The 4th International Conference
″Advanced Composite Materials Engineering ″
COMAT 2012
18- 20 October 2012, Brasov, Romania

SEM STUDY ON FRACTURE BEHAVIOR FOR PA 6 COMPOSITES USED ON AUTOMOTIVE PARTS

A.D. Botezatu*, M.I. Ursu, O.E. Gradin, M.C. Rusu
Department of Materials Engineering, Renault Technologie Roumanie,
*domnica-angelica.botezatu@renault.com

Abstract: *This work presents a study on failure behavior for PA 6 matrices reinforced with different type of glass charge. SEM analysis of the fracture surfaces from reinforced polymers revealed differences between fracture behaviors due to reinforcement's type, taking into account the contact surface between the polymeric matrices and glass charge. PA 6 samples reinforced with glass fibers and glass spheres were analyzed. For polymeric matrix reinforced with glass spheres it was observed a fracture behavior represented by ductile faces. Matrices reinforced with long glass fiber showed a fragile fracture behavior due to the plasticization effect of the polymer. A scanning electronic microscope (SEM) analysis was used to visualize the damage process on the crack faces.*

Keywords: *PA6 composite, SEM analysis, glass fibers reinforced polymer, fracture behavior*

1. INTRODUCTION

Polymer composites represent an important category of materials used in automotive industry due to their advantages compared to traditional materials: improved physical - mechanical properties and non-expensive processing. One of most significant class of polymeric composites is represented by the fiber reinforced polyamides composites, which are able to offer strength and toughness comparable or better than traditional metallic materials. Having a lower density, specific strength and modulus these fibers reinforced polyamides could be considered good substitutes for metals in many weight-critical applications [1-3].

As it is already known, polyamides represents polymers with good mechanical properties, high strain and wear strength [4-5]. There are many studies in literature concerning the glass fibers reinforced polyamides which showed that the good mechanical properties are given by the matrix and glass fibers properties, combined with the load transfer capacity at the interface matrix - glass fibers [6].

Glass fibers mainly used for glass-reinforced plastics are obtained by fusion spinning of alumino-borosilicate glass having in its composition less than 1 wt% alkali oxides [7]. The incorporation of short and long glass fibers in polyamide 6 matrix increased elastic modulus, work of fracture and flexural strength [4-7].

A large number of auto vehicle parts (dashboard elements, break pedals, fans, handles etc.) based on glass fibers reinforced PA 6 give a significant weight reduction of cars, resulting a higher performances and lower fuel consumptions. During the service life of the cars, the vehicle parts are submitted to impact, cyclic loads or vibrations (low or high intensity). The influence of these factors could lead to their failure in service and their replacement, consequently.

Various parameters affect the fracture behavior of glass fibers reinforced PA6 composites, including the impact velocity, the specimen geometry, the impactor size, impact energy, clamping mode, the matrix properties, and the reinforcement geometry. There are numerous possible modes of damage in polymeric composites: matrix deformation, micro-cracking, interfacial debonding, lamina splitting, delamination, fiber breakage and fiber pull-out. In some of the cases when the damage cannot be visually detected, damaged components will continue to fulfill their function unless the damage obviously affects the safety of the structure or aesthetic aspect [8-10]. Taking into account these aspects, clearly results why it is very important to predict and to understand the failure behavior in the damaged component during its service life.

The objective of this paper is to investigate the fracture behavior of two types of glass fibers reinforced PA 6 (30¨% GF and 20%GS – 10%GF). Morphology and fractography were done using scanning electronic microscopy (SEM).

2. RESULTS AND DISCUSSION

A large number of studies have indicated that plastic deformation of fiber-reinforced polyamides is governed by the nature of fibers, its percentage, size, shape and orientation in the polymer matrix [11,12]. Simultaneously, the fragile or ductile behavior of the fiber reinforced polymer composites is conditioned by the thickness of the material subjected to stress (Figure 1). Thus, a thick material will limit the detachment phenomena due to a high level of shear shrinkage into the constraint area, favoring a fragile fracture of the material.

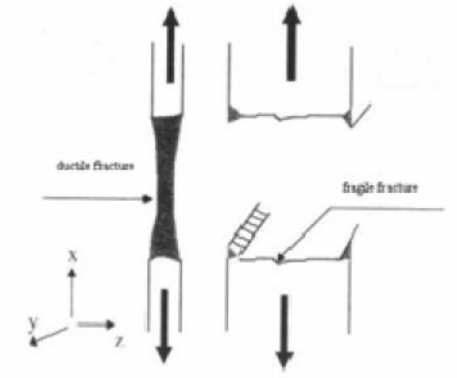

Figure 1: The influence of material thickness on the fracture behavior

The investigations of the fracture behavior presented by this paper were carried out on different vehicle parts based on polyamide 6 composite reinforced with glass fibers and glass spheres. The fracture behavior was investigated by SEM analysis and it was focused on the influence of the type of glass charge.

Representative SEM micrographs of the surface from a fractured 30% glass fibers reinforced polyamide 6 composite are presented in Figure 2. Short glass fibers are intimately mixed in the matrix and are distinguishable. The fibers are preferentially aligned in flow direction for injection molded part. Both the micrographs show that most of the glass fibers are pulled out (see the pull out fibers and pull out holes). The fibers surface seems to be smooth and without any presence of residual matrix indicating a poor adhesion between glass fibers and PA 6 matrix, most probably due to the non-treatment of the fibers. Thus, the fracture takes place at the interface matrix – fiber. These characteristics clearly show a brutal fragile fracture for the 30% GF reinforced PA 6 composite.

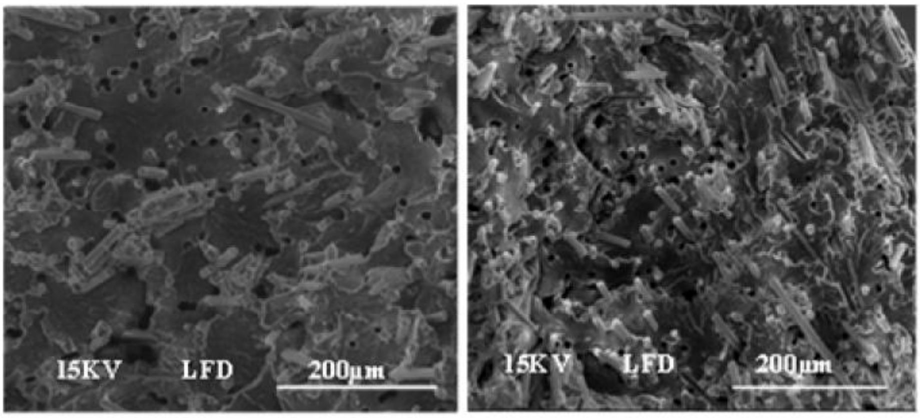

Figure 2: Scanning electron micrographs of brutal fragile fracture for 30% GF reinforced PA 6

The glass fibers take up greater stress in the composite, reducing the matrix stress, which is too small to promote matrix-governed deformation such as rubber cavitations and matrix shear yielding. In contrast, the micrographs from Figure 3 show ductile fracture behavior further reduced in the ligament region of the matrix. Some plastic deformation can be observed in the matrix ligaments. This kind of fracture behavior mostly appears in the propagating area of the crack. After a ductile behavior presented in the propagating area, the crack is propagated into the rest of the polymer matrix following a brutal fragile behavior.

Figure 4 represents scanning electron micrographs of a fracture behavior of 20% glass spheres and 10% glass fibers reinforced polyamide 6 composite. Analysis of these cracked surfaces puts in evidence a fragile fracture behavior, poorly revealed on this type of material. Glass fibers and glass spheres are mixed in the matrix and are clearly distinguishable. The fracture behavior is accompanied with noticeable de-bonding between the matrix and the reinforcing fibers. However, the adhesion between glass spheres and PA 6 matrix appears to be stronger. This observation is indicative of a strong interface with good stress transfer from the polymer matrix to the glass spheres, due to a higher contact between the glass spheres and the PA 6 matrix.

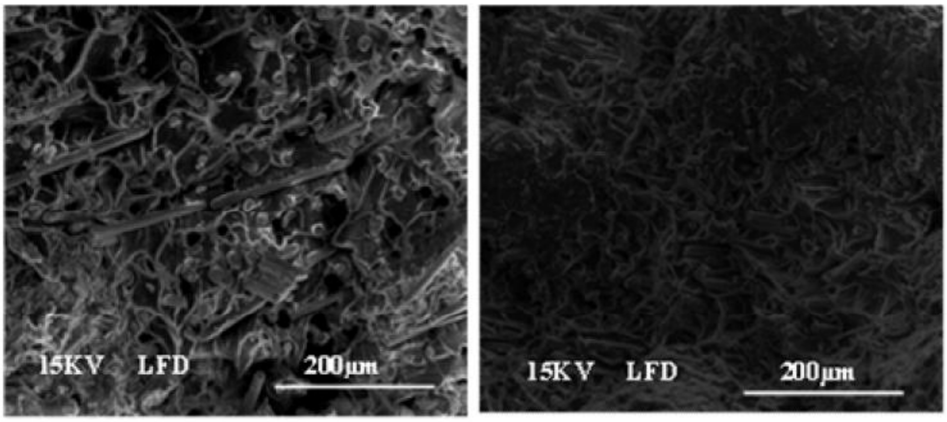

Figure 3: Scanning electron micrographs of ductile fracture for 30% GF reinforced PA 6

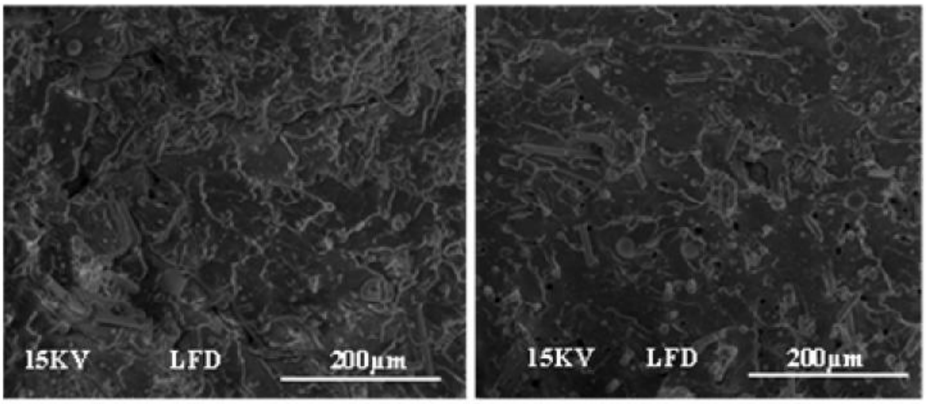

Figure 4: Scanning electron micrographs of a fragile fracture for 20% GS – 10% GF reinforced PA 6

Figure 5 presents a ductile fracture for the 20% glass spheres and 10% glass fibers reinforced polyamide 6 composite. Ductile fracture is preferred in most applications and is characterized by an extensive plastic deformation ahead of crack (necking). In these cases, the crack resists further extension unless applied stress is increased. The ductile behavior of fracture is accompanied by slow propagation and important energy absorption before fracture.

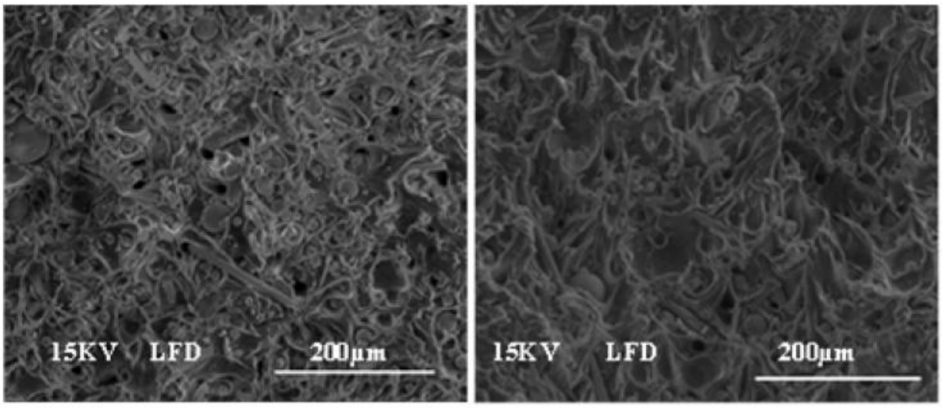

Figure 5: Scanning electron micrographs of a ductile fracture for 20% GS – 10% GF reinforced PA 6

In general, three main steps are distinguished for the ductile fracture behavior: formation of micro-voids, growth of these voids and formation of the shear bands. At microscopic scale ductile fracture surfaces are represented by rough and irregular areas, consist in micro-voids and dimples. The ductile fracture behavior is a slow process giving a large time for the problem to be corrected. Also, due to the high plastic deformation, more strain energy is needed to cause ductile fracture.

3. CONCLUSION

In this study, the effect of glass charge on fracture behavior of the PA 6 composites was investigated using scanning electron microscopy (SEM). Differences have been observed in the fracture behavior of glass fibers reinforced PA 6 and glass spheres reinforced PA 6.

The crack faces were observed into various micrographs illustrating the type fracture for the analyzed materials: micro-cracks, matrix cracks, fracture at the interface polymer matrix – glass charge and fibers crack. For the 30% glass fibers reinforced polyamide 6 were observed micro-cracks accompanied by de-bonding polymer matrix – glass fibers.

For the 20% glass spheres and 10% glass fibers reinforced polyamide 6 composite were observed a good adhesion between glass spheres and polymer matrix.

In conclusion, the 30% GF reinforced PA 6 composite presents a brutal fragile fracture behavior, while a ductile fracture behavior is corresponding to the 20% glass spheres and 10% glass fibers reinforced polyamide 6.

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