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Multi continuous finite element technique study of various composite materials

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ABSTRACT

The primary focus of this essay is the multi-continuum method's examination of composite materials. The most common fibres utilised are Kevlar, carbon fibre, and glass fibre. All fibre reinforced composites are analysed using Ansys and Autodesk composite analysis software. In this work, hybrid fibre composites and simple composites were evaluated, and a perfect hybrid composite that meets the requirements of the given load condition was created.

Keywords: fiber, Multi continuu, composites, Carbon, Glass, micromechanics, Kevlar, FEM

INTRODUCTION

An amalgam of two or more different parts or phases is referred to as a composite. Three additional requirements must typically be met before we can refer to a material as a composite. First, both components need to be present in proper ratios. Second, the constituent phases must have distinctly different characteristics from one another, making the composite's characteristics stand out from those of the constituents. [1-4] Finally, a synthetic composite is typically created by purposefully blending the basic parts using a variety of techniques. It is crucial to be able to identify these components because, on a microscopic level, composites have two (or more) chemically different phases that are separated by a clear interface. The constant component that is frequently but not always present in higher amounts The conventional wisdom holds that when adding another component to create a composite, the matrix's inherent properties are enhanced. [5-9] A composite might have a matrix made of ceramic, metal, or polymer. The focus of this text will be polymer matrix composites due to their economic significance (PMCs). One of the key factors in determining the efficiency of the reinforcement is its geometry; in other words, the reinforcement's size and shape affect the mechanical properties of composite materials. The reinforcement is typically described as fibrous or particle.

[10-13] The length of a fibrous reinforcement is significantly longer than the cross-sectional dimensions. However, the aspect ratio—also referred to as the length-to-crosssection ratio—can vary widely. Long fibres with high aspect ratios provide continuous fiber-reinforced composites in single-layer composites, while short fibres with low aspect ratios are used to create discontinuous fibre composites (block C). The discontinuous fibres' orientation could be random or desired. In the

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context of a continuous fibre composite, unidirectional refers to the usually seen preferred orientation and the corresponding random The primary aim of the current study is to investigate the behaviour of CSB designed in accordance with Indian Standard 800-2007, British Standard (BS 5990: Part 1:1990, BS 5990-1:2000 & steel work design guide to BS 5990-1:2000), and ASTM Standard (ANSI/AISC 360-10:2010 when subjected to static two-point load in order to evaluate the ultimate moment carrying capacity response and def to see whether it is actually feasible in the building sector. An older design code-designed building's structural elements are not strong enough to support the bending moment. In recent years, structures have been subjected to critical loading, necessitating the use of structural parts or elements with larger moment carrying capacities. It is challenging to update designs for castillated beams that adhere to older construction codes with regular apertures to meet the demands of the present. It is necessary to modify such castellated beams for various web opening patterns that can support secondary services. One may compare these castellated beams to solid beams. With a new aperture pattern developed through this research, castellated beams may now be built to their maximum moment carrying capability while also controlling deflection.

[14-15] This is the next phase in the fabrication process. This method involves saw-tooth cutting to create a hexagonal hole or any other design in the web of a steel piece. On a small scale, it is finished using a gas cutter. When manufacturing is done on a large scale in a factory, mechanised cutting systems with CNC-controlled cutting heads are typically utilised. There is a potential that the beam section could buckle when being cut with a gas cutter machine because of the heating process. The beam section should be fixed along its edge by a particular arrangement with the aid of bolting and fastening in order to prevent this buckling.

The assumption that we make completely determines the accuracy of the finite element analysis. It has long been shown that this method is inappropriate for fiber-reinforced composites. This completely removed any interaction between the matrix material and the fibres. Using conventional techniques, fibre failure is demonstrated earlier than predicted by experiment. The multi continuum technique combines micromechanics with conventional structural analysis, resulting in a notable improvement in the accuracy of the findings. We can confidently optimise the design in this way without spending money on expensive experiments.

Multiple continuum approach

Garnich and Hansen were the ones who initially brought forward the concept of multicontinuum dynamics. Hill's early explanation of the deconstruction of strain and stress from a composite to its component parts served as the foundation for the multicontinuum notion. Mayes and Hansen later improved the failure analysis approach that Garnich and Hansen had initially proposed. The von Mises failure criterion has been modified by Nelson and Hansen, who have also offered better alternatives.

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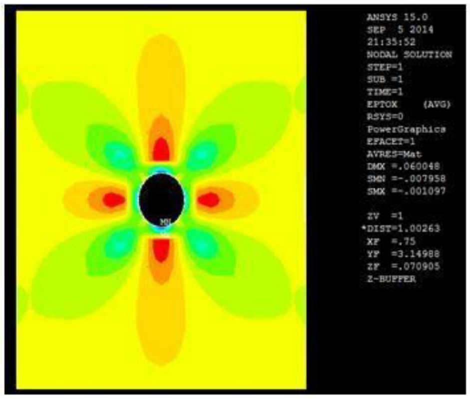

Fig. 1 traditional method

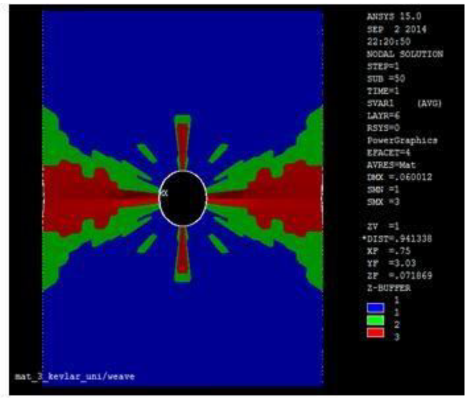

Fig. 2 Using MCT

The traditional continuum mechanics that form the basis of the multicontinuum are built upon, with the most accurate micromechanics used when necessary. The average constituent strains and stresses are then separated from the composite data using the composite and constituent connections that have been established. Micromechanics analysis is used to create the linkages between the components and the composite that are required.

Materials

We chose carbon fibre, glass fibre, and kevlar because of how frequently they are used in commercial and home settings. Fiber reinforced composites have significantly altered the industrial environment of today. Glass fibre is extremely affordable, and its simple manufacturing process makes it ideal for economic applications. However, glass fibre is greatly impacted by humidity and wear and tear. The gasoline tanks and bulletproof jackets of Formula One cars and military vehicles are made of Kevlar. Kevlar has a highly special quality that makes it strong enough to stop a bullet in its path even if it lacks much rigidity. However, because carbon fibre is so expensive, it is mostly utilised in high-performance automobiles and space equipment. Carbon is more rigid than most other materials and is many times stronger than steel. The table below includes a list of mechanical characteristics along with the matrix material.

Table 1 fiber Description

Properties of Fibers used[1]						
Fiber type	Unidirectional			Weave		
Fiber name	Glass	Carbon[2]	Kevlar	Glass	Carbon	Kevlar
Fiber ref no.	**9036**	**9037**	**9038**	**9039**	**9040**	**9041**
Description	S2/S0381	T700/2510	Kevlar-49	1800/510A-40	T700/510A-40	kavlor49
cured thickness	0.233	0.183	0.28	0.417	0.625	0.28
Matrix type	Epoxy	epoxy	Epoxy	Vinyl Ester	Vinyl Ester	epoxy
VolumeFraction	72%	49.5%	60%	40	56	60
Density($\frac{g}{cm^3}$)	1.91	1.50	1.384	2.2	1.6	1.3
E11 (GPa)	48.6	125	75.84	22.2	56.1	39.625
E22 (GPa)	13.6	8.4	5.5	20.3	57.1	39.625
+S11 (MPa)	1530	2170	1378.8	359	1130	801
+S22 (MPa)	58.5	48.9	29.64	315	1040	801
-S11 (MPa)	1200	1450	275.76	436	450	161
-S22 (MPa)	274	199	137.89	389	387	161
Gxy (Gpa)	4.07	4.23	2.06	3.9	4.2	2.15
Sxy (Mpa)	132	155	62.05	40.3	47.5	290
Sxz (Mpa)	67.9	86.1	65.2	57.1	59.3	138
v12	0.263	0.309	0.34	0.14	0.07	5.18

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The material properties were initially input into the Autodesk composite analysis tool. Use the macro provided below to import the material attributes into Ansys. The second parameter of this macro command specifies the material reference number that was predefined by the Autodesk software.

COMPAN,9038,7,3,1,1,0,0,0,0,0,0,0,0,0,0.10,0.01,0

Table 2 layer properties

Layers[3]	I and XII	II and XI	III and X	IV and IX	V and VIII	VI and VII
Ply angle	0°	0°	+45°	-45°	+90°	-90°
Mat 1	9039	9039	9036	9036	9039	9039
Mat 2	9040	9040	9036	9036	9040	9040
Mat 3	9041	9040	9037	9037	9037	9040
Mat 4	9041	9041	9036	9036	9040	9040
Mat 5	9039	9039	9038	9038	9040	9041
Mat 6	9040	9040	9040	9040	9040	9040
Mat 7	9040	9040	9039	9039	9041	9041
Mat 8	9037	9037	9037	9037	9037	9037
Mat 9	9039	9039	9040	9040	9038	9037

The problematic material is then applied to a specified layer using the Ansys preprocess instructions covered in a later section of this work. Since fibre reinforced composites are an anisotropic material, each direction of measurement reveals different mechanical characteristics. All composites have the same [(+0)2(45)(90)]s ply arrangement to maintain a standard in analysis. Only the fiber's substance is altered in this arrangement to meet the needs.

Preprocessing and solution

The ASTM D3039 is the basis for this test. A tiny hole with a diameter of 0.25 inches was added to the testing requirements to improve notchsensitivity. The plate used has a thickness of 0.144 inches and measures 6 inches by 1.5 inches. The plate is made up of 12 layers, each of which is 0.012 inches thick.

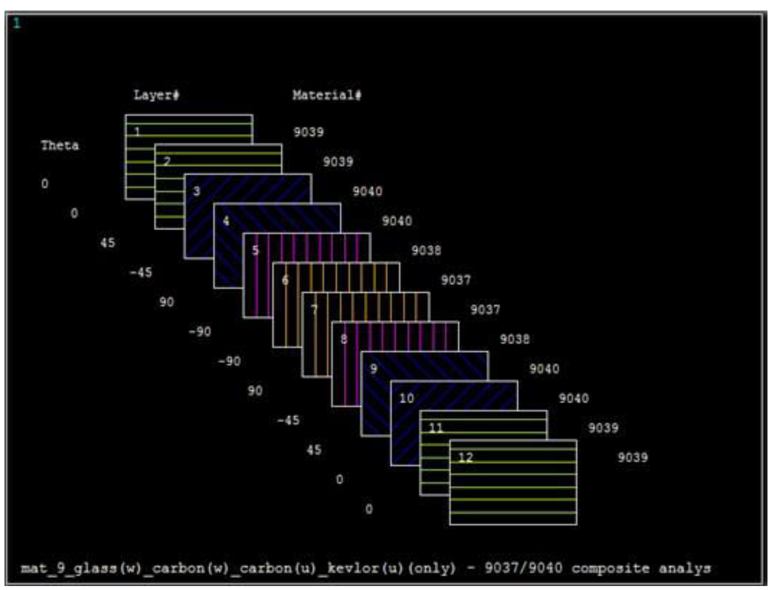

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Fig. 3 Mat 9 section plot

Due to the boundary requirements, the bottom portion of the plate is fixed, and all degrees of freedom were constrained. A constant displacement of 0.06 inches is also provided to imitate the tensile test conditions. Each layer is described by the command that is given.
SECDATA, 0.006,9040,45,3

The figure displays the mat 9 layup plot. Theta, a value that is supplied together with the given command, in this case, provides the angle for the layer orientation. Because it incorporates the advantages of both solid and shell elements. The selection of Keyopt supports the -p formulation. To define an adequate mesh, NDIV=1 is chosen in the Z direction in each side. A size of 0.075in is defined in order to mesh this composite with nearly accurate results.

Post processing.

The Autodesk composite analysis plugin defined each matrix and merged failure in the state variable (SVAR). There were three defined values for the state variable. The table gave the meaning of certain values. Utilizing the code provided below, solutions were obtained. The elements listed in the condition are chosen by the ESEL command. The elements chosen by the ESEL Command are counted and saved in a variable using the *GET command. Then, for processing, these values are saved in the user-defined database LAY SVR.

Data from all materials and for all layers were gathered, analysed, and interpolated to create a graph showing the relationship between layer material failures and layer number. By dividing the number of items on failure by the total number of elements on the layer, the percentage of failure is calculated.

```
*DIM,LAY_SVR,TABLE,12,3,,LAYER,SVAR
*DO,LAY,1,12,1              !___DO LOOP
LAYER,LAY
ETABLE,ETAB1,SVAR,1,AVG
ESEL,S,ETAB,ETAB1,3  !_ELEMENT SELECTION
*GET,SVR1,ELEM,,COUNT  !_ELEMENT COUNT
LAY_SVR(LAY,1)=SVR1
*ENDDO
```

Figures 6 and 7 below illustrate the matrix failure % and % of combined failure for the layers of mats 1, 3, 4, 5, and 7. Glass and Kevlar are the only fibres present in mats 1 and 3, respectively. Various fibre combinations are used to create Mats 4, 5, and 7. The table above provides an explanation of all the data. When researchers check the solution, researchers see that mat 4 has a lot

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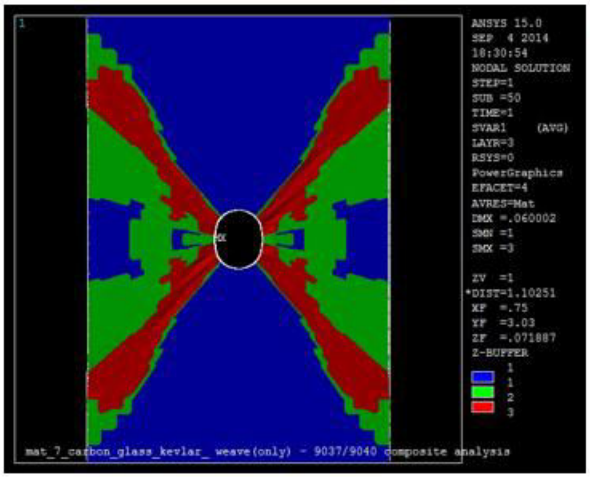
of matrix failures, but they are mostly tolerable mixed failures, which indicates that the matrix material needs to be greatly improved in order to be usable in this situation.



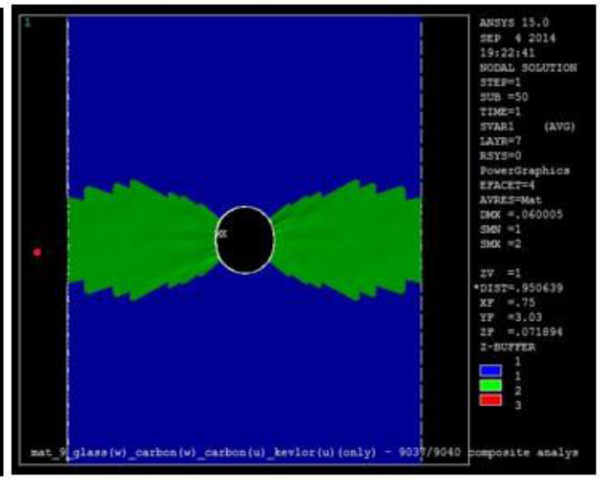


Fig. 4 mat_9 layer 6   Fig. 5 mat_7 layer 4

For mat 7, the third and fourth layers of the matrix fail most frequently, but the first and second layers also fail in combination, demonstrating that the carbon fibre layer also fails together with the matrix material. The load is often transferred to the fibre layer rather than the matrix layer.

Figures 8 and 9 depict the matrix and the combined failure of additional composite materials. These composite materials have a different type of distortion than the earlier ones. Although Mat 2 has very less failure rates—its constant fibre failure rate is only 5.2%—it is composed of carbon fibre, which is very expensive in comparison to other materials. Due to the carbon composition of the 45 degree layer, Mat 6 doesn't produce particularly spectacular results. Both Mat 8 & 9 deliver satisfactory results, however Mat 9 is more durable and less expensive due to its optimised layer arrangement. Mat 9 indicates zero fibre failure, which really is what we were expecting, even in certain tiers.

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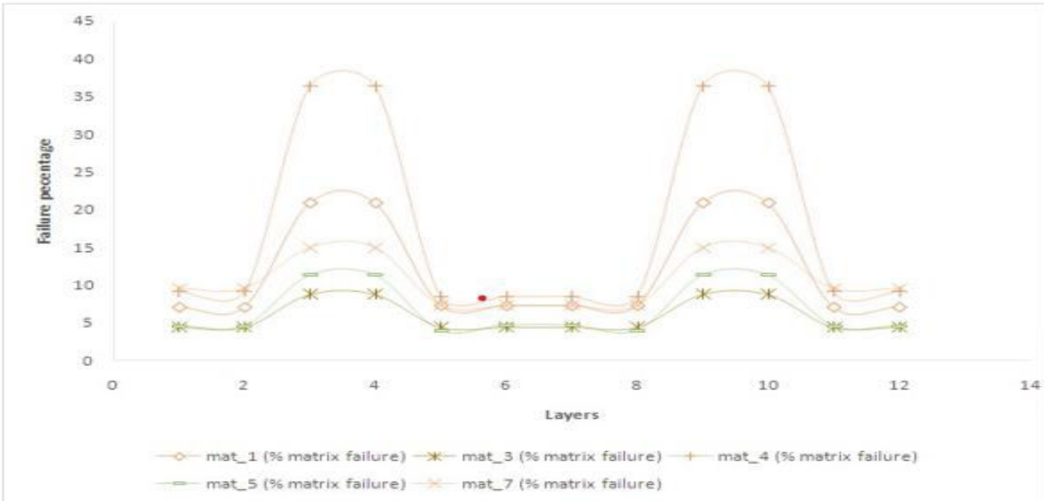

Fig. 6 Graph depicting Mat 1 to 7 matrix failure

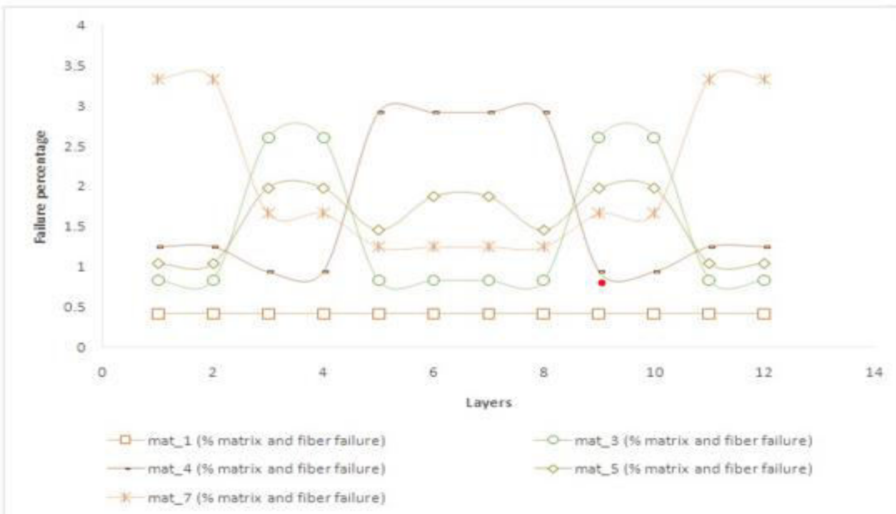

Fig. 7 Mat 1 to 7 matrix and fibre failure graph

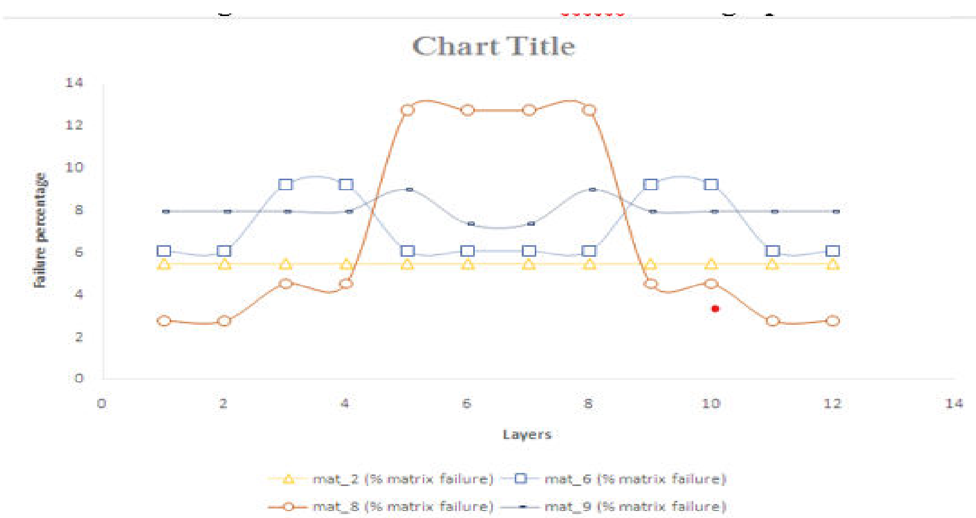

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Fig. 8 Graph depicting Mat 2 to 9 matrix failure

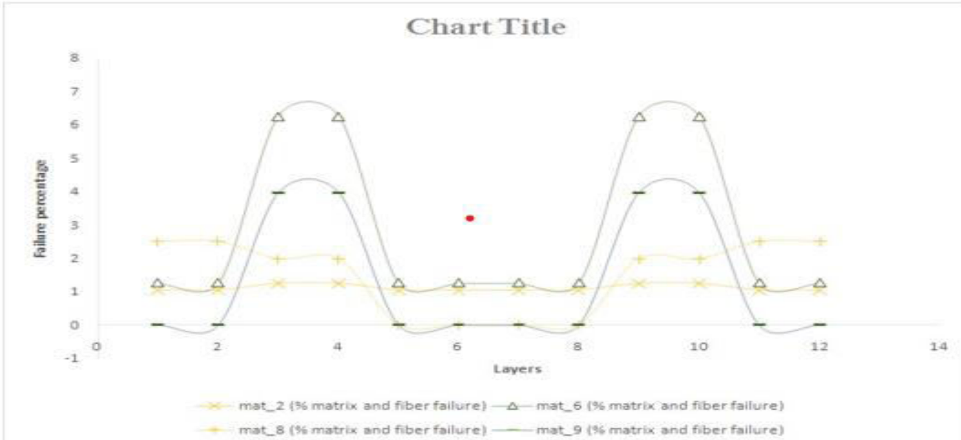

Fig. 9 Graph depicting Mat 2 to 9matrix and fibre failure

Conclusion

The use of fibre reinforced composite materials in industry has motivated design engineers to put in a lot of effort into precisely forecasting composite failure. These composites are exceedingly difficult to simulate because of their nonlinear features. There are numerous ways to deal with this type of issue, but the most of them don't produce the desired outcomes. The multi continuum technique, which provides comprehensive insight into the fibre failure in all levels of the material, is practically best suited for composite analysis. The best goods for the market and the growth of humanity are made possible by this approach, which makes the modelling of composite materials simple and economical.

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