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Tensioned Fabric Structures in Jungle Design Shape

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ABSTRACT

Tensioned fabric structure became a topic of discussion for many engineers because of its lightweight. This structure manages to resist all loads such as wind and rain. Due to the light in weight, tensioned fabric structures are normally designed to be in the form of equal tensioned surface or minimal surface. The major objective of this study is to generate three Jungle forms with minimal surface or equal tensioned surface to apply in infrastructure and to propose an alternative for engineers to consider the Jungle minimal surface models. More study found out that minimal surface of tensioned fabric structure help in sustainability the environment. The form of tensioned fabric structure of this structure was applied using mathematical equation which was then generated through MATLAB. The three Jungle forms tensioned fabric structure show minimal surface. The study might inspire the engineers to implement Jungle shape in tensioned fabric structures.

Keywords: Tensioned fabric structure; minimal surface; equal tensioned surface; jungle shape

INTRODUCTION

Tensioned fabric structure (TFS) has been in use for about 30 years. To provide secure structural support, the fabric cover is stretched. The fabric in the TFS is sewn together at seams and tightened to a rigid support system using mechanical or cable techniques to produce the roof structure (Yee et al. 2018). Tensioned fabric structures are among the world's most efficient design solutions. In any application, whether it is for sheltered workspaces, safe storage for valuable equipment and materials, or something else, this efficiency means operations can use their structure. Industries that use this TFS include entrances, walkways, sports stadiums, amphitheaters, carports, retail, exhibitions, landmarks, etc. There are several criteria to consider when choosing the type of membrane fabric to be used. The lifespan of a membrane structure is mostly determined by the durability of the membrane fabric. The resistance to degradation from UV radiation and wicking, attacks from organic matter, and the preservation of seam strength significantly affect its longevity (Son 2007). The properties of fabric structure are influenced by the coating materials used, such as polyvinylchloride (PVC), polytetrafluoroethylene (PTFE), and ethylene tetrafluoroethylene (ETFE). Bridgens & Birchall (2012) have discussed that the principle of shape in TFS is the ability to resist all applied loads in tension. The canopy's surface must be double-curved and prestressed to withstand both uplift and down-forces (usually caused by wind and snow, respectively). Example of application of TFS is Riyadh Stadium known as the King Fadh Stadium in Saudi Arabia. It is mainly used for football matches, but it still has athletics facilities. The roof has a diameter of 288 meters and is composed of 24 identical cantilevered sections as shown in Figure 1. The centre is opened in compliance with international legislation about natural turf height (Task Committee on Tensioned Fabric Structures, 2013). TFS thus designed with provided sufficient curvature to resist environmental loads as tensile forces in the fabric's plane. The design of the canopy is very important in its ability to withstand all the applied tension loads such as wind load, snow load and rain. Apart from that, the fabric more efficient, tensioned fabric is often more structurally efficient and cost-effective for large span roofs than conventional methods (Bridgens et al. 2004).

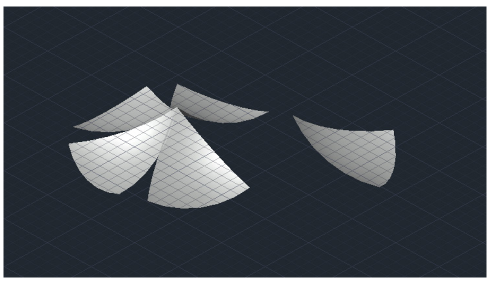
FIGURE 1. Tensioned Fabric Structure

METHODOLOGY

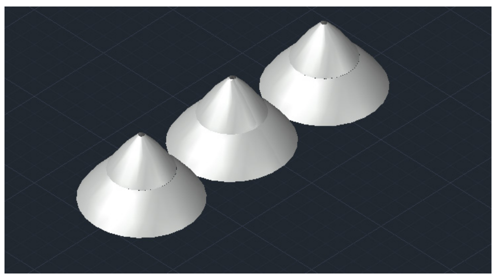
In this study, three of the models have been proposed. First of all, a rough model was created for the TFS from a Jungle model using AutoCAD to give an idea in choosing the equation. A new minimal surface Jungle form in a TFS was proposed for the infrastructure used because the Jungle form have no mathematical equation (no clear solution). A large number of models are inspired by nature that looks like a tree that provides shady protection. Also, the proposed model looks like a mountain that gives the illusion around a Jungle area. Following that, three Jungle forms of tensioned fabric structures were developed using suitable equations from internet sources. It needs to be diversified to obtain a perfect equation that fits the model. The models' coordinates (x, y, and z axis) were then identified and analyzed in Microsoft Excel for compatibility of the shape for the model of the TFS. The equation of the models was generated with at least 50 points for the coordinates of x, y, and z axis in the Microsoft Excel. The types of equations used in tensioned fabric structures in Jungle form as shown in Table 1. Figure 2 presents the Jungle models.

TABLE 1. Types of equations for the Jungle form

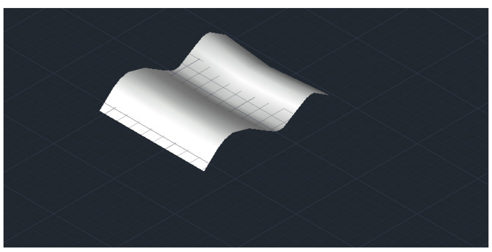
Type of Model for Jungle Form	Equation
1	$z = 2x^2+y^2+2xy-6x-4y+5$
2	$z = \cos(x)-\cos(y)$
3	$z = \sin(y)-x^2$



(a)



(b)



(c)

FIGURE 2. (a) Jungle model 1 (b) Jungle model 2 (c) Jungle model 3

Figure 3 shows the coordinates of x, y and z axis in Jungle form 1, Jungle form 2 and Jungle form 3, respectively. The different 3D views of the three Jungle forms as shown in Figure 3 (a), 3 (b) and 3 (c). The coordinates of x, y and z axis consists minimum of 50 points. In Figure 4 (a), the coordinates of x-axis and y-axis consists of 1 until 25.5 which the interval is 0.5. In Figure 4 (b), the coordinates of x-axis and y-axis consists of -1 until 8.8 as the interval is 0.2. In Figure 4 (c), the coordinates of x-axis consist of -1.5 until 1.685 which the interval is 0.065, while coordinates of y-axis consist of -4 until 18.05 and the interval is 0.45. In the process, iterative calculation using these coordinates have to be carried out in order to achieve the perfect criteria. If the geometry is not suitable into the MATLAB for minimal surface, the equation should be replacing with new ones. The coordinates were plotted into Jungle forms using the mathematical equations. Figure 4 shows the result of Jungle forms from Microsoft Excel.

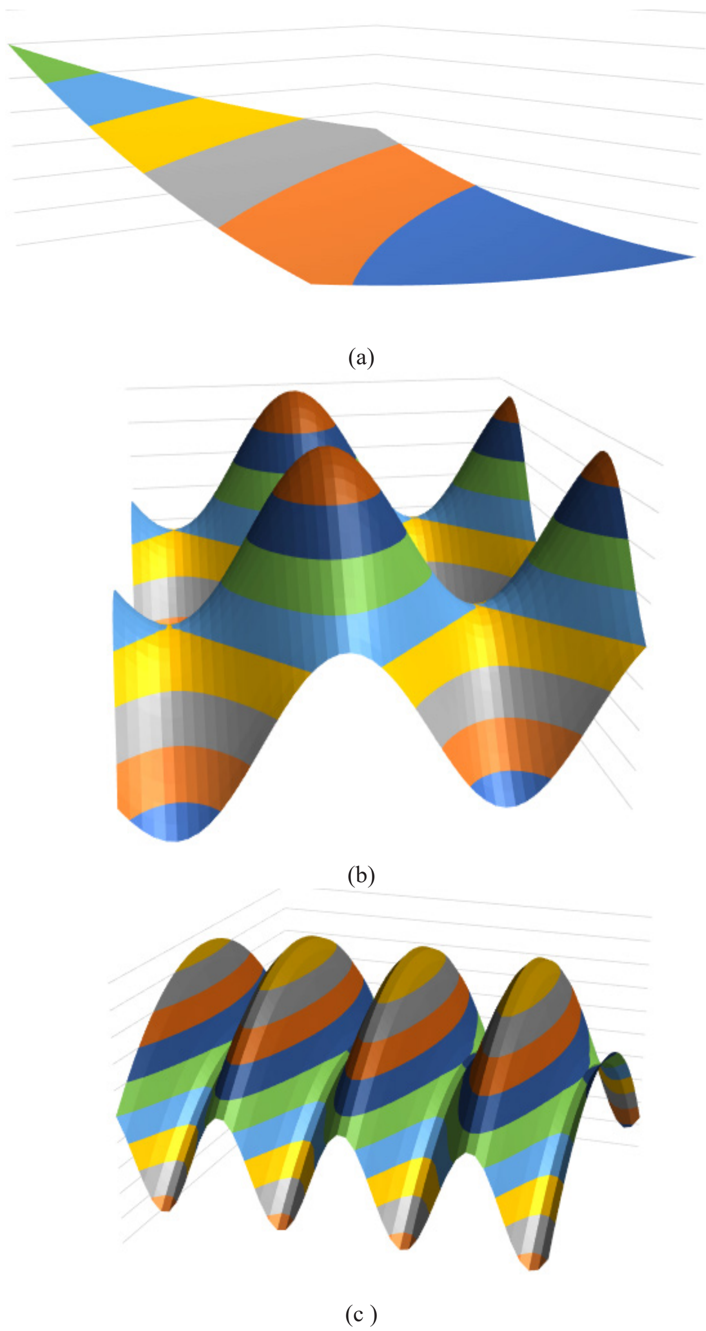


FIGURE 3. (a) Jungle form 1 (b) Jungle form 2 (c) Jungle form 3

		x-axis →														
	z-axis	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
y-axis ↓	1	0	0.5	2	4.5	8	12.5	18	24.5	32	40.5	50	60.5	72	84.5	98
	1.5	0.25	1.25	3.25	6.25	10.25	15.25	21.25	28.25	36.25	45.25	55.25	66.25	78.25	91.25	105.25
	2	1	2.5	5	8.5	13	18.5	25	32.5	41	50.5	61	72.5	85	98.5	113
	2.5	2.25	4.25	7.25	11.25	16.25	22.25	29.25	37.25	46.25	56.25	67.25	79.25	92.25	106.25	121.25
	3	4	6.5	10	14.5	20	26.5	34	42.5	52	62.5	74	86.5	100	114.5	130
	3.5	6.25	9.25	13.25	18.25	24.25	31.25	39.25	48.25	58.25	69.25	81.25	94.25	108.25	123.25	139.25
	4	9	12.5	17	22.5	29	36.5	45	54.5	65	76.5	89	102.5	117	132.5	149
	4.5	12.25	16.25	21.25	27.25	34.25	42.25	51.25	61.25	72.25	84.25	97.25	111.25	126.25	142.25	159.25
	5	16	20.5	26	32.5	40	48.5	58	68.5	80	92.5	106	120.5	136	152.5	170
	5.5	20.25	25.25	31.25	38.25	46.25	55.25	65.25	76.25	88.25	101.25	115.25	130.25	146.25	163.25	181.25
	6	25	30.5	37	44.5	53	62.5	73	84.5	97	110.5	125	140.5	157	174.5	193
	6.5	30.25	36.25	43.25	51.25	60.25	70.25	81.25	93.25	106.25	120.25	135.25	151.25	168.25	186.25	205.25
	7	36	42.5	50	58.5	68	78.5	90	102.5	116	130.5	146	162.5	180	198.5	218
	7.5	42.25	49.25	57.25	66.25	76.25	87.25	99.25	112.25	126.25	141.25	157.25	174.25	192.25	211.25	231.25
	8	49	56.5	65	74.5	85	96.5	109	122.5	137	152.5	169	186.5	205	224.5	245

(a)

		x-axis →														
	z-axis	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
y-axis ↓	1	0	0.5	2	4.5	8	12.5	18	24.5	32	40.5	50	60.5	72	84.5	98
	1.5	0.25	1.25	3.25	6.25	10.25	15.25	21.25	28.25	36.25	45.25	55.25	66.25	78.25	91.25	105.25
	2	1	2.5	5	8.5	13	18.5	25	32.5	41	50.5	61	72.5	85	98.5	113
	2.5	2.25	4.25	7.25	11.25	16.25	22.25	29.25	37.25	46.25	56.25	67.25	79.25	92.25	106.25	121.25
	3	4	6.5	10	14.5	20	26.5	34	42.5	52	62.5	74	86.5	100	114.5	130
	3.5	6.25	9.25	13.25	18.25	24.25	31.25	39.25	48.25	58.25	69.25	81.25	94.25	108.25	123.25	139.25
	4	9	12.5	17	22.5	29	36.5	45	54.5	65	76.5	89	102.5	117	132.5	149
	4.5	12.25	16.25	21.25	27.25	34.25	42.25	51.25	61.25	72.25	84.25	97.25	111.25	126.25	142.25	159.25
	5	16	20.5	26	32.5	40	48.5	58	68.5	80	92.5	106	120.5	136	152.5	170
	5.5	20.25	25.25	31.25	38.25	46.25	55.25	65.25	76.25	88.25	101.25	115.25	130.25	146.25	163.25	181.25
	6	25	30.5	37	44.5	53	62.5	73	84.5	97	110.5	125	140.5	157	174.5	193
	6.5	30.25	36.25	43.25	51.25	60.25	70.25	81.25	93.25	106.25	120.25	135.25	151.25	168.25	186.25	205.25
	7	36	42.5	50	58.5	68	78.5	90	102.5	116	130.5	146	162.5	180	198.5	218
	7.5	42.25	49.25	57.25	66.25	76.25	87.25	99.25	112.25	126.25	141.25	157.25	174.25	192.25	211.25	231.25
	8	49	56.5	65	74.5	85	96.5	109	122.5	137	152.5	169	186.5	205	224.5	245

(b)

		x-axis →														
	z-axis	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
y-axis ↓	1	0	0.5	2	4.5	8	12.5	18	24.5	32	40.5	50	60.5	72	84.5	98
	1.5	0.25	1.25	3.25	6.25	10.25	15.25	21.25	28.25	36.25	45.25	55.25	66.25	78.25	91.25	105.25
	2	1	2.5	5	8.5	13	18.5	25	32.5	41	50.5	61	72.5	85	98.5	113
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	3	4	6.5	10	14.5	20	26.5	34	42.5	52	62.5	74	86.5	100	114.5	130
	3.5	6.25	9.25	13.25	18.25	24.25	31.25	39.25	48.25	58.25	69.25	81.25	94.25	108.25	123.25	139.25
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	5	16	20.5	26	32.5	40	48.5	58	68.5	80	92.5	106	120.5	136	152.5	170
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	6.5	30.25	36.25	43.25	51.25	60.25	70.25	81.25	93.25	106.25	120.25	135.25	151.25	168.25	186.25	205.25
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	7.5	42.25	49.25	57.25	66.25	76.25	87.25	99.25	112.25	126.25	141.25	157.25	174.25	192.25	211.25	231.25
	8	49	56.5	65	74.5	85	96.5	109	122.5	137	152.5	169	186.5	205	224.5	245

(c)

FIGURE 4. (a) Coordinates of x, y and z axis for Jungle form 1 (b) Coordinates of x, y and z axis for Jungle form 2 (c) Coordinates of x, y and z axis for Jungle form 3In model optimization for each of the Jungle form, models of tensioned fabric

structures have been analyzed using MATLAB from the coordinates of X, Y and Z directions which was imported from Microsoft Excel. In Figure 5 shows the coordinates of X and Y direction have been imported to the coding. In X and Y coordinate input consists of starting point, interval point and last point. Z coordinate is based on the equation on every model of Jungle form. Figure 6 shows coding of parameter in minimal surface. The parameter contains of mean curvature (H), Gaussian curvature (K) and Principal curvature (P1 & P2). Coding to optimize the Jungle model was prepared by Ts. Syahrul Fitry Bin Senin.

```
%% THIS SCRIPT HAS BEEN WRITTEN BY Ts. SYAHRUL FITHRY SENIN
% DATED 7/6/2021
% Please cite my name (Ts. Syahrul Fithry Bin Senin) when using this code
% in your work

% Jungle model 1 Generator and its Curvature computation

clear all
clc

x = [1:0.5:25.5]; % The x corrdinate
x = repmat(x,length(x),1);

y = [1:0.5:25.5]'; % The y coordinate input
y = repmat(y,1,length(y));

z = (2.*x.^2)+(y.^2)+(2.*x.*y)-(6.*x)-(4.*y)+5; % the z coordinate based on equation


%% K = Gaussian curvature
%  H = mean curvature
% (P1,P2) = the principal curvatures
```

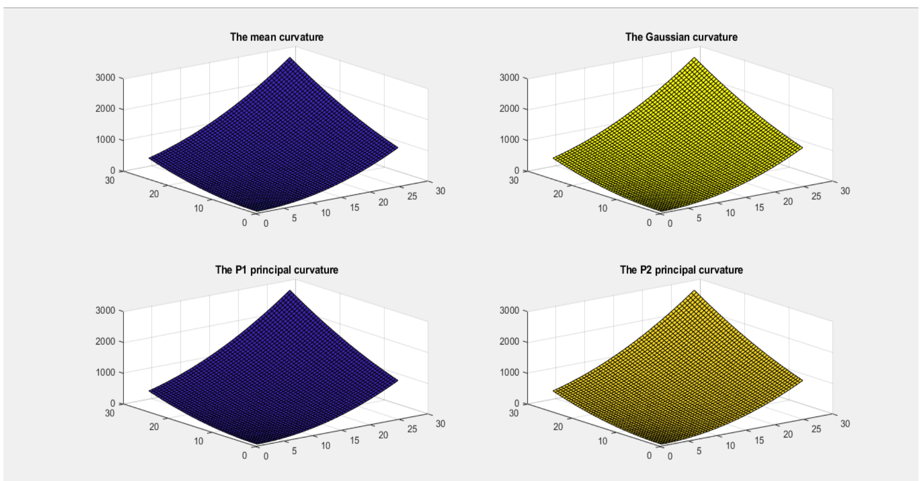
FIGURE 5. Coding for Coordinates of X, Y and Z direction

```
[K,H,P1,P2] = SYAHRUL_CURVATURE(x,y,z);  % Compute the parameters of Surface Curvatures

%% To plot some parameters

subplot(221)
surf(x,y,z,H,'facecolor','interp'); % To view the mean curvature
title(' The mean curvature')

subplot(222)
surf(x,y,z,K,'facecolor','interp'); % To view the Gaussian curvature
title(' The Gaussian curvature')

subplot(223)
surf(x,y,z,P1,'facecolor','interp'); % To view the Principal (P1) curvature
title(' The P1 principal curvature')

subplot(224)
surf(x,y,z,P2,'facecolor','interp'); % To view the Principal (P2) curvature
title(' The P2 principal curvature')
```

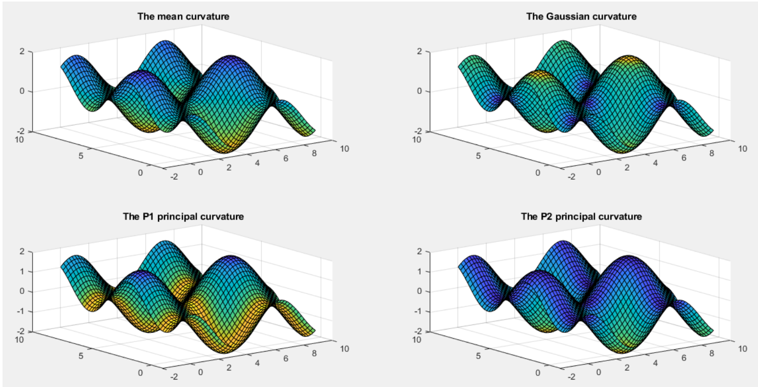
FIGURE 6. Coding of Parameter in Minimal Surface

RESULTS AND DISCUSSION

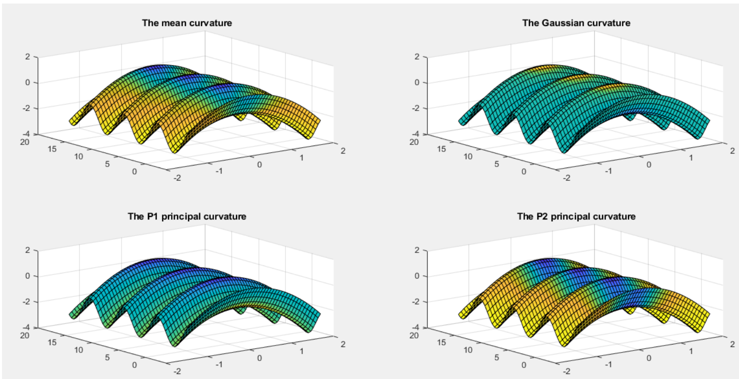
Computational analysis for new models of tensioned fabric structure in Jungle form using MATLAB have been proposed. The models are based on nature because there are no available equations for Jungle. Based on the results, mean curvature, Gaussian curvature and principal curvature were obtained. The mean curvature of the models is 0 as the properties of minimal surface whose mean curvature H disappears at each surface point. In the other words, minimal surface is a surface with mean curvature, H which is equals to zero at all points. the Gaussian curvature of a surface at a point is the product of the principal curvatures, P1 and P2. Figure 7 shows the parameters of minimal surface in Jungle form 1, Jungle form 2 and Jungle form 3. The Jungle form 1, Jungle form 2 and Jungle form 3 are surface that locally minimizes its area.



(a)



(b)



(c)

FIGURE 7. (a) Minimal surface for Jungle form 1 (b) Minimal surface for Jungle form 2 (c) Minimal surface for Jungle form 3

CONCLUSION

The output of the study was to propose 3 models of Jungle form to be used in TFS and was suitable as in minimal surface models. The model begins with by developed the equation that defines the x, y, and z axis for each model and checks the form of the assumptions. The 3 Jungle form models leading to very interesting applications such as the light roof tensile structures. The models of Jungle form in TFS could be applied as a choice in infrastructure by the structural engineer.

ACKNOWLEDGEMENT

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DECLARATION OF COMPETING INTEREST

None

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