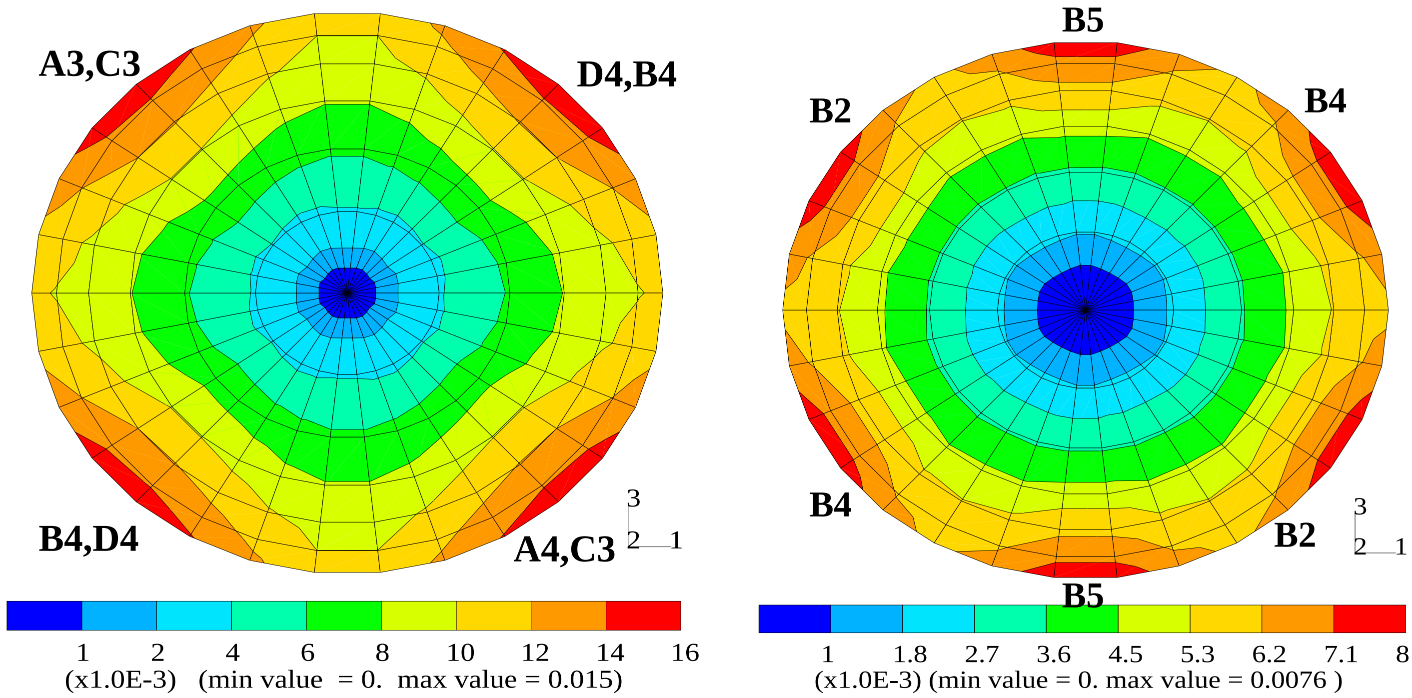
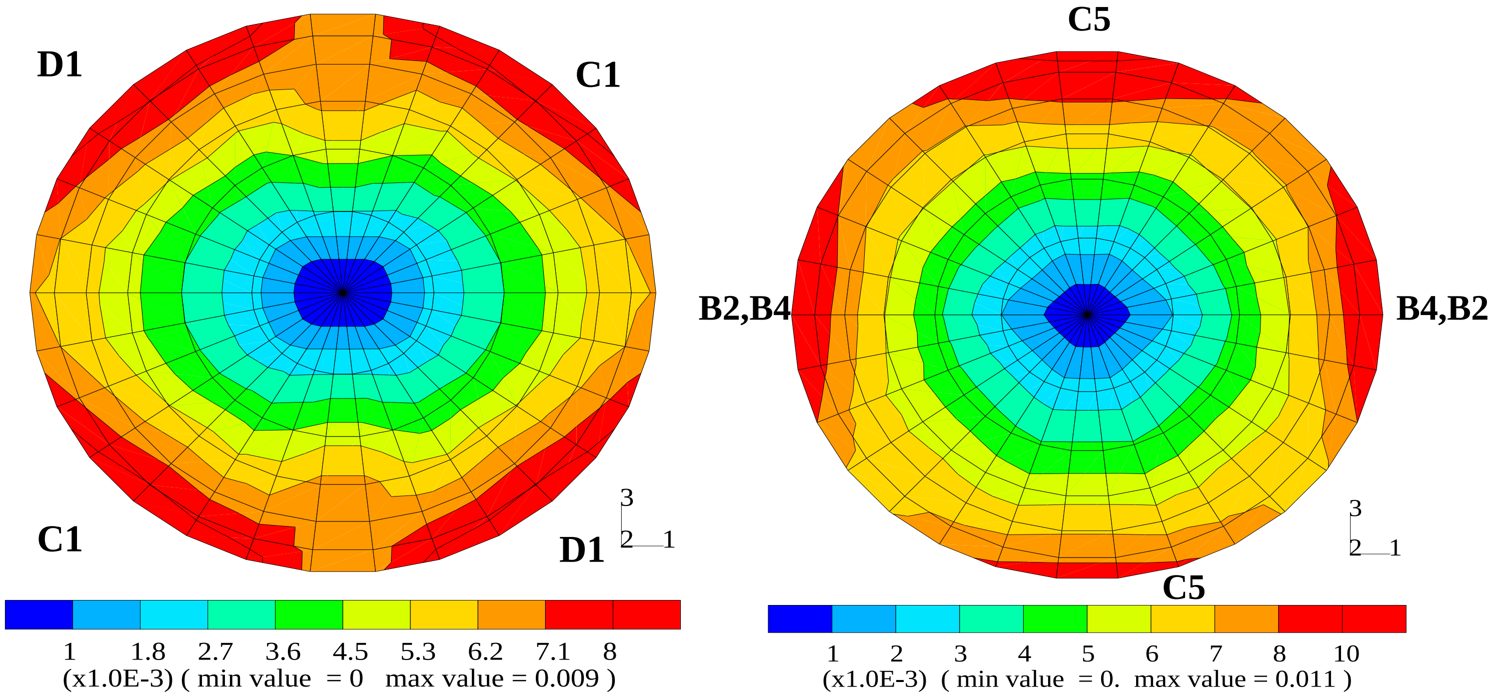
TORSION OF SINGLE CRYSTAL BARS
(Copper)

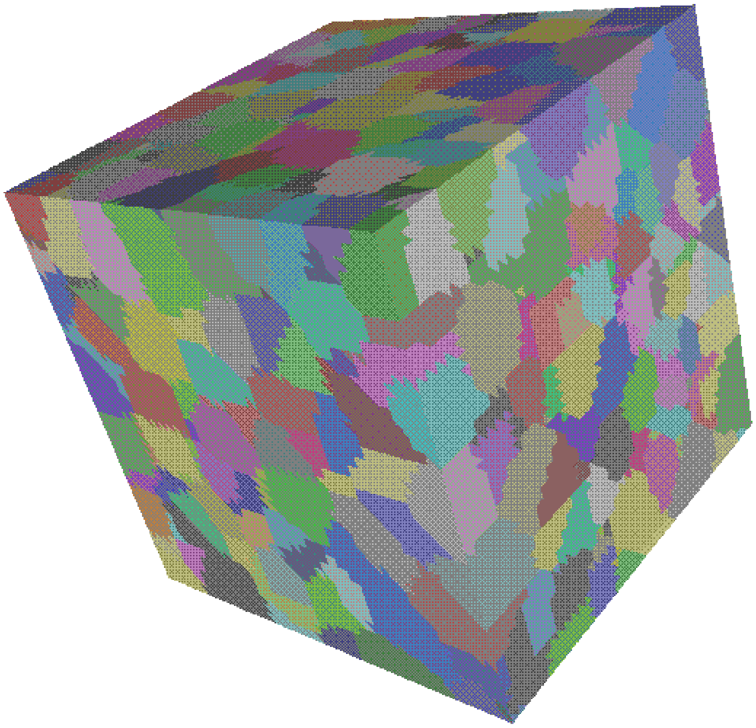


equivalent plastic strain in one section
left : axis 2 $=[001]$**, axis 1** $=[100]$
right : axis 2 $=[111]$**, axis 1** $=[1\bar{1}0]$



left : axis 2 $=[011]$**, axis 1** $=[100]$
right : axis 2 $=[11\bar{2}]$**, axis 1** $=[1\bar{1}0]$

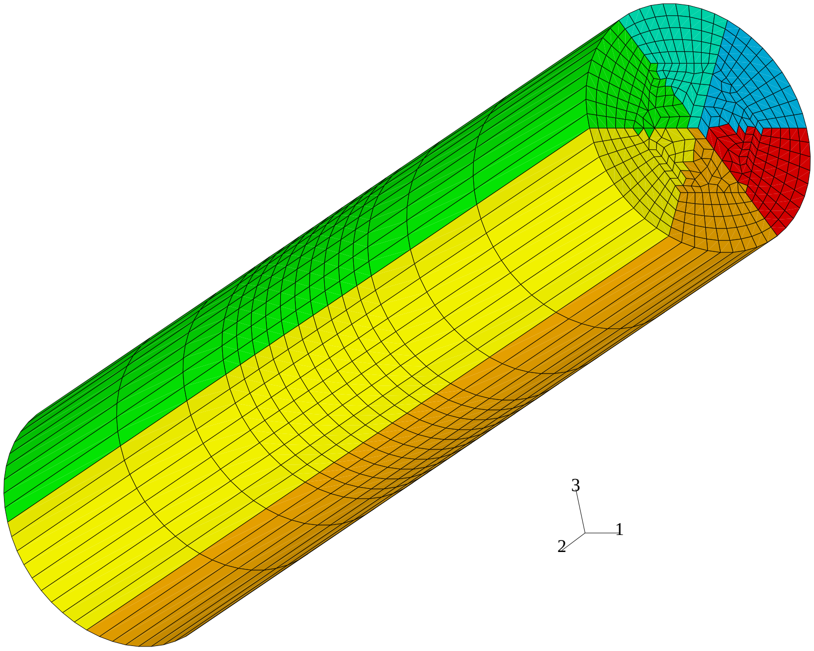
PARALLEL COMPUTING OF MULTICRYSTALLINE AGGREGATES



synthetic polycrystalline aggregate
(D. JEULIN, L. DECKER, Ecole des Mines de Paris)
256x256x256 pixels, 15583 grains

so-called Multiphase Element technique, 20-node bricks

ZéBuLoN FE code with parallel implementation
developed by F. FEYEL, F.X.ROUX at ONERA



6 subdomains (IBM-SP2, Ecole des Mines de Paris)

PRESENTATION OF THE CALCULATIONS

Constitutive equations

$$\dot{\underset{\sim}{\varepsilon}}^p = \sum_{s=1}^{12} \dot{\gamma}^s \{\underline{l}^s \otimes \underline{z}^s\}$$

$$\dot{\gamma}^s = < \frac{\mid \tau^s - x^s \mid - r^s}{k} >^n \; sign(\tau^s)$$

$$r^s = r_0 + q \sum_r h_{sr}(1 - \exp(-bv^r))$$

$$x^s = c\alpha^s \quad and \quad \dot{\alpha}^s = \dot{\gamma}^s - d\dot{v}^s\alpha^s$$

$$C_{11} = 159309\mathrm{MPa}, C_{12} = 121945\mathrm{MPa}, C_{44} = 80943\mathrm{MPa}$$

$$r_0 = 0.8\mathrm{MPa}, q = 3.6\mathrm{MPa}, b = 1.6, c = 3402\mathrm{MPa}, d = 3597$$

$$h_{ii} = 1, h_{12} = 4.4, h_{13} = h_{14} = h_{15} = 4.75, h_{16} = 5.$$

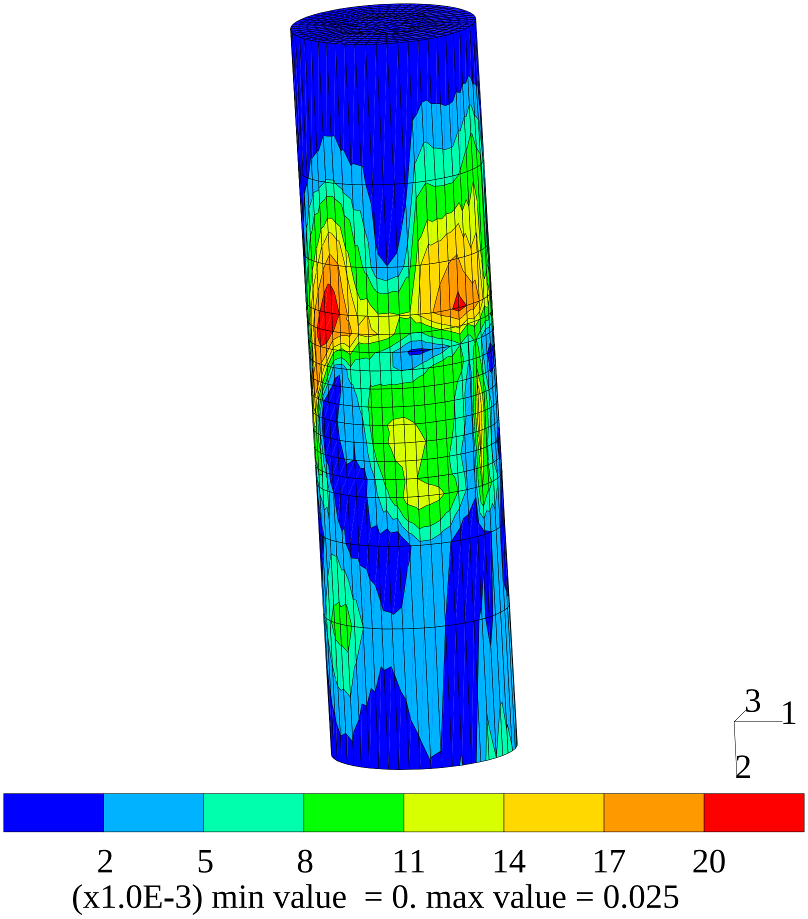
[Méric, Cailletaud, Gaspérini 1994]

8 specimens are considered under torsion:

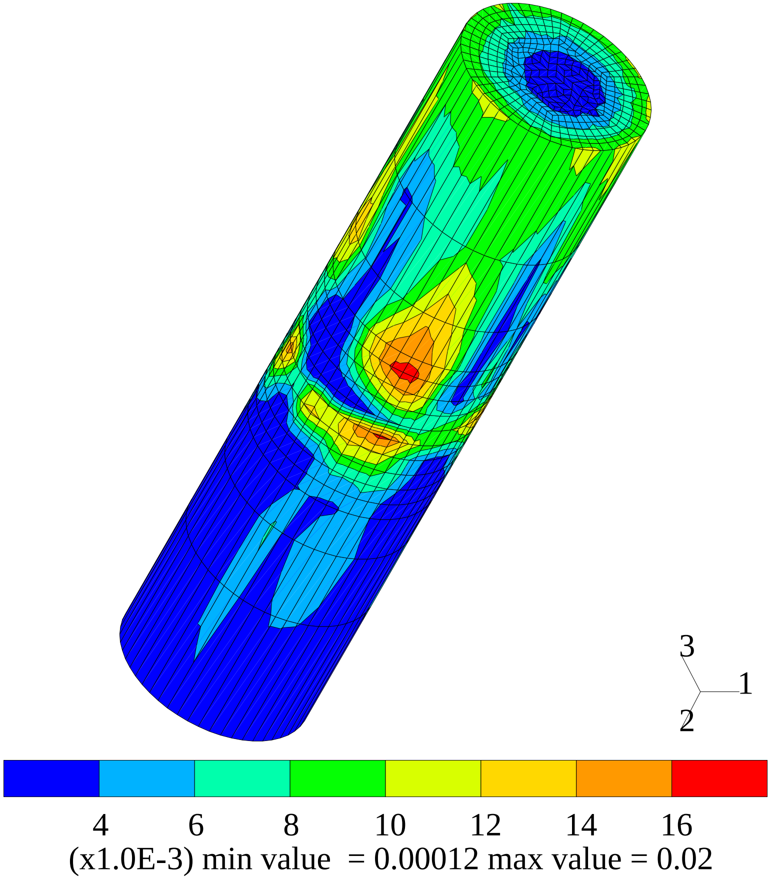
- **test A : specimen with 23 grains;**
- **test B : same microstructure as A but a different distribution of orientations (different realization);**
- **test C : 79 grains;**
- **test D : same as C but a different realization of orientation distribution;**
- **test E and F : 332 and 976 grains respectively;**
- **test G : in this specimen, a different orientation is attributed to each Gauss point;**

STRAIN LOCALIZATION

equivalent plastic strain :

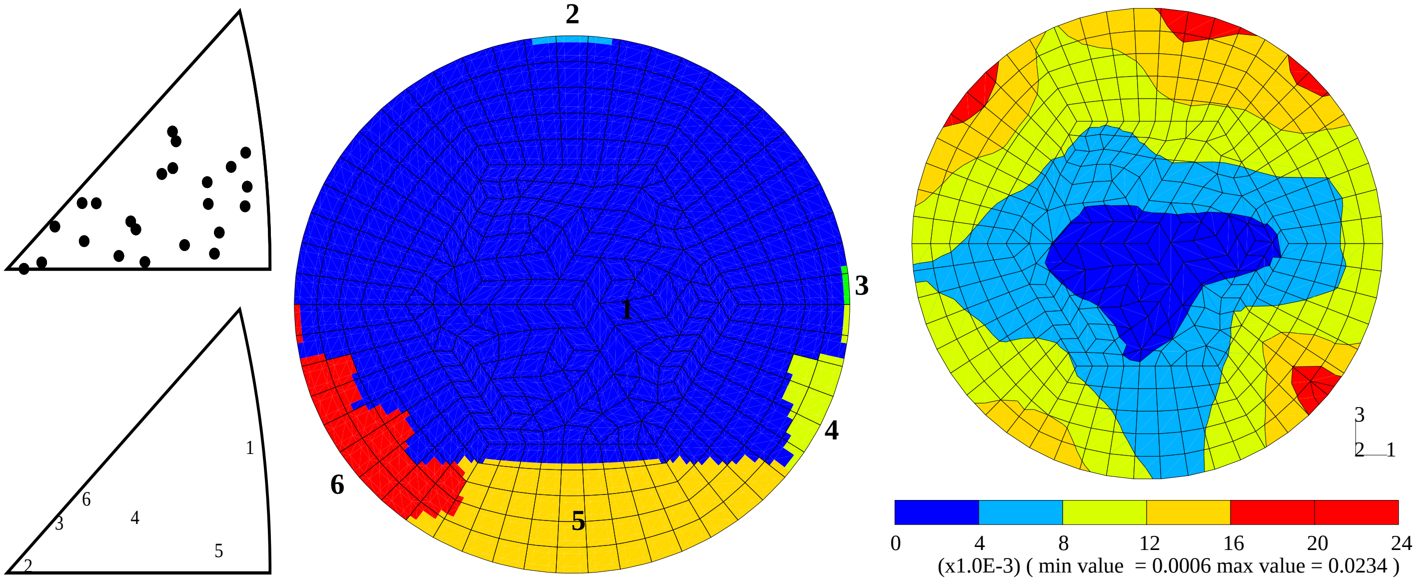


specimen A (23 grains)

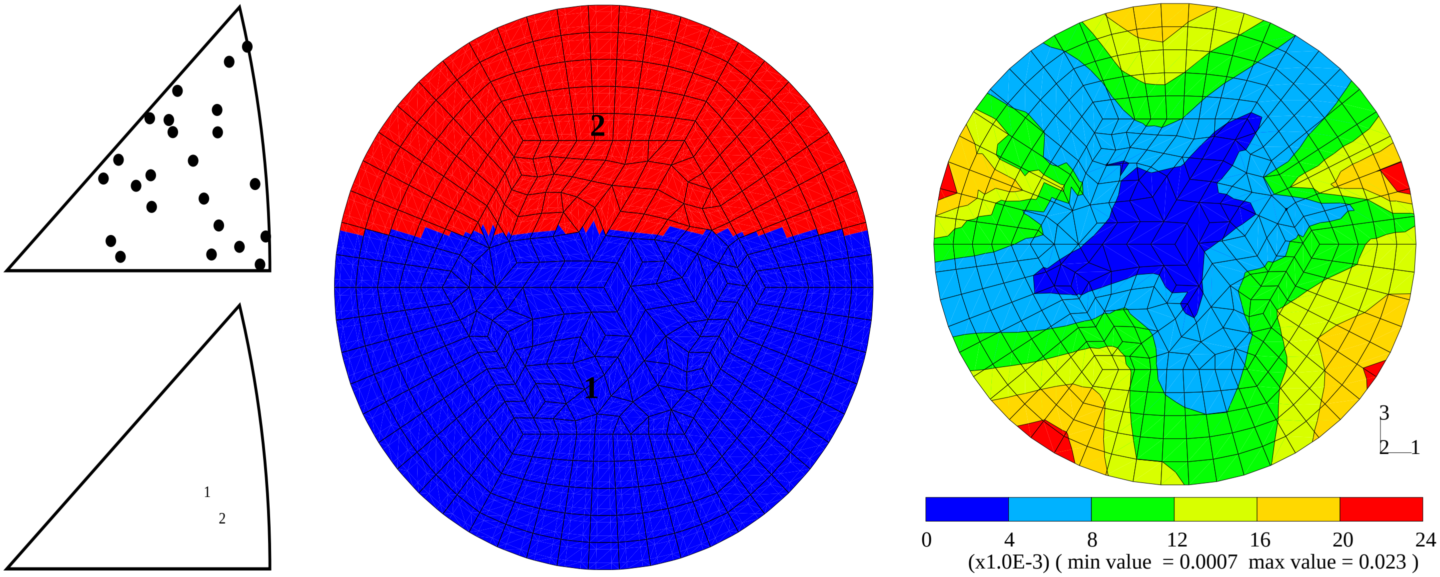


specimen C (79 grains)

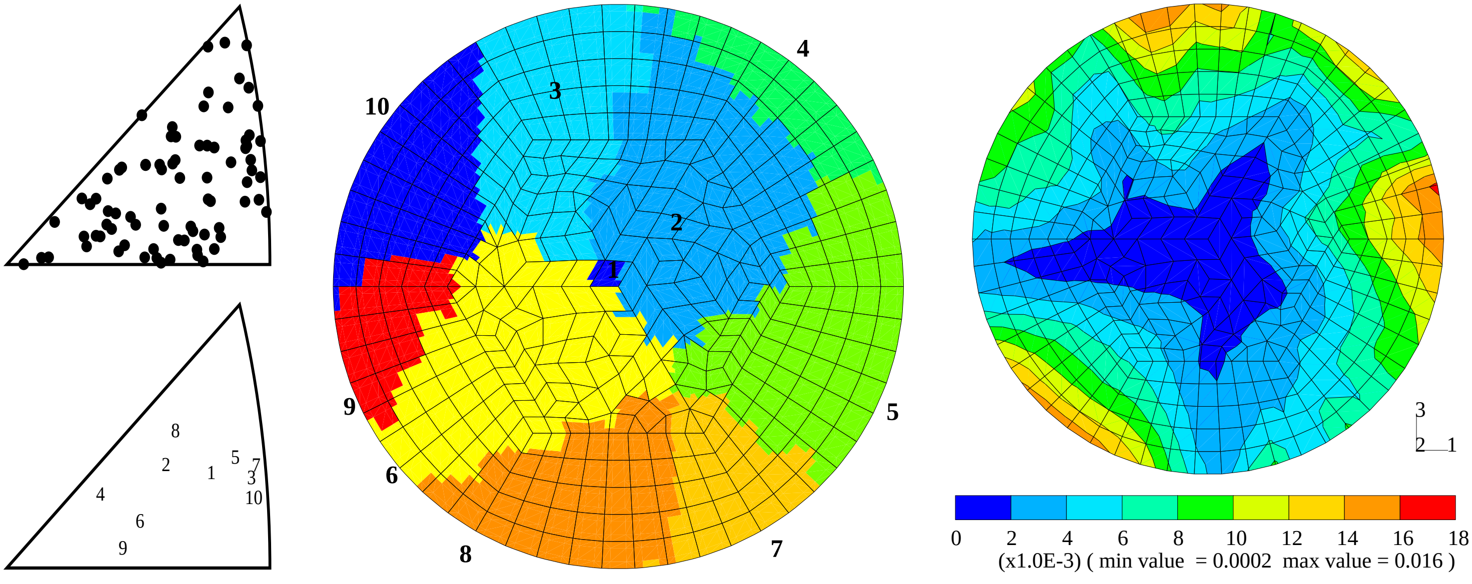
SECTIONS OF THE SPECIMENS



one section of specimen A : grains distribution (middle), their orientations (bottom left), the plastic deformation at the end of the test (right), orientations of all grains in A (top left corner, axis 2 in the standard triangle)

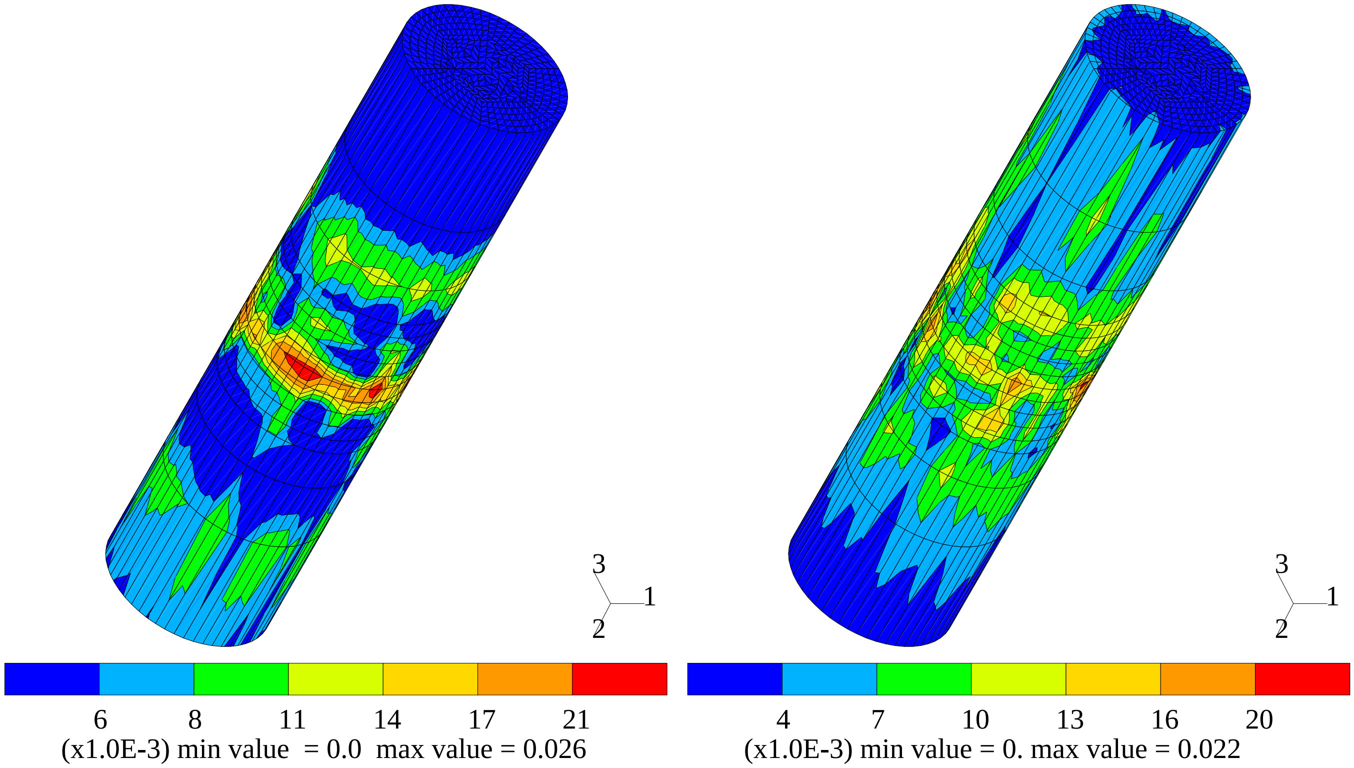


one section of specimen B

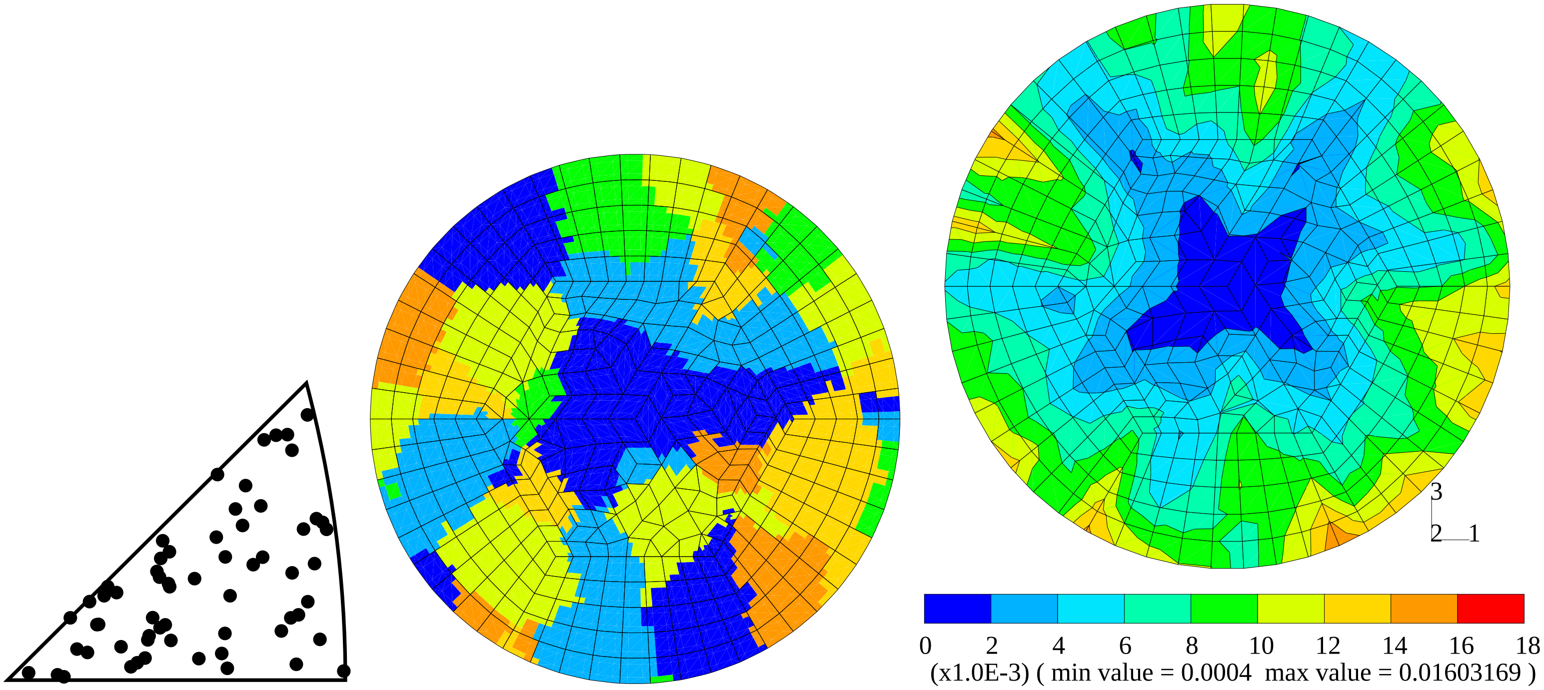


one section of specimen C

TRANSITION TO POLYCRYSTALLINE BEHAVIOUR

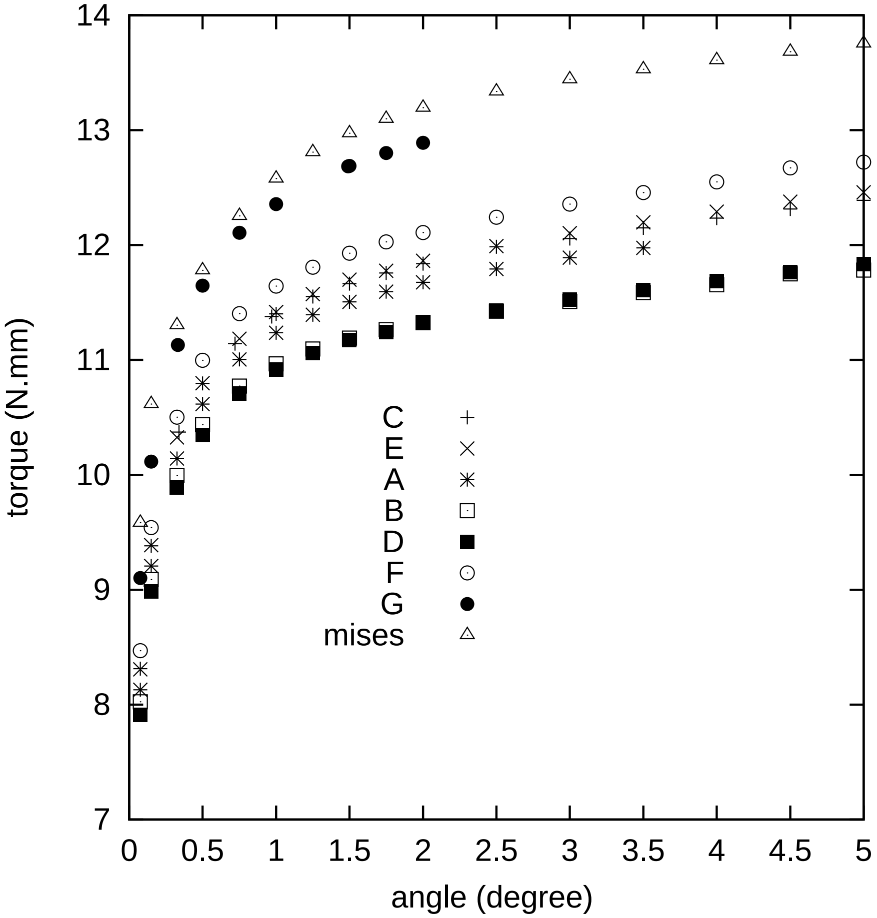


equivalent plastic strain on specimens with 332 (left) and 976 grains (right)

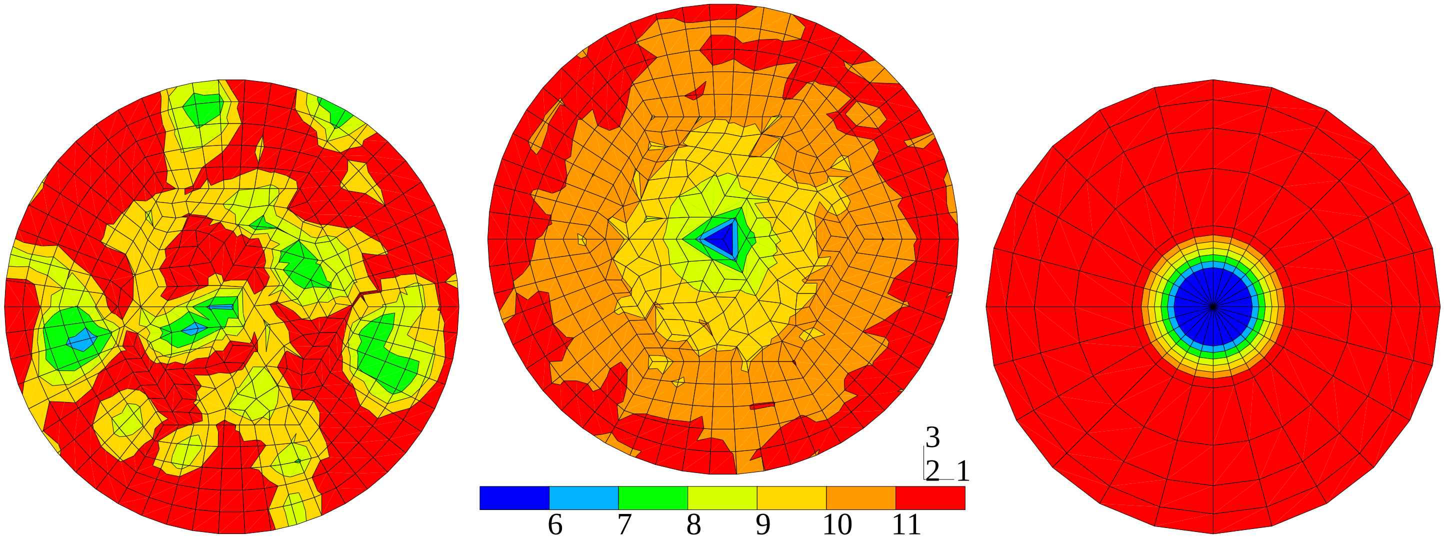


one section of specimen F : grain orientations and equivalent plastic deformation

TORQUE-ANGLE RESPONSE

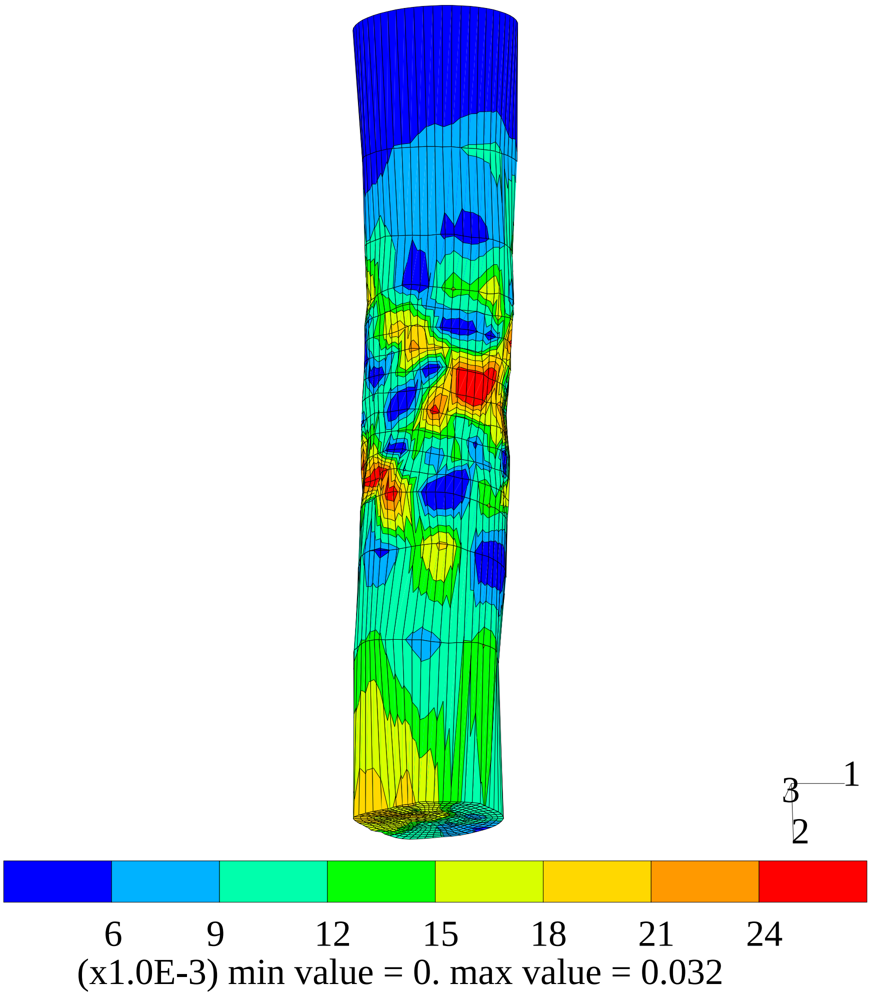


torque-angle curves for multicrystalline and polycrystalline aggregates
comparison with the response of an equivalent Mises body

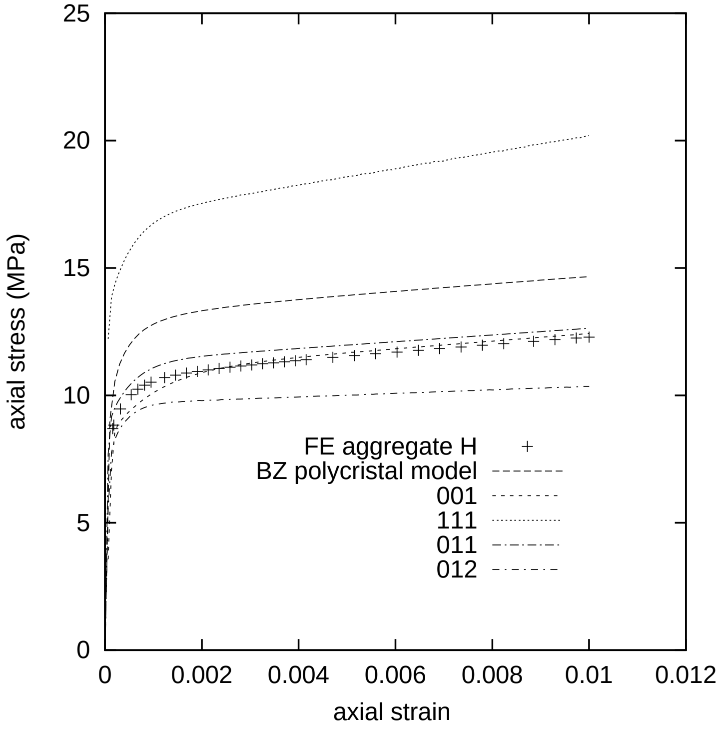


Mises contour on a section of specimens F, G and for the equivalent Mises body

TENSILE BEHAVIOUR



strain localization under tension for 976 grains!



overall tensile curves

MAIN CONCLUSIONS

1. In a single or coarse grain wire undergoing torsion, both strong radial and circumferential strain gradients develop.

2. For wires made of up to about 1000 grains, deformation localizes in some weak sections of the specimen. This holds true for torsion but also, in a less pronounced manner, in tension. Such localization phenomena make the interpretation of the overall response torque/angle very difficult. Note that experimental observations of the specimen are not reported in [1].

3. As a result of the previous point, the overall response of the multicrystal is weaker than that of the homogenized polycrystal.

4. If non local effects are needed to account for additional hardening due to strong strain gradients in coarse grain wires, this should not be done in an extension of Mises-type elastoplasticity but within the framework of generalized crystal plasticity as in [2] and [3].

[1] Fleck N.A., Müller G.M, Ashby M.F., Hutchinson J.W., Acta Metall. Mater., Vol. 42, No. 2, pp. 475-487, 1994.
[2] Shu J.Y., Fleck N.A., King W.E., in MRS Fall Meeting Proc., Symposium W, 1996.
[3] Forest S., Cailletaud G., Sievert R., Arch. Mech., Vol. 49, pp. 705-736, 1997.

ON SIZE EFFECTS IN TORSION OF MULTI- AND POLYCRYSTALLINE SPECIMENS

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