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IMPACT OF NUMBER OF LAYERS ON THE PERFORMANCE OF THE DEFLECTION FOR SYMMETRIC AND ANTI-SYMMETRIC CROSS-PLY LAMINATES

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ABSTRACT

This study investigates the effect number of layers and orientation angle on laminated composite plates in terms of the stresses and displacements or deflections that they experience. Using the finite element system software ABAQUS, comparative research is carried out in order to explore the influence of number of layers and orientation angle on the behaviour of stresses and deflections of simply supported laminated composite plates when subjected to a load that is distributed evenly.

Key words: Number of layers, Boundary conditions, Deflections, Stresses.

1. INTRODUCTION.

Because of their high specific stiffness and strength, excellent fatigue resistance, long durability, and many other superior properties in comparison to ordinary plates, laminated composite plates are widely used in the construction of high-performance structures in a variety of industries, including aerospace, civil, marine, automotive, and other high-performance structures. When it comes to the right and efficient use of such laminates, a more complicated study is required in order to effectively forecast the elastic response of these structures when they are subjected to external loading. This includes aspects such as deflection and stress analysis. Generally speaking, these structures need to have a high level of reliability assurance in order to accurately anticipate the maximum load that the structure is capable of withstanding, in addition to the fact that the failure process is very important [2-13]. A composite structural material is referred to be laminated when it is manufactured by mixing two or more elements that are glued together by strong adhesives. Laminates may be made from a variety of other materials. As illustrated in Figure 1a, laminated composite plates are produced by creating plates consisting of two or more thin layers of materials that are bonded together. These plates may be either cross-ply laminates or angle-ply laminates.

In the case of cross-ply laminates, the laminates are oriented alternatively at 0^0 and 90^0. The laminates can be either symmetric cross-ply (00 /90^0/90^0/0^0) or anti symmetric cross-ply (0^0/90^0/0^0/90^0) as shown in Fig.(1-b). In the case of angle-ply laminates, the orientation angle θ alternates from lamina to lamina either symmetric angle-ply (+θ0/ -θ^0/ -θ^0/ +θ^0) or anti-symmetric angle-ply (+θ^0/ -θ^0/ +θ^0/ -θ^0) as shown in Fig.(1-c).

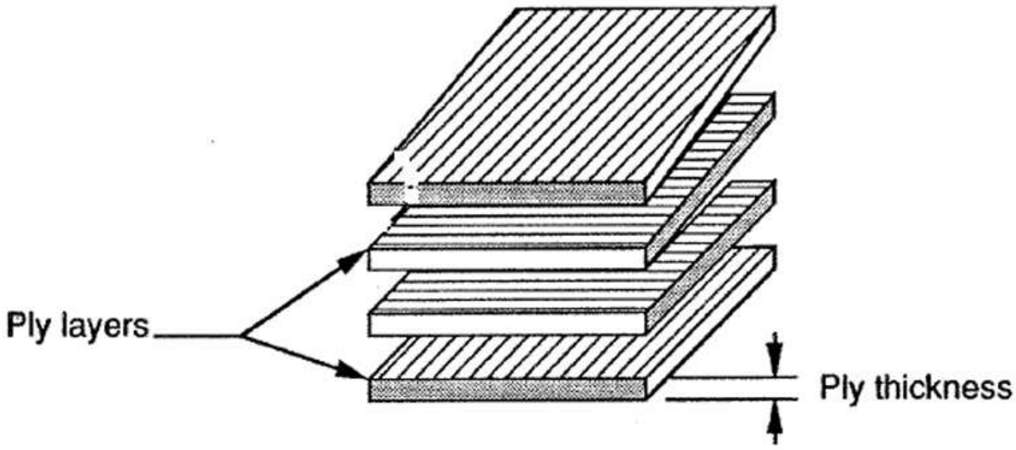

Fig. (1-a) laminated composite plate.

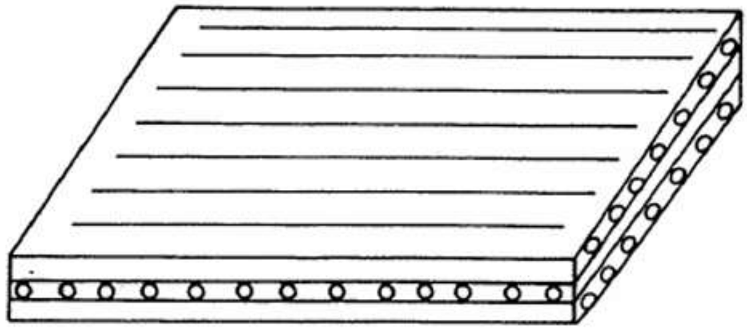

Fig. (1-b) Cross-ply laminate.

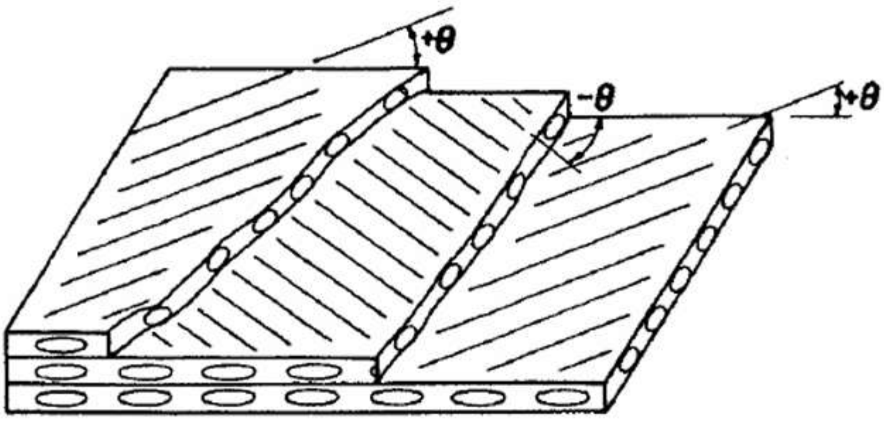

Fig. (1-c) Angle-ply laminate.

It is possible to conduct an analysis of laminated composite plates by using analytical and numerical techniques. Furthermore, the laminated plate theories are needed in order to offer an accurate analysis of laminated composite plates [13]. The classical lamination theory (CLT), the first-order shear deformation theory (FSDT), and the higher-order shear deformation theory (HSDT) are the three types of shear deformation theories and theories. When it comes to the study of the complicated structural behaviour of laminated composite plates, the finite element approach is particularly adaptable and effective. A substantial amount of study has been conducted using the finite element approach in order to investigate the vibrations and dynamics, buckling and post-buckling behaviour, failure and damage analysis of laminated composite plates [2-13]. As a result, the purpose of this research is to investigate the impact that the aspect ratio, the number of layers, and the orientation angle have on the behaviour of laminated composite plates with regard to stresses and deformations by making use of the finite element system ABAQUS. The consideration is given to a laminated composite plate that is simply supported and loaded with a load that is distributed evenly. During the process of doing the analysis for displacements and stresses, both cross-ply and angle-ply laminates with symmetric and antisymmetric arrangements are taken into consideration.

2. NUMERICAL EXAMPLE.

To find out how number of layers, and orientation angle affect the behaviour of laminated composite plates, we look at a laminated composite plate that is supported on all four sides and has dimensions (a x b) and a thickness (h). We do this while applying a uniform load of 10 N/m^2, as shown in Fig. (2). A is always 1 meter long, b is always 0.5 meter long, and it changes based on the aspect ratio, which can be 1, 2, 3, or 4. The plate's total thickness (h) is 1 mm.
For this study, laminates are made up of hybrid plates with four, six, eight, or ten orthotropic plies made of the same material and the same thickness. The total thickness stays the same. It looks at both cross-ply and angle-ply laminates that are set up in symmetric and antisymmetric ways. The direction angle ¸0 for angle-ply laminates is 30^0, 45^0, and 60^0, as shown in Table (1).

The materials properties are given as E1 = 215 e^9 $N\backslash m^2$, E_2 = 23.6 e^9 $N\backslash m^2$, E_3 = 23.6 e^9 $N\backslash m^2$, G_{12} = 5.4 e^9 $N\backslash m^2$, G_{13}= 5 e^9 $N\backslash m^2$, G_{23} = 5 e^9 $N\backslash m^2$, ν_{12}= 0.3, ν_{13}= 0.2 and ν_{23}= 0.2 for Young's modulus, shear modulus and Poisson's ratio respectively where 1, 2, and 3 are principle material directions as shown in Fig. (2).

Fig. (2) Geometry of a laminated plate.

Table (1) Orientation of symmetric and anti-symmetric arrangements for cross ply and angle-ply laminates.

Laminate type.	Number of layers.	Type of arrangement.	Orientation.
Cross-ply	4 layers	Symmetric	0/90/90/0
		Anti-symmetric	0/90/0/90
	6 layers	Symmetric	0/90/0/0/90/0
		Anti-symmetric	0/90/0/90/0/90
	8 layers	Symmetric	0/90/0/90/90/0/90/0
		Anti-symmetric	0/90/0/90/0/90/0/90
	10 layers	Symmetric	0/90/0/90/0/0/90/0/90/0
		Anti-symmetric	0/90/0/90/0/90/0/90/0/90
Angle-ply	4 layers	Symmetric	+θ/ -θ/ -θ/ +θ
		Anti-symmetric	+θ/ -θ/ +θ/-θ
	6 layers	Symmetric	+θ/-θ/ +θ/ +θ/ -θ/ +θ
		Anti-symmetric	+θ/ -θ/ +θ/ -θ/ +θ/ -θ
	8 layers	Symmetric	+θ/ -θ/ +θ/ -θ/ -θ/ +θ/ -θ/ +θ
		Anti-symmetric	+θ/ -θ/ +θ/ -θ/ +θ/ -θ/ +θ/-θ
	10 layers	Symmetric	+θ/ -θ/ +θ/ -θ/ +θ/ +θ/ -θ/ +θ/ -θ/ +θ
		Anti-symmetric	+θ/ -θ/ +θ/ -θ/ +θ/ -θ/ +θ/ -θ/ +θ/ -θ

3. RESULTS AND DISCUSSION.

Following the completion of the study, the values for the center deflection as well as the maximum normal stress in direction X have been acquired. The findings that were collected are evaluated in order to investigate the impact that the aspect ratio a/b, the number of layers, and the orientation angle have on the stresses that are present in laminated composite plates. As a means of simplifying the presentation, the findings are shown in the following charts:

Effect of number of layers.

For both symmetric and anti-symmetric cross-ply laminates, the influence of the number of layers on the performance of the center deflection is shown in Figure (3).

The influence of the number of layers on the performance of the maximum normal stresses in direction X is shown in Figure (4), which compares symmetric and anti-symmetric cross-ply laminates.

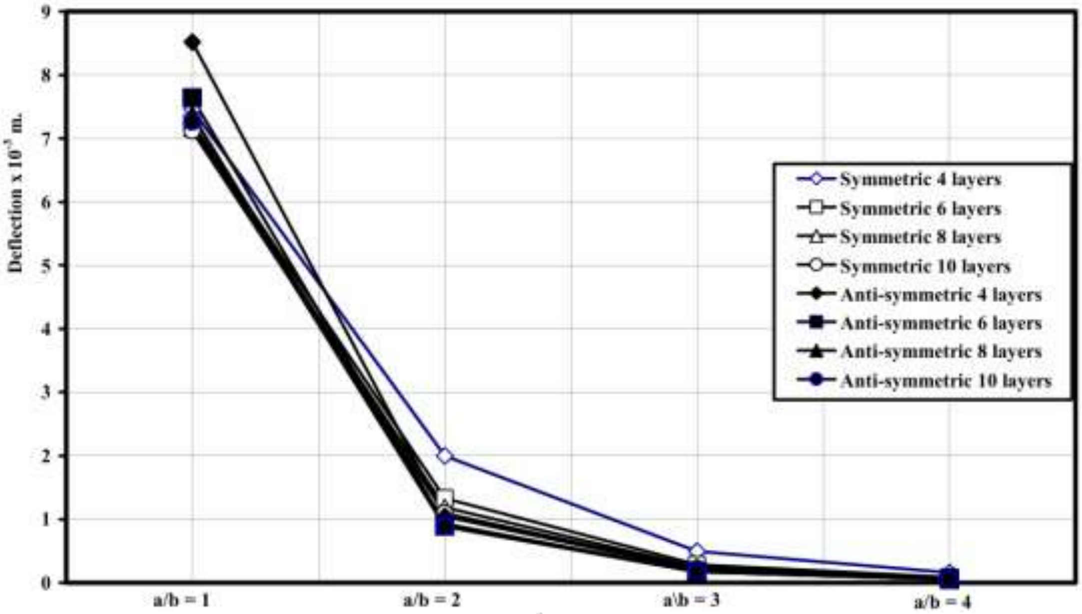

Fig.(3) Effect of number of layers on the performance of the deflection for symmetric and anti-symmetric cross-ply laminates.

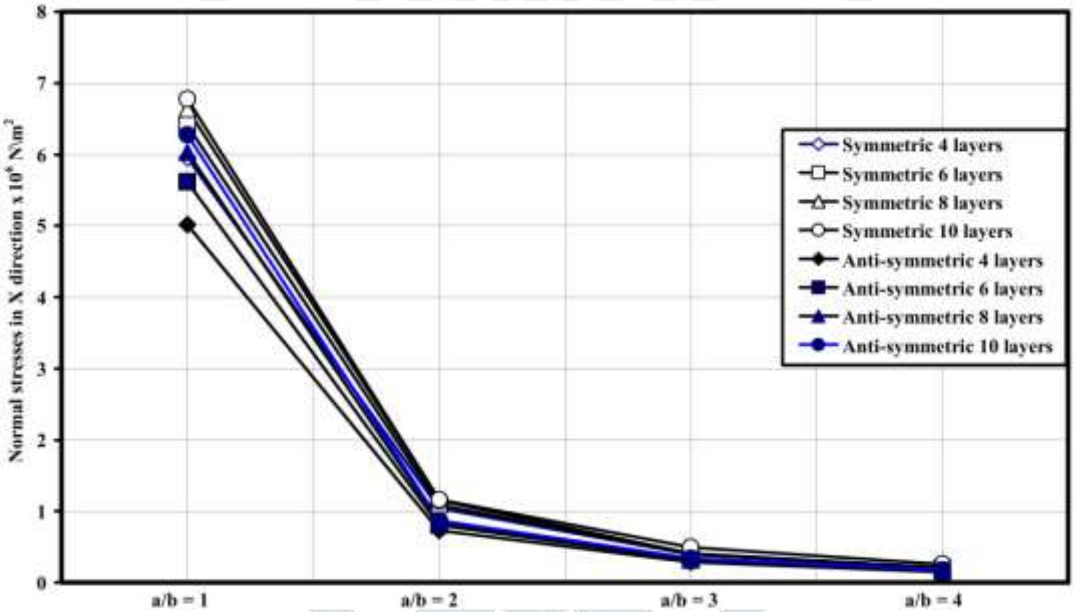

Fig.(4) Effect of number of layers on the performance of the normal stresses in direction X for symmetric and anti-symmetric cross-ply laminates.

The influence of the number of layers on the performance of the center deflection is shown in Figure (5), which is applicable to both symmetric and anti-symmetric 30^0 angle-ply laminates.

For both symmetric and anti-symmetric 30^0 angle-ply laminates, the influence of the number of layers on the performance of the maximum normal stresses in direction X is shown in Figure (6).

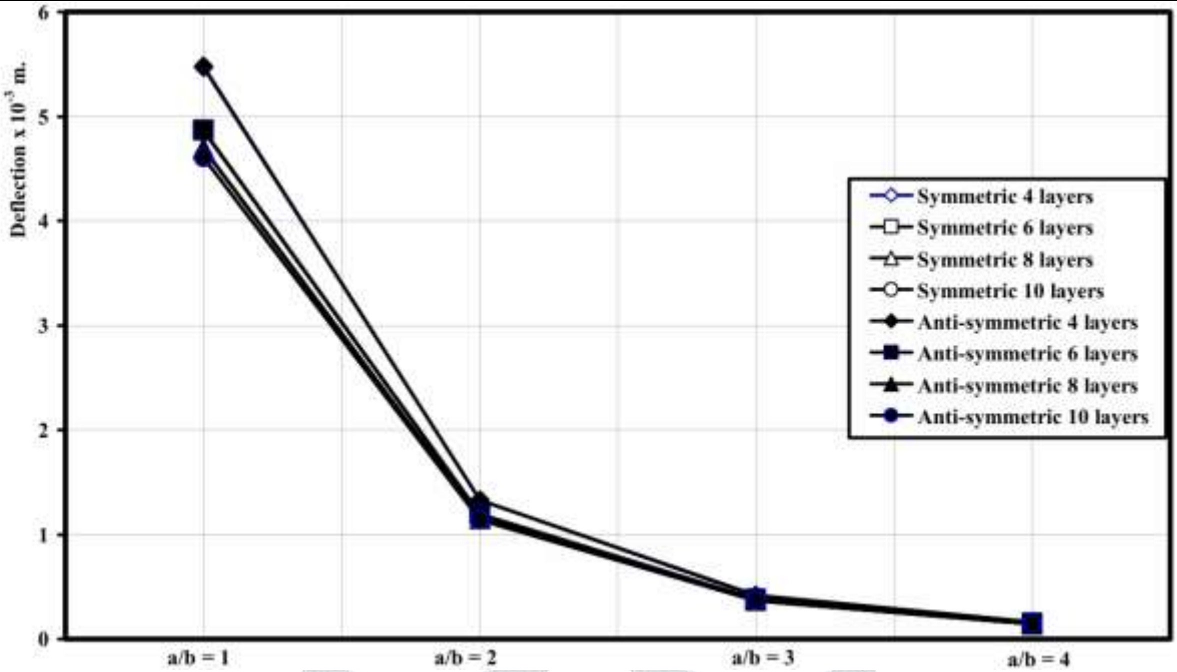

Fig.(5) Effect of number of layers on the performance of the deflection for symmetric and anti-symmetric angle-ply 30^0 laminates.

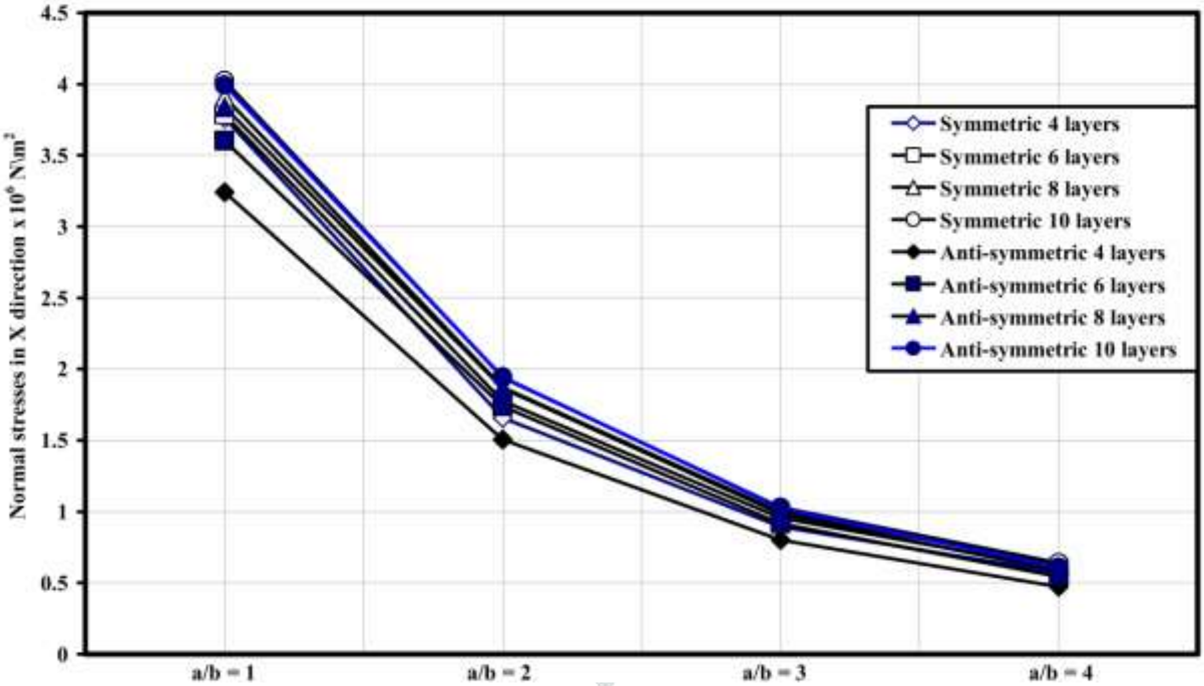

Fig.(6) Effect of number of layers on the performance of the normal stresses in direction X for symmetric and anti-symmetric angle-ply 30^0 laminates.

The effect of the number of layers on the performance of the maximum normal stresses in direction X for symmetric and anti-symmetric 45^0 angle-ply laminates is shown in Figure (8), while Figure (7), which shows the effect of the number of layers on the performance of the central deflection, shows the effect of the number of layers on the performance of the maximum normal stresses.

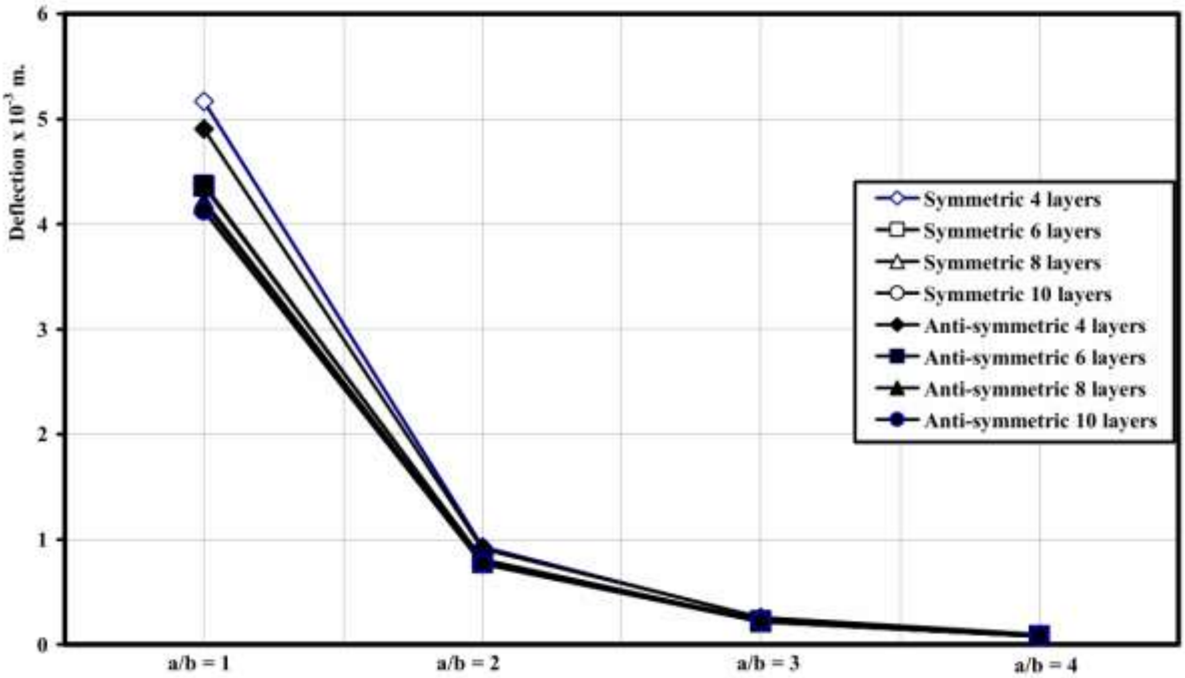

Fig.(7) Effect of number of layers on the performance of the deflection for symmetric and anti-symmetric angle-ply 45^0 laminates.

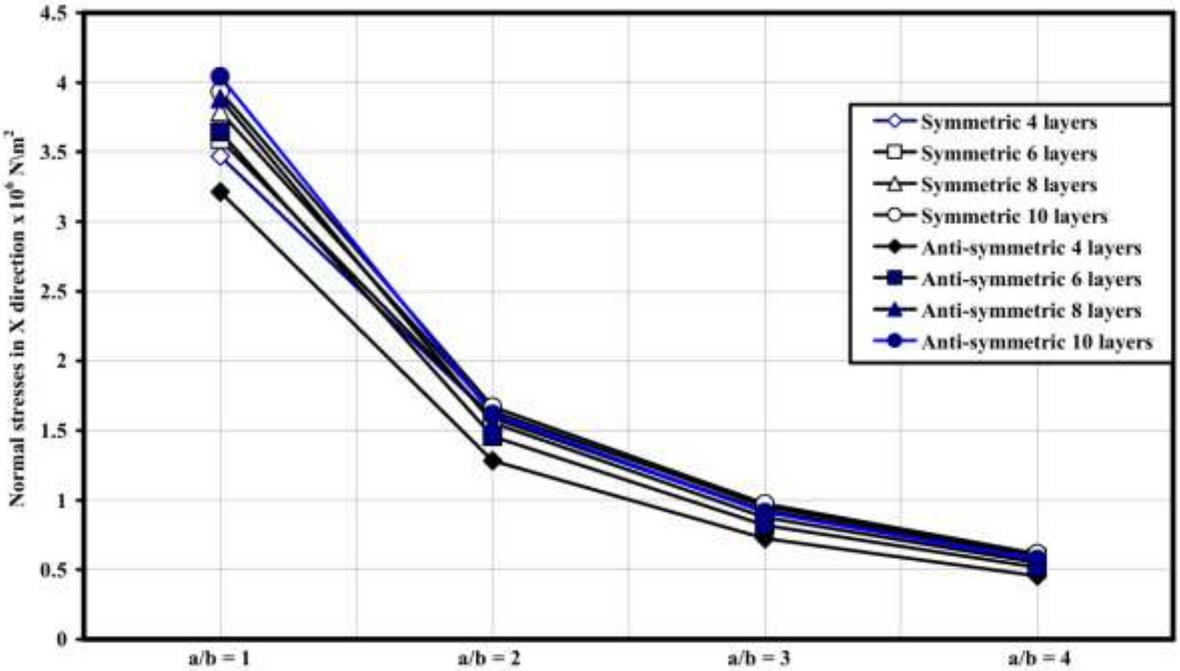

Fig.(8) Effect of number of layers on the performance of the normal stresses in direction X for symmetric and anti-symmetric angle-ply 45^0 laminates.

Effect of orientation angle.

When it comes to angle-ply laminates, the deflection and normal stresses are almost identical for both symmetric and antisymmetric configurations. Figure 9 illustrates the impact that the orientation angle has on the center deflection performance of symmetric laminates with angles of 30^0, 45^0, and 60^0 angle-plys. Figure 10 illustrates the impact that orientation angle has on the performance of maximum normal stresses in direction X for symmetric laminates with angles of 30^0, 45^0, and 60^0 angle-plys.

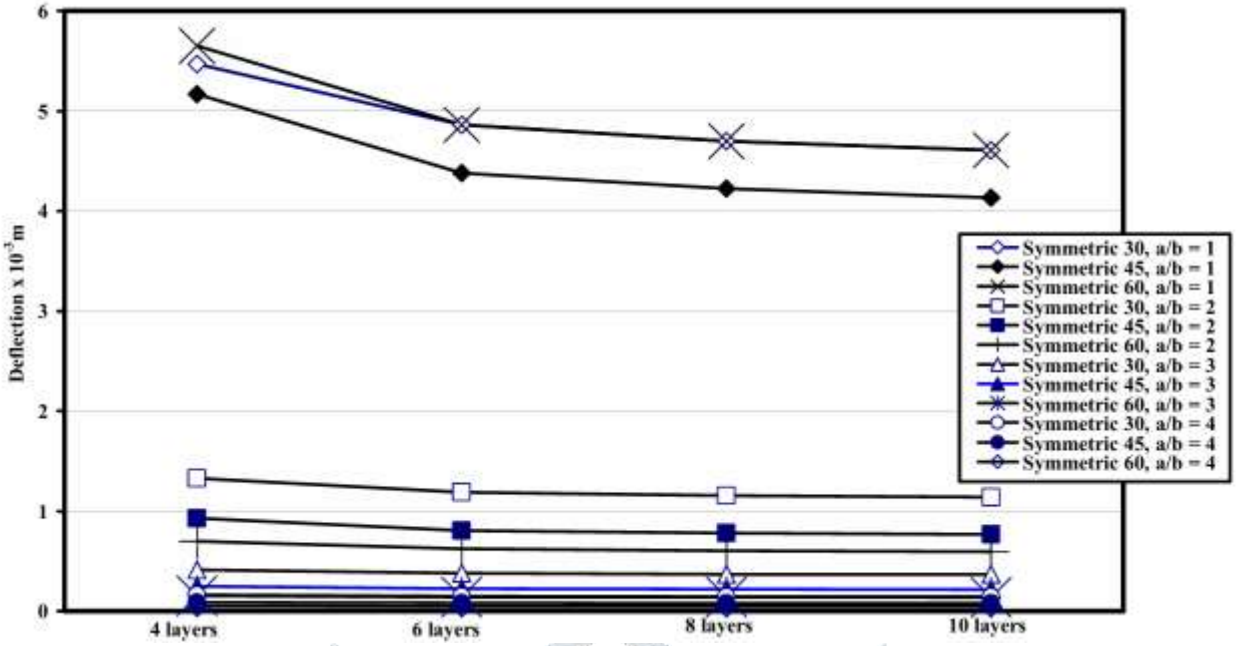

Fig.(9) Effect of orientation angle on the performance of the deflection for symmetric angle-ply 30^0, 45^0 and 60^0 laminates.

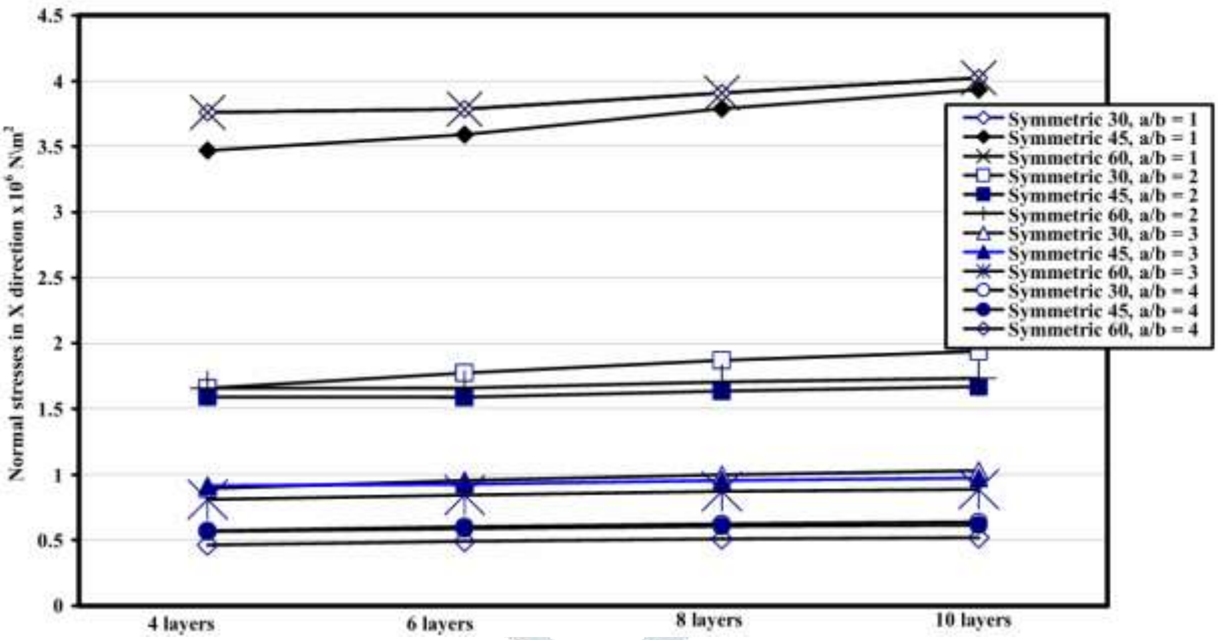

Fig.(10) Effect of orientation angle on the performance of the normal stresses in direction X for symmetric angle-ply 30^0, 45^0 and 60^0 laminates.

4. CONCLUSIONS.

In this research, an analysis of laminated composite plates under uniform distributed load has been carried out in order to investigate the impact of number of layers, and orientation angle on the deflection and stresses that are present in laminated composite plates. As a consequence of the findings that are presented in this article, the following conclusions may be drawn:

When the aspect ratio is equal to or less than 2, the deflection reduces as the number of layers rises for cross-ply and angle-ply laminates with symmetric and anti-symmetric arrangements. When the aspect ratio is equal to or less than two, the normal stresses in cross-ply laminates with symmetric and anti-symmetric layouts grow as the number of layers increases. Increasing the number of layers in angle-ply laminates with symmetric and anti-symmetric arrangements causes the normal stresses to grow in proportion to the aspect ratio. This phenomenon occurs as the number of layers increases. There is no correlation between the symmetric and anti-symmetric arrangements and the deflection and normal stresses of angle-ply laminates. This is because the aspect ratio and the number of layers both rise as the number of layers increases.

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