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Study of Virtual Design and simulation of Rotary Engine Based on Pro/E

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Abstract

At the present, due to intensified awareness of environmental protection and petroleum resources running low in the world, it is urgent to develop a engine of technical performance with manifold excellent. Aiming at the existing drawbacks of the reciprocating piston engines and the triangle rotor engine, A new kind of engine with simple, novel institution, special principle, low power consumption, low emission, low noise and low cost is designed, sometimes called " Rotary engine " for short. Through computer virtual simulation technology, the scientific rationality of collaborative work in different structures and the novelty of working principles are verified. It lay foundation for development of highly efficient energy-saving engine in the furture.

Keywords: *Reciprocating piston engine; Triangle rotor engine; Rotary engine; Virtual emulation*

1. Introduction

In the 21st century, decisive factors of car development form are the environmental protection and energy saving. With rapid growth of automobile production to the atmospheric pollution and a large amount of consumption of oil resources, known as the "heart" of automotive engine, paid close attention to more and more by people. Advanced engine technology in automobile energy saving, environmental protection technology development plays a decisive role. Increasingly stringent emission regulations and the deepening understanding of the energy saving people, it makes the high efficiency and low emissions vehicle engine technology to attract highly attention. Thus to promote technology innovation of traditional internal combustion engine.

According to the piston movement in a different way, piston engine is divided into reciprocating piston and rotary piston. Reciprocating piston engine working cycle is implemented through the piston, crank-link mechanism, its main advantages are high thermal efficiency, reliable operation, good airtightness and reliability of power transmission, its defect is not fully balanced for inertia force and inertia moment caused by reciprocating motion of piston group, make engine running stability decline, limit development of high speed engine [1]. In recent years, new techniques of reciprocating piston engine emerge one after another, such as gasoline engine in cylinder direct injection technology, variable valve timing mechanism, variable displacement technology, *etc*. These techniques to a certain extent reduce the engine emissions, improve its power performance, but because of the limitation of crank link mechanism, make the engine can't be improved in the aspects of noise and vibration control. Nearly 200 years, there have been a variety of rotary piston engine, most schemes are unresolved issues because of gas tightness. Since the 1950s, a new rotary piston engine have been trial-produced abroad, there are mainly West Germany wankel design of triangle rotor engine (or rotary engine), American

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Carl design of double rotary piston engine, Lerch design of differential type rotary engine design, and so on [2].Among them, the most successful is rotor engine. In recent years, our country also carried out relevant research [3-5], abroad has also done a lot of work in related [6, 7], reference (3~7) is part of the work. Rotary engine saved loosely structured crank-link mechanism and valve timing mechanism of reciprocating engine, and does not produce reciprocating inertia force; The structure has the advantages in the compactness, light quality, good quality at high speed, runs steady, little noise [8]. But because rotary engine cylinder sealing line is longer than that of reciprocating engine, so rotary engine gas leakage is higher than reciprocating engine at a low speed; In addition, rotary engine has a long and narrow combustion chamber, and its surface to volume ratio is big, its dynamic performance and fuel economy is also lower than that of reciprocating engine at low speed.

Aiming at the existing disadvantages of the traditional engine, a kind of circle cylinder rotary internal combustion engine was designed with high efficiency, energy-saving, hybrid power, hereinafter referred to as "rotary engine. It apply to various oil and gas fuel, meanwhile, also apply to motorcycles, automobiles, tractors, ships, helicopters, *etc*. [9]

2. Structure and Working Principle of Rotary Engine

Rotary engine is one kind of internal combustion engine, with the help of cycloid institutions, it can make piston movement in circular cylinder to achieve internal energy to kinetic energy transform. It consists of piston cycloid institutions, eccentric shaft institutions, piston added distance gear ring institutions, timing gear institutions, central principal axis and cylinder body. When you start the engine, using plug valve port type valve mechanism to distribute gas for combustion chamber from center spindle axis(center spindle axis is two compartment structure, combustible mixture gas input from one end, after combustion is completed, exhaust gas output from the other end). Four stroke (including intake, compression, power, and exhaust) will be finished in turns in four combustion chamber. A cylinder during power stroke, then piston rocking beam swing with it, and drive two eccentric shaft rotation through piston added distance gear ring mechanism, eccentric shaft transfer torque to central principal axis and output power through timing gear mechanism. Meanwhile, central principal axis transfer part torque to other two eccentric shafts in reverse, make four eccentric shafts cooperate with each other to complete intake, compression and exhaust of other three combustion chamber.

3. Advancement of Rotary Engine

It has special working principle: adopting unique circle cylinder rotary design, make two adjacent piston has characteristics of relative compression work, can significantly improve the engine power output. It has simple-compact structure: adopting eccentric shaft mechanism and piston added distance gear mechanism, make the engine more simple and compact, volume and weight greatly reduced. It has small noise and low power consumption: Eccentric shaft eccentricity is only 1/4 of traditional engine crankshaft eccentricity, inertial forces impact of piston reciprocating movement is small, cock body has no closed impact, can effectively reduce the noise.

4. Virtual Design of Rotary Engine

4.1. Choice of Design Software

There are many mechanical CAD/CAM software with distinct functions on the market, the rotary engine is designed with the Pro/E software of American PTC Company Corporation.

4.2. Design of Main Parts

4.2.1. Two-Dimension Design

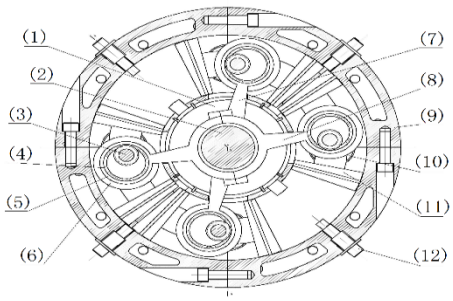
The longitudinal section diagram and the cross-section diagram of main parts of the rotary engine as shown in Figure 1 and 2.

4.2.2. Three-Dimension Design

In the process of modeling of the rotary cylinder engine parts, mainly involving the physical features of the engine parts, here we can break down the physical features.

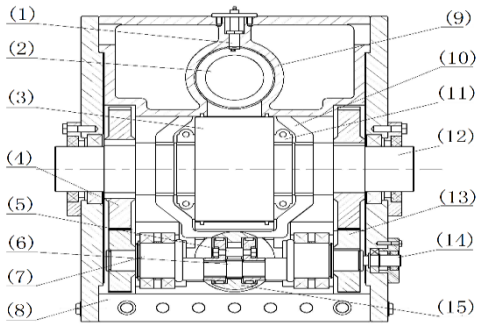
(1) Piston cycloid

The piston cycloid structures consist of circular wedge piston, piston stent and piston rocking beam. Two piston stents are fixed on both ends of the piston rocking beam, four circular wedge piston symmetry are respectively installed on piston support two symmetrical face. Four pistons and two piston stents, with support of the eccentric wheel and the added distance gear of piston, always works along cylinder center curve of cylinder body, according to the set itinerary for reciprocating cycloid movement. The cycloid kinetic energy of piston reciprocating will be output by eccentric shaft device, timing gear mechanism, central spindle output. As shown in Figure 3.



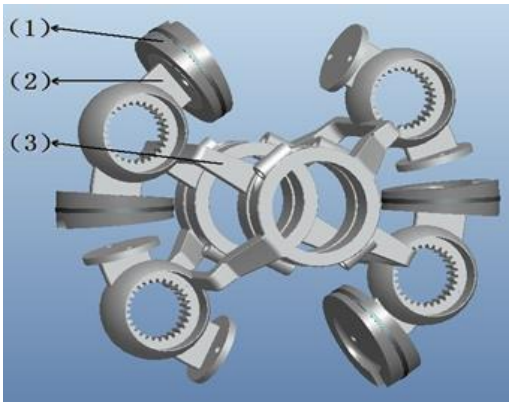
(1) Intake and Exhaust Rotor (2) Spindle(Valve) (3) Pinion Shaft (4) Gear Ring (5) Eccentric Wheel (6) Piston Stent (7) External Rocking Beam of Piston Stents (8) Interior Rocking Beam of Piston Stents (9) Cylinder Body (10) Eccentric Shaft (11) Piston (12) Oil Atomizer

Figure 1. Longitudinal Section Diagram of Rotary Engine



(1) Oil Atomizer (2) Piston (3) Intake and Exhaust Rotor (4) Spindle Big Spindle Timing Gear (5) Eccentric Wheel (6) Pinion Shaft (7) Eccentric Shaft (8) Cylinder Body (9) Cylinder Tube (10) External Rocking Beam of Piston Stents (11) Interior Rocking Beam of Piston Stents (12) Central Principal Axis(valve) (13) Eccentric Shaft Small Timing Gear (14) Attachment Drive Shaft (15) Piston Stent

Figure 2. Cross-Section Diagram of Rotary Engine



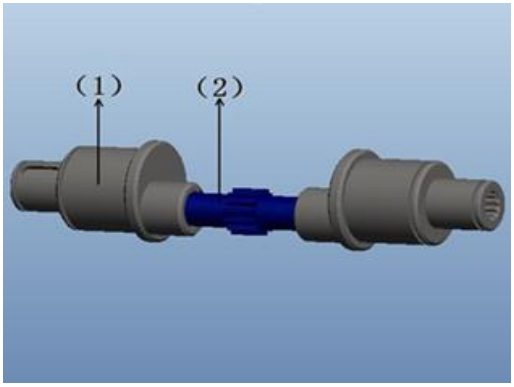
(1) Piston (2) Piston Stent (3) Piston Rocking Beam

Figure 3. Piston Cycloid

Piston cycloid institutions greatly simplify the overall structure of the piston, eliminate the friction between the piston and cylinder, improve the efficiency of the engine, and reduce the piston to the requirement of material. Eccentric shaft mechanism make the working principle of cycloid motion of piston is more reasonable and reliable, structure is simpler and more compact.

(2) Eccentric shaft

The eccentric shaft structures consist of two eccentric shafts and one little quill shaft. The external end-surface of the eccentric shaft is equipped with a small timing gear. Two shaft head of little quill shaft are respectively fixed in the eccentric hole of inner end face of two eccentric shaft, and make two eccentric shaft is symmetrically an organic whole. With the support of the added distance gear mechanism, make always piston work along the cylinder center curve of cylinder body. As shown in Figure 4.

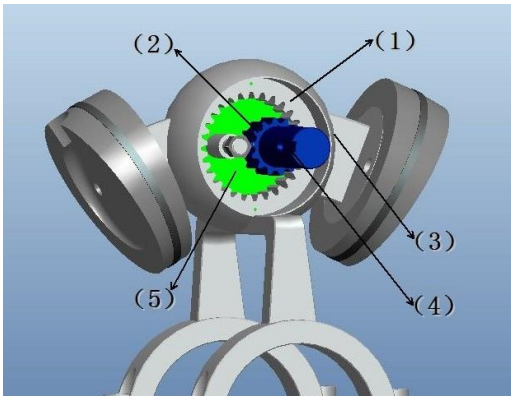


(1) Eccentric Shaft (2) Small Thru-Shaft

Figure 4. Eccentric Shaft

(3) Piston added distance gear

The ring gear and small gear compose a whole part. According to the set angle, the ring gear is fixed in the center of the bracket of piston pin hole, the small gear is fixed on the small -middle diameter of axle shaft, and which mesh with the inner ring gear according to the set of punctuation. Because of the eccentric support, and always maintain the internal ring gear and the small gear meshing wheelbase. As shown in Figure 5.



(1) Inner Gear Ring (2) Small Pinion (3) Pinion Shaft (4) Small Thru-Shaft (5) Eccentric Wheel

Figure 5. Piston Added Distance Gear

(4) Timing gear

The big spindle timing gear and the small spindle timing gear compose a whole part. The outer circle of the big spindle timing gear equipped with the small timing gear meshing teeth; According to the set angle, The small timing gear is fixed on the eccentric shaft, its gear ratio can be designed as 1:2;1:4.1:6.8 (the machine gear ratio of 1:4). The institutions control both correct time of piston 3 check points, and correct time of cylinder port switch. As shown in Figure 6.

(1) Big Spindle Timing Gear (2) Small Spindle Timing Gear (3) Eccentric Shaft

Figure 6. Timing Gear

4.3. Virtual Assembly of Rotary Engine

4.3.1. Summary of Virtual Assembly

The virtual model technology is a new engineering technology. By using this technique, the engineers can establish a model of mechanical system on the computer, combined with 3d visualization processing to simulate system's movement and the dynamic characteristics under the realistic environment, and to elaborate and optimize system design and process according to the results of the simulation. Virtual model technology not only help enterprises to shorten product cycle, reduce cost and improve product quality, but also change process of product design.

4.3.2. Development Process of Virtual Assembly

Rotary engine is made up of many sub assembly and parts. Under the environment of Pro/E Virtual design and development of rotary engine is also start from these sub assembly and its parts. Through the analysis of the principle of the rotary engine, using Pro/Mechanical module to complete the virtual assembly according to certain cooperation relation, and form a digital platform of rotary engine [10]. From the overall analysis, carries on virtual development of the rotary engine according to the process shown in Figure 7.

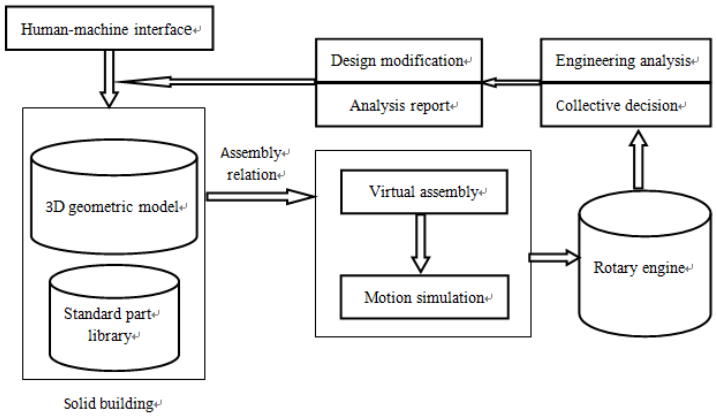


Figure 7. Development Process

4.3.3. Principle and Application of Virtual Assembly

We adopt the bottom-up (down - top) assembly model in the actual process of rotary engine modeling design. First, subassembly are assembled, these parts will be assembled into a whole after check. As long as the assembly is successful, to modify parts of individual characteristics will not affect the assembly constraint relations, this saves time and brings convenience for change design. Such changes will be automatically reflected in the later parts model corresponding assembly parts, so as to ensure the data model of integration, to avoid the design work of repetition. The Rotary engine model tree is shown in Figure 8.

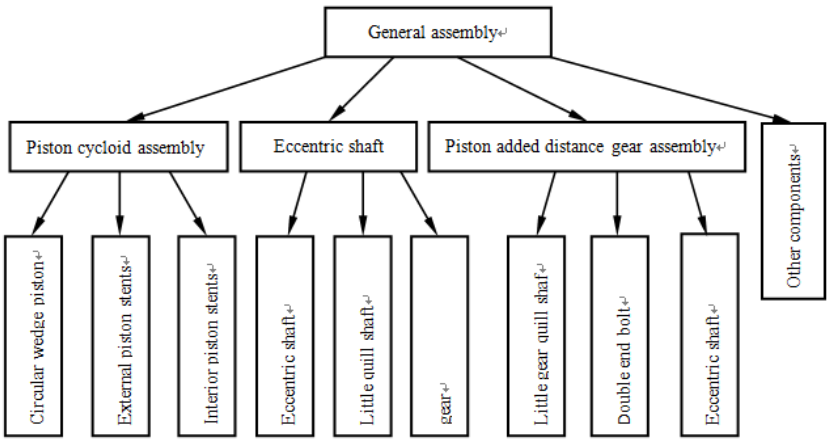


Figure 8. Model Tree

4.3.4. Virtual Assembly Results and Institutions Connection Detection

Rotary engine the final assembly drawing is shown in Figure 9. When component assembly is completed, you can proceed to the institutional environment, and check whether institutions are connected correctly, as shown in Figure 10.

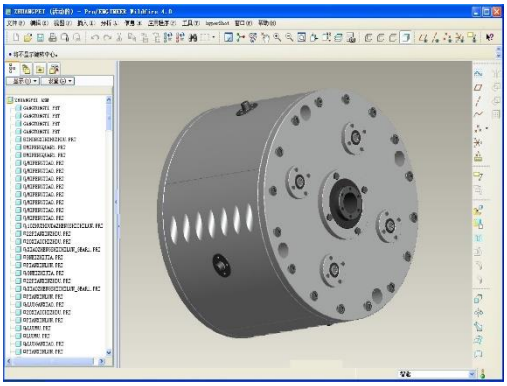


Figure 9. Assembly Drawing

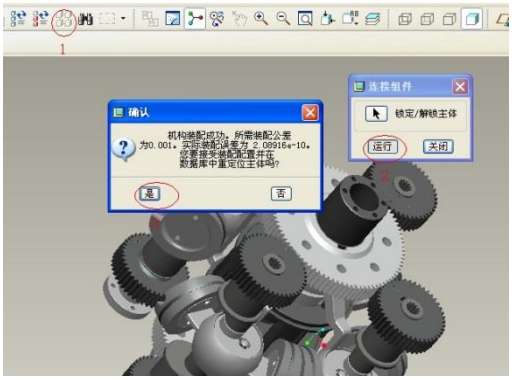


Figure 10. Institutions Connection Detection

5 Motion Simulation of Rotary Engine

Pro/E software provides the mechanism motion simulation function, that makes it is difficult to express and design movement on the 2d view, now became very intuitive and easy to modify, and greatly simplify design and development process, shorten development cycle, reduce development costs, also improve products quality [11].

Motion simulation results can be displayed in the form of animation, and output in the form of parameters, we can know whether interference occur between parts, according to the simulation results for the design of parts modified, until the parts do not produce interference. In deducing the motion, we can observe and record analysis, or measure values such as position, velocity, acceleration, or force, then with graphical representation these values; we can also create path curve and motion envelope, the motion is described by using physical method.

5.1. Virtual Assembly of Rotary Engine

In order to conveniently define connection and servo motor in mechanism module, to hide the cylinder body and unnecessary parts (bearings, bolts, end cover, *etc*.), Figure 11 shows the results after processing.

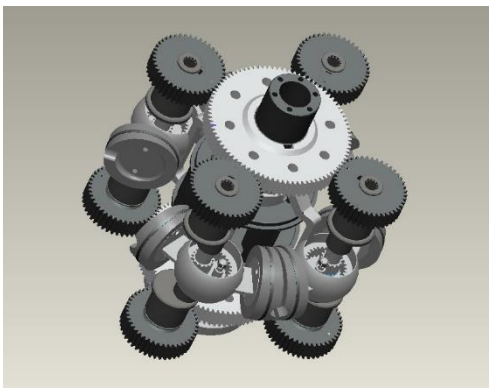


Figure 11. Internal Visual

5.2. Defining Gear Connection

Gear connection belongs to special connection, its use can control two movements shaft connection, when used must access institutional environment. The first main body (appointed bracket) usually remain stationary, the second subject to movement, Based on gear connection type that you created that can be called a gear

and small gear. If you want to change the main body orientation of in gear connection that satisfy other practical constraints, to meet the organization easier regeneration or specified components outline of servo motor, can use "drag" dialog box for the gear body configuration direction. In gear connection, two sport bodies surface don't have to touch each other to work. Because gear connection is regarded as speed restrictions, not based on the model set, so gear ratio can be specified directly. But in creating a rotary engine gear connection, because instant rotational position of four timing gears is relevant, so initial position of gear must be restrained strictly in "drag" action, and take photos as initial position of mechanism motion simulation to ensure successful completion of motion simulation. After gear connection definition completion is shown in Figure 12.

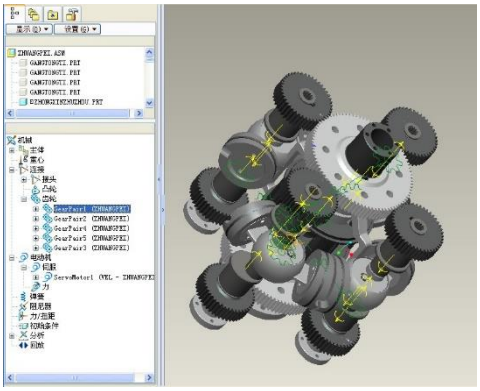


Figure 12. Defining Gear Connection

5.3. Defining Servo Motor

Servo motor has two kinds, one kind is motion axis servo motor for creating clearly defined on a certain direction of movement, and the other is geometric servo motor. Rotary engine needs only a motion axis servo motor to load into eccentric gear in mechanism motion simulation.

5.4. Defining and Running Analysis

As soon as you established model and set up work environment, it can be analyzed. Analysis types are to be determined according to working state of the model and obtaining parameter types. You can obtain the analysis results and parameters after analysis,

5.4.1. Mechanism Analysis Summary

Mechanism analysis types include five kinds: position analysis, motion analysis, dynamic analysis, force balance analysis and static analysis. Position analysis is a series of component analysis, it is driven by servo motor. Position analysis can simulate mechanism motion, satisfy the servo motor outline and any joints, cam mechanism follower, Geneva mechanism follower or gear pair connection requirements, and records of each component in the location data, and don't consider force and quality when analyzing. Therefore, don't need to specify quality attributes of institutions, the model dynamic primitives such as spring, damper, gravity, force/torque and force motor *etc.*, will not affect position analysis.

5.4.2. Defining and Running Position Analysis

According to set the working environment, to create a new analysis in institutions module, then run the analysis.

5.5. Measurement and Playback

5.5.1. Measurement

Measure helps to understand and analyze effects of moving mechanism, and can provide information to improve mechanism design. If you want to calculate and check the measurement results, you must first run analysis or recovering from the previously saved analysis results.

5.5.2 Playback

Using the "replay" dialog to view analysis results set. Each of result set is stored in a file, the file can be running in another process. Using the "replay" command to check interference pattern of parts in mechanism, Different parts of the analysis can be combined into a video to show the force and the torque on mechanism influence, and track measurement value in analysis. You can capture playback result set as".Avi "or ".mpeg "file or ".JPEG", ".TIFF" or ".BMP" file, also can save moving envelope. The playback results capture the animations is shown in Figure 13 and 14.

Figure 13. Diameter Split Animation

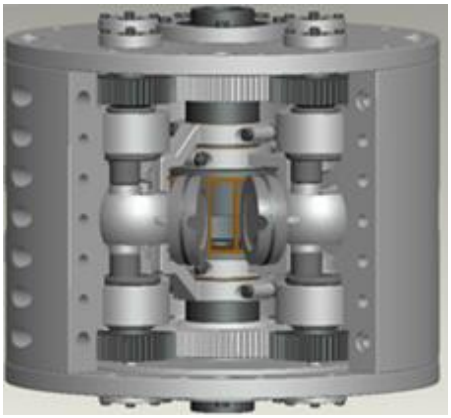


Figure 14. 3-D Animation Figure

6. Conclusion

(1) Based on Pro/E software environment, the article explored virtual design of the rotary engine and simulation process.

(2) Using Pro/E software for rotary engine parts modeled, then virtual assembly of parts were made from bottom to top under the Pro/E's environment, and simulated the Rotary engine movement in mechanism module. Through the mechanism movement simulation, movement condition of the rotary engine parts was intuitively reflected, and can be used to analyze the rationality of the design, finally, animations output as expression of display design thought.

(3) By virtual design and movement simulation on rotary engine, facilitate improvement of rotary engine structure, greatly shorten the manufacturing time of prototype, reduce manufacturing costs, and improve work efficiency.

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