Transilvania University of Brasov
FACULTY OF MECHANICAL ENGINEERING

COMEC 2021

Brașov, ROMANIA, 21-23 October 2021

THE INFLUENCE OF INCLUSIONS ON THE ELASTIC PROPERTIES OF SOME PREPREGS

Horatiu Teodorescu-Draghicescu[1], Cezar Afilipoaei[1], Florin Teodorescu[2]

[1] Transilvania University of Brasov, ROMANIA, draghicescu.teodorescu@unitbv.ro cezar.afilipoaei@unitbv.ro

[2] Politehnica University of Bucharest, ROMANIA, florin.teodorescu@ltpc.pub.ro

Abstract: *Within this paper, the influence of the inclusions on the elastic properties of four types of random oriented Sheet Molding Compounds have been computed. A representative area element (RAE) has been considered in which the fiber is seen inserted in a 1 mm square of matrix. Various distributions of RAE features have been computed and then taken into account in simulation of elastic properties of these materials with different fibers volume fractions.*

Keywords: *Sheet Molding Compound, Representative area element, Prepreg, Elastic properties*

1. INTRODUCTION

During the last ten years, the Department of Mechanical Engineering within Transilvania University of Brasov has been involved in the research of the mechanical properties of various polymer matrix composites (PMCs). A short description of the most important papers and results are presented below. In the wide range of PMCs, the prepregs like Sheet Molding Compounds (SMCs) occupy a well-defined place in these researches. For instance, in case of a 27% fibers volume fraction SMC, the upper and lower limits of the homogenized coefficients have been computed [1]. A homogenization method as well as some averaging methods have been used to predict the elastic properties of these materials. Hysteresis behavior of polyester resin reinforced with randomly oriented glass fibers and ceramic particles has been determined in static cyclic tension-compression tests performed with various test speeds, load limits and number of cycles [2, 3]. The maximum hysteresis effect is recorded at 10 mm/min test speed. Mechanical properties of various composite laminates based on epoxy resin reinforced with glass, carbon and Kevlar49 fibers, subjected to off-axis loading system have been computed. These simulations are graphically presented [4]. Four types of composite laminates based on epoxy resin reinforced with Chopped Strand Mats (CSMs) of different specific weights and RT800 glass fabrics have been developed and subjected to three-point and four-point bend tests. Using FEA, the strain distributions of these laminates have been simulated and compared with experimental data [5]. Resistive stress analysis has been used also to determine the most important mechanical properties of four layers CSM reinforced epoxy resin subjected to four-point bend tests. Strain gages have been applied between layers and load-time distributions have been experimentally determined during tests [6]. Basic mechanical properties have been experimentally determined on twelve layers glass fabric-reinforced polyester resin specimens subjected to tensile loads on weft direction until break [7]. The most important mechanical properties have been also determined in a simple tensile test on a 0.4 mm thickness 2/2 carbon twill weave fabric impregnated with epoxy resin, used as skins for an advanced ultralight sandwich composite structure with expanded polystyrene as core [8]. Mechanical properties of glass fiber-reinforced HDPE and LDPE as well as carbon fiber-reinforced epoxy resin have been determined experimentally using three-point bend tests [9]. Stratimat 300 glass fibers with 300 g/m^2 specific weight has been used to reinforce Heliopol 9431ATYX_LSE resin in hand lay-up process. A 6 mm thick composite laminate plate with five layers has been cured from which nine specimens have been cut using a diamond powder mill being under protection of a specific cooling system [10]. A new unidirectional Torray T700 carbon fibers-reinforced composite laminate based on Huntsman XB3585 epoxy resin has been developed in Resin Transfer Molding process with applications in the automotive industry. Numerical simulations have been carried out on this type of laminate subjected to off-axis loading systems [11]. An experimental analysis of an advanced composite U-beam pultruded profile based on isophtalic polyester resin reinforced with unidirectional glass fibres and overlay veil has been carried out to determine its most important mechanical properties [12]. To increase the overall stiffness of a composite laminate is usual to use a polyester mat embedded as core in thin structures[13]. Mechanical behavior of natural fiber composites subjected to tensile test and dynamic mechanical analysis (DMA) have been performed also [14]. Other important results in the field of polymer matrix composites have been published in papers [15-17].

2. MATERIAL AND METHOD

Within this paper we have study the influence of the inclusions shape and orientation on the elastic properties of various prepregs like Sheet Molding Compounds (SMCs). As material we have used random oriented SMCs with various fibers volume fractions, namely R-SMC15, R-SMC27, R-SMC45 and R-SMC60. We have used a representative area element (RAE) of a prepreg in which the fiber is seen as an ellipsoidal inclusion in 1 mm square matrix. The specific features of the RAE as well as the intersection points of the inclusion with the coordinate axes system are presented in Figs. 1 and 2.

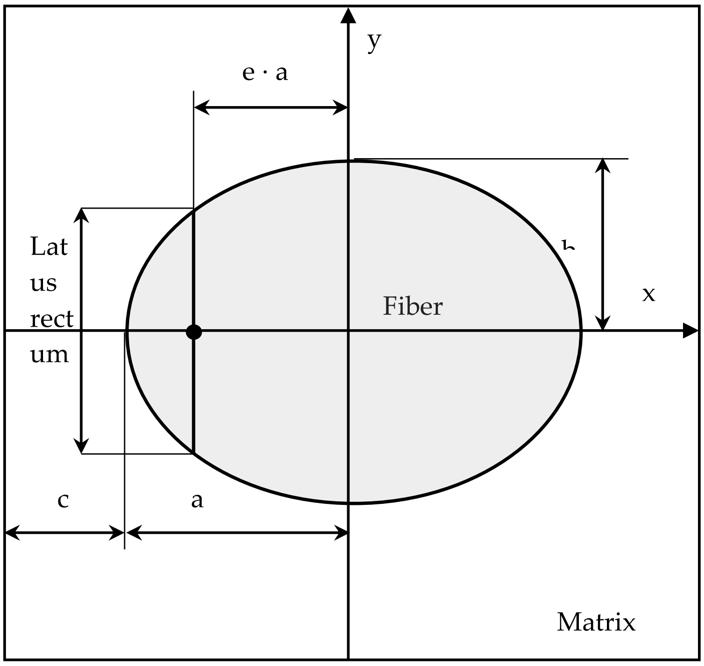

Figure 1: Ellipsoidal inclusion inserted in a 1 mm square matrix SMC

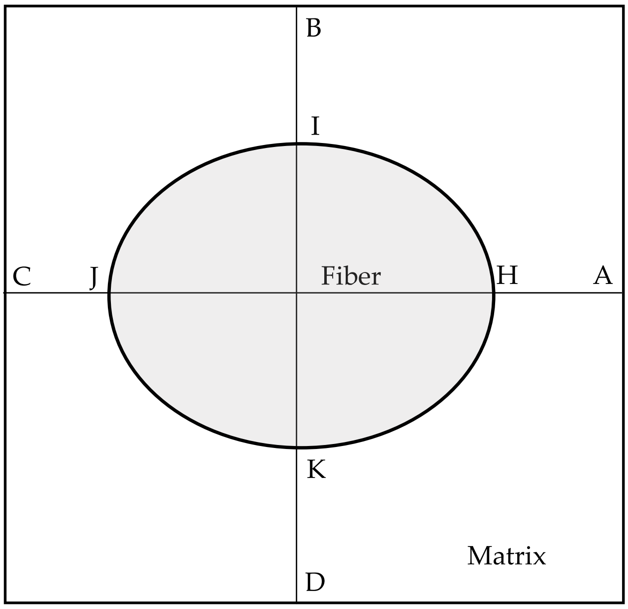

Figure 2: Intersection points of the inclusion with the coordinate axes system

The coordinates of points H, I, J, K for the angular variations ± 15 ° and ± 30 ° of the ellipsoidal inclusion with respect to the x-axis in case of b/a = 0.8 are given below. The ellipse area is $A = \pi ab$ and the ellipse eccentricity is $e = sqrt\ (1-b^2/a^2)$. The latus rectum (LR) of a conic section is the line segment that passes through the focus, is perpendicular to the major axis and has both endpoints on the curve. The LR presents the following expression: (2b^2/a). We have computed various distributions between the RAE relations.

	H	**J**	**I**	**K**
R-SMC15 (0°)	(0.244,0)	(-0.244,0)	(0,0.195)	(0,-0.195)
R-SMC15 (±15°)	(0.237,0)	(-0.237,0)	(0,0.196)	(0,-0.196)
R-SMC15 (±30°)	(0.223,0)	(-0.223,0)	(0,0.201)	(0,-0.201)
	H	**J**	**I**	**K**
R-SMC27 (0°)	(0.327,0)	(-0.327,0)	(0,0.262)	(0,-0.262)
R-SMC27 (±15°)	(0.318,0)	(-0.318,0)	(0,0.264)	(0,-0.264)
R-SMC27 (±30°)	(0.299,0)	(-0.299,0)	(0,0.27)	(0,-0.27)
	H	**J**	**I**	**K**
R-SMC45 (0°)	(0.423,0)	(-0.423,0)	(0,0.338)	(0,-0.338)
R-SMC45 (±15°)	(0.41,0)	(-0.41,0)	(0,0.34)	(0,-0.34)
R-SMC45 (±30°)	(0.386,0)	(-0.386,0)	(0,0.348)	(0,-0.348)
	H	**J**	**I**	**K**
R-SMC60 (0°)	(0.488,0)	(-0.488,0)	(0,0.39)	(0,-0.39)
R-SMC60 (±15°)	(0.474,0)	(-0.474,0)	(0,0.393)	(0,-0.393)
R-SMC60 (±30°)	(0.446,0)	(-0.446,0)	(0,0.402)	(0,-0.402)

3. RESULTS

The influence of the shape and orientation of ellipsoidal inclusion in case of various prepregs with different fibers volume fractions is presented in Figs. 3-10.

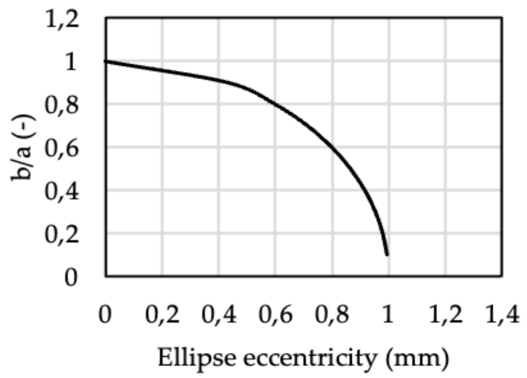

Figure 3: Distribution of ellipse axis ratio vs. ellipse eccentricity

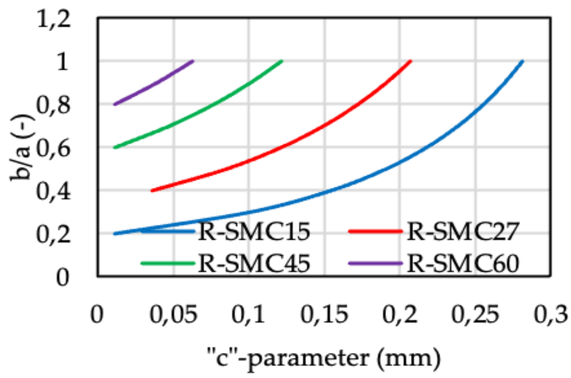

Figure 4: Distribution of ellipse axis ratio vs. „c”-parameter

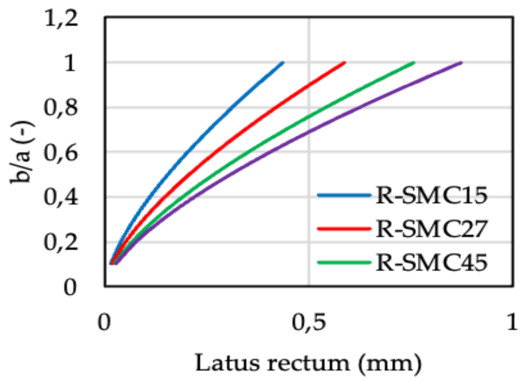

Figure 5: Distribution of ellipse axis ratio vs. Latus

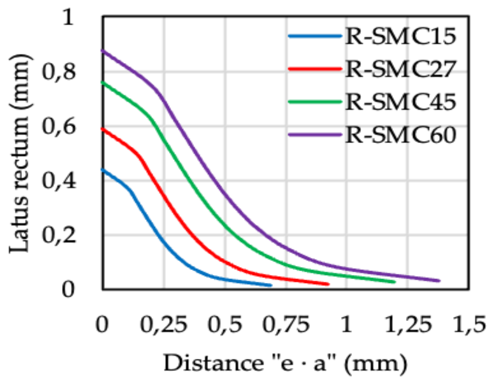

Figure 6: Distribution of Latus Rectum vs. "e · a"

Rectum

distance

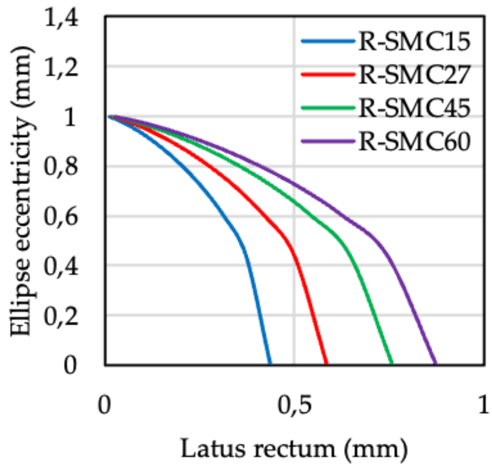

Figure 7: Distribution of ellipse eccentricity vs. Latus Rectum

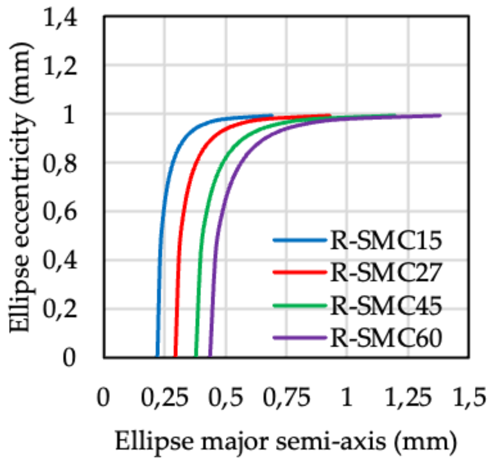

Figure 8: Distribution of ellipse eccentricity vs. ellipse major semi-axis

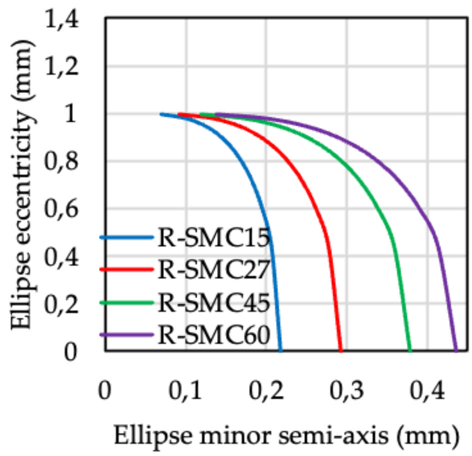

Figure 9: Distribution of ellipse eccentricity vs. ellipse minor semi-axis

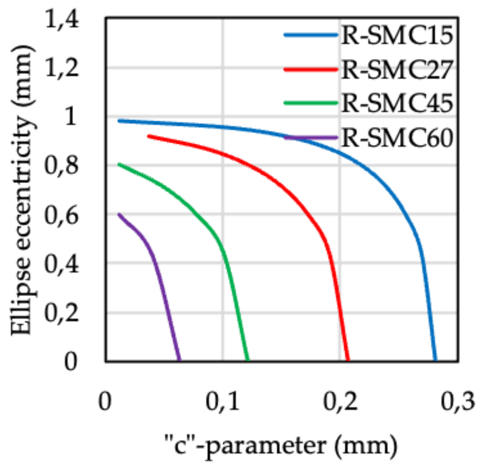

Figure 10: Distribution of ellipse eccentricity vs. „c"-parameter

Taking into account these results, following elastic properties have been computed and presented in Figs. 11-17.

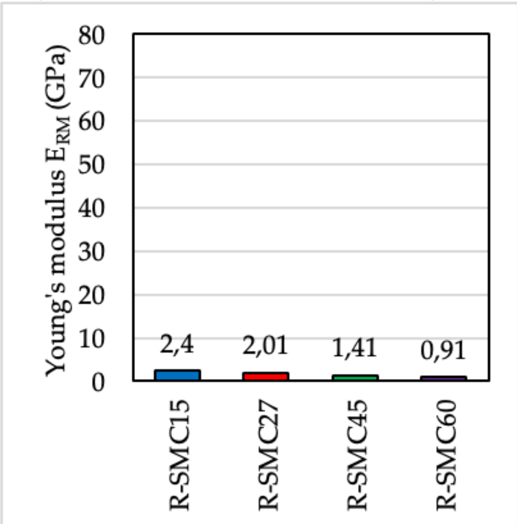

Figure 11: Distribution of replacement matrix Young's modulus

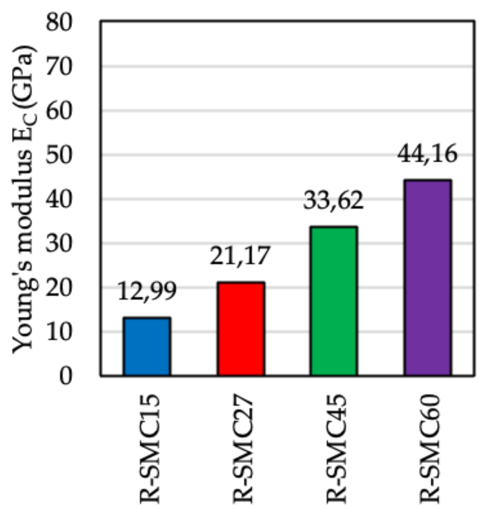

Figure 12: Distribution of composite Young's modulus

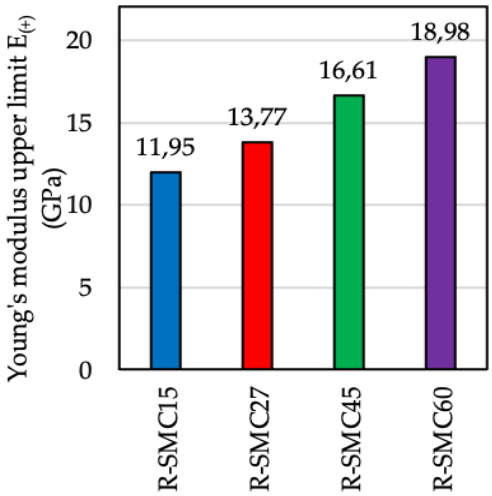

Figure 13: Distribution of Young′s modulus upper limit

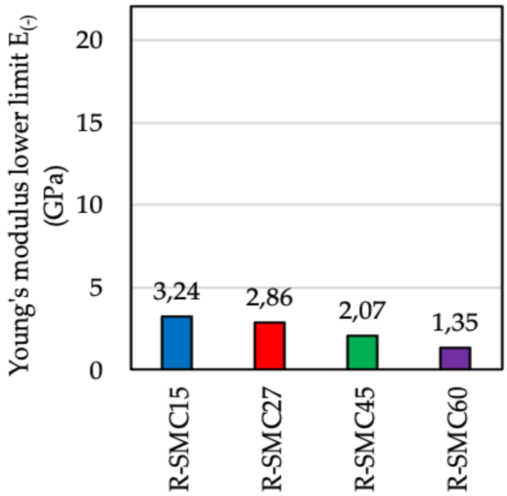

Figure 14: Distribution of Young′s modulus lower limit

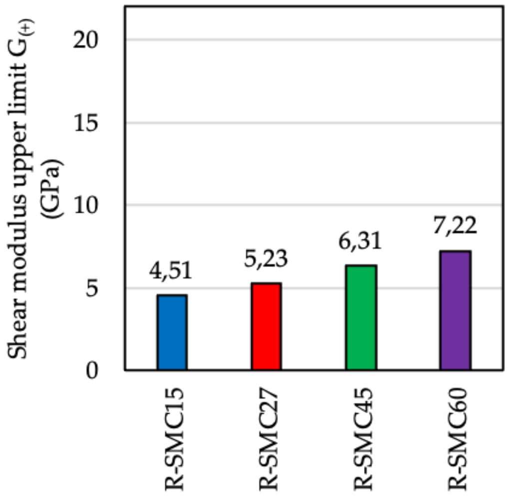

Figure 15: Distribution of shear modulus upper limit

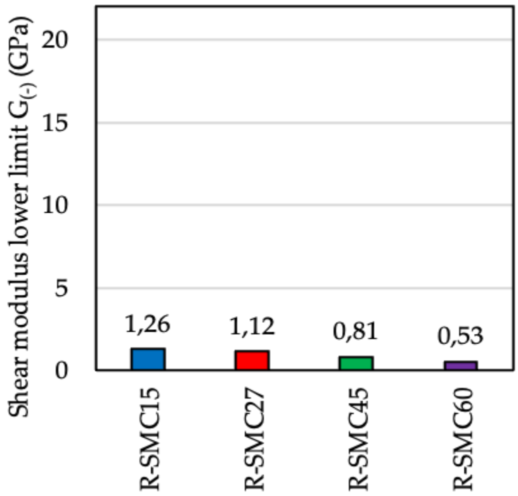

Figure 16: Distribution of shear modulus lower limit

4. CONCLUSION

The influence of shape and orientation of inclusions plays an important role in the elastic properties of random oriented Sheet Molding Compounds. It can be noticed that the replacement matrix Young′s modulus of various R-SMCs with different fibers volume fractions presents a decreased distribution with the increase of fibers volume fraction. The overall composite Young′s modulus shows an increased distribution with the increase of fibers volume fraction. The same trend has been noticed at the distribution of Young′s modulus and shear modulus upper limit with the increase of fibers volume fraction. Young′s modulus and shear modulus lower limit present a decreased distribution with the increase of fibers volume fraction.

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