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Geometrical analysis and design of motion transmitting element for mobile vehicles

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Abstract: The range of speed or torque of motors is limited to some degree. Industrial vehicles working in factories are required to realize both outputting a large force when they carry loads and moving with high velocity when they move to the destination. However, it is impossible to realize those requirements if the conventional reduction devices is used. Velocity variation devices using gears are widely used to change the velocity ratio between input and output shafts. 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 variation method that can transmit motion precisely is proposed, in which a motion transmitting element is used. In this report, the geometrical analysis method of the motion transmitting element is proposed, and the expressing method of the curve using dispersed points is proposed and the calculation method of the inclination and the distance concerning the curve is developed. Based on the proposed method, the geometrical form of the transmitting element is analyzed.

Keywords: ratio variation

I. INTRODUCTION

The range of speed or torque of motors is limited to some degree considering the size, weight and cost of the motors. Industrial vehicles 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. 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. 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 changing process. Therefore it is impossible to change the velocity while transmitting rotation between the input and output shafts. In order to solve this problem, velocity variation method that can transmit motion precisely is proposed in our research, in which a motion transmitting element is used. In this report, the geometrical analysis method of the motion transmitting element is proposed. A variety of motion characteristics of the motion transmitting element are possible but it is necessary to obtain the inclination of each point on the curve and the distance between the points on the curve in order to calculate the geometrical form of the motion transmitting element. The expressing method of the curve using dispersed points is proposed and the calculation method of the inclination and the distance concerning the curve is developed. Base on the proposed method, the geometrical form of the transmitting element is analyzed.

II. VELOCITY VARIATION METHOD

In the proposed velocity variation method, as shown in Fig.1, there are 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. When the clutches T_A is engaged, the gear pair A works and the velocity ratio of gear pair A is realized. When the clutches T_B is engaged, the gear pair B works and the velocity ratio of gear pair B is realized. In the change of the working gear pair from gear pair A to gear pair B, the clutches T_C is engaged, and gear pair C works.

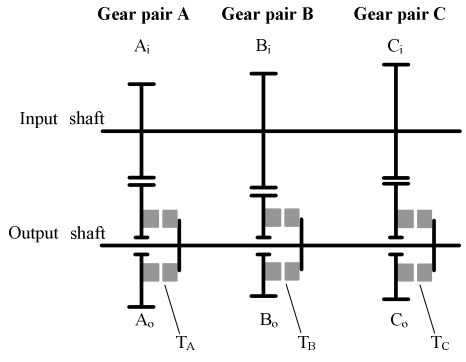


Fig.1. Structure of the Velocity Ratio Variation Device

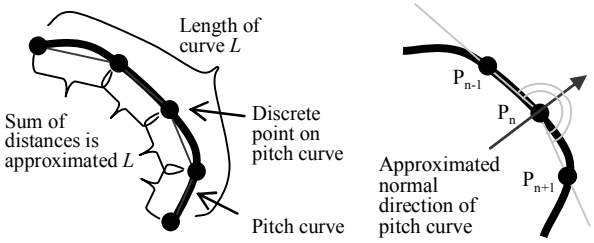
In the pitch curve of noncircular gear pair C, there are four sections. The pitch curve of the noncircular gear pair C is partly same as that of gear pair A, and partly same as that of gear pair B. Those parts of pitch curve are smoothly connected. Therefore, the velocity ratio can be changed from that of gear pair A to that of gear pair B while gear pair C works. Therefore, the rotational motion is precisely transmitted from the input shaft to the output shaft.

III. ANALYZING METHOD OF GEOMETRICAL PROPERTY

The noncircular gear has such a complex profile form that it is difficult to analyze its geometrical form. An analyzing method of geometrical property of noncircular gear is developed. The profile of a gear is generated by the relative motion between the tool and the work material along the pitch curve of the gear. Therefore, the profile of the gear can be calculated by investigating the locus of the profile of the tool. If the pitch curve of the gear is expressed by a mathematical function, the length of the pitch curve of the gear L and the angle ϕ of the normal direction of the pitch curve can be obtained, which are essential to calculate the locus of the profile of the tool. However, it is impossible to express any pitch curve by the mathematical function. Therefore, to deal with various forms of noncircular gears, a method to express the pitch curve by the set of the discrete points is proposed. In this method, the pitch curve of a gear is composed of the set of the discrete points, and corresponding profile is calculated based on the points. The length L and the angle ϕ are calculated using approximation. Figure 2 shows the concept of the approximation. The length L is approximated by the sum of the distances between the discrete points on the pitch curve as shown in Fig. 2(a). The angle ϕ of the normal direction on point P_n is approximated by that of the bisector of the angle between the line passing through points P_{n-1} and P_n, and that through points P_n and P_{n+1}. Suppose that the coordinate for the discrete points on the pitch curve are (x_i, y_i) (i=0, 1, 2, ...). The length L and the angle ϕ corresponding to the pitch point (x_n, y_n) are approximated as follows.

$$L = \sum_{i=1}^{n} \sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2} \tag{1}$$

$$\phi = \frac{\tan^{-1}\dfrac{y_{n+1} - y_n}{x_{n+1} - x_n} + \tan^{-1}\dfrac{y_n - y_{n-1}}{x_n - x_{n-1}}}{2} - \frac{\pi}{2} \tag{2}$$



(a) Approximation of length of pitch curve (b) Approximation of normal direction

Fig. 2 Approximation in the proposed method

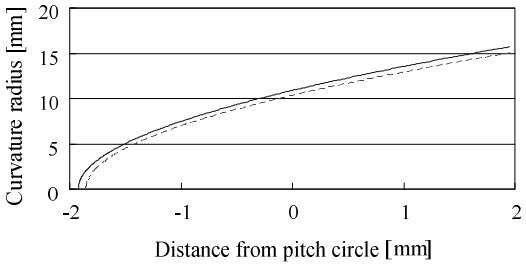


Fig. 3 Curvature radius of profile of gear C

Based on the above discrete point method, the numerical analysis program to calculate the profile of the noncircular gear is developed. Figure 3 shows curvature radius of two different teeth of a noncircular gear. The profile of the noncircular gear is calculated without any problem by using the developed program. Figure 3 shows that there is a different of form between two teeth.

VI. CONCLUSION

In this research, the velocity ratio variation device that can realize precise transmission of the rotation from the input shaft to output shaft is treated. The expressing method of the curve of the motion transmitting element using dispersed points is proposed and the calculation method of the inclination and the distance concerning the curve is developed.

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