The Self-centering, Power-driven and External-clamping Device Based on Self-locking Worm and Worm Gear and Crank - Connecting Rod Drive

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Abstract—The working principle of a self-centering, power-driven and external-clamping device is induced. The device is based on self-locking worm and worm wheel and slot-and-crank drive. Its mechanical properties and calculation formula is also given out. After the device being driven by gear motor, output torque rotates the driving and driven gears first, and then transmits the driving force to the upper and the lower worms; Then the upper and the lower worms rotate their meshing worm gears separately and the worm gears sway the upper and the lower crank-connecting rods articulated in worm gears; Lastly, three times amplification of the force is realized by the force-amplifier of the upper and the lower crank connecting rods. The device can center automatically up and down and clamps the workpiece. Besides, the device is with less energy conversion equipments, compact structure, well flexibility and high greenization.

Keywords- self-locking; worm and worm gear; crank-connecting rod; self-centering; electric clamping

I. INTRODUCTION

With the development of science and technology, the fixture has been developing from one kind of auxiliary means into a complete range of technological equipment[1]. The fixture is an essential part in mechanical processing. The machine tool technology being high-speed, efficient, accurate, composite, intelligent and environmentally friendly, the fixture technology is moving in the way of high-precision, efficiency, module, combination, common use and thrift [2]. The functions of the fixture mainly includes: ① The assistant time is shortened, the production efficiency is increased and the processing cost is reduced. ②The processing precision is guaranteed and the process quality is stable. ③ The technical requirements for workers are reduced, also the labor strength of workers is reduced, and the safety in production is ensured. ④It is easy to keep the production balance in the automatic and assembly-line production [3].

The power sources of fixture have manual clamping, pneumatic clamping, hydraulic clamping and electric clamping, etc. Although the manual clamping has the advantage of environmental friendliness, it has a fatal flaw; that is the clamping force can not be big enough because of limited manpower. For instance, the high-frequency operated fixture requires that the hand force is less than 150 N; The low frequency operated fixture requires that the hand force is limited within 600 N. Otherwise, it will lead to high intensity of labor [4-5]. Hydraulic and pneumatic fixtures take the hydraulic oil and compressed air as working medium, by which deliver and control energy. The transfer and conversion routes of them is that hydraulic pump or air compressor transforms the mechanical energy of motor to the pressure energy of fluid, then the pressure energy of fluid is transformed to the mechanical energy of cylinder or piston through hydraulic cylinder(hydraulic motor) or air cylinder(air motor) to produce clamping force and drive the load. The electrical transmission can drive directly without any mediums. The transfer and conversion routes of electrical fixture are that the mechanical energy produced by motor is transformed to the clamping components directly by intermediate transmission mechanism (normally with self-locking links) and the clamping components output clamping force.

In can be seen that the hydraulic and pneumatic fixtures are with more intermediate links and energy loss [6].In addition, hydraulic and pneumatic transmission is harmful to the environment due to the leakage and volatilization of hydraulic oil and compressed gas [7-8].

Hence, the fixtures of hydraulic and pneumatic transmission can not adapt to the requirement of green manufacture. Although electrical fixture is superior to manual fixture, hydraulic fixture and pneumatic fixture, the pure point moving fixture in electrical fixtures exists the disadvantages of small force magnification of the intermediary agency, large volume, difficult to change the spatial location and the need of powerful motor. Considering of the weakness of above fixtures, a power-driven, self-centering and external-clamping device based on self-locking worm and worm gear and crank-connecting drive is designed to realize the purpose of clamping workpiece.

Although the worm and worm gear has the advantages of smooth transmission, small shock and noise and gaining larger reduction ratio through only single stage drive, there is a little discussion about the fixture based on the drive of worm and worm gear currently [9]. A self-centering, power-driven and external-clamping device is gained by means of combining worm and worm gear with the crank connecting rod and the gear drive in series. The device can realize three times amplification of the force and has good self-locking performance. So the issue of the need of powerful motor in the pure point moving fixture of electrical fixtures is solved. The device are with the characteristics of compact structure, easy operation, well flexibility, high greenization and the nonlinear change of output force and displacement. Electrical drive can possess the function of transmission without any media, so it generates less pollution and meets the requirements of green manufacture which can lower the consumption of resource and reduce the impact on environment, which is comparatively a more advanced way of transmission [10].

II. THE WORKING PRINCIPLE AND MECHANICS ANALYSIS

A. The working principle of the electrical-clamping device which increases the force by secondary tandem

The transmission of the worm and worm gear can transform movement and power between the two axis which are perpendicular to each other and not intersect and be self-locking [11]. The crank-connecting rod mechanism can transmit force and change the way of movement and transform the rotary motion of crank to move back and forth in straight line[12]. Utilizing above characteristics of the transmission of worm and worm gear and crank-connecting rod mechanism and combining them, the electrical-clamping device which increases the force by secondary tandem is designed. The schematic diagram is shown in figure 1. This device consists of gear motor, worm and worm gear, crank-connecting rod and indenter.

The working principle of the electrical-clamping device which increases the force by secondary tandem is that after the device being driven by gear motor, output torque rotates the worm first, then the teeth on the worm mesh the worm gear to rotate it clockwise, the force of the device is amplified for the first time at this moment; Then the rotation of the worm gear swings the crank-connecting rod articulated in it and the connecting rod moves downward in a straight line, the force of the device is amplified for the second time at this moment; Lastly, the indenter outputs clamping force and the workpiece is clamped. If the gear motor is stopped now, the whole clamping device will be self-locked. After the workpiece being processed, the gear motor is access to the reverse power supply and the worm rotates the worm gear counterclockwise, then the connecting rod articulated in worm gear moves upward in a straight line to loosen the workpiece.

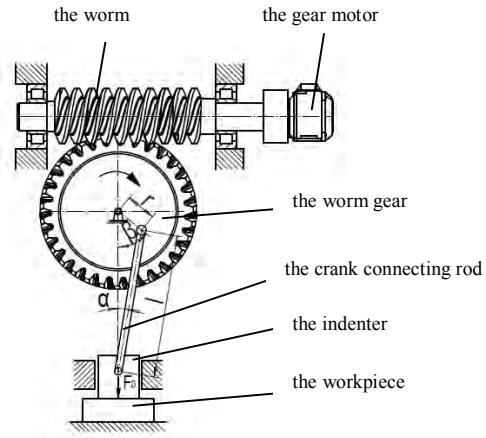

Figure 1. The schematic diagram of the electrical-clamping device which increases the force by secondary tandem

B. The working principle of the self-centering, power-driven and external-clamping device

The electrical-clamping device which increases the force by secondary tandem shown in figure 1 increases the clamping force by utilizing the transmission of the worm and worm gear and the crank connecting rod, which achieves the effect of reinforcement without high power motor. The clamping device shown in figure 1 can be evolved for the efficient purpose of cutting the clamp ing time of workpiece, centering automatically, etc[13]. Arranging the two sets of electrical-clamping devices which increase the force by secondary tandem symmetrically using symmetrical relationship, a self-centering, power-driven and external-clamping device can be gained. The operating principle of this device is shown in figure 2. This device mainly consists of gear motor, driving and driven gears, two sets of electrical-clamping devices which increase the force by secondary tandem. The electrical-clamping device which increases the force by secondary tandem concludes worm, worm gear, crank-connecting rod, indenter, etc. The worm's position should be fixed both in axial direction and circumferential direction to ensure the stability of transmission. Two sets of up and down electrical-clamping devices which increase the force by secondary tandem need to be calibrated symmetrically. The gear motor is an inversion mechanism that outputs big torque without any intermediate links by reducer, which is a green and pollution-free transmission technology [6]. The flexibility of crank-connecting rod mechanism's direction is very good, which can change the output force's position easily according to the actual clamping requirements.

The working principle of the self-centering, power-driven and external-clamping device is that after the device being driven by gear motor, output torque rotates the

driving gear; then the driving gear transmits the driving force to the driven gears and the upper and the lower worms first through gear engagement; The force of the device is amplified for the first time at this moment. The upper worm meshes the upper worm gear to rotate it clockwise and the lower worm meshes the lower worm gear to rotate it counterclockwise. The force of the device is amplified for the second time at this moment. After that, the upper and the lower worm gears swing the upper and the lower crank-connecting rods articulated in them to make the upper connecting rod move downward in a straight line and the lower connecting rod move upward in a straight line, then the upper and lower indenters get close to the outside surface of the workpiece separately; The force of the device is amplified for the third time by utilizing the angle effects of the upper and lower crank-connecting rods at this moment. Lastly, the output force of the upper and the lower indenters act on the outside surface of the workpiece separately and the clamping movement is completed. If the gear motor is stopped now, the whole clamping device will be self-locked, which means that the upper and the lower clamping force of the workpiece can be kept throughout the whole processing. After the workpiece being processed, the gear motor is access to the reverse power supply. So the upper worm will rotate the upper worm gear counterclockwise and the upper crank-connecting rod articulated in the upper worm gear will move upward in a straight line; The lower worm will rotate the lower worm gear clockwise and the lower crank-connecting rod articulated in the lower worm gear will move downward in a straight line. Thus the workpiece will be loosened.

the efficiency of machining workpiece are improved, which can achieve the aim of saving labor and time and being efficient. The device will not consume the energy when the gear motor is stopped, which can further realize "greenization".

It's necessary for the device to have the self-locking function when the external-clamping device is designed. There are two kinds of self-locking ways which are commonly used currently; one is based on the principle that the driving force is smaller than the friction force or the driving torque is smaller than the friction torque, such as inclined-wedge, spiral, cam, etc; the other is based on the principle of no dead point. The essence of the worm and worm gear mechanism is spiral mechanism. So a single-start worm should be used and an appropriate lead angle should also be chosen to ensure the reliable of self-lock. The lead angle is less than 3.5 degrees normally. The smaller the lead angle is, the more stable the self-lock, the more distinct the reinforcing effect and meanwhile the lower the transmission efficiency and the clamping speed.

The crank-connecting rod mechanism which is in tandem with the worm gear is to transform the rotary motion of the worm gear to the rectilinear motion needed when clamping the workpiece. The crank-connecting rod mechanism is a force-amplifier based on angle effect and its output force and displacement have the characteristics of nonlinear variation. That is to say, the indenter has the characteristic of long stroke length and fast speed when the angle is relatively larger. When the angle decreases, the stroke of the indenter becomes relatively smaller and the output force increases rapidly to output great clamping force.

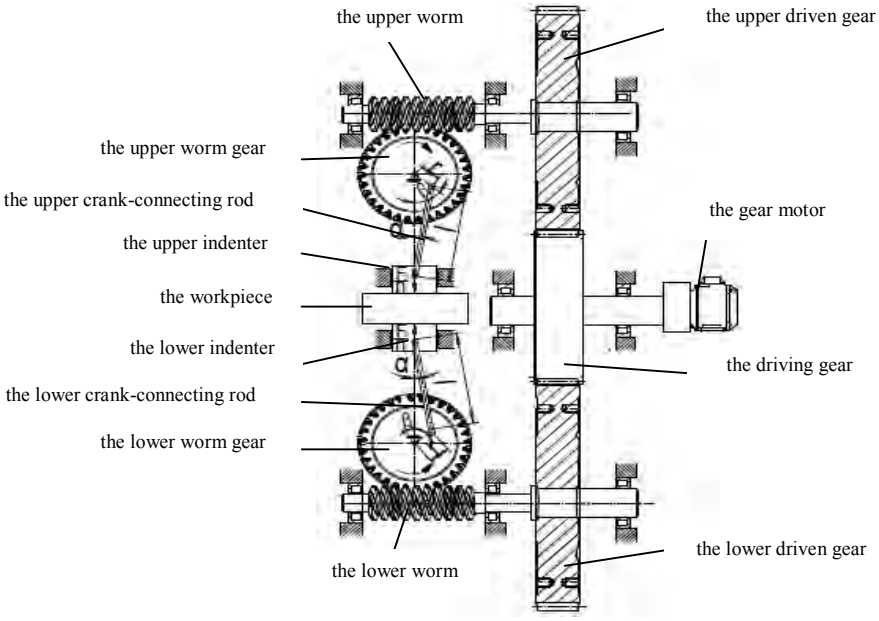

Figure 2. The schematic diagram of the self-centering, power-driven and external-clamping device

The upper and the lower electrical-clamping devices which increase the force by secondary tandem are arranged symmetrically to make the upper and lower indenters output the equal and opposite force, which can realize self-centering. So the time of adjusting fixture is shorten and

C. Mechanical calculation

If the torque inputted by motor is , the output forces of the upper and lower indenters are.

$$\frac{F_o}{n} = \frac{T_1}{r \cdot (\tan\alpha \cos\beta + \sin\beta)} \cdot \frac{z_2}{z_1} \cdot \frac{z_4}{z_3} \cdot \eta_1 \cdot \eta_2 \quad (1)$$

In the formula, n is the number of the electrical-clamping device which increases the force by secondary tandem; z_2 is the number of teeth of the driven gear; z_1 is the number of teeth of the driving gear; z_4 is the number of teeth of the worm gear; z_3 is the number of threads of the worm; r is distance from the center of the worm gear to the hinge joint of the connecting rod; α is the pressure angle of the crank-connecting rod mechanism and β is the driving angle of the crank-connecting rod mechanism; η_2 is the transmission efficiency of the worm and worm gear; η_1 is the transmission efficiency between the crank-connecting rod and indenter. When the rotating speed is relatively slower, is influenced mainly by the meshing efficiency of the worm gear pair, its calculation formula is

$$\eta_1 = \frac{\tan\gamma}{\tan(\gamma + \varphi)} \quad (2)$$

In the formula, γ is the lead angle of reference cylinder (°); φ is the meshing frictional angle (°) and is determined by μ which is the meshing friction coefficient; that is $\varphi = \arctan\mu$.

The shape of workpiece that can be clamped by this clamping device is square when the n is 2; the shape of workpiece that can be clamped by this clamping device is cylindrical when the n is 3. So the range of application of the gripping device can be enlarged.

III. CONCLUSION

1) The power-driven and external-clamping device is driven directly by electricity; so the transmission route of energy is short and the conversion equipment is less. Besides, the mechanism of the device is simple and compact and the total cost is reduced greatly.

2) The clamping force of the clamping state can be kept unchanged without any additional energy input by using the self-locking principle of the worm and worm gear mechanism; So the operation is reliable and the labor intensity is reduced. Besides, the device does not exist any environmental pollution and has a high degree of greenization.

3) The device which increases the force by connecting the worm and worm gear, the crank-connecting rod and the transmission of the gear tandem can acquire high force increase ratio and has an obvious effect on increasing the force. Meanwhile, the output force and displacement of the crank-connecting rod mechanism have the characteristic of being nonlinear; So the feed of indenter is fast when the pressure angle is big and the clamping force increases rapidly when the pressure angle is small.

4) The flexibility of crank and connecting rod mechanism's direction is very good, so the output can be rearranged according to the clamping requirements. Hence, the multi-directional clamp and the change of clamping direction is realized in low cost, which enlarges the range of clamp.

5) The upper and the lower electrical-clamping devices which increase the force by secondary tandem are arranged symmetrically, which makes the upper and lower indenters output the equal and opposite force.

ACKNOWLEDGMENT

Supported by National Natural Science Foundation of China 51205266, Suzhou Municipal Scientific Program of China SYG201326, and Jiangsu Planned Projects for Postdoctoral Research Funds 1101121C.

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