FAILURE SIZE EFFECT ON DIFFERENT NOTCHED CONFIGURATIONS BY FFM

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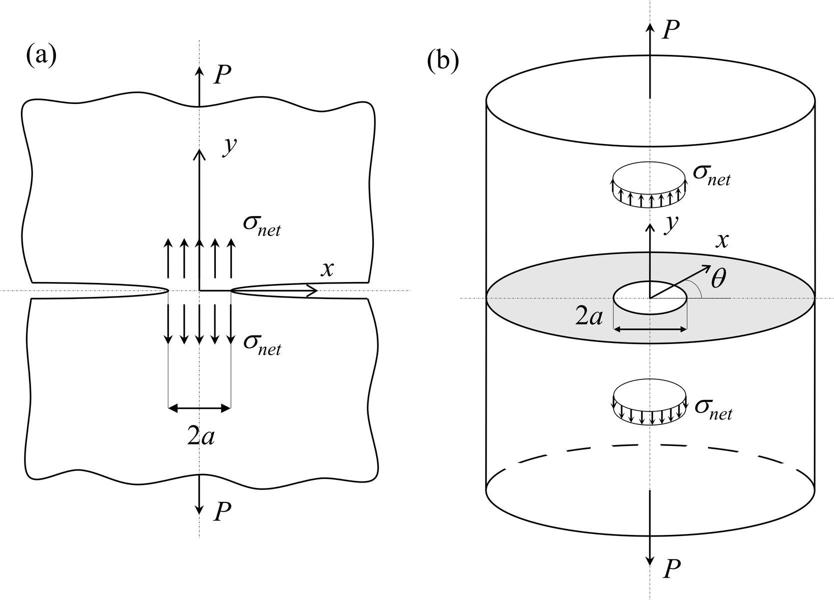
Introduction

Cracks and notches represent the most common source of stress raisers in mechanical elements. In this field, **Finite Fracture Mechanics** (**FFM**) is a coupled fracture initiation criterion which allows to provide strength predictions based on the simultaneous fulfilment of a stress condition and the energy balance. FFM rests on the assumption of finite crack advance, in contrast to **Linear Elastic Fracture Mechanics** (**LEFM**) which assumes crack growth to develop continuously. These features enable FFM to provide reliable failure estimations for plain, notched, cracked elements: in comparison, LEFM only works for geometries with a sufficiently large crack. Indeed, FFM is able to catch the transition from strength to toughness-governed failure regimes as the characteristic size of the stress-raiser varies. With the focus on the size effect of failure, FFM has been recently applied to brittle materials in presence of Penny-Shaped cracks and spherical cavities. Likewise, FFM was shown to provide close predictions to the well-established **Cohesive Crack Model** (**CCM**).

Research activity

"Ligament size effect for largely cracked tensile structures"

Alberto Sapora, Francesco Ferrian, Pietro Cornetti, Hossein Talebi, Majid R. Ayatollahi



FFM

$$\begin{cases} \sigma_y(x=a-l)=\sigma_c \\ \int_{a-l}^{a} K_{I\sigma}^2(a')da' = K_{Ic}^2 l \end{cases}$$

Avg - FFM

$$\begin{cases} \int_{a-l}^{a} \sigma_y(x)dx = \sigma_c l \\ \int_{a-l}^{a} K_{I\sigma}^2(a')da' = K_{Ic}^2 l \end{cases}$$

CCM

$$\begin{cases} K_I = K_{I\sigma} - K_{I\sigma_c} = 0 \\ w = w_\sigma - w_{\sigma_c} = w_c \end{cases}$$

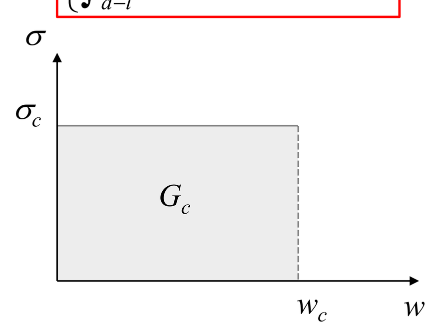


Fig. 1 (a) Doubly cracked plate and (b) cracked cylindrical bar.

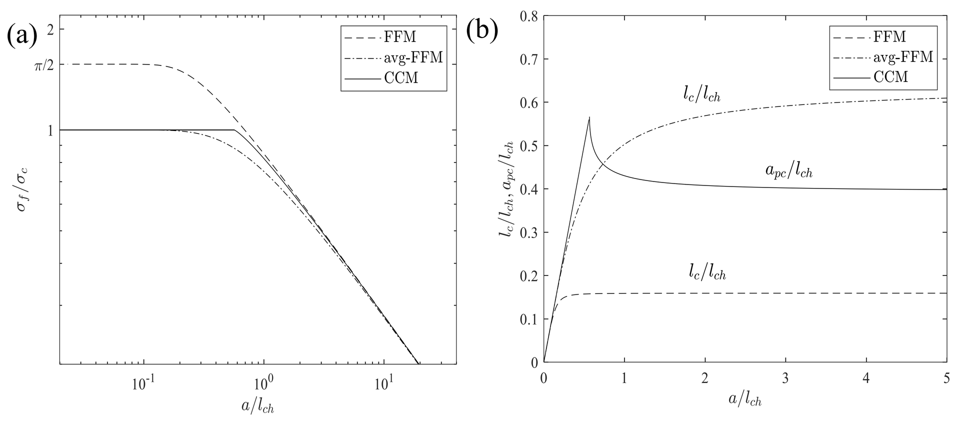


Fig. 2 (a) Strength estimations for the cracked plate and (b) Critical crack advancements.

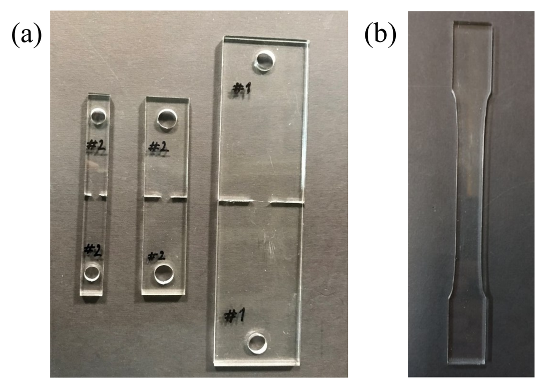


Fig. 3 (a) Analysed geometries and (b) example of dog – bone specimen.

Avg - FFM

$$\begin{cases} \frac{\sigma_f}{\sigma_c} = \frac{\pi}{2}\frac{l_c}{a}\left[\frac{\pi}{2} - \operatorname{atan}\left(\frac{1-l_c/a}{l_c/a\sqrt{2a/l_c-1}}\right)\right]^{-1} \\ \frac{\sigma_f}{\sigma_c} = \sqrt{\frac{\pi l_{ch}}{4a^2}\frac{l_c}{\ln\left[1/(1-l_c/a)\right]}} \end{cases}$$

CCM

$$\begin{cases} \frac{\sigma_f}{\sigma_c} = \frac{a_{pc}}{a}\sqrt{\frac{2a}{a_{pc}}-1} \\ \frac{\sigma_f}{\sigma_c} = \left[\frac{\pi l_{ch}}{4a} + 2\ln\left(\frac{a}{a-a_{pc}}\right)\right]\frac{1}{2\cosh^{-1}\left[a/(a-a_{pc})\right]} \end{cases}$$

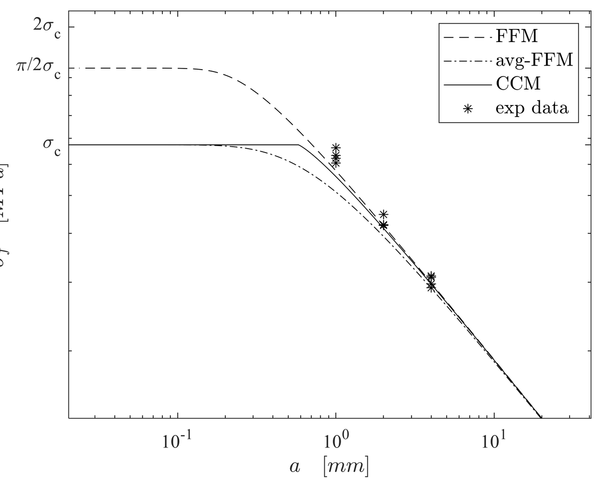


Fig. 4 Tensile strength of PMMA specimens.

"Crack tip shielding"

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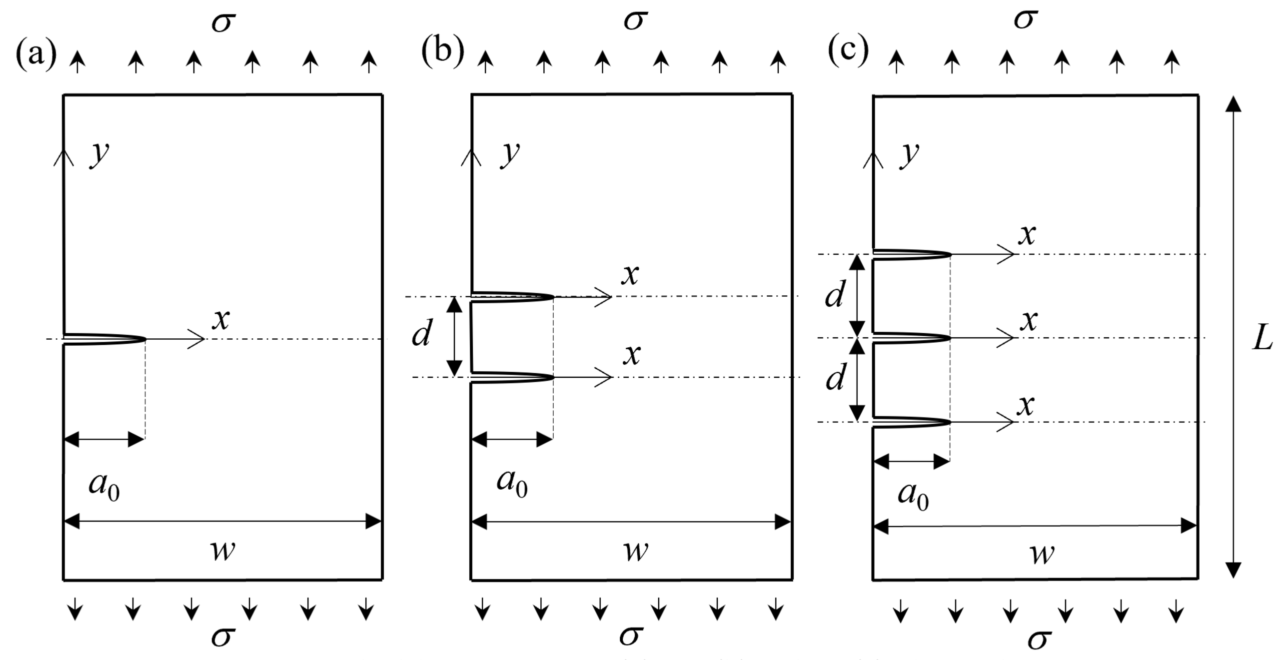

Fig. 5 Tensile slab presenting one (a), two (b) or three (c) edge cracks.

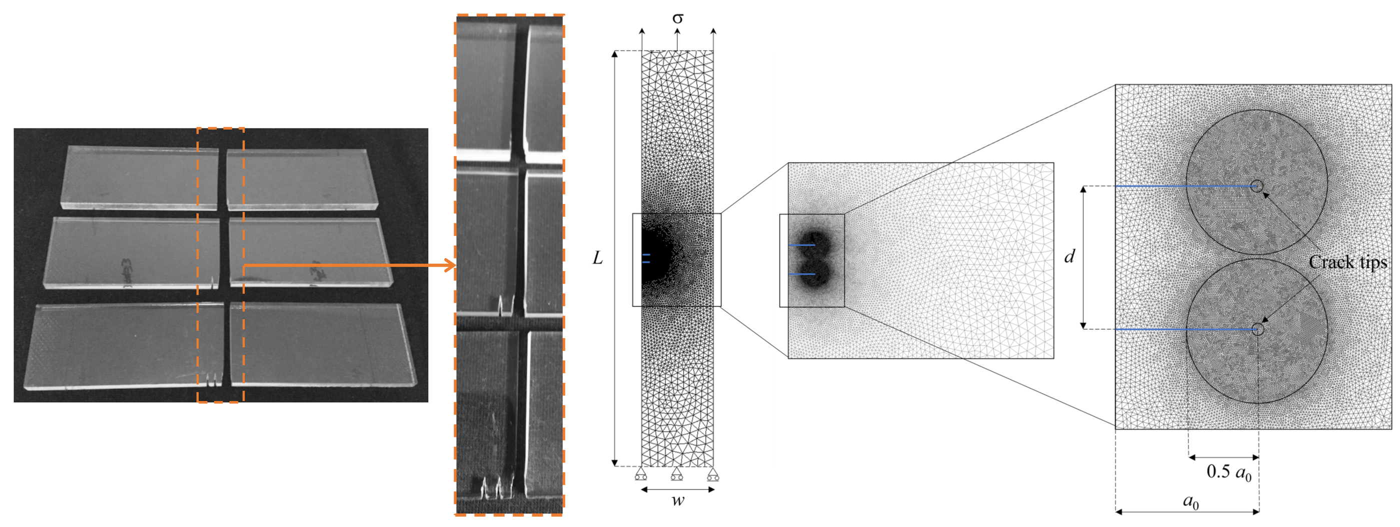

Fig. 6 Crack shielding: (a) Tested geometries.

Fig. 7 Finite element model for the doubly cracked plate.

№ *cracks*	$\sigma_{f,avg}$ [MPa]	σ_f - FFM [MPa]	Deviation %	σ_f - avg FFM [MPa]	Deviation %	σ_f -LEFM [MPa]	Deviation %
1	12.4	13.1	+5.6	12.8	+3.2	13.2	+6.5
2	15.7	16.7	+6.4	15.9	+1.2	17.1	+9.0
3	17.0	17.3	+1.8	16.5	–2.9	17.6	+3.5

Table 1 Failure stresses related to tensile PMMA cracked samples.

"Failure Size effect on Brazilian disks with a circular hole"

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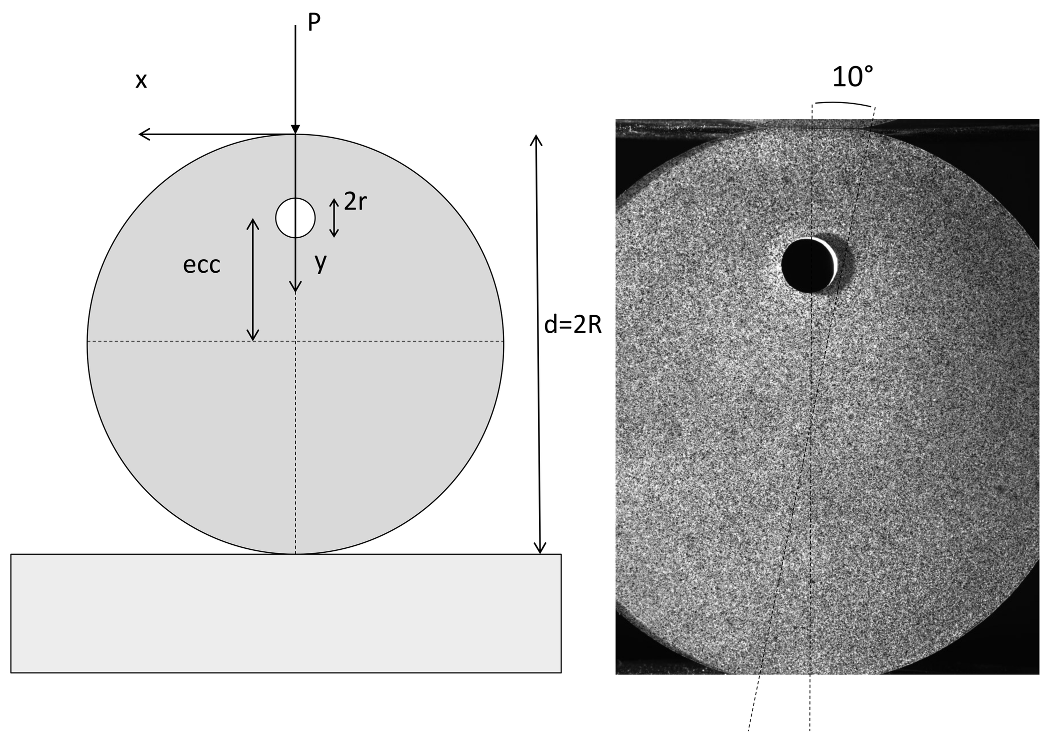

Fig. 8 Analysed Brazilian configuration.

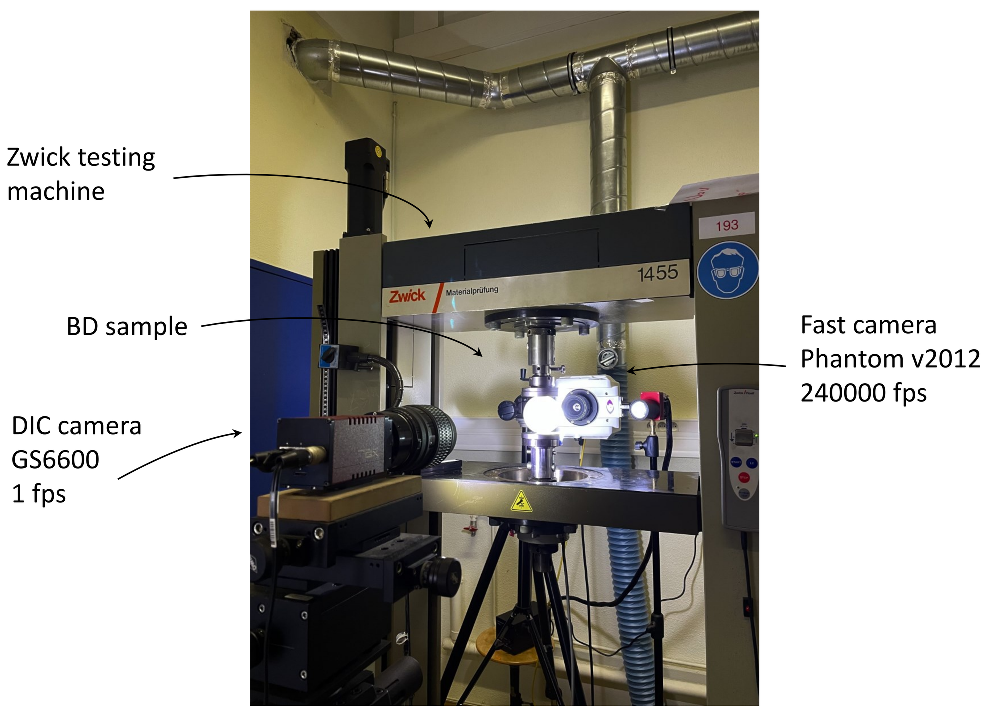

Fig. 9 Experimental setup.

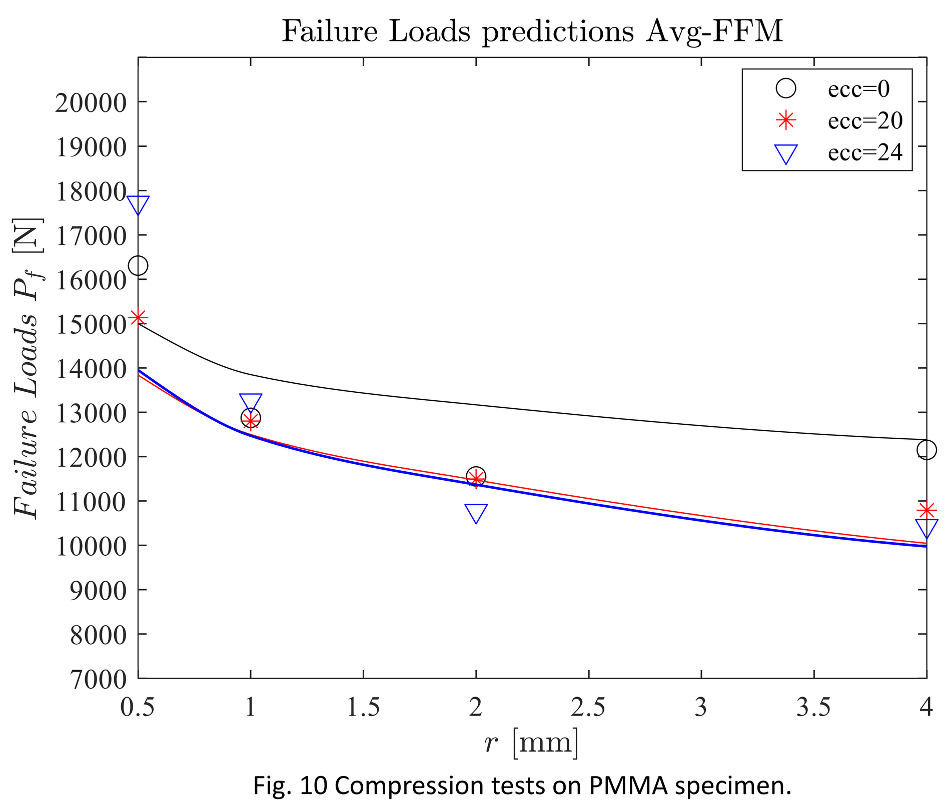

Fig. 10 Compression tests on PMMA specimen.

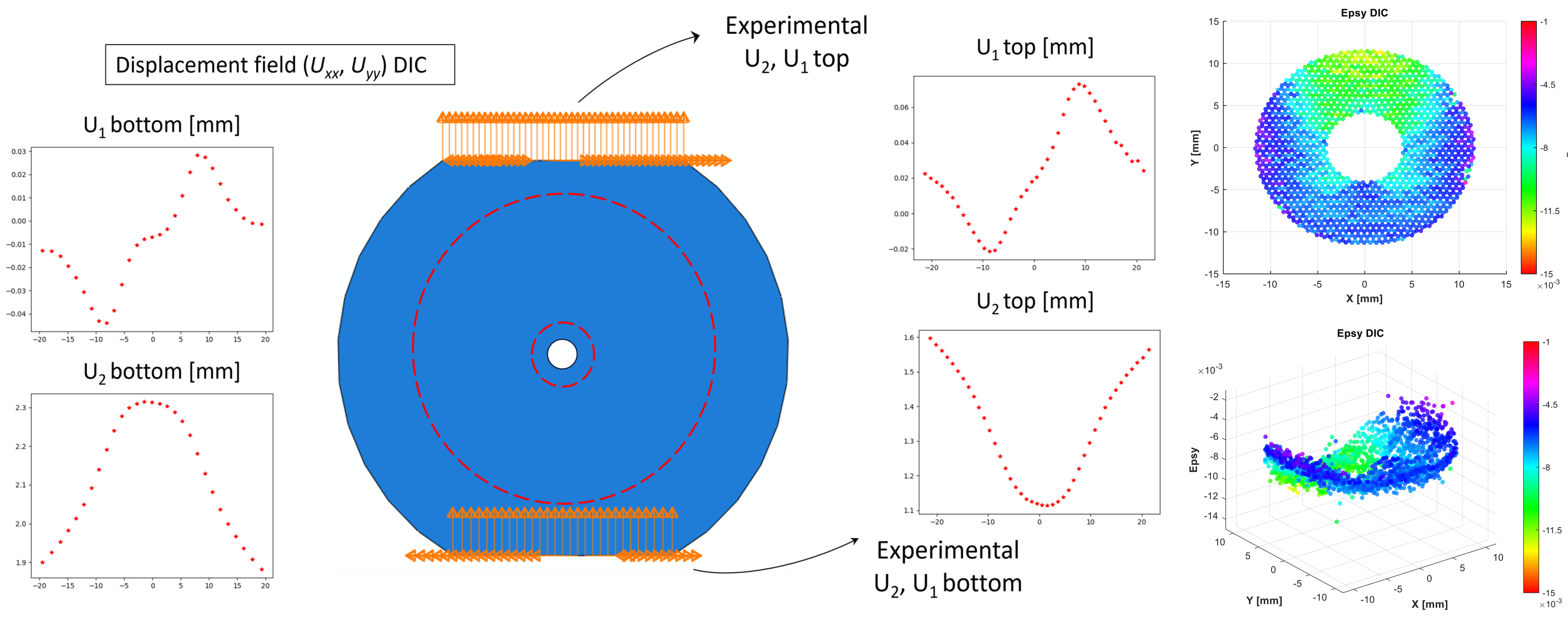

Fig. 11 Determination of elastic properties: comparison between the displacement field provided by DIC and the one given by FEA.

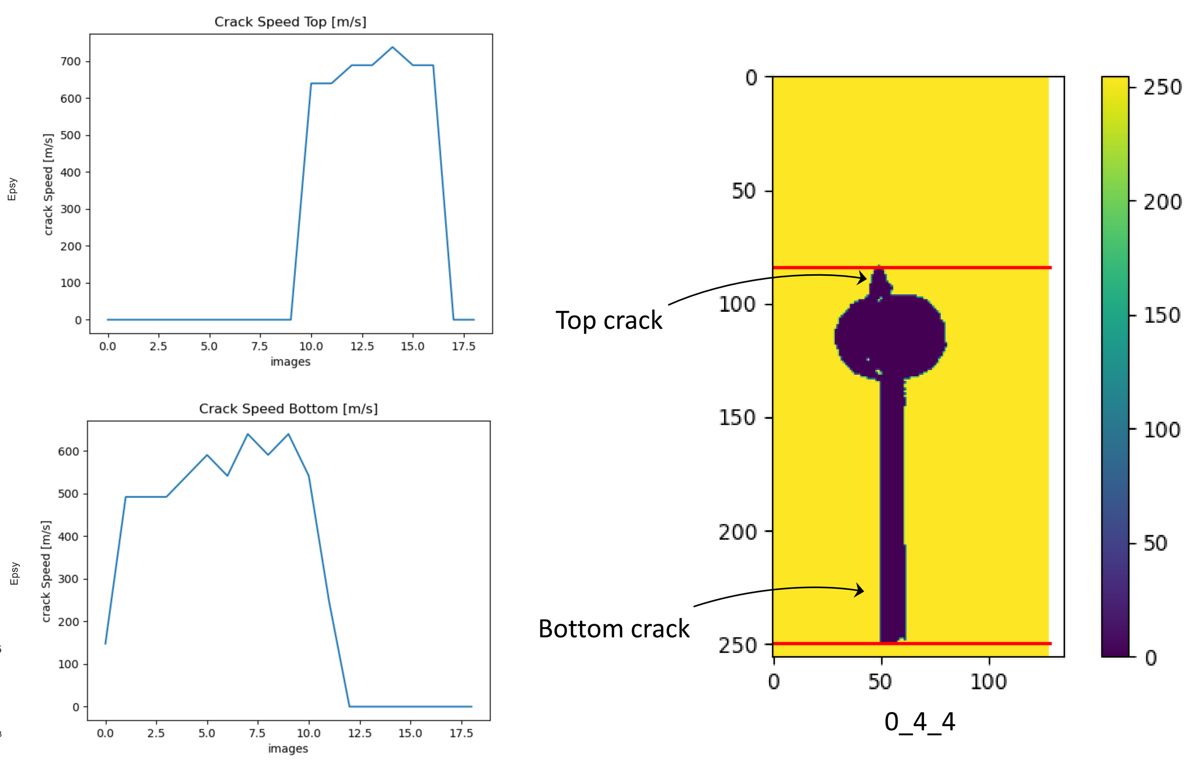

Fig. 12 Crack speed determination using Phantom v2012 Fast Camera with 240000 fps.

Publications & conferences

Published articles

- "Size effects on spheroidal voids by Finite Fracture Mechanics and application to corrosion pits", Ferrian et al. *Fatigue Fract Eng Mater Struct*. (2023) 46:875–885.
- "Ligament size effect in largely cracked tensile structures", Sapora et al. *Theoretical and Applied Fracture Mechanics* (2023) 125:103871.
- "Crack tip shielding and size effect related to parallel edge cracks under uniaxial tensile loading", Ferrian et al. *International Journal of Fracture* (2023) submitted.

Conferences and Workshops

- 3rd Newfrac workshop, ESIS European Structural Integrity Society TC16, Torino, January 17-20, 2023.
- 27th International Conference on Fracture and Structural Integrity (IGF27), Roma, February 21-24, 2023.
- Seventh International Conference on Computational Modeling of Fracture and Failure of Materials and Structures (CFRAC 2023), Prague, June 21-23, 2023.
- Euromech Colloquium 635 on Finite fracture mechanics, Lyon, September 12-14, 2023.

Indicatore Attività di Ricerca

Indicatore R: 133.42

50N: 125

Ore attività didattica

Hard skills score: 207.61

Soft skills score: 60

Total score: 287.21