INVESTIGATION OF VIBRATION RESPONSE OF AUXETIC META MATERIALS FOR VIBRATION DAMPING

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Abstract

Vibration control is critical to many practical engineering systems in order to minimize the detrimental effects caused by unavoidable vibrations and noises. Metamaterials and auxetic structures, which have attracted increasing interest in interdisciplinary research fields, possessmany peculiar physical properties, including negative Poisson's ratios, nonlinear, and tunable stiffness features, and thus offer promising applications for vibration control. In this work, six different auxetic structures will be developed namely collapsed regular hexagon, double arrowhead, star honeycomb, hexagonal re-entrant honeycomb, lozenge grid, and square grid. Additive manufacturing will be used to manufacture the aforementioned structures using the fused deposition modelling (FDM) technique. Vibration testing will be carried out using an electro-dynamic shaker to investigate the vibrational response of the developed auxetic structures. Frequency response function (FRF) plots will be plotted for the vibrational data for different test cases. Finally, a comparison is made to find the best auxetic structure for vibration damping.

Keywords:Auxetic, Vibration,damping,AdditiveManufacturing,Frequency response function.

Introduction

Materials Science and engineering have been taking a prominent position in almost all development activities since time immemorial. Materials have given rise to the invention of several technologies, including transportation, agriculture, housing, food science, environment, medicine and health, information and communication, and structural materials like textiles. The challenge is to increase the developments and applications of these materials of required properties and making them affordable to cost to satisfy the needs of humankind. The list is numerous which includes metals, polymers, plastics, ceramics, glass, composites, and fibrous materials. Fibrous materials have a very broad meaning, and they can be categorized as plastics, rubber, textiles, paper, glass, food, the human body, etc. Fibers can be classified into two major groups as natural and manmade or manufactured. Natural fibers are abundantly available in nature that is biodegradable and sustainable and have played a major key role in humanity. Synthetic fibers, however, are cheaply produced compared to natural ones. Auxetic textile materials are an integral part of these fibrous structures. However, these fibers can be transformed into a broad range of structures such as yarns, fabrics, cloths, and composites by utilizing various textile manufacturing technologies like spinning, weaving, knitting, braiding, and textile structural composite processing, etc. These manufacturing processes feature the grounds for satisfying the needs of contemporary societies as they help to transform raw materials into finished products incorporating organized and engineered structures. Fibrous textile material has a wide range of applications starting from the clothing sector to the biomedical field, civil engineering, filtration, fiberoptics, aerospace, automobile industries, and energy storage and harvesting applications. However, specific properties of these products can be achieved only by judicious use of the engineering design principle Engineering design relates to determining the shape of the product and its elements, the selection of materials from which they are to be made, and the selection of the relevant technological processes. This article is a comprehensive review of the advances made in the engineering of various auxetic textile materials and structures with special reference to their production, properties, and applications.

Statement of the Problem

The general design tools for parametric modeling can be explained as follows: For creating sketches in a plane Sketch entity are used. The major tools in sketch entities are lines commands, rectangles

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commands, circles commands, ellipse commands, and arcs commands. These tools are used for creating sketches. Geometric relations are created using the tools known as Sketch relations. To capture the design intent these relations are used. Vertical, horizontal, dashed line, parallel, perpendicular, coincident and tangent are the sketch relations. Boss and cut tools are utilized for creating basic features to the design. Revolving tools, extrudes tools, loft tools, sweeps tools, are the tools of the cut and boss tools. These tools are objected to creating extrude revolve features, features, loft features and sweep features to the model. The design dimensions are defined by using tools known as dimensions. The drawings of the model can be made by utilizing the general modeling instruments and the general drawings can be changed over to the geometry of the desired model.Themodeling of the auxetic beams isdoneby usingAutoCADPart Design as shown in fig-1 and 3D modelling in fig-2 and final AUTOCAD Design in fig-3The unit cells are taken in the design of the beams. Thus, the modeling of auxetic beams is done by using AutoCAD Part Design. Now export the files in STL format to start the 3D printing.

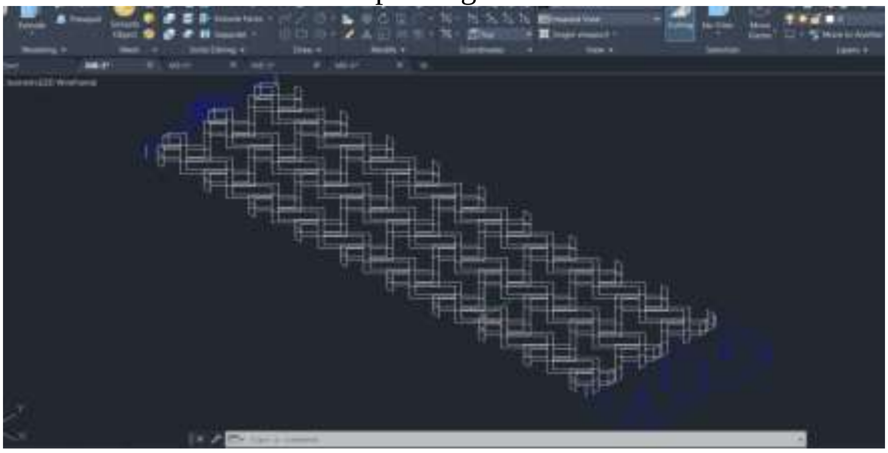

Fig-1.CAD Design Part

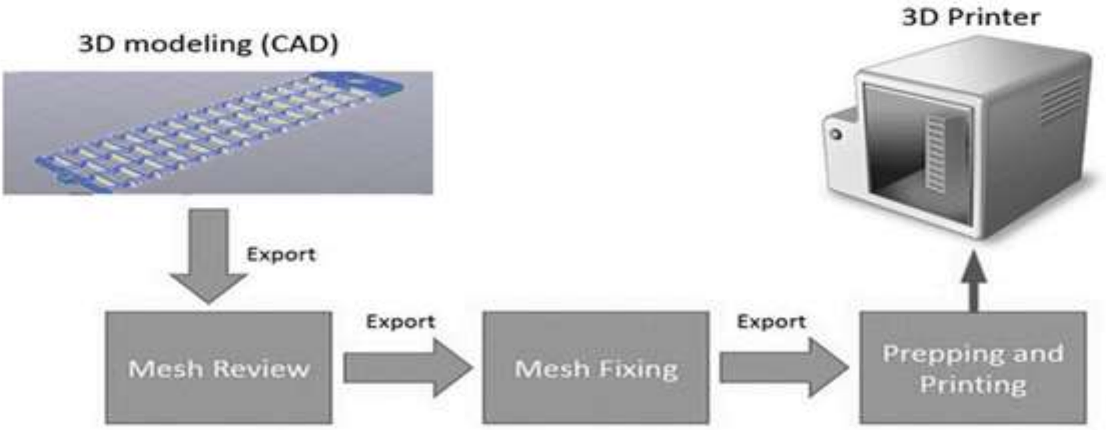

Fig-2 3D-Modeling

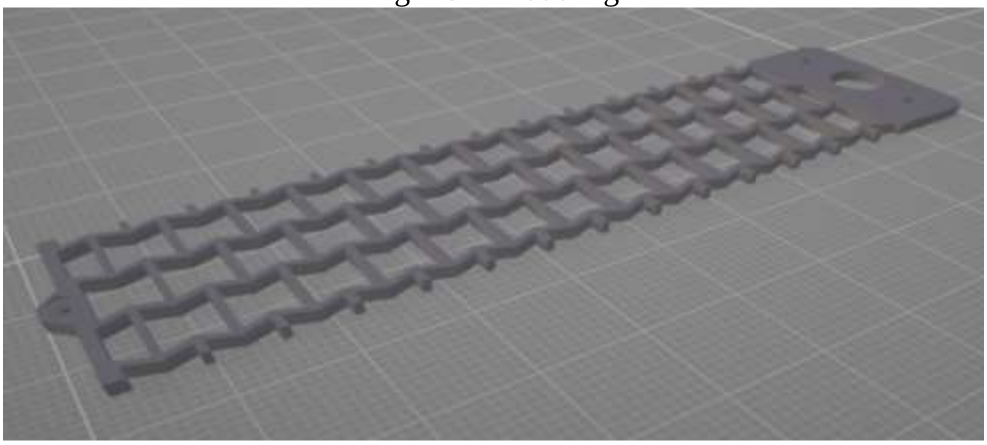

Fig-3 AUTOCAD Design

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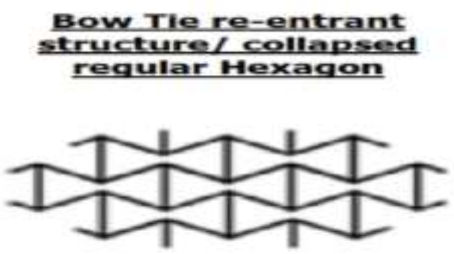
Review of Literature

Nitin R. Keskar[1] found in his research that silicate α-cristobalite, has a negative Poisson's ratio (NPR) due to the intrinsic rigid structure of the silicate. Further researchers have confirmed that zeolites, cat skin, show auxeticity. The natural auxetic materials are also categorized into two classes according to their source of origin i. e., mineral auxetic and biological auxetic. Certain examples of mineral auxetic materials are iron pyrite mono crystal, zeolites, silicates, thermal graphite, rocks with micro-cracks in the structure, arsenicwith a single crystalline structure, cadmium, and alpha cristobalite silica crystal. Whereas other than these materials, certain natural biological structures also fall under the category of natural auxetic materials like the cancellous bone in humans, cow teat skin, cat skin, and salamander skin.Larsen et al. [2] have discovered arrow-head re-entrant structure by modifying the four-node quadrilateral using a computational design tool. It is a truss structure where an isosceles triangular structure is the unit cell with a re-entrant base side and showed the NPR effect. As the tensile load is applied on the arrowhead structure the load gets transferred to the neutral sides of the structure and the unfolding of the reentrant sides takes place resulting inauxeticbehavior as the arrowhead structure widens, likewise on compression of the base cell in the horizontal direction the triangle collapse which further results in a contraction inthe vertical direction thereby showing the auxetic behavior.Miller et al. [3] tested the flatwise compression properties of the hexachiral and tetra-chiral honeycomb structures where these structures were composed of cylinders connected withsixorfourligaments respectively.Mukhopadhyay andAdhikari [4]developedan analyticalmodelfortheirregularauxetichoneycomb. Lakes and Witt designed a 3D structure as shown in with auxetic properties., a Tetrakaidekahedron model for the foam cells which could be used as filtersor seatcushionsandinananalyticalmodelof3Dauxetichoneycombstructurehavebeendevelopedbased on energy method which exhibited auxeticbehaviorin all the threeprincipaldirections.ThesestructurescouldexhibitNPRinboththetensileandcompressionmodes,therefore couldbe usedina wide rangeofapplications.Kim et al. [5] proposed a rotating polygonal prism structure, where the value of n is varied as3,4,and6,whichdeformsbytherelativerotationofthen-gonialcomponentprismunitsandgave an analyticalmodelforpredictingthe Poisson'sratioofthethreestructures.

Jiangetal [6].reviewedtheintrinsicandextrinsicatomisticmechanismfor theauxeticnanomaterials based on the atomistic simulations. NPR is caused due to the intrinsicmechanisms,withoutexternalengineering,whereastheextrinsicmechanismcausesNPRinthe material when the internal structure or geometry of the material is changed and itincludespatterning,buckling,rippling,andothermechanisms.

RESULTS AND DISCUSSIONS:

The vibration analysis of the printed auxetic structures are carried out by considering them as beams. The experimental setup consistsmodal shaker, accelerometers, dataacquisition (DAQ), power supply, and a computer(PC). The input to the shaker is given using out-DAQ. Both the DAQ and the shaker are connected to a power supply. The shaker moves up and down as shown in the Fig to createvibrations. These vibrations are captured using acetometers. The data is transferred from DAQ toPC using LabVIEWsoftware. Then the information of the modal response of the structure is included in the FRF, inparticularmodaldamping and naturalfrequencies. The change in the energy with change in frequency of vibration is shown in the FRFs.The lowerthe energy valueatparticular frequencythebetterthe vibrationdamping. The graphs are drawn use log10 scale. In all the cases the auxetic structures have thebettervibration damping capabilitiesthan continuous beamsare shown in figures [4-15].



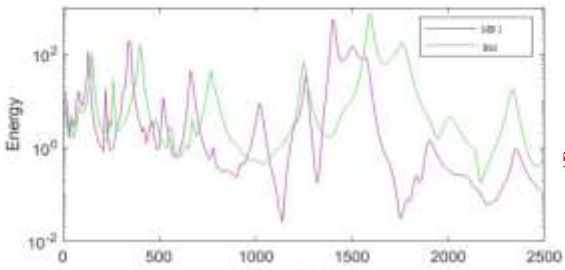


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Fig-4

Fig-5

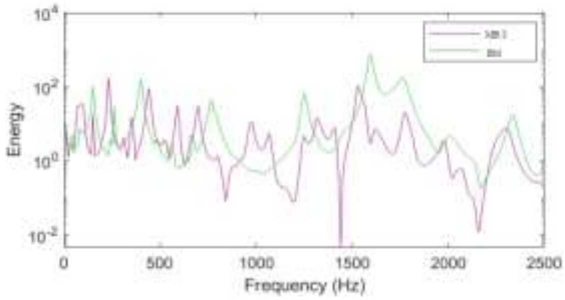

Fig-6

Fig-7

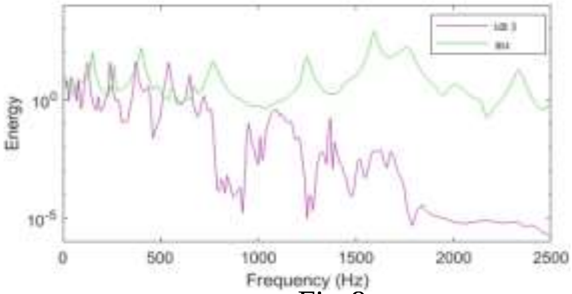

Fig-8

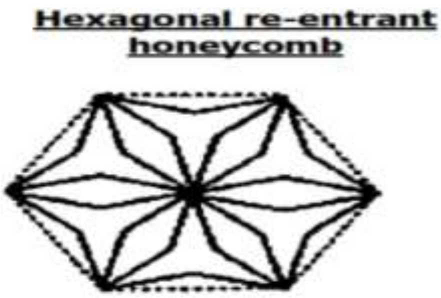

Fig-9

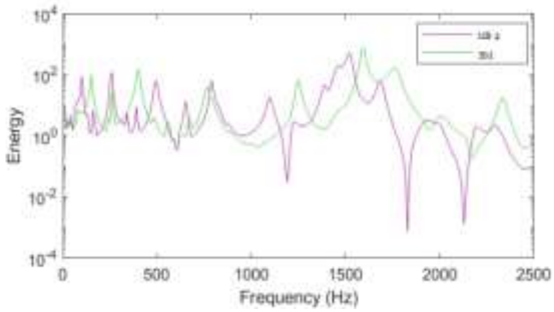

Fig-10

Fig-11

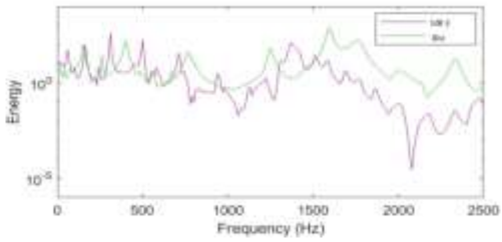

Fig-12

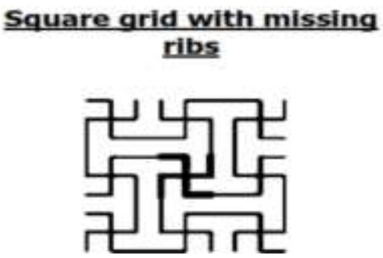

Fig-13

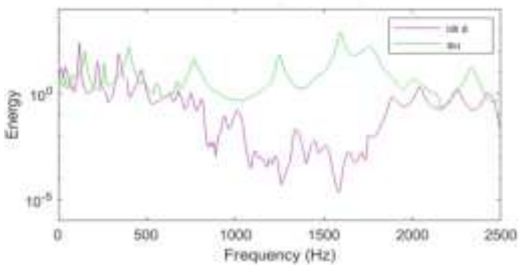

Fig-14

Fig-15

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A final comparison is made on the vibration damping effects of auxetic structures using FRF plot. shows the comparison and it is found that the auxetic structure MB3 has the best damping and is best suitable for the industrial applications as shown in Fig 16.

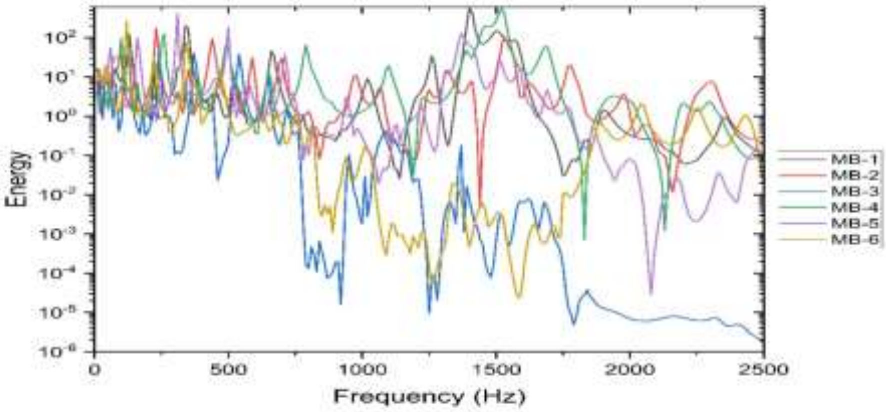

Fig-16

Conclusion

In this work, six different auxetic structures will be developed namely collapsed regular hexagon, doublearrowhead, starhoneycomb,hexagonalre-entranthoneycomb,lozengegrid,andsquaregrid.Additive manufacturing will be used to manufacture the aforementioned structures using the fuseddeposition modeling (FDM) technique. Vibration testing was carried out using an electro-dynamicshaker to investigate the vibrational response of the developed auxetic structures. Frequency response function (FRF) plots will be plotted for the vibrational data for different test cases. In allthecasestheauxeticstructureshave better vibrationdampingcapabilitiesthan continuous beams.A final comparison is made on the vibration damping effects of auxetic structures using FRF plotand it is found that the auxetic structure star honeycomb has the best damping and is best suitablefortheindustrialapplications.

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