Advances in Engineering Research, volume 120
International Forum on Energy, Environment Science and Materials (IFEESM 2017)

Research and Development of Rotary Booster

Song Ding, Jing Xu, Juan Dong, Hongyan Zhou, Fengtao Zhang
School of Mechanical Engineering，Changchun Normal University，Changchun 130032，China
dingsong08@163.com

Keywords: Rotate booster; lever; crank rocker mechanism; crankshaft

Abstract: In order to realize the utilization of kinetic energy of micro natural energy, a kind of rotary booster is proposed. Through adjusting the length ratio at both ends of the lever, the force value is magnified by times and the rectilinear direction of force is transformed to the rotary direction with lever-type double-sleeve crank and rocker mechanism. The structure design of rotary booster is conducted, based on which the major design parameters that influence the performance of rotary booster are analyzed and relevant design parameters are provided. Taking the 5:1 ratio at both ends of the lever, case design is conducted for trial manufacturing of the model machine. Through model machine test, the effect of approximate force magnification of booster can be realized. The test result proves the rationality of design of rotary booster.

Introduction

Electric energy is the material basis for people to survive and engage in all the productive activities. Existing power generation modes mainly include thermal power, hydroelectric power, wind power, solar power and nuclear power. For a long time, the mass exploitation and depletion of oil, gas and ore fuels have supported the rapid development of industrialization; however, the mass exploitation and depletion have been outrageously absorbing and consuming the limited resources on the earth and emitting a large amount of harmful gases and dusts, resulting in problems including greenhouse effect of the earth and air pollution and severe threats to physical health of human beings.

Since the breakout of oil crisis in 1973, foreign and Chinese scholars have been profoundly studying renewable resources like wind and water, which includes the research on power generation equipment, research on power generation system, supervision of power generation and operation and control of power generation, etc. Nevertheless, foreign and Chinese scholars’ research on power generation of renewable resources is mainly limited to places with abundant wind and water power. In this paper, aiming at a number of mountain areas in China with long-time slow and unstable wind speed and places with abundant micro energy that are neglected and wasted due to smaller unit kinetic energy, such as streams in Southern mountain areas, based on research on energy conversion, rotary booster is proposed and corresponding structure design and trial manufacturing of model machine are conducted. The kinetic power of micro energy is magnified through rotary booster so as to realize the improvement and effective utilization of kinetic power of micro energy. Rotary booster can be used as the kinetic energy source of operation in mountain areas, the temporary power supply of power generation and so on.

The Working Principle of Rotary Booster

Lever booster is applied as the existing booster method. Through changing the length ratio at both ends of the lever, the force at the output end of the lever is magnified but the force at both ends of the lever is rectilinear. Through designing the mechanical transmission mechanism, the rotary booster mechanism is designed in this paper and the basic structure of the rotary booster is shown as Fig.1（1. lever 2. lever support 3. connecting rodI 4. eccentric wheel 5. driven gear 6. eccentric wheel support 7. input axis 8. driving gear 9. crankshaft 10.connecting rod II）, consisting of the lever, the connecting rod, the eccentric gear, the gear, the crankshaft and so on. The transmission form of force and movement is: the turning of the input axis 7 promotes the driving gear 8 and the driven gear 5 to turn in mesh; the driven gear 5 and the eccentric wheel 4 are coaxial on the support 6; the force and movement are transmitted to the eccentric wheel to turn through 5; the fixed-axis rotation of the eccentric wheel is converted to the up-and-down motion of the lever 1 through the connecting rod 3; the acting force is magnified through the lever; the lever 1 is connected to the connecting rod 10 at the other end of the support 2; the force and movement are transmitted to the crankshaft 9 through the connecting rod 10; through the length ratio at both ends of the lever, the force is magnified by times and the crankshaft transforms the up-and-down straight motion of the lever into the fixed-axis rotational output.

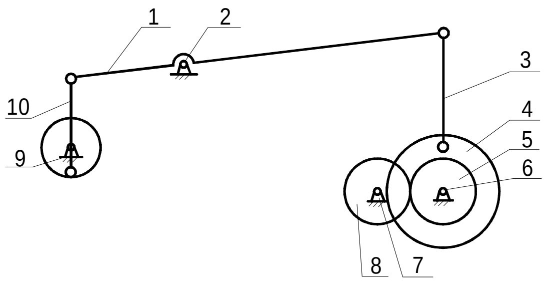

Fig.1 The basic structure of the rotary booster

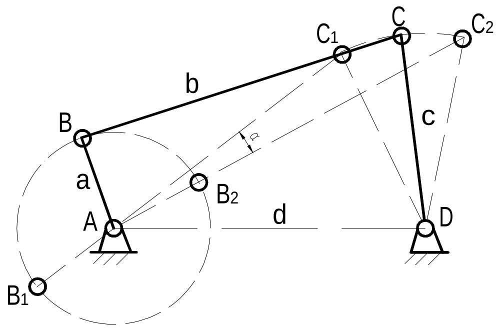

Fig.2 The crank rocker mechanism

The Structure Design of Rotary Booster

The overall motion of rotary booster can be divided according to the lever support into two parts on the left and right for analysis and both parts can be simplified into four-lever mechanism. The rotary motion of the eccentric wheel on the right of the lever support and the up-and-down swing of the lever driven by the connecting rod constitute the crank rocker mechanism; on the left of the lever support, the up-and-down swing of the lever and the crankshaft rotation driven by the connecting rod constitute the crank rocker mechanism.

The crank rocker mechanism can be analyzed through design of the motion trail. There are three points for function and motion requirement for the gear:

1.realize the up-and-down motion the longer end of the lever and the rotary motion of the eccentric wheel, the up-and-down motion the shorter end of the lever and the rotary motion of the crankshaft;

2.The whole booster equipment moves uniformly;

3.The motion continuity.

As shown in Fig.2, the length of the four-lever mechanism are a, b, c and d and the extreme positions. In order to satisfy the requirement 1 of the gear, the crank rocker mechanism is necessary for the four-lever mechanism. The lever AB rotates around the turnover pair A so there is a lever length condition as shown in formula 1. When the lever length, a, b, c and d, satisfy the formula 1, the four-lever mechanism belongs to the crank rocker mechanism that can realize the up-and-down motion of the lever and the rotary motion of the eccentric wheel and the crankshaft.

$$\begin{cases} a+b \le c+d \\ a+c \le b+d \\ a \le b, a \le c, a \le d \end{cases} \tag{1}$$

Assuming the crank AB as the driving link, during the process that AB rotates for one round around point A, the crank AB is collinear to the connecting rod BC twice, as shown in Fig.2. At this time, the connecting rod BC separately remains in the two extreme positions whose intersection angle is α. When the crank uniformly rotates for 180°+α clockwise from AB1 to AB2, the rocker moves from DC1 to DC2 and the time is t1. When the crank rotates for 180°-α from AB2 to AB1, the rocker moves from DC2 to DC1 and the time is t2. The rocker accomplishes a reciprocating motion as the crank accomplishes a turnover. The reciprocating speed ratio of rocker is K as shown in formula 2.

Because the crank rotates uniformly and (180°+α)≥(180°-α), t1≥t2, v2≥v1 and the reciprocating speed ratio K≥1. When K>1, there is a sharp turnover in the motion process and the rocker does not move uniformly in the motion process of positive and negative directions. In the design requirement of the drive mechanism, uniform motion is required so it is required that α=0 and K=1. When α=0, the crank is collinear to the connecting rod at the two extreme positions. The crank exactly passes through its turnover center through the force that is exerted by the connecting rod on the moving part so the stuck phenomenon that makes the crank rotate appears. In order to realize the normal operation the mechanism, three groups of the same mechanisms are designed and the phase difference between each group is 120°, as shown in Fig.3, where there are three crank throws in the crankshaft and the phase difference between each crank throw is 120°. There are three positive gears on the input axis in Fig.3（1. crankshaft 2. crank 3. eccentric wheel 4. driven axle 5. driven gear 6. driven axle 7. driven gea）, which can ensure the motion coordination of three groups of mechanisms. The eccentric wheel, the driven gear and the eccentric axle consist of one group and there are three groups whose phase difference of eccentric holes of the three groups is 120°, one-to-one corresponding to the three crank throws on the crankshaft.

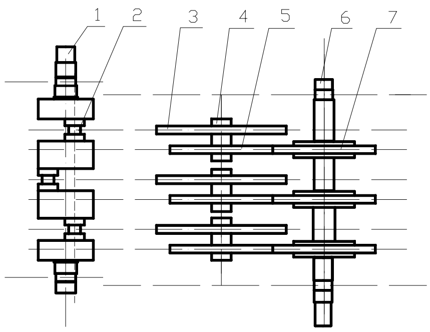

Fig.3 Combination mechanism

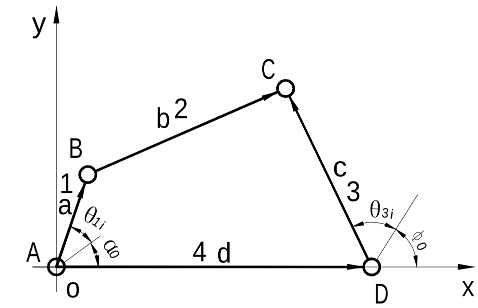

Fig.4 The simplified four-lever mechanism analytic model

According to the scheduled motion rule design, the positions, length and size of the lever, the connecting rod, the eccentric wheel and the crankshaft are simplified into two similar four-lever mechanisms. The simplified four-lever mechanism is analytically designed according to the scheduled motion rules, as shown in Fig.4.

On the basis that the relative intersection angles of each component are not changed, the mechanism can be magnified or narrowed in proportion so relative length can be applied to the design variable of the component. $a/a=1$, $b/a=l$, $c/a=m$, $d/a=n$, According to the coordinate established in Fig.4, formula 2 is acquired through projection of sagittal coordinate axis of each lever.

$$\begin{cases} l\cos q_{2i} = n + m\cos(q_{3i} + j_0) - \cos(q_{1i} + a_0) \\ l\sin q_{2i} = m\sin(q_{3i} + j_0) - \sin(q_{1i} + a_0) \end{cases} \quad (2)$$

Formula 2 is rearranged and simplified to formula 3.

$$\cos(q_{1i} + a_0) = P_0\cos(q_{3i} + j_0) + P_1\cos(q_{3i} + j_0 - q_{1i} - a_0) + P_2 \quad (3)$$

Where some parameters can be pre-selected according to structural size for the five undetermined parameters in formula 3 so as to conduct structure design.

Numerical Examples of Design of Rotary Booster

Rotary booster can be simplified to two crank and rocker mechanisms. According to the condition of lever length, the booster with booster ratio of 1:5 is designed in this paper. Initially, the shorter lever end is selected as 130mm and the longer one is 650mm, which are separately regarded as the rockers in the two crank and rocker mechanisms. In order to ensure that the lever weight exerts no effects on the overall performance of the booster, the counterweight of both ends of the lever are reallocated.

When the lever is placed on the support and both ends are not connected to the connecting rod, the lever is ensured to be level.

According to design calculation, the length from the shorter end to the hole center of the connecting rod is 448mm and the length from the longer end to the hole center of the connecting rod is 741mm. The connecting rod to both ends consist of two parts. There is an adjustment screw in the middle of the two parts of connecting rod and the adjustment screw can slightly adjust the size of the connecting rod with the adjustment range of 0-10mm. As for the crank in the crank and rocker mechanism, the shorter end is the crank throw on the crank axle and the longer end is the eccentric wheel. The distance between the crank throw center to the center of crank axle is 45mm and the centers of the three crank throws are at an angle of 120°. The distance between the eccentric hole of the eccentric wheel and the axle center is 225mm and the phase difference of the eccentric holes of the three eccentric wheels is 120°。

Experimental Analysis on Rotary Equipment

In order to testify the booster performance of rotary booster, the experimental model machine of 1:5 rotary booster is designed and manufactured as shown in Fig.5. In Fig.5, the input end of the trial rotary booster is connected to the output end of the decelerator whose total transmission ratio is 24. The output end of the decelerator is connected to the Y112M-4 motor. In the experiment, the input speed of the booster is 60r/min. The output end of the booster is connected to the input end of the jugged and chained booster to improve the output rotation rate. The output end of the jugged and chained booster is connected to the KZ10GF motor that is connected to parallel bulb circuit.

Firstly, the output end of the motor is connected to the input end of the motor and the motor does not work. When the motor is connected to the alternator as shown in Fig.5（1. Lever counterweight 2. lever support 3. connecting rod 4. crankshaft 5. Eccentric wheel 6. speeder 7.reducer）, the alternator is switched on, after which the motor works normally and the bulb shines stably with stable ammeter and voltmeter reading. During the operating process, the booster operates stably. The three groups of lever mechanisms are installed alternately by 120°, which can solve the stuck phenomenon that appears when the crank is collinear to the connecting rod at the two extreme positions. The experiment proves the feasibility of the design of the rotary booster.

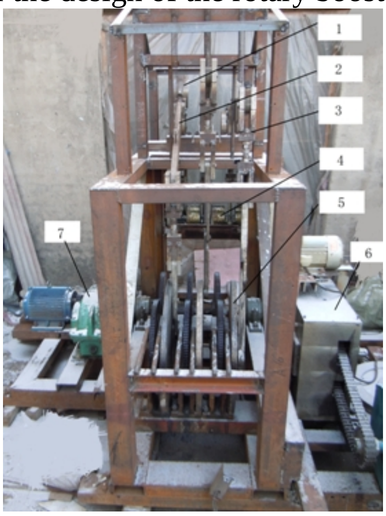

Fig.5 Prototype model of rotary booster

Conclusion

In this paper, the size parameters and assembly methods of each component of the rotary booster are designed. Through experiment of the model machine, the magnification of force by times can be realized with stable operation, proving the rationality of the design of the rotary booster.

Acknowledgements

This work was financially supported by Natural Science Foundation of Changchun Normal University.

References

[1] YANG Yongping, YANG Zhiping, WANG Ningling: Proceeding of the CSEE. Vol. 33 (2013)

[2] ZHANG Xi, KANG Chongqing. Automation of Electric Power Systems. Vol. 38 (2014)