COMMON STRUCTURAL RULES FOR
BULK CARRIERS

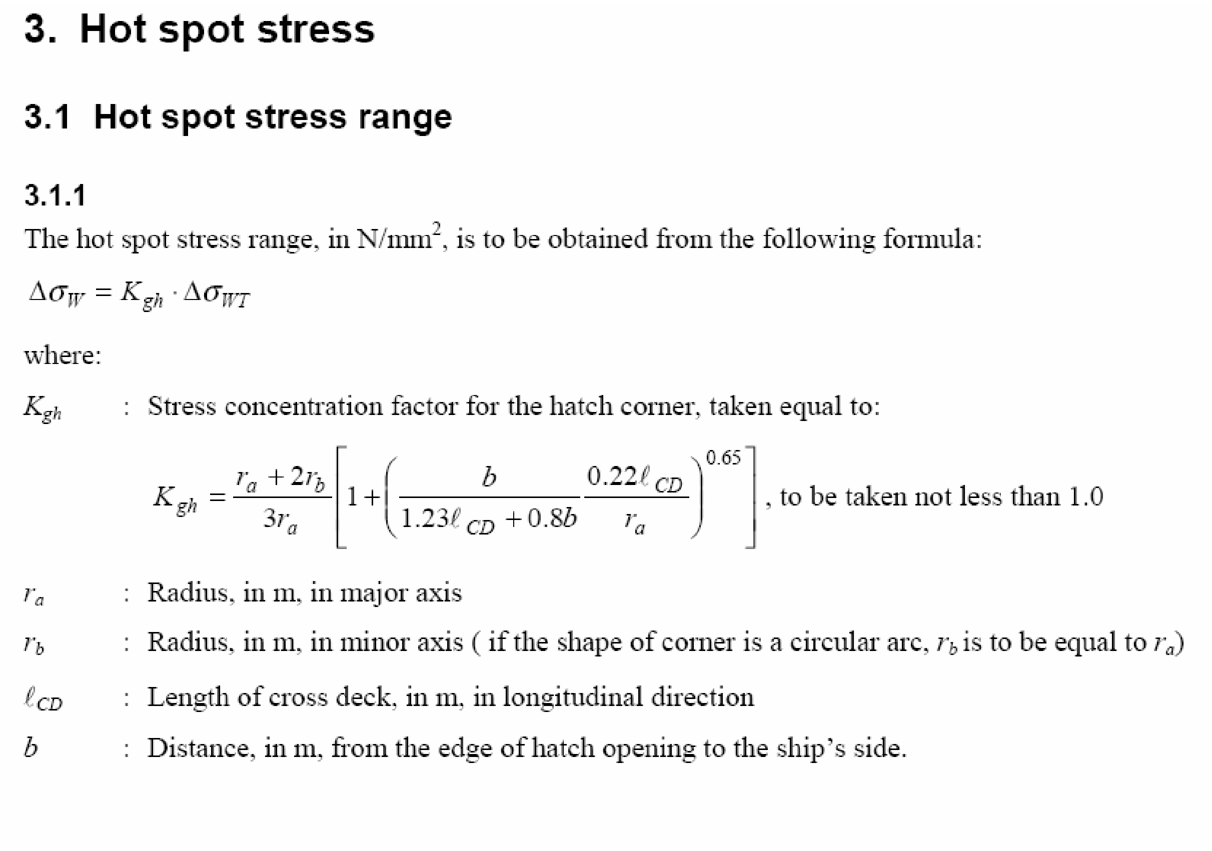
Stress concentration factor for the hatch corners

Doubts in the CSR bulk formula (K_{gh})

COMMON STRUCTURAL RULES FOR
BULK CARRIERS

Chapter 8 - Fatigue check of structural details

Section 5 – STRESS ASSESSMENT OF HATCH CORNERS



3. Hot spot stress

3.1 Hot spot stress range

3.1.1

The hot spot stress range, in N/mm^2, is to be obtained from the following formula:

$$\Delta\sigma_W = K_{gh} \cdot \Delta\sigma_{WT}$$

where:

K_{gh} : Stress concentration factor for the hatch corner, taken equal to:

$$K_{gh} = \frac{r_a + 2r_b}{3r_a}\left[1 + \left(\frac{b}{1.23\ell_{CD} + 0.8b}\,\frac{0.22\ell_{CD}}{r_a}\right)^{0.65}\right]$$, to be taken not less than 1.0

r_a : Radius, in m, in major axis

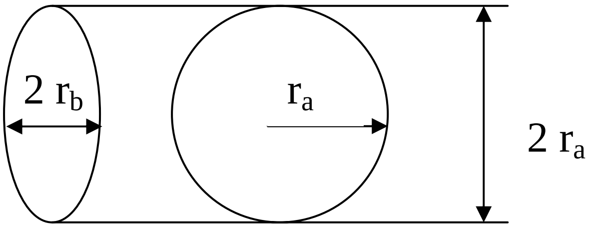
r_b : Radius, in m, in minor axis (if the shape of corner is a circular arc, r_b is to be equal to r_a)

ℓ_{CD} : Length of cross deck, in m, in longitudinal direction

b : Distance, in m, from the edge of hatch opening to the ship's side.

Correction factor for elliptic corners

In the bulk formula, r_a is used for rounded corners (the radius in major axis) as a basis for elliptic corners. They attribute a correction factor to take into account the influence of elliptic shape.
Here is the equivalence between the two shapes:



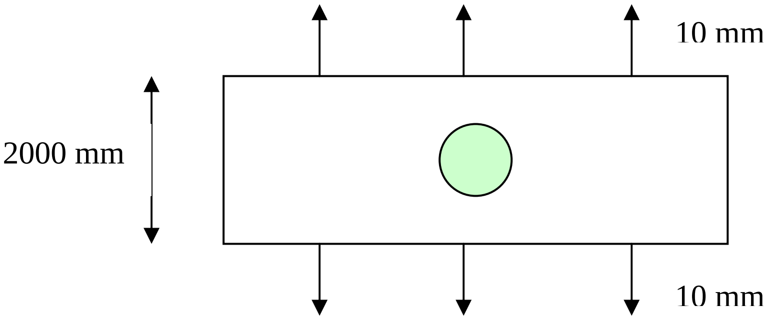
with the following correction factor to apply to get the elliptic stress concentration factor from the rounded one:

$$f_c = \frac{1}{3} + \frac{2r_b}{3r_a}$$

Here follow the original text describing the correction factor:

> *This correction factor gives the ratio of stress concentration for the tension of an infinite width thin element with an elliptic hole to that with a circular hole. In this equation, r_a denotes the radius in major axis and r_b denotes the radius in minor axis. This correction factor can be applied to the stress concentration factor for the fillet shoulder with circular arc shape of radius r_a.*

We test the correction factor with ANSYS 9.0 finite element software. We used shell elements of 10 mm thickness. We model plates of 2 by 6 meters with holes in the middle and impose displacements of 20 mm in the small direction as shown in the figure below. We use a 206000 MPa Young modulus and a 0.3 Poisson ratio.

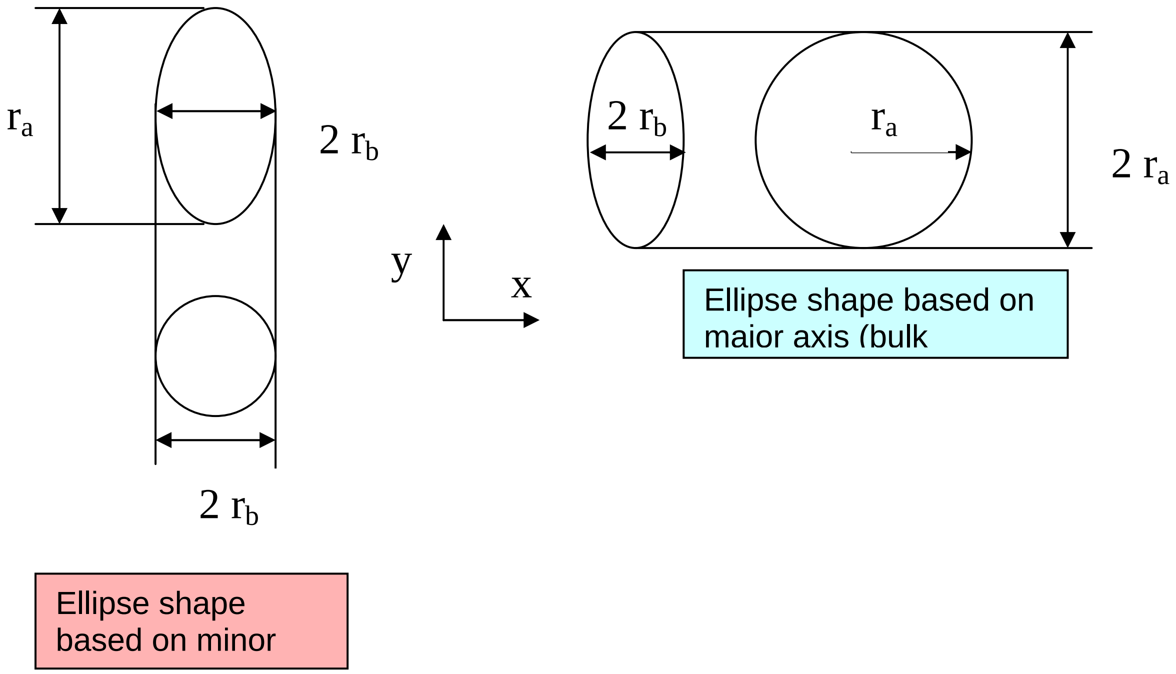


We compare six different shapes to the circular one.

Dimensions of the compared ellipses

Shape	**Arm length in x axis**	**Arm length in y axis**
Circular hole	200	200
Ellipse 1	50	200
Ellipse 2	75	200
Ellipse 3	100	200
Ellipse 4	200	250
Ellipse 5	200	300
Ellipse 6	200	400

Ellipse shapes 4, 5 and 6 are other kind of ellipse shape that those used for bulk formula. The reference axis is the minor one.



Measures

- Mean stress

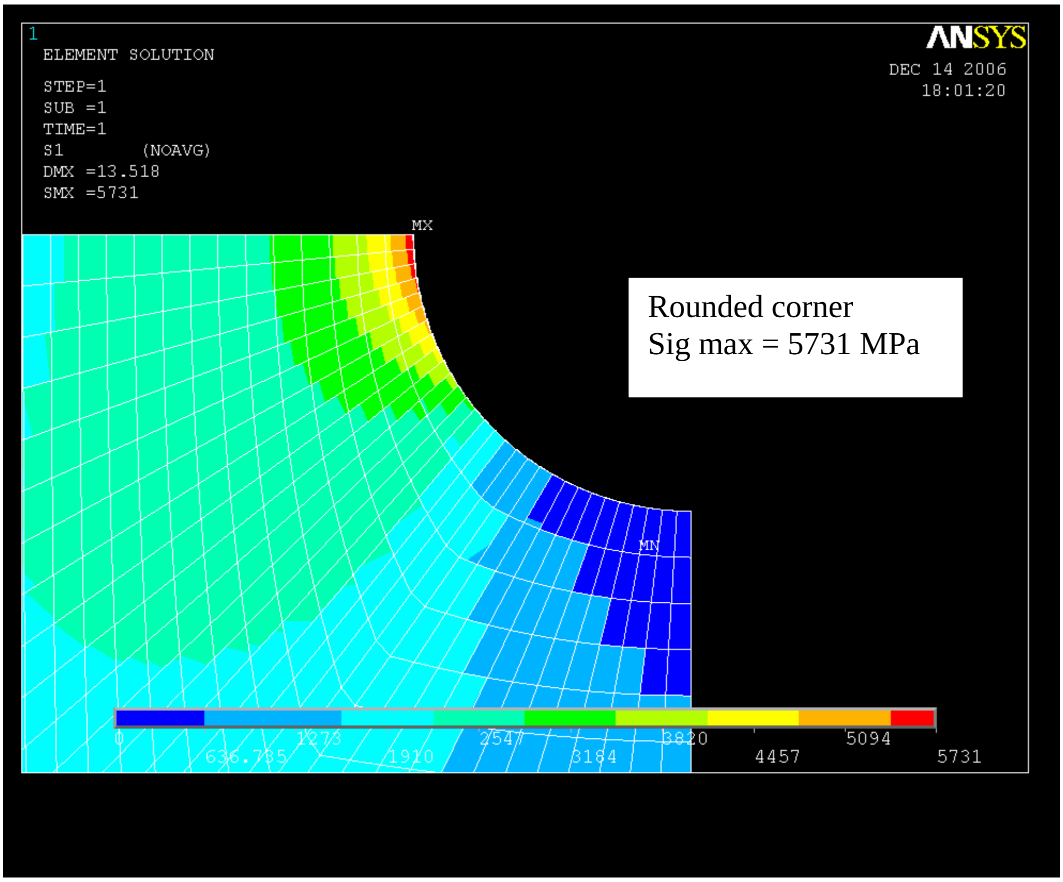
The mean stress is calculated as follow for a simple tensile test without any hole:

$$\sigma_{mean} = E\ \varepsilon$$
$$\varepsilon = 0.01$$
$$\sigma_{mean} = 2060 \quad MPa$$

- Maximum stress

This is the greatest principal stress read in the model as shown on the following pictures.

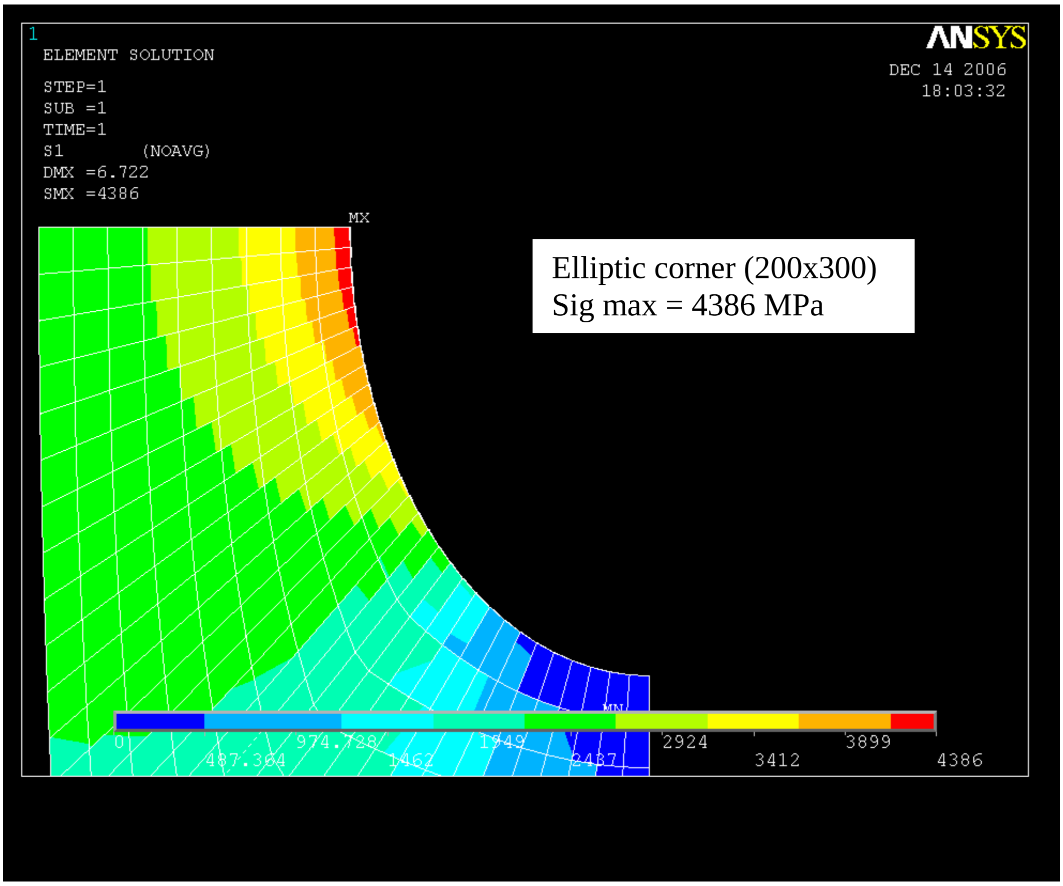
ANSYS 9.0 tests



```
1
ELEMENT SOLUTION

STEP=1
SUB =1
TIME=1
S1       (NOAVG)
DMX =13.518
SMX =5731
```

```
DEC 14 2006
18:01:20
```

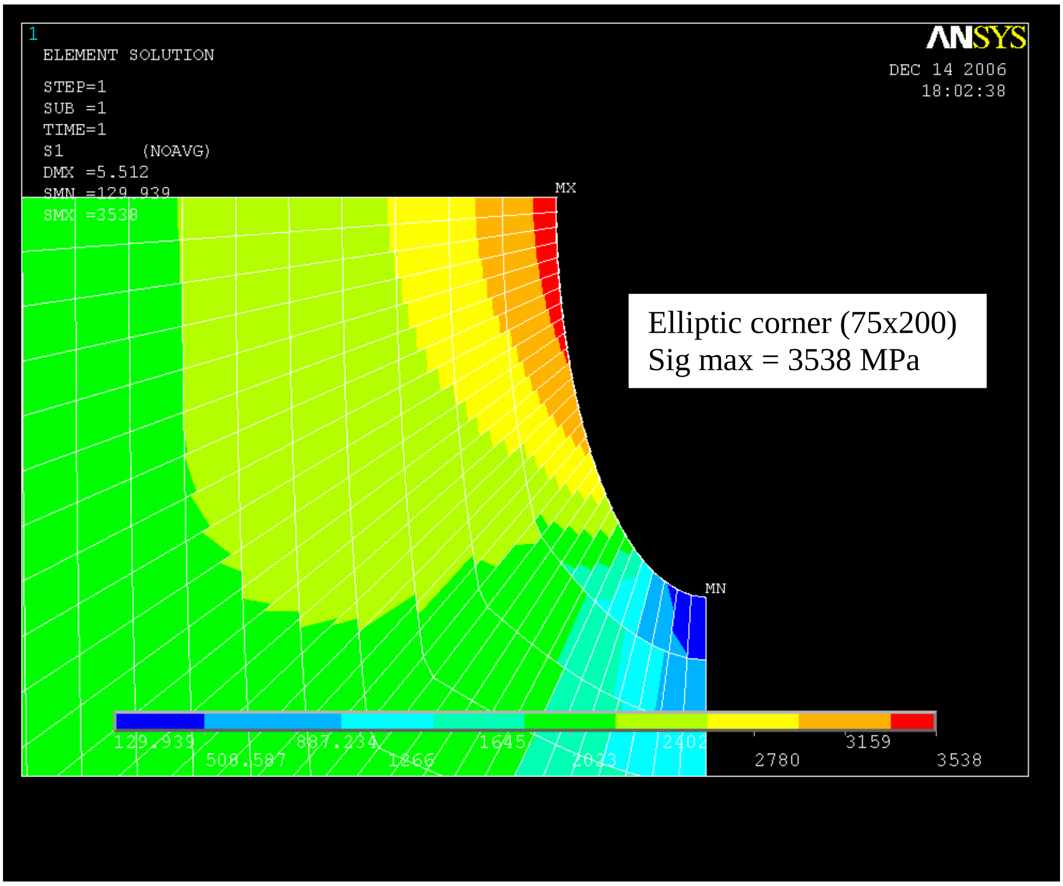
Rounded corner
Sig max = 5731 MPa



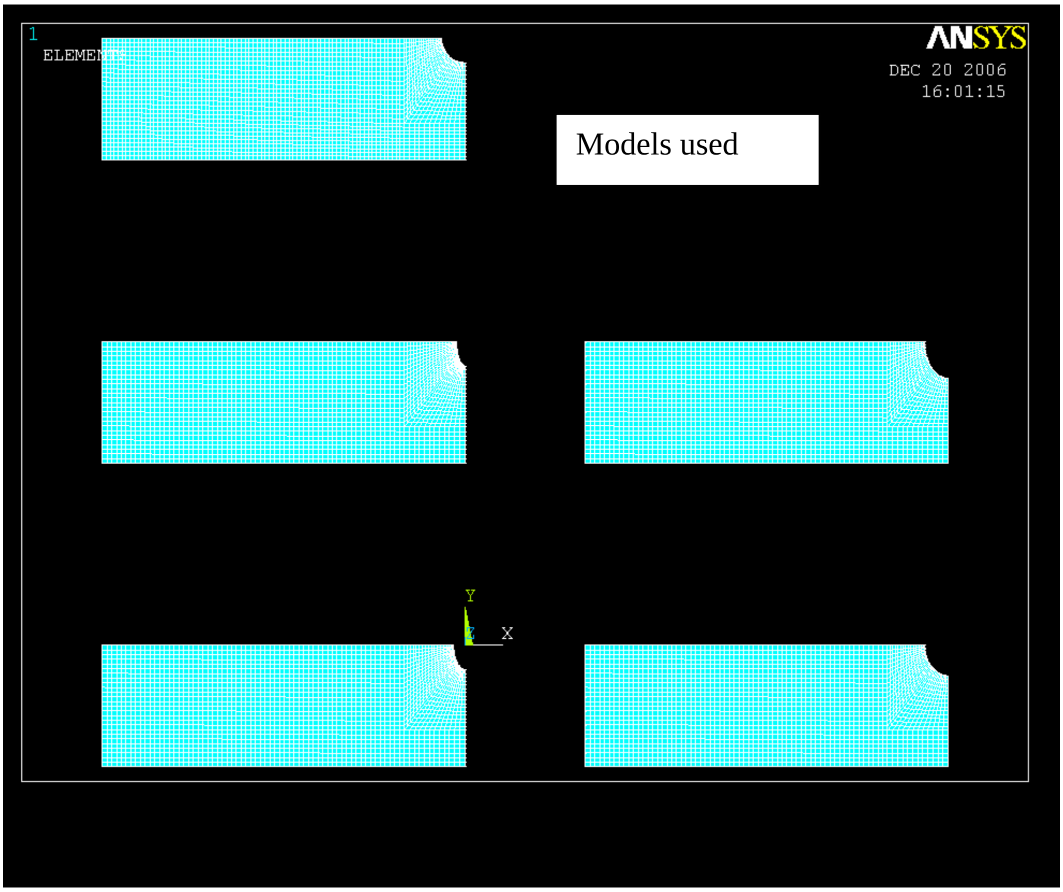
```
1
ELEMENT SOLUTION

STEP=1
SUB =1
TIME=1
S1       (NOAVG)
DMX =6.722
SMX =4386
```

```
DEC 14 2006
18:03:32
```

Elliptic corner (200x300)
Sig max = 4386 MPa



Elliptic corner (75x200)
Sig max = 3538 MPa



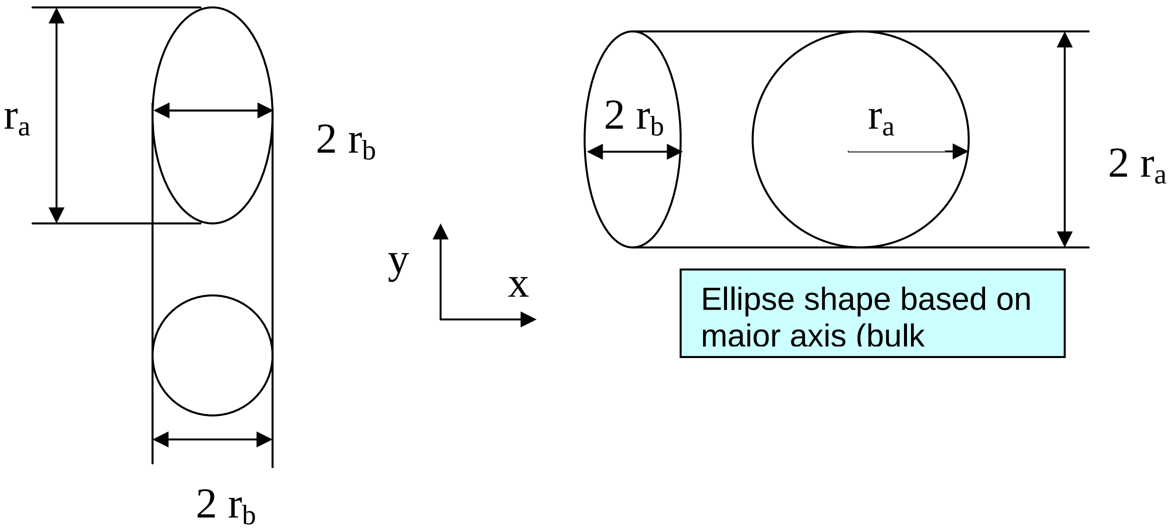
Models used

Results

Comparison between Kt eval (f_c) and Kt real (ANSYS software) for the different ellipses

Shape	dimensions	Maximum stress	Kt real (Max stress/2060)	Correction factor f_c	Kt evaluated (2.78* f_c)	Kt eval /Kt real
Circular hole	200x200	5731	**2.78**	**1**		
Ellipse 1	50x200	3057	1.48	0.5	1.39	0.94
Ellipse 2	75x200	3538	1.72	0.58	1.62	0.94
Ellipse 3	100x200	4009	1.95	0.67	1.85	0.95
Ellipse 4	200x250	4928	2.39	0.87	2.42	1.01
Ellipse 5	200x300	4386	2.13	0.78	2.17	1.02
Ellipse 6	200x400	3702	1.8	0.67	1.85	1.03

We can see that r_b radius is a more conservative basis than r_a to evaluate the influence of an elliptic shape. The error is a bit less than for r_a and the Kt obtained is over evaluated (r_b basis) instead of being under evaluated (r_a).



Ellipse shape based on major axis (bulk

Ellipse shape based on minor