RESEARCHES REGARDING THE MECHANICAL BEHAVIOUR OF SOME POLYMER COMPOSITE STRUCTURES

Claudiu FLOREA[1], Horaţiu IANCĂU[1] , Liana HANCU[1] and Ştefan COTAE[1]

ABSTRACT: Currently, polymeric composite materials are of great interest from scientific and technical point of view. This justifies both the development of research in this area and the expansion of production for such materials. This paper presents the mechanical behavior of polymer composite structures made by RTM process (Resin Transfer Molding) depending on the degree of reinforcement and the fiber orientation angle. Based on the results of the tensile tests, comparative studies were made in order to determine the influence of reinforcement degree and fiber orientation angle upon the tensile strength.
KEY WORDS: Composite materials, Resin Transfer Molding, tensile strength.

1 INTRODUCTION

Attempts of obtaining high performance materials have led to the development of new product classes known as composite materials.

Composites are the first materials whose internal structural arrangement is designed by humans, making them favorable resistance. Composite applications are so vast that many specialists consider that after the Stone Age and then metal, humanity is currently in full development era of composites of all kinds.

As a general definition, composite materials are mixtures of two or more different components, the properties of which complement each other, to result in a material with properties superior to those specific component, (Şomotecan, 2000).

The choice of technology depends on the following factors: the geometry of the part or product, the structure of the material, part dimensions, dimensional accuracy and quality of parts, manufacturing series, destination of parts, etc, (Iancău&Nemeş, 2003).

To highlight the influence of reinforcement degree Mf and orientation angle θ on the tensile strength, composite plates were made by RTM process, (fig.1). This is a process characterized by low pressure in a closed mold where a mixed resin and catalyst are injected. The mold is usually containing a fiber pack or a fiber preform. After the resin is cured, the mold can be opened and the finished component removed.

[1] Universitatea Tehnica din Cluj-Napoca, Str. Constantin Daicoviciu nr 15, 400020 Cluj - Napoca, Romania
E-mail:florea_claudiu_81@yahoo.com; Iancau.Horatiu@ tcm.utcluj.ro;liana.hancu@tcm.utcluj.ro;stefan_cotae@ yahoo.com.

A wide range of resin systems can be used including: polyester, vinylester, epoxy, phenolic and methyl methacrylates, combined with pigments and fillers including aluminum trihydrates and calcium carbonates, if required. The fiber pack can be glass, carbon, aramid, or a combination of these, (Tero, 2005).

Figure 1 shows an RTM installation.

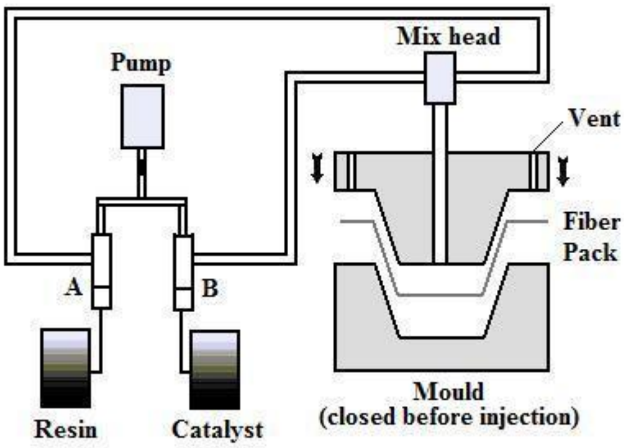

Figure 1. Resin Transfer Molding installation

2 MANUFACTURE OF COMPOSITE PLATES USING RTM PROCESS

To achieve composite plates we used an installation designed and made within the PhD thesis (fig.2), located in the Research Laboratory of Materials and Competitive Manufacturing Parts from Technical University of Cluj-Napoca.

Figure 2. Experimental installation of RTM

In this experiment we used composite plates reinforced with fiberglass in the form of balanced fabric 300 g/m2 , impregnated with polyester resin Norsodyne I 20282 I special for RTM process.

Plates were coded according to Table 1. The specimens cut from these plates were labeled with the same code as the plate.

Table 1. Coding the composite plates

Nr. crt.	Specimen code	Number of layers	Reinforcement degree *Mf* [%]	Orientation angle θ [^{0}]
1	A1	6	41	0º
2	A2	7	46	0º
3	A3	8	51	0º
4	A4	9	53	0º
5	B1	6	41	30º
6	B2	7	46	30º
7	B3	8	51	30º
8	B4	9	53	30º
9	C1	6	41	45º
10	C2	7	46	45º
11	C3	8	51	45º
12	C4	9	53	45º
13	D1	6	41	60º
14	D2	7	46	60º
15	D3	8	51	60º
16	D4	9	53	60º

The reinforcement degree *Mf* of composite plates was calculated using the formula:

$$M_f = \frac{m_f}{m_c} \times 100 \quad [\%] \qquad (1)$$

where: m_f - fiber weight and m_c - total weight of the composite material.

3 TENSILE TESTING

Determination of tensile strength through tensile testing is the most general and important resistance test. The method consists in applying a load along the main axis of the specimen, with a constant speed until failure or until the elongation reaches a predetermined value. For the tensile tests, 5 specimens were taken from each plate.

Plates were cut from the composite plates to the desired dimensions on Water Jet Cutting Machine OMAX Jet Machining Center 2626 (fig.3), located in Unconventional Technologies Research Laboratory and Competitive Manufacturing from the Technical University of Cluj-Napoca.

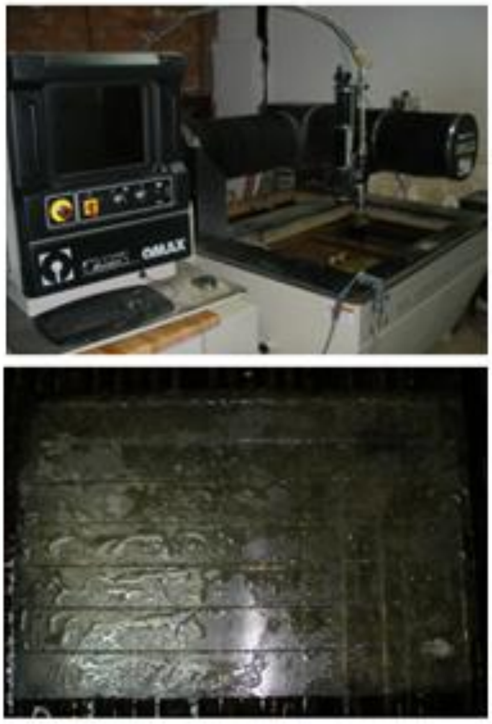

Figure 3. Waterjet Cutting Machine OMAX Jet Machining Center 2626

Specimens dimensions and test data are in accordance with ISO 527-4 3 [ISO 97]. Specimens dimensions shown in figure 4 are: L = 250 mm, h = 25 mm, b = 2 – 3,2 mm.

To prevent the crushing or the breaking of the specimen because of the pressing from the machine jaws, end tabs were glued using a slow curing adhesive, Bison Epoxy Universal. End tabs were made from a laminate composed of fiber reinforced epoxy resin.

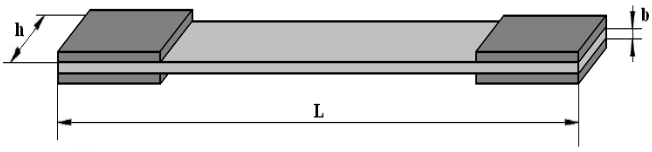

Figure 4. Tensile test specimen

For the tensile test was used an universal testing machine type Zwick/Roell Z150 (fig. 5), located in The Research Centre on Sheet Metal Forming Technology CERTETA from the Technical University of Cluj-Napoca.

Figure 5. Tensile test machine Zwick/Roell Z150

The tensile test machine is equipped with a computer control system with the ability to draw the diagrams of the variation of the force during traction and to calculate, based on section area specimens, the breaking strength, the elasticity modulus and the maximum strength. For fixing, longitudinal axis of specimens must be aligned to the test machine columns.

Speed test was 2 mm/min., and the tensile strength (σr) was calculated using the relationship:

$$\sigma_r = \frac{F_{\max}}{A}[MPa]$$
(2)

where: Fmax - the maximum force required to break the specimens, [N];

A - initial cross-sectional area, [mm2].

Tensile test were made at a temperature of 20 -22 ° C.

3.1 Experimental results

The tensile test results, the maximum breaking strength and the elasticity modulus for composite strucures made by RTM process are presented in table 2.

The specimens, subjected to tensile strength, are shown in Figure 6.

Figure 6. Specimens subjected to tensile strength

Table 2. Mechanical characteristics obtained after tensile test

Nr. Crt.	Specimen code		Specimens size Width [mm]	Specimens size Thickness [mm]	Section area [mm^2]	Longitudinal modulus E [MPa]	Maximum force [N]	Tensile strength [MPa]	Average tensile strength [MPa]
1	A1	A11	25.3	2.7	68.3	4970	13510	197.8	207.6
2		A12	25.4	2.7	68.5	4927	15200	221.8	
3		A13	25.3	2.8	70.8	4265	14400	203.3	
4	A2	A21	25.3	2.5	63.2	5393	15120	239.2	248.9
5		A22	25.3	2.5	63.2	6103	15870	251.1	
6		A23	25.3	2.6	65.7	5577	16845	256.4	
7	A3	A31	25.3	2.7	68.3	7265	20039	293.4	271.3

8		A32	25.3	2.7	68.3	6293	18591	272.2	
9		A33	25.3	2.7	68.3	5567	16959	248.3	
10	A4	A41	25.3	2.8	70.8	7687	21389	302.1	297.5
11		A42	25.3	2.8	70.8	7664	21346	301.5	
12		A43	25.4	2.8	71.1	6953	20541	288.9	
13	B1	B11	25.4	3.1	78.7	2206	10400	132.1	135.5
14		B12	25.4	2.7	68.5	2987	9560	139.5	
15		B13	25.4	2.9	73.6	2930	9930	134.9	
16	B2	B21	25.4	2.7	68.5	3320	9790	142.9	144.9
17		B22	25.4	2.6	66.04	3453	9750	147.6	
18		B23	25.4	2.7	68.5	3282	9880	144.2	
19	B3	B31	25.4	2.6	66.04	4823	12825	194.2	180.6
20		B32	25.4	2.7	68.5	4092	12501	182.5	
21		B33	25.4	2.7	68.5	3813	11309	165.1	
22	B4	B41	25.4	2.7	68.5	4297	13400	195.6	200.4
23		B42	25.4	2.7	68.5	4086	14100	205.8	
24		B43	25.4	2.7	68.5	4242	13700	200	
25	C1	C11	25.3	2.3	58.1	1712	4566	78.6	87.4
26		C12	25.4	2.4	60.9	1936	5566	91.4	
27		C13	25.4	2.4	60.9	2246	5620	92.2	
28	C2	C21	25.4	2.7	68.5	2593	7790	113.7	121.4
29		C22	25.4	2.9	73.6	3576	10289	139.8	
30		C23	25.4	2.8	71.1	2887	7850	110.4	
31	C3	C31	25.3	2.7	68.3	3383	10327	151.2	151.2
32		C32	25.3	2.7	68.3	3919	10504	153.8	
33		C33	25.4	2.8	71.1	3562	10565	148.6	
34	C4	C41	25.4	2.7	68.5	4070	11665	170.3	166.8
35		C42	25.4	2.7	68.5	3992	11412	166.6	
36		C43	25.4	2.6	66	3792	10791	163.5	
37	D1	D11	25.3	2.4	60.7	1966	5426	89.4	87.5
38		D12	25.3	2.4	60.7	1989	5438	89.6	
39		D13	25.3	2.4	60.7	1714	5068	83.5	
40	D2	D21	25.4	2.6	66	3110	8566	129.8	123.4
41		D22	25.4	2.8	71.1	2994	8575	120.6	
42		D23	25.4	2.8	71.1	2983	8518	119.8	
43	D3	D31	25.5	2.5	63.7	3543	10478	164.5	158.6
44		D32	25.4	2.6	66	3683	10553	159.9	
45		D33	25.4	2.8	71.1	3641	10764	151.4	
46	D4	D41	25.4	2.5	63.5	3959	11150	175.6	174.4
47		D42	25.3	2.7	68.3	3944	11488	168.2	
48		D43	25.3	2.6	65.7	4275	11786	179.4	

In the case of composites for which orientation angle is 0 ° the breaking of fibers was produced without the appearance of a "zone-flow" of material, which can be seen in the figure 7.a, but for the other angles of orientation the breaking occurred with the appearance of an approximate flow area of the material as seen in the figure 7.b, 7.c. and 7.d. Those stress-strain diagrams show significant influence of the fiber orientation angle towards the direction of application on the mechanical behavior of the composites to the same degree of reinforcement.

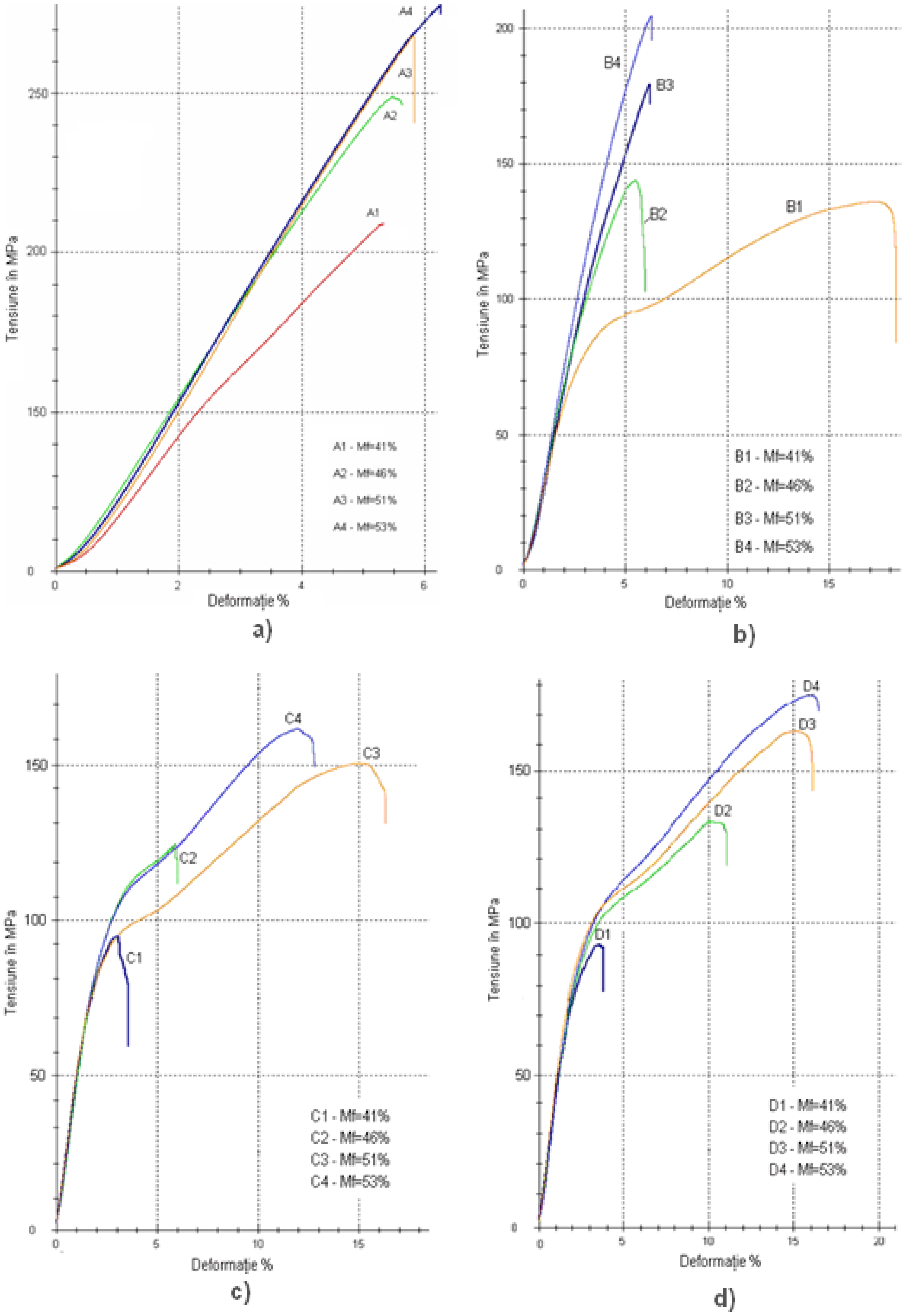

Figure 7. Stress - strain diagrams for composites reinforced with fiberglass fabric in the form of biaxial
a) orientation to 0^0, b) orientation to 30^0, c) orientation to 45^0d,) orientation to 60^0.

The variation of the tensile strength depending reinforcement degree M_f and orientation angle θ of fiber in composite is presented in figure 8. It should be noted that the arrangement of reinforcement material inside the mold was made at the different angles, taking into account the direction of the warp.

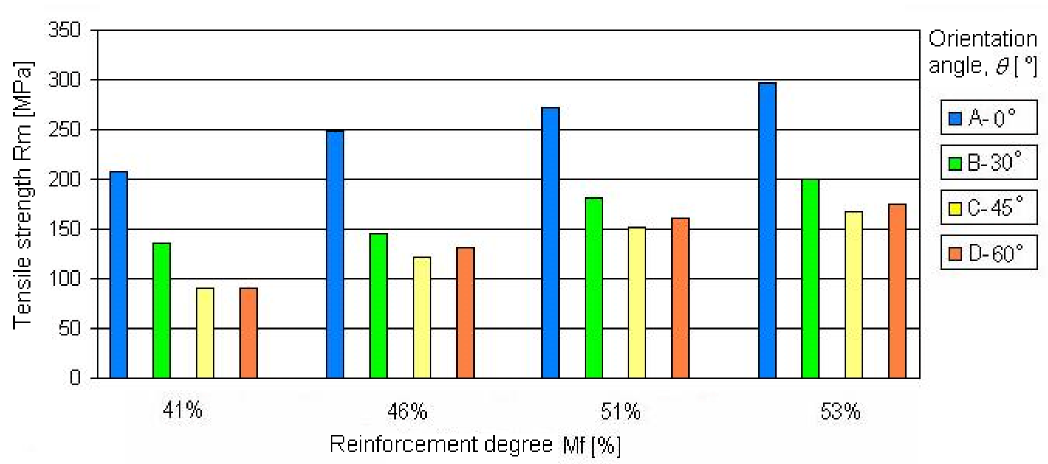

Figure 8. The variation of the tensile strength depending of reinforcement degree M_f and orientation angle θ

4 CONCLUDING REMARKS

As can be seen from the above figure an important role is the reinforcement degree *Mf*. The more that is higher the greater the mechanical properties of the composite. In the case of composites with a reinforcement degree of 53%, value of the *Rm* is greater with 32% than in the case of composites with a reinforcement degree of 41%.

A key factor is the architecture of reinforcing material. The direction of the fibers from the warp must be the same as the request.It is noted that for reinforcement angle greater than 0º tear resistance decreases significantly.

It can be seen that the resistance of breaking in the direction of the fibers decreases once with increasing angle of orientation until the orientation of the fibers 45 and, in this case *Rm* is with 57% lower than in the case of orientation to 0°, after which the value of resistance increases from a 45º angle orientation up to 90º.

The reinforcement degree of composite structures is closely related to the architecture of the reinforcement material. Is not sufficiently a high degree of reinforcement when the reinforcing material is not positioned in the direction of mechanical stress.

5 REFERENCES

►Barbero, E.J. (2011). Introduction to composite materials design, second edition, Ed. Taylor & Francis, USA

►Berthelot, J.M. (1999). Matériaux composites. Comportement mécanique et analyse des structures., 3e édition, Editions TEC & DOC, Paris

►Decolon, C. (2000). Structures composites: calcul des plaques et des poutres multicouches, Hermès Science Publications, Paris

►Florea, C. (2012). ”Contribuții privind îmbunătățirea procesului de fabricație a materialelor compozite utilizând procedeul Resin Transfer Molding” Teză de doctorat, Universitatea Tehnică din Cluj-Napoca, Romania

►Iancău, H., Nemes, O. (2003). Materiale compozite. Concepţie si fabricaţie., Ed. Mediamira, Cluj- Napoca, Romania

►Şomotecan M. (2000). Compozite. Calcul de rezistenţă., Ed. U.T. Pres, Cluj-Napoca, ISBN 973-9471-28-5;

►Tero, M. (2005). Materiale compozite realizate prin procedeul RTM. Editura Napoca Star, Cluj-Napoca, Romania

6 NOTATION

The following symbols are used in this paper:
θ = orientation angle;
σ_r = tensile strength at break;
A = initial cross-sectional area;
E = longitudinal modulus;
Fmax = the maximum force required to break the specimens;
m_c = composite weight;
m_f = fiber weight;
M_f = reinforcement degree;
Rm= tensile strength.