

Vibration Damping for Transmission Line Conductors

Author: Sarah Chao Sun
Company: Dulhunty Power (Aust.)
Nationality: Australian

Co-Author: Joe Yung
Company: Dulhunty Yangzhou Line Fittings
Nationality: Canadian

1. Abstract

Wind-induced vibration of overhead conductors is common worldwide and can cause conductor fatigue near a hardware attachment. As the need for transmission of communication signals increase, many Optical Ground Wires are replacing traditional ground wires. In the last twenty years All Aluminium Alloy Conductors (AAAC) have been a popular choice for overhead conductors due to advantages in both electrical and mechanical characteristics. Unfortunately AAAC is known to be prone to Aeolian vibration. Vibration dampers are widely used to control Aeolian vibration of the conductors and earth wires including Optical Ground Wires (OPGW). In this paper, the authors present the results of laboratory testing of the performance of vibration dampers on AAAC conductors. The authors emphasize the importance of choosing appropriate design tension, type, quantity and placement of vibration dampers to avoid failure of lines.

2. Keywords

Aeolian vibration, transmission line vibration, overhead conductors, vibration dampers

3. Contact

Sarah Chao Sun, Dulhunty Power, 7 Byfield Street, North Ryde, NSW 2113, Australia
Telephone 61 2 9870 7277 Fax 61 2 9870 7299, sarah@dulhunty.com

Joe Yung, Dulhunty Yangzhou Line Fittings, Zhun Qiao, Jiangdu, Jiangsu, P R China, 225233
Telephone 0514 684 2462, Fax 0514 684 2463, joe.yung@dulhuntychina.com

4. Introduction

Wind-induced vibration or Aeolian vibration of transmission line conductors is a common phenomenon under smooth wind conditions. The cause of vibration is that the vortexes shed alternatively from the top and bottom of the conductor at the leeward side of the conductor. The vortex shedding action creates an alternating pressure imbalance, inducing the conductor to move up and down at right angles to the direction of airflow. The conductor vibration results in cyclic bending of the conductor near hardware attachments, such as suspension clamps and consequently causes conductor fatigue and strand breakage. Conductor fatigue damage has been observed 3 years after line construction. The first sign of conductor damage is usually a broken strand under the hardware attachment clamp (Figure 1).

In recent years, AAAC conductor has been a popular choice for transmission lines due to its high electrical carrying capacity and high mechanical tension to mass ratio. The high tension to mass ratio allows AAAC conductors to be strung at a higher tension and longer spans than traditional ACSR (Aluminium Conductor Steel Reinforced) conductors. Unfortunately the self-damping of conductor decreases as tension increases. The wind power into the conductor increases with span length. Hence AAAC conductors are likely to experience more severe vibration than ACSR.

As the need for the transmission of communication signals increase, many OPGW are replacing the existing earth wires or are being used on the newly constructed lines. It is also important to ensure OPGW does not experience damage from Aeolian vibration. Similar to ACSR, AAAC and other conductors, the solution is to ensure an appropriate tension is chosen and suitable vibration dampers are installed and correctly placed (Reference no. 1).



Figure 1. A broken strand on an AAAC conductor three years after construction.

The “Stockbridge” type vibration damper is commonly used to control vibration of overhead conductors and OPGW. The vibration damper has a length of steel messenger cable. Two metallic weights are attached to the ends of the messenger cable. The centre clamp, which is attached to the messenger cable, is used to install the vibration damper onto the overhead conductor. Figure 2 shows an asymmetrical type of Stockbridge vibration damper. The asymmetrical vibration damper is a multi-resonance system with inherent damping. The vibration energy is dissipated through inter-strand friction of the messenger cable around the resonance frequencies of the vibration damper. By increasing the number of resonances of the damper using asymmetrical design and increasing the damping capacity of the messenger cable the vibration damper is effective in reducing vibration over a wide frequency or wind velocity range.

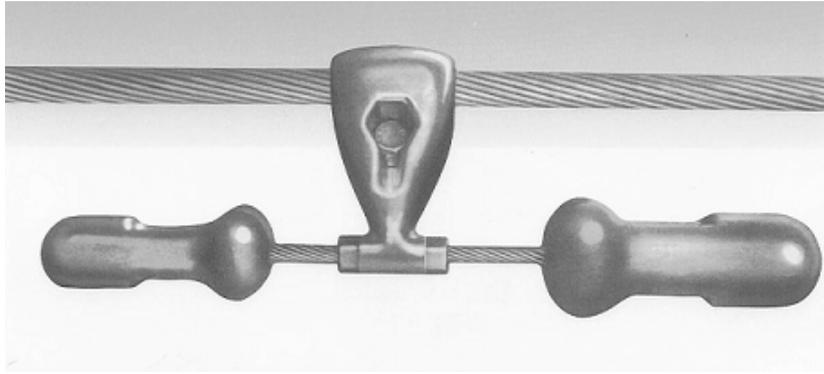


Figure 2. A photograph of asymmetrical Stockbridge vibration damper

The frequency of vibration of the conductor is proportional to wind velocity and inversely proportional to the diameter of conductor as shown in Equation 1.

$$f = 0.185 v/d \quad \text{(Equation 1)}$$

Where f is frequency in Hz

V is wind velocity perpendicular to the conductor in m/s

d is diameter of conductor in m

Hence the smaller the conductor, the higher the frequency range of vibration of the conductor. The vibration damper should meet the requirement of frequency or wind velocity range and also have mechanical impedance closely matched to that of the conductor. The vibration dampers also need to be installed at suitable positions to ensure effectiveness across the frequency range. The power dissipation of the vibration dampers should exceed the wind power so that the vibration level on the conductor is reduced to below its endurance limit. The endurance limit was derived by fatigue tests on conductors for ACSR by EPRI (Reference No. 2).

Many factors affect the vibration level of the conductor, including the design data of conductor, the tension in the coldest month of the year, the terrain, wind direction, the suspension type and span length. High tension results in low damping in the conductor and large amplitude of vibration. Open flat terrain is most favourable to conductor vibration. Hence in the situation of high tension and open flat terrain it is of utmost importance to ensure the conductor is protected by an adequate number of vibration dampers.

The method of evaluating the performance of Stockbridge dampers includes analytical method, field method and laboratory test method. The analytical method uses line design data and mechanical impedance test results of the vibration damper to predict the vibration level on the line. The laboratory test method utilises a 30m-length conductor span (References 3 and 4). The field test is in accordance with the CIGRE guide to vibration measurements on overhead lines (Reference 5). The previous analytical studies (References No. 6 and 7) show that neglecting the rotational components of impedance matrix of the vibration damper does not affect the calculated efficiency (also known as ISWR – Inverse Standing Wave Ratio) results and may affect local bending strain. The mechanical impedance of vibration dampers, which is measured using a shaker, can be used to predict the efficiency results of the test span.

5. Method

The laboratory test was carried out on a 30m-length span. The test set-up is as shown in Figure 3. The span is terminated at the ends using two square clamps and constant tension is maintained on the test span.

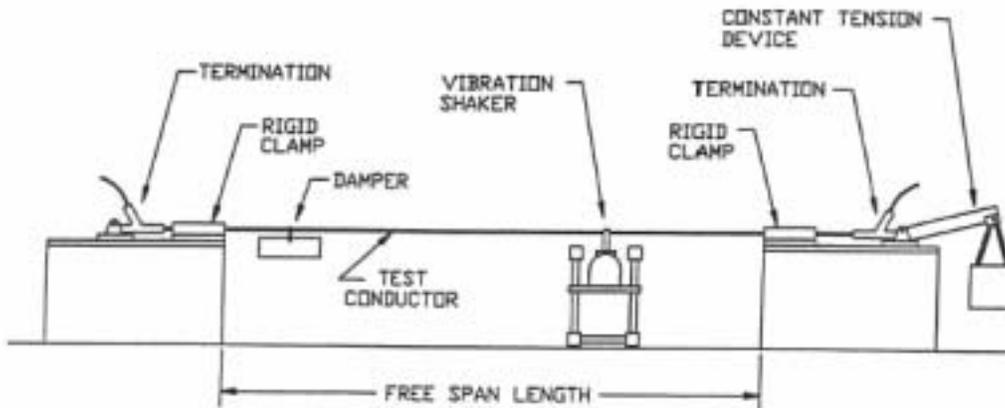


Figure 3, Test set-up (Reference No. 3)

The conductor code name “Oxygen” AAAC1120 has an overall diameter of 23.8mm and mass per unit length of 925kg/km. The tension of test span was 18.4kN and 25% of the calculated breaking strength. A vibration shaker was located near one end of the span. The power of shaker was adjusted at resonant frequencies of the conductor to ensure that the anti-node velocity of the conductor was 0.2m/s. The power method was used. An asymmetrical type of Stockbridge damper, commercially known as model “4D30”, total mass of 2.5kg, was installed at 0.85m from the end of the span opposite to the shaker on the conductor.

6. Results

The efficiency results are shown in Figure 4. The acceptance curve is as per Australian Standard 1154.1 (Reference no. 4). The results show that the efficiency of the 4D30 vibration damper on Oxygen conductor has exceeded the acceptance curve in the frequency range 10Hz to 53Hz or wind velocity range 1.3m/s to 6.8m/s. The power dissipation of a vibration damper is presented in Figure 5. The wind power (Reference No. 8) of a 125m conductor is also presented in Figure 5. It shows that the power dissipation of a vibration damper exceeds the wind power of a 125m span in the frequency range from 10 to 53Hz.

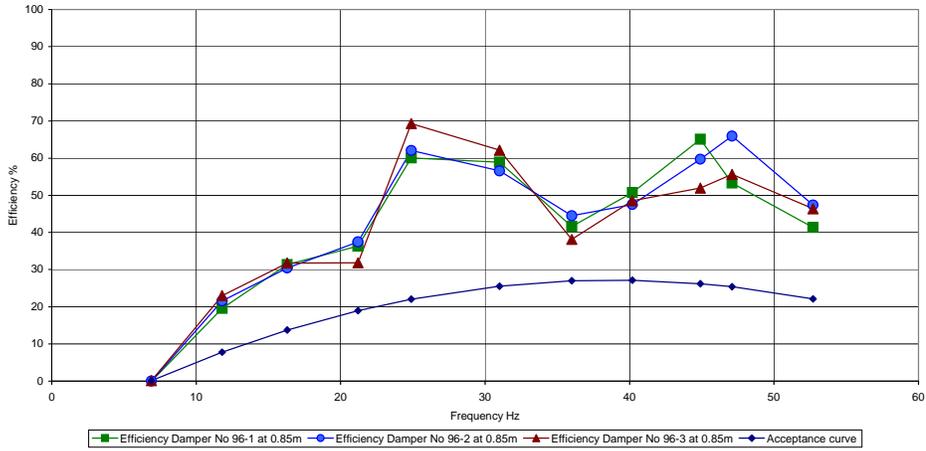


Figure 4. The efficiency of vibration damper 4D30 and the acceptance of AS1154.1-1985.

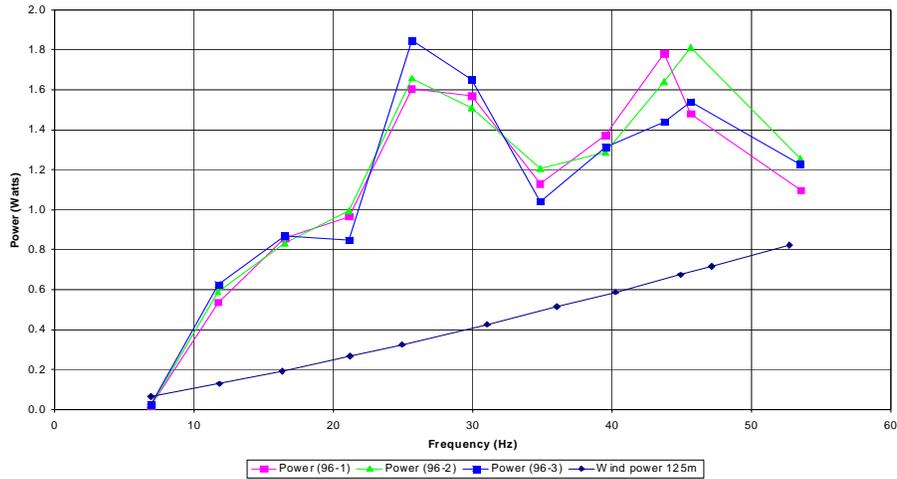


Figure 5, Power dissipation of a vibration damper 4D30 and wind power of a 125m-length span.

7. Discussions

The damper effectiveness tests were also conducted for the 4D20 vibration damper, total mass 1.4kg, on Krypton AAAC1120 conductor diameter 16.3mm and Nitrogen AAAC1120 conductor diameter 21.0mm. The effectiveness of the 4D40, total mass of 4.7kg was tested on Sulphur AAAC1120 diameter 33.80mm. The test results of efficiency exceeded the acceptance criteria and the power dissipation of a vibration damper exceeded wind power of a 125m span (Reference No. 9).

The results of damper effectiveness on OPGW are presented in References 9 and 10.

8. Conclusions

The performance of vibration dampers of asymmetrical Stockbridge type on AAAC1120 conductors has exceeded the requirements of international standards in the wind velocity range of Aeolian vibration.

It is critical at the line design stage to choose the appropriate initial tension of conductor and install vibration dampers that are capable of reducing the vibration level to below the safe limit of the conductor.

9. Acknowledgements

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