Numerical Study of Composite Fiberglass Cross Arms under Statics Loading and Improvement with Sleeve Installation

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Abstract. In this paper, the structural deformation of fiberglass composite cross arms under statics loading were numerically simulated using the ANSYS software. The alternate variant of cross arms with one-meter sleeve span installed on both arms was considered as an improvement study. By comparing both cross arms systems, it is found that the total deformation was reduced from 127.49 mm to 95.367 mm by introducing the sleeve. Besides, the stress level appears to be lowered in the cross arms with sleeve installed. The sleeve is regards as a viable solution to reduce both deformation and stress level of cross arms, thus lengthen its life span and saving maintenance costs.

Keywords: *ACP simulation; cross arms; fiberglass composite; statics structural deformation*

1. Introduction

In electrical transmission tower, cross arm is the structure responsible to hold the transmitting wires in place. The cross arms not only must be rigid enough to sustain the electrical cables, but also able to withstand the dynamic wind load, especially during the windy or stormy days. A failed cross arm will cause disruption to the electrical transmission and incurs additional maintenance costs to the electrical provider. Additionally, broken cross arm will lower the electrical wires near to ground, risking the pedestrians that happened to walk by. Therefore, it is necessary to study the reliability of cross arms of transmission tower to ensure safe and cost-effective electrical transmission [1-2].

This paper is devoted to study the structural rigidity of cross arms system that being used in the typical transmission tower. Numerical simulation is the prime methodology of current research, executed by utilizing the ANSYS Composite PrepPost (ACP) module. In fact, ACP module had been used by previous researchers to simulate the structural behaviour of composite material [3-4]. Furthermore, the sleeve span is introduced as a potential solution to reduce deformation and stress on the cross arms, thus enhancing its reliability. Therefore, two cases of cross arms, with and without sleeve will be simulated and have their results compared side-by-side to justify the effectiveness of sleeve installation.

2. Numerical simulation

Using the commercial available numerical simulation software, ANSYS, the composite structures of the cross arms were modelled and subsequently solved for the applied load. The cross arms' fibreglass composite layers and their orientations were defined in the ANSYS Composite PrepPost (ACP) module; whereas the boundary conditions of statics loading were input in the ANSYS Mechanical module. The materials properties of composite arms, tie members and steel connectors were given in Table 1. Additionally, the composite details (thickness and orientation) were presented in the Table 2.

Table 1. Material properties of the composite and structural steel contained in the cross arms system.

Material properties	Composite	Structural steel
Young modulus in x, E_x (MPa)	16000	200000
Young modulus in y, E_y (MPa)	4800	200000
Young modulus in z, E_z (MPa)	1440	200000
Poisson's ratio, $\nu_{xy} = \nu_{yz} = \nu_{xz}$	0.28	0.3
Shear, modulus, $G_{xy} = G_{xz} = G_{yz}$ (MPa)	4000	76923
Density, ρ (kg/m^3)	1800	7850

Table 2. Thickness and fabric orientation of each composite layer in the cross arms and tie members.

Composite layer	Thickness (mm)	Fabric orientation (°)
First (*outer*)	0.5	45
Second	0.5	−45
Third	0.7	90
Forth	3.6	0
Fifth (*inner*)	0.7	45

The numerical model of cross arms system was meshed with size function adaptive, to generate both hexagonal and quadrilateral meshes as illustrated in Figure 1. Hexagonal meshes were mainly applied on rectangular parts while quadrilateral meshes were adopted in rounded or curved parts. The mesh sizing of the numerical model was varied to attain the optimum grid, as part of mesh independent study (refers Section 3.1).

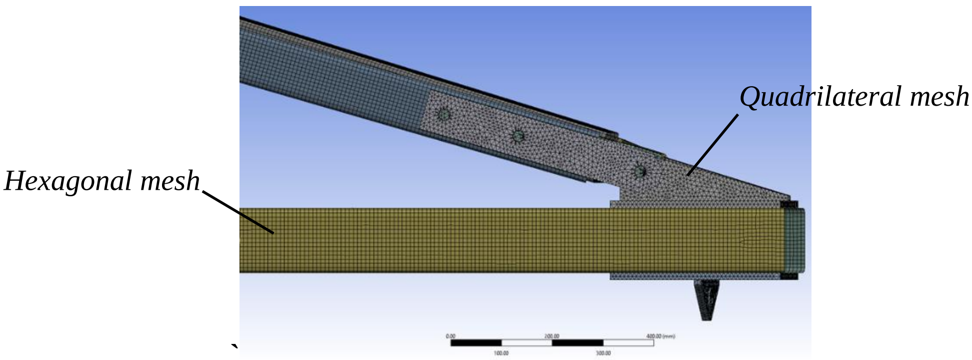


Figure 1. The adaptive hybrid mesh that being implemneted on the cross arms numerical model.

There are mainly two types of boundary conditions being applied on the cross arms system, for instance fixed support (FS) at the back ends of each cross arms/tie members and force loading at the front end. The force boundary condition applied on the numerical model is equivalent to the loadings of electrical wires on the cross arms. It has the following force components: $F_x = -23208$ N, $F_y = -42496$ N and $F_z = -3262$ N, resultantly acting in the direction indicated by the red arrow as shown in Figure 2.

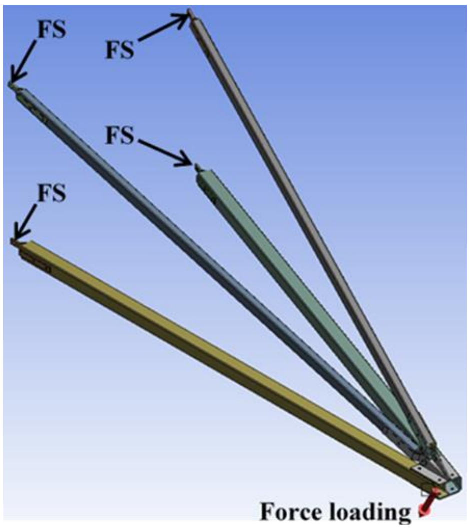


Figure 2. Summary of boundary conditions that being applied on the cross-arms numerical model. The abbreviation "FS" denotes to fixed support boundary condition that applied on the cross arms hinges.

The numerical model of cross arms was later solved to determine the total deformation and von Mises stress at each composite layer. Similar simulation procedures were repeated on cross arms system with one-meter sleeve span installed on both cross arms. Each sleeve has similar thickness and composite layer as that of the cross arm itself. The sleeve will be wrapping around cross arms tightly, such that it appeared the thickness of cross arms were doubled at that particular region.

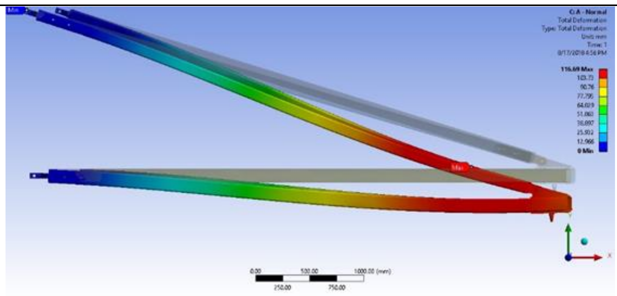
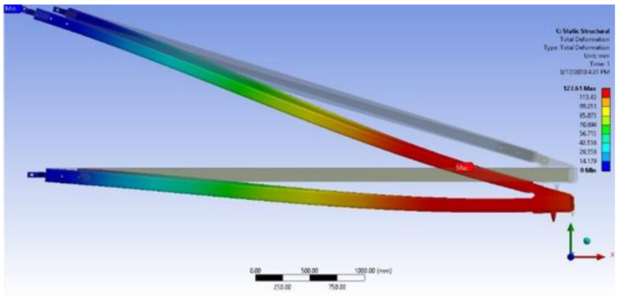
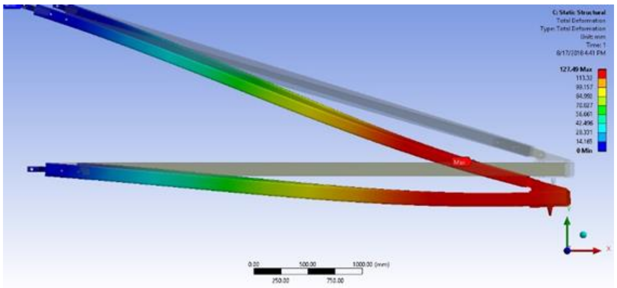
3. Result and Discussions

3.1 Mesh independency study

A mesh independency study was performed to ensure the accuracy of numerical model is not effected by the mesh details. The results of current independency study were presented in Table 3. Taking the standard cross arms numerical model, its mesh details were manipulated from default to very fine, while observing the changes in their deformation contours.

From Table 3, it is found that both fine and very fine meshes yield similar numerical results with maximal deformation value around 127 mm. Therefore, it is justified that the mesh independent had been achieved in the present simulation. Subsequent deformation and stress data will be based on the numerical model with very fine mesh that being optimized.

Table 3. The deformation contours obtained using numerical model with different grid resolutions.

Mesh	Grid resolution	Maximal total deformation (mm)	Deformation contour
1	Default	116.69	
2	Fine	127.61	
3	Very fine	127.49	

3.2 Deformation

Figure 3 depicts the comparison between the deformation contours of standard cross arm and cross arms with sleeve installed. Table 4 presents the peak deformation and deformation value at the mid-span of the cross arms in both cases. Generally, the deformation gradually increases toward the loading end of the cross arm, where the peak deformation would be observed near the front end where the electrical wires loading is being applied on the cross arm. Besides, it is found that the installation of sleeve on the cross arms effectively reduce the peak deformation by 25.19%. At the mid-span of the cross arms where the sleeve being installed, the deformation reduction is found to be 30.09%.

Table 4. Deformation values of both cross arm systems.

	Peak deformation (mm)	Mid-span deformation (mm)
Standard cross arm	127.49	102.01
Cross arm with sleeve installed	95.37	71.32
Percentage reduction with sleeve installation	**25.19%**	**30.09%**

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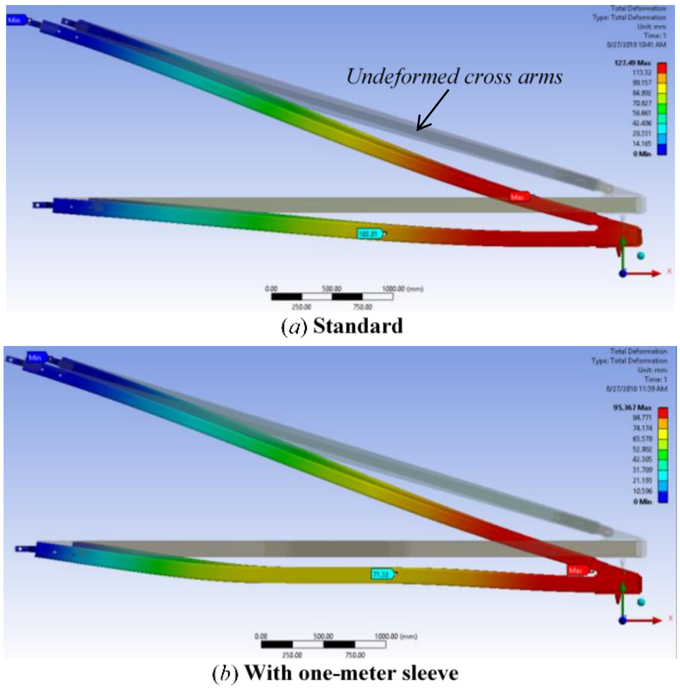


Figure 3. Comparison of deformation between (*a*) the standard cross arm without sleeve and (*b*) the cross arm with one-meter sleeve installed, upon being subjected to statics loading.

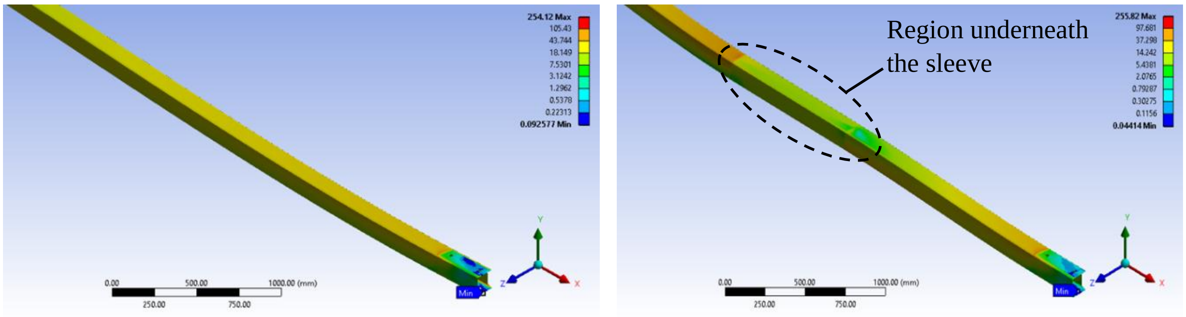
3.3 Stress

Table 5 presents the maximal localized stress at each composite layers. It is found that the third composite fibre layer has the lowest localized stress as compared to other layer, which is due to its 90° fibre orientation. Meanwhile, the forth layer possess the highest localized stress as compared to other. Furthermore, the introduction of sleeve span on the cross arms appeared to not drastically reduce the stress level. Noticeable reduction of stress is found at the third layer, about 36.88%; while for the first and fifth layers, the stress is slightly increased with sleeve introduction.

Table 5. The maximal stress at each composite layers for both cross arms cases.

Composite layer	**Maximal localized stress (MPa)**	
	Standard	**With sleeve**
1 (outer)	254.12	255.82
2	210.64	210.31
3	178.30	112.54
4	262.95	269.08
5 (inner)	228.31	228.55

However, the stress value presented in Table 5 is rather localized and occur in small region. Figure 4 depicts the stress contours of whole cross arms. It is found the stress level is averagely in the ranges of 47 – 105 MPa (for standard cross arm) and 37 – 97 MPa (for cross arm with sleeve). Besides, the region underneath the sleeve has significantly lower stress level (about 5 -14 MPa). Overally, the sleeve installation reduced the stress level on the cross arms.



(*a*) Standard cross arm (*b*) Cross arm with sleeve installed

Figure 4. Comparison of stress contours of first (outer) cross arm composite layer between both cases.

4. Conclusions

The deformation of fiberglass composite cross arms subjected to statics loading of electrical wires were successfully simulated using the commercial available software, ANSYS. In particular, two cases of cross arms system were considered: standard cross arms and cross arms with one-meter sleeve span installed on both lower arms. Numerical mesh was optimized to lower potential computational error. It is found that the introduction of sleeve able to reduce both deformation and stress level at the cross arms, making less prone to fatigue failure and thus more reliable for long term usage.

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