THE EFFECT OF THE ORIENTATION OF A CRACK ON THE CRITICAL BUCKLING LOAD IN A HYBRID COMPOSITE.

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Reçu le 12 Juillet 2015 – Accepté le 12 Janvier 2016

Résumé

Dans ce travail, une analyse de la déformation a été réalisée sur des plaques composites hybrides rectangulaires avec ou sans entaille circulaire à l'aide de la méthode des éléments finis. La résistance à la déformation de la tôle laminée soumise à la compression uniaxiale est mis en évidence en fonction des orientations des fibres. Les résultats montrent que l'augmentation de l'épaisseur de la couche d'aluminium améliore sensiblement la résistance au flambement. Quelle que soit l'orientation de la fissure de la charge critique de flambement reste stable.

Mots Clés *: flambage, composites hybrides, analyse par éléments finis, le crack.*

Abstract

In this work an analysis of buckling was carried out on rectangular plates hybrid composites with and without circular notch using the finite element method. The buckling strength of the laminated plate subjected to the uniaxial compression is highlighted according to the orientations of the fibers. The results show that increasing the thickness of the aluminum layer significantly improves the resistance to buckling. Whatever the orientation of the crack the critical buckling load remains stable.

Keywords*: buckling, hybrid composites, finite element analysis, crack.*

ملخص

في هذا العمل أجري تحليل التواء بها على مستطيلة المركبة لوحات الهجين مع وبدون الشق دائرية باستخدام طريقة العناصر المحدودة. وسلط الضوء على قوة التواء من لوحة مغلفة يتعرض لضغط ذو محورين وفقا لتوجهات الألياف. وأظهرت النتائج أن زيادة سمك طبقة الألومنيوم يحسن بشكل كبير من المقاومة لالتواء. مهما كانت توجه الكراك يبقى الحمل التواء حرجة مستقرة.

الكلمات المفتاحية *: التواء، والمركبات الهجينة، وتحليل العناصر المحدودة، الكراك.*

1. INTRODUCTION

Composite materials are a combination of components with complementary mechanical properties. They have many advantages over conventional materials; include for example, their lightness and flexibility of form [1]. The design and numerical simulation of the response undamaged composites are made extremely difficult because of their complex behavior [2].

The structural instability is a major concern in the safe and reliable design of composite plates. Several studies of the stability of laminated plates were concentrated on rectangular plates [3-6It is known that the resistance to buckling of the rectangular plate depends on the boundary conditions [4], orientations of plies [4, 5,7] and geometric relationships [4, 6, 7,8].

A laminate composite material plate comprising a notch find widespread applications in various fields of construction such as aerospace, marine, automotive and mechanics.

In the literature, there are several published studies on the buckling of composite plates, Akbulut et Sayman [9] conducted an analysis of buckling of a rectangular composite laminate with a central circular notch. Kong et al. [10] conducted an analysis on the buckling have numerically and experimentally for composite plates with a hole. Hamani et Ouinas [11] have worked on the buckling of plates in asymmetric composite in the presence of a crack at the notch root.

In the present study a buckling analysis was carried out on thin plates laminated in hybrid composites using finite elements. The effects of the aluminum layer, the orientation of the crack on the critical buckling load is highlighted.

II- Modeling by finite element

In this study, we considered a thin square plate with a circular notch in the center of graphite / epoxy of length H=100 mm. The ratio between the length H and the width W is H / W = 1. The mechanical characteristics of the material studied are shown in Table 1. The plate is considered solicited to uniaxial load in the vertical direction under the applied stress amplitude σ = 100MPa. We assume the existence of a crack from circular notch radius R=4mm. The crack length is constant a=20 mm ; only its orientation that varies with angle α relative to the horizontal (Fig.6). In this model, the finite element method is used for determining the buckling parameter. We used quadrilateral elements (SR8) with reduced integration as shown in Fig.1. The resolution was made in a state of plane stress. The plates used are made up of six to eight plies of composite and two layers of aluminum alloy. The thickness of each ply of the plate is e=0.127 mm. The positioning of the metal layers is highlighted.

	E_1 (MPa)	E_2(MPa)	ν_{12}	G_{12}(MPa)	G_{13}(MPa)	G_{23}(MPa)	Epaisseur (mm)
Composite	130340	9655	0.29	5586	5586	4827	6 x 0.127
Aluminium	72400	-	0.33	-	-	-	2 x 0.127

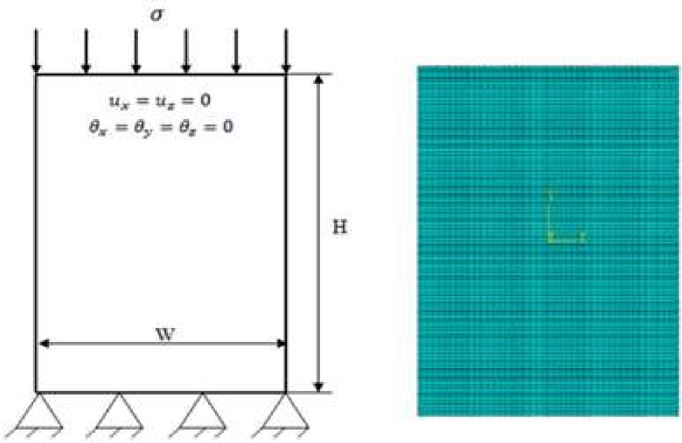

Table 1. Mechanical properties of the plate material.

Fig. 1. Details and mesh of the plate

III- Convergence curve :

To find the optimal mesh for the calculation we took two materials, the first a conventional composite material and the second hybrid. The calculation was made for a single plate with an orientation of 45 ° fibers. Note that by increasing the number of items it not there a big difference to the result obtained, so we opted for the calculation for a 8000 element mesh.

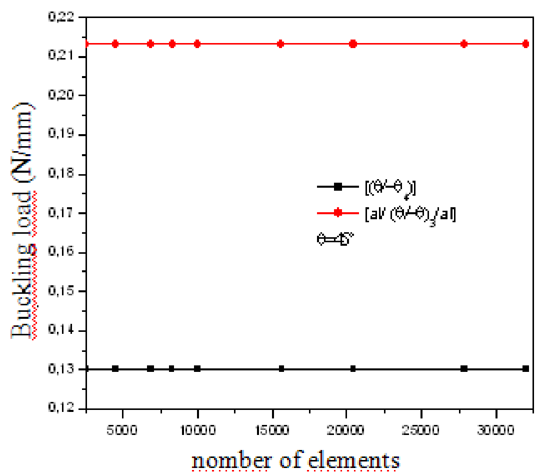

Fig. 2.convergnce curve

IV-Buckling load :

In this section, we study the variation of the buckling load as a function of the orientation of fibers relative to the applied load. Fig. 3 shows the evolution of the buckling load as a function of the orientation of fibers of the composite material. The variation of the load is obtained for five different stacking sequence of plies, in the first case we have a classic composite materials with a sequence [(θ/-θ)4] and in the other four cases, we provided a hybrid composite of two aluminum layers with sequences (al/(θ/-θ)3/al) , (θ/-θ/θ/al/al/-θ/θ/-θ) (al/θ/-θ/θ/-θ/-θ/θ/-θ/θ/al) (θ/-θ/θ/-θ/al/al/-θ/θ/-θ/θ) respectively and for an applied load of 1N/mm. It is noticed that the buckling load reaches large maximum values when the fibers are oriented in an interval varying from 50° to 90°. This is due to the fact that the load applied becomes parallel to the fiber. The minimal values are obtained when the orientation of fibers is lower than 30°. Note also that the hybrid materials with aluminum layers outside have a good resistance to buckling when the fibers are oriented in an interval varying from θ= 0° to θ= 45° in comparison with the other materials.

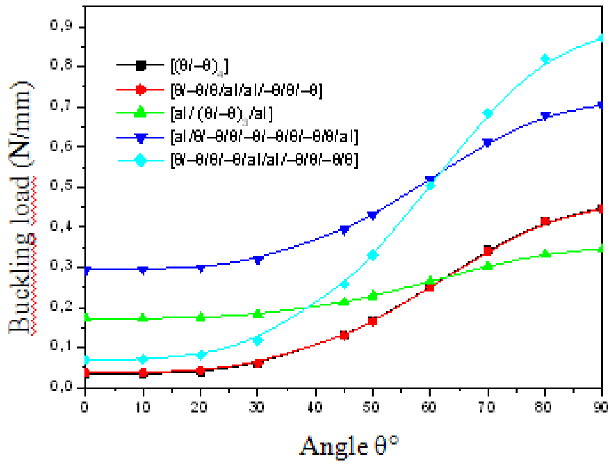

Fig. 3. Variation of the buckling load as a function of θ°.

Figures 4 and 5 show the variation of the buckling load as a function of the orientation of fibers for different values for the thickness of the aluminum layer. On the other side, the layer composite remains constant and equal to 0.127 mm. The figures clearly show that the critical buckling load increases proportionally with the increase of the angle of orientation of the fibers. Furthermore, when the angle θ ° is less than 30°, values of the critical load are almost constant while beyond this angle, the load increases rapidly. The effect of the thickness is clearly shown, increasing the latter, the critical buckling load increases and this is valid for any orientation of fibers. Comparing the two figures, there is a slight difference in the values of the buckling load, when the aluminum layers are outside, the critical load decreases, in this case the maximum load is obtained for the plate with aluminum layers inside (N_{max} = 2.93 N/mm

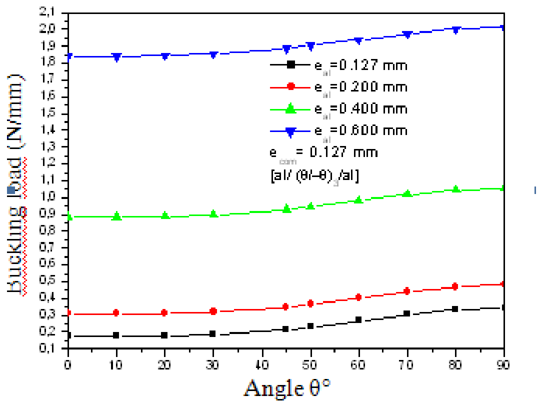

Fig. 4. Variation of the buckling load as a function of orientation θ° (hybrid composite (al/(θ/-θ)3/al)).

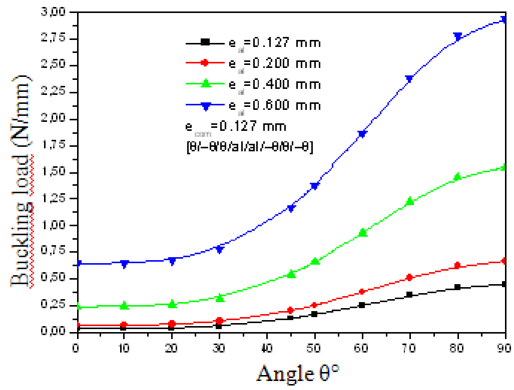

Fig. 5. Variation of the buckling load as a function of orientation θ° (hybrid composite (θ/-θ/θ/al/al/-θ/θ/-θ)).

In this section, we made a comparison between these five materials to see the effect of the thickness of the aluminum layer on the buckling load. Firstly by using a conventional composite material is of eight plies each having a thickness e=0.127 mm, other materials are hybrid composite materials with layers of composite of thickness e= 0.127 mm and aluminum layers of thickness e=0.400 mm, the difference between hybrid materials lies in the location of the aluminum layers . The latters are both outside and inside.

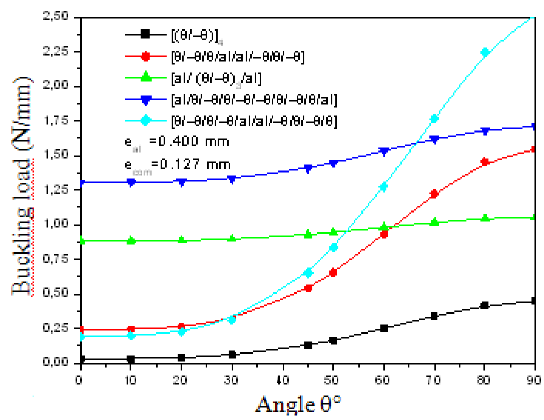

Fig. 6. Variation of the buckling load as a function of orientation θ°.

We note that the critical buckling load is low when the fiber orientation is lower than 30°. Beyond this orientation, the load increases sensibly. This behavior is probably due to the fact that the fibers become parallel to the applied load. We note however that the load is greater for hybrid composites .This explains the importance of the thickness of the aluminum layer.

V- Effect of cracking on the charge of buckling

In this case, we assume a plate with a notch is assumed radius R=4 mm and a length of crack a=20 mm, only the orientation of the crack at an angle α varies as shown in Figure 6. The considered plate is subjected to the same boundary conditions as above. therefore in this figure, the mesh of crack by quadratic elements is shown.

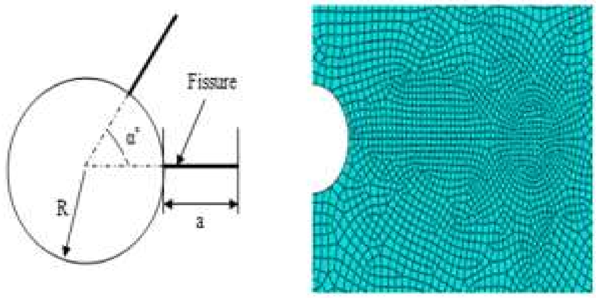

Fig. 7. Schematic representation and mesh at the notch and crack.

In Figures 8, 9, 10, 11 and 12 has traced the variation of the buckling load as a function of the orientation of the crack for deferent fiber orientations θ=0°, θ=45° and θ=90° respectively. It is noted for each figure that regardless of the orientation of the crack, the buckling load is almost stable. On the other side, we notice that when the fibers are oriented at an angle θ=90° that is to say perpendicular to the applied load, the critical buckling load reaches maximum values.

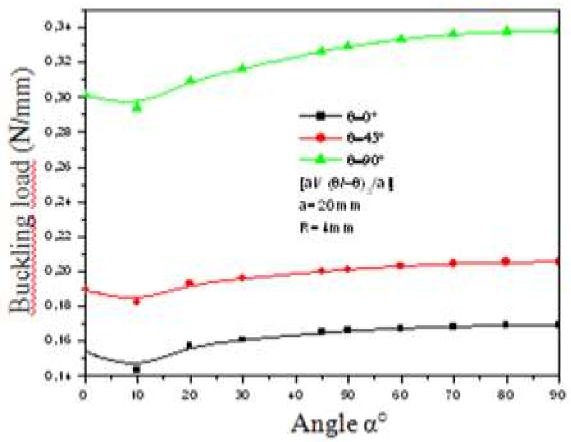

Fig. 8. Variation of the buckling load as a function of orientation α° (hybrid composite (al/(θ/-θ)$_3$/al)).

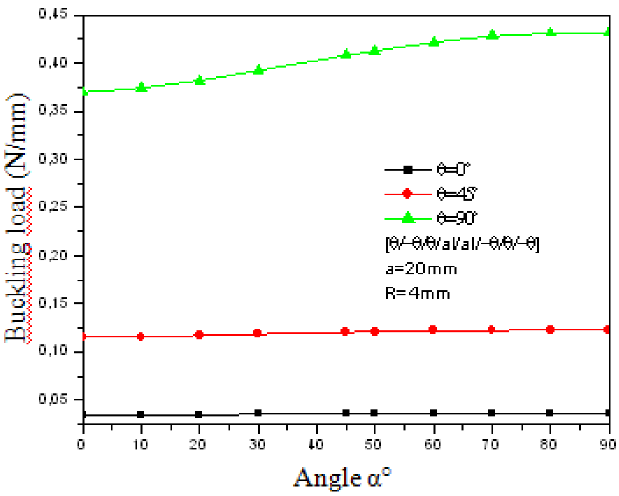

Fig. 9. Variation of the buckling load as a function of orientation α° (hybrid composite (θ/-θ/θ/al/al/-θ/θ/-θ)).

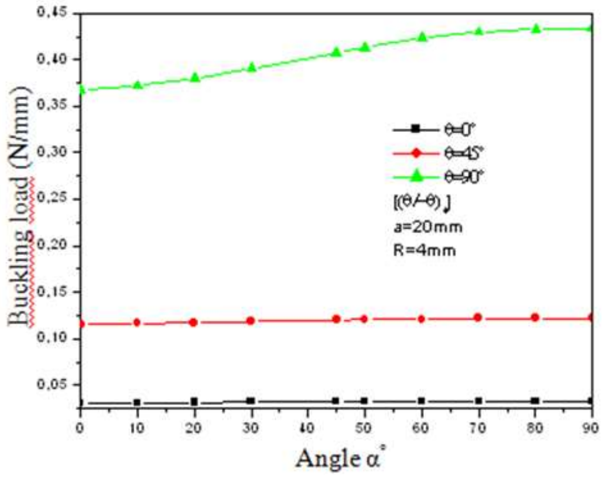

Fig. 10. Variation of the buckling load as a function of orientation α° (composite [(θ/-θ)$_4$]).

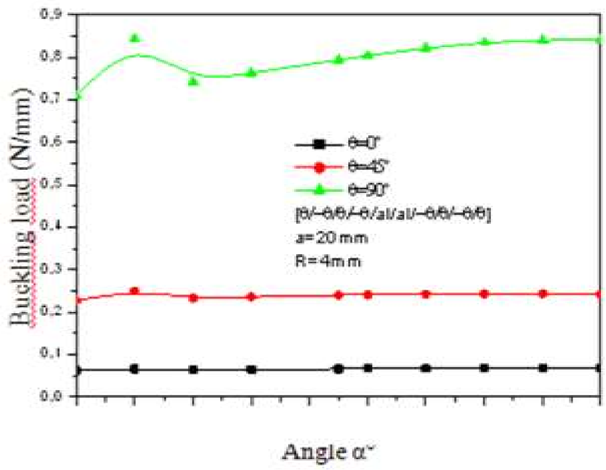

Fig. 11. Variation of the buckling load as a function of orientation α° (composite (θ/-θ/θ/-θ/al/al/-θ/θ/-θ/θ)).

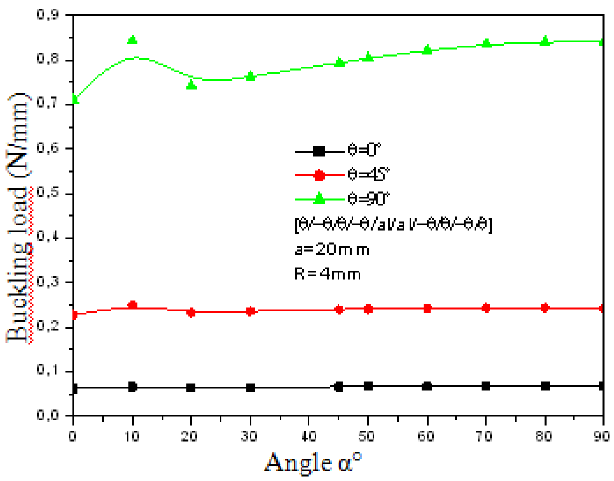

Fig.12. Variation of the buckling load as a function of orientation α° (composite (al/θ/-θ/θ/-θ/-θ/θ/-θ/θ/al)).

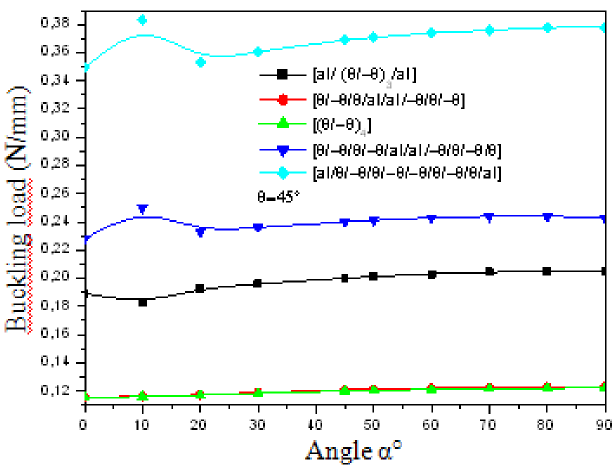

Fig. 14. Variation of the buckling load as a function of orientation α°

On this last part, we show a comparison between materials listed above to see the effect of the orientation of the crack on the critical buckling load. In Figures 13, 14, it is found that when the fiber orientation angle is θ=0°, θ=45°, the critical load for hybrid composite materials whose aluminum layers are outside is much higher to other materials, while figure15 shows that for θ=90°, the latters have small values of the critical buckling load.

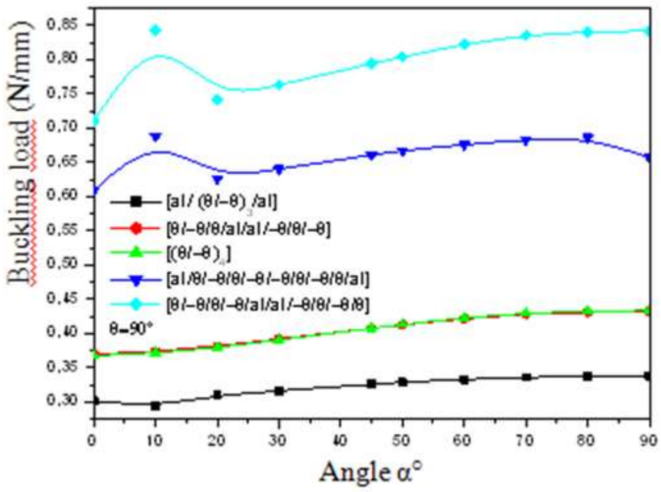

Fig. 15. Variation of the buckling load as a function of orientation α°

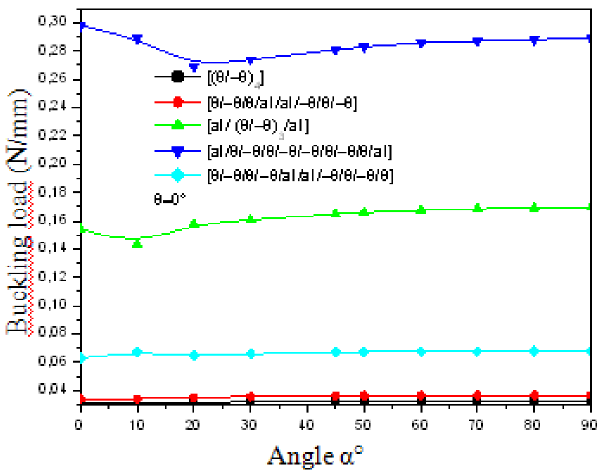

Fig. 13. Variation of the buckling load as a function of orientation α°

VI-Conclusion

The study aims to determine the effect of fiber orientation on the critical buckling load, the latter is obtained for five different materials. Analysis of the results allows us to draw the following conclusions:

- the critical buckling load reaches maximum values when the fibers are oriented in an interval ranging from 50° to 90°.

- when the angle θ ° is less than 30 °, the values of the critical load is almost constant.

- Hybrid materials with aluminum layers outside have a good resistance to buckling when the fibers are oriented in an interval ranging from θ= 0° to θ= 45°.

- by increasing the thickness of the aluminum layer, buckling load increases.

- by increasing the number of layers of the composite, buckling load increases.

As regards the orientation of the crack in the plate we note :

- Regardless of the orientation of the crack, the buckling load is almost stable.

- when the fibers orientation angle is θ=0°, θ=45°, critical load for hybrid composite materials whose aluminum layers are outside is far superior to other materials.

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