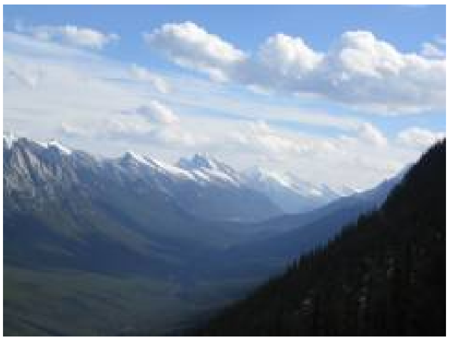
(a) A city market.

(b) Forest landscape.



(c) Mountain landscape.

(d) A tile decoration.

Figure 7: A number of pictures with no common theme.

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REFERENCES