fonderie ariotti

UNIVERSITY OF TRENTO

Finite element modeling investigations on a ductile cast iron EN-GJS-600-3 yield locus under biaxial stresses

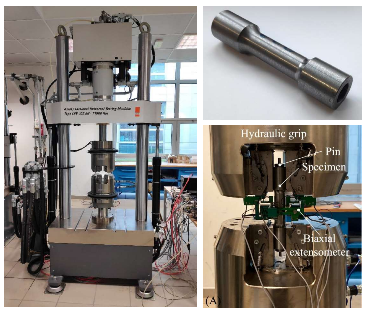
M. Pedranz[a*], T. Curtolo[a], V. Fontanari[a], D. Lusuardi[b], M. Benedetti[a]

[a]Department of Industrial Engineering, University of Trento, via Sommarive 9, 38123 Trento, Italy

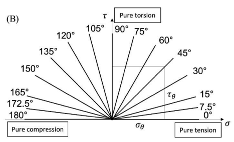
[b]Fonderie Ariotti, Adro (BS), Italy

Experimental data

The yield domain of a ductile cast iron (DCI) EN-GJS-600-3 was investigated by testing tubular specimens under several biaxial loading conditions. The morphology, distribution and dimensions of graphite nodules were characterized through light optical metallography and computed tomography. The yield locus of the material deviates from that predicted by von Mises. It is well-fitted by the three-dimensional invariant-based criterion proposed by Camanho. This work presents finite element simulations to investigate the deviation from the von Mises yield domain.



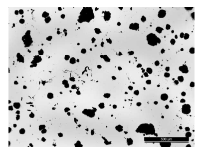
Biaxial tests (axial + torsion) under strain control



Loading ratio

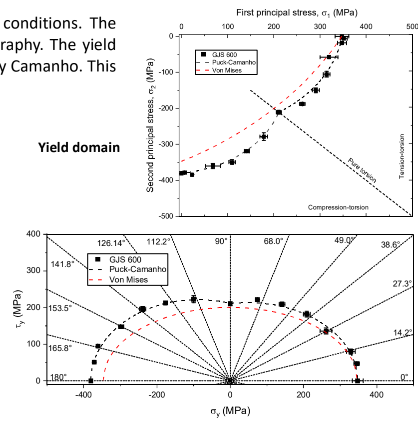
$$\frac{\tau}{\sigma} = Tan(\theta)$$

Material characterization through light optical metallography and computed tomography



	Computed tomography	Optical metallography
Graphite fraction (%)	8.2 ± 0.1	8.4 ± 0.4
Mean nearest-neighbour distance (µm)	-	104 ± 43
Nodules diameter (µm)	65 ± 31	62 ± 40

Yield domain

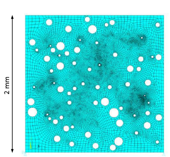


Ref: Benedetti et al. "Yield and fracture loci for a ductile cast iron EN-GJS-600-3 under biaxial stresses," *Fatigue & Fracture of Engineering Materials & Structures*, vol. 45, no. 3, Mar. 2022

2D models

2D simulations were performed plane stress conditions. For tensile axial components, the graphite nodules were modeled as circular voids. Instead, for compressive axial components, the effect of graphite nodules is no longer negligible. Therefore, it was decided to model them as compressible fluids surrounded by the matrix and with an initial circular shape. This assumption is reasonable as graphite is a solid lubricant with very low mechanical strength and therefore able to easily deform even at low applied stresses. A Python® script was implemented to generate 50 different 2D rectangular domains with dimensions of approximately 2 x 2 mm, where the graphite nodules are dispersed according to the experimental data. The yield strength and plastic modulus of the matrix were tuned according to the experimental axial curves, looking for the best fit. All the 50 domains were then simulated under several biaxial loading conditions.

	Computed tomography	Optical metallography	2D models
Graphite fraction (%)	8.2 ± 0.1	8.4 ± 0.4	8.1 ± 0.1
Mean nearest-neighbour distance (µm)	-	104 ± 43	83 ± 5
Nodules diameter (µm)	65 ± 31	62 ± 40	68 ± 32

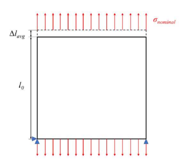


Python script → 50 different domains with dimensions 2 x 2 mm

Matrix → Bilinear kinematic material

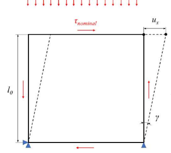
Elements PLANE183 from the ANSYS element library → Plane stress behavior

Graphite nodules → Circular voids



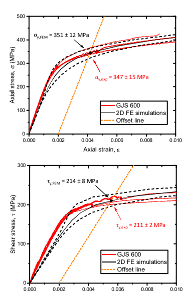
Axial strain

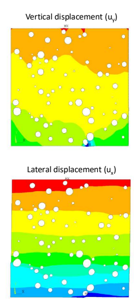
$$\varepsilon = \frac{\Delta l_{avg}}{l_0}$$

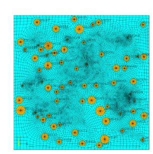


Shear strain

$$\gamma = ArcTan\left(\frac{u_x}{l_0}\right)$$







Graphite nodules → Compressible fluid

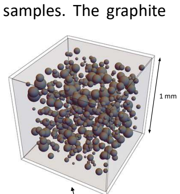
Elements HSFLD241 from the ANSYS element library

Bulk modulus = 750 GPa

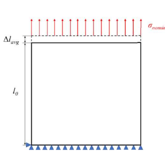
3D model

Because of the very large computational power required for 3D simulations, it was decided to investigate only one 3D domain, generated by another Python® script. The spatial arrangement and dimension of graphite nodules were set according to experimental data collected through computed tomography (CT) scans and observations on metallographic samples. The graphite nodules were modeled as spherical voids.

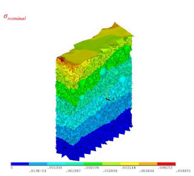
	Computed tomography	Optical metallography	3D model
Graphite fraction (%)	8.2 ± 0.1	8.4 ± 0.4	8.1
Mean nearest-neighbour distance (µm)	-	104 ± 43	89
Nodules diameter (µm)	65 ± 31	62 ± 40	67 ± 27



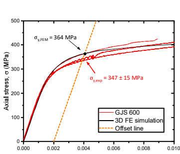
Domain generated by a Python script



Axial strain → $\varepsilon = \frac{\Delta l_{avg}}{l_0}$



Vertical displacement (u_y)

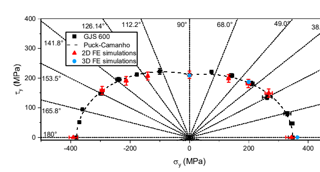


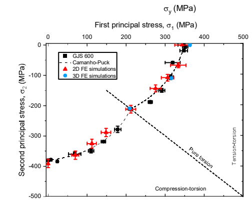
Matrix → Bilinear kinematic material

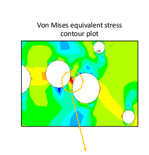
Elastic modulus = 210 GPa
Yield strength = 435 MPa
Plastic modulus = 3.75 GPa

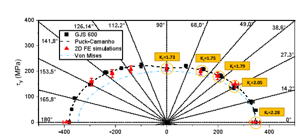
Results

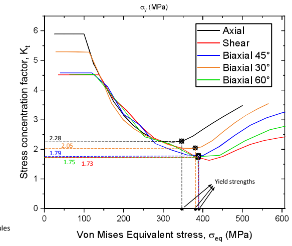
The numerical results are in accordance with the experimental data, thus predicting the deviation from the von Mises yield domain. In all the loading conditions, the stress concentration factor (K_t) is lower than the axial one.











Contacts: matteo.pedranz@unitn.it