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REINFORCEMENT SHAPE PARAMETERS FOR SHEET MOLDING COMPOUNDS

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Abstract: *Different shape parameters of reinforcement have been used to predict the elastic properties of a 27% fibers volume fraction Sheet Molding Compound (SMC). Since reinforcement in common SMCs presents an elliptical shape in different planes, two kinds of parameters have been chosen, first, the ratio between ellipse axes and second, the ellipse eccentricity as input data in computational approach. Various distributions between these parameters as well as their tendency equations have been computed. The numerical approach shows a significant anisotropy of 27% fibers volume fraction SMC.*
Keywords: *sheet molding compound, shape parameters, reinforcement, R^2-factor, anisotropy*

1. INTRODUCTION

Sheet Molding Compounds (SMCs) are prepregs in the form of a thermosetting resin mixed with reinforcement and additives, in which all components are manufactured in automated installations [1]. The obtained prepreg is then cut in required shape ready to be used in a compression molding process. SMCs present two significant advantages compared to composites manufactured in hand lay-up process, such as accurate control of resin-to-reinforcement ratio and the use of styrene free thermosetting resins. Prepregs reinforcement is either chopped strand mats or glass fabric impregnated with liquid epoxy or polyester or polyimide resin [2]. The resin system used in the SMCs is obtained, usually by dissolving catalyst into a solvent, after which the reinforcement is passed through a resin bath, subsequently removing excess resin. Such impregnated reinforcement is placed in an oven to evaporate the solvent and to carry out the resin curing in an intermediate stage. The SMC is then cooled and on its both sides a polyethylene film is applied, after which is wrapped. However, this method is rarely used due to environmental reasons. Another method is more often used, in which the viscosity of the resin is minimized by using temperature for a short period of time and then the reinforcement component is impregnated in the liquid resin, under the influence of vacuum. The aim of the paper is to develop reinforcement shape parameters to predict the elastic properties of a 27% fibers volume fraction SMC-R27 composite material. Other important aspects in the field of composite materials are presented in papers [3-14].

2. REINFORCEMENT SHAPE PARAMETERS

To predict the elastic properties of SMC-R27 composite material with 27% fibers volume fraction, which is a strong anisotropic composite, a representative area element has been considered formed by a square matrix of side 1, in which reinforcement material in form of an elliptical fiber of area 0.27 has been embedded. To lighten the computing method, to this kind of representative area element, following reinforcement shape parameters have been developed (Fig. 1):

- Ellipse great semi-axis, denoted with *a*;
- Ellipse small semi-axis, denoted with *b*;
- Distance from the great semi-axis to the margin of representative area element, denoted with *c*;
- Ellipse eccentricity, denoted with *e*.

In order to compute the distribution between these shape parameters, twenty ellipse *b/a* semi-axes ratios have been computed and used as input data to determine the tendency equation as well as their R^2-factor. The R^2-factor is called coefficient of determination and shows how much of the variance dependent variable is explained by the estimated equation. For a good adjustment of the regression equation to the computational data, it is necessary that this factor should be close to 1. The representative area element with some of the *b/a* semi-axes ratios has been presented in Fig. 2.

The intersection point coordinates of the ellipse great and small semi-axes with the x_1 and x_2 axes of the representative area element are important values taken into consideration as input data in the computational approach.

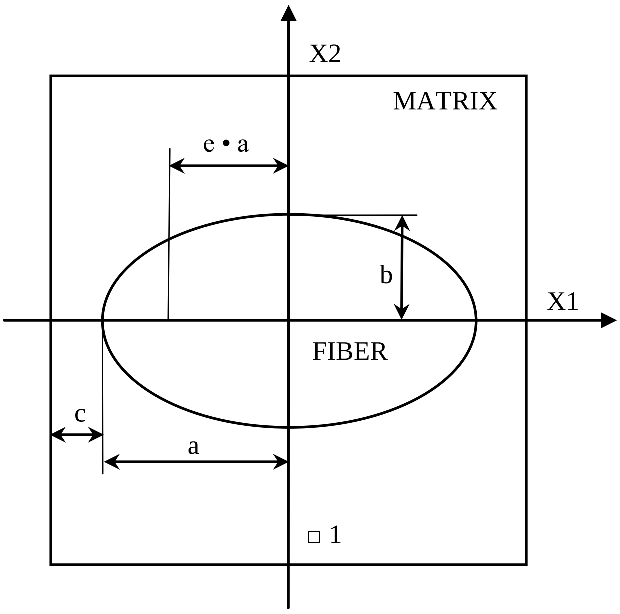


Figure 1: Representative area element of a SMC-R27 composite with reinforcement shape parameters

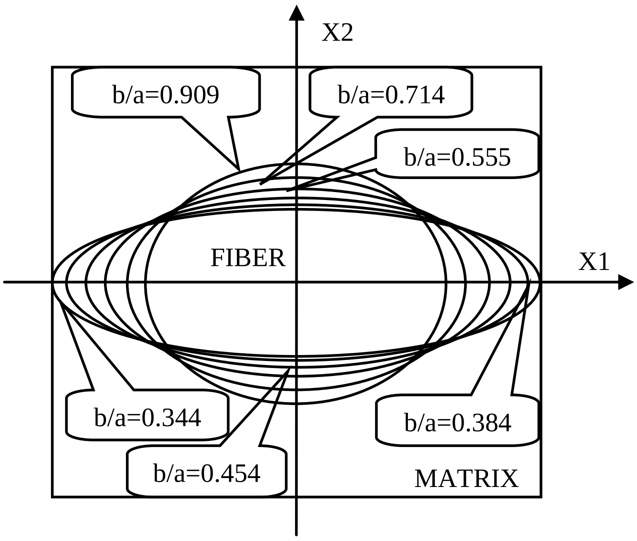


Figure 2: Representative area element with different *b/a* ratios of SMC-R27 elliptical reinforcement

3. RESULTS

Various reinforcement shape parameters distributions with their R^2-factor in case of a SMC-R27 composite with 27% fibers volume faction are shown in Figs. 3 – 9. Their tendency equations are presented below. Distribution of *b/a* versus ellipse eccentricity:

$$y = -17.042x^4 + 39.669x^3 - 34.48x^2 + 12.541x - 0.6804 \tag{1}$$

Distribution of *b/a* versus parameter *c*:

$$y = 154.54x^4 - 23.44x^3 + 7.4379x^2 + 1.2646x + 0.3432 \tag{2}$$

Distribution of parameter *a* versus *c*:

$$y = -0.9999x + 0.4999 \quad (3)$$

Distribution of parameter *b* versus *c*:

$$y = 3.9097x^3 + 0.2706x^2 + 0.3649x + 0.1708 \quad (4)$$

Distribution of parameter *c* versus ellipse eccentricity:

$$y = -53.878x^6 + 178.03x^5 - 233.1x^4 + 150.5x^3 - 47.89x^2 + 5.9647x + 0.207 \quad (5)$$

Distribution of parameter *a* versus ellipse eccentricity:

$$y = 54.304x^6 - 179.34x^5 + 234.64x^4 - 151.38x^3 + 48.136x^2 - 5.9913x + 0.293 \quad (6)$$

Distribution of parameter *b* versus ellipse eccentricity:

$$y = -12.559x^6 + 41.372x^5 - 54.097x^4 + 34.856x^3 - 11.122x^2 + 1.3731x + 0.293 \quad (7)$$

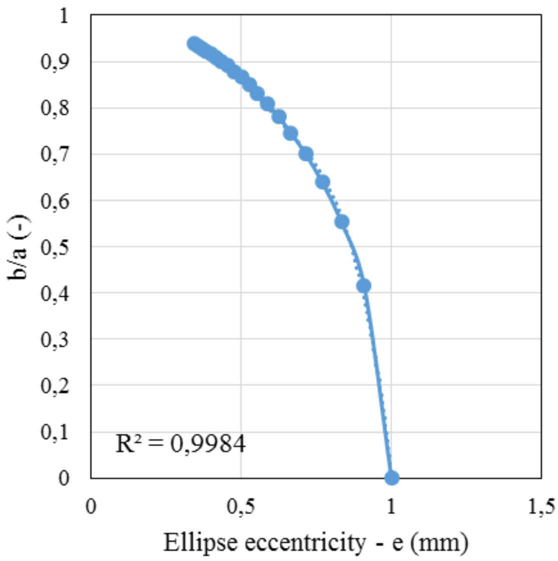


Figure 3: Distribution of *b/a* ratio according to ellipse eccentricity in case of a SMC-R27 composite

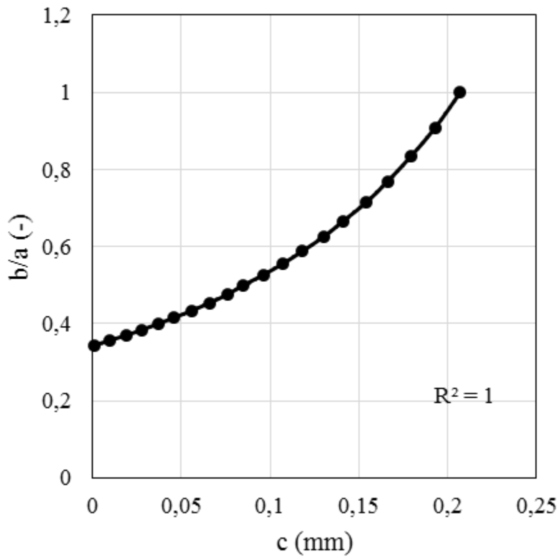
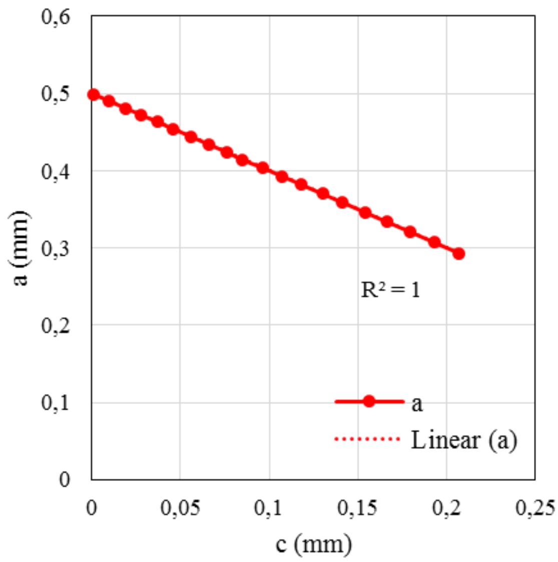


Figure 4: Distribution of *b/a* ratio according to parameter *c* in case of a SMC-R27 composite



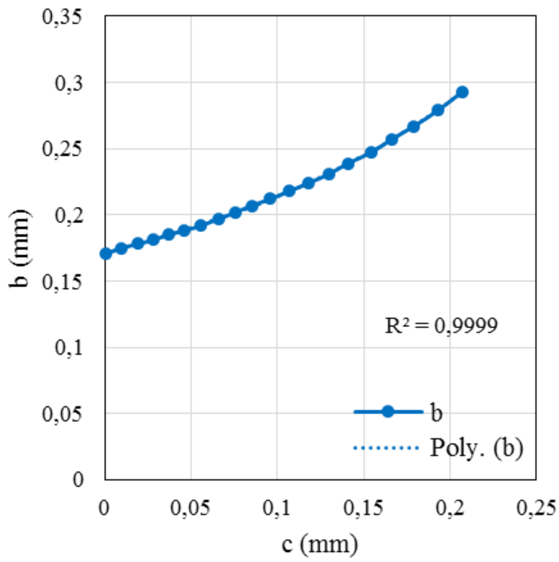


Figure 5: Distribution of parameter *a* according to parameter *c* in case of a SMC-R27 composite

Figure 6: Distribution of parameter *b* according to parameter *c* in case of a SMC-R27 composite

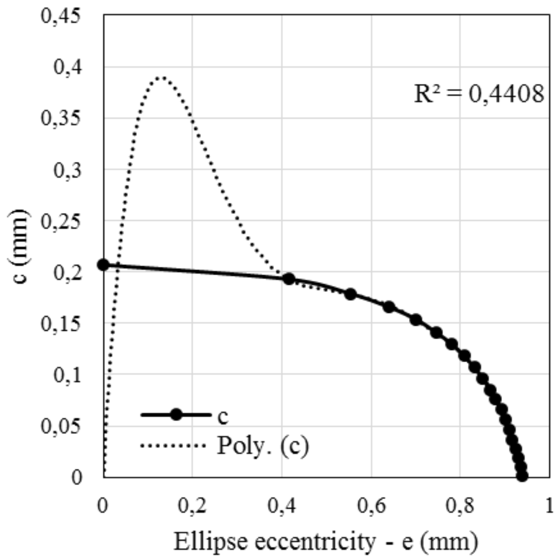


Figure 7: Distribution of parameter *c* according to ellipse eccentricity in case of a SMC-R27 composite

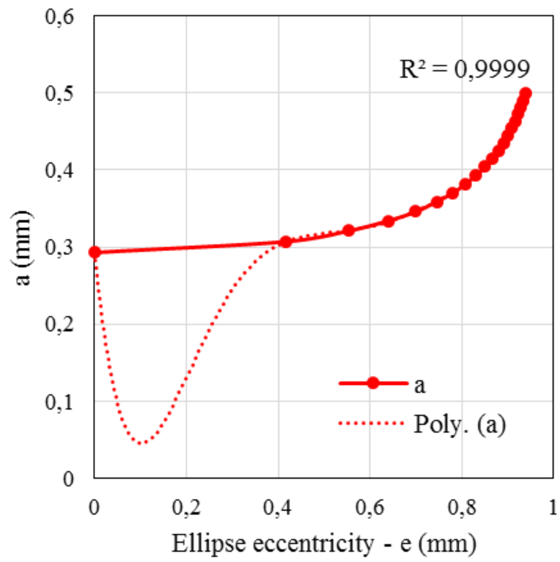


Figure 8: Distribution of parameter *a* according to ellipse eccentricity in case of SMC-R27 composite

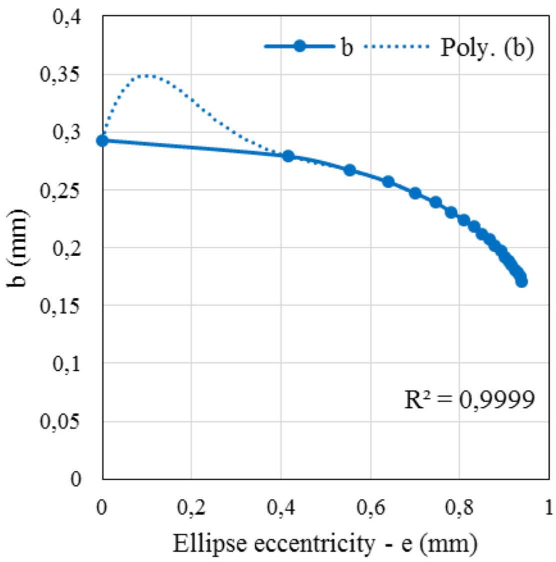


Figure 9: Distribution of parameter *b* according to ellipse eccentricity in case of SMC-R27 composite

4. DISCUSSION

It can be noticed that with the increase of ellipse eccentricity of the representative area element of SMC-R27 composite, the ellipse great semi-axis increases and the ellipse small semi-axis decreases, both distributions start from the same value, namely 0.293. Maximum values deviation 0.328 between ellipse great and small semi-axes occurs at an ellipse eccentricity 0.938. The distance distribution from the great semi-axis to the margin of the representative area element present a decrease tendency starting from 0.207 and having a maximum values deviation of 0.498. With the increase of ellipse eccentricity the distance distribution from great semi-axis to the margin of representative area element presents a more decreasing tendency than that of the distribution of ellipse small semi-axis, starting from 0.086 in case of cylindrical shape reinforcement and ending with 0.17 in case of maximum ellipse eccentricity. Parameter with the greatest maximum values deviation of 0.206, in terms of ellipse eccentricity, is the ellipse great semi-axis while the parameter with the smallest maximum values deviation of 0.122, is the ellipse small semi-axis. It can be noticed also that up to 0.416 ellipse eccentricity there are only two values in the distributions of reinforcement shape parameters while in the half of this interval there are fourteen values in these distributions.

5. CONCLUSION

Distributions of reinforcement shape parameters have been computed in case of a SMC-R27 composite material with 27% fibers volume fraction using a representative area element of this kind of composite. This computational approach will be used in further researches to determine upper and lower limits of the elastic properties of common prepregs.

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