

# Influence of Various Biomass Smoldering Flue Gas on Physical Characteristics of High Voltage Transmission Line

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**Abstract.** Through intelligent resistivity tester and universal tensile testing machine, the physical properties of steel-cored aluminum strand above smoldering biomass fuel were analyzed. The results show that compared with the original aluminum single wire, the resistivity of each aluminum single wire under each biomass smoldering condition increases, and the increase amplitude increases with the decrease of the height of the aluminum single wire. The height of the steel core aluminum strand has no obvious effect on the tensile strength before and after smoldering. When the height of the steel-cored aluminum strand from the combustible surface is 5 cm, the Young 's modulus of all aluminum single wires decreases, among which the Young 's modulus of aluminum single wires after smoldering Eucalyptus leaves and poplar sawdust decreases the most. When the height of the steel-cored aluminum strand from the fuel surface is 15 cm and 25 cm, the Young 's modulus of the aluminum single wire after smoldering of different fuels varies (224.4-821.9 MPa). When the height of the steel-cored aluminum strand from the combustible surface is 5cm, the flue gas temperature is high, and the outer aluminum strand of the steel-cored aluminum strand can absorb a certain amount of heat, thereby causing a small shape change occurrence.

**Keywords:** biomass smoldering; steel core aluminum stranded wire; physical characteristics; forest vegetation; forest fire.

## 1. Introduction

As a big country of energy production and consumption, China's energy distribution is extremely uneven. Cross-regional power grid integration project has played an important role in alleviating regional power shortage [1]. However, cross-regional transmission lines inevitably pass through the mountains covered by forest vegetation, and more and more accidents of transmission line tripping and outage caused by mountain fires seriously affect the safety and reliability of the power grid. According to statistics, from 2009 to 2010, Guizhou power grid 220 KV and 500 KV transmission lines a total of 71 wildfire trip accidents [2-3]. Fire occurs, incomplete combustion of biomass fuel gas, ashes and charged particles formed by the mixed smoke covered high-voltage transmission lines, resulting in a sharp decline in transmission line gap insulation strength, and thus the occurrence of line tripping accident. These charged particles form a particle chain bridge line gap will not only reduce the air gap insulation strength between high-voltage transmission lines, may also be attached to the high-voltage transmission lines resulting in increased resistivity, is not conducive to long-term operation of high-voltage transmission lines [4].

In the study of the changes of physical and chemical properties of transmission lines before and after fire, Young-Dal Kim et al [5] conducted tensile experiments on fresh wires, artificial flame baked wires and forest flame damaged wires. It is considered that the loss point of 20 % of the rated tensile strength of the wire can be used as the life limit of the wire. Dae-Dong Lee et al [6] tested and analyzed the mechanical and electrical properties of wires after fire by using a self-made artificial dust test device. Sung-Duck Kim et al [7] tested the tensile strength and elongation at break of ACSR conductor (cross-sectional area of 480 mm<sup>2</sup>) after exposure to artificial flame. It was found that in the initial stage of exposure to flame, the tensile strength of outer aluminum strand and galvanized steel strand after exposure to fire was higher than that of fresh conductor, but with the increase of exposure time, the mechanical strength of aluminum strand decreased significantly. Zhenhua Wang [8] conducted a fire test on LGJ-120/20 ACSR using an electric

furnace and an alcohol spray lamp, and tested the wire quality, mechanical properties and apparent morphology after fire. It was found that ACSR had a slight mass loss (about 0.012 %~0.073 %) under high temperature radiation of the electric furnace. Under high heat flame simulated by alcohol burner, the surface morphology of ACSR outer aluminum strand changes greatly, the tensile strength of conductor decreases by 83.4 %, and the elongation at break increases by 17.3 %.

In summary, although the predecessors have studied the physical characteristics of the wire ACSR under flame conditions, and also have studied the biomass composition under different combustion conditions, there is no research on the physical characteristics of ACSR under biomass smoldering conditions. In this study, the influence of biomass smoldering on high-voltage transmission lines was experimentally studied. The influence of smoldering flue gas on steel-cored aluminum strands during smoldering was investigated. The aluminum single wire of the outer layer of the steel-cored aluminum strand before and after smoldering was subjected to resistivity test and mechanical property test to analyze the influence of biomass smoldering flue gas types on the physical properties of aluminum single wires.

## 2. Materials and Methods

### 2.1. Experimental Samples, Experimental apparatus and instruments

In this experiment, in order to achieve the accuracy, systematicness repeatability and close to the real fire source of the experiment, five biomass fuel samples were collected as combustion materials for smoldering experiments. They were eucalyptus leaves, eucalyptus branches, kidney fern, surface mixed biomass fuel, poplar sawdust. In this study, common poplar sawdust was added as one of the smoldering materials, and the source was Nanjing Jiangbei Forest Processing Plant.

In this study, a test device for the influence of high-voltage transmission lines under smoldering flue gas atmosphere was independently designed. The device can realize the damage experiment of high voltage transmission lines under different working conditions while smoldering biomass combustibles. The overall size of the container is 50.00 cm × 10.00 cm × 10.00 cm. The top is designed to be open, and the left, front and back are made of fire-resistant glass to facilitate the observation of smoldering of biomass fuels during the experiment. Among them, there were 35 holes in the front fireproof glass, which were mainly used to insert thermocouple sensors to realize temperature acquisition during the combustion of biomass fuels. The left and back sides were mainly used for real-time observation. The right end used two electric heating plates with a heating surface size of 10.00 cm × 10.00 cm to fit each other to achieve controllable heating conditions. The fixed power of the electric heating plate is 330 W, and the maximum heating temperature is 400 °C. Because smoldering is difficult to maintain when the heat loss is large during the smoldering process, the bottom of the smoldering container was made of quartz plate material, which can achieve a certain thermal insulation effect, and its position was on the same level as the bottom electric heating plate.

Table 1. Biomass smoldering experimental conditions

Experiment number	Heating method and set temperature	biomass type	Moisture content (%)	Particle size (mesh)	Combustible height (cm)
1	Bottom and end heating plates (330 W) started simultaneously, heated from room temperature to	Poplar sawdust	10	7-35(0.5~2.8 mm)	5
2		eucalyptus sawdust	10		5
3		eucalyptus leaves	10		5
4		kidney fern	10		5

5	400 °C and continued to heat until 10800 s	Surface mixed biomass	10		5
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### 3. Result and Dscuisions

#### 3.1. Influence of Flue Gas Type on Resistivity of Aluminum Single Wire

Figure 3 shows the influence of different kinds of biomass smoldering flue gas on the resistivity of aluminum single wire at different heights.

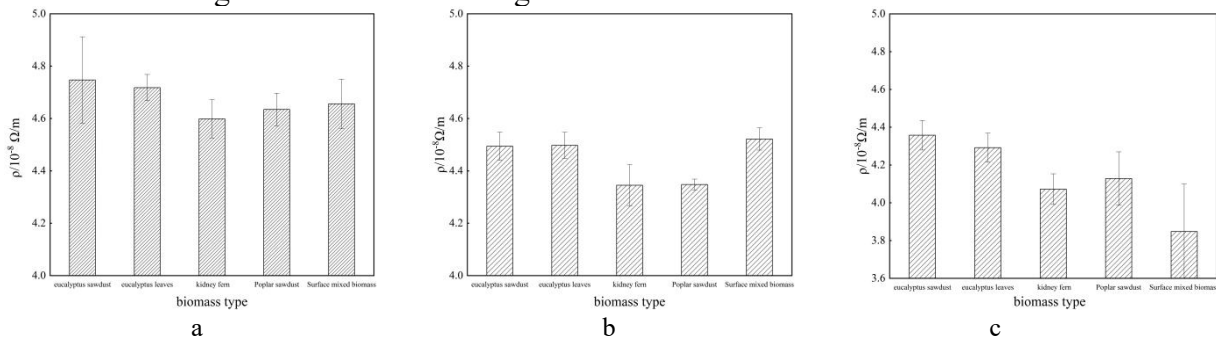


Fig. 3 Effect of fuel type on wire resistivity distance from wire to fuel surface: (a 5 cm; b 15 cm; c 25 cm)

When the distance between the steel core aluminum strand and the combustible surface is 5 cm, the resistivity of the aluminum single wire reaches the maximum value of  $4.7471 \times 10^{-8} \Omega \cdot m$  under the smoldering flue gas atmosphere of eucalyptus sawdust, and the resistivity of the aluminum single wire under the smoldering condition of eucalyptus sawdust and eucalyptus leaves is small. At the height of 15 cm and 25 cm, the aluminum single wire resistivity is the smallest under the atmosphere of kidney fern smoldering smoke. The literature points out that different types of biomass fuels have large differences in volatility. Woody materials (eucalyptus sawdust, eucalyptus leaves, poplar sawdust) are more complex than herbaceous plant materials (kidney ferns) in terms of compactness and molecular structure composition. Moreover, the pyrolysis temperature of wood-based materials shifts to the high temperature side, and the fixed carbon structure generated after devolatilization has a high degree of aromatization, so it is more stable in the smoldering stage. Therefore, the time of smoke generation in the smoldering stage of wood-based materials is longer, which has a greater impact on aluminum single wire. The activation energy of renal fern and eucalyptus leaves is smaller than that of other materials, and the degree and speed of combustion are faster. Eucalyptus leaves contain macromolecules such as proteins, and their volatiles have a greater effect on aluminum single line than renal fern.

#### 3.2. Effect of biomass smoldering flue gas on mechanical properties of conductor

In this study, the mechanical properties of aluminum single wire were analyzed from two aspects of tensile strength and elastic modulus (Young's modulus). the minimum tensile strength of hard aluminum wire with nominal diameter  $d$  in the range of 3.0-3.5 mm is 165 Mpa. After many measurements, the diameter of the aluminum single wire used in this study is in the range of 3.0-3.5 mm. The maximum tension and tensile strength of the measured aluminum single wire are shown in the figure 4:

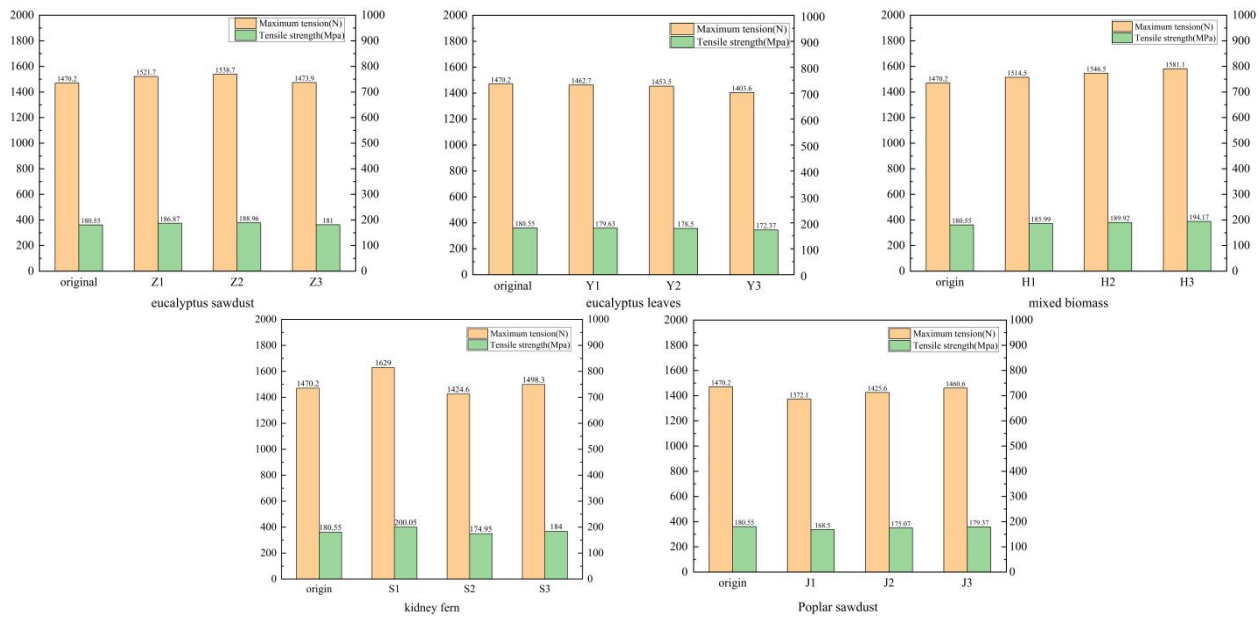


Fig. 4. Maximum tensile strength and tensile strength of aluminum single wire (In the sample name, S, H, J, Y and Z represent the conductor after smoldering of kidney fern, mixed biomass, poplar sawdust, eucalyptus leaves and eucalyptus sawdust, respectively. 1, 2 and 3 represent the height of the conductor from the combustible surface of 5, 15 and 25 cm, respectively)

As can be seen from the figure, biomass combustible smoldering had little effect on the tensile strength of the outer aluminum single wire of the steel-cored aluminum strand. Compared with the original wire, the maximum reduction percentage of the tensile strength of the aluminum single wire after smoldering is 6.7 % (J1), but the tensile strength of all aluminum single wires after smoldering was greater than the minimum specified in the standard. Among the aluminum single wires after smoldering of five biomass fuels, the tensile strength of aluminum single wires after smoldering of poplar sawdust and eucalyptus leaves generally decreased, and the tensile strength of some aluminum single wires after smoldering of other fuels increased. The height of the steel core aluminum strand had no obvious effect on the tensile strength before and after smoldering.

Young's modulus is calculated by the data obtained from the universal tensile test. The stress ( $\sigma$ )-strain ( $\epsilon$ ) curve is made according to the stress and strain data. The fitting straight line and the fitting formula are obtained by the linear fitting curve. The slope value of the fitting straight line is the Young's modulus value. The calculation results are as follows:

Table 2. Standard and measured values of Young's modulus of aluminum single wire

Sample name	young's modulus (MPa)
Original wire	616.4
S1	502.1
S2	472.4
S3	821.9
H1	512.2
H2	655.5
H3	370.8
J1	373.6
J2	634.9
J3	224.4
Y1	376.4
Y2	379.5
Y3	279.2
Z1	552.6
Z2	639.4
Z3	547.3

The measured value of the test is compared with the original wire. It can be seen that the Young's modulus of aluminum single wire decreases significantly after smoldering of eucalyptus leaves, while the Young's modulus of aluminum single wire varies under smoldering of other fuels. When the height of the steel core aluminum strand from the combustible surface is 5 cm, the Young's modulus of all aluminum single wires decreases, and the decrease range is 10.4 %-39.4 %. The Young's modulus of aluminum single wires after smoldering of eucalyptus leaves and poplar sawdust decreases the most. This is mainly because when the height of the steel-cored aluminum strand from the combustible surface is 5 cm, the flue gas temperature is high, and the outer aluminum wire of the steel-cored aluminum strand can absorb a certain amount of heat, resulting in slight deformation. When the height of steel core aluminum strand from the combustible surface is 15 cm and 25 cm, the Young's modulus of aluminum single wire after smoldering of different combustibles varies, and there is basically no law. Since the flue gas temperature is lower than 50 °C when the height from the combustible surface is 15 cm and 25 cm, its influence on the steel-cored aluminum strand decreases or even negligible with the decrease of the flue gas temperature, so the Young's modulus of the upper aluminum single wire changes irregularly.

#### 4. Summary

Compared with the original wire, the resistivity of each wire under biomass smoldering conditions increased, and the increase rate increased with the decrease of wire height. When the distance between the wire and the combustible surface is 5 cm, the resistivity of the wire under the smoldering smoke atmosphere of eucalyptus sawdust reaches the maximum, while at the height of 15 cm and 25 cm, the resistivity of the wire under the smoldering smoke atmosphere of kidney fern is the smallest.

Among the aluminum single wires after smoldering of five biomass fuels, the tensile strength of aluminum single wires after smoldering of poplar sawdust and eucalyptus leaves generally decreased, and the tensile strength of some aluminum single wires after smoldering of other fuels increased. The height of the steel core aluminum strand has no obvious effect on the tensile strength before and after smoldering. When the height of the steel core aluminum strand from the combustible surface is 5 cm, due to the relatively high flue gas temperature, the aluminum single wire is greatly affected by the temperature, and the Young's modulus of all aluminum single wires decreases. Among them, the Young's modulus of aluminum single wires after smoldering of eucalyptus leaves and poplar sawdust decreases the most. When the height of the steel core aluminum strand from the combustible surface is 15 cm and 25 cm, the flue gas temperature is lower than 50 °C, and the aluminum single wire is less affected by the temperature. The Young's modulus of the aluminum single wire after smoldering of different combustibles varies (279.2-821.9 Mpa).

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