A Multi Energy Complementary Energy Collection Device for Railway

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Abstract: High speed railway provides a convenient, fast, safe and economical way for people to travel. In the process of railway operation, there is potential energy that can be reused. Based on daily observation and considering the safety of train operation, the team made full use of vibration, wind and solar energy, applied knowledge and technology of vibration mechanics, aerodynamics and opto-thermodynamics, and integrated them into a multifunctional energy collection device. After the theoretical calculation, flow field simulation and actual detection of track wind energy, the mechanical three-dimensional model with multi energy power generation device and safety protection device as the main body is constructed, and the safe installation distance is calculated and discussed. Secondly, the team designed the connection of the actual circuit and built the miniaturization model by using MCU. Finally, the team estimated the energy that the device could convert through theoretical calculation.The device can be used in special environment of Railway (tunnel, mountain area, non-electrified railway section). In line with the characteristics of convenience, low price, stability and safety, energy is collected and applied from the existing railway environment, which reduces the demand for stringing power supply and saves electric energy. It has broad application prospects.

1. Introduction

1.1 Device Structure

According to the system diagram (see Fig. 1), the device is mainly composed of the following parts (see Fig. 2):

(1) The protection net of fan (to prevent device parts from flying out, to protect device and train operation safety)

(2) Vertical axis fan

(3) Device base and control device protection box (the circuit and other controllers are placed in the box to make the device more concise)

(4) Spring damping

(5) Vibration generator

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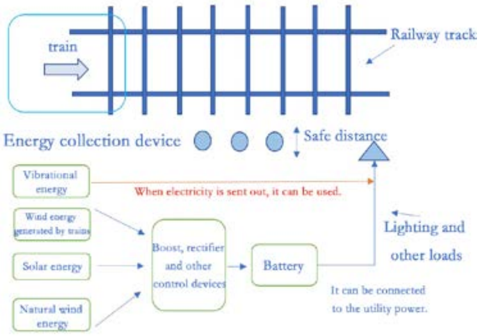


Fig.1 E Structure

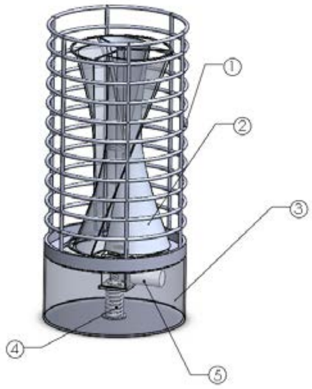


Fig.2 Device Structure

1.2 Vertical Axis Wind Turbine with New Blades

The team innovatively combined the flexible solar cells with the blades (see Fig. 2), that is, proposed a new wind solar complementary mode, which connected the rotating solar cells with the brush of the conductive slip ring (see Fig. 4), and output electric energy through the conductive ring. Without great influence on the fan power, the utilization rate of energy was further improved in the same space and the same device.

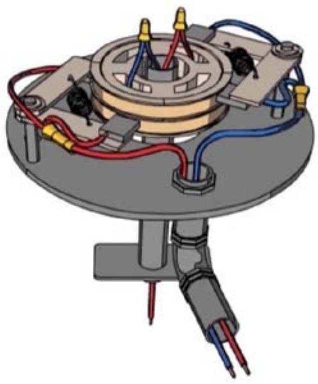


Fig.3 Lade

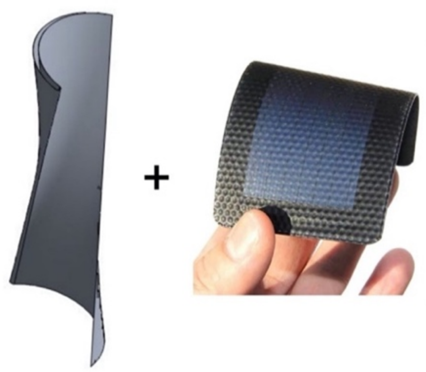


Fig. 4 Slip ring

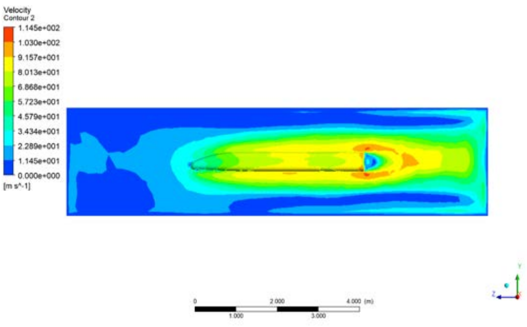
1.3 Vibration Generator

The team designed a vibration generator, which is mainly composed of shock spring, circular rack, ordinary gear, bevel gear and generator. In the process of vibration, the spring rebounds to drive the rack up and down, and the bevel gear rotates in one direction through the installation of one-way bearing, and then drives the generator to generate electricity continuously.

2. Model Construction and Feasibility Analysis

2.1 1 Simulation and Mathematical Model Calculation

The team built a three-dimensional model of the train and carried out Fluent Analysis[1] in ANSYS:



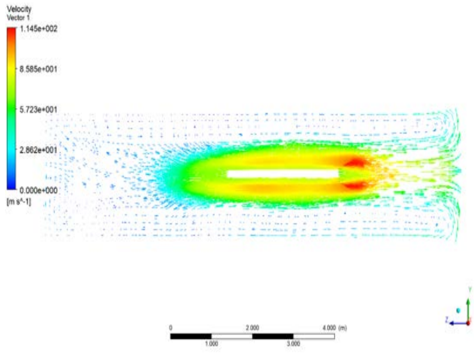


Fig.5 L Velocity Vector Diagram Fig. 6 Cloud Chart of Overall Velocity Distribution

The distribution of train wind on both sides of the train when the train is running at speed is as follows, and the train is regarded as a flat plate. The maximum boundary layer thickness at the rear of the train δ has the following relations with the train speed v_∞, air kinematic viscosity v and train length x [2].

$$\delta = 0.37 \cdot (\frac{v}{v_\infty x})^{\frac{1}{5x}} = 0.37x \cdot (R_{ex})^{\frac{1}{5}} \quad (1)$$

When T=20℃, $v = 15 \cdot 10^{-6} m^2 \cdot s^{-1}$ .Suppose the train length is 150m, $v_\infty = 200 km \cdot h^{-1} = 56 m \cdot s^{-1}$.

The boundary layer at the end of the train is obtained:

$$\delta = 0.37 \cdot (\frac{v}{v_\infty x})^{\frac{1}{5x}} = 0.37x \cdot (\frac{15 \cdot 10^{-6}}{56 \cdot 150})^{\frac{1}{5}} = 0.988m$$

Wind speed at the distance y from the train:

$$v_x = v_\infty (\frac{y}{\delta})^{\frac{1}{7}} \quad (2)$$

According to the calculation, we take 1 meter as the installation distance

2.2 Calculation of Electric Quantity

As shown in the figure below, the relationship between wind speed and power generation is approximately quadratic:

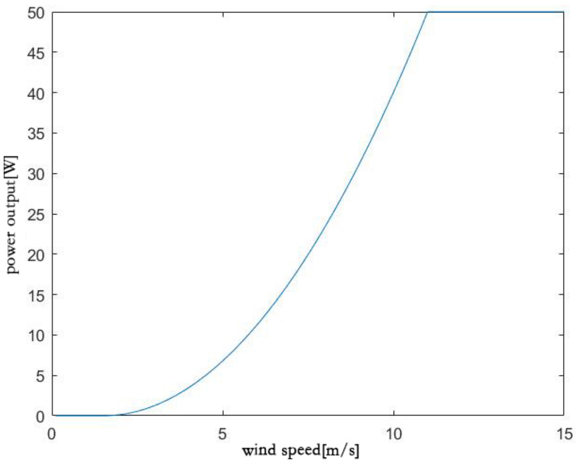


Fig.7 Relationship between Wind Speed and Power

In this unit, when the wind speed is 1.5m/s, the generating power is approximately 0; when the wind speed is 11m / s, the generating power is 50W.

$$P = 0.554 \times (S - 1.5)^2 \quad (3)$$

The p is the generating power of the unit and S is the wind speed. When a train passes by, the power generation W is:

$$W = P \times t \qquad (4)$$

$$t = \frac{L}{V} \qquad (5)$$

Where l is the length of the train and V is the running speed of the train Speed.

2.3 Wind Energy Calculation Results

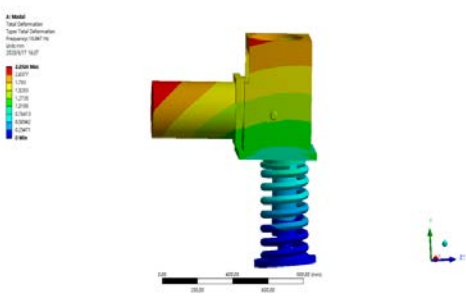
In this project, a high-speed train with 16 carriages is studied, and the length of each carriage is 26.6m. The electric energy generated by a train passing by at different speeds with a distance of 1m is calculated respectively.

Table 1 Wind Energy Generated by a Single Train At Different Speeds

Train speed [km/h]	Generating capacity [J]
200	106.10208
250	166.3680614
300	229.1804928
359	293.440384

2.4 Vibration Energy Analysis

Using ANSYS Workbench, the natural frequency and vibration mode of the vibration device are obtained by using the default material structural steel. The first-order resonance frequency of the ground beside the train track is about 20Hz[3], which is consistent with the first-order natural frequency of the device, so it can achieve the starting condition of the device and realize vibration power generation.(It consists of rack of 17 teeth, gear of 20 teeth and bevel gears of 1, 2 and 3 teeth of 35 teeth.Take the effective number of teeth of rack vibration as 10, then the number of teeth of gear rotation for one time of up and down vibration is 20, that is, the shaft can rotate one circle.)



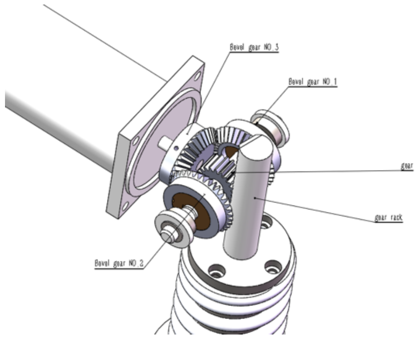


Fig.8 St Order Resonant Mode Shape   Fig. 9 Second Order Resonant Mode Shape

When the train speed is 350km/h and the natural frequency of the ground vibration is 20 Hz, the motor speed is 1200r/min. The motor can reach the rated voltage of 30V and the rated current of 200mA at the speed of 1200r/min. For a 16 car high-speed train, the length of each car is 26.6m, and the vibration energy that can be collected when the train passes by can be calculated as follows:

$$t = \frac{L}{v} = \frac{26.6 \times 16}{350/3.6} s = 4.3776s \qquad (6)$$

$$W = UIt = 30 \times 0.2 \times 4.3776 = 26.2656J \qquad (7)$$

2.5 Solar Energy Analysis

The equipment adopts three flexible solar panels with the size of 365mm×85mm and the rated power of 2W.According to the actual situation of each section of the solar energy analysis.

3. Application

(1) For example, in special sections such as tunnels in long railway sections, mountainous areas and non-electrified railways, after using the above devices, a large amount of secondary energy can be reused to provide power for signal lights in cross sections and partial lighting circuits in tunnels.

(2) For the power supply of some unmanned railway crossings, the intelligent railway can be built by using this device, and the power generated by this energy can be used to provide energy for warning signs, safety bars, warning lights and so on.

(3) For urban rail transit, a large number of train wind energy devices can be collected along the subway.

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