Creative Design of Transmission Device for Workpiece Transfer in Production Line

Rongyu Ge¹,*, Miaomiao Xin², Jialiang Wu² and Xiaomei Ni²

¹School of Mechanical Engineering, University of Jinan, Jinan, 250022, China
²School of Mechatronics Engineering, Qilu Institute of Technology, Jinan, 250200, China

*me_gery@ujn.edu.cn

Abstract. It is necessary for the workpiece transfer system in the production line to realize periodic indexing and reciprocating oscillation motion. In view of the complicated structure of the traditional transmission device and the need of multiple driving motors, a creative design integrating the indexing transmission and the oscillating transmission is made based on the globoidal cam mechanism. Taking the material transfer system in the LED beam splitter as a design example, structural design and 3D modeling were carried out, and the 2D drawings were obtained. The virtual prototype of the overall transmission is established by the dynamic simulation software ADAMS and the angular displacement of the three output shafts is simulated. The simulation results verify that the scheme can meet the requirements of the workpiece transfer system.

1. Introduction
In the automatic production line, the workpiece transfer system must realize the coordination between various technological actions, mainly including periodic indexing motion and reciprocating oscillation [1]. The former realizes intermittent rotation of multi-station rotary table, while the latter realizes grasping and handling of workpieces between different worktables. For the existing workpiece transfer system, indexing and oscillating actions are performed by different intermittent mechanisms, and driven by different motors, as shown in figure 1, which has disadvantages such as complex structure, multiple sensors feedback required, difficulty to control the coordination from multiple power sources. An innovative transmission device using single power source to meet the multiple technological actions is designed in this paper, which is much simpler and more compact.

2. Functional principle of implementation scheme
According to the process requirements of the workpiece transfer system, the transmission device needs to convert the rotating motion from the motor not only into intermittent indexing motion of the work table but also intermittent reciprocating oscillation for the feeding manipulator. There are many mechanisms to fulfil indexing movement like cam indexing mechanism, ratchet mechanism, groove wheel mechanism and incomplete gear mechanism, and also many mechanisms to complete oscillating movement like crank-rocker mechanism, crank-slider mechanism, cam mechanism with oscillating followers and so on. Therefore, the cam mechanism can meet two requirements simultaneously. The globoidal cam mechanism, because of its compact structure, high load capacity, low noise, high transmission accuracy and high reliability, is widely used in various production lines [2]. According to
the motion form of follower, it is divided into oscillating globoidal cam and indexing globoidal cam mechanism. Based on the globoidal cam mechanism, a combined transmission device integrating the indexing drive device and oscillating drive device is accomplished to transform the single input motion into multiple output motion. In other words, multiple globoidal cams are installed on the same input shaft and different followers on different output shaft mesh with the corresponding cams respectively, so diverse indexing or intermittent reciprocating output motion can be achieved through the design of cam profile, as is shown in figure 2. This innovative design requires only one motor to directly transfer torque to multiple groups of cam mechanisms, so indexing motion and oscillating motion are controlled by a power input, and the coordination of output action is just controlled by cam profile. This control method is very simple and reliable.

3. Design example

3.1. Structure design

LED light splitter is a kind of equipment to classify LED according to the wavelength, light intensity and voltage of the diode. At present, the combination of compound cam device and indexing cam device is generally adopted in the mechanical system of LED light splitter [3]. The disk cam in the compound cam is used to control the reciprocating motion of the mechanical gripper in the X direction, and cylindrical cam in the compound cam is applied to control the reciprocating motion in the Y direction. The indexing cam device intermittently transfers the LED to the designated position. The disadvantages of this system are that multiple motors are required to control each intermittent mechanism separately, there are many maintenance failure points and complex structure, and it is difficult to be assembled. When the LED market becomes increasingly competitive, higher and higher requirements are put forward for the sorting speed of splitter. It is problematical for the existing mechanical structure to meet the high-speed condition. The motion cycle diagram of the mechanical drive system of a LED light splitter on the market is shown in figure 3.
A driving device fulfilling the indexing and oscillating motion based on the globoidal cam mechanism is designed, which replaces the original material transfer system of LED splitter. As shown in figure 4, the device consists of a power input shaft and three output shafts. The oscillating globoidal cam I, oscillating globoidal cam II and the indexing globoidal cam are installed on the input shaft in turn. As a result, the power input can actuate the three output shafts to achieve the specified movement law shown in figure 3. Both the oscillating output shaft I and output shaft II with the swing angle of 20°, connected with the material receiving plate through the curved arm, will control the movement of the gripper in the X direction and Y direction. In this way, the material transmission of LED is executed replacing the original cylindrical cam and disk cam mechanism. The indexing output shaft with the indexing angle of 45°, connected with the material feeding plate through the synchronous belt transmission, will accomplish the material feeding movement replacing the original indexing cam mechanism.

Figure 4. Schematic diagram of innovative material transmission system in LED light splitter.

3.2. Three-dimensional modeling
In order to kinematics simulation, part and assembly modelling for the transmission device containing indexing and oscillating motions should be made. The working surface equation between the indexing cam and oscillating cam is similar but the motion law function of follower [4]. Working surface equation of the globoidal cam is especially complex [5], so that it is difficult to directly establish its mathematical model in 3D software. Some software are integrated with the modeling method of the offset surface, and it can indirectly realize the precise modeling of complex regular surface. Here, Pro/E software is used as a tool for the model of the globoidal cam mechanism.

According to the theoretical surface equation, two benchmark curves are firstly created by software command “by equation”. Then, “variable cross section scanning” is used to generate the theoretical surface and then “offset” to generate two working surfaces of globoidal cam with offset distance R, the radius of rollers, as shown in figure 5. At last the overall 3D entity of cam body is finished through commands such as “boundary blending”, “surface merging”, “materialization”, etc.

Figure 5. Modeling process of globoidal cam surface.
In the assembly module of Pro/E, two vertical input axes and output axes are established according to the center distance between cam and following plate, as shown in figure 6. Taking two axes as assembly datum, the globoid cam and the follower are connected by a pin for assembly. The “pin connection” and “groove connection” are used to fully define the driven plate connection for limiting the roller of the following disk. For the definition of groove connection, take a certain point P of roller axis as “point on the line”, and select the theoretical line corresponding to point P as “groove axis”. Further using the mechanism module of Pro/E, the servo motor is defined with the globoidal cam as the active part, so as to realize the motion simulation and collision interference inspection of the globoidal cam mechanism.

![Diagram](image)

**Figure 6.** Assembly process of arc cam mechanism

After the assembly of the main transmission system is completed, the other parts of the device are assembled, including the box body, the fastener on the shaft and so on. Figure 7 shows the overall 3D model of the combined transmission device.

![3D Model](image)

**Figure 7.** 3D model of combined drive.

3.3. Creation of engineering drawings

After 3D model creation is completed, engineering drawings need to be generated to meet production requirements, as shown in figure 8.

As can be seen from figure 8(a), three sets of globoidal cams are mounted on the input shaft, which are two oscillating cams and one indexing cam. The driven turntable meshes with the cam to drive the output shaft to rotate according to the defined motion. Two sections of the box wall with holes are added inside the box body for mounting deep groove ball bearings, which ensure the stability of the input shaft with the tapered roller bearings at both ends of the shaft together.
As can be seen from figure 8(b), an eccentric end cap is used at both ends of the output shaft to adjust the center distance between the input shaft and the output, that is, the gap between the cam ridge and the driven roller. After the eccentric end cap is rotated, its relative position is fixed by a set screw. At one end of the input shaft and at both ends of the output shaft, a screw-on adjustment cover is applied to adjust the clearance of the tapered roller bearing and achieve axial positioning.

4. Dynamic simulation

A partial 3D assembly model of the combined transmission was introduced into the mechanical system dynamics analysis software ADAMS. Each part is applied with a fixed pair or a rotating pair. The rotary drive of the input shaft is set to 300r/min, and a contact force is added between each roller and the cam. Stiffness coefficient is $K = 7.5 \times 10^3 N / mm^2$, with force linear index $e=1.5$ and damping $C = 750 N \cdot S / mm$. As shown in figure 9, a virtual prototype of the device is built.

Dynamic simulation of the model in the ADAMS/view module should be operated to verify the correctness of the transmission design. The actual angular displacement of the three output shafts is illustrated in figure 10. The simulated angular displacement curve is consistent with the given theoretical angular displacement curve, shown in figure 3. The two oscillating plates have a swing
angle of 20°, the indexing turntable has an indexing angle of 45°, and the motion coordination relationship between the three output shafts is also consistent with the design requirements.

![Figure 10. Simulation of angular displacement of three output motions.](image)

5. Conclusions
In the automatic production line, it is often necessary to achieve the indexing or oscillating movement due to the requirements of the production process. However, most existing devices or institutions can only achieve a single movement. At the same time, the intermittent globoidal cam mechanism on the automatic production line gradually replaces the traditional intermittent mechanism because of its high precision and good dynamic performance. Therefore, a combination device of indexing and oscillating transmission based on globoidal cam is designed and its 3D model is constructed to realize the motion transmission from single input to three outputs. The virtual prototype model of the device is established by ADAMS software, and the simulation analysis is carried out, which provides the reference for the design of this type of device in the future.

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