Behaviour of Wool Fibres Reinforced Composite Materials

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Abstract. The work described in this paper refers to the production of laminate composite materials reinforced with portuguese wool fibres.
A mechanical characterisation in tension, flexion and impact of wool fibres reinforced composite materials is made.
A brief description of the production and test setups of the wool fibres reinforced composite materials is made.
The use of these animal fibres is pointing also to the ecological problem of composite materials recyclability.

Introduction

The growing concern of the science relatively to the environment it takes to the search of alternatives to use of products and raw materials less noxious to environment. In the case of the composite materials, they have been coming to be search of matrices and reinforcements originating from renewable sources that allow a satisfactory mechanical behaviour with a low environmental impact. In the case of the thermosetting matrix composites, the difficulty meets in recycling the material in an effective way, what is complicated by the fact of being a combination of different components, difficult to separate. One possibility is minimizing the impact of these materials, indispensable of the point of view of the modern industry. In this sense, less noxious matrices and reinforcements can be investigated, research that still has a long road to travel.
This research seeks alternative roads in the production of thermosetting reinforced polymers. This research has a progressive approach, being devoted in a first phase in search of reinforcements with natural fibres. In way to guarantee the economic sustainability of a possible solution, the research bases on materials that one can find with easiness, coming from of production excesses or of characteristic productions of some country. Besides the inherent environmental benefit of the use of these materials, its validation could represent an interesting economical opportunity for the producers.
This research is about the mechanical characterization of composite materials reinforced with fibres of ovine wool, characteristic of some district of Portugal.
In a first stud, the mechanical behaviour obtained went substantially inferior to the common synthetics reinforcements, like the glass fibre. In some cases, it was verified that the reinforcement took to a degradation of the mechanical behaviour of the matrix resin, when other researches aimed mechanics characteristics of this kind of composite materials above the obtained results [1,2].

The research has been conduced in the sense of optimising the compatibility of the fibre with the matrix, in way to improve its characteristics, removing the maximum of the fibre moisture retain in the natural state and with the expose to the atmosphere.
They would be produced laminates with different fibre volume percentage. In way to have an idea of the real value of these fibres to reinforcing composites materials, a mechanical properties comparison with classical glass fibres composites was made.

Work Development

We start the work making some composites of thermoset polymeric matrix (Epoxy – Reapox 520/D526; REA Industries), having as reinforcement a mat of wool fibres, without treatment (just with a first productor's washing) and wool tissue provided by the enterprise "Ecolã", whose head-office is in Manteigas – Portugal, in a way that would allow us to have the first idea of the characteristics of the material.
The composites, with wool tissue were made by hand lay-up and the composite with wool mat by compression moulding (Fig. 1-3). They were made at ambient temperature and without fibres treatment. In the all cases, composites were subjected to enough pressure to guarantee homogeneity. The fibre volume percentage in the final composite was 30%.


Fig. 1 - Lay up of the composite reinforced with tissue


Fig. 2 - Introduction of wool fibres in the mould


Fig. 3 - Wool fibres with epoxy resin in the mould

During the process, we noticed some difficulty in fibre impregnation, both in the tissue and in the mat. Nevertheless, the final result presented a very satisfactory impregnation, from which resulted an extremely homogeneous composite.
After a 8 days cure at ambient temperature, the plates obtained were cut in samples. Traction tests were made for the tissue and mat reinforced composites and flexion tests for the tissue reinforced composite.
The traction and flexion samples were tested in according of ISO 527 and ISO 14125 Standard with a test speed of 2mm/min, in an *INSTRON 4208* universal testing machine with a load cell of 10kN (Fig. 4-5).

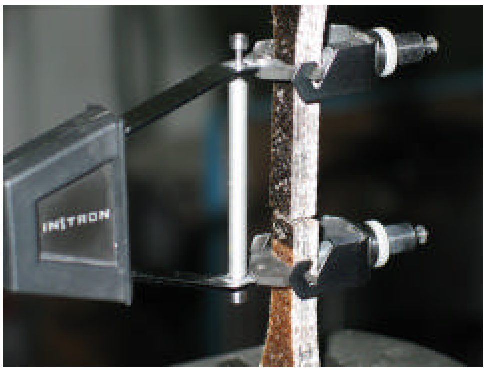
Fig. 4 - Traction test

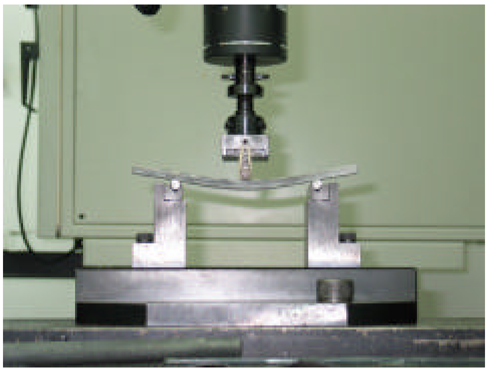
Fig. 5 - Flexion test

The results (Table 1) were below the resin values without reinforcement, which can invalidate this material as reinforcement. Nevertheless, some articles of other investigators show us that wool could effectively be used with that aim. [2]

It is necessary to study possible treatments to the fibres to improve the behaviour of the fibre/matrix interface, so that the properties of the composite can be improved to the needed ones.

We decided to subject the fibres to a thermal treatment, as a way to eliminate the moisture present in the fibres. Also we decide to make a traditional glass reinforced composite with mat of 400g/m2 with the same epoxy matrix to compare the mechanical behaviour.

So for the news wool reinforced composites, the wool tissue was treated in an oven at a constant temperature of 105ºC for 4 hours. After the thermal treatment of the wool tissue, three new composites with different volume contents of fibres (28,0%, 33,5% and 41,0%) were made by hand lay-up and compressed in a hoot plate press, during 2 hours at 40ºC. A post cure treatment (8 hours at 20ºC + 24 hours at 40ºC) was made before cutting the samples to mechanical characterisation in traction and flexion on the same test conditions of the first wool composites analysed in this research work.

The results of the mechanical characterisation of all composite laminates produces are presented in the Table 1.

Table1. Mechanical tests results

		Without Thermal Treatment		With Thermal Treatment			Matrix Resin
Composite	Glass Mat	Wool Mat	Wool Tissue	Wool Tissue	Wool Tissue	Wool Tissue	Reapox 520/526
Fibre volume %	30,5	30,0	30,0	28,0	33,5	41,0	
Traction tests results							
E [GPa]	7,34		3,26	3,61	3,86	4,21	3,50
STDesv	0,380		0,093	0,289	0,076	0,0038	
σ [MPa]	128,87		35,22	38,75	40,81	41,46	70,00
STDesv	8,054		2,110	2,204	1,405	0,055	
Flexion tests results							
E_f [GPa]	6,01	2,17	3,13	3,2	3,37	3,83	
STDesv	0,670	0,390	0,124	0,076	0,129	0,098	
σ_f [MPa]	179,82	47,4	52,60	74,67	75,67	85,43	
STDesv	15,400	8,547	4,070	2,445	3,507	1,870	

In comparison to the composite reinforced with glass fibres, the behaviour of the wool fibres composites is substantially inferior, in the range of 50% for the Young modulus and 100% for the tensile an flexion strength.

The obtained results check an improvement of the results of the fibres with thermal treatment relatively to the fibres without thermal treatment. It is interesting to verify that the difference of results is accentuated when compared substantially the traction tests results. This difference is very clear, if we compare the tension strength variation.

So much in traction as in flexion, the Young modulus is improved relatively to the values of the pure resin matrix.
Relatively to the ultimate tensile strength, the values obtained for the different wool/epoxy composites produces still meet substantially below the values of the pure resin matrix.
Complementary a pilot impact stud for the wool/epoxy composites with thermal treatment of wool fibres was made according the ISO 179 standard (Fig. 6-7 and Table 2).

Fig. 6 – Impact test machine

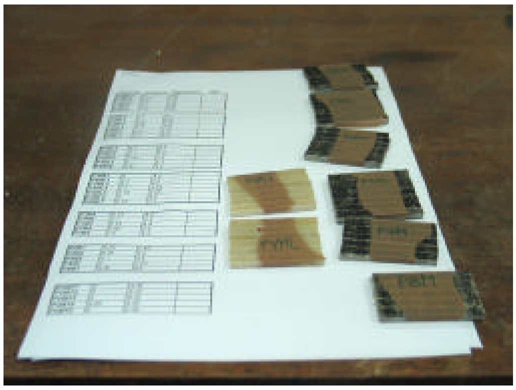

Fig. 7 – Impact samples

Table2. Impact tests results

	Without Thermal Treatment	With Thermal Treatment			Matrix Resin
Composite	Glass Mat	Wool Tissue	Wool Tissue	Wool Tissue	Reapox 520/526
Fibre volume %	30,5	28,0	33,5	41,0	
Impact Strength [KJ/m²]	71,075	4,347	6,779	12,728	26/28

Analysing the results of the impact test, we can concluded that in ours present development stage of the wool fibres reinforced composites, the impact strength of this ones are substantially lower than the one of the matrix epoxy resin of the composite, and lower than the one of the composite reinforced with glass fibres.

Conclusions

A poor interface fibre-matrix adhesion could conduce to the appearance of defaults in the composite materials that weakened it and influence an inferior performance in relation with the matrix.
The fibres absorb lots of humidity and have the possibility of the presence of natural fat. These are also two potential weakening agents.
It is also imposed a study more deepened relatively to the fibre/matrix interface, through its modification in chemical terms, and the study of its influence in the mechanical behaviour of the composite material.
It is interesting, however, to verify that the obtained results present, of the point of view of the tensile strength, quite close results of another natural fibres, like of the hemp fibres (without treatment) [3,4,5,6], which indicate that we can be in the presence of a material with an interesting possibility in what plays to the study of the reinforcement fibres for composites materials, since the

study of the reinforcement with animal fibres is quite explored than the reinforcement with vegetable fibres.
In spite of the results obtained to the moment they point for a low adaptation of this fibre type while reinforce for an composite material, it doesn't invalidate its use in components non subjects to significant mechanical solicitations, could be an real alternative, that has a clear advantage of the point of view of the environmental protection and of the sustained development.

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References

[1] A.S. Blicblau, R.P. Coutts, A. Sims, “Strength of raw wool polyester composites”, Swinburn University of Thecnology + CSIRO Division of Forrest Products – Melbourne - Australia

[2] S. Gonçalves, P. Vieira, J.L. Esteves, “*Mechanical Characterisation of Woll Fibres for Reinforcing of Composite Materials*”, ECCM 11 -11 th European Conference on Composite Materials - ECCM 11, Rhodes, Greece, 31/5-3/6/2004.

[3] C. Romão, “Study of the Mechanical Behaviour of Composite Polymeric Materials Reinforced with Natural Fibres", Dissertation presented for obtaining a Master's degree in Mechanical Engineering, from the Engineering Faculty in the University of Porto, 2003.

[4] Project SAPIENS POCTI/40201/EME/2001, “Mechanical behaviour of Composites of Polymeric Matrix Reinforced with Natural Fibres”, Final Report of activity, 2004.

[5] P. Vieira, C. Romão, A.T. Marques, J.L. Esteves, “Mechanical Characterisation of Natural Fibre Reinforced Plastics”, MATERIAIS 2003, II International Materials Symposium April, 14-16, 2003.

[6] C. Romão, P. Vieira, F. Peito, A.T. Marques and J.L. Esteves, “*Single Filament Mechanical Characterisation of Hemp Fibres for Reinforcing Composite Materials*”, Molecular Crystals and Liquid Crystals, Taylor & Francis Group, Volume 418, pp. 87/[815]-99/[827], 2004.