A STUDY OF THE DAMPING OF A SANDWICH MATERIAL FUNCTION OF THE INTERFACE CORE/SKIN BY VISCOELASTICITY

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SUMMARY: This study concerns the damping capacity of the battens in Olympic sailing-ships (Tornado class). Battens are made of sandwich material beams. During competitions, the batten (which stiffen the sails) may be exposed to humid air, to sun or water. The moisture content, the temperature of these sandwich parts may change with time and also affect the interface (core/skin). These changes, in turn, affect the thermal and mechanical properties, resulting in an alteration of the performance of the sail. These alterations are not fully understood today. To use the full potential of the sail, the viscoelastic behaviour of the batten (function of temperature and moisture content) must be known. Two types of interfaces for the sandwich are here examined to see their viscoelastic properties with the help of a viscoelasticimeter and especially their damping capacities which have a great influence on the behaviour of the sail.

KEYWORDS : sandwich, batten, viscoelasticity, damping, phase angle, interface, water absorption.

INTRODUCTION

Nowadays everybody can see the expanding applications of the composite materials. The high technology of composites initially evolving in the aerospace industry has spread over many other areas. One typical example can be found in the field of sailing: The Tornado catamaran is an exciting sailing machine, which demands highly boat handling skills to achieve real straight line speed as required in Olympic regattas. The production of these boats use a lot of composite parts for the hull, deck, subdeck, bulkheads… The battens which affect the form of the sail are also in composite materials and especially in sandwich construction. They have two main functions: they allow to add roach to the back edge of the sail, and they act as a load shearing device for the yarns in the sailcloth which makes up the leech of sails. The battens affect the form and the behaviour of the sail in light air, moderate air and heavy air, they are exposed to humid air, to sun or water. The moisture concentration, the temperature of the sandwich parts of the battens may change with time and also affect the interface (core/skin). These changes in turn affect the thermal and mechanical properties, resulting in an alteration of the performance of the sail. For the time being these alterations are not fully understood and are the purpose of this paper. A lot of work has been done on composite materials and particularly on sandwich materials [1][2][3][4]. When the core of the sandwich construction and the matrix of the skins are polymeric materials, the viscoelasticity plays a major role. For the battens the damping capacity is of primary importance and has not yet been completely studied. The aim of this scope is to understand and compare the damping capacity of two types of battens used for racing in connection with temperature and water concentration.

MATERIALS AND EXPERIMENTAL METHODS

Sandwich beams consist of two thin sheets made of one ply (thickness 0.2mm) quasi-unidirectional composite material (glass fiber as reinforcement and epoxy as matrix) and a soft core of PVC foam of density 0.11 (thickness 5mm). These three elements are bonded manually either with an epoxy glue (material A) or a polyurethane glue (material B). The thickness of this bond between the core and the skin is about 0.3mm. The fibers in the composite skins are either parallel (L) or transverse (T) to the length of the samples. Finally the test specimen may be dried (S) or kept for four days in water (H) prior investigation. So the code for a specimen test includes three digits. For example A/L/H signifies: a sample bonded with an epoxy glue (A), with fibers in the skins parallel to the length of the beam (L), and sample kept for four days in water (H).
Static experiments have been conducted with a classical three points bending apparatus. We have recorded the stiffness of the specimens: F/d (force over the deflection at the mid-point). The specimens had the same geometry i.e.: same length (L), width (l) and thickness (e) for the beams (L.l.e = 215.20.6 mm^3).
A viscoelasticimeter (Metravib Instrument) has been used to record the dynamic mechanical spectra E', E'' (the complex moduli) and tan δ (the ratio of energy lost/energy stored per deformation cycle, i.e. E''/E', δ: the phase angle) versus temperature at a frequency of 10 Hz in three points bending mode (distance between the two end knife edges: 44mm) and in the temperature range of 20°C to 70°C. We imposed a sinusoidal displacement with a preselected amplitude of 10 μm or 130 μm. Only the phase angle δ was measured and used due to the complexity and lack of validity for getting the complex moduli (E' and E'') and because we are primarily concerned with damping of the samples. During this study, we worked at the same stiffness (F/d or force on displacement) for all samples to be able to compare them. So therefore, we adapted the width of the samples (L.l.e = 63.11.6 mm^3).

RESULTS

QUASI-STATIC INVESTIGATIONS

The static tests used dried sample beams at room temperature. Because of the relative heterogeneity of the sandwich beam, we have noted 1 the top face of a sample and 2 the bottom face of it, and we have chosen to place it in the three points bending apparatus with either the face 1 or the face 2 in tension in order to verify if we got the same results.
The samples with the same glue and same orientation present the same stiffness independently of the face in tension (table 1). For a selected type of glue, there are significant variations between the values measured longitudinally (L) and transversely (T). This is quite normal because the skin is composed with a quasi unidirectional ply. But we have noted that with the same orientation (L or T) the A samples have a bigger stiffness than the B samples

which is more surprising. Indeed the only difference between the A and the B samples is the nature of the glue used to bond the three parts of the sandwich construction.

Table 1. Stiffness of the samples in three points bending and relative variation in stiffness function of the face in tension.

Sample	Orientation	Face in tension	Stiffness (kN/m)	Relative variation
A	T	1	4.54	((*A/T/1*) – (*A/T/2*))/(*A/T/1*) = 0.009
		2	4.50	
	L	1	7.39	((*A/L/1*) – (*A/L/2*))/(*A/L/1*) = 0.003
		2	7.37	
B	T	1	3.56	((*B/T/1*) – (*B/T/2*))/(*B/T/1* = 0.09
		2	3.28	
	L	1	5.69	((*B/L/1*) – (*B/L/2*))/(*B/L/1*) = 0.02
		2	5.58	

We find that the relative variations can reach 27% (table 2). This illustrates the strong influence of the glue.

Table 2. Relative variation in stiffness function of nature of the glue (A or B)

Orientation	Face	Relative variation
L	1	((*A/L/1*) – (*B/L/1*))/(*A/L/1*) = 0.23
	2	((*A/L/2*) – (*B/L/2*))/(*A/L/2*) = 0.24
T	1	((*A/T/1*) – (*B/T/1*))/(*A/T/1*) = 0.22
	2	((*A/T/2*) – (*B/T/2*))/(*A/T/2*) = 0.27

We have carefully examined the sections of the samples with an optic microscope (figure 1).

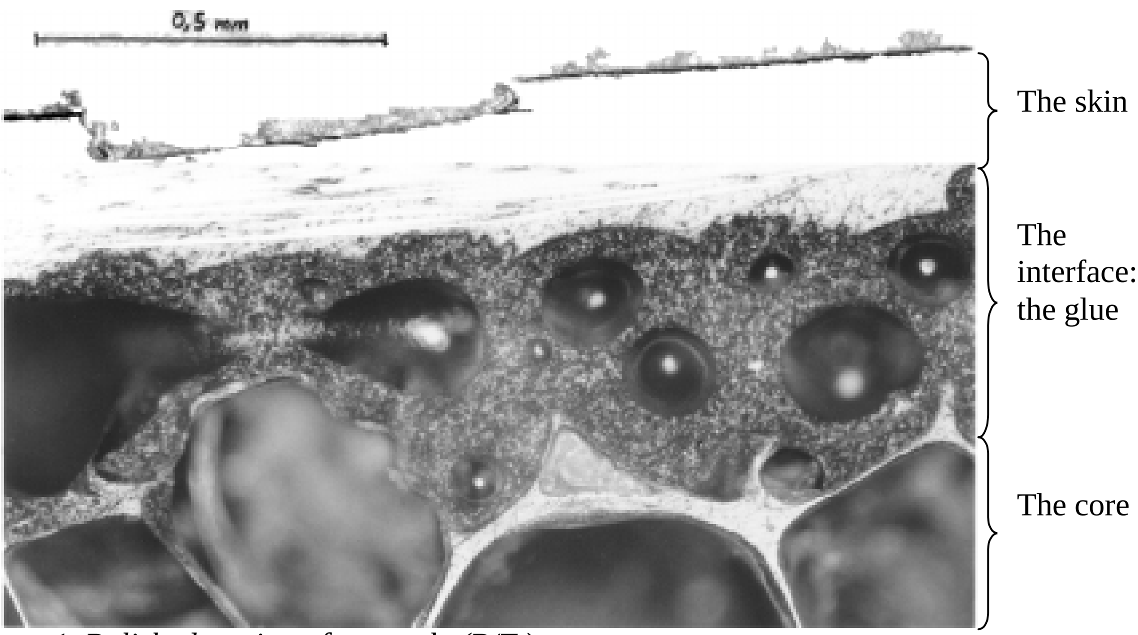

Figure 1. Polished section of a sample (B/T)

We can easily distinguish the different parts of the sandwich: the skin, the interface (the glue) and the core. We have noted after a full examination of the sections of the samples that the thickness of the glue was very regular on the length with the A samples and very much irregular with the B samples. As an extreme case in some portions of the B samples there was not even any glue (Figure 1. Polished section of a sample B/T). In fact people who realised these sandwiches had much more difficulties to bond the three parts of the B samples than on the A samples.

DYNAMIC TESTS

Prior tests in dynamic have been conducted at room temperature on dried samples: Three points bending (simply supported) in dynamic is not as easily realised as in static. Many cautions are necessary in order to prevent undesirable effects like the motion of the sample in the apparatus or the crushing of the skins and the core due to an excessive repeated pressure exerted at the location of the knife edges. To compare the different samples we have chosen to fix a same stiffness (F/d) for all of them by changing their width.
Preliminary tests concerned the control of the linear viscoelastic property of the sandwich. For all samples and particularly for the sample A/L (figure 2) we have verified that in the range of displacements encountered (10µm to 100µm), there was no significant variation of the stiffness at a frequency of 10Hz.

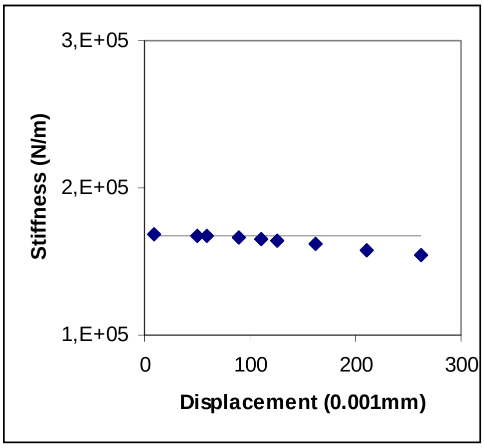

Figure 2. Variation of the stiffness (F/d) with the imposed displacement for a sample (A/L/S) for an imposed frequency of 10Hz.

In figure 3 we have drawn the variation of the phase angle δ on the displacement for dried samples at room temperature. We note that the nature of the glue (A or B) has a great influence on the damping capacity of the samples. The value of the damping capacity is always lower for the A samples. The phase angle is larger in the case of the B samples comparatively to the A samples. For the A samples, the orientation of the reinforcement (L or T) has no effect on the damping capacity at low displacement and a major effect as soon as the displacement increases. But for the B samples the influence of the reinforcement is very low independently of the displacement.

Similar tests have been conducted according to the temperature (from room temperature to 70°C) with dried samples and samples with moisture. Prior to these tests, samples have been kept in water for four days. In all cases, the quantities of water absorbed or desorbed are very low indicating the impermeability quality of these sandwich constructions.

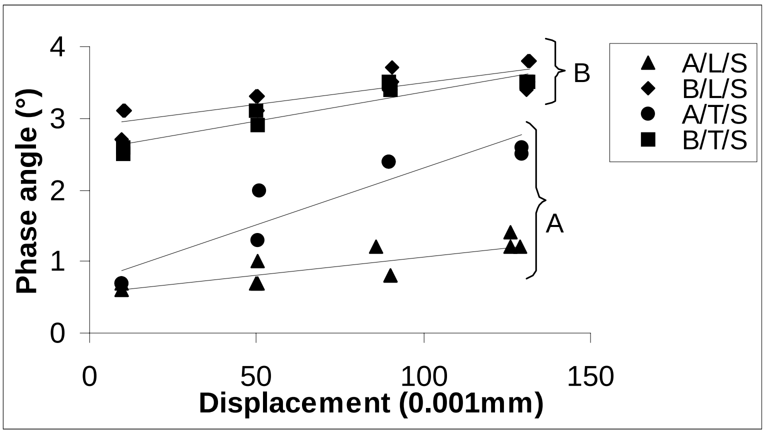

Figure 3. Variation of the phase angle δ with the displacement (at room temperature and for dried samples)

Table 3 Water absorbed prior to test and water desorbed after dynamic test.

Samples	Orientation	Absorbed water (%)	Desorbed water (%)
A	L	0	-0.1
	T	1	-0.02
B	L	2.2	0.1
	T	3	0.2

The dynamic mechanical spectrum (see figure 4) displays the variation of the phase angle δ at a frequency of 10 Hz and an imposed displacement of 10µm.

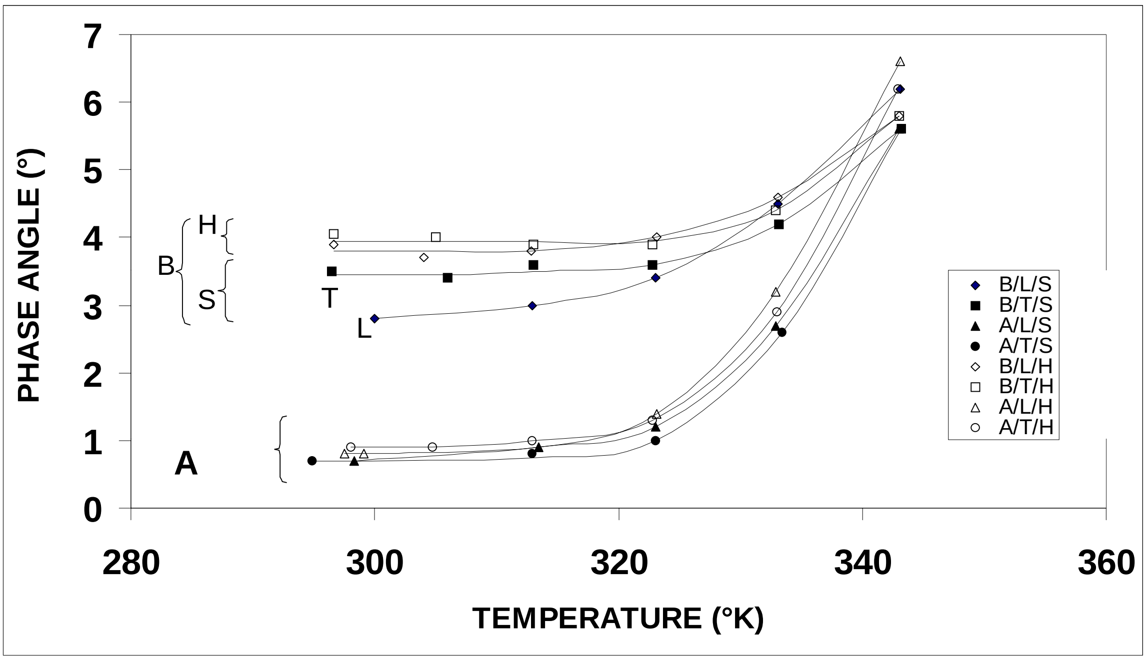

Fig. 4: phase angle δ versus temperature for dried samples and samples with moisture

The different curves show the same tendency : a threshold at about 320°K separating a first part where the curves are horizontal and a second part where they increase in a power law. The increasing of the phase angle is a manifestation of the beginning in the mechanical relaxation of the polymeric core of the sandwich material. At a temperature of order 340°K the values of the phase angle δ for all samples have become equivalent. The materials (A) and (B) do not behave in the same manner although they are identical except the nature of the interface which is relatively surprising. The (A) beams always present a lower δ therefore a less damping capacity. This difference comes essentially from the quality of fabrication of the samples.

The effect of water on the curves is visible at ambient temperature. The values of the phase angle for the dried samples are always lower than the ones for the samples with moisture. Apparently the effect of water is much better pronounced for the (B) samples than the (A).

The effect of the orientation of the fibers is complex at ambient temperature. For the (A) samples it appears that the orientation has no effect at all on the phase angle δ although it affects a lot the (B) samples. The damping capacity is always lower for the longitudinal (L) orientation compared to the transverse (T).

Tests conducted at an imposed displacement of 130µm confirm the same tendencies. Nevertheless for the (A) samples, the distinction for δ between the orientations of the fibers becomes possible, and the gap between the values of δ for the (A) and (B) samples decreases a lot.

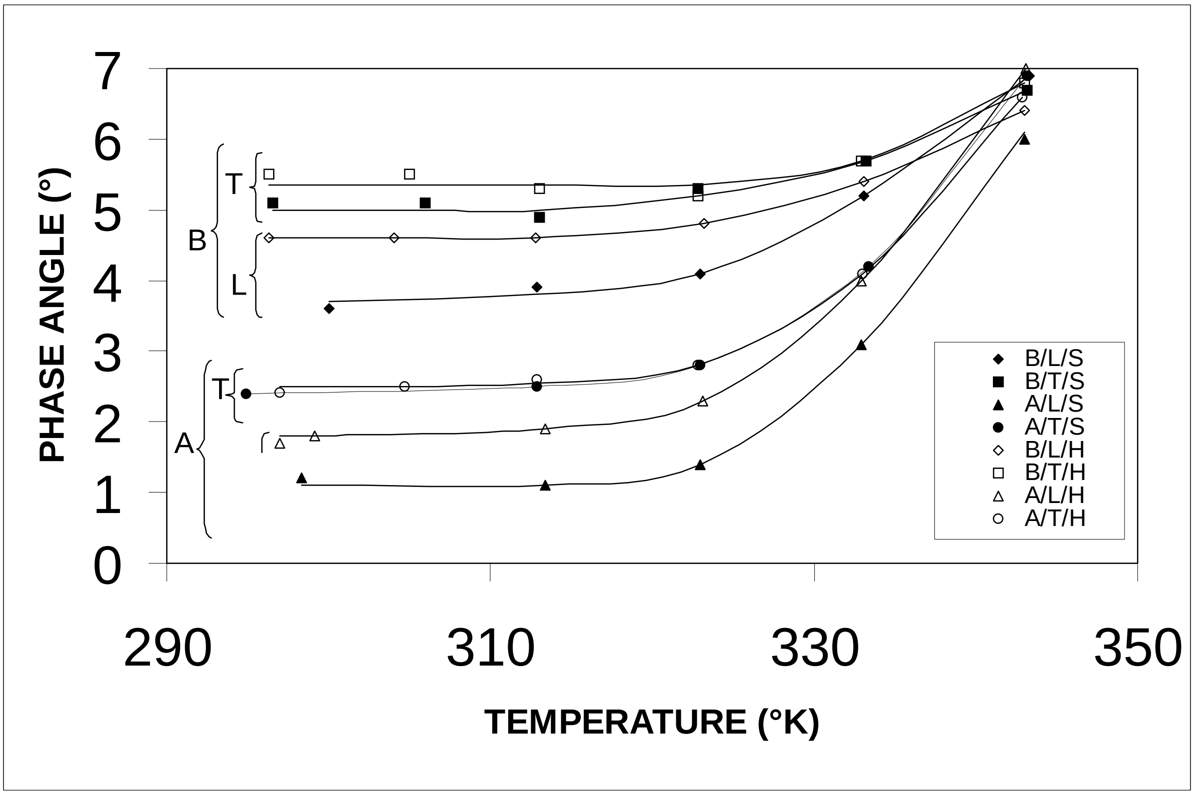

Fig. 5: phase angle δ versus temperature for dried samples and samples with moisture

CONCLUSION

The nature of the interface between the core/skin changes the damping capacity of the batten. In competition, one wishes to lower the damping capacity of the batten to improve the performance of the sail. The (A) samples are at this point of view more advisable than the (B).

It appears that for the (A) samples the effect of water or fiber orientation has no effect on their damping capacity. But the dynamic tests show that when the imposed displacement increases, the damping capacity of the (A) samples increases. The choice of material (A) or (B) is then more difficult.

Acknowledgements: the authors wish to thank “l’Ecole Nationale de Voile – Service Recherche et Développement” for its support in this work.

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