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Design and teaching feedback of switching steering transmission device in production line

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Abstract: *The transmission device is composed of rotary motion mechanism and vertical motion mechanism. The rotary motion mechanism is composed of synchronous belt transmission planetary gear train composed of synchronous belt transmission and upper and lower connecting arms to ensure that the product rotates 90 ° counterclockwise and 90 ° clockwise; The vertical motion mechanism is composed of cylinder, ball and spline transmission technology. The transmission device is flexibly implanted into the curriculum with the carrier of new technology and new process, which feeds back the teaching, and takes the curriculum thought and politics as the guide to implement the teaching.*

Keywords: *design of switching steering transmission device for production line, teaching feedback, synchronous belt drive planetary gear train, ball spline drive*

1. Introduction

The production line switching and steering transmission device is composed of rotary motion mechanism and vertical motion mechanism. The mechanical principle of synchronous belt drive, planetary gear train, cylinder and ball spline is applied to transfer the products from production line a to production line B, or transfer the products from station 1 to station 2, so as to ensure the placement orientation of products and meet the working conditions of the production line, Realize automatic switching of production line. The transmission device realizes intermittent periodic movement based on the working movement beat of "descent- clamping-rising-rotation-descent-loosening-rising-rotation", which promotes the technical automation and intelligent efficiency of the production line.

2. Mechanical principle of transmission

The 90 ° automatic transposition load transfer device of products on the production line belongs to the translational turntable load transfer device. The overall design scheme of the load transfer device is shown in Figure 1. The load transfer device is composed of rotary motion mechanism and vertical motion mechanism, and the degree of freedom of the load transfer device is $F=3\times n-2\times P_L-P_H=3\times 4-2\times 3-4=2$. The number of degrees of freedom of the mechanism is the number of original motions of the mechanism. Two original motions are required for the 90 ° automatic transposition and load transfer device of a product on the production line. One motor drives the rotary motion mechanism to rotate, and one cylinder drives the vertical motion mechanism to move up and down in a straight line.

2.1. Rotary motion mechanism of transmission device

The rotary motion mechanism of the transmission device applies the mechanical principle of synchronous belt transmission and planetary gear train to design and develop a synchronous belt transmission planetary gear train mechanism[3], that is, the rotary motion mechanism is composed of synchronous belt transmission and synchronous belt transmission planetary gear train mechanism composed of synchronous belt transmission and upper and lower connecting arms, so as to ensure that the product rotates 90 ° counter clockwise and 90 ° clockwise, both revolution and rotation[3].

When the rotary motion mechanism works, the Datong step wheel is fixed on the frame and does not rotate. The motor drives the upper and lower connecting arms to rotate 90 ° counterclockwise. The connecting arm drives the small synchronous wheel to rotate 90 ° counterclockwise[4].Under the action of meshing force and friction, the synchronous belt rotates clockwise, driving the small synchronous wheel to rotate clockwise by 90 °.The small synchronous wheel has both revolution and rotation,

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forming the synchronous belt transmission planetary gear train mechanism. The product rotates synchronously through the ball spline shaft and air claw connected with the small synchronous wheel, so the product has both revolution and rotation, 90 ℃counterclockwise revolution and 90 ℃clockwise rotation. The product is transferred from production line A to production line B, from station 1 to station 2, to ensure the product placement orientation, meet the working conditions of the production line, and realize the automatic switching of the production line[4].

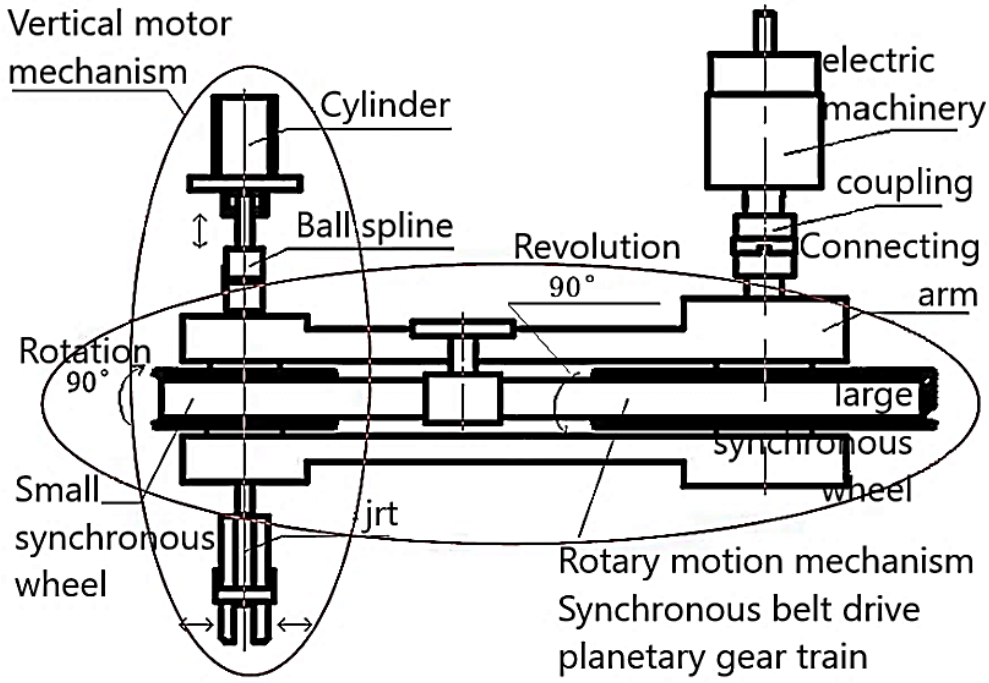

Figure 1: overall design scheme of switching steering transmission device of production line

Datong step wheel is fixed on the frame and does not rotate, that is, n_1=0(r/min), assuming that the number of teeth Z_1=40, the pitch diameter d_1=63.66(mm), and the outer diameter d_{01}=62.52(mm);The small synchronous wheel has both revolution and rotation, the number of teeth Z_4=20, the pitch diameter d_4=31.83(mm), and the outer diameter d_{03}=30.69(mm);The upper and lower connecting arms are respectively installed and connected with the Datong step wheel and the small synchronous wheel through the angular contact ball bearing and its rotating pair, but the large synchronous wheel is fixed and does not rotate. Driven by the upper and lower connecting arms and the synchronous belt drive, the small synchronous wheel has both revolution and rotation, forming the synchronous belt drive planetary gear train.

n_H is the speed of the upper and lower connecting arms. The reverse method is used to add a common speed "-n_H" around the connecting arm to the synchronous belt transmission planetary gear train. The transmission ratio of the synchronous belt planetary gear train mechanism is calculated by transforming the gear train. Assuming n_H=10(r/min),the mechanism rotates counterclockwise

ψ_H=90 °;because $i_{14}^{H}=(n_1-n_H)/(n_4-n_H)=(-1)^0\times(z_4/z_1)=20/40=0.5$, so $(n_1-n_H)/(n_4-n_H)=0.5$, that is, (0-10)/(n_4-10)=0.5, n_4=-10 (r/min);Because $i_{H4}=n_H/n_4=\psi_H/\psi_4$,so (10/-10)=90°/$\psi_4$,$\psi_4$=-90 °;that is, the small synchronous wheel rotates 90 ℃clockwise.

2.2. Transmission vertical motion mechanism

The vertical movement mechanism of the transmission device is composed of air cylinder and ball spline transmission technology. The air cylinder, as a prime mover, drives the ball spline shaft to move vertically up and down. The product is installed and connected to the ball spline shaft and air claw, so the product realizes vertical movement up and down. The ball spline is equipped with a bearing sleeve on the outer diameter of the spline outer cylinder to make it rotate or stop using the outer cylinder[1]. Therefore, one shaft can carry out two motion modes: rotation and straight line. Its precise linear motion and torque transmission are realized through the ball. Ball spline technology can ensure zero clearance in rotation direction and high positioning accuracy; Keep smooth in high-speed operation; The noise produced during operation is relatively low; Save space[1].

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3. Mechanical structure design of transmission device

The design engineering assembly drawing of the production line switching steering transmission device is shown in Figure 2.

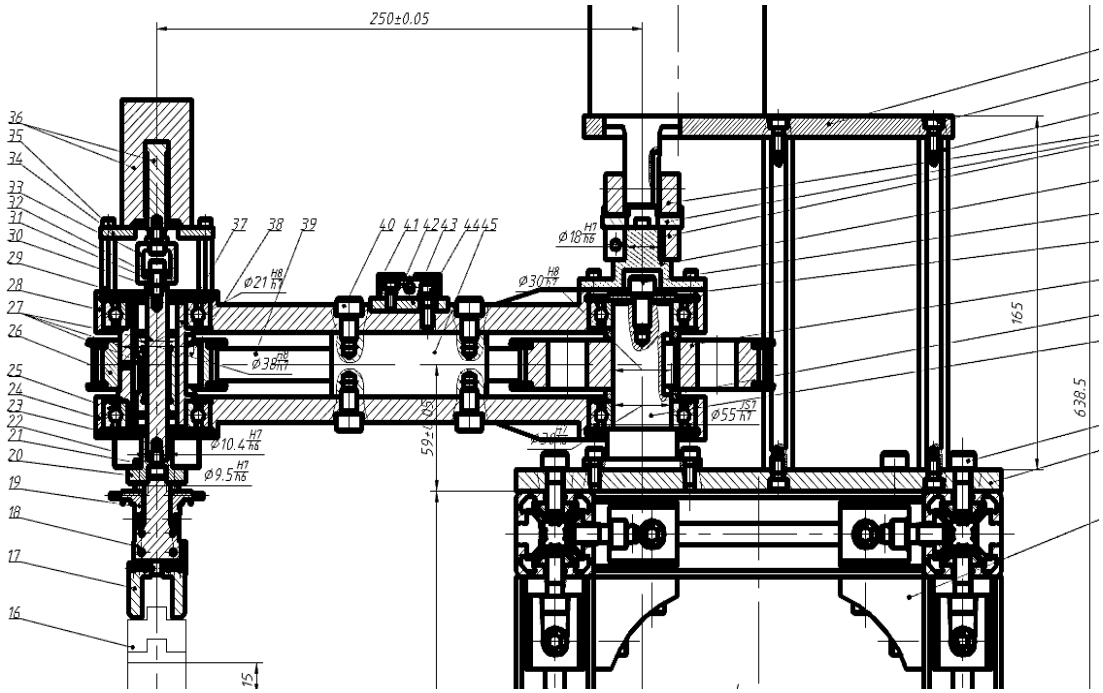

Figure 2: engineering assembly drawing of production line switching steering transmission device design

The three-dimensional diagram of the production line switching steering transmission device design is shown in Figure 3.

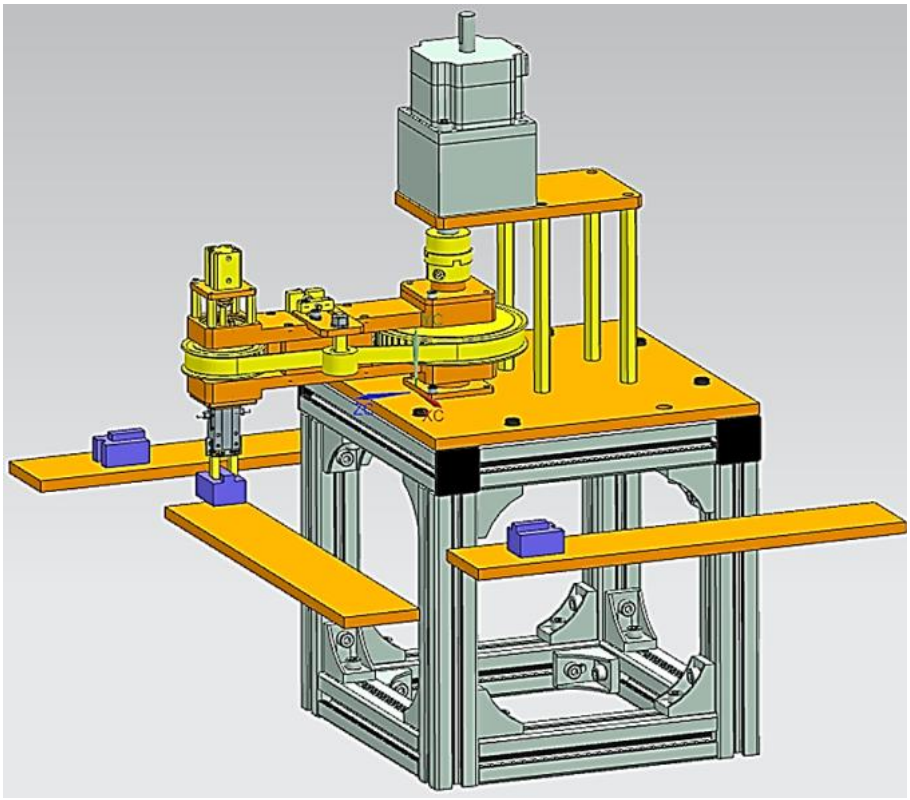

Figure 3: Three dimensional diagram of production line switching steering transmission device design

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4. Teaching practice of scientific research feedback

The transmission device is flexibly implanted into the teaching with the carrier of new technology and new process. See Table 1 for the teaching contents of the flexible implantation course, and finally form a comprehensive teaching case and textbook case. The development of teaching is arranged to students with visual and entrepreneurial work tasks. The first intuition for students is enterprise products, so that students can realize the value and significance of the project. Secondly, new technologies and processes are flexibly embedded in the course teaching, so that students can experience the beauty of machinery and the advancement of productivity, and improve students' interest and motivation. Thirdly, the student team completed the comprehensive engineering training project, experienced the whole process of mechanical transmission design, consolidated the knowledge and skills of mechanical principles and parts, received ideological and political education, and achieved the teaching objectives of the course[2].

Table 1: Contents of new technology carrier flexible implantation course

Serial number	Original content of the course	New technical content added	Curriculum thought and Politics
1	Drawing mechanism motion diagram	Draw the motion diagram of the design mechanism	Grasp the key of the problem
2	Calculating degrees of freedom	Calculate the design degrees of freedom	The philosophical relationship between restraint and freedom
3	Belt drive	Synchronous belt drive	Turn pressure into power, and transform advantages and disadvantages
4	Gear train	Planetary gear train	Divergent reverse thinking
5	Screw drive	Ball screw, ball spline	"Made in China" and "national confidence"
6	Shaft design	Expansion sleeve	Teamwork and close support
7	Bearing	Lead screw bearing, linear bearing, rolling bearing	Localization of wheel bearings of Luoyang high speed railway, Cultivate students' feelings of family and country
8	Standard parts, general parts and purchased parts	Motor,air cylinder, electric cylinder, suction cup, air claw, etc	Development law of spiral rise
9	Kinematics and dynamics calculation And transmission ratio distribution	Calculate the kinematics, dynamics parameters and transmission ratio distribution of the design	Cultivate students' correct design ideas and enhance their awareness of innovation and competition; Cultivate students' work style of being serious, rigorous, diligent, meticulous and excellence

In order to make the teaching cases more targeted and adaptive, it is necessary to study the decomposition level of the knowledge module of the mechanical principle and design course, screen, supplement and reorganize the course knowledge composition, and match the teaching cases with the knowledge points, abilities and teaching objectives; Refine the teaching requirements of mechanical principle and design and course design into smaller knowledge points, study a variety of teaching strategies and methods suitable for small and micro knowledge points, study and summarize the ability objectives of small and micro knowledge points, and make the course teaching more effective[2].

The transmission device is applicable to the course design of mechanical principle and design of mechanical engineering undergraduate specialty. After teaching synchronous belt drive, planetary gear train and ball spline drive, it is implemented as a project-based teaching [2].The teaching hours are 2 weeks. See Table 2 for the main teaching contents.

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Table 2: project teaching module 1 of production line switching steering transmission device design

<table>
<tr><td colspan="7">Task of project-based teaching module 1:
overall scheme design of production line switching steering transmission device</td></tr>
<tr><td colspan="2">Teaching class</td><td>Mechanical Engineering (undergraduate)</td><td>Lecture course</td><td>Course design of mechanical principle and design</td><td>Credit hours</td><td>8</td></tr>
<tr><td rowspan="4">teaching target</td><td>Capability objectives</td><td colspan="5">1. Have the ability to determine the performance parameters and functional indicators of the transmission device;
2. Have the ability to draw the overall scheme design of the transmission device.</td></tr>
<tr><td>Knowledge objectives</td><td colspan="5">1. Master the mechanical principle of planetary gear train driven by synchronous belt;
2. Master the mechanical principle of ball spline transmission.</td></tr>
<tr><td>Curriculum thought and Politics</td><td colspan="5">1. The course contains rich ideological and political education elements (patriotism, great country craftsman spirit, national pride, etc.);
2. Be familiar with the synchronous belt drive planetary gear train, ball spline drive and manufacturers, encourage students to select excellent domestic products and celebrate patriotism;
3. Be familiar with mechanical design and national standards for parts, and strictly implement them;
4. Establish a work style of teamwork, mutual learning, serious research and excellence.</td></tr>
<tr><td>Ability training case</td><td colspan="5">1. Determine the performance parameters and functional indexes of the transmission device;
2. Draw the overall design scheme of the transmission device.</td></tr>
<tr><td>teaching material</td><td colspan="5">1.Wangzhe, liumeihua, editor in chief.Fundamentals of mechanical design (less class hours), Beijing China Machine Press (6th Edition)</td></tr>
<tr><td colspan="2">Teaching steps</td><td colspan="3">Teaching content</td><td>Teaching means and instructions</td></tr>
<tr><td rowspan="2">Preparation before class</td><td>Teacher complete</td><td colspan="3">1. Multimedia courseware,3D and video animation of transmission device,and task arrangement on superstar platform;
2. Understand the learning situation, select engineering cases, and create a classroom atmosphere suitable for discussion in teaching;
3. Give students thinking questions in advance:
(1) Working principle and form of synchronous belt transmission planetary gear train;
(2) Working principle and form of ball spline transmission.</td><td rowspan="2">1. Flipping classroom teaching mode: send case materials to students in advance, list thinking problems, let students consult materials, collect information, think and explore, and initially form case analysis and solutions.</td></tr>
<tr><td>Student completion</td><td colspan="3">1. Mechanical principle of planetary gear train driven by synchronous belt;
2. Mechanical principle of ball spline transmission.</td></tr>
<tr><td colspan="7">Classroom teaching implementation</td></tr>
<tr><td colspan="2">Stage</td><td>Steps and contents</td><td>Ideological and political content</td><td colspan="2">Teaching devices</td></tr>
<tr><td colspan="2">1. Determine the overall design scheme of the transmission device
(2.5 Class hours)</td><td>1. The transmission device is composed of rotary motion mechanism and vertical motion mechanism. Analyze the mechanical principle, structure, parameters and action of the transmission device, interference inspection and simulation analysis;
2. The rotary motion mechanism adopts synchronous belt transmission planetary gear train;
3. The vertical moving mechanism adopts ball spline transmission;
4. Draw the motion diagram of the transmission mechanism.</td><td>1.Grasp the essence of the problem and highlight the key factors through analysis.</td><td colspan="2">1. Drawing method: teachers demonstrate and lead students to draw the motion diagram of transmission mechanism and determine the overall design scheme;
2. Presentation method: students explain the motion diagram of transmission mechanism;
3. Online and offline mixed teaching.</td></tr>
<tr><td colspan="2">2. Determine the action beat of the transmission device
(2 Class hours)</td><td>1. Product:adapter,made of plastic, rubber, glass and aluminum, with size of W40×D30×H26, weight about 0.5kg;
2. Action and beat:descend(0.75s)→clamp the workpiece(0.75s)→rise(0.75s)→+90°revolution,-90°rotation(1s)→ descend(0.75s)→loosen the workpiece(0.75s)→rise(0.75s). The production beat is 5.5s in total;
3. Production line configuration: "one for two" to meet the production beat and realize balanced production.</td><td rowspan="2">1. Have a high sense of responsibility for each calculation data. A data error will lead to the error of the whole design result, and establish a serious, rigorous and meticulous work attitude and style;
2.Calculate in strict accordance with the design criteria and cultivate the sense of responsibility and standard.</td><td colspan="2">1. Calculation method: the teacher demonstrates and leads, and the students analyze the action and beat of the transmission device and determine the timing distribution of each beat;
2. Display method: Video Explanation of transmission device production line configuration, and explanation of "one driven by one" and "one driven by two".</td></tr>
<tr><td colspan="2">3. Determine the performance parameters of synchronous belt transmission planetary gear train
(1.5 Class hours)</td><td>(1) Revolution speed 90°/s (i.e.π/2 (rad/s)),n=15r/min, time t=1s;
(2) Rotation speed 180°/s (i.e.π(rad/ s)),n=30r/min,time t=1s;
(3)The mechanism rotates 90 °counterclockwise and 90 ° clockwise, which forms a synchronous belt transmission planetary gear train;
(4) The ratio of synchronous gear teeth is set to 1:2.</td><td colspan="2">1. Three dimensional animation display of planetary gear train mechanism of synchronous belt transmission, which is discussed by teachers and students or students through differentiated grouping;
2. Flipped classroom teaching mode: students consult materials, collect information, think and explore, and initially form case analysis and solutions.</td></tr>
<tr><td colspan="2">4. Determine the performance parameters of ball spline transmission(2 Class hours)</td><td>(1)Lifting stroke:10-15mm,lifting speed: 20mm/s,Lifting time:t=0.5s to t=0.75s;
(2) Air claw stroke:3-5mm on one side, speed v=4-6.67mm/s.</td><td>1. Encourage students to learn the national standards of mechanical design and parts and strictly implement them.</td><td colspan="2">1. Three dimensional animation display of ball spline drive, teacher-student discussion or student discussion;
2. Integrate ideological and political education to promote learning interest and enthusiasm to participate in classroom discussion.</td></tr>
</table>

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5. Conclusions

This teaching case can be used as a more comprehensive and standardized engineering design training for students majoring in mechanical engineering to cultivate students' ability to solve practical engineering problems. Case teaching can be combined with mechanical science and technology competitions such as the National College Students' mechanical innovation design competition and the National College Students' engineering training comprehensive ability competition. The annual project-based case teaching can be determined according to the theme of the science and technology competition (such as carbon free car, carton packaging machine, coin sorter, etc.), and excellent design works and students can be selected for competition. The mechanical science and technology competition not only reflects the needs of the current society and enterprises, but also highlights the development direction of science and technology in the future. It has higher requirements for the reserve of students' professional knowledge and the application of comprehensive ability. It can stimulate students' innovative driving force, improve the level of engineering design and practical ability, and improve the teaching effect of the course.

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(2) This paper is the research results of the comprehensive research project of R & D back feeding teaching of Wenzhou Polytechnic " Research on R & D and back feeding teaching of production line switching and load transfer device " (WZYYFFP2021009).

(3) This paper is the research result of the teaching construction and teaching reform research project "Design of switching steering transmission device for production line"(WZYJGSX2113)of Wenzhou Polytechnic.

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