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Research Article

Novel Design and Comparision of Structural and Modal Analyses of Auxetic Geometry versus Honeycomb Geometry

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ABSTRACT

Auxetic structures are popular, since they have much application area. Depending on these areas of their usage, auxetic structures are subject to various loads and vibrations. Within the scope of this study, a special form of auxetic structure was created inspired by honeycomb structure, both auxetic and honeycomb models were modeled in Ansys software by keeping the edge length of this structure and honeycomb structure equal. Since both structures are considered to be used as core material in composites, it is considered that the surface areas are close to each other. Structural and modal analyses were applied to the models and auxetic structure was shown to give better results.

Keywords: Auxetic modeling; Honeycomb Modeling; Foam Structures; Structural Analysis; Modal Analysis

INTRODUCTION

The Auxetic materials have an extraordinary feature unlike the materials with a positive Poisson ratio. The biggest difference of these materials compared to conventional materials is that displacement occurs directly proportional as a function of the direction of the applying force. The experimental and modeling studies on auxiliary materials showed that these materials have superior properties which can be listed as follows:

- Better sliding module.
- Extra friction resistance.
- Acoustic behavior.
- Superior energy absorption (impact, ultrasonic and sonic).
- Wet efficiency.
- Adhesion (interface / matrix) strength.
- Thermal impact resistance.
- Rupture strength.

In the past century, some assumptions about the negative Poisson ratio were emphasized, and at the same time the first experimental study was done by Roderic Lakes [1] on foam structures with a negative Poisson ratio. In 1991, Ken Evans [2] used the term “auxetic” for materials with a negative Poisson ratio. Moreover, the term Auxetic comes from the Greek word “auxetikos”, meaning “Containing the property of counter-intuitively expanding when being stretched”.

MATERIALS AND METHODS

Recently, various experimental, numerical as well as experimental and numerical studies have been done on auxetic structures. The experimental studies on the Auxetic structures have been focused on the improvement of the strength and energy absorption properties of composite materials [3-8]. Hou et al. [3] examined the impact resistance of carbon fiber reinforced composites including the sandwiched form of polymeric core, which they produced in 3D form in auxetic form. The impact strength of the core material in auxetic form showed better results in repeated loads. They compared the auxetic structures created in two different forms and observed that the stress concentration effects of these structures produced quite different results [6].

There are various numerical studies about Auxetic structures. In numerical studies, auxetic structures have been generally modeled in different shapes, these models have been created in foam form [9-13] and honeycomb form [14-17] and mechanical analysis have been carried out in Computer Aided Engineering (CAE) programs. They modeled novel auxetic structures and analyzed the mechanical properties of these models such as Young’s modulus and Poission’s ratio [10]. They emphasized that the obtained analysis results are quite remarkable. Auxetic structures are also mentioned in various applications such as medical, sports and it is explained that the mechanical strength results obtained from numeric studies are very useful for these applications [13,14].

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In addition to all these studies, experimental and numerical researches are performed and good results are obtained in the mechanical properties of auxetic structures in different forms [18-21]. When all the studies are examined, it is seen that the mechanical strengths and energy absorption of auxetic structures give better results. In this study, as an alternative material to the core materials in honeycomb form, an auxetic-shaped core material with similar dimensions was modeled, and structural and modal analyses of both models were made using ANSYS.

Analysis of auxetic and honeycomb structures

This theoretical study is inspired by a hexagonal geometry. When modeling auxetic and honeycomb structures, rods of 40 mm length were used. Two of these bars are mutually positioned so that they are parallel to each other. The other bars are positioned with these bars at an angle of 14o horizontally. The auxetic structure was formed by inward positioning of the rods making an angle of 14o with the horizontal, and the honeycomb structure was formed by the external positioning, as seen in (Figure 1).

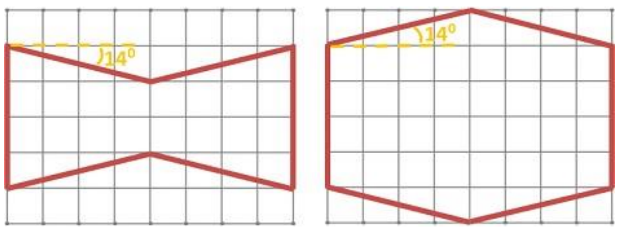

Figure 1: Modeling of the structures: Auxetic Structure, Honeycomb Structure.

In the first step of the study, it is aimed that the structures cover equal surface areas. Each structure is designed to be combined side by side to fill a rectangular geometry with a surface area of 180X240 mm^2. The structural integrity figure which fills the rectangular geometry is shown in (Figure 2).

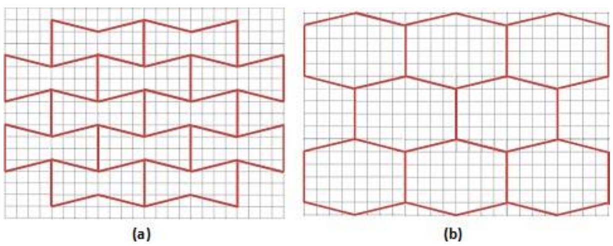

Figure 2: Integrities of a) Auxetic Structure, b) Honeycomb Structure.

While creating structural integrity with 180X240 mm^2 surface area for each structure; 12 auxetic structures and 8 honeycomb structures were used.

The structural integrities of auxetic and honeycomb structures have same lengths which dimension is 240mm. The total area of auxetic structural integrity and honeycomb structural integrity are 28800mm^2 and 32000mm^2, respectively. The structural integrities of auxetic and honeycomb structures were solved via Ansys 14.5 computer aidded engineering (CAE) program after they were modeled geometrically, and then the structural and modal analyses.

Analysis of auxetic and honeycomb structures

The key point numbers and coordinates which were used in the geometrically generation of the auxetic and honeycomb structural integrities via Ansys 14.5 were listed in (Table 1) and (Table 2).

KP#(X,Y)					
1(40,0)	8(80,30)	15(80,70)	22(80,90)	29(80,130)	36(120,160)
2(80,10)	9(120,40)	16(120,60)	23(120,100)	30(120,120)	37(160,150)
3(120,0)	10(160,30)	17(160,70)	24(160,90)	31(160,130)	38(200,160)
4(160,10)	11(200,40)	18(200,60)	25(200,100)	32(200,120)	
5(200,0)	12(240,30)	19(240,70)	26(240,90)	33(240,130)	
6(0,30)	13(0,70)	20(0,90)	27(0,130)	34(40,160)	
7(40,40)	14(40,60)	21(40,100)	28(40,120)	35(80,150)	

Table 1: The key point numbers (KP#) and coordinates (X,Y) of the auxetic structural integrity.

KP#(X,Y)			
1(0,10)	8(0,50)	15(0,110)	22(0,150)
2(40,0)	9(40,60)	16(40,100)	23(40,160)
3(80,10)	10(80,50)	17(80,110)	24(80,150)
4(120,0)	11(120,60)	18(120,100)	25(120,160)
5(160,10)	12(160,50)	19(160,110)	26(160,150)
6(200,0)	13(200,60)	20(200,100)	27(200,160)
7(240,10)	14(240,50)	21(240,110)	28(240,150)

Table 2: The key point numbers (KP#) and coordinates (X,Y) of the honeycomb structural integrity.

Shell element was selected in the Ansys models, and the thickness of element was defined as 1 mm. After the modeling of structural integrities, mesh was generated as 0.5mm size.

RESULTS AND DISCUSSIONS

In the study, static-structural and modal analysis were applied to the auxetic and honeycomb structural integrities which were modeled in the Ansys. The models were fixed from the left edges and 100N/mm distributed loads were applied from the right edges. The stress intensity results of auxetic and honeycomb structure integrities were obtained from static-structural analysis were shown in Figure 3.

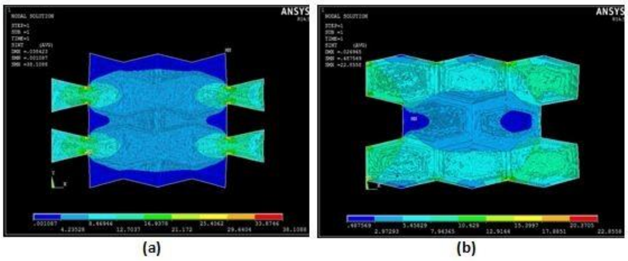

Figure 3: The static-structural analyses of structural integrities; a) Auxetic b) Honeycomb.

The maximum stresses were obtained 38 MPa and 22.85MPa for the auxetic and the honeycomb models as seen in the Figure 3. Besides, the maximum displacement was obtained 0.038 mm for the auxetic model; the maximum displacement was obtained 0.027 mm for the honeycomb model. The maximum stress in auxetic structure was found to be 40% higher than that of in honeycomb structure. Also, the maximum displacement of auxetic structure was 29% higher than that of honeycomb structure.

The frequency results of auxetic and honeycomb structure integrities obtained from modal analysis were shown in Figure 4. Four modes values were calculated in the analyses.

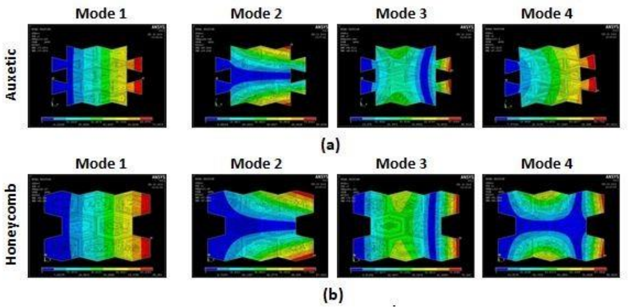

Figure 4: The modal analysis of structural integrities; a) Auxetic, b) Honeycomb.

CONCLUSION

In this study, two different geometries are modeled, one is conventional and the other is auxetic. Static-structural and modal analyses were applied to the modeled geometries. In the modeling of both geometries, it is planned to fit the surface area of 180X240 mm2. Findings obtained as a result of the analyses are listed below:

- Although the surface area of the auxetic structure integrity is 10% less than the honeycomb structure, the maximum stress in the auxetic structure is 40% higher than that of the honeycomb structure.
- When the modal analysis is examined, it is seen that the maximum displacement for both integrities is in the marginal regions in 4 modes.
- For each mode, the natural frequency in the structural intensity of the honeycomb structure was more pronounced than auxetic structure.
- When the 4th mode of both structural integrities is examined, minimum displacement occurs in auxetic structure whereas the maximum displacement occurs in honeycomb structure.
- When the first 3 modes are examined, it is seen that the displacements in the auxetic are higher than those in honeycomb structure. In the case of resonance, it is obvious that the auxetic structure model will be displaced more.

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