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Design of a Cart based on Thermoelectric Power Generation Technology

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Abstract

The power of the thermoelectric vehicle is derived from thermoelectric power generation, with mechanical transmission achieved through gear drive. The cam mechanism utilizes a spatial cam structure. The design of the cam is accomplished, and the entire vehicle modeling is done using CATIA. In addition, based on predefined sensing points, the vehicle's travel route is generated using MATLAB software, and corresponding analysis and processing are completed for this route. The design of the vehicle in this paper reduces the vehicle weight to the maximum extent possible without affecting the performance and ensures the vehicle mileage. In the meantime, the accuracy of the mechanical transmission of the vehicle is ensured while saving production costs and reducing energy consumption.

Keywords

Thermoelectric Power Generation; Mechanical Design Schemes; Cart Design.

1. Introduction

The thermoelectric power generation vehicle, as a new type of environmentally friendly transportation tool, has a broad application prospect [1]. With the global demand for sustainable energy continuously increasing, such vehicles can effectively reduce dependence on fossil fuels and improve energy conversion efficiency through thermoelectric power generation technology. They are not only suitable for urban transportation to reduce carbon emissions but can also utilize waste heat in industrial processes to increase the reuse of energy. In addition, thermoelectric power generation vehicles show great potential in off-grid and remote areas, disaster relief, military operations, and the fields of education and research. With the development of smart cities and Internet of Things technology, these vehicles can also be integrated into intelligent transportation systems to further enhance the efficiency and sustainability of urban transportation. Overall, thermoelectric power generation vehicles, with their environmentally friendly, efficient, and adaptable characteristics, are expected to play an increasingly important role in the fields of transportation and energy [2].

2. Analysis of the Working Principles and Corresponding Functions of Key Components

2.1 Thermoelectric Power Generation Structure

The thermoelectric power generation is based on the Seebeck effect: This effect describes the phenomenon where an electromotive force is generated in a closed circuit made of two different metals or alloy materials when there is a temperature difference at the two junctions [3].

The thermoelectric Power Generation Structure is composed by alcohol burner, alcohol burner stand, alcohol burner wind guard, thermoelectric power generation chip. The function of these components can be concluded as follow: the alcohol burner is placed on the alcohol burner stand, and the

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thermoelectric chip's heated surface is heated by the alcohol burner. Continuous heating of the heated surface creates a temperature difference between the top and bottom surfaces of the thermoelectric chip, thereby generating electrical energy to drive the motor to operate [4].

2.2 Drive Structure

The drive system of the thermoelectric vehicle consists of a camshaft, shaft, gears, push rod, linear guide rail, and rocker arm. It utilizes two sets of gear ratios, 30:1 and 33:1, to transmit power from the rear wheels to the camshaft [5]. The motor, powered by electrical energy generated by the thermoelectric power generation chip, drives the gears to rotate. The first gear ratio set reduces speed and increases torque, propelling the vehicle, while the second gear ratio set ensures that the camshaft makes exactly one full rotation after the vehicle completes its journey. The camshaft also drives the push rod, which slides along the linear guide rail under the cam's push. Solidly connected to the rocker arm via a sliding groove, the push rod allows the rocker arm to swing within a certain angle during different push strokes, enabling the vehicle's steering. This integrated system guarantees the vehicle's normal forward movement and controllable steering while maintaining efficiency.

2.3 Rocker Arm Structure

The component composition includes the push rod, linear guide rail, and rocker arm. The camshaft drives the push rod, which is placed on the linear guide rail and slides under the cam's push. The push rod is solidly connected to the rocker arm via a sliding groove. At different push strokes, the rocker arm can swing within a certain angle, thereby achieving the steering of the vehicle.

3. Selection of Design Schemes

3.1 Selection of Callback Mechanism

The torsion spring, spring, rubber band and cam groove are selected for the callback. The advantages and disadvantages can be included as follows:

Torsion Spring Callback requires a fixed connection with the rocker arm, which demands high precision in the size of the front wheel part, making it difficult to implement in practice. Spring Callback Scheme: When the torque is too large, it can cause the push rod to slide quickly on the cam, thus preventing the cam from matching the path.

Rubber Band Callback Scheme: The rubber band callback has the advantages of low economic cost, simple assembly, and high adjustability (the callback force can be linearly changed by adjusting the number of rubber bands).

Cam Groove Callback Scheme: This can free the callback part from the elastic force, pushing the push rod forward through the support force inside the cam groove, and achieving the rebound of the rocker arm through the support force outside the cam groove. This mechanical structure is very ingenious, but it has high requirements for cam programming, and the difficulty of cam entity modeling is relatively large, with higher costs. The cam groove callback scheme is shown in Fig. 1.

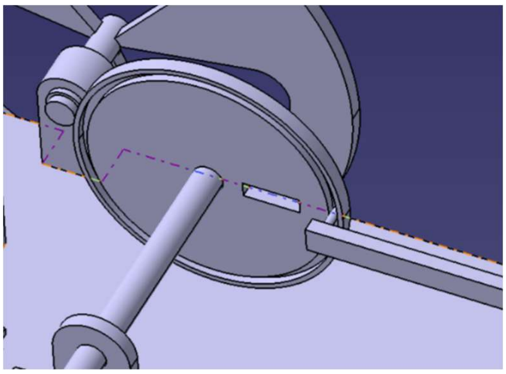

Fig. 1 Cam groove callback scheme

3.2 Selection of Transmission Part

Similarly, the transmission part can also be divided into two schemes which are Gear Transmission and Belt Transmission, respectively. Some benefits and drawbacks can be included as follows:

Gear Transmission: Among various transmission forms, gear transmission is the most widely used in modern machinery. Gear transmission has the advantages of high precision, which can effectively improve the trajectory controllability of the cart, wide range of application, long service life, and high transmission efficiency [6].

Belt Transmission: The structure of belt transmission is simple, it is not easy to slip, and the cost of raw materials is relatively low, but there are issues with belt transmission.

3.3 Selection of Cam Scheme

Common types of cams include the following:

Circular Cam: It belongs to the spatial cam mechanism, which can provide a larger stroke for the driven member.

Disc Cam: The basic form of the cam, but the stroke of the driven member cannot be too large, otherwise the change of the cam is too large, which is not conducive to the operation of the cam mechanism, so it is generally applied to occasions with a shorter stroke. However, obviously, the stroke requirement of this product is longer, so we will use the circular cam.

3.4 Selection of Steering Scheme

There two schemes for the selection of steering, which are Gear Steering and Rocker Arm Steering, respectively. As for the former, this scheme differs from the rocker arm, directly achieving the steering of the cart through the gear transmission structure (rack and pinion, gear). However, this steering method is constrained by the gear transmission ratio, requiring high precision and also imposing high strength requirements on the gears, making it difficult to implement in physical modeling. As for the last, this transmission structure has a higher adaptability to the cart and requires less precision in the fitting of physical components, making it easy to implement, as shown in Fig. 2.

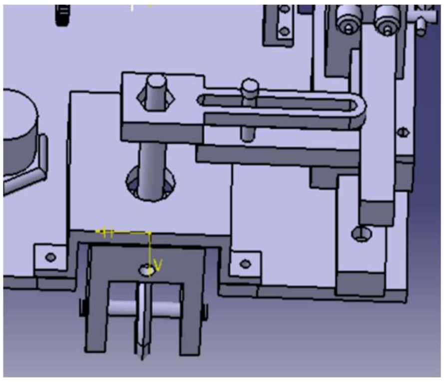

Fig. 2 Rocker arm steering

4. Cart Design Description

4.1 Route Design

As for the total distance calculation, we input the pre-set coordinates into MATLAB to first determine the general route of the cart. Then, we use SolidWorks to adjust the route, changing the curvature of the route to ensure the smooth operation of the cart. Secondly, *L* is the total length of our route, which is initially set at 18 meters. By calculating the circumference of the rear wheel, which used:

$$C=\Pi*d \tag{1}$$

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Furthermore, we find that the distance traveled by the rear wheel in one rotation is 565.49 mm by inputting d=180 mm into (1). By dividing L by C, we can roughly estimate that the rear wheel will rotate between 31 and 33 turns. Therefore, the total distance of the cart, L, is set to 18.663 meters. The route of the cart is shown in Fig. 3.

Fig. 3 The route of the cart

4.2 Design of Transmission Ratio

Since the cart is designed to complete 33 rotations, we aim for the cart to make exactly one full rotation after running the entire course during the cam design. Therefore, we can determine that the transmission ratio from the rear wheel to the cam is 33:1. The transmission ratio from the motor to the rear wheel depends on the running time of the cart. In the initial design, the cart's running time is planned to be between 4 and 6 minutes. In terms of motor selection, we choose a motor with a rated speed of 225 revolutions per minute (rpm). If we set the transmission ratio from the motor to the rear wheel at 30:1, then the speed of the motor transmitted to the rear wheel through gear transmission will be reduced to 1/30th of the motor's speed, which is 7.5 rpm. Thus, the running time is 4.4 minutes. This transmission ratio meets our preset for the cart's running time, so we ultimately determine the two sets of transmission ratios for the cart to be 33:1 and 30:1, respectively.

4.3 Cam Design

designtrajectory.m wheel.txt

```
clear; %Clear the workspace variables
clc; %Clear the command line
M=178.774;%the width of the cart
m=0;%front wheel track offset
E=28.939;%handlebar width
L=144.686;%the length of the cart
e=57.113;%base circle radius


XYR=textread('wheel.txt');
X=XYR(:,2);%the X-coordinate of the trajectory
Y=XYR(:,3);%the Y-coordinate of the trajectory
R=XYR(:,5);%the R-coordinate of the trajectory
plot(X,Y,'b-'),hold on,axis equal;%draw the path


s(1)=0;%set an initial value for the journey
for i=2:10000
    s(i)=s(i-1)+sqrt((X(i)-X(i-1))^2+(Y(i)-Y(i-1))^2)*(R(i)-M/2)/R(i);%Calculate the distance the driving wheel has traveled when the cart reaches the ith point
end

ct=s./s(10000)*2*pi;
rou=e+E*sin(atan(L./(R+m)));
polar(ct,rou');
```

Fig. 4 Travel data

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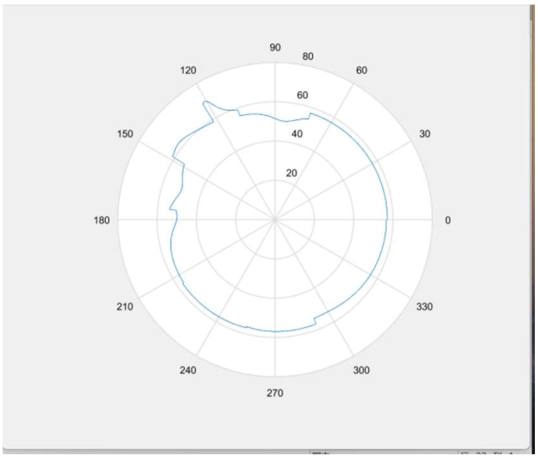

Fig. 5 Preliminary cam structure

Based on the transmission ratio obtained from the design and the export and adjustment of the route point set and curvature comb diagram in NXUG software, a programming language containing X (horizontal coordinate), Y (vertical coordinate), and *R* (radius of curvature) is written. The travel data is segmented into 10,000-point sets, as shown in Fig. 4, and the preliminary cam structure is depicted by repeating calculations based on the radius of curvature at each point, as shown in Fig. 5. Subsequent data is refined to achieve a high-degree trajectory route to reach a smooth and reasonable structure of the cam.

5. Physical Production

1) The four shafts carrying the gears are mounted on the support bracket and secured with snap rings. The bearings on the shafts are flange bearings, which are fixed by the flange of the bearing itself and the snap ring.

2) All components that need to be fixed to the base plate are secured using screws and nuts (the motor is fixed to the base plate using a matching kit bracket).

3) The larger wheel on the right side of the cart is the driving wheel, which propels the cart forward, while the smaller wheel on the left side is the driven wheel.

4) The two sensors are securely fastened to the base plate with threads and nuts.

5) The driving wheel is fixed to shaft with screws, and the connection method is shown in Fig. 6.

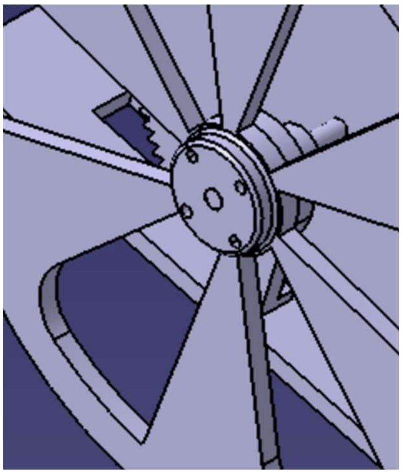

Fig. 6 Connection method of driving wheel

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6. Market Prospects

With the increasing global emphasis on environmental protection and sustainable development, devices utilizing renewable energy are becoming more popular. Thermoelectric power generation, as a clean energy technology, is expected to gain recognition in the market where environmental awareness is growing. The thermoelectric power generation car, as an attempt of thermoelectric power technology in the field of vehicle engineering, has opened a new path for new energy vehicles. Correspondingly, other types of renewable energy technologies, such as solar photovoltaic and wind energy, may compete with thermoelectric power generation cars. Therefore, thermoelectric power generation cars need to be competitive in terms of cost, efficiency, and reliability. In the mechanical field, we must strive to work on the power conversion structure to ensure the basic performance of the vehicle while reducing energy loss [7].

The demand for renewable energy and the degree of policy support varies across different countries and regions, which may affect the development prospects of thermoelectric power generation cars in the international market. Under the background of China's vigorous promotion of low-carbon emission reduction policies [8], it is undoubtedly a great benefit to thermoelectric power generation cars [9].

With the comprehensive development and progress of our country's economy and technology, the new energy vehicle industry has brought high economic benefits to the construction and development of society, and at the same time has attracted a large number of investors [10].In general, the market prospects for thermoelectric power generation cars are optimistic, especially in the context where environmental protection and sustainability are increasingly valued [11]. However, their success also depends on the comprehensive effects of various factors such as technological innovation, cost-effectiveness, policy support, and market demand.

7. Summary

This article presents a small car employing thermoelectric power generation for eco-friendliness and sustainability. Powered by thermoelectric technology and featuring gear-driven mechanical transmission and a spatial cam, the car's route is designed and analyzed using Matlab for cam creation. CATIA software is used for overall vehicle modeling, aiming to enhance travel distance by reducing weight with lightweight materials, without sacrificing performance or mechanical precision, and to lower production costs and energy use.

The research highlights the growing global energy demand and environmental concerns, making simple, quiet, durable, and eco-friendly thermoelectric power generation a focus. The car’s key components, including the thermoelectric structure, drive system, and rocker mechanism, are analyzed for functionality. Design selection covers callback mechanisms, transmission parts, cam options, and steering schemes. The car's design details route planning, transmission ratios, and the manufacturing process.

The market outlook is positive for the thermoelectric power generation car, a clean energy solution, especially with China’s low-carbon policies. Despite competition from other renewable technologies, the car’s success hinges on innovation, cost-effectiveness, policy support, and market demand.

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