

3D digital concept design of the wind-powered water-lifting device

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Abstract: *The development of wind energy resources is important for changing the structure of China's energy industry, of which wind power generation has broad development prospects and resource advantages. The application of wind power for water lifting and irrigation is a new trend. In this paper, we propose a wind-powered water-lifting device based on a vertical axis wind turbine and develop a three-dimensional digital concept design for it.*

Keywords: *wind energy wind turbine water lifting and irrigation digital design*

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I. INTRODUCTION

As one of the three major resources of human society, energy plays a pivotal role in promoting the progress and development of society. And in the current context of high-quality economic development, reform and opening up continue to advance, more need for energy and other industries to vigorously support. In the past development history of our country, the energy required for industrial production relied mainly on electricity generated from fossil fuels as raw materials. This energy structure relies on the advantages of China's rich fossil fuel resources, such as coal mines, to provide a constant source of power for industrial development, while also directly causing air pollution, the greenhouse effect, and other environmental problems. Considering the specific situation and economic development needs of our country, the complete deactivation of fossil fuels is not a good solution, and finding sustainable and clean energy sources to gradually replace fossil fuels in the energy mix is undoubtedly the best choice at the moment^[1,2]. Wind energy is sustainable and clean energy that meets the requirements of ecological development, and as a natural resource, it has the advantages of short cycle time, low cost, and large volume^[3].

In the use of wind energy resources, wind power generation is a general trend^[4]. China's vast territory, whether on land or sea, many blocks can be used as platforms for installing wind power generation devices, which brings great convenience to the development of the wind power industry^[5]. Wind power has a wide range of applications, and the use of wind power technology for water lifting and irrigation is a new trend^[6]. In some remote areas where the grid voltage cannot be delivered, the use of wind power to extract water can not only solve the water of farmers' daily life but also improve and enhance the wind power technology in production practice^[7].

Based on the demand of applying wind power generation to water-lifting irrigation, this paper proposes a concept of a wind-powered water-lifting irrigation device based on the research of vertical axis wind power generation devices^[8] at home and abroad and uses SolidWorks software to make a three-dimensional digital concept design of it based on the actual materials.

II. THREE-DIMENSIONAL DESIGN

2.1 Design of key components

(1) Wind turbine blade

The blade is one of the most important parts of the entire wind turbine, which determines the wind energy utilization efficiency, swept area, and other basic characteristics of the wind turbine^[9].

The blade of the device needs to have good movement performance and corrosion resistance, used to adapt to the open air working environment, so in the shape of the wind cup type resistance difference type blade^[10], the production material is PVC board. The three-dimensional model of the blade is shown in Figure 1. The overall length of the blade is 250mm, the chord length is 40mm, and the thickness of the blade is 3.5mm at the thickest point and 1.5mm at the thinnest point.

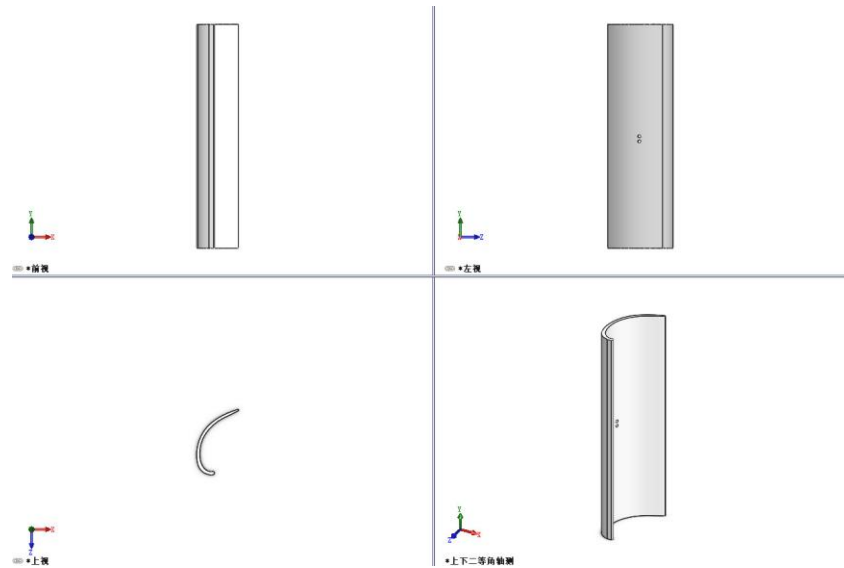


Figure 1 Wind turbine blade model

Modeling process: On the newly created sketch, use the spline curve command to draw a closed shape as shown in the top view, and then perform a stretch of a given length. Finally, the sketch of the threaded hole is drawn on the reference plane perpendicular to it and excised to obtain the blade 3D model.

(2) Alternators

The generator selected in this paper is a brushless three-phase permanent magnet synchronous generator. The generator has a lighter overall mass, smaller size, no internal brush and slip ring structure, eliminating the sliding contact part, and no excitation loss, so it has high conversion efficiency and reliability. The main components of the generator model include the housing, front and rear end caps, front and rear end bearings, stator and its windings, rotor core, rotor squirrel cage, permanent magnets, etc. The 3D model of a permanent magnet synchronous generator is shown in Figure 2.

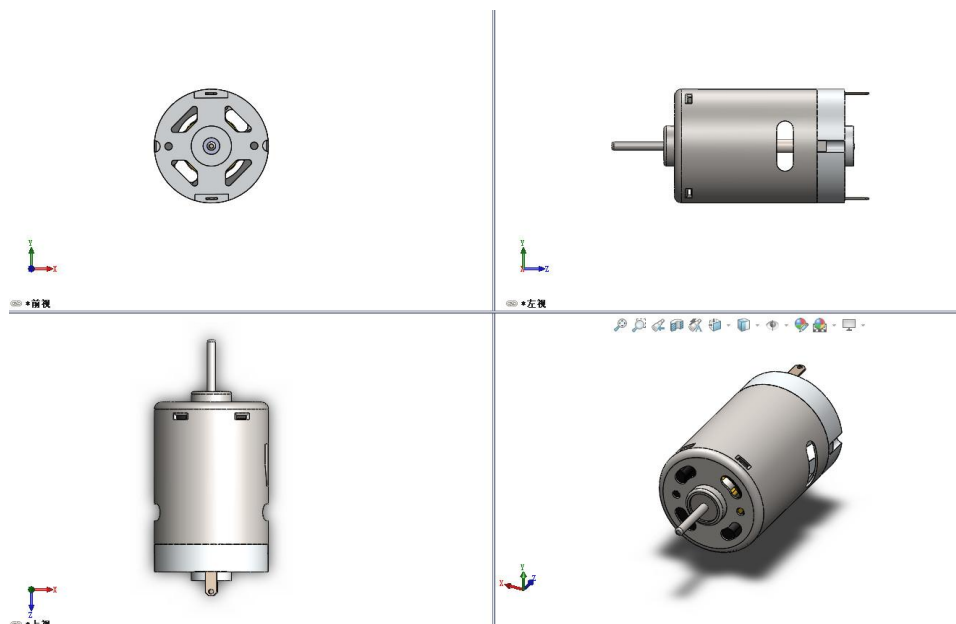


Figure 2 Permanent magnet synchronous generator model

Modeling process: Since the internal structure of the generator is too complex and is not the focus of this design, the generator is designed to simplify the model. Find a similar generator model on the Internet, and then further modify and scale it to match the other parts of the wind turbine.

(3) Battery

The main function of the battery is to store the electrical energy generated by the generator and output it at the designated link. The battery is mainly composed of positive and negative plates, a spacer, a shell, a rubber cap, an electrolyte, and other parts. The model of the battery is drawn according to the physical drawing and somewhat simplified according to the actual situation, and the 3D model is shown in Figure 3.

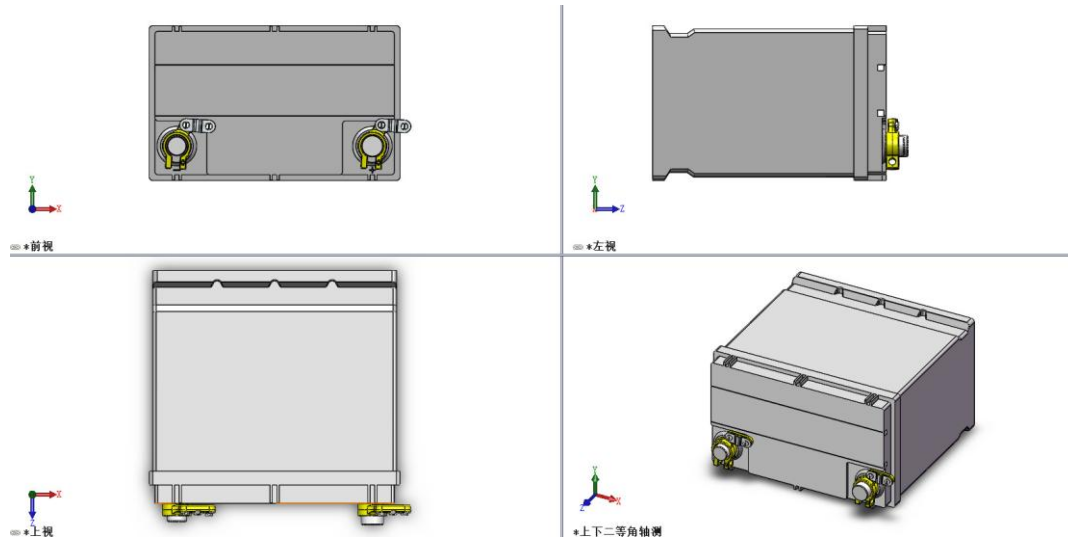


Figure 3 Battery model

Modeling process: First, draw a battery shell, and then draw a sketch on the corresponding face for stretching and cutting. Final chamfering. The electrodes of the battery are represented by two cylinders. When drawing the fixture for fixed joints, first draw the circular shape on a blank sketch for stretching, and then perform the corresponding excision and chamfering. Finally, the battery and the electrode, and the fixture are mated to get the complete battery model.

(4) Inverter

In this device, the inverter converts the DC power output from the battery to 220V AC power for the magnetic pump. Since the inverter must work in a dry environment, the inverter and battery are installed in a waterproof case. The main components of a general inverter include semiconductor devices, inverter drivers, and internal control circuits consisting of capacitors, inductors, and resistors. The 3D model of the inverter is shown in Figure 4.

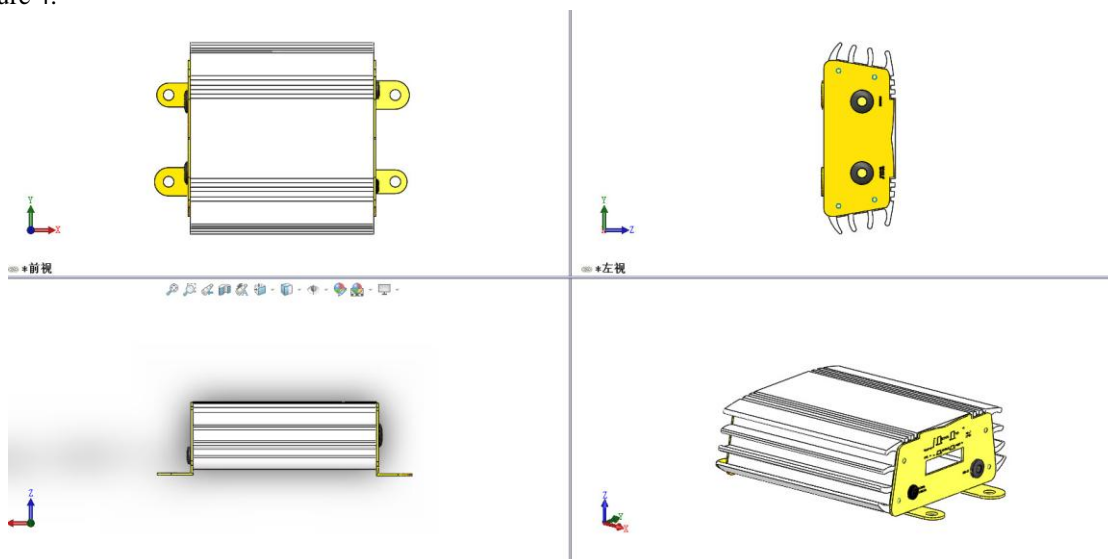


Figure 4 Inverter model

Modeling process: Since the internal structure of the inverter is too complex and not the focus of the design, the design was found on the Internet for similar models and then scaled down to an equal scale and further modified. Then add a fixed foot at the base plate for bolting, so that it can fit with other parts.

(5) Magnetic Pumps

The magnetic pump is the last link of the whole installation as an electrical device, which plays the role of lifting and draining water. The installation position of the magnetic pump is located at the bottom of the overall frame. The pump foot has four 10mm holes for bolting to the PP base plate. The components of a magnetic pump can be divided into pump casing, pump shaft, impeller, passive magnet, O-rubber ring, active magnet, motor, etc. Considering that the model only needs to accurately reflect the external structural characteristics of the magnetic pump as well as the spatial dimensions, the internal complex details are appropriately simplified. The overall three-dimensional view of the magnetic pump model is shown in Figure 5.

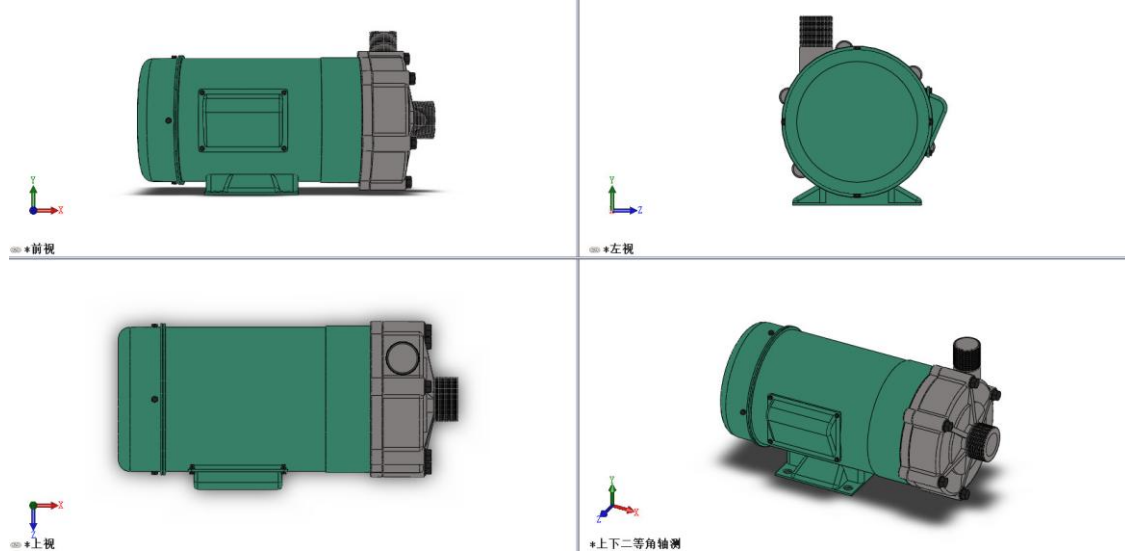


Figure 5 Magnetic pump model

Modeling process: The front-end pump casing is first modeled by drawing the corresponding figure on a blank sketch, stretching, and then detailing, such as chamfering, rounding, etc. The sketch of the outlet is then sketched on the horizontal datum for a certain length of stretching. Then sketch the bolt hole from the end face of the pump cover, and finally excise it to get the model of the pump casing; The modeling of the motor casing first draws the corresponding circle on the blank sketch, stretches, and then draws the casing so that the thickness of the casing is 3mm, and finally draws the bolt holes to get the model of the motor casing. The modeling of the motor casing starts with drawing the corresponding circle on the blank sketch, stretching and then extracting the casing so that the thickness of the casing is 3mm, and finally drawing the bolt holes to get the model of the motor casing. Finally, the built model is assembled to get the complete model of the magnetic pump.

2.2 Overall structural design

The overall model of the device was designed by SolidWorks software, which is an easy-to-use mainstream modeling software with excellent sketching, feature creation, and assembly design functions and strong compatibility. In SolidWorks software build a model of each part, each part for the corresponding fit, and assembly into subassemblies. Then the subassemblies are assembled as a whole to get the overall model, which is then imported to KeyShot software for post-material rendering to get the final model as shown in Figure 6.

The overall modeling of the device includes the wind turbine blades, the generator, the battery, the inverter, and the magnetic pump in addition to the water tank, the base plate, the overall frame, and various other connecting parts.

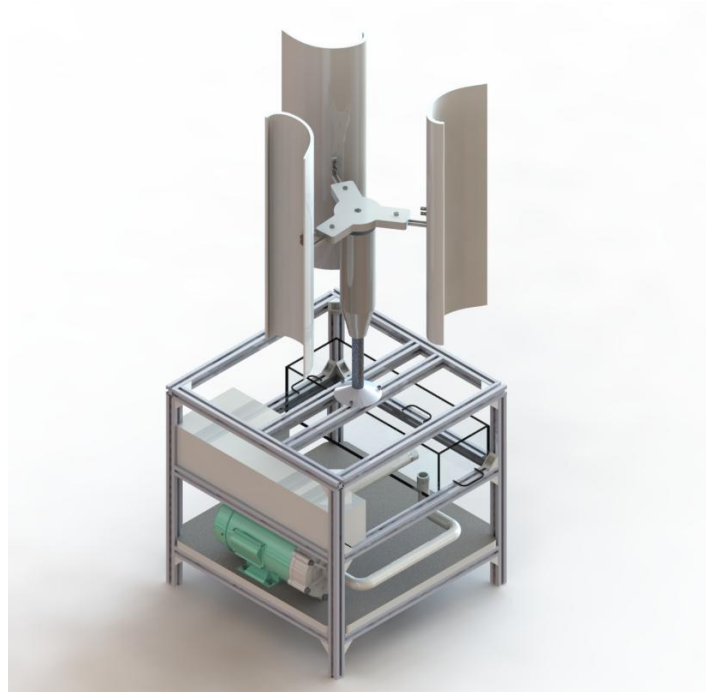


Figure 6 Total assembly model

(1) Right-angle blade beam

The connection between the wind turbine blade and impeller using a right-angle blade beam and triangle printing pieces with each other, to bolt fastening.

The right-angle blade beam uses hardware stamping as material, which is lighter and more uniform than ordinary forgings and castings and has greater strength. The 3D model of the blade beam is shown in Figure 7.

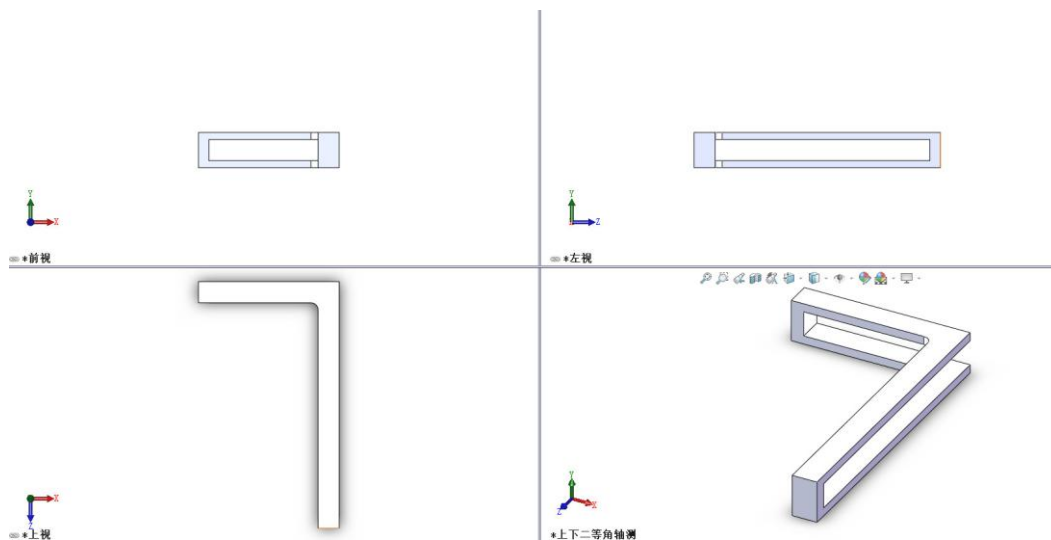


Figure 7 Blade beam model

Modeling process: First draw the shape shown in the top view on the new sketch and stretch it to a certain length. Then create a new sketch in the left view and make excision of a certain length. Finally chamfering to get the complete 3D model.

(2) Triangular fastener

In this design, the triangular fastener is made of common PLA material and processed by a 3D printer. This material is inexpensive and non-polluting, and its strength is suitable for use as a fastener here. Its 3D model is shown in Figure 8.

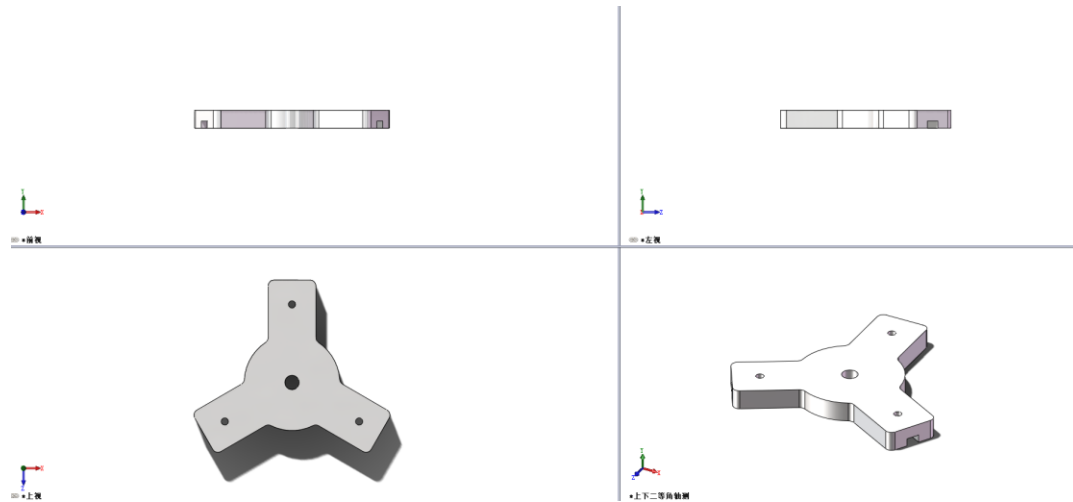


Figure 8 Triangular fastener model

Modeling process: First draw the shape of the top view on a blank sketch and stretch it to a certain height. Then sketch the mating slot on the side of the protruding rectangular body and make a certain length of excision. This is followed by a detailed part, including screw holes for fixing and spindle bearing connection holes. Finally, chamfering is performed to obtain the 3D model of the triangular fastener model.

(3) Chassis

The bottom of the wind turbine is connected to the chassis by the thread, which is easy to disassemble and install, and at the same time highly reliable. The chassis is mounted on the top level of the overall frame and fastened to the 2 aluminum trusses by 3 T-nuts. The material of the chassis is aluminum alloy, low density, high strength, and easy to process. The overall 3D model is shown in Figure 9.

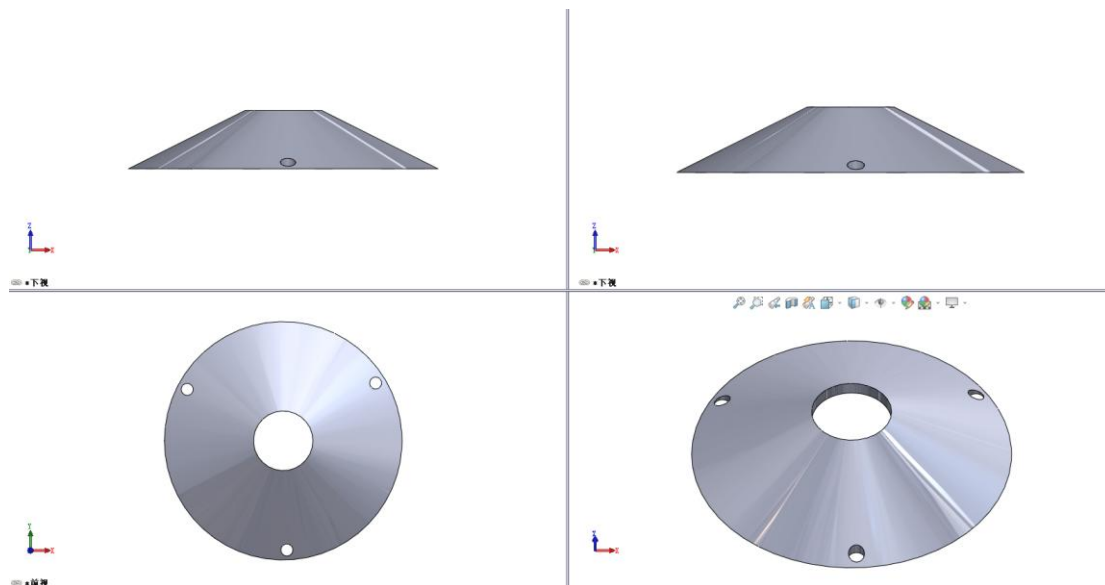


Figure 9 Aluminum alloy chassis model

Modeling process: First draw a circle on a blank sketch in the shape of the top view, and then create a datum plane parallel to the top view plane. Sketch a circle of smaller size on the newly created datum, and get a round platform after the release of the sample. Then a certain thickness of the shell is drawn, and then the threaded holes for interfacing with the connecting shaft at the bottom of the wind turbine and the three bolt holes for mounting are drawn by the excision command. Finally, a scan excision was performed to draw the threads in the holes to obtain a 3D model of the aluminum alloy chassis.

(4) Base plate

The base plate is located at the bottom of the overall frame and has holes of corresponding dimensions, which are bolted to hold the magnetic pump. The base plate is made of a 15mm thick PP board and has an overall mass of approx. 6000g when combined with the electric pump and is located at a horizontal height of 60mm from the

floor. The overall center of gravity of the unit is shifted to a lower level, greatly enhancing its stability of the unit. The model of the base plate is shown in Figure 10.

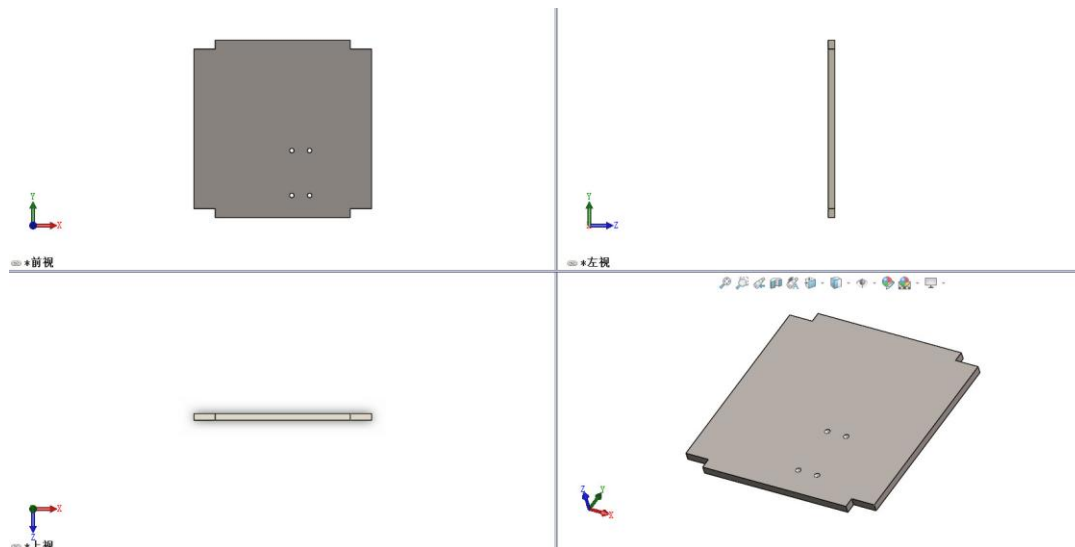


Figure 10 Base plate model

Modeling process: The outer contours of the drawing and the through-hole edges are drawn on the new sketch datum as shown in the previous view, and then stretched to a certain thickness to obtain the required 3D model.

(5) Framework

The frame of the unit is made of aluminum profiles with a cross-section of 20×20 mm with 36 aluminum alloy angle codes and 72 T-nuts. Of the total of 18 aluminum profiles, 10 are 360mm in length and 4 each are 380mm and 400mm in length. The dimensions of the entire model frame are $400 \times 400 \times 420$ mm and its 3D model is shown in Figure 11.

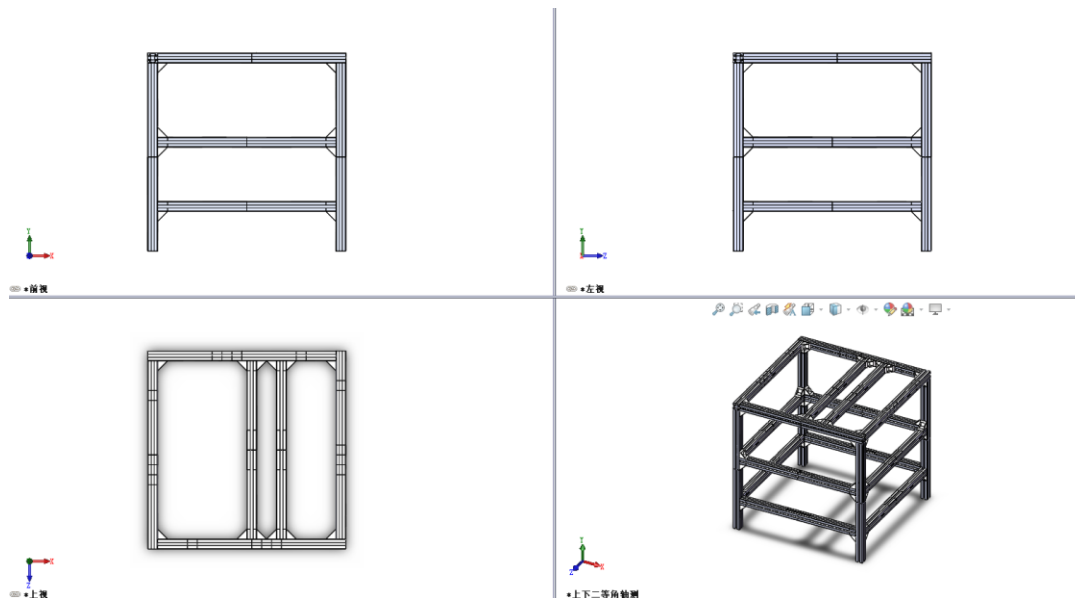


Figure 11 Overall model of the framework

Modeling process: For modeling aluminum profiles, the cross-section is first sketched on a blank sketch and then stretched in various lengths to obtain various lengths of aluminum profiles. For the modeling of the aluminum alloy angle code, the outline is first sketched and stretched in a blank sketch, then the corresponding side is drawn and cut out, and finally the chamfering is carried out to obtain the model of the aluminum alloy angle code. For the T-nut, download the relevant model from the internet and scale it down appropriately so that it fits with the components. When the final assembly is carried out, each aluminum profile is fastened to each other by means using an alloy angle code and a T-nut.

III. CONCLUSION

Wind-powered water lifting irrigation has a good development prospect and application value in the field of wind energy utilization and wind power generation, while the vertical axis wind turbine based on wind cup type resistance difference type blade has the characteristics of low noise, small size, and all-round wind exposure, which meets the working requirements of the open-air environment. The three-dimensional digital concept design of the wind-powered water-lifting device proposed in this paper is modeled using SolidWorks software and has considerable reliability and feasibility in the design of the model structure and materials.

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