Deviation Modeling of RV Retarder Parts Based on Probability Statistics and Vector

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Abstract: **RV reducer is a high precision and efficient new transmission, widely used in the joints of the robot. Size deviation directly affects the accuracy of RV reducer drive, so the research bias RV reducer expression and its effect on driving accuracy has become the focus of this paper. In this paper, the components and transmission structure of RV reducer are analyzed to classify the deviations. According to the types of deviations, mathematical models of deviation are established to establish mathematical models of deviations. Finally, the input shaft is taken as an example to verify the validity of the model.**

Keywords: RV reducer, Deviation modeling, Transmission accuracy

I. INTRODUCTION

RV reducer as the industrial robot joint with high precision gear drive core device, the domestic chemical industry robot plays an important and far-reaching significance. Since the reducer was researched and prepared, researchers at home and abroad made a great deal of researches on the influencing factors of the transmission accuracy and how to improve the transmission accuracy. The earliest foreign scholar Blanche et al. [1-2] started with geometry, established geometric model, carried out systematic error analysis and experimental research, and provided research ideas for future generations to do related research. Japan's Nikko and so on [3-5] from the quality of the spring equivalent to establish the equivalent mass spring model to derive the RV reducer drive formula, how to improve the accuracy of the RV reducer drive provides a feasible method. Literature [6] started with the transmission chain error, studied the transmission error of gear drive and two-stage cycloidal planetary gear transmission. It has the advantages of high transmission efficiency, stable transmission, strong carrying capacity, compact structure and long service life. A planetary gear drive is composed of the input shaft, the involute center wheel, the three mutual 120 degree involute planetary gear, three crankshaft, bearings, planet carrier composition; two-stage cycloidal pin gear transmission is composed of two A 180-degree interaction of each cycloid wheel, pin gear, output disk composition, the planet carrier and the output plate bolted together with the speed of rotation, by bolts to the housing fixed to the location to be installed. RV reducer, and concluded that the transmission error mainly comes from the second-stage reduction mechanism. Reference [7] aimed at the static hysteresis of RV reducer influencing factors, the establishment of a matrix mathematical model of static hysteresis analysis, and derive the error distribution mathematical model. Literature [8] According to the mathematical model of RV reducer, taking into account the various parts machining error, assembly error and bearing clearance error of the combination of transmission accuracy, using numerical differential method to obtain the sensitivity of each combination to find out the impact The main error of the system transmission accuracy and its influence law. Literature [9] classifies the sources of RV retarders. Combined with the digraph, a directed graph model reflecting the transfer of RV reducer bias is established. Although predecessors have done a lot of research on the precision of RV reducer transmission, there are still some shortcomings in the modeling of deviations of RV reducer components.

Based on the mathematical method of probability statistics and vector representation, this paper establishes the deviation model of the deviation expression of the components of RV reducer. The specific research contents are as follows.

II. DEVIATION CLASSIFICATION

2.1 RV reducer components and their transmission principle

RV reducer is a new type of transmission mechanism composed of a first-class planetary

RV reducer transmission principle is through an involute planetary gear meshing transmission to complete the first deceleration, planetary gear fixed on the crankshaft, crankshaft driven together around the central wheel revolution at the same time rotation, crankshaft rotation with the swing The wire wheel rotates, meanwhile, the cycloidal wheel and the pin gear make meshing rotation to complete the second deceleration. Figure 1 for the RV reducer structure diagram.

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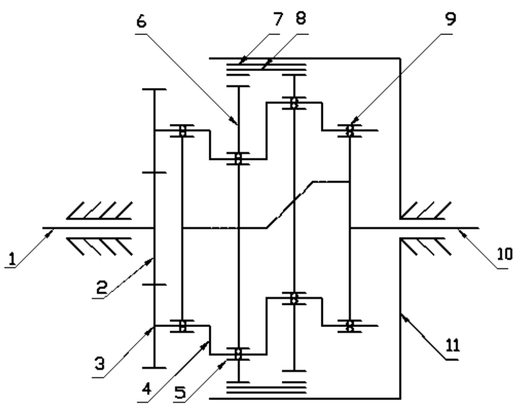

Figure 1 RV reducer structure diagram

1 Input shaft 2 Center wheel 3 Planetary gear 4 Crankshaft 5 Bearing I6 Cycloid gear 7-pin gear housing 8-pin gear pin 9 Bearing II10 Output plate (output shaft) 11 Housing

2.2 Deviation classification

Based on the previous analysis of the components that make up an RV reducer and its transmission principle, the deviations of the components can be classified as follows.

(1) The deviation of the geometric position of the part is recorded as the first type of deviation E1, which can be analyzed from two aspects. First, the deviation of the geometric positioning of the part is expressed by ε, such as the deviation of the diameter dimension of the input shaft, the input shaft straight line and the center wheel axis Concentricity deviation; Second, the geometric deviation of the part is expressed as θ, such as the input shaft axis and the crankshaft axis parallelism deviation.

(2) The geometric deviation of the part is recorded as the second type of deviation E2, including flatness deviation, cylindricity deviation, straightness deviation, line profile deviation, etc., such as the profile of the cycloidal line surface.

(3) The assembly position deviation of parts is recorded as the third type of deviation E3, which can be divided into two aspects: firstly, the position of the parts is changed and then the deviation occurs due to the clamping positioning; second, due to the existence of the clearance fit, Uncertain, then poor students.

Part assembly position deviation and geometric position deviation, geometric deviation of three kinds of deviations produce coupling, together, and ultimately affect the RV reducer drive accuracy.

Figure 2 shows the RV reducer two stage cycloid gear reduction simplified simplified plan, Figure 2 hole position deviation for the first type of deviation E1; Figure 2 axis hole cylindrical deviation for the second type of deviation E2; Figure 2 axial hole clearance with the location of the parts led to the uncertainty of the third type of deviation E3.

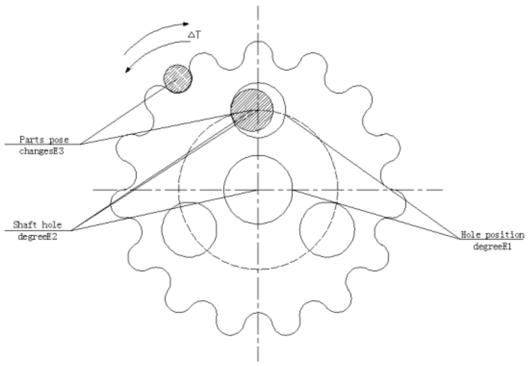

Figure 2 Three examples of bias expression

III. DEVIATION MODEL

Based on the above classification of deviations, a unified multi-deviation expression model of parts and components is established by using the method of probability and statistics and vector method, which includes: multivariate deviation statistics model and multivariate deviation vector expression model.

3.1 Multiple deviation statistical model

The construction of multivariate deviation statistical model based on probability statistics is the basis for constructing multivariate deviation statistics, cumulative deviation analysis and assembly accuracy prediction. Assuming the components of the deviation vector obey the normal distribution in all directions:

$$\Delta u \sim (u_1, S_1), \Delta v \sim (u_2, S_2), \Delta w \sim (u_3, S_3),$$

$$\Delta\alpha \sim (u_4, S_4), \Delta\beta \sim (u_5, S_5), \Delta\gamma \sim (u_6, S_6) \quad (1)$$

Where u_i represents the mean, s_j represents the variance, $1 \le i, j \le 6$.

The multiple deviation statistical model is:

$$F(E_i) = (2\pi)^{-3}|B|^{-1/2} e^{-1/2 * (E_i - u)^T B^{-1} (E_i - u)} \quad (2)$$

In the formula:

$$u = (u_1, u_2, u_3, u_4, u_5, u_6) \quad (3)$$

Means the mean vector, B indicates that the covariance matrix is:

$$B = \begin{pmatrix} S_{11} & S_{12} & S_{13} & S_{14} & S_{15} & S_{16} \\ S_{21} & S_{22} & S_{23} & S_{24} & S_{25} & S_{26} \\ S_{31} & S_{32} & S_{33} & S_{34} & S_{35} & S_{36} \\ S_{41} & S_{42} & S_{43} & S_{44} & S_{45} & S_{46} \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & S_{56} \\ S_{61} & S_{62} & S_{63} & S_{64} & S_{65} & S_{66} \end{pmatrix} \quad (4)$$

In the formula: $S_{ij} = \sigma_{ij}$, $1 \le i, j \le 6$.

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3.1.1Deviation domain expression

Assuming that the deviation domain coordinate system is fixed with the geometric coordinate system, the location information of the deviation domain location is the same as the deviation location information and the direction information. The size of the deviation and the boundary, with the type of functional geometry, upper and lower deviation limit. Figure 3 shows the plane deviation domain expression:

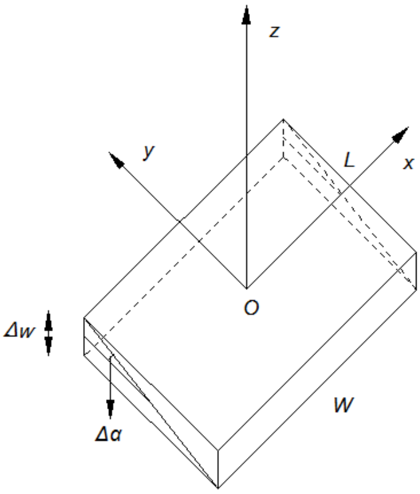


Figure 3 Plane deviation domain expression

3.2 Multiple deviation vector expression model

In the three-dimensional coordinate system based on vector method to build components of multiple deviation vector expression model, from the distance and angle of two aspects, six dimensions of expression deviation, multivariate deviation vector expression model shown in Figure 4, Figure 5 is the part distance deviation vector expression model , Figure 6 is a part angle deviation vector expression model.

Multivariate deviation vector expression model formula is:

$$\varphi = \varepsilon + \theta \qquad (5)$$

Where ε represents the deviation vector caused by distance, θ represents the angle caused by the deviation vector.

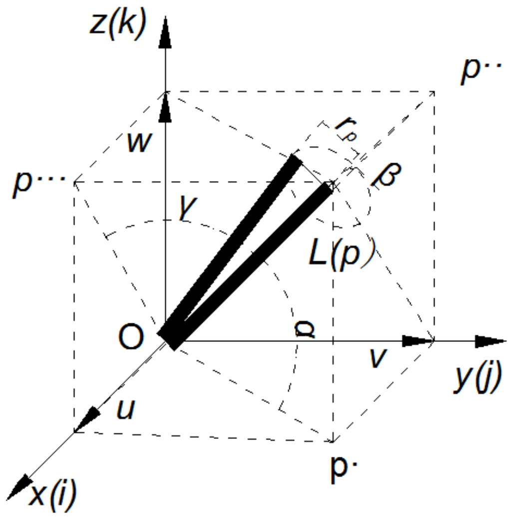


Figure 4 Multiple deviation vector representation model

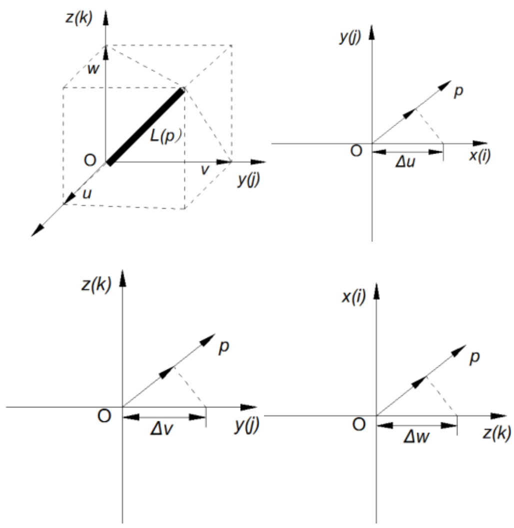
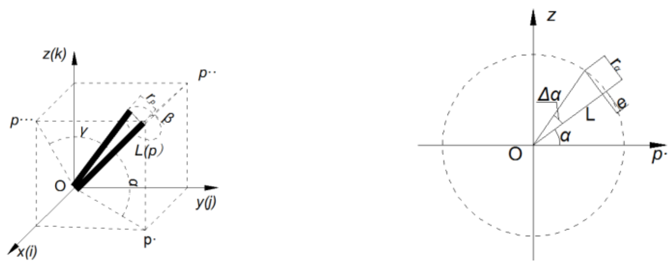


Figure 5 Parts distance deviation vector expression model

Part distance deviation vector expression model mathematical formula:

$$\varepsilon = \Delta u(ip) + \Delta v(jp) + \Delta w(kp) \qquad (6)$$



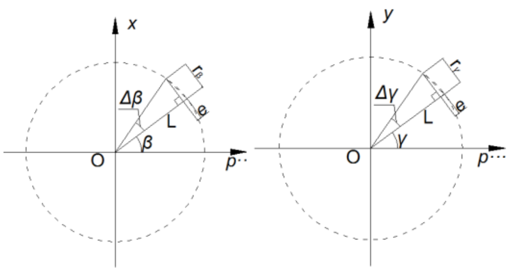


Figure 6 Part angle deviation vector expression model

Part angle deviation vector expression model mathematical formula is:

$$\theta = \Delta\alpha r_{\Delta\alpha}(p) + \Delta\beta r_{\Delta\beta}(p) + \Delta\gamma r_{\Delta\gamma}(p) \qquad (7)$$

In the formula : $r_{\Delta\alpha}$、$r_{\Delta\beta}$、$r_{\Delta\gamma}$Indicates the action radius of angle, $r = \mathcal{L} \times \sin\omega$ (8)

IV. EXAMPLE DEMONSTRATION

Based on the establishment of the multivariate deviation expression model, the validity of the model is verified by taking the input shaft deviation as an object of study. Figure 7 shows the deviation expression of the input shaft in the three-dimensional coordinate system.

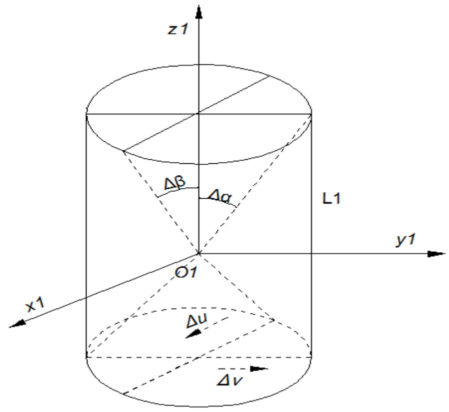


Figure 7 Deviation expression of input shaft in three-dimensional coordinate system

4.1 Based on Probability Statistics to Build Multivariate Deviation Statistical Model

Assuming the diameter of the input shaft size deviation of the upper and lower tolerance are: τ_1、τ_2,$\Delta\tau = \tau_1 - \tau_2$. Deviation vectors are:

$$\begin{cases} \max\Delta u = \max\Delta v = \Delta\tau \\ \max\Delta\alpha = \max\Delta\beta = \frac{2\Delta\tau}{\mathcal{L}_1} \\ \Delta w = \Delta\gamma = 0 \end{cases} \qquad (9)$$

The expectation from (3) is:

$$u = \left(\frac{\max\Delta u}{2}, \frac{\max\Delta v}{2}, 0, \frac{\max\Delta\alpha}{2}, \frac{\max\Delta\beta}{2}, 0\right) (10)$$

The constraint is:

$$\begin{cases} \Delta u + \frac{\Delta\beta * \mathcal{L}_1}{2} \le \Delta\tau \\ \Delta v + \frac{\Delta\alpha * \mathcal{L}_1}{2} \le \Delta\tau \end{cases} \qquad (11)$$

Each variance obtained were as follows:

$$\begin{cases} \sigma_1 = \sigma_2 = \frac{\Delta\tau}{6} \\ \sigma_3 = \sigma_6 = 0 \\ \sigma_4 = \sigma_5 = \frac{\Delta\tau}{3\mathcal{L}_1} \end{cases} \qquad (12)$$

From (4) the covariance matrix is obtained:

$$B = \begin{pmatrix} S_{11} & 0 & 0 & 0 & S_{15} & 0 \\ 0 & S_{22} & 0 & S_{24} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & S_{42} & 0 & S_{44} & 0 & 0 \\ S_{51} & 0 & 0 & 0 & S_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$= \begin{pmatrix} \frac{\Delta\tau^2}{6} & 0 & 0 & 0 & \frac{\Delta\tau}{6} \times \frac{\Delta\tau}{3\mathcal{L}_1} & 0 \\ 0 & \frac{\Delta\tau^2}{6} & 0 & \frac{\Delta\tau}{6} \times \frac{\Delta\tau}{3\mathcal{L}_1} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{\Delta\tau}{6} \times \frac{\Delta\tau}{3\mathcal{L}_1} & 0 & \frac{\Delta\tau}{3\mathcal{L}_1}^2 & 0 & 0 \\ \frac{\Delta\tau}{6} \times \frac{\Delta\tau}{3\mathcal{L}_1} & 0 & 0 & 0 & \frac{\Delta\tau}{3\mathcal{L}_1}^2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \qquad (13)$$

Incorporating (10) and (13) into the multivariate deviation statistics model (2) gives a statistical representation of the input shaft deviations.

4.2 In the three-dimensional coordinate system based on vector method to build components of the multi-deviation vector expression model

After analysis we can see:

$$\begin{cases} \max\Delta u = \max\Delta v = \Delta\tau \\ \Delta w = 0 \end{cases} \qquad (14)$$

$$\begin{cases} \max\Delta\alpha = \max\Delta\beta = \frac{2\Delta\tau}{\mathcal{L}_1} \\ \Delta\gamma = 0 \end{cases} \qquad (15)$$

From (7) can be obtained:

$$\begin{cases} r_{\Delta\alpha} = \mathcal{L}_1 \times \sin\Delta\alpha \\ r_{\Delta\beta} = \mathcal{L}_1 \times \sin\Delta\beta \\ r_{\Delta\gamma} = \mathcal{L}_1 \times \sin\Delta\gamma \end{cases} \qquad (16)$$

Bring (14) into (6) Deviation from the input shaft's distance:

$$\varepsilon_1 = \Delta\tau(ip) + \Delta\tau(jp) \qquad (17)$$

Take (15) and (16) into (7) to obtain the deviation caused by the angle of the input shaft:

$$\theta_1 = 2\Delta\tau \times \sin\Delta\alpha(\wp) + 2\Delta\tau \times \sin\Delta\beta(\wp) + 2\Delta\tau \times \sin\Delta\gamma(\wp) \quad (18)$$

The (17) and (18) into (5) available output shaft deviation vector expression is:

$$\varphi_1 = \varepsilon_1 + \theta_1 \quad (19)$$

V. CONCLUSION

According to the structure and transmission principle of RV reducer, a three-dimensional coordinate system is established. Based on the method of probability and statistics and vector representation, a model of multivariate deviation expression is established. The model is developed from three directions along x, y, z, x, y, z, axis rotation angle of multiple deviation statistics and expression, more refined and accurately reflect the size of the deviation. Finally, the model is validated by the input shaft deviation, which verifies the validity of the model. The built model can express the component deviations more accurately than the previous model. In order to study the influence of component deviation on transmission accuracy, a solution is provided.

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