A study of lightweight interphase spacer

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***Abstract*— If an interphase spacer is set up in an existing tower, reinforcement of the tower might become necessary because the conductor tension increases. Moreover, to improve the deterrent effect of the galloping phenomenon, the installation number might need to be increased. Therefore, there is a high necessity for a light type interphase spacer.**

In this study, the effects of mitigation of galloping amplitude and the extent of reduced interphase distance are compared between a normal interphase spacer and a new lightweight one. Also, the mechanical strength of the new lightweight interphase spacer was evaluated, and the effectiveness was confirmed.

I. Introduction

If an interphase spacer is set up in an existing tower, reinforcement of the tower might become necessary because the conductor tension increases. Moreover, to improve the deterrent effect of the galloping phenomenon, the installation number might need to be increased. Therefore, there is a high necessity for a light type interphase spacer.

Therefore, to adopt a new lightweight interphase spacer (Figure 1) having been proposed by NGK Insulators Ltd., our company evaluated the effects of mitigation of galloping amplitude and the mechanical strength of the new lightweight interphase spacer by the simulation that used FEM analysis code "CAFSS" that CRIEPI had developed. This paper reports on the outcome.

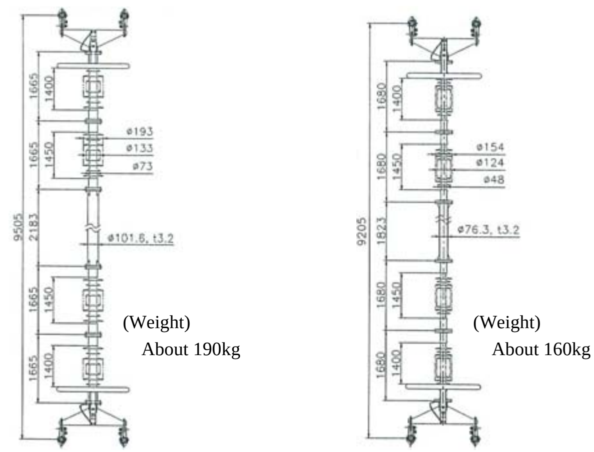
II. Analytical model and Analysis condition

A. Analytical model

An analytical model of a 275 kV transmission line (ACSR330sq) that has the highest needs of our company was made as an evaluation of the interphase spacer, and the model was in a 300 m span and a 400 m span, and "Three equal spans" and a "Single span" were made respectively.

In this study, a three-phase analytical model was made, and the galloping deterrent effect was evaluated with the interphase spacer. Here, one phase of the three-phase analytical models was taken out beforehand, and sensitivity analysis to find the condition in which galloping is generated easily was performed.

In the following, the analytical model used to evaluate the spacer is called a "Full model", and the analytical model used for the sensitivity analysis is called a "Partial model".



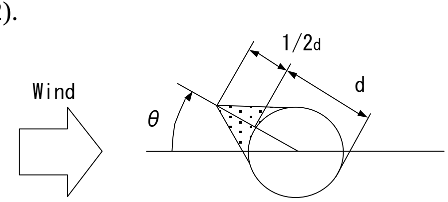
Usual interphase spacer   Lightweight interphase spacer

Fig. 1 Interphase spacer

B. Analysis condition

1) Snow-accretion shape and Wind properties

The snow-accretion shape used was a triangle 1/2d(0.9 in the specific gravity). And, the wind properties used was fluctuating wind speed for which a realistic wind was assumed, and the mean wind speed becomes 20 m/s and 30 m/s (Refer to Figure 2).



* Figure shows the windward snow accretion

Fig. 2 Snow-accretion shape and Initial snow-accretion angle

2) Initial snow-accretion angle

The sensitivity analysis was executed by assuming the angle to be a parameter, and using the Partial model. The peak magnitude of galloping in the sensitivity analysis found the angle as a 10-degree step, input the angle to the Full model, in addition, changed up and down in 5-degree steps, and found the angle that became a peak magnitude.

3) Evaluation position

Figure 3 shows the position in which the amounts etc. of the amplitude were evaluated.

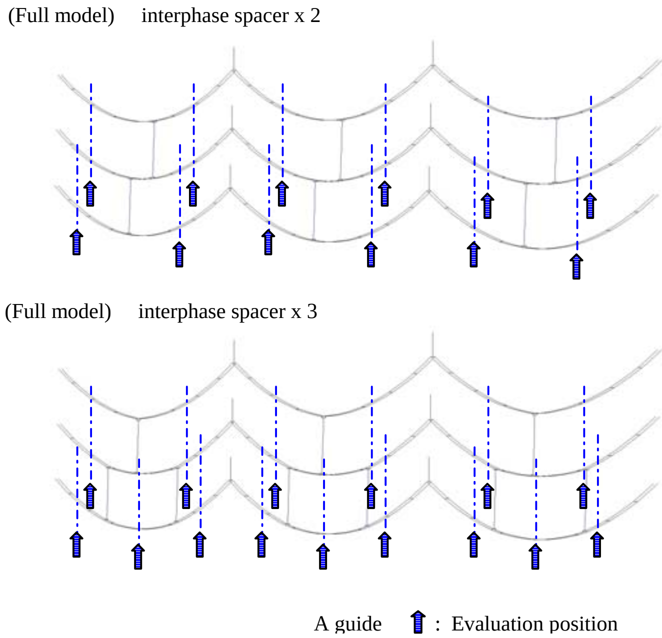


Fig. 3 Evaluation position in analytical model

III. Evaluation of vibrational property

A. Sensitivity analysis by Partial model

Three points in the span of each analytical model have been extracted from the CAFSS analytical results of 24 cases. Also, the peak magnitudes etc. in the horizontal direction and vertical direction were compared (Figure 4).

The following were confirmed in this analysis.

=>In windward snow-accretion amplitudes at a wind speed of 20 m/s is larger than the amplitudes at a wind speed of 30 m/s.

=>In windward snow-accretion at a wind speed of 20 m/s, the amplitude at a 300 m span is larger than the amplitude at a 400 m span.

=>In leeward snow-accretion, when the initial snow-accretion angle is in the range from -10~10 degrees, the amplitude is large.

From the above-mentioned, the analysis condition of the Full model was decided as follows.

=>Span 300 m
Wind speed: 20 m/s, windward snow-accretion,
Initial snow-accretion angle: -30 degree

=>Span 400 m
Wind speed: 30 m/s, leeward snow-accretion,
Initial snow-accretion angle: 10 degree

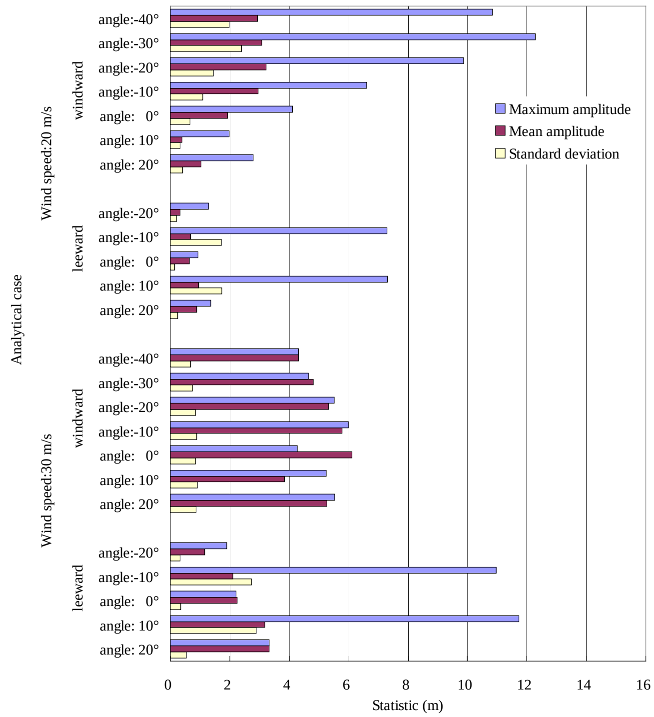


Fig. 4 (a) Comparison of statistics (vertical direction)
(Three equal spans: 300 m, About 2/4 in the second span)

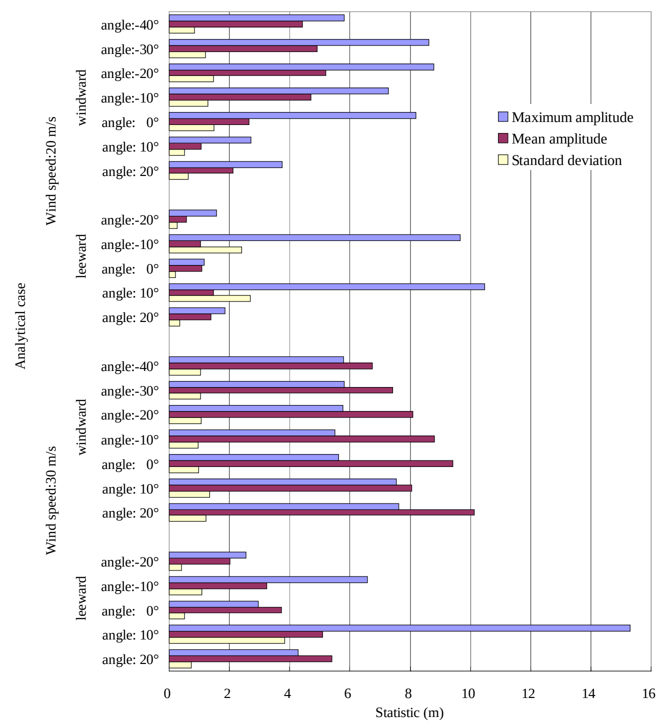


Fig. 4 (b) Comparison of statistics (vertical direction)
(Three equal spans: 400 m, About 2/4 in the second span)

B. Evaluation of deterrent effect by the Full model

1) The effects of the mitigation of the galloping amplitude of a normal interphase spacer and the new lightweight one

The initial snow-accretion angle that had been obtained from the results of the sensitivity analysis was applied to the Full model. In addition, it changed up and down by 5-degree steps, and the galloping deterrent effects of the spacer were compared (Figure 6). Here, the compared items are the maximum amplitude (vertical direction) and minimum distance of each phase, and, in addition, the minimum distance of each phase on the displacement chart (Refer to Figure 5).

The following were confirmed by this analysis.

=>In windward snow-accretion, the maximum amplitude when the new lightweight interphase spacer is set up increases from 5~10% compared with the normal one, and the distance between the phases decreases from 10~15%. It can be judged that the effects of mitigation of galloping amplitude of the new lightweight interphase spacer decreases slightly more than the usual one. However, the distance between the phases on the displacement chart is kept at 3 m or more in all cases and it doesn't short-circuit.

=>In leeward snow-accretion, the distance between the phases when the new lightweight interphase spacer is set up tends to become smaller than that of the normal one. However, it can be judged that there is no great disparity in the maximum amplitude and the distance between the phases on the displacement chart, and the effects of mitigation of the galloping amplitude is equal.

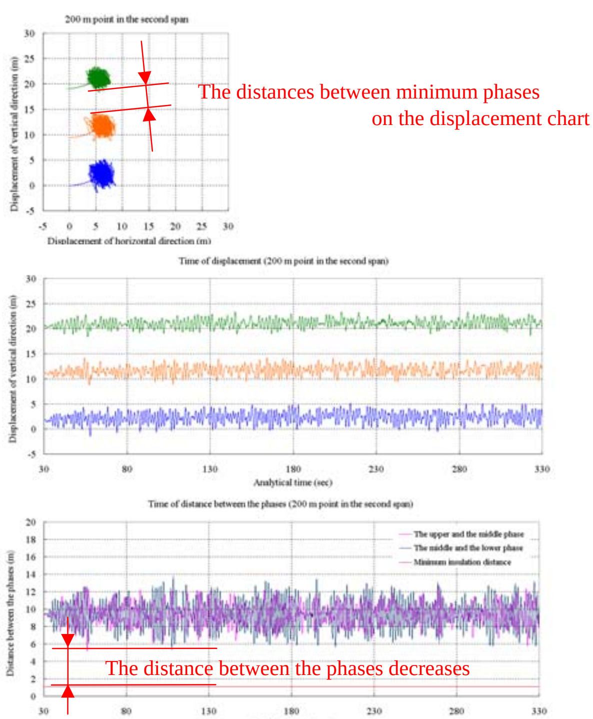


Fig. 5 Response analysis example

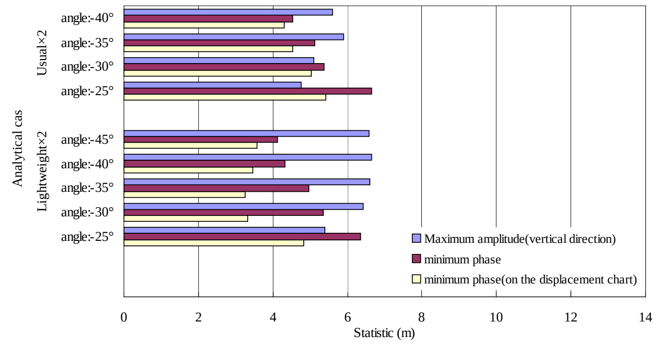


Fig. 6 (a) Comparison of statistics
(Three equal spans: 300 m, Wind: 20 m/s, Windward snow-accretion)

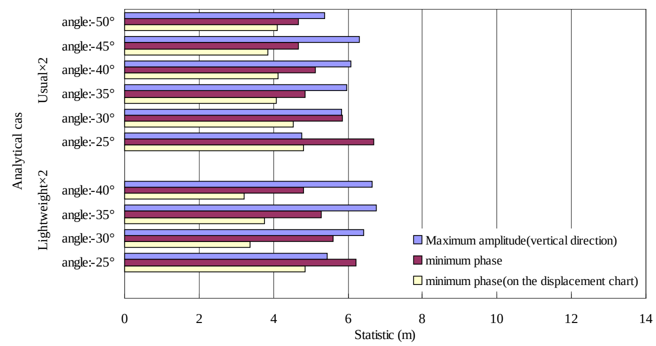


Fig. 6 (b) Comparison of statistics
(Single spans: 300 m, Wind: 20 m/s, Windward snow-accretion)

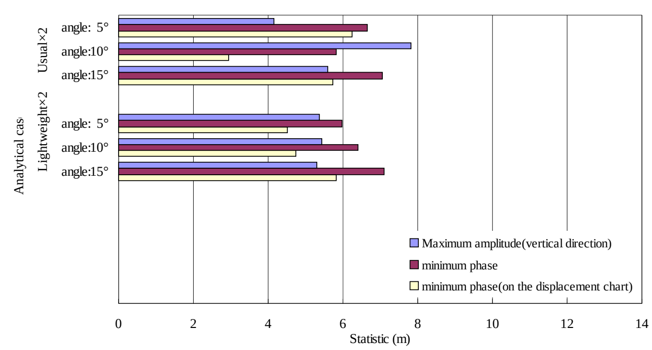


Fig. 6 (c) Comparison of statistics
(Three equal spans: 400 m, Wind: 30 m/s, Leeward snow-accretion)

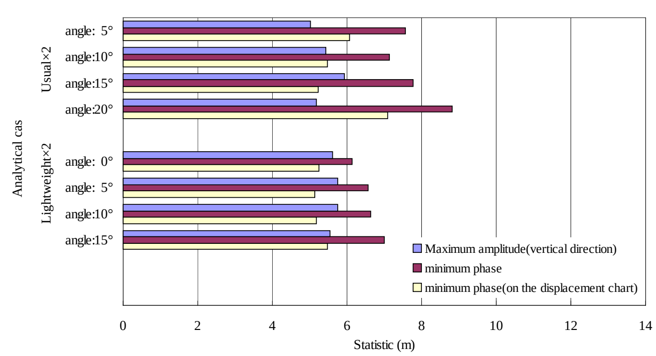


Fig. 6 (d) Comparison of statistics
(Single spans: 400 m, Wind: 30 m/s, Leeward snow-accretion)

2) Influence of installation quantity of the new lightweight interphase spacer

In a lightweight interphase spacer, the effects of mitigation of the galloping amplitude by three installations can be expected by making the best use of its lightweight. Wherein, the effect was evaluated.

In this analysis, as well as the preceding clause, three items of the peak magnitude etc. were compared (Figure 7).

The following were confirmed by this analysis.

=>In the windward snow-accretion, in the installation of three spacers, the maximum amplitude decreases from the maximum by 20%, and the distance between the phases increases from the maximum by 49%. Therefore, the effects of mitigation of the galloping amplitude improve.

=>In the leeward snow-accretion, in the installation of three spacers, there is no big difference in the distance though the peak magnitude increases from the maximum by 51% because of the evaluation position. Therefore, the effects of mitigation of the galloping amplitude are roughly equal.

C. Evaluation of line tension fluctuation by the Full model

The responses of the line tension fluctuation were compared using the Full model. The analytical case does not necessarily correspond for the analytical case where the maximum tension appears and the analytical case where the amount of the maximum amplitude appears.

The maximum tension etc. were extracted and compared among the three cases (the analytical case where the maximum amplitude appears and the analytical cases before and after that) (Figure 8).

The following were confirmed by this analysis.

=>In the comparison of initial tensions, two lightweight interphase spacers are smaller than two normal ones. Moreover, three lightweight interphase spacers are smaller than two normal ones. Especially, the decrease in a single span is remarkable.

=>In the comparison about the average tension and the maximum tension, the tension of the windward snow-accretion is larger than that of the leeward snow-accretion, also, two lightweight interphase spacers are smaller than two normal ones, and, three lightweight ones are smaller than two normal ones.

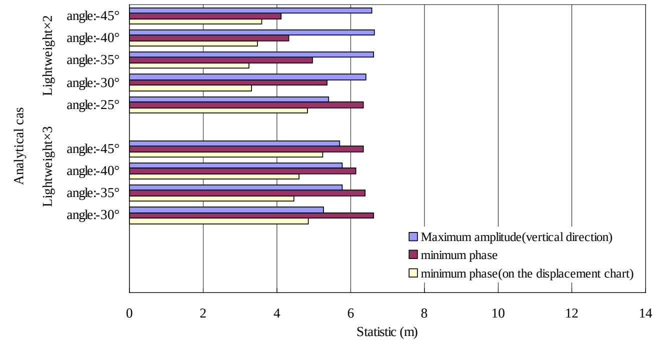


Fig. 7 (a) Comparison of statistics
(Three equal spans: 300 m, Wind: 20 m/s, Windward snow-accretion)

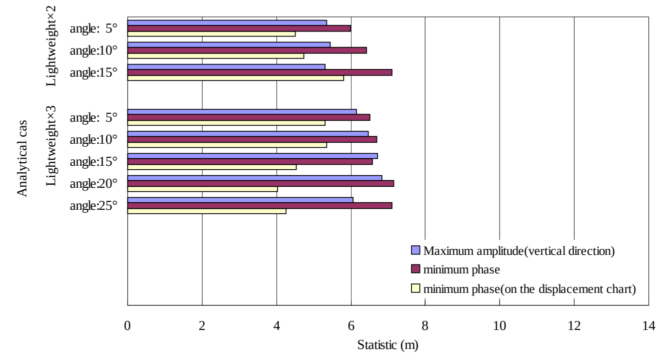


Fig. 7 (b) Comparison of statistics
(Single spans: 300 m, Wind: 20 m/s, Windward snow-accretion)

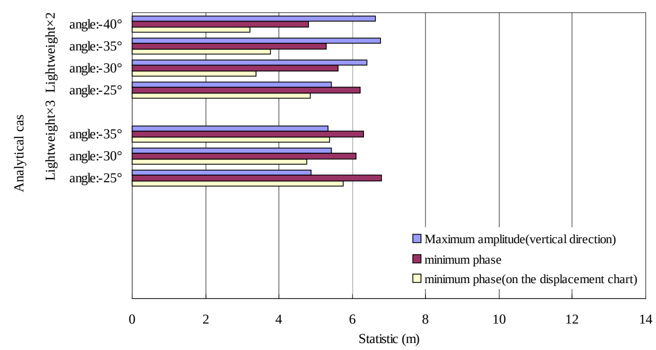


Fig. 7 (c) Comparison of statistics
(Three equal spans: 400 m, Wind: 30 m/s, Leeward snow-accretion)

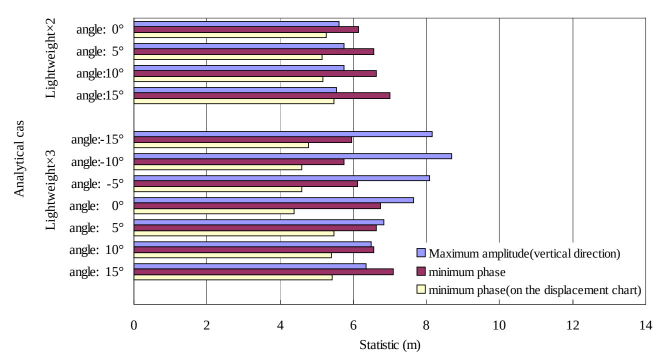


Fig. 7 (d) Comparison of statistics
(Single spans: 400 m, Wind: 30 m/s, Leeward snow-accretion)

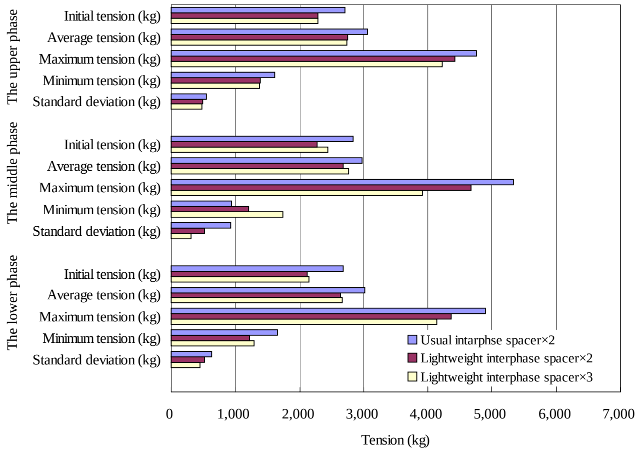


Fig. 8 (a) Comparison of statistics
(Three equal spans: 300 m, Wind: 20 m/s, Windward snow-accretion)

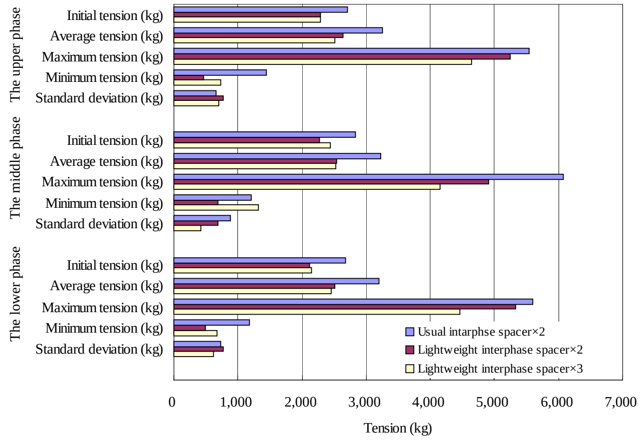


Fig. 8 (b) Comparison of statistics
(Single spans: 300 m, Wind: 20 m/s, Windward snow-accretion)

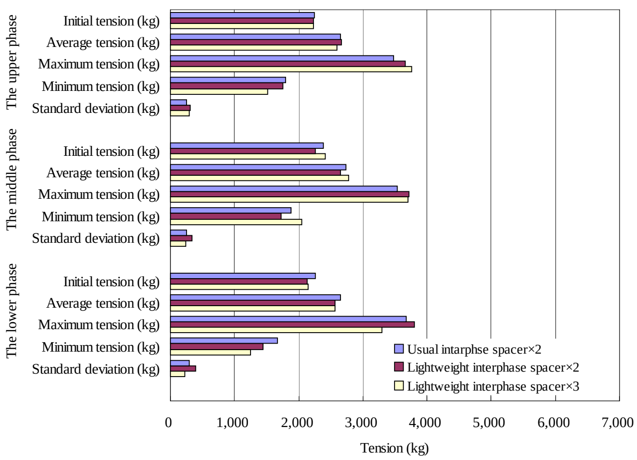


Fig. 8 (c) Comparison of statistics
(Three equal spans: 400 m, Wind: 30 m/s, Leeward snow-accretion)

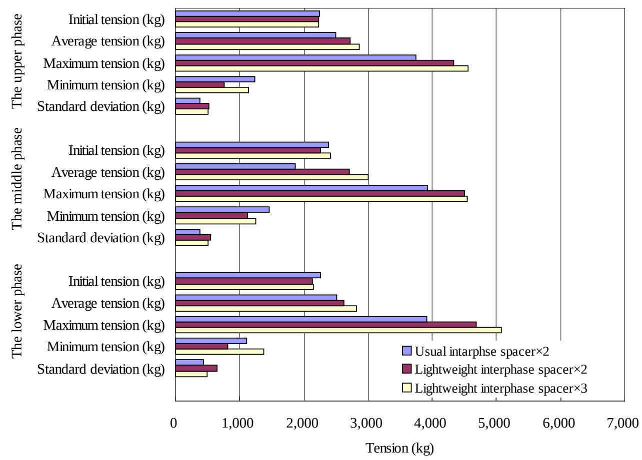


Fig. 8 (d) Comparison of statistics
(Single spans: 400 m, Wind: 30 m/s, Leeward snow-accretion)

IV. Evaluation of Mechanical Properties

A. Evaluation of the mechanical strength at the bending stress caused by galloping

The bending moment generated in the lightweight interphase spacer was extracted from the simulation analysis result, and the bending stress caused by galloping was evaluated.

It was assumed that the maximum value of the bending stress and the maximum value of the compressive stress worked at the same time, and it was compared with the design stress using expression (1). The amount of transformation of the new lightweight interphase spacer is large, and the characteristic of the bending load and the generation stress becomes nonlinear. However, because linear analysis is used for the new lightweight interphase spacer due to the convenience of CAFSS, the simulation result cannot be used as it is. Wherein, it is converted to nonlinear by using the bend test (Figure 9) outcome of the new lightweight interphase spacer (The characteristic of the bending load and the generation stress: Figure 10). Figure 11 shows the bending stress ratio.

$$\sigma = \frac{P}{A} + \frac{M}{Z} \qquad \ldots\ldots \quad (1)$$

σ : Stress (kg/mm^2)
P : Compressive power (kg)
A : Sectional area (=1134(mm^2))
M : Bending moment (kg-m)
Z : Section modulus (=5387(mm^3))

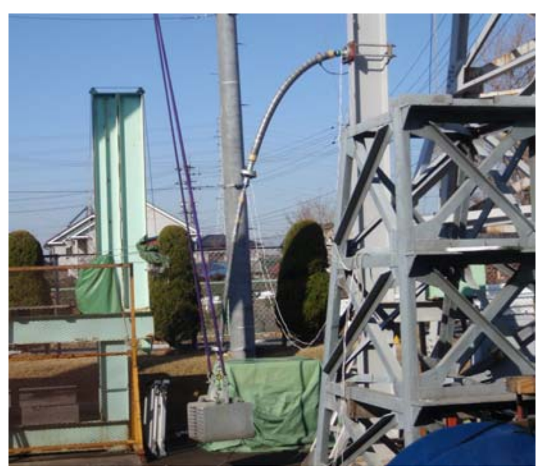


Fig. 9 The bend test of the new lightweight interphase spacer

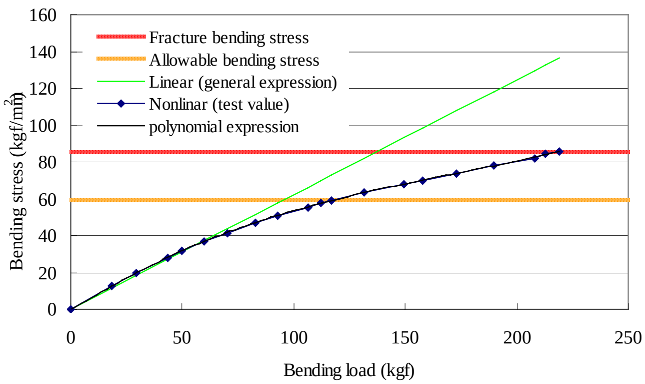


Fig. 10 Bending loading - Bending stress characteristic of the new lightweight interphase spacer (Linear - Nonlinear)

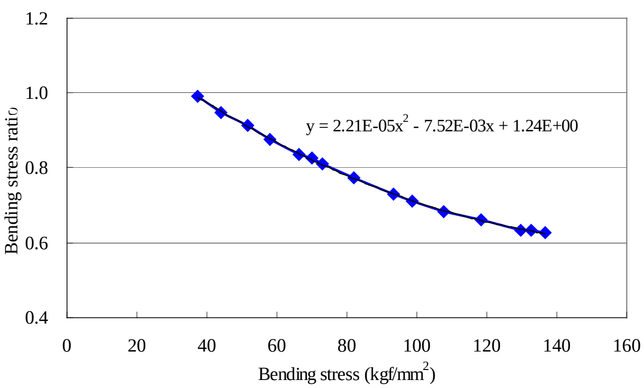


Fig. 11 Bending stress ratio of the new lightweight interphase spacer (Linear - Nonlinear)

Figure 12 shows the stress (bending stress, compressive stress, and combined stress) generated in the new lightweight spacer at the galloping. As shown, the bending stress is predominant at the galloping, and it becomes smaller than the allowable bending stress (60 kg/mm^2).

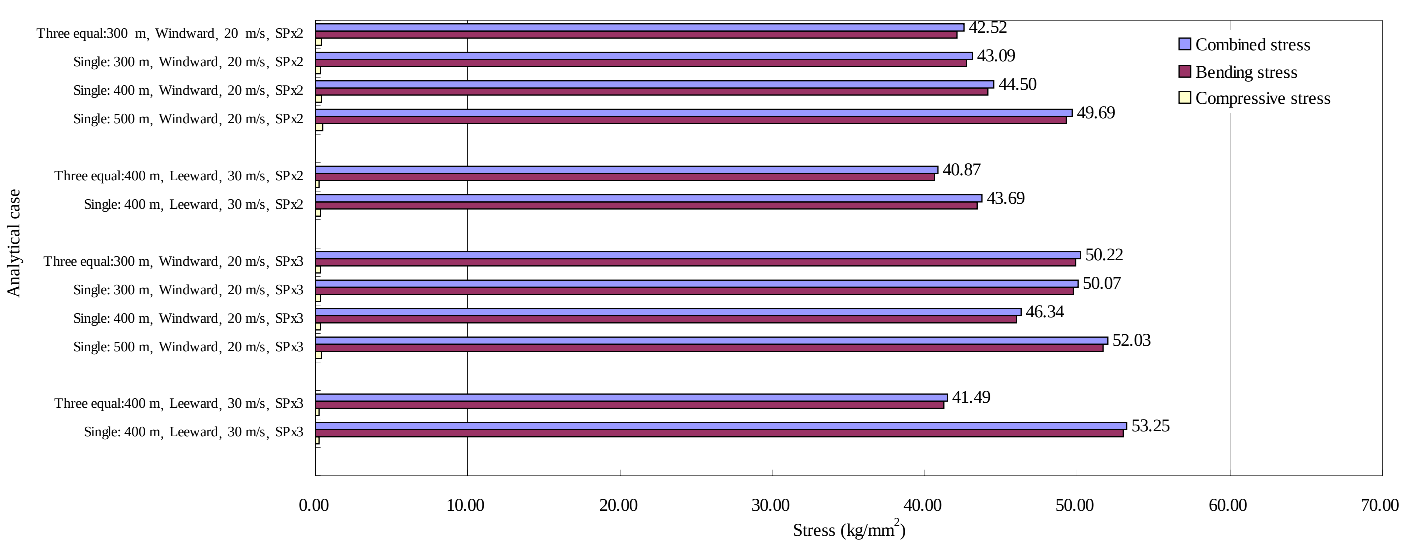


Fig.12 Stress comparisons of each analytical cases

Moreover, because the stress distribution of each analysis condition is about 40~55 kg/mm^2 regardless of the analysis condition, other analysis conditions are assumed not to deviate greatly from this range.

V. CONCLUSION

In this study, a 275 kV transmission line is modeled for FEM simulation "CAFSS" developed by CRIEPI. The effects of mitigation of galloping amplitude and the extent of reduced interphase distance are compared between a normal interphase spacer and a new lightweight one. Also, the mechanical strength of the new lightweight interphase spacer is evaluated.

Findings of this study are summarized as follows.

=>The lightweight interphase spacer is as effective as the normal one in preventing a short-circuit.

=>The lightweight interphase spacer can endure bending stress caused by galloping.

=>The lightweight interphase spacer is very effective in reducing the increasing amount of line tension. It is noteworthy that the line tension with three lightweight interphase spacers is less than the tension with two normal ones.

This result is expected to contribute to the installation design of interphase spacers in the future.

In this study, I received large cooperation from Mr. Matsuda of NGK Insulators Ltd., Transmission Design Section. On this occasion, I want to give my appreciation for Mr. Matsuda.

VI. REFERENCES

[1] M.Simizu, "Analysis of Cables' Galloping." CRIEPI Report No. U95057, March, 1995 (Japanese only)