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USING THE GLASS FIBRES IN RECYCLING AGRICULTURAL PLASTIC WASTE

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Abstract: The wide-spread presence of plastic material in municipal and agricultural waste has significantly raised the ecology concern in Europe leading to laws and regulations aimed at controlling and reducing waste production, encouraging recycling and reuse as well. Recycling of plastic waste is not new but is a slowly developing process because using recycled materials is limited due to worse properties of recycled plastics if compared to virgin ones. The mechanical recycling of polymers determines a loss of some of their original chemical, physical and mechanical properties due to the role played by some of the degradation factors they were subjected to during their working life. One of the possibilities to improve the properties of plastic products is using diverse fillers like glass or carbon fibres. In this paper, the properties of plastic profiles obtained through mechanical recycling of agricultural plastic material mixed with glass fibres (70% LDPE + 30% glass fibres) were analyzed. The results of the tensile, bending and compression tests here reported show that the mixture of recycled plastic from agricultural application with a suitable different material could be considered as an interesting option for the improvement of the mechanical characteristics

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of these new regenerated products, paving the way to an increase in the sustainability of the agricultural applications.

Key words: *agricultural plastic waste, recycling, plastic bars, glass fibres, mechanical properties.*

INTRODUCTION

The increased use of plastic in agriculture, especially in horticulture and protected cultivation, generates large quantities of agricultural plastic waste that needs to be dealt with. This created a growing concern about the ecology and energy sustainability of the agricultural production [9]. Some data suggest that agriculture, in Europe, is responsible for using 47.5 Mt of plastics in 2007 [2].

In the scientific community, it is common opinion to consider the mechanical recycling as one of the most appropriate systems for the management of plastic waste and by enabling its re-using [1]. Recycling of mixed plastics waste is not new [6]. The first industrial applications in Japan date from 1973. It is well known that it is possible to manufacture rods, stakes, bars, boards, plates, etc. from mixed plastic waste. It is considered an environmental friendly alternative for the plastic waste disposal. Government legislations and regulations in force in different parts of the world similar to the one implemented by the European Union envisage the use of 85% recyclable materials in automotives by 2015 [5], further increase attention towards natural fibres and their composites [11].

So far, the scientific analysis conducted agree that recycled materials are usually characterized by worse mechanical properties compared to those of raw materials. The reasons for this can be found in the fact that agricultural plastic material, especially films, are subjected to many different degradation factors during their application period. On the other hand, the reprocessing phase itself introduces also some stresses in the new material, connected with the different working steps (washing, granulating, pelletizing, extrusion, etc.) that are necessary for the recycling of heterogeneous plastic materials [6]. The mechanical properties of the recycled material may be also influenced by the presence of other factors, such as additives: *e.g.*, the addition of starch to LDPE blends increases the tensile strength and the elongation at break and reduces the Melt Flow Index (MFI) values [10]. Among the functional additives, natural fibres have become a common material for the manufacture of filled plastics as well [8]. It was stated [11] that natural fibres are advantageous in comparison to glass, carbon or similar inorganic fibres in a polymeric matrix due to their low energy cost, positive contribution to global carbon budget, greater deformability, biodegradability, combustibility, ease of recycling, less abrasiveness to processing equipment, lower cost, renewable nature, non-toxicity, high specific strength, etc. On the other side it was stated [4] that adding the glass fibres into the mixture of PET can improve tensile strength and tensile modulus. In their experiment they used PET mixture that contained 10, 20 and 30% of glass fibres. It was also stated [3] that glass fibres are the most used reinforcing materials in structural reinforced thermoplastic since they have high tensile strength and high chemical resistance.

Previously carried eexperimental tests on bars recycled from the post-consumed agricultural plastic films [12] show what mechanical properties of the recycled materials can be expected if additives like calcium carbonate and talc are added in the extrusion process. The experimental determination of their mechanical characteristics enabled the estimation about the possible use of these regenerated plastic profiles in the industrial and/or agricultural sectors, as constructive elements of light structures (*e.g.*, fences, vineyard pergola, little shelters, etc.).

In this paper, the properties of plastic profiles obtained through mechanical recycling of agricultural plastic waste (APW) mixed with glass fibre (70% LDPE + 30% glass fibres) were analyzed. The results of the mechanical tests here reported show that the mixture of recycled plastic from agricultural application could be considered as an interesting option for the improvement of the mechanical characteristics of these new regenerated products.

MATERIAL AND METHOD

Recycled manufactured products were obtained through the mechanical recycling of agricultural plastic films previously used during years 2004-2006 for covering tunnel-greenhouses in a farm located near Lecce (Southern Italy). The plastic recycled bars were produced by an Italian manufacturer for the stockpiling, selection and mechanical recycling of heterogeneous plastic wastes (Alfa Edile, Brindisi). After the collection and transportation to the recycling factory, the plastic films were granulated, melted at about 220 °C and introduced into the extruder to produce 1.5 m long square section bars with the average side equal to 49.4 mm. Ten recycled bars obtained exclusively from regenerated granule of APW were realized in order to compare them with ten recycled bars obtained from 70% of regenerated granules of APW and 30% of glass fibres.

The mechanical properties of these bars were analyzed in the Laboratory for Testing Material of the University of Basilicata (Potenza), by using a computerized universal press machine Galdabini PMA 10 type. The environmental conditions during the trial were: mean room temperature 20 °C, mean relative humidity 70%. From the recycled bars, specimens were obtained according the following dimensions:

- Tensile test: strip-specimen, width 49.4 mm, thickness 5.85 mm, length 190 mm;
- Compression test: cubic-specimen obtained directly by cutting the bars, side = 49.4 mm;
- Bending test: bar-specimen, section 49.4 mm x 49.4 mm, span length 1,100 mm.

Tensile tests were performed, according to the Italian UNI 8422 Standard [14], with a length between vices of 70 mm and a constant deformation speed equal to 10 mm min^{-1}.

Compression tests were performed at a constant deformation speed equal to 10 mm min^{-1}. During these axial tests the Young modulus (E) was calculated based on the tension value at the end of the elastic proportional phase (σ) and the corresponding deformation (ε).

Bending tests were performed at a strain constant speed of 70 mm min^{-1} according with the Italian Standard UNI 7219-73 [13], through the application of a load in the mid-span of a free length of 1.00 m between the supports.

In order to completely assess the strain properties of these new alternative materials, by the tensile tests the values of Poisson coefficient 1/m (obtained through the measurements of the strain in the y cross-direction of application of the load), of shear modulus G (obtained from measured values of E and 1/m) and percentage elongation at yield were obtained too.

RESULTS AND DISCUSSION

Different materials have different properties and therefore behave in different ways under given conditions. If materials are to be used as structural elements, their behavior under load, which is mostly mechanical in nature, must be known. The internal resistance of the material to withstand the applied load is called stress. In that sense the materials recycled from APW and mixture of APW and glass fibres were tested in conditions of tensile, compression and bending stress, in order to define their mechanical properties and to explore the possibilities of using them as structural elements.

In terms of tensile strength (Tab. 1) mixture of APW and glass fibres showed a higher maximal resistance compared to the mixture of the APW. In the area of elastic deformation recycled APW mixture showed higher resistance leading to conclusion that in the terms of tensile stress adding the glass fibres to the APW has lowered the material elasticity.

Table 1. Results for the maximum resistance of the tested recycled materials

Test	*APW*		*APW + glass fibres*	
	σ_e *(N mm^{-2})*	σ_{max} *(N mm^{-2})*	σ_e *(N mm^{-2})*	σ_{max} *(N mm^{-2})*
Tensile	*6.42*	*10.60*	*8.98*	*14.57*
Compression	*5.17*	*20.00*	*9.81*	*19.15*
Bending	*1.90*	*5.45*	*4.62*	*27.22*

By lowering the material resistance adding of glass fibres also caused a significantly lower elongation at break (Fig. 1, Table. 3) causing the new recycled material to be more brittle.

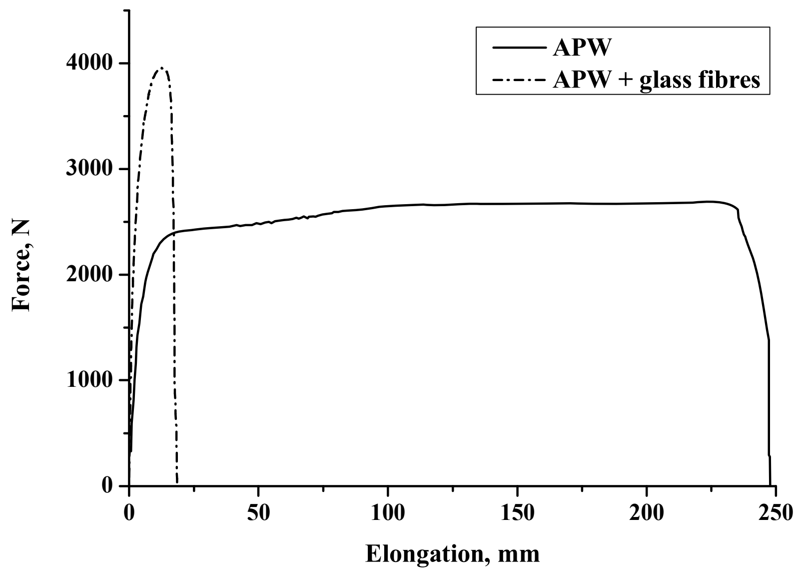

Figure 1. Force-elongation diagram of the preformed tensile tests

Concerning that glass itself is a brittle material this can explain the tensile properties of the recycled mixture of APW and glass fibres in terms of strength and elasticity. A lower quantity of glass fibre could have been probably more suitable for enhancing the mechanical properties of the regenerated profile, without giving it this fragile behavior. Recycled APW showed as more ductile material (Fig. 1) because it can stand large strains before failure.

When compression test is analyzed it can be seen that recycled mixture of the APW and glass fibres showed higher strength at the end of the elastic phase (Tab. 1). On the diagram of the behavior of the recycled materials during the compression test (Fig. 2) it can be seen that the mixture of the APW and glass fibres showed often (three samples over ten) a clear final break, while the APW only material was not finally broken, because the maximum load of the testing equipment (55,000 N) was reached without determining a clear final rupture of the tested specimens. Therefore, the maximum strength of this material was set to more than 22.54 N mm^{-2}.

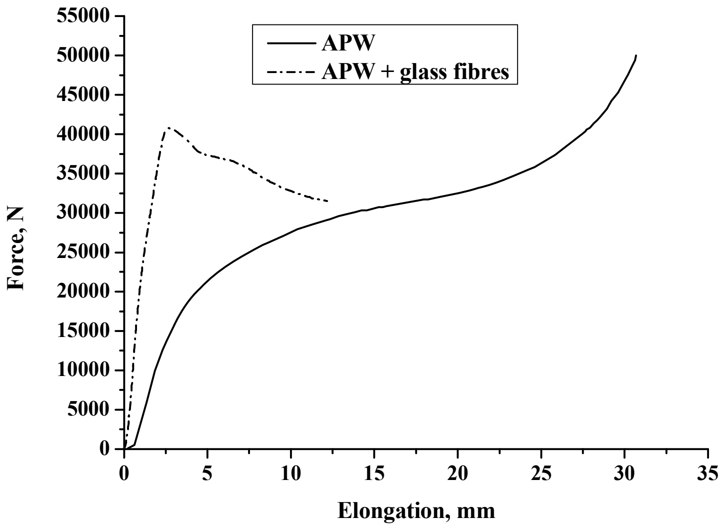

Figure 2. Force-elongation diagram of the compression tests;

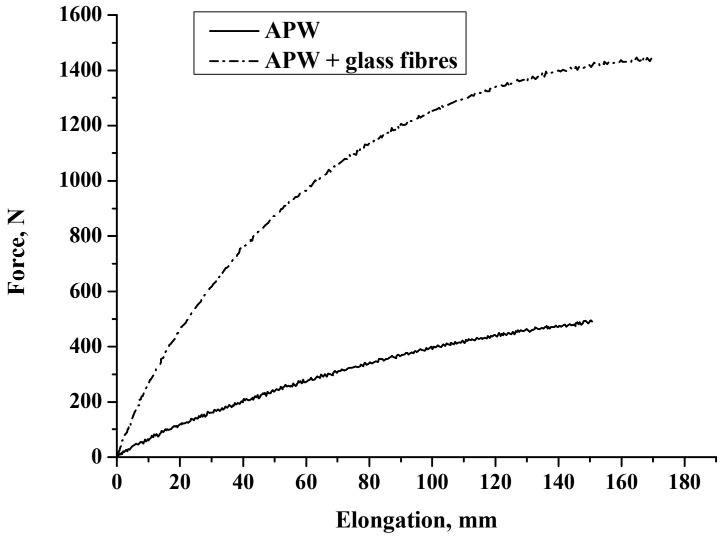

Figure 3. Force-elongation diagram of the preformed bending tests

The bending tests that were performed showed that the recycled mixture of APW and glass fibres has an higher resistance at the end of the elastic phase, compared with the recycled APW material (Tab. 1, Fig. 3). This could be also due to the contribution to the shear resistance given by the glass fibre. During the bending tests, for both of the materials the maximum travel stroke of the testing machine (170 mm) was not enough to cause the break of the specimens, due to high elasticity of these materials.

The analysis of the Young modulus (Tab. 2) showed that recycled mixture of APW and glass fibres has significantly lower flexibility, showing the higher values of Young modulus in all the three categories of test. It can be concluded that adding of 30% glass fibres in the APW could only partially improve the overall material flexibility.

Table 2. Results for the Young modulus of the tested recycled materials

Test	*E (N mm^{-2})*	
	APW	*APW + glass fibres*
Tensile	*114.54*	*433.64*
Compression	*119.90*	*614.05*
Bending	*305.67*	*1204.22*

The values of the elongation at break pointed out which of the two materials is the most deformable. It can be seen (Tab. 3) that recycled APW only has significantly higher values of the maximum elongation at break.

Table 3. Values for the strain characteristics of the recycled materials during tensile stress

	APW	*APW + glass fibres*
Maximum elongation at break (%)	*394.10*	*44.07*
Poisson coefficient	*0.46*	*0.47*
Shear modulus in the elastic phase (N mm^{-2})	*39.22*	*147.50*

For most metals and many other materials, values for the Poisson coefficient range from 0.25 – 0.35. Tested materials showed finally very similar values that are close to the theoretical upper limit that is 0.5 (rubber comes close to this).

CONCLUSIONS

One possible way of dealing with the growing quantities of agricultural plastic waste is the mechanical recycling, which enables their re-utilization in the agricultural sector through the realization of the cheap and effective products able to improve the sustainability of the agricultural production. Recycling is not a new technology, but it is in constant development since a lot of polymers during the recycling process lose their original mechanical properties leaving the recycled materials with the characteristics that narrow their possibilities of reusing.

Adding some additives into the mixture of agricultural plastic waste before the recycling process was considered by many researchers. In this paper, adding glass fibres into the APW and recycling such material was analyzed in the sense on how does this mixture behave in conditions of tensile, compression and bending stress. Results can serve for the analysis of possible use of the tested materials in some agricultural applications as construction elements or light structures. Recycled APW showed good tensile and compression characteristics. The addition of the glass fibres, in terms of tensile stress, has lowered the APW elasticity, causing the new recycled material to be more brittle. Concerning the compression test, the recycled mixture of the APW with glass fibre showed higher strength at the end of the elastic phase but, at the same time, a lower maximal strength. In conditions of bending stress both materials showed a similar behavior. It can be concluded that the mixture of APW and glass fibres in ratio 70% and 30% causes the new material to be more brittle and sensitive to tensile and compression loads. This makes this material unlikely employable for the realization of structural elements. A different quantity, with a lower percentage, of glass fibre inside the APW mixing, however, could probably usefully contribute to an improvement of the mechanical characteristics of the new regenerated profiles and consequently to their diffusion in the market.

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KORIŠĆENJE STAKLENIH VLAKANA PRI RECIKLAŽI PLASTIČNOG OTPADA IZ POLJOPRIVREDE

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Sažetak: Intenzivno korišćenje PE i LDPE u poljoprivredi, u poslednjih par decenija, dovelo je u pitanje ekološku održivost poljoprivredne proizvodnje ali je i iniciralo uvođenje i stavljanje na snagu regulatva i zakona kojima se kontroliše i smanjuje generisanje plastičnog otpada uz istovremenu stimulaciju uvođenje procesa reciklaže. Reciklaža kompleksnog plastičnog otpada iz poljoprivrede nije nova tehnologija ali je tehnologija čije su usvajanje i primena veoma spori obzirorom na činjenicu da je njihova reciklaža ograničena mehaničkim karakteristikama recikliranih materijala koje su znatno lošije od karakteristika izvornih materijala. Reciklirani polimeri se karakterišu gubitkom određenih hemijskih, fizičkih i mehaničkih osobina nastalim usled degradabilnih faktora kojima su materijali bili izloženi tokom svog perioda eksploatacije neposredno pred reciklažu. Jedan od načina da se osobine recikliranih materijala poprave je i dodatak određenih aditiva kao što su čestice drveta, stakla, kalcijum-karbonata i dr. U ovom radu su date karakteristike materijala nastalog reciklažom plastike iz poljoprivrede i njenom kombinacijom sa staklenim vlaknima u količini od 30%. Rezultati testova na istezanje, sabijanje i savijanje ukazuju da se dodvanjem adidtiva u vidu staklenih vlakana u plastični otpad iz poljoprivrede, mehaničke karakteristike ovako reciklirane mešavine mogu poboljšati dajući novi materijal koji bi ponovo moga naći svoje mesto u poljoprivrednoj proizvodnji.

Ključne reči: *plastični otpad iz poljoprivrede, reciklaža, plastični profili, staklena vlakna, mehaničke karakteristike*

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