SHEET MOLDING COMPOUNDS. CHOPPED STRANDS REORIENTATION MODELS

Florin Teodorescu[1]
[1] Politehnica University of Bucharest, Bucharest, ROMANIA, e-mail: florin.teodorescu@ltpc.pub.ro

Abstract: *This paper presents some original chopped strands reorientation models induced in the production of prepregs like Sheet Molding Compounds (SMC). The fibers reorientation due to their impact with the SMC conveyor belt depends on the fiber's contact angle with the resin paste. These chopped strands reorientation models put into evidence the cases in which this fibers reorientation is maximum and minimum. The speed of the fibers cutting unit and the moving production line of SMCs play an important role in this reorientation.*
Keywords: *sheet molding compounds, chopped strands, prepreg, fibers reorientation models, resin*

1. INTRODUCTION

One of the successful representatives of the group of fibers-reinforced plastics is the mixture composed of a continuous fabric of short glass fibers, resin, fillers and additives, also designated as prepreg of Sheet Molding Compound (SMC). In SMC materials, anisotropy and intense fibers orientations are formed during their processing. The increasing use of high mechanical and thermal SMC constructive elements makes it necessary to pay more attention to the occurrence of dispersion of values resulting from material characterization tests. Starting from the prescribed safety factors and the dimensioning of the structures, taking into account the real existence of the dispersion of the mechanical properties, one can achieve a systematic over-dimensioning in the construction of the SMC parts [1-5]. This can lead, in single cases, to an increase of up to five times the actual thickness of the construction element. This over-dimensioning is an inconvenience limiting the competitive, economic and technological capacity compared to conventional materials. In order to shorten the time needed to develop a SMC structure, the introduction of simulation programs has been accelerated. For a more accurate modeling of fibers-reinforced composite materials and to achieve a calculus closest to reality, a reproducibility of the material with clear dispersion areas must be ensured. It has been recorded several times that despite the many installations and technological developments, it has not been possible to produce a SMC semi-product with a reproducibility and satisfactory constancy. SMC prepregs are obtained as semi-finished products in so-called SMC impregnation plants. Prior to entering the SMC plant, colorants and thickeners are added to the resin. Of particular importance to the quality of the finished part is the achievement in the resin paste of regular and constant glass fiber moistening [6-10]. For this purpose, it is necessary to evacuate the air pores in the resin paste-glass fibers mixture. After the glass fiber resin impregnation process, the SMC blank is rolled onto a roll and covered with a foil that does not allow the styrene to evaporate. The rolls thus packed are stored at a constant temperature of between three and four weeks to raise the prepreg viscosity for further processing. Thickening is necessary to prevent the resin from fluidizing during processing and, on the other hand, it is necessary to ensure the transport of glass fibers through matrix to the flow processes of prepreg in mold. After the maturing period, the prepreg can be stored at ambient temperature or can be maintained for processing up to six months if the blank is cooled. A too long storage period is to be avoided because increasing the viscosity will limit the flow ability of the blank in mold. The SMC blank is further processed in hydraulic heated molds. Cuts from the blank are cut manually or automatically using a cutter, and then placed in mold. Depending on the desired flow directions, the molds can be covered 30% to 70% with multi-layered cuts. The amount of the required material is obtained from the prepreg weight plus an addition for the burrs. The working pressures (between 80 and 120 bar) are calculated according to the SMC recipe and the conditions imposed to the flow paths of the blank in mold. High amounts of glass fiber or filler, as well as long flowing spaces or the existence of ribs require high molding pressures. Typical temperatures of the die parts are between 145 and 155° C. At present, shortcut presses are used to process the SMC blank, adjusting the parallelism of the mold parts. The blank speed of deformation is adjusted so that the glass fibers are not affected by a too high flow rate. The viscosity of the pre-impregnated fabric must be chosen so as to achieve a simultaneous flow of the resin paste and glass fibers, and the forming cavity must be fully filled. When the molding process has ended, the pressing force acts at the maximum value. The pressure acts until the curing reaction (hardening) is complete [11-17].

2. CHOPPED STRANDS REORIENTATION MODELS

It is known that in the case of chopped glass strands mats, there is a dependence between the speed of the SMC production line and the fibers plane orientation in its advancement direction. The literature does not mention additional information on this chopped glass strands orientation effect, orientation induced in the SMC manufacturing process. Below are some models to highlight this phenomenon. The spatial orientation of a free-falling fiber to the SMC production line can be described in a Cartesian coordinate system through the angles α and β (Fig. 1). When a fiber having an orientation angle β > 0 reaches the SMC conveyor's belt, its contact point with the resin paste receives a speed component in the X direction and consequently a fiber's reorientation in the direction of the angle α (Figs. 2 and 3).

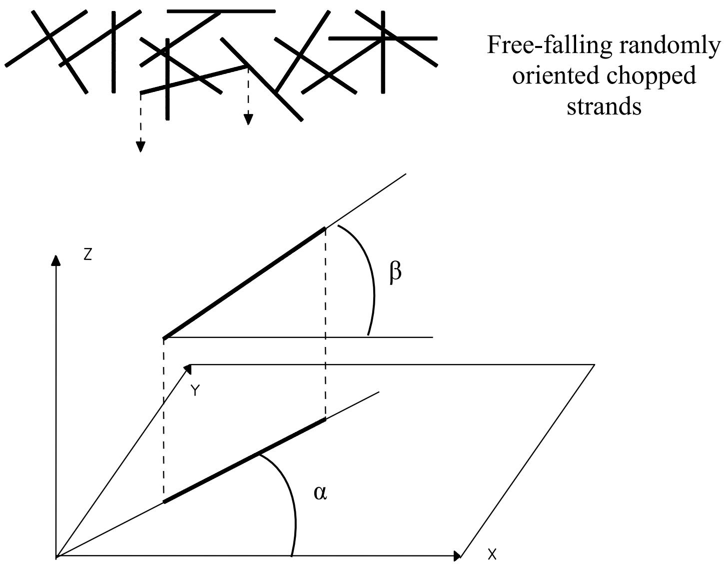

Figure 1: 3D free-falling fiber orientation on the SMC production line

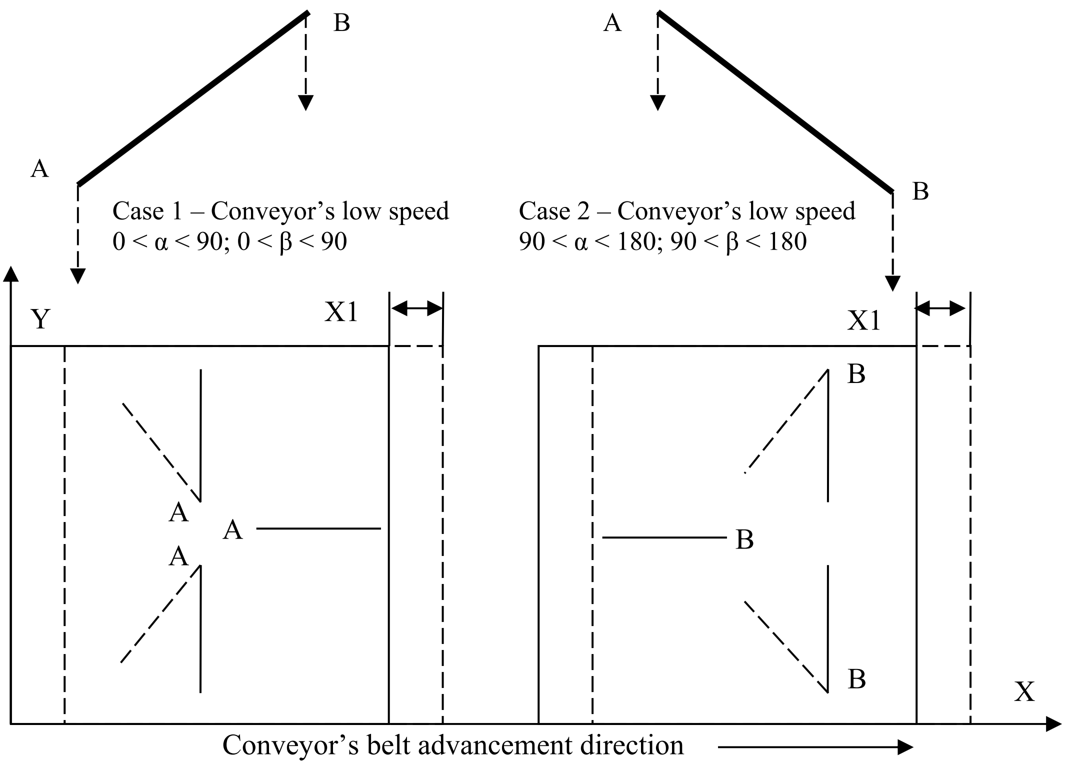

Figure 2: Conveyor's belt low speed influence on the fibers reorientation

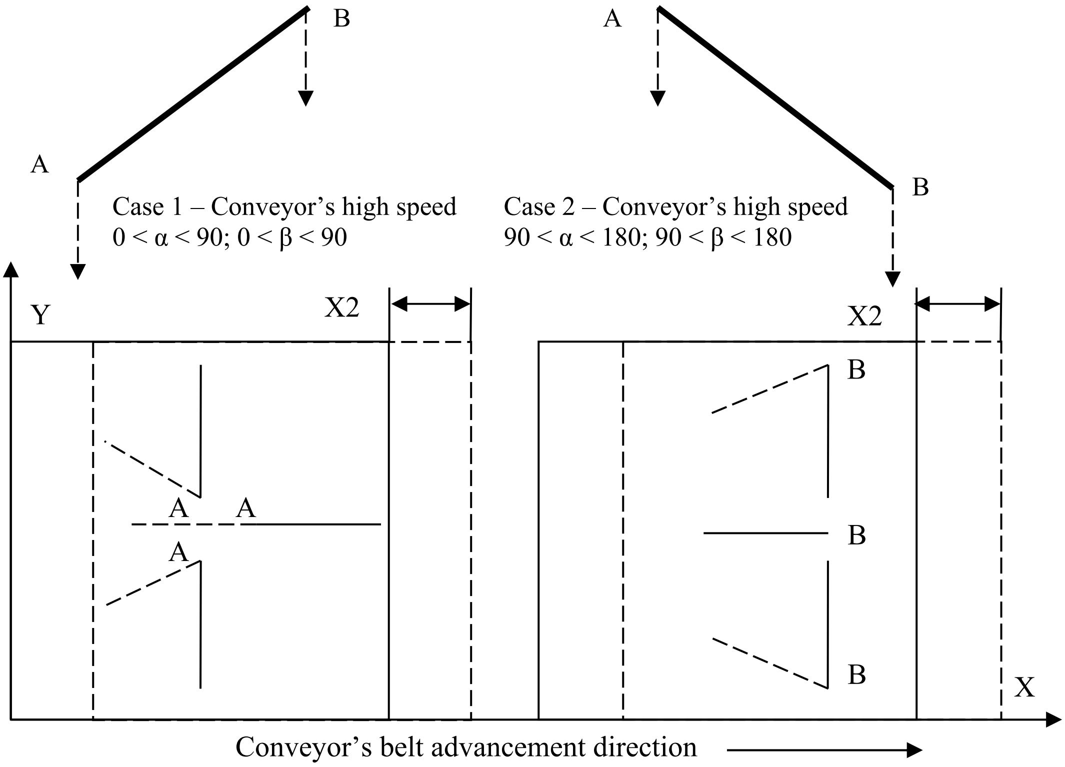

Figure 3: Conveyor's belt high speed influence on the fibers reorientation

In the hypothesis of neglecting possible interactions with other fibers, as well as by accepting a cylindrical shape of the fibers in order to estimate the resistance of the air, a single fiber, falling from a height of 300 to 800 mm, would reach a speed between 1.5 and 2.8 m/s at the impact with the SMC conveyor's belt. These values would be approximately 10 times higher than the usual production speeds (0.18 to 0.3 m/s) obtained in SMC plants.
Figs. 2 and 3 illustrate how the fibers being in free fall and randomly oriented in space are reoriented when the conveyor's belt is reached due to its relative movement. To the left of Fig. 2, the plausible case of a fiber reorientation is shown, fibers reaching the conveyor's belt with their "A" end (0 <α < 90; 0 <β < 90), in the case of a low speed conveyor' belt displacement. The fibers are exaggerated represented in the dotted position, being reoriented approximately perpendicular to the conveyor's belt advancement direction. In the second case (90 <α < 180°; 90 <β < 180), the fibers reorientation would result in an approximately parallel arrangement in the conveyor's belt advancement direction. The increase in the speed of SMC conveyor's belt, as shown in Fig. 3, could also lead in case one to a reorientation of the fibers, parallel to its direction of displacement. In SMC installations, in case of a small distance between the fibers cutting unit and the resin paste film, the fibers are not in a free fall but due to the peripheral speed of the cutting rollers (1.5 ... 4 m/s) and due to the fibers cutting process, a preferential orientation appears on their fall, perpendicular to the conveyor's belt advancement direction. In this case, a reorientation of the parallel fibers along the production line would be an inevitable consequence even at conveyor's belt low speeds. In fact, the fibers reorientation phenomenon is more complex because strong interactions occur between falling fibers.

3. CONCLUSION

Simple free-fall fibers tests on the SMC conveyor belt show that the fiber reorientation due to the impact depends on the fiber contact angle β with the resin paste. The smaller the angle β, the more the fiber reorientation given by the angle α is smaller. For an angle β = 90 (case in which the fiber falls perpendicular to the production line), the reorientation is maximum, and for β = 0 (where the fiber falls in the production line) the reorientation is null. From these simple models, it can be concluded that the proportion of fiber reorientation in the direction of production is primarily influenced by the distance and speed of the fibers cutting unit as well as by the speed of the SMC conveyor's belt.

REFERENCES

[1] Teodorescu-Draghicescu, H., Vlase, S., Homogenization and Averaging Methods to Predict Elastic Properties of Pre-Impregnated Composite Materials, Comp. Mater. Sci., 2011, 50, 4, 1310-1314.

[2] Teodorescu-Draghicescu, H., Vlase, S., Scutaru, L., Serbina, L., Calin, M.R., Hysteresis Effect in a Three-Phase Polymer Matrix Composite Subjected to Static Cyclic Loadings, Optoelectron. Adv. Mat., 2011, 5, 3, 273-277.

[3] Vlase, S. Teodorescu-Draghicescu, H., Motoc, D.L., Scutaru, M.L., Serbina, L., Călin, M.R., Behavior of Multiphase Fiber-Reinforced Polymers Under Short Time Cyclic Loading, Optoelectron. Adv. Mat., 2011, 5, 4, 419-423.

[4] Vlase, S. Teodorescu-Draghicescu, H., Călin, M.R., Serbina, L., Simulation of the Elastic Properties of Some Fibre-Reinforced Composite Laminates Under Off-Axis Loading System, Optoelectron. Adv. Mat., 2011, 5, 4, 424-429.

[5] Teodorescu-Draghicescu, H., Stanciu, A., Vlase, S., Scutaru, L., Călin M.R., Serbina, L., Finite Element Method Analysis Of Some Fibre-Reinforced Composite Laminates, Optoelectron. Adv. Mat., 2011, 5, 7, 782-785.

[6] Stanciu, A., Teodorescu-Draghicescu, H., Vlase, S., Scutaru, M.L., Călin, M.R., Mechanical Behavior of CSM450 and RT800 Laminates Subjected to Four-Point Bend Tests, Optoelectron. Adv. Mat., 2012, 6, 3-4, 495-497.

[7] Vlase, S., Teodorescu-Draghicescu, H., Călin, M.R., Scutaru, M.L., Advanced Polylite composite laminate material behavior to tensile stress on weft direction, J. Optoelectron. Adv. M., 2012, 14, 7-8, 658-663.

[8] Teodorescu-Draghicescu, H., Scutaru, M.L., Rosu, D., Calin, M.R., Grigore, P., New Advanced Sandwich Composite with twill weave carbon and EPS, J. Optoelectron. Adv. M., 2013, 15, 3-4, 199-203.

[9] Modrea, A., Vlase, S., Teodorescu-Draghicescu, H., Mihalcica, M., Calin, M.R., Astalos, C., Properties of Advanced New Materials Used in Automotive Engineering, Optoelectron. Adv. Mat., 2013, 7, 5-6, 452-455.

[10] Vlase, S., Purcarea, R., Teodorescu-Draghicescu, H., Calin, M.R., Szava, I., Mihalcica, M., Behavior of a new Heliopol/Stratimat300 composite laminate, Optoelectron. Adv. Mat., 2013, 7, 7-8, 569-572.

[11] Heitz, T., Teodorescu-Draghicescu, H., Lache, S., Chiru, A., Calin, M.R., Advanced T700/XB3585 UD carbon fibers-reinforced composite, J. Optoelectron. Adv. M., 2014, 16, 5-6, 568-573.

[12] Teodorescu-Draghicescu, H., Vlase, S., Stanciu, M.D., Curtu, I., Mihalcica, M., Advanced Pultruded Glass Fibers-Reinforced Isophtalic Polyester Resin, Mater. Plast., 2015, 52, 1, 62-64.

[13] Scutaru, M.L., Teodorescu-Draghicescu, H., Vlase, S., Marin, M., Advanced HDPE with increased stiffness used for water supply networks, J. Optoelectron. Adv. M., 2015, 17, 3-4, 484-488.

[14] Modrea, A., Gheorghe, V., Sandu, V., Teodorescu-Draghicescu, H., Mihalcica, M., Scutaru, M.L., Study of a New Composite Material Rt800 Reinforced with Polyte 440-M888 in Endurance Conditions, Procedia Technology, 2016, 22, 182-186.

[15] Teodorescu-Draghicescu, H., Gheorghe, V., Munteanu, R., Szava, I., Modrea, A., Advanced RT300 Glass Fabric/Polylite Composite Laminate Simulation, Procedia Engineering, 2017, 181, 293-299.

[16] Teodorescu-Draghicescu, H., Scarlatescu, D., Vlase, S., Scutaru, M.L., Nastac, C., Advanced high-density polyethylene used in pipelines networks, Procedia Manufacturing, 2018, 22, 27-34.

[17] Stanciu, M.D., Ardeleanu, A.F., Teodorescu-Draghicescu, H., Reverse engineering in finite element analysis of the behaviour of lignocellulosic materials subjected to cyclic stresses, Procedia Manufacturing, 2018, 22, 65-72.