SSLP317- Validation of macro-command RAFF_XFEM on a multi-fissured plate

Summarized:

The purpose of this document is validating the macro command RAFF_XFEM [U7.03.51] which makes it possible to obtain a field "of error" *a priori* in order to feed a process of refinement of mesh.

1 Problem of reference

1.1 Geometry

One considers a square plate $2D$ of with dimensions unit, centered in the beginning.
This plate comprises 2 cracks and 2 inclusions (interfaces):

- an inclusion of the type notches length $L_e=0,6$ and of radius $R_e=0,05$, centered in $E(0;-0,3)$,
- a circular inclusion of radius $R_c=0,05$ centered in the beginning,
- a non-opening horizontal rectilinear crack length $L_A=0,2$ centered in $A(0,3\ ;0,25)$,
- a non-opening horizontal rectilinear crack length $L_B=0,2$ centered in $B(-0,2\ ;0,25)$.

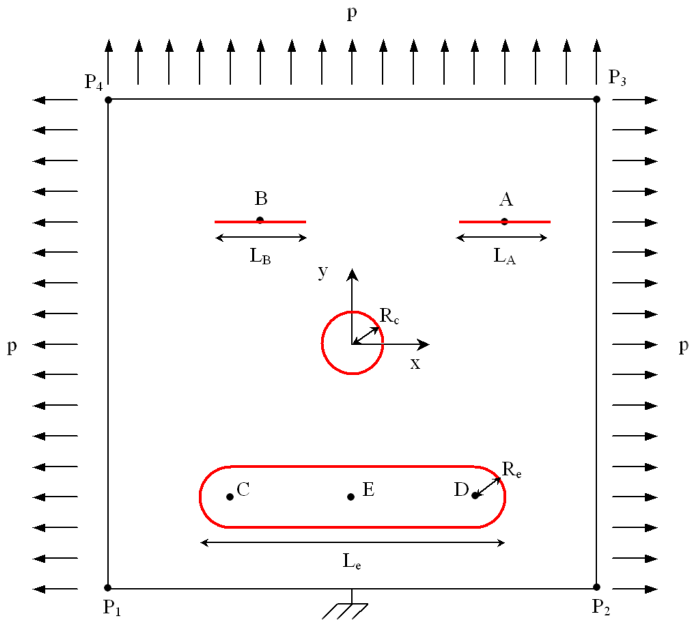

Figure 1.1-1: diagram of the multi-fissured plate

1.2 Properties of the material

the material has the following properties:

- Young modulus: $E=205\,000\,MPa$
- Poisson's ratio: $\nu=0,3$

1.3 Boundary conditions and loadings

The computation mechanical imports little in this test because one only seeks to test the criterion of refinement *a priori*. The computation mechanical is given only on a purely illustrative basis in modelization A.

One considers a loading of tension of $p=1\,MPa$ on the sides left, right-hand side and higher of the plate. The lower face is clamped.

1.4 Short description of the various modelizations

All the modelizations return in the frame of the representation of cracks and the interfaces by the method X-FEM associated with the level sets.

The modelization A an indicator calculates outdistances some (fields at nodes). The test will relate to the value of this indicator in various nodes. The methodology of refinement of mesh used is simplest (criterion expressed as a percentage of meshes refined), but is not inevitably optimal in term of number of meshes.

The modelization B an indicator calculates outdistances some (fields at nodes). The interest of this modelization is to show a more optimal methodology in term of number of meshes. Tests will relate to the size of meshes in the refined zone.

The modelization C an indicator by zone calculates (by meshes). Methodology presented is succeeded and most robust. It is this indicator and this methodology which one advises. For the moment, the indicator by zone functions only on one crack or an interface.

2 Reference solution

2.1 Méthode de calcul used for the reference solution

2.1.1 Modelization A

the test relates to the value of the error indicator in output of RAFF_XFEM. One notes $I(M)$ the value of this indicator at the unspecified M point.

At the point P_1 in bottom on the left of structure, the indicator is worth opposite distance to the point of the notch nearest, that is to say $I(P_1)=-(CP_1-R_e)$.

At the point P_2 in bottom on the right of structure, the indicator is worth opposite distance to the point of the notch nearest, that is to say $I(P_2)=-(DP_2-R_e)$.

At the point P_3 in top on the right of structure, the indicator is worth opposite distance to the right end of crack on the right, that is to say $I(P_3)=-A'P_3$ where $A'=A+\frac{L_A}{2}\vec{x}$.

At the point P_4 in top on the left structure, the indicator is worth opposite distance to the left end of crack on the left, that is to say $I(P_4)=-B'P_4$ where $B'=B-\frac{L_B}{2}\vec{x}$.

2.1.2 Modelizations B and C

the test relates to the value of the diameter of smallest nets. If h_0 is the initial size of meshes, h_c the target size of meshes after refinement, then the minimal number of call to Homard to reach h_c is $\text{nb\_raff}=E(n)+1$, with $n=\frac{\ln(h_0)-\ln(h_c)}{\ln(2)}$. After refinement, the size of meshes the most refined is $h=\frac{h_0}{2^{\text{nb\_raff}}}$.

2.2 Results of reference

2.2.1 Modelization A

With the numerical values used in the test, one finds:

$$I(P_1)=-(\sqrt{0{,}25^2+0{,}2^2}-0{,}05)\approx-0{,}27015621187164246$$

$$I(P_2)=-(\sqrt{0{,}25^2+0{,}2^2}-0{,}05)\approx-0{,}27015621187164246$$

$$I(P_3)=-\sqrt{0{,}25^2+0{,}1^2}\approx-0{,}26925824035672524$$

$$I(P_4)=-\sqrt{0{,}25^2+0{,}2^2}\approx-0{,}32015621187164245$$

2.2.2 Modelizations B and C

With $h_0=\frac{\sqrt{(2)}}{20}$ and $h_c=\frac{h_0}{10}$, one finds $h=0{,}0044194$.

3 Modelization A

3.1 Characteristic of the modelization

the interfaces and the cracks are defined by of level sets.
The mesh initial 3 times of continuation are refined, using the indicator in distance provided by RAFF_XFEM. Each time, one refines 20% of meshes the most sullied with “error”.

3.2 Characteristics of the mesh

The mesh initial is healthy: it consists of 20×20 linear quadrangles.

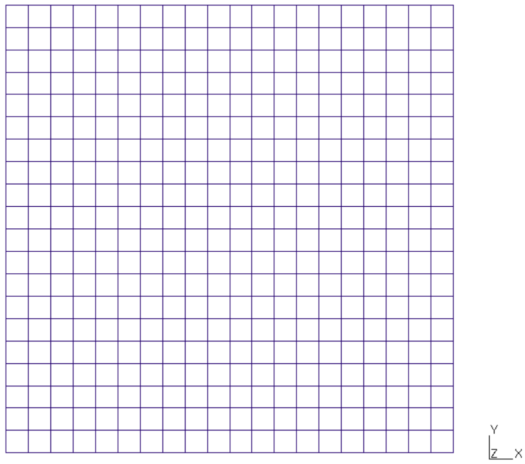

Figure 3.2-1: initial sane mesh

3.3 Quantities tested and results

One tests the value of the error indicator in output of RAFF_XFEM at the points P_1 P_2, P_3 and P_4, for each refined mesh.

Standard	identification	Reference of reference	% tolerance
$I(P_1)$	-0,270156	"ANALYTIQUE"	0.1%
$I(P_2)$	-0,270156	"ANALYTIQUE"	0.1%
$I(P_3)$	-0,269258	"ANALYTIQUE"	0.1%
$I(P_4)$	-0,320156	"ANALYTIQUE"	0.1%

For information, the mesh obtained after refinement is presented on Figure 3.3-1. It is noted that for the interfaces, they are not only the meshes close ones to the interfaces which are refined, but all meshes contained in inclusion. That is due to the way in which Homard manages the connection by conformity of the cut out quadrangles. This phenomenon does not appear with triangles. This is why in the continuation of the modelizations, one will prefer to start from an initial mesh of triangles.

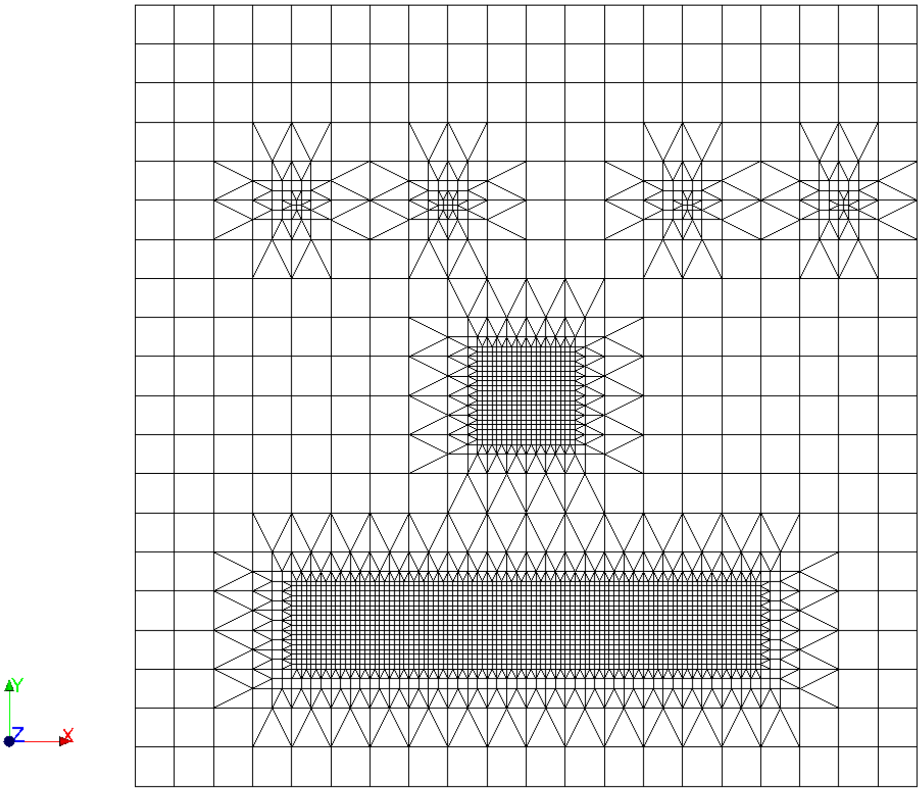

Figure 3.3-1: sane mesh refined

4 Modelization B

4.1 Characteristic of the modelization

the interfaces and the cracks are defined by of level sets.
The indicator in distance provided by RAFF_XFEM is used.

The interest of this modelization is to present a methodology more optimal than that used in modelization A. the idea is better to control the numbers of meshes to be refined and meshes cuts it in the end of the process of refinement.

Knowing the initial size of meshes, and by setting a target size, one will refine as many times as necessary in order to obtaining in the zones of interest of meshes of size adequate.

4.2 Characteristics of the mesh

The mesh initial is healthy: it consists of 20×20 linear quadrangles, which one cross into two in order to obtain from the triangles (see explanation to the §3.35). This mesh is presented on Figure 4.2-1.

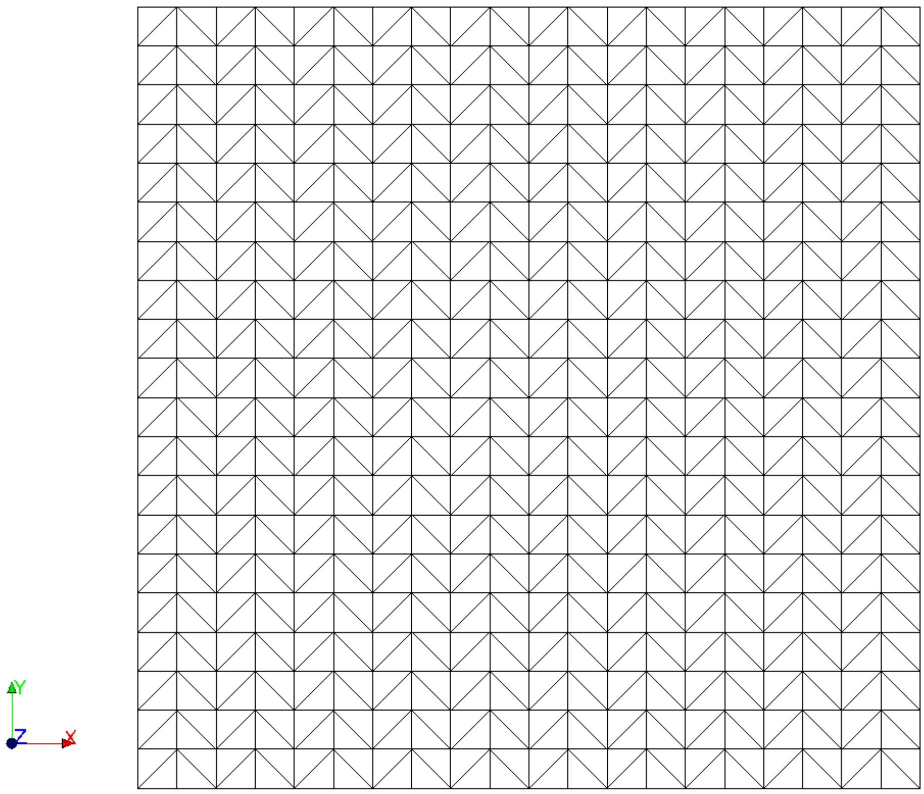

Figure 4.2-1: initial sane mesh

One applies the procedure of refinement as described in [U2.05.02] for the indicator in distance. This procedure makes it possible to better control the size and the number of mesh with refinement. After refinement, one obtains the mesh presented on Figure 4.2-2. It is interesting to note that meshes strictly included in the zone of interest (for example around the bottom n°1 of crack centered in A) do not have all the same size (see Figure 4.2-3).

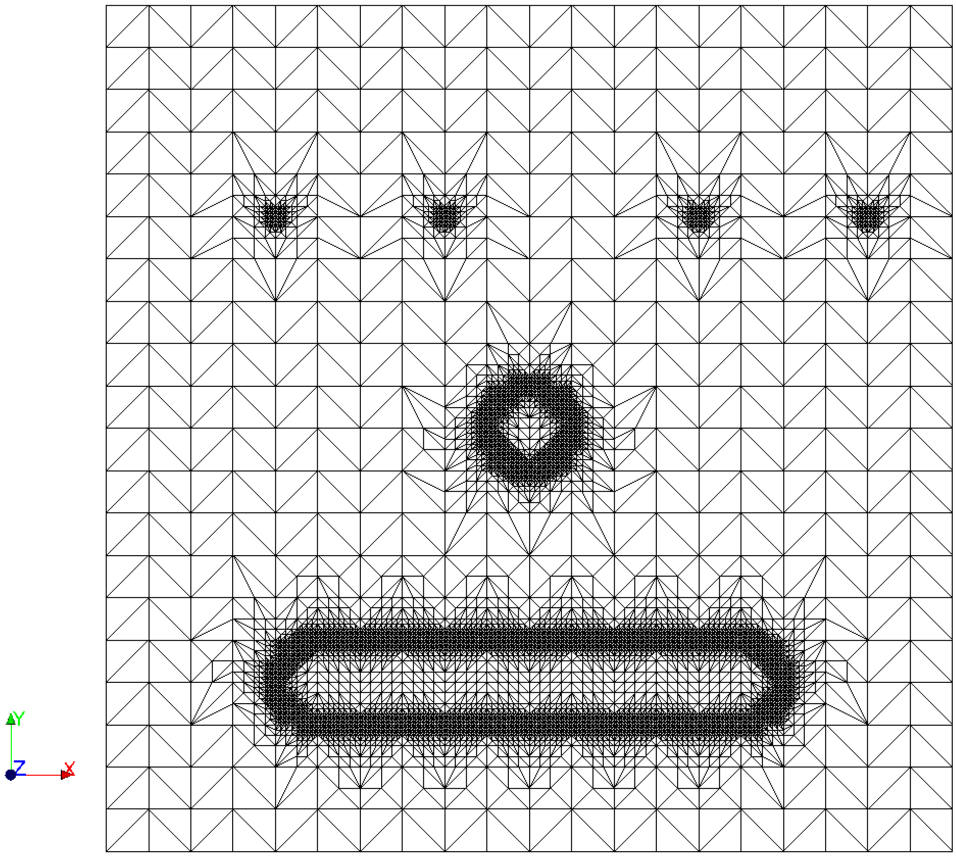

Figure 4.2-2: sane mesh refined

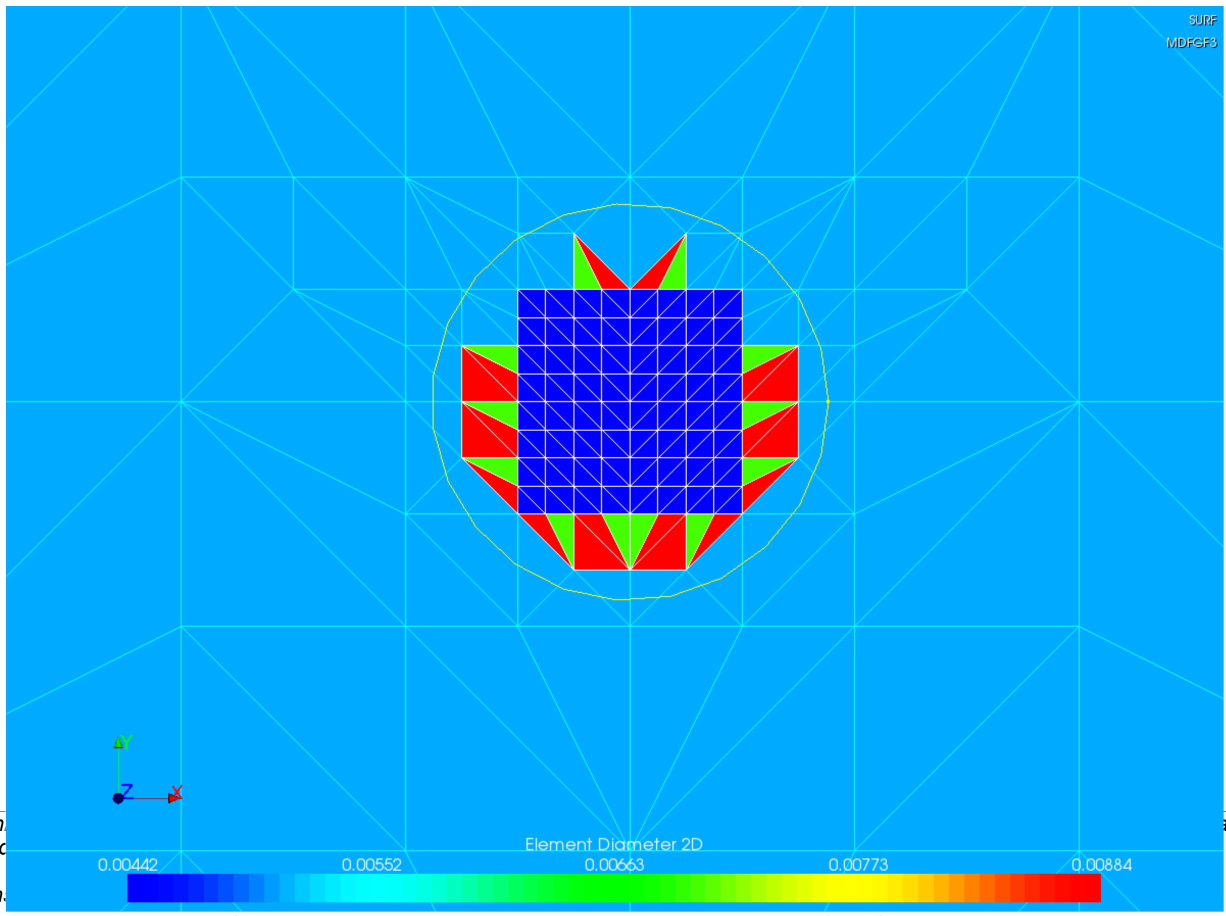

Figure 4.2-3: refined sane mesh - zoom around the crack tip n°1 of crack centered in A and card of sizes in the zone of interest

4.3 Quantities tested and results

One tests the value of the minimal size of meshes.

Standard	identification	Reference of reference	% tolerance
$min(h)$	0,004419	"ANALYTIQUE"	0.1%

This test will be improved when one can better test the cards.

5 Modelization C

5.1 Characteristic of the modelization

the interfaces and the cracks are defined by of level sets.
The indicator by zone provided by RAFF_XFEM is used.

The interest of this modelization is to present succeeded methodology the pus, which uses the indicator by zone.

5.2 Characteristics of the mesh

The mesh initial is the same one as that of the current modelization B
. Taking into account the limitations of the indicator by zone, one refines only around the crack tips of crack centered in A. After refinement, one obtains the refined mesh presented on Figure 5.2-1. It is interesting to note the good regularity of the sizes of meshes in the zone of interest (see Figure 5.2-2).

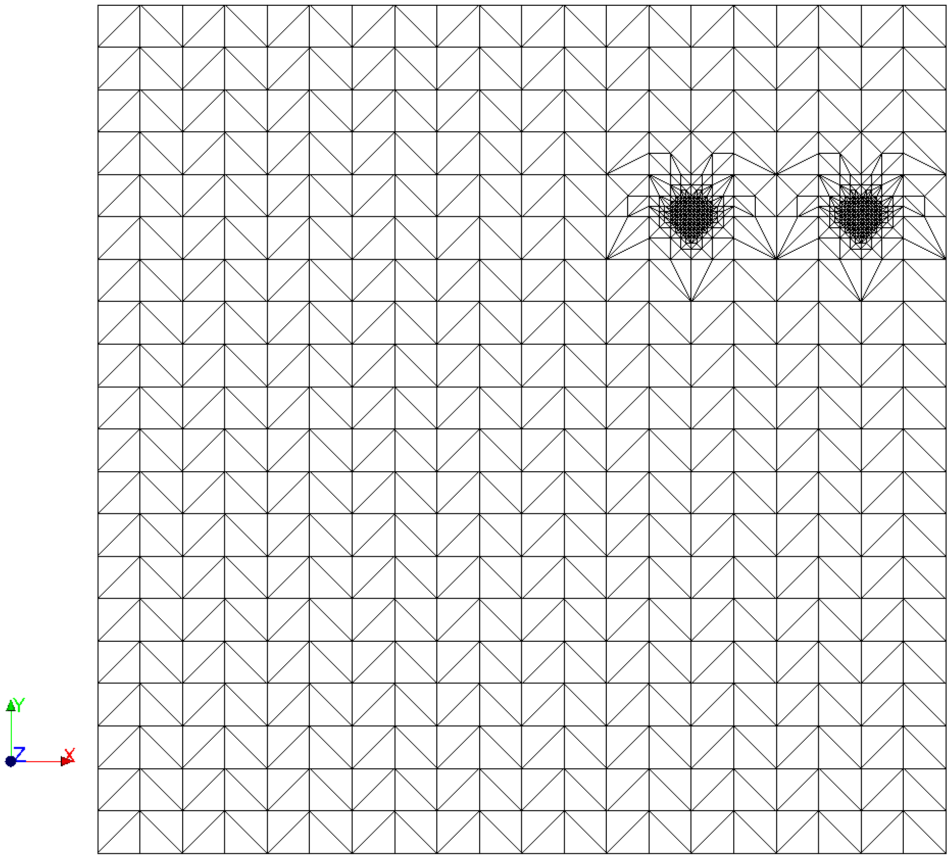

Figure 5.2-1: sane mesh refined

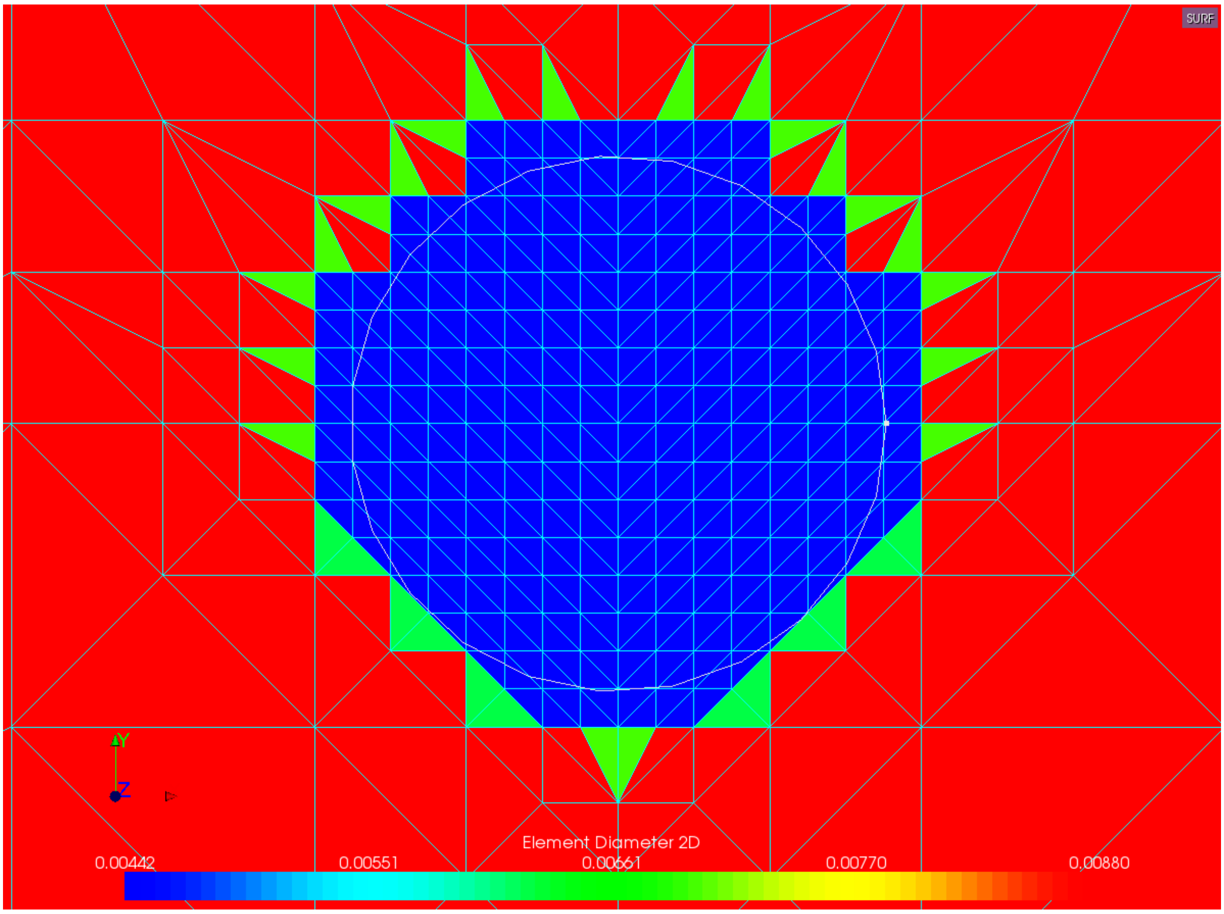

Figure 5.2-2: refined sane mesh - zoom around the crack tip n°1 of crack centered in A and card of sizes in the zone of interest

5.3 Quantities tested and results

One tests the value of the minimal size of meshes.

Standard	identification	Reference of reference	% tolerance
$min(h)$	0,004419	"ANALYTIQUE"	0.1%

This test will be improved when one can better test the cards.

6 Summary of the results

This test made it possible to validate macro-command RAFF_XFEM.
This command is also validated for interfaces.