IOP Conference Series: Materials Science and Engineering

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To cite this article: D Mohamad *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **530** 012028

Numerical Simulation on the Statics Deformation Study of Composite Cross Arms of Different Materials and Configurations

D Mohamad[1], A Syamsir[2], Z Itam[1], H A Bakar[3], A Abas[3]*, F C Ng[3], M F Razali[3] and S A H A Seman[3]

[1] Department of Civil Engineering, Universiti Tenaga Nasional, 43000 Kajang, Malaysia.

[2] Institute of Energy Infrastructures (IEI), Universiti Tenaga Nasional, 43000 Kajang, Malaysia.

[3] School of Mechanical Engineering, Universiti Sains Malaysia, Engineering Campus, 14300, Nibong Tebal, Penang, Malaysia.

Corresponding author *: aizatabas@usm.my

Abstract. This study focuses on the deformation of cross arms made from composite material under static loading. Two materials properties of fiberglass with are assigned to the cross arms model and it is subjected to a load at the one end of the cross arms. A bracing support is then installed, and the deformation and stress experienced by the cross arms are observed and compared with the case where no bracing support is used. The results obtained show that material B has lower deformation value, but experienced greater stress compared to material A. The bracing managed to reduce the total deformation by about 12% and 20% for material A and B respectively. The reduction of stresses experienced by the cross arms ranges from 4% to 30%.

***Keywords**: composite; cross arms; bracing; static structural*

1. Introduction

Fiber-composite is one of the engineering material with high performance in terms of its strength and stiffness [1]. Fiberglass is one of the fiber-composite that is widely used. The applications of fiberglass ranges from food processing to power generation industries. This is due to its characteristic which it is easily moulded and shaped into complex forms. In the power generation industry, fiberglass was introduced as an insulation material for distribution and transmissions system as an additional component to the basic insulator [2]. Grzybowski and Disyadej [2] stated that the main reason is because fiberglass has high dielectric strength. In the case of fiberglass utilized in the distribution line pole, it is considered as a non-uniform composite material with fiber as the main element and resins and filers as the additional components [3]. In this study, the focus will be on the application of fiberglass in the cross arms of the transmission tower. Cross arms, one of many components that build the transmission tower, acts as a support to the transmission conductor [4]. It is constantly subjected to wind loads, its self-weight and other loads such as unexpected broken wire conditions, erections and maintenance [5]. Hence, the common materials used for the cross arms are wood, steel and fiberglass [4]. However, fiberglass is better because of its insulating characteristic and it has a greater mechanical strength to weight ratio, compared to the other two [4].

IOP Conf. Series: Materials Science and Engineering **530** (2019) 012028 doi:10.1088/1757-899X/530/1/012028

Therefore, this study aims at investigating the deformation of the composite cross arms under static loadings using finite element approach. A composite material for the cross arms with different material properties are tested in two different conditions, a cross arms without bracing support and a cross arms with a bracing support. The total deformation and stresses experienced by the cross arms will be evaluated and compared.

2. Numerical simulation

2.1 Finite element analysis (FEA)

Finite element method (FEA) is a numerical technique that benefitted from the computational power to obtain the approximation solutions of boundary value problems or field problems. The field is the domain that is represented by a physical structure. The field variables are the variables that governed by the differential equations and the boundary conditions are the values on the boundaries of the fields. The values of the field variable calculated at the nodes are used to determine the values at non-nodal points by means of interpolation. For a three-node triangle example, the field variable can be represented such as:

$$\varphi(x,y) = N_1(s,y)\varphi_1 + N_2(s,y)\varphi_2 + N_3(s,y)\varphi_3 \tag{1}$$

Where φ_1, φ_2 and φ_3 are the values of the field variable at the nodes, N_1, N_2 and N_3 are the interpolation functions. This Eq.1 is also known as the shape function.

2.2 Shell element

Shell elements are suitable to model thin structures. Thin structure denotes a geometry where one dimension is so small compared to the other two dimensions. Shell elements separate the deformation on the surface and in the normal direction, hence simplify and creating a more efficient simulation. It is usually done by meshing the surface that representing the structure and providing the section data to create the shell thickness. There are three assumptions to be made when implementing the shell element: (1) stresses are assumed to be linear through the thickness; (2) the center surface does not experience any bending and (3) the membrane stresses are uniform over the thickness.

For this simulation, the thickness to be associated with the 3D model is 6 mm. It is set in the ANSYS ACP model setup. The 6 mm thickness later is divided and oriented according to the composite material as stated in Table 2.

2.3 3-D model

Each cross arm was designed and assembled using SOLIDWORKS 2017 software. Figure 1 (a) shows the cross arms design while Figure 1 (b) shows the cross arms with a bracing installed to the four arms. The material properties for the cross arms were later assigned in ANSYS ACP.

(a) (b)

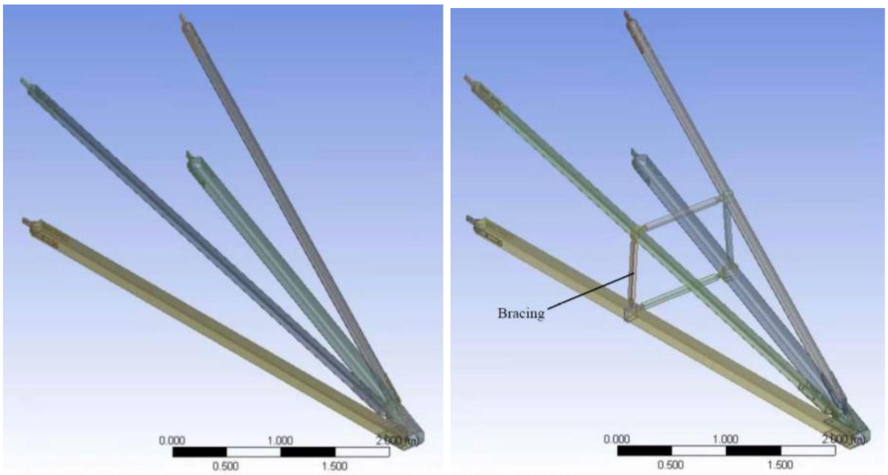


Figure 1. The 3-D model of: (a) the cross arm and; (b) cross arm with bracing

2.4 Material properties

Two composite material properties, A and B are assigned to the cross arms as tabulated in Table 1. Besides that, the material A is made to be only five layers of composite material while material B is made to have nine layers of composite material. Table 2 shows the fiber orientation and thickness for each layer of the material A and B.

Table 1. Material properties for the cross arm

Material	Ex (MPa)	Ey (MPa)	Ez (MPa)	Vxy=Vyz=Vxz	Gxy (MPa)	Gxz (MPa)	Gyz (MPa)	Density (g/cm^3)
A	16000	4800	1440	0.28	4000	4000	4000	1.8
B	36300	10890	3267	0.28	4280	4280	4280	1.9

Table 2. The composite layer and its fiber orientation and thickness for each material

Layer	Material A		Material B	
	Fiber orientation	Thickness (mm)	Fiber orientation	Thickness (mm)
1	45	0.5	0	0.7
2	-45	0.5	45	0.7
3	90	0.7	0	0.7
4	0	3.6	-45	0.7
5	45	0.7	0	0.7
6	-	-	-45	0.7
7	-	-	0	0.7
8	-	-	45	0.7
9	-	-	0	0.7

2.5 Boundary conditions (BCs)

For the simulation, a couple of BCs have been assigned to the cross arms model. Each ends of the cross arms leg is assigned with a fixed support, as shown in Figure 2 (a). The load is applied to the top end of the cross arms as in Figure 2 (b).

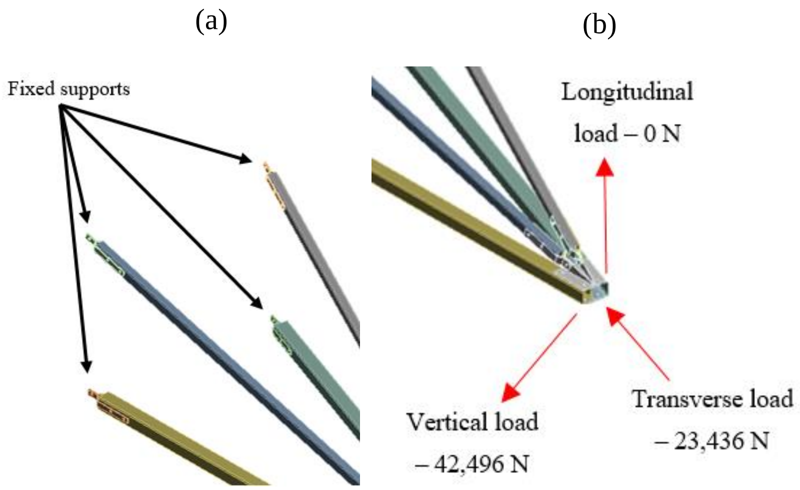


Figure 2. Boundary conditions for: (a) fixed supports; (b) load applied

3.0 Results and Discussion

3.1 Maximum deformation

The total deformations and stresses experienced by the cross arms for material A and B, with and without bracing are tabulated and presented in this section. Table 3 is the total deformation experienced by the cross arms for material A and B, with and without the support of the bracing. The deformation distribution of both cases in each material is similar, where the maximum deformation happens in the region where the load is applied and the minimum deformation occurs in the region where the fixed supports are applied.

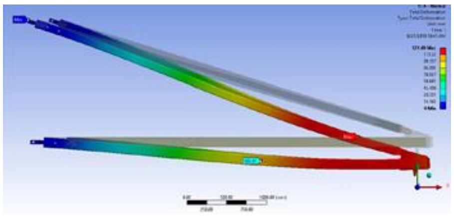
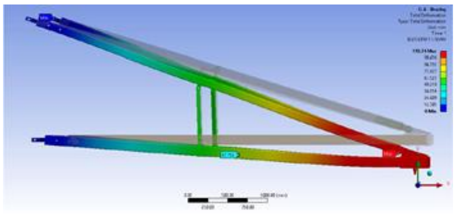
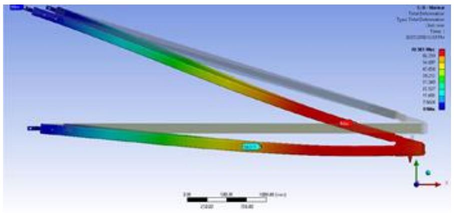
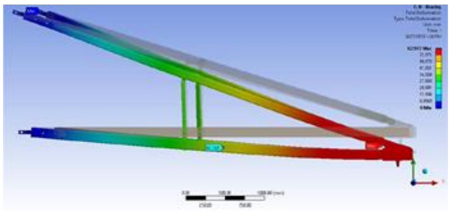
For material A, the maximum deformation of the cross arms without the bracing support is around 127 mm, and it is located near the region where the load is applied. However, with the support of the bracing, the maximum deformation managed to be reduced to 111 mm, a reduction of 12%. For material B, the maximum deformation of the cross arms for the standard case is 79 mm, while the case where the bracing is installed is 63 mm. A decrease of 20% in maximum deformation is obtained for the material B. This results shows that the installation of bracing is capable of reducing the maximum deformation experienced by the cross arms.

As for the comparison between material A and B, material B experienced a lower maximum deformation for both cases (standard: 79 vs. 127 mm; bracing: 63 vs. 111 mm). Table 4 shows the total deformation contour for material A and B for the case of with and without bracing.

Table 3. Maximum deformation for material A and B for case of with and without bracing.

Configuration	Maximum deformation (mm)		Percentage reduction
	Standard	Bracing	(%)
Material A	127	111	12.6
Material B	79	63	20.3

Table 4. Comparison of deformation experienced by different material for cross arm with and without bracing.

Deformation	Standard	Bracing
Material A		
Material B		

3.2 Maximum stress

The maximum stress for material A and B for cases of with and without bracing support are recorded in Table 5 and 6 respectively. Each layer experienced different stress magnitude and the presence of bracing reduced the stress exerted to the cross arms for both materials. In material A, the used of bracing lower the maximum stress value more than 5% in each layer. The highest reduction achieved is at layer 3, where the maximum stress obtained before and after the placement of bracing is 178.30 MPa and 124.58 MPa respectively, a reduction of approximately 30%.

A similar observation is recorded for material B, where the bracing support reduced the maximum stress subjected to the cross arms with a reduction of more than 5%. The maximum reduction achieved is at layer 5, where the maximum stress obtained before and after the placement of bracing is 153.84 MPa and 143.36 MPa respectively, a reduction of 6.81%. For the comparison between material A and B, material B seems to be experiencing greater maximum stress compared to material B, as tabulated in Table 5 and 6.

Figure 3 shows the plotted maximum stress for material A and B in each layer. The maximum stress experienced at each layer seems to be lower for the layer close to the center and higher at the outer layer of the material. The distribution of stress for both materials for each case seems to be similar where the maximum stress recorded is in the tip region of the cross arms. Figure 4 shows the stress distributions at layer 1 for material A for case of without and with bracing. The distributions of stress in each layer is also similar, in both material, for both cases. Hence, for simplicity, only layer 1 of material A is included in this paper.

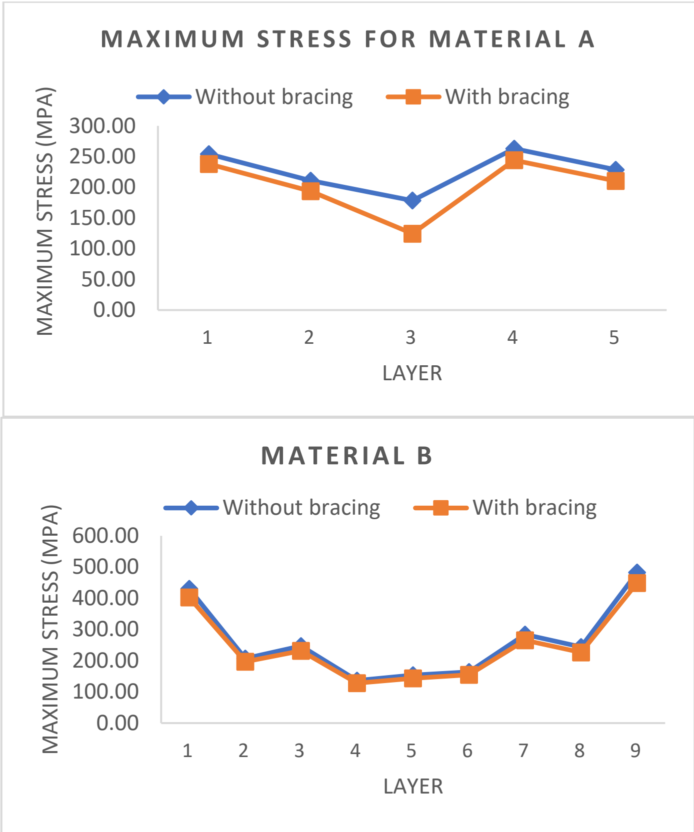


Figure 3. Maximum stress recorded for material A and B at each layer.

Table 5. Maximum stress at each layer, with and without bracing for material A.

Layer	Maximum stress (MPa)		Percentage difference (%)
	Standard	Bracing	
1	254.12	238.17	6.28
2	210.64	193.58	8.10
3	178.30	124.58	30.13
4	262.95	243.96	7.22
5	228.31	210.22	7.92
Bracing	-	2736.80	-

Table 6. Maximum stress at each layer, with and without bracing for material B.

Layer	Maximum stress (MPa)		Percentage difference (%)
	Standard	Bracing	
1	429.99	402.95	6.29
2	207.40	197.09	4.97
3	247.20	231.59	6.31
4	136.50	128.02	6.21
5	153.84	143.36	6.81
6	284.25	265.02	6.77
7	244.41	226.89	7.17
8	482.24	449.34	6.82
9	284.25	265.02	6.77
Bracing	-	1745.20	-

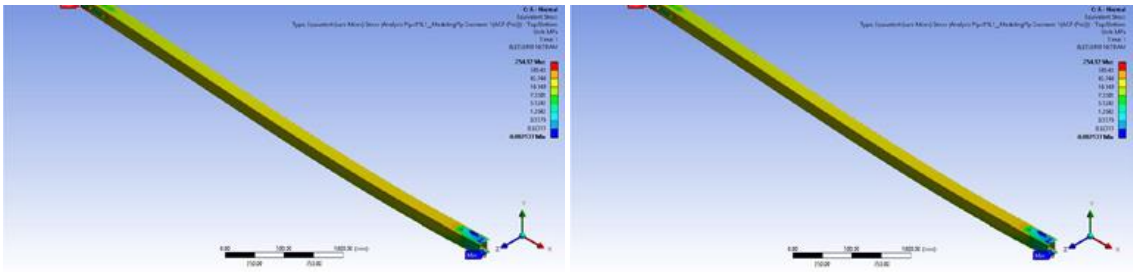


Figure 4. Stress distributions for: (a) without bracing; (b) with bracing.

4. Conclusion

The study aimed at investigating the total deformation and maximum stresses experiencing by the cross arms of different composite material with and without the support of a bracing. The simulations performed concluded that the bracing helped reduced the total deformation and maximum stresses subjected to the cross arms for both materials. The installation of bracing reduced the total deformation around 12% and 20% for material A and B respectively. For the maximum stress parameter, the bracing managed to decrease the stresses underwent at each layer for both materials. The percentage reduction ranges from 4% to 30%. Between the two materials, material B recorded a lower deformation, but experienced greater stresses compared to material A.

Acknowledgement

TNB Seeding Fund funds this research for Universiti Tenaga Nasional (U-T-S-RD-17-05). Author would like to thank TNB Transmission Line Division and TNB for financial support.

References

[1] W Chen, Q Meng, H Hao, J Cui and Y Shi 2017 Quasi-static and dynamic tensile properties of fiberglass/epoxy laminate sheet *Construction and Building Materials* Vol 143 pp 247-258

[2] S Grzybowski and T Disyadej 2008 Electrical performance of fiberglass crossarm in distribution and transmission lines *IEEE/PES Transmission and Distribution Conference and Exposition* pp 1-5

[3] S Grzybowski and X Li 2006 Electrical degradation of fiberglass distribution line pole *IEEE Transactions on Dielectrics and Electrical Insulation* Vol 13 pp 927-934

[4] A Nadhirah, Beddu D Mohamad, M Zainoodin, S Nabihah, N Mubin and et al. 2017 Properties of Fiberglass Crossarm in Transmission Tower-A Review Vol 12

[5] N P Rao, S J Mohan and N Lakshmanan 2005 A Study On Failure Of Cross Arms In Transmission Line Towers During Prototype Testing *International Journal of Structural Stability and Dynamics* Vol 05 pp 435-455