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Research on the velocity variation method for precise motion transmission

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Abstract: A wide range of speed or torque is required for some types of robots. It is possible for the motors to realize some range of speed or torque but the range is limited to some degree considering the size, weight and cost of the motors. Therefore it is impossible to realize those requirements if a reduction device with a ratio is used. Velocity variation devices using gears are widely used in the industrial fields. However, the motion transmission from the input shaft to the output shaft is interrupted during the velocity ratio variation process. In order to solve this problem, velocity ratio variation method that can transmit motion precisely in the changing process of velocity ratio is proposed in this report. The process of changing the velocity ratio in the proposed method is developed and the experimental device that can change the velocity ratio is constructed. The experimental results show that the proposed device can transmit motion precisely between the input shaft and the output shaft while changing velocity ratio and it is confirmed that the proposed method is effective to realize the precise motion transmission.

Keywords: ratio variation

I. INTRODUCTION

A variety of robots usually use some reduction devices with high ratio because they must support the high load in their motion and they require high torque to accomplish it. The reduction devices decrease the velocity and therefore the velocities of the robots are limited to some extent. However, a wide range of speed or torque is required for some types of robots. Moving robots used in the industrial fields are required to realize both outputting a large force when they carry loads and moving with high velocity when they move to the destination in order to shorten the moving period. It is possible for the motors to realize some range of speed or torque but the range is limited to some degree considering the size, weight and cost of the motors. Therefore it is impossible to realize those requirements if the reduction device with high ratio is used. If the velocity ratio between input and output shafts is changed, a wide range of speed or torque can be realized even if the ability of the motor is limited in speed or torque. Velocity variation devices using gears are widely used in the industrial fields and there are many research reports in terms of device control and mechanisms. Cylindrical gears such as spur gears have advantages in high torque capacity, precise rotation transmission and high efficiency and that is the reason why cylindrical gears such as spur gears are used in a variety of devices. In a geared transmission, it is needed to change the working gear pairs to vary the velocity ratio of the transmission. However, the motion transmission from the input shaft to the output shaft is interrupted during this process. Therefore it is impossible to change the velocity ratio while transmitting rotation between the input shaft and the output shaft. In order to solve this problem, velocity ratio variation method that can transmit motion precisely in the changing process of velocity ratio is proposed in this report. Design of the experimental device of the proposed velocity variation method is carried out. The process of changing the velocity ratio in the proposed method is developed and the experimental device that can change the velocity ratio is constructed. The experimental results show that the proposed device can transmit motion precisely between the input shaft and the output shaft while changing velocity ratio and it is confirmed that the proposed method is effective to realize the precise motion transmission.

II. VELOCITY VARIATION METHOD

Figure 1 shows the schematic model of the basic structure of the velocity variation device. This device accommodates two shafts, i.e. input shaft and output shaft, and three gear pairs A, B and C, and three clutches T_A, T_B and T_C. The gear pairs A and B are composed of typical circular gears, and gear pair C is composed of noncircular gears. Gears A_o, B_o and C_o can be connected to the output shaft by engaging the clutches T_A, T_B and T_C, and then they rotate together with the output shaft. In contrast, gears A_i, B_i and C_i are

fixed to the input shaft, which rotate at the same speed as the input shaft.

Suppose that the velocity ratio of the gear pair A is r_A, and that of the gear pair B is r_B. In the pitch curve of noncircular gear pair C, there are four sections as shown in Fig.2. The pitch curve of the noncircular gear pair C is partly same as that of gear pair A, and partly same as that of gear pair B. Those parts of pitch curve are smoothly connected. In the four sections, the velocity ratio is constant at r_A, it changes to r_B, it is constant at r_B, and it changes to r_A respectively.

The proposed velocity ratio variation process from r_A to r_B is explained. Under the condition that the clutch T_A is engaged, and the other clutches are disengaged, the velocity ratio is r_A. When the meshing of gear pair C comes into the section corresponding to r_A, the clutch T_C is engaged, and, after the engagement of clutch T_C, the clutch T_A is disengaged. Then the meshing of gear pair C transits to the section corresponding to r_B. In the section corresponding to r_B, the clutch T_B is engaged, and, after the engagement of clutch T_B, the clutch T_C is disengaged. Through this process, the transition from r_A to r_B is completed. At all steps in this process, at least one of the clutches is engaged. Therefore, the rotational motion is precisely transmitted from the input shaft to the output shaft.

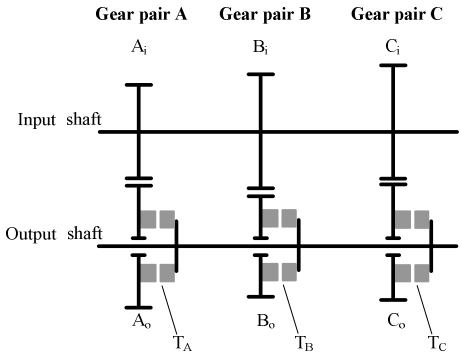

Fig.1. Structure of the Velocity Ratio Variation Device

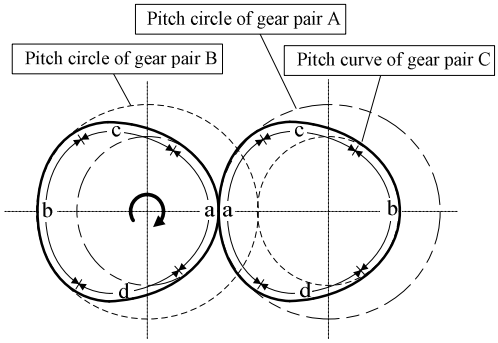

Fig.2. Pitch curve of gear pair C

III. EXPERIMENT

The experimental device based on the proposed ratio variation method is designed and constructed. Experiment of the velocity ratio variation from r_A to r_B is carried out. The experimental result is shown in Fig.3. The velocity ratio is calculated from the rotary encoder attached to the input and output shafts. The designed value of r_A is 0.8, and that of r_B is 1.25. Figure 3 shows that the velocity ratio is smoothly changed during the varying process. In the conventional geared transmission, it is impossible to transmit the rotation during the velocity ratio varying process. Thus, the velocity ratio might become zero or negative in the conventional transmission. In contrast, the velocity ratio in Fig.3 dose not become zero or negative. This result indicates that the proposed system solves this problem.

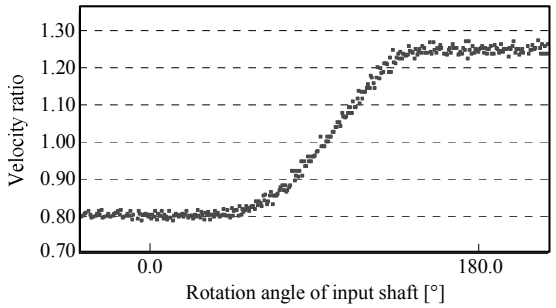

Fig.3. Experimental result when the ratio is changed

VI. CONCLUSION

In this research, the velocity variation method that realizes precise transmission of the rotation from the input shaft to output shaft, is proposed. The experimental device based on the proposed method is constructed, and the fundamental experiment is carried out. The result shows that the proposed device is capable to transmit rotation during the velocity ratio varying process.

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