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Design of the transmitting device for motion control of robots

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Abstract: 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. Moving robots used in the industrial fields are required to realize outputting a large force in some cases, and moving with high velocity in other cases. Therefore a velocity variation system is an ideal method in which the velocity ratio between input and output shafts is changed. However, the motion transmission from the input shaft to the output shaft is interrupted during the velocity ratio variation process in the conventional velocity variation system. In order to solve this problem, velocity variation method that can transmit motion precisely is proposed. The principle of this velocity ratio variation method is explained and its components are considered. The required conditions to the design of the transmitting element of this variation device are clarified in order to realize transmitting motion precisely. By this analysis, it is confirmed that the proposed ratio variation method can change the velocity ratio while transmitting the motion precisely between the input shaft and the output shaft.

Keywords: ratio variation

I. INTRODUCTION

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. 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. Therefore a velocity variation system is an ideal method in this point. Velocity variation devises using gears are widely used in the industrial fields. Cylindrical gears such as spur gear 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 of the transmission. However, the motion transmission from the input shaft to the output shaft is interrupted during this process. This leads to an important problem in the field of robots. In order to solve this problem, velocity variation method that can transmit motion precisely is proposed in our research. In this method, each transmitting element must satisfy each condition, which is different among each element. The required conditions to the design of the transmitting element are clarified in order to realize transmitting motion precisely. By this analysis, it is confirmed that the proposed ratio variation method can change the velocity ratio while transmitting the motion precisely between the input shaft and the output shaft.

II. VELOCITY VARIATION METHOD

In the proposed velocity ratio variation method, there are two shafts, i.e. input shaft and output shaft, three gear pairs A, B and C, and three tooth clutches T_A, T_B and T_C as shown in Fig.1. 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. In contrast, gears A_i, B_i and C_i are fixed to 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. 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.

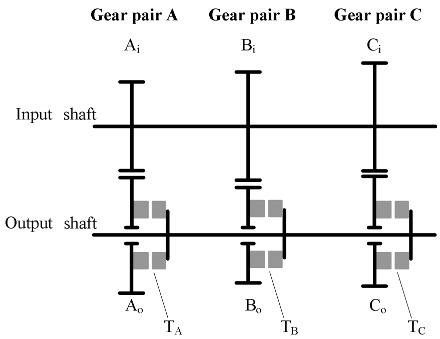

Fig.1. Structure of the Velocity Ratio Variation Device

III. CONDITIONS OF TRANSMITTING ELEMENTS

In the proposed velocity ratio variation method, tooth clutch is used to transmit the motion precisely. However, to use the tooth clutch, it is required that the dog teeth on the output shaft side and that on the gear side are in appropriate condition so that they can be meshed. Suppose the numbers of the dog teeth of tooth clutches T_A, T_B and T_C are n_d. The case that the velocity ratio is changed from r_A to r_B, and returned form r_B to r_A is considered. At the initial state, all of tooth clutches T_A, T_B and T_C can be engaged. In addition, gear pair C meshes in the middle of the section corresponding to velocity ratio of gear pair A.

First, suppose that the input shaft is rotated N_A times, and then the velocity ratio variation process starts, in other words, clutch T_C is engaged, where N_A is natural number. After the rotation of N_A, the difference between the rotational angle of the output shaft and that of gear C_o is $2\pi N_A(r_A - 1)$. To engage clutch T_C, this value must be integral multiple of pitch between the teeth of the clutch. This condition is expressed as follows, where J_1 is arbitrary integer.

$$2\pi N_A(r_A - 1) = \frac{2\pi J_1}{n_d} \tag{1}$$

Secondary, the output shaft is rotated by π, and then clutch T_B is engaged. To engage clutch T_B, considering the difference between the rotational angle of the output shaft and that of gear B_o, following condition must be satisfied, where J_2 is arbitrary integer.

$$2\pi N_A(r_A - r_B) + \pi(1 - r_B) = \frac{2\pi J_2}{n_d} \tag{2}$$

Thirdly, the output shaft is rotated N_B times, and then clutch T_C is engaged. To engage clutch T_C, considering the difference between the rotational angle of the output shaft and that of gear C_o, following condition must be satisfied, where J_3 is arbitrary integer.

$$2\pi N_B(r_B - 1) = \frac{2\pi J_3}{n_d} \tag{3}$$

Finally, the output shaft is rotated by π, and then clutch T_A is engaged. To engage clutch T_A, considering the difference between the rotational angle of the output shaft and that of gear A_o, following condition must be satisfied, where J_4 is arbitrary integer.

$$2\pi N_B(r_B - r_A) + \pi(1 - r_A) = \frac{2\pi J_4}{n_d} \tag{4}$$

These equations are organized, and the following conditions to the design of the transmitting element are clarified, where Z is set of integer.

$$\left.\begin{array}{l} n_d(r_A - r_B) \in Z \\ \dfrac{n_d(1 - r_A)}{2} \in Z \\ \dfrac{n_d(1 - r_B)}{2} \in Z \end{array}\right\} \tag{5}$$

VI. CONCLUSION

In the system proposed in our research, precise transmission of the rotation from the input shaft to output shaft is realized. The required conditions to the design of the transmitting element are clarified. It is confirmed that the proposed ratio variation method can change the velocity ratio while transmitting the motion precisely between the input shaft and the output shaft.

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