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V. Popov[1]
Zhang Weiyu[2]

DYNAMIC ANALYSIS AND EVALUATION OF CABLE LAYING ON BRIDGE UNDER TYPHOON ENVIRONMENT

[1]Vinnytsia National Technical University, Ukraine
[2]Guangdong University of Finance and Economics, China

Анотація

Це наукове дослідження описує моделювання електрифікаціного кабелю типу XLPE 220 кВ (модель YJLW02-127/220), який буде прокладено вздовж морського переходу через міст KV-2500 мм2). Об'єктами дослідження є чисельна модель електромагнітного теплового структурного мультифізичного поля, яка розроблена за допомогою програмного забезпечення для моделювання "Comsol". Отримане пульсуюче зміщення було прикладене, як динамічне навантаження, на кабель, щоб отримати характеристики динамічного відгуку кабелю. Були проаналізовані комбіновані впливи на кабельну систему в рамках аналізу методами будівельної механіки, вибору місця планування, планування кабелю мосту та інших комплексних аспектів. Зазначені модельні наукові дослідження є важливими та актуальними для теоретичних досліджень роботи реальних мостових споруд.

Ключові слова: міст, тайфун, динамічний аналіз та оцінка, амплітуда напружень

Abstract

In this scientific work, the 220 kV XLPE cable (model: YJLW02−127/220) will be laid along a sea-crossing bridge KV-2500 mm²) as the research object, the electromagnetic-thermal-structural multi-physical field numerical model is established by using "Comsol" simulation software. Applying the obtained pulsating displacement as a load on the cable so as to obtain the dynamic response characteristics of the cable. Have been analyzed the combined impacts on cables system within the analysis of methods of construction mechanics, planning site selection, bridge cable planning and other comprehensive aspects. The specified model scientific studies are important and relevant for the theoretical studies of work of real bridge constructions.

Key words: bridge, typhoon, dynamic analysis and evaluation, stress amplitude.

Introduction

In recent years, more and more high-voltage large-section cables are laid on bridges. Compared with submarine cables and underwater cables, bridge cable laying has the characteristics of low construction cost, convenient construction and high economy. At the same time, it is also convenient to carry out cable repair and maintenance work in the future. However, bridge cables are vulnerable to external environmental factors in the actual operation process. External environmental factors such as vehicle running and wind force cause bridge vibration to act on the cable. Especially in typhoon weather, the vibration of the bridge is intensified, which makes the cable move greatly [1]. When the cable moves by a large margin, the stress and structural characteristics of the body structure layer will change. Resulting in reduced operational reliability of the cable. Therefore, it is of great significance to carry out the dynamic response analysis of bridge cables under typhoon weather for the reliable and stable operation of cables [2 – 3].

Main part of research

In order to solve the important scientific problem of assessing the strength and reliability of the cable system, we will consider a finite-element model of the stress-strain state of a real cable by voltage 220 kV.

The main research method of this scientific research work is to use "Comsol" simulation software to establish the electromagnetic-thermal-structural multi-physical field numerical model. The obtained pulsating displacement is applied to the cable as a load so as to obtain the dynamic response characteristics of the cable.

The main technical characteristics of the research object – high power electrification cable is shown in Table 1 and at figure 1 [2 – 3].

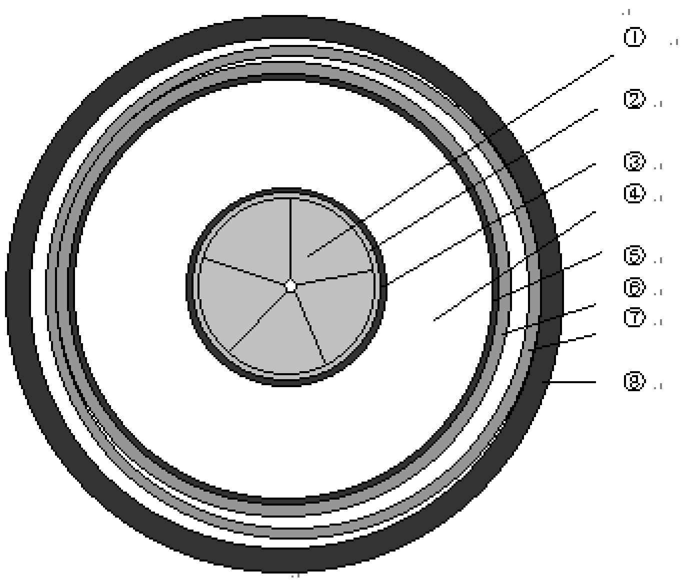

Figure 1 – Cross section of the electrification cable and marking of its main components.

Table 1 – Technical characteristics of the structural components of the electrification cable

YJLW02-Z 1×2500 mm^2 127/220kV			
The number of parts of cable	Cable construction	Thickness (mm)	Dimension (mm)
①	Conductor	60.4	60.4±0.5
②	Semi-conductive Tetoron tape	0.8	62.0
③	Conductor shield	1.5	65.0
④	XLPE insulation	24.0	113.0±1.5
⑤	Insulation shield	1.0	115.0±1.5
⑥	Semi-conductive buffer water-blocking tap	4.2	123.4
⑦	Corrugated aluminum sheath	2.8	143.1±2.0
⑧	Semi-rigid flame-retardant PVC sheath (Including asphalt protective layer and graphite semi-conductive layer)	5.0	153.1±2.0

The modeling of the cable system was carried out using finite element methods by dividing its structure into three-dimensional pyramidal, prismatic, tetrahedron and hexahedron triangulation components (fig. 2 - 3).

The process of finite-element modeling is standard, it corresponds to the process of modeling with volumetric finite elements that simulate the operation of the components of a high-voltage cable.

The algorithm for creating a finite-element model is shown in fig. 4 [1 – 3].

Automatically formed according to the algorithm shown in fig. 4, the triangulation grid allows you to solve the important contact problem of cooperation of high-voltage cable components (parts), which are diverse in terms of physical, mechanical and conductive properties, and evaluates their stress state during joint work.

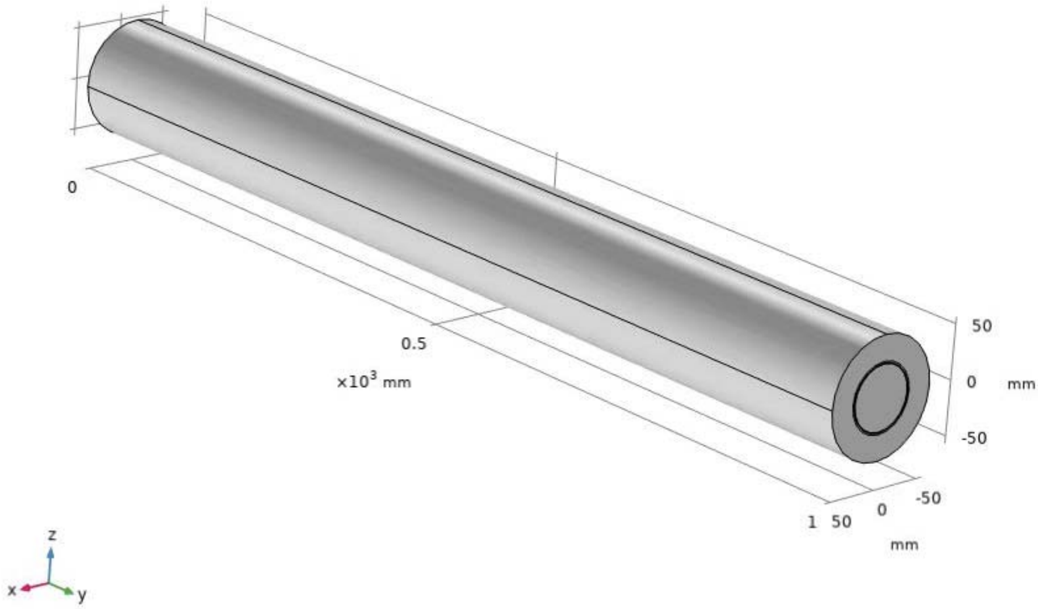

Figure 2 – Schematic (3D-visualization) diagram of modeling.

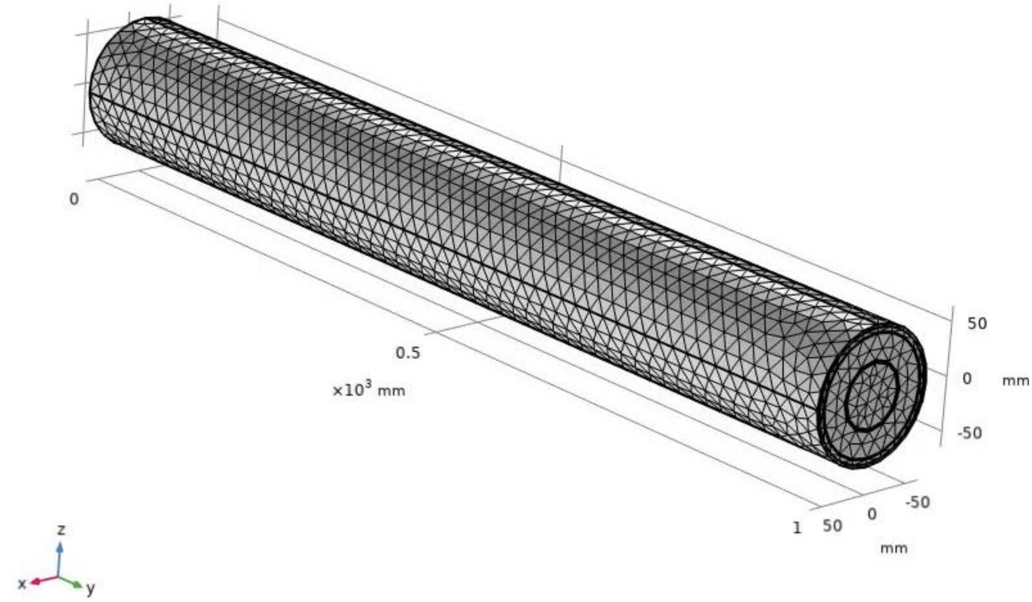

Figure 3 – Schematic diagram of the finite elements grid division (3D-visualization).

The simulation results show that in typhoon weather, the cable is forced to move. The maximum stress amplitude on the metal structure layer of the cable occurs near the anchor ear fixation. The higher the typhoon wind speed and wind power level, the lower the allowable current carrying capacity of the cable laid on the bridge (see table 2).

The experimental results of typhoon speed research at 15 m/s have been taken as an example for illustration. In the following researches, the experimental simulation results and conclusions under different wind speeds such as from 15 m/s to 40 m/s will be described in detail. Different wind speeds correspond to different typhoon grades, which provides a theoretical basis for practical application.

The simulation experiment is carried out when the typhoon wind speed is 15m/s, and the stress distribution analysis diagram of the whole cable of the research object within the most important components of the cable: copper conductor and aluminum sheath is as follows is as follows (see figure 6).

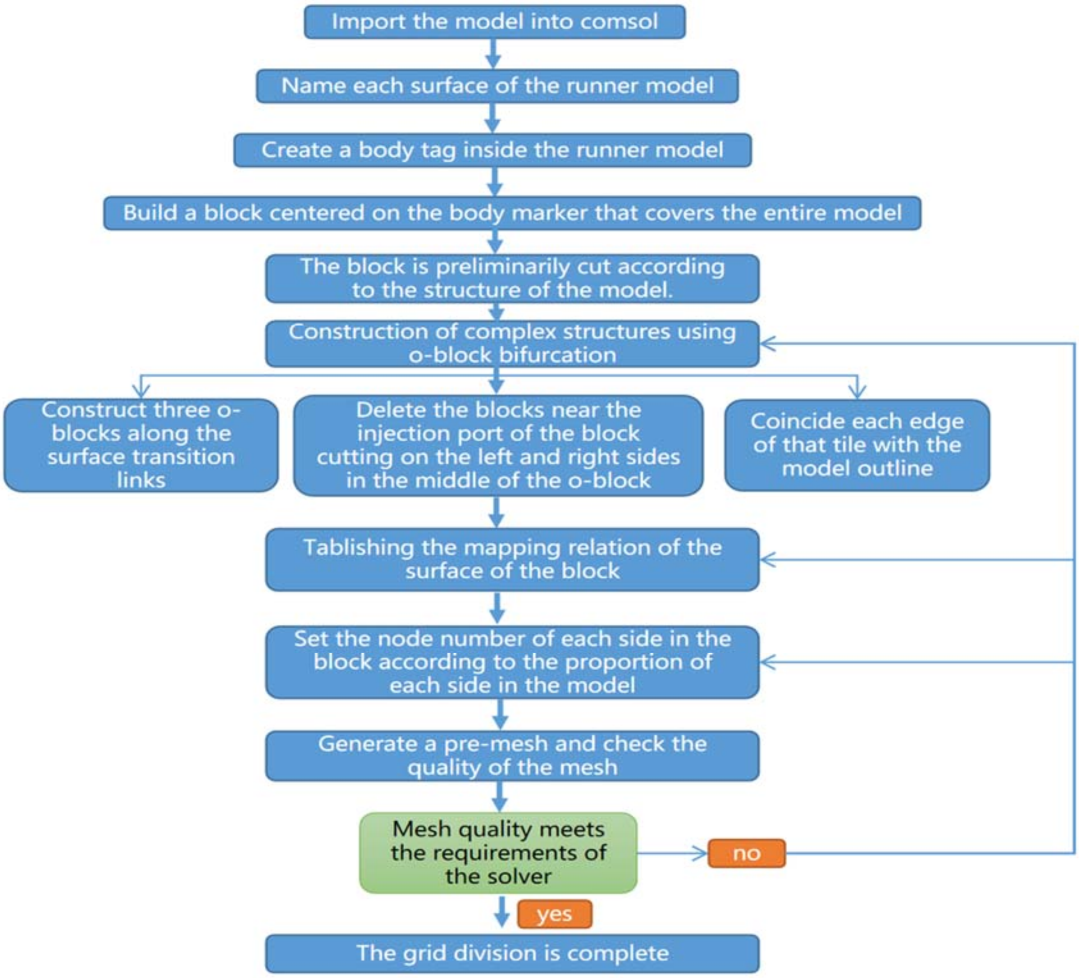

Figure 4 – Flow chart of mesh generation of hexahedron mechanism.

Table 2 – The data table of maximum stresses in conductor elements of the cable power network

Wind speed (m/s)	Maximum stress amplitude [kPa]	
	Copper Conductor	Aluminum Jacket
15	39	76
20	68	132
25	104	204
30	149	292
35	201	395
40	262	513

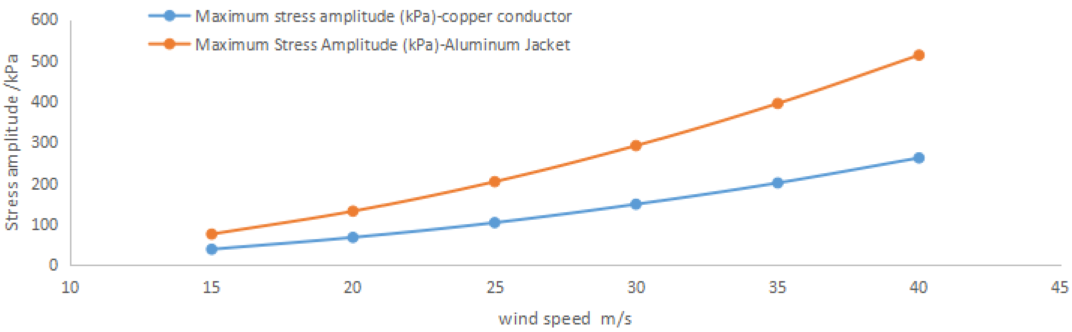

Figure 5 – The stress amplitude of cable structure layer corresponding to different wind speed value

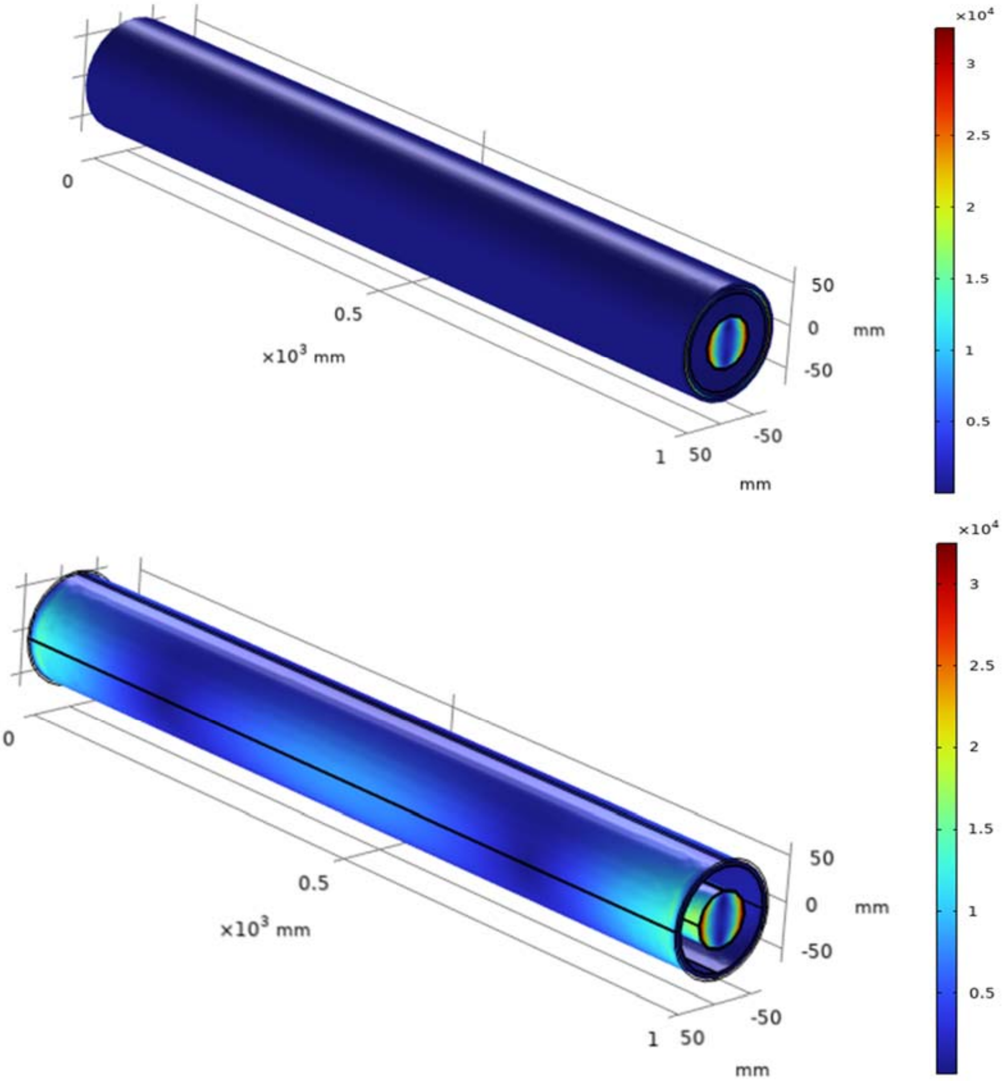

Figure 6 – Stress distribution (wind speed 15 m/s) of: a – cable as a whole, copper conductor and aluminum sheath (the stresses are designed according to the Huber-Hankey-Mises enegetic theory)

Conclusions and constructive suggestions

In this scientific work, have been done the numerical experiment of determining the stress-strain state of a high-voltage bridge cable under a variety of wind speeds (a brief description will only show the typhoon with a wind speed of 15 m/s). Taking the cable laying of the cross-sea bridge as the simulation scene, the simulation experiment of the cable stress under different wind speeds is carried out.

By studying the experimental data and summarizing the experience, the stress amplitude of the cable under the corresponding wind speed is obtained. It provides some practical guiding significance for the details of cable laying in bridge construction. According to the experiment and analysis, the conclusions and suggestions are as follows:

1. In typhoon weather, the cable produces pulsating displacement.
2. The maximum stress amplitude on the metal structure layer of the cable occurs near the anchor ear fixation.
3. The relationship between the stress of the copper core conductor layer and the aluminum sheath layer of the cable and the different typhoon grades is established.
4. Compared with 10 typhoons (wind speed is about 25m/s), the stress on the metal sheath of the cable increases by nearly 80% in the typhoon of force 13 (wind speed of 35m/s).

Therefore, have been suggested that more attention should be paid to the stress change and damage of the metal jacket of the bridge cable under a certain level of typhoon.

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Попов Володимир Олексійович — к.т.н., доцент кафедри будівництва, міського господарства та архітектури, Факультет будівництва, цивільної та екологічної інженерії, Вінницький національний технічний університет, м. Вінниця, Україна, email: v.a.popov.vntu@gmail.com. ORCID 0000-0003-2379-7764

Чжан Вейю — бакалавр, Гуандунський фінансово-економічний університет, Китай. E-mail: 1500404360@qq.com .

Popov Volodymyr O. — Ph.D. Docent of department of civil engineering, architecture and municipal economy, Faculty of Civil and Environmental Engineering, Vinnytsia national technical university, Vinnytsia city, Ukraine, email: v.a.popov.vntu@gmail.com. ORCID 0000-0003-2379-7764

Zhang Weiyu — Bachelor, Guangdong University of Finance and Economics, China. E-mail: 1500404360@qq.com.