Workshop « Soft Material Models »
les 01 et 02 juin 2023 à l'Ecole Centrale Casablanca, Maroc

FE fracture analysis of two elastomers NR and SBR using the integral J

Adel HAMDI[1], Zaineb BACCOUCH[2]

[1]Applied Mechanics and Engineering Laboratory (LMAI), National School of Engineers of Tunis (ENIT), Tunis el Manar University (UTM), TUNISIA.
[2] Laboratory of Electromechanical Systems (LES), National School of Engineers of Sfax (ENIS), University of Sfax, TUNISIA.

Abstract

The knowledge of fracture behavior of elastomers necessitates the understanding of crack initiation and propagation phenomena that represent difficulties related to the deformation of elastomers. The aim of this study is to analyse numerically the three-dimensional finite elements' method of fracture behavior of two rubber materials, which are filled Natural rubber (NR) and filled styrene butadiene rubber (SBR). The method was carried out on Single Edge Notched in Tension (SENT) and Pure Shear (PS) specimens based on energy parameters. It is particularly interested in the evolution of J-integral given by Rivlin and Thomas theoretical formulation.

Keywords: NR and SBR; Fracture; Integral J; SENT and PS specimens, FEM.

Methodology

We seek to calculate the integral J under monotonic loadings, of a hyperelastic material NR.

The formulation of the considered carbon-black filled NR is 100% SMR 10 CV and 50% N650 in mass.

To obtain a wide range of loading conditions, set of experiments composed of Equibiaxial Tension (ET) and Pure Shear (PS) tests were performed on thin specimens of 3 mm thickness (Fig. 1).

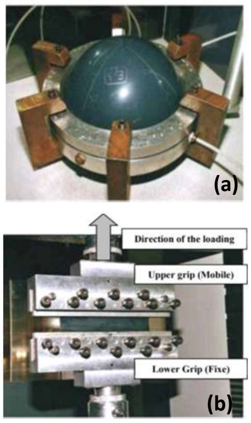

Fig. 1: Experimental set-up of: **(a)** Equibiaxial; **(b)** Pure Shear tests.

Also, an hydrostatic compression test have been achieved to determine the bulk modulus of the considered materials.
In Table 1 the mass compositions of these materials are summarized.

Tab.1: Formulations of the NB and SBR elastomers.

Compositions	NR	SBR
SMR 10 CV 60	100	--
SBR 1502	--	100
Carbon black N650	25	--
Carbon black N330	--	60

- The loading calculations were achieved by imposing incremental displacement at all the nodes located on one end of each specimen.
- We calculated the J-integral through four contours (Fig. 2).

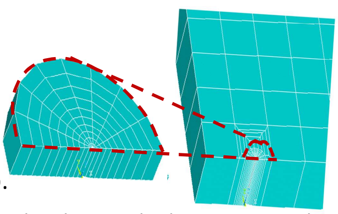

Fig. 2: Finite elements models of Single Edge Notched in Tension and Pure Shear specimens.

Results and discussion

As a function of crack sizes and for different strain levels:

- The plotted graphs show that the values of the J-integral become constant from the second contour (Fig. 3).
- The disturbance was marked in the values of the J-integral, which correspond to contour 1 located near the crack.
- The J-integral evolution of PS specimen presents a constant amount regardless of the crack size near the edge effect.

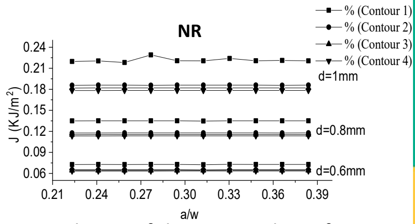

Fig. 3: Evolution of the J-integral as a function of the ratio a/w for PS tests.

This result verifies the linear form of the J-integral, equivalent to the energy T, given by the theoretical formulation of Rivlin and Thomas (Fig. 4).

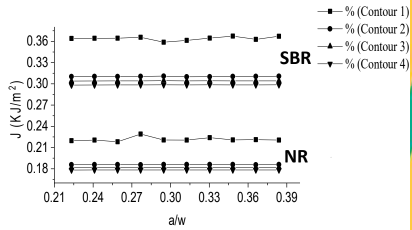

Fig. 4: Comparison between NR and SBR (d = 1mm).

- The J-integral is proportional to the values of loading conditions because the increase of those latter increases crack growth characterized by the parameter of Rice (Fig. 5).
- The small difference between NR and SBR was estimated for SENT specimens.

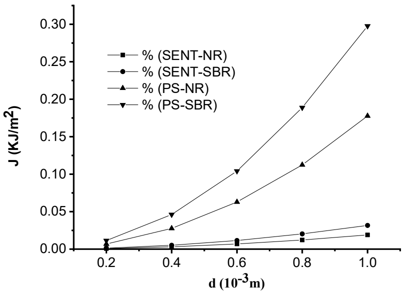

Fig 5. Evolution of the J-integral as a function of d for SENT and PS specimens (a/w = 0.34).

This result is related to the specimen geometry effects of the crack propagation.

Conclusion and perspectives

The results obtained by numerical and analytical analyses of fracture behavior in rubber materials NR and SBR, carried out on SENT and PS specimens, have led to the following conclusions:

- The J-integral, calculated far from the heavily deformed crack-tip, confirmed the property of independence from the contour of Rice's J integral demonstrated theoretically by Rice. *This property which is the first condition to satisfy this integral represents a fracture energy criterion.*
- Contrary to the results obtained with SENT specimens, the evolution of the J-integral for PS specimens presents a constant amount regardless of the crack size near the edge effect. *This result confirms the linear form of the J-integral expressed by the theoretical formulation of Rivlin and Thomas.*

References

1. Hamdi A., Boulenouar A., Baccouch Z., FE fracture analysis, using the integral J and tearing energy T parameters, of a natural rubber NR. *Poly. Eng Sci.*, 2021; 1-7.
2. Hamdi A., Naït Abdelaziz M., Aït Hocine N., Benseddiq N., Heuillet P., Fracture criteria of rubber like-materials under plane stress conditions, *Poly. Test.*, 2006, 25: 994-1005.
3. Hamdi A., Naït Abdelaziz M., Aït Hocine N. , Benseddiq N., A new generalized fracture criterion of elastomers under plane stress loading, *Poly. Test.*, 2007, 26: 896-902.

Centrale CASABLANCA