Research on Dynamic System of New Energy Food truck

Yufei Gao Yun Guo * and Yawen Zhu

Mechanical Engineering college, Shanghai University of Engineering Science, Shanghai 200336, China
graceguo1980@usst.edu.cn

Abstract: Mobile Food truck is very popular in Europe and America because of its convenient and quick advantages. But the study found that the majority of mobile Food trucks using traditional power and energy systems that is not very beneficial for environmental protection. In recent years, the field of mobile Food truck has the trend of light weight, convenience, multifunction and so on. How to make the use of Food truck cleaner, lower carbon and how to make it become a kind of green, environmental protection and healthy diet culture is very worthy of research and promotion of the subject for the office concentration of large and medium-sized cities.

1. Research background and significance

Nowadays, "fast food" culture is very popular because of its short production time and easy to purchase and popular. Now, the streets are full of mobile snack cars which is the embodiment of the catering culture in today's society and a symbol of fast-paced life[1] (see Figure. 1).

Figure 1 The college dining car at Columbia.

Traditional fast food trucks also need to be improved such as energy types, conversion efficiency Food truck layout, internal structure and cooking utensils. The team optimizes the design of traditional mobile Food trucks in energy, space, range of use, safety and health to create a new energy mobile Food truck that is more environment-friendly, more compact and more convenient so that it can also highlight the more characteristic and economic value of the catering culture.

2. Design scheme

First of all, loading different cooker appliances according to the functional of the requirements. Then chose the type of electrical equipments and Fig out the different power. Finally according to the required electricity, select a reasonable power source type and optimized the subsystem in the vehicle to meet the needs of different people.

The research group optimizes the design of a new energy mobile Food truck according to the objective conditions of Songjiang University Town in Shanghai. The design scheme is as follows:
2.1 Calculation and Analysis of Energy Consumption of Food Truck

Small vehicle size and low speed are the main design requirements of campus mobile Food truck. Therefore, the Food truck is set as low energy storage, high battery life mode, small volume and low speed. The highest speed in 50-60Km/h is the main characteristics of campus Food truck. It located in the teaching area of Songjiang University City in Shanghai and provides students with staple food snacks and some snacks such as beverages and desserts. Departure site is within 15Km of destination. The following assumptions are made for the day's work schedule of the Food truck (see Table 1):

### Table 1. Details of Cookware Use

| Time          | Kettle | Sausage Machine | Fridge | Air Conditioner | Soybean Milk Machine | 3D Food Printer | Teppanyaki |
|---------------|--------|-----------------|--------|-----------------|----------------------|----------------|------------|
| 7:30-8:30     |        |                 |        |                 |                      |                |            |
| 8:30-9:45     |        |                 |        |                 |                      |                |            |
| 9:45-10:25    |        |                 |        |                 |                      |                |            |
| 10:25-11:30   |        |                 |        |                 |                      |                |            |
| 11:30-13:00   |        |                 |        |                 |                      |                |            |
| 13:00-14:30   |        |                 |        |                 |                      |                |            |
| 14:30-15:00   |        |                 |        |                 |                      |                |            |
| 15:00-16:50   |        |                 |        |                 |                      |                |            |
| 16:50-19:00   |        |                 |        |                 |                      |                |            |

The following is the calculation of the power consumption of the electrical appliances in the 7:30-8:30 period.

1. Energy consumption of Baking Machine during Breakfast peak period

   According to the survey, 85 students chose roast sausage as breakfast during morning rush hour.

   \[ W_1 = P_1 \cdot t \]  

   In
   \[ W_1 \]  —— Energy consumption for baking 24 sausages (Kwh)
   \[ P_1 \]  —— Rated power (Kw) of the sausage
   \[ T \]  —— The time taken to bake 24 sausages (H), \( T = 0.25 \) H

   In order to meet the needs of the students, the roasting machine will continue to work for at least 1 hour and making 96 hot dogs so the energy consumption of the roasting machine is 1.5 Kw during the early peak period. The remaining is 11. When the flow of people becomes less, the roasting machine will be turned to keep warm.

2. Energy consumption in the long running process of refrigerator

   The comprehensive power consumption of refrigerator is 1.19 (KW h / 24 h), considering the frosting, opening and closing of refrigerator, so the comprehensive power consumption of refrigerator should be larger than that of 1.19 (KW h / 24 h), so the energy consumption of refrigerator can be increased by 10% unfavorable factors.

   \[ W_2 = (W + 0.1W) \cdot \frac{H}{24} \]  

   In
   \[ W_2 \]  —— Energy consumption of refrigerators during early peak hours (Kwh)
   \[ W \]  —— Integrated Energy Consumption of Refrigerator (KWh)
   \[ H \]  —— Early rush hour of dining car (H), \( H = 1h \)

3. Air conditioning energy consumption

   Assume that the air conditioner is operating under standard conditions. During this time period, the outdoor temperature, the indoor temperature, and the air conditioner cooling load output value are always in accordance with the rated power input, and the air conditioning energy consumption is

   \[ W_3 = P_3 \cdot T \]  

   In
   \[ W_3 \]  —— energy consumption of air conditioning during early peak hours (Kwh)
   \[ P_3 \]  —— Comprehensive air conditioning energy consumption (Kwh)
   \[ T \]  —— dining car morning peak working time (h), \( T=1h \)

   Therefore, the energy consumption of air conditioning in early peak period is 0.9375Kwh.

   However, the outdoor temperature and indoor heat dissipation of the Food truck are constantly changing, so the operating conditions of the air conditioning are fluctuating which is for protecting the circuit and make the power of the air conditioner increased by 50%. The maximum power of air conditioning is 1125W and the average power is 937.5W. [2] (see Figure 2):
Finally, the energy consumption of the new energy Food truck is 46.8Kwh.

2.2 Power source selection
Based on our previously condition's analysis and the specific parameters of each battery were determined. lifetime and cost under fixed operating conditions were compared (see Table 2):

| Battery Type            | Weight (Kg) | Volume (L) | Life (year) | Cost |
|-------------------------|-------------|------------|-------------|------|
| Lead acid battery       | 1337        | 520        | 1.36        | +    |
| Ferric phosphate battery| 390         | 1052       | 5.5         | ++++ |
| Nickel-cadmium battery  | 850.9       | 497.9      | 1.36        | ++   |
| Lithium-ion battery     | 425         | 117        | 2.74        | +++  |
| Flywheel                | 312         | 106        | 20          | ++++ |
| Photovoltaic pane       | 45m²        | 15         |             | ++++ |

From the comprehensive analysis of the battery each battery has its specific advantages and disadvantages. In order to make energy more efficient and energy saving we consider hybrid power and finally determine that the power source of this work is flywheel photovoltaic cells. [3]

3 flywheel photovoltaic wing design

3.1 Calculation of driving force
The energy consumption of the Food truck is 9.09KW h from the calculation of the operating conditions of the Food truck and the capacity of the battery can be calculated by the following formula:

\[ Q = \frac{W_M}{V \eta_q} \]  

In 
- \( Q \) —— the battery capacity, (A.h)
- \( W_M \) —— energy consumption in dining car driving mode
- \( V \) —— battery voltage, (the voltage here is 48V)
- \( \eta_q \) —— The total efficiency of the battery inverter system (calculated here based on the empirical value of 0.6)

The battery capacity of the flywheel is at least 316A.h from the above formula.

3.2 Calculation of PV power
The solar PV panels shall meet the total energy of the Food truck in the fixed mode and calculate the power required for the PV module from the following formula:

\[ W_P = \frac{W_{df}}{\eta_g T_{pf}} \]  

In 
- \( W_P \) —— the total power to be configured for the solar photovoltaic wing, (W)
- \( W_{df} \) ——The energy consumed by the dining car in a fixed mode (KW·h),
- \( T_{pf} \) —— peak sunshine hours
- \( \eta_g \) —— The total efficiency of the photovoltaic power generation section (calculated by
the empirical value of 0.65). The configuration power is 17500W.

### 3.3 calculation of photovoltaic wing area

According to the standard sunshine and temperature of 25 °C. The photovoltaic wing area needed to produce the electric energy consumption of the Food truck appliances in fixed mode is estimated as follows:

\[
S = \frac{W_G}{P_N H}
\]

\[S\] — the PV wing area (m²);
\[W_G\] — energy consumption in the fixed mode of the dining car (Kw·h);
\[P_N\] — Power generated by 1m² photovoltaic wing (PN=0.105KW);
\[H\] — Lighting time (h), assuming 8 hours of light per day.

Finally, the area of the photovoltaic wing is 44.89 m².

### 3.4 calculation of flywheels

Since the specific power of the flywheel is very high the power required for the operation of the Food truck can be completely satisfied. Simply design the flywheel for energy storage. Flywheel design indicators in the automotive industry are shown in Table 3:

| Field of application | power / Kw | Maximum speed / (r / min) | Rim speed / (m / s) | Rotor material | Rotor mass / Kg |
|----------------------|------------|----------------------------|---------------------|----------------|----------------|
| Car                  | 150        | 40000                      | 900                 | composite fiber | 60             |

The energy stored in the flywheel is:

\[E = \frac{1}{2} J \omega^2 \]  

\[E\] — the energy stored in the flywheel (KWh);  
\[J\] — the moment of inertia of the flywheel rotor shaft (Kg·m²);  
\[\omega\] — flywheel rotor running angular velocity (rad/s);

According to the analysis of the above working conditions, the energy consumption of the Food truck is 46.8 KW per day. However, referring to the latest research, the self-discharge of the carbon cellulose flywheel in one day is 5% and the energy conversion efficiency is about 95%. The flywheel needs to store energy not less than 46.8 KW·h and the specific energy of the existing flywheel is not higher than 150 W / Kg so the flywheel weighs 312kg / h.

According to the calculation, it is concluded that the solar wing area of the campus Food truck is 44.89m² and can supply the Food truck continuously without interruption. If the 312Kg flywheel is used in cloudy and rainy days the working time of the whole day can be maintained. So the photovoltaic flywheel only needs half of its separate power supply parameters and now it can work all day. That is the 44.89m² photovoltaic wing and the 156Kg flywheel. The final daily sales can be completed at 1000 times. The daily output of photovoltaic wing can reach 40 KWhs and the output power of flywheel can reach 150 Kw. The use of Food truck is generally not more than 15 Kw which fully meets the requirements of use.

In addition to being the power source for the Food truck the flywheel photovoltaic wing is also a folding telescopic shade (see Fig 5 below). Customers can shade and rest when shopping. After the photovoltaic winging the effective sunshade area is 30 m².

### 4. Principle and performance analysis of flywheel photovoltaic system

The flywheel photovoltaic system consisting of photovoltaic wings and flywheels is shown in Fig 3.
When the light is sufficient, the photovoltaic wing is used to generate electricity and driving the motor to work so as to drive the flywheel rotation to store energy instead of the traditional battery. When the electric appliance needs electricity the generator is driven by the flywheel to generate electricity. Thus realizing the conversion of light energy-electric energy-mechanical energy-electric energy. According to the electrical power, the extra power of the photovoltaic wing is stored in the flywheel when the sunshine is not enough and the flywheel can not meet the power demand. The energy storage effect of the flywheel is also relatively strong. After charging during the day and working on the power system of the cooker at night, there is no problem. Therefore, it will not be because the energy source will be converted into a new energy source dominated by solar energy. That has an impact on its use.

To be sure, the flywheel's power can be received from a foldable photovoltaic wing. The function of charging the external power supply is also designed (that is, the external power supply charging interface is set up) to ensure that the system can work normally under the condition of long time without sunlight. The system is also equipped with a backup battery pack on the body of the car in order to prevent the Food truck from running normally under special circumstances. The standby battery pack is connected in parallel with the flywheel through switches to provide the flywheel with no normal power supply and startting the backup battery pack to power the car. The backup battery pack uses lithium cells with a power of 4 kW and 6 kW. The standby battery pack is 80% of full-charged in a normal state.

All electrical energy of the power system is processed through the electronic control system and sent to the various electrical equipment. The electrical control system is the central system, and the storage device is the flywheel and the backup battery pack (which can be a lithium battery). The power system includes the power unit of the cooker, driving power unit and auxiliary power unit which are all load. When the folding photovoltaic wing is charged and the load is working simultaneously the power supply controller can judge the load and the power of the photovoltaic wing. When the power of the photovoltaic wing is insufficient, the electric control system can discharge the flywheel. If the power of photovoltaic wing is surplus, the electric control system will charge the flywheel which can balance the peaks and troughs and prolong the service life of the flywheel.

5. Innovation and application
1) According to different situation and function we need to carry on the private customization of the energy saving Food truck and realize the comprehensive energy saving.
2) PV wing flywheel power system can fundamentally save energy and achieve zero emissions.
3) The flywheel photovoltaic wing is not only the power source of the Food truck but also the folding and expanding sunshade shed with an effective sunshade area of 30 m2.
4) Food 3D intelligent thermoelectric printing technology can accurately control nutrition and realize food intelligent manufacturing and achieve its own energy saving 50%.

Acknowledgements
This project is supported by National Natural Science Foundation of China (Grant No. 51606116).

References
[1] Yufei Gao, Grace Guo., Multifunctional mobile Food truck based on photovoltaic flywheel hybrid
[2] Haoli Yan, Grace Guo. An Intelligent Thermoelectric spray head for Food 3D Printer [P]. ZL201820710743.1

[3] Wangbin. American fuel cell vehicle Freedom CAR cooperation plan [J]. Global outlook for science and technology economy. 2013(05): 9-11

[4] Weizheng Kong. Analysis of Energy-saving and Emission reduction of Electric vehicles based on full cycle Energy efficiency [J]. 2012(09):64-67

[5] Feng Wen, Wang Shujuan, Ni Weildou. Environmental, economic and energy assessment of hydrogen energy system about fuel cell vehicles [J]. Aeta Energiae Solaris Siniea. 2003(3):394-400

[6] Kong Weizheng, Li Qionghui, Wang Xiaolu. Energy saving and emission reduction analysis of electric vehicles based on full cycle energy efficiency [J]. China Electric Power. 2012(09):64-67.