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Incorporation Effect of an Organic Load Resulting from Cores's Date in a Composite Biomechanical Material by Stress Analysis

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Abstract: This study relates the incorporation effect of a natural organic load (date core's pellets) in a laminated composite woven containing methyl methacrylate of orthopedic use. The goal of this research was the improvement of the existing product used as human prosthesis tibiale which presents failures in the form of microfissurings, of transverse cracks and a delamination on the layers level. This consists to implement a new hybrid composite with reinforcement fiber glass and particles of date cores. A characterization was carried out by varying the number of folds on the level of the initial orthopedic composite to know the sequence influence stacking on the mechanical behavior. Another characterization is carried out on the new hybrid composite. Within the framework of this approach, a comparative results study obtained of the stress intensity factors shows a significant increase in the mechanical characteristics and highlights the mechanical resistance improvement of the new laminate. This research was first experiment incorporation of this granulated kind in a polymeric matrix for the manufacture orthopedic composite used and open prospects to other applications hybrid composite.

Key words: Composite materials, laminated, granulated, characterization, mechanical behavior

INTRODUCTION

If the plastics have advantages in term of lightness and cost, they miss rigidity however. The contribution of the reinforcements is likely to bring back them at the awaited level competitiveness (Kaltz and Milewsky, 1987). The advantages concerned are multiple: Better mechanical resistance, knowledge of the influence of the interaction fiber glass and granulated of date cores on the mechanical behavior and its clogging effect reducing thus certain types of degradations like delaminating. The defects of the composite of the prosthesis tibiale degraded imply an analysis of the failures, consequence of the various requests supported by the tibiale part during all the cycle of life of the prosthesis. The nature of the requests is given starting from the analysis of the cycle of walk on which the choice of the tests is based (Menager, 2002; Seireg and Arkivar, 1975).

A characterization is carried out in inflection on the reinforcement twill glass fiber 3D. It consists in regarding fabric as a laminate according to the directions (0°), (90°) and intermediaries (45°et -45°) (Dalmaso and Mezieres, 1998). To improve the dimensional and functional stability of the orthopedic composite, a natural load was introduced into the orthopedic composite like charges reinforcing by holding account of granulometry, the glass fiber meshes and the viscosity of the resin used. A hybrid composite thus is obtained, then characterized in the same way that the orthopedic composite. This study shows the performances obtained by this incorporation on the mechanical behavior of the prosthetic composite.

MATERIALS AND METHODS

The implementation of the composites (orthopedic and hybrid) is carried out by vacuum moulding with the bag. The laminates are piled up and impregnated at ambient temperature and moulded vacuum with assistance of a machine with depression between mould (film PVC) and against mould (film PVC) (Documentation Technique, 2006).

Composite of reference (orthopedic): It consists of an organic matrix containing methyl methacrylate and of a woven reinforcement including: a reinforcing glass fiber and a fabric perlon having an absorbing role. The textile reinforcement made up of several folds reinforcing laid out according to the orientations $[90/45_2/0]$ (Giesler and Dammert, 1973).

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Hybrid composite: In addition to the components of the reference composite, a natural load: The date core pellet was built-in thus forming the hybrid composite. Obtaining this new reinforcement requires three phases: -phase of preparation: Washing, drying with the drying oven and weighing. -Phase of crushing -phase of sifting.

The pellet obtained has a median diameter (average) equivalent with that of the largest sphere passer by through the meshes of the sieve and can be valid for the mesh constituting the reinforcement of glass fiber such as (Giesler and Dammert, 1973):

$$d_{moy}.\ \text{granulated} < d_{moy}.\text{maille fabric} \quad (1)$$

The smoothness of date cores granulat is thus characterized by the location parameter which is the average diameter (Allen, 1988).

The weightings' of the passer results for each size class are summarized in Table 1.

Table 2 shows results of the date cores granulated sifting.

The content of class is determined by the ratio mass of this class and the total mass (Melcion, 2000). A class represents the passer by and the refusal of each sieve.

The size of granulated is characterized by the average diameter (d_{moy}) which can be calculated according to the results of the sifting analysis according to the formula:

$$d_{moy} = \frac{\sum_{i=1}^{n} \beta_i d_i}{\sum_{i=1}^{n} \beta_i} \quad (2)$$

β_i is the content of narrow size class in %, n is the number of sizes classes di is the arithmetic average, d_i diameter of the narrow class in Misters.

d_{moy} = 0.12 mm d_{moy} is the average diameter of date cores granulat. The recovered pellets have a minimal diameter of 0. 05mm corresponding to the last sieve meshs.

Table 1: Weighing of the "passer by" results for each classes size

Size classes in mm	-0.208 +0.147	-0.147 +0.100	-0.100 +0.08	-0.08 +0.05	-0.05 +0.00
Mass classes in g	25	20	15	10	08

Table 2: Results of sifting

Classes sizes (mm)	Classes masses (g)	Contents classify β (%)	Accumulated contents Σβ according to (+)	Accumulated contents Σβ according to (-)
$-d_{max}$+0.208	30	27.77	27.77	99.96
-0.208+0.147	25	23.15	50.92	72.19
-0.147+0.100	20	18.51	69.43	49.04
-0.100+0.080	15	13.88	83.31	30.53
-0.080+0.050	10	9.25	92.56	16.65
-0.05+0.000	08	7.40	99.96	7.40
Total	108	99.96	/	/

EFFECT OF DATE CORES GRANULATE INCORPORATION

The study of the effect of date cores granulate incorporation will relate primarily to the mechanical behavior of the structure in service. In this context, our work will be interested in the study of the stress intensity factor evolution of various types laminates. Four series of stratifications are manufactured according to Table 3.

The inflection generates a made up state of stress within materials tested: tensile stresses are maximum in the convex part, the compressive stresses are maximum in the concave part and shear stresses are maximum on the axis principal of the test-tube. So the ratio thickness at the distance between supports governs the ratio constraint normal (traction/compression)/stress shear. Consequently, the deformation is a function of material resistances. Under these conditions, the theory of the beams makes it possible to express (Crawczack, 1997):

$$\sigma_f = \pm \frac{3FL}{2bh^2} \quad (3)$$

The normal constraint in inflection: (3) At the implementation time both composites of the study, the rate of vacuum is important, but is cancelled under the action combined of under air pulling of the resin capillary push, then the massage. The comparison of the images observed with the MEB (scanning electron microscope)

Table 3: Test-tubes composition for the deflection

Series	Standard series of composite
Ref1	1 layer of perlon+1 layer of glass fiber
Ref3	2 layers of perlon+2 layers of glass fiber
Hyb1	Hyb1 2 layers of perlon+2 layers of glass fiber+5 grams of granulated of Hybrid dates
Hyb2	2 layers of perlon+2 layers of glass fiber+10 grams of granulated of dates

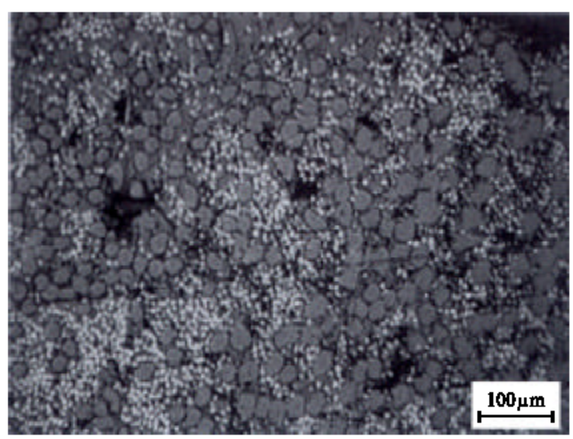

Fig. 1: Micrography of one intermingled with powder and Polyamide carbon fibers (Bernet *et al.*, 1999)

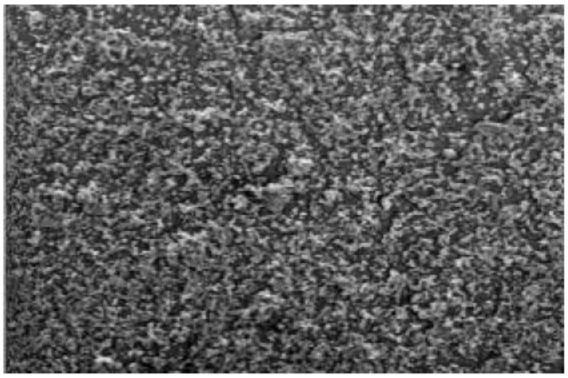

Fig. 2: Micrography of one intermingled with fiber glass twill and granulated of date cores observed to the MEB during the development of the hybrid composite

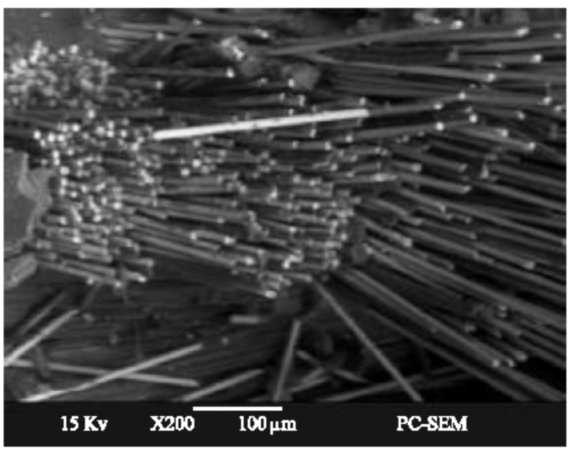

Fig. 3: Fracture topography of prosthetic

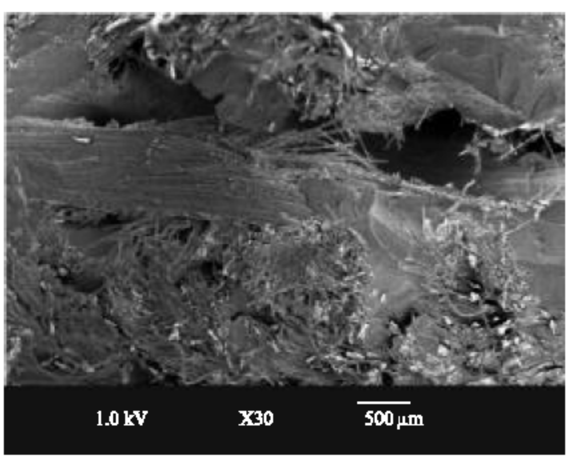

Fig. 4: Fracture topography of hybrid composite

of the hybrid composite realized at the laboratory and a micrography of one intermingled with polyamide and carbon fibers shows that the consolidation carbon fibers/polyamide tested by Bernet *et al*. (1999) where polyamide impregnation having not uniformly set out again (Fig. 1).

On the hybrid composite level of the study, Fig. 2 shows homogeneous and uniform date cores pellets distribution. It is necessary also to take into account the phenomenon of date cores granulate intermingling around the fabric wicks in the case of the hybrid composite with reinforcements granulated and woven like illustrates in Fig. 3 and 4.

Figure 3 shows the sample fractography of the prosthetic composite. It appears fibers decoherence of glass fiber and illustrates the fiber rupture in transverse.

Figure 4 shows the fracture topography of the hybrid sample. It appears in the image a consolidation due to date cores granulate. The fibers appear well intermingled. This phenomenon is responsible for the mechanical behavior of this material.

MEASUREMENTS OF THE STRESS INTENSITY FACTOR K_{IC}

The stress intensity factor requires the use of the elasticity theory in relation to a factor of form.

$$K_C = \sigma_f Y \sqrt{a_0} \quad (4)$$

Y is a factor of form integrated to mitigate the finalized size problem of the test-tubes. The selected parallelepipedic test-tube is notched and requested in inflection three points.

Figure 5 Individual test-tube edge notch flexure specimen for deflection test three points.
The expression of the K_{IC} is following form:

$$K_{IC} = \sigma_f Y \sqrt{a_0} \quad (5)$$

$$\sigma_f = \frac{3}{2} F \frac{(S)}{bh^2} \quad (6)$$

b and W: Respectively the width and the depth of the test-tube

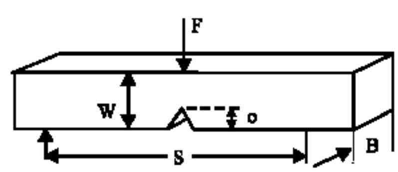

Fig. 5: Individual test-tube edge notch flexure specimen for deflection

Table 4: Values of K_{IC} for the various composites ref1

Series Ref1	h (mm)	B (mm)	a_0 (mm)	a_0/ w	Y	F (N)	σ_f MPa	K_{IC} MPa√m
Ref1.1	2.5	21.6	0.5	0.2	1.869	23.72	14.5	18.970
Ref1.2	2.5	21.6	1.0	0.4	2.232	16.85	10.3	22.989
Ref1.3	2.5	21.6	1.5	0.6	3.386	21.59	13.2	54.706
Ref1.4	2.5	21.6	1.8	0.72	3.914	29.77	18.2	95.454

K_{IC} = 48.029MPa√m, C_V = 1.6%, SD = 0.225 Mpa√m

Table 5: Values of K_{IC} for the various composites ref3

Series Ref3	h (mm)	b (mm)	a_0 (mm)	a_0/w	Y	F (N)	σ_f MPa	K_{IC} Mpa√m
Ref3.1	3.3	19.4	0.5	0.15	1.916	65.04	25.4	34.066
Ref3.2	3.3	21.6	1.0	0.30	1.991	54.17	19.0	37.829
Ref3.3	3.3	21.6	1.5	0.45	2.423	63.86	22.4	66.432
Ref3.5	3.3	21.6	1.8	0.545	2.938	61.87	21.7	85.431

K_{IC} = 55.939 Mpa√m, C_V = 00%, SD = 00 0.4 Mpa√m

Table 6: Values of K_{IC} for the various composites hyb2

Series Hyb2	h (mm)	b (mm)	a_0 (mm)	a_0 / w	Y	F (N)	σ_f Mpa	K_{IC} Mpa√m
Hyb2 .1	3.3	22	0.5	0.15	1.916	119.064	41.00	54.989
Hyb2 .2	3.3	22	1.0	0.30	1.991	122.25	42.1	83.821
Hyb2 .3	3.3	22	1.5	0.45	2.423	90.04	31.00	91.938
Hyb2 .4	3.3	22	1.8	0.545	2.938	109.77	37.80	148.815

K_{IC} = 94.890 Mpa√m, C_V = 1.06%, SD = 0.4 Mpa√m

Table 7: Values of K_{IC} for the various composites hyb1

Series Hyb1	h (mm)	B mm	a_0 (mm)	a_0/w	Y	F (N)	σ_f MPa	K_{IC} MPa√m
Hyb1.1	2.5	21.6	0.5	0.2	1.869	29.00	17.72	23.183
Hyb1.2	2.5	21.6	1.00	0.4	2.232	23.00	14.05	31.359
Hyb1.3	2.5	21.6	1.5	0.6	3.386	46.00	28.11	116.500
Hyb1.4	2.5	21.6	1.8	0.72	3.914	34.00	20.77	108.933
Hyb1.5	2.5	21.6	2.00	0.80	6.609	32.00	19.64	183.0190

K_{IC}moy = 92.598MPa√m, C_V = 10.4%, SD = 2.09 Mpa√m

"S" : The distance between supports

a_0 : The length of notch.

Y : Coefficient without dimensions whose numerical value depends initially on the ratio (a_0/W) and on twinge 1/W.

The expression of Y arises in the theoretical form:

$$Y = A_0 - A_1(\frac{a_0}{W}) + A_2(\frac{a_0}{W})^2 - A_3(\frac{a_0}{W})^3 + A_4(\frac{a_0}{W})^4 \quad (7)$$

Factor of form Y:

$$Y = 1.99 - 2.47(\frac{a_0}{W}) + 12.97(\frac{a_0}{W})^2 - 23.17(\frac{a_0}{W})^3 + 24.80(\frac{a_0}{W})^4 \text{ Flexion pure} \quad (8)$$

The values of the stress intensity factors are given in Table 4-7.

Variation of the stress intensity factor K_{IC} with the ratio a_0/w: The variation of the stress intensity factor K_{IC} according to the ratio a_0/w is illustrated on Fig. 6.

The stress intensity factor evolution explains the propagation of the crack according to the a_0/w ratio. The cracking phenomenon tends to follow the way of less resistance and progresses under the loading effect through the matrix, fiber and even the interface matrix fiber. Cracking does not advance solely in the plan of the initial notch but follows the way known as of the weak link which is often broken (junction).

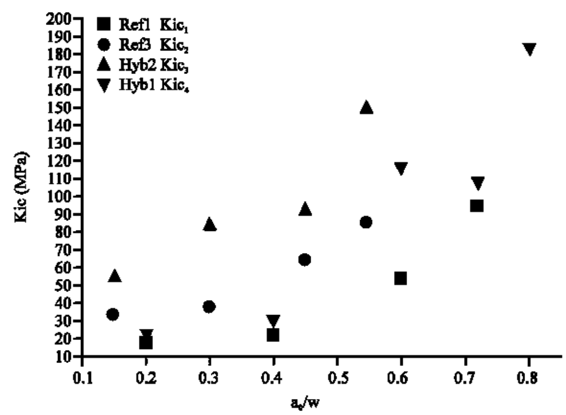

Fig. 6: Variations Comparison of the K_{IC} values according to a_0/w

The values of a_0/w for these orthopedic composites with woven reinforcements lie between 0,15 and 0,80: 0,15 <a0/W <0,80]. For the various series, the K_{IC} also moves with the ratio a_0/W However, it was noted that the evolution of a0/w is relatively important of a stratification with another, which influences the behavior of the composite.

Table 8: Kic moy according to the rate of date cores powder incorporation

Type of composite	Kic moy MPa√m
Ref3 (no built-in of PDC)	55.939
Hyb1(built-in of 05 grs of PDC)	92.598
Hyb2 (built-in of 10 g PDC)	94.890

Influence sequence of stacking on the K_{IC}: Taking into consideration K_{IC} value of the series Ref3 and Ref1 without incorporation loads, one notes a notable evolution because of the stacking sequence (Ref3: 2 fibers layers glass. In a material made up of pure resin, the increase thickness involves a reduction in tenacity, i.e. of the stress intensity factor value (Sol and Bel, 1989; Fernando and Williams, 1980). The composite laminated then charged of was granulated with date cores with an aim performances improvement of the orthopedic composite. The composites of the series Hyb2 And Hyb1 gave stress intensity factors more important than those of the no built-in composites like illustrates it the values of the K_{IC} of Table 8.

CONCLUSION

The date cores powder incorporation had an increase effect of the mechanical characteristics allowing the structure a good mechanical behavior. The rigidities (stress intensity factors) obtained on the standard composites Hyb1 and Hyb2 are more consequent than those of the Ref3 composite (Table 5). Other experiments (inflection in dynamics) are in hand to test the impact of the organic load incorporation. The study carried out made it possible to highlight new performances of the orthopedic composite. This application can be extended to other fields, in particular the biomedical one (dental prosthesis). In term of prospect, a study on the capacities coloring of the date cores powder will be undertaken in order to optimize the duality coloring effect and reinforcing effect.

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