Simulation and analysis of the dynamics of 2K-V gearbox based on RecurDyn

ABSTRACT: The 2K-V reducer is characterized by large transmission ratio, large load carrying capacity, high transmission accuracy and smooth transmission, and it is of great significance to study its dynamic characteristics. Taking a certain type of 2K-V reducer as the research object, a parametric three-dimensional model was established in SolidWorks, and the dynamics model of 2K-V reducer was established by RecurDyn. After simulation and analysis, the key zero part transmission speed curve and transmission error are obtained. The research method has certain guiding significance for the precision design of 2K-V reducer.

Keywords: 2K-V, dynamics simulation, transmission error.

INTRODUCTION

2K-V reducer is a core component mainly used in industrial robot joints, which mainly has the advantages of compact structure, large transmission ratio, high transmission precision, long service life and low noise. In recent years it is also widely used in aerospace, automation equipment, CNC machine tools and other fields. In this paper, a simplified geometric model is used to establish a 2K-V reducer dynamics model, and the dynamic response curves of key components are obtained. The research method has a certain guiding significance for the precision design of RV reducer.

1. 2K-V REDUCER TRANSMISSION PRINCIPLE

The 2K-V reducer is a closed differential gear train, which consists of an input gear, a planetary wheel and a planetary carrier. The enclosed part is a cycloid-needlewheel planetary drive mechanism consisting of a crankshaft, cycloid wheel, needle gear and needle gear housing. When the spur gear is shifted, the input shaft is turned opposite to the spur gear. When the differential gear changes speed, the crankshaft rotates, the eccentric cam drives the oscillating wheel to swing, the crankshaft eccentric shaft is symmetrically arranged, and the two oscillating wheels swing synchronously in opposite directions. The two oscillating wheels oscillate in the same process, with a phase difference of 180°. The oscillating wheels oscillate and press the pinion pin to produce relative rotation with the output flange[3].

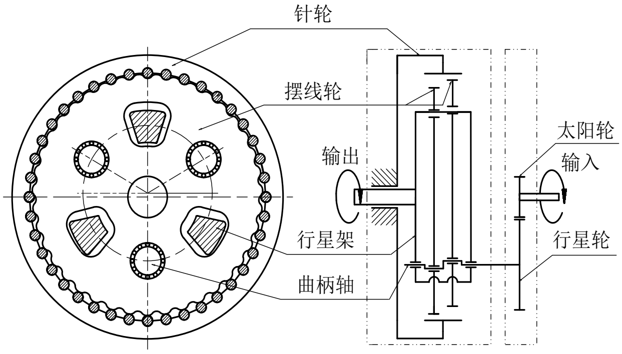

Fig. 1. 2K-V reducer transmission principle sketch

2. 3D MODELING OF 2K-V110E REDUCER

According to the 2K-V110E engineering drawings were modeled by SoildWorks software, the modeling results are shown in Figure 2 below.

Fig. 2. Cutaway view of 2K-V reducer

After the establishment of 2K-V110E three-dimensional model needs to be assembled on its parts, this paper takes the cycloid pinwheel as the reference for assembly. After assembly, it is necessary to carry out the interference test, mainly to check the fit between the parts of the assembly and whether the modeling of the parts is correct, after the inspection of the reducer does not have interference problems.

3. 2K-V110E REDUCER DYNAMICS SIMULATION MODELING

3.1 Material parameter setting and constraint type setting

To import the 2K-V110E 3D model into RecurDyn, you need to save the 3D model as (*.x_t) format via SoildWorks.[1] Then set the model name, unit system and gravity direction, where the unit system in this paper is MMKS (millimeter, kilogram, newton, second). After importing the geometric model of the parts need to be edited independently, for the model material to add, according to Table 1 to set the settings.

Table 1. Material Properties of 2K-V110E Reducer Components

Name	materials	Young's modulus （N/mm^{2}）	Poisson's ratio （μ）
Input shaft	20CrMo	2.11E+05	0.292
Spur gear	20CrMo	2.11E+05	0.292
Input flange	QT450-10	1.73E+05	0.3
Needle gear housing	QT450-10	1.73E+05	0.3
Output flange	QT450-10	1.73E+05	0.3
Crank shaft	20CrMnMo	2.07E+05	0.254
Swivel arm bearing	GCr15	2.19E+05	0.3
Cycloidal wheel	20CrMo	2.11E+05	0.292
Needle tooth pin	GCr15	2.19E+05	0.3

By setting the constraint types for the 2K-V110E reducer, the simulation achieves the effect of actual operation in a realistic environment. The setting of constraint types is essentially the setting of the motion relationship between the parts of the reducer, and once the constraint relationship between the parts is determined, the degrees of freedom of the mechanism are also determined. Theoretically, the more accurate the constraints between parts are set, the more accurate the motion relationship will be, but this will cause a lot of wasted arithmetic power[7]. In order to avoid the above problems, first of all, we have a full understanding of the 2K-V110E reducer mechanism motion transfer, and only set the motion vice that conforms to its output logic to maximize the simulation of real operation. The component constraints are shown in Table 2 below.

Table 2. 2K-V110E reducer parts constraint type

Binding subject 1	Binding subject 2	Type of constraint
input shaft	ground	rotating disk
spur gear	input shaft	gear pair
Input flange	Output flange	stationary sub
Needle gear housing	ground	stationary sub
Output flange	Needle gear housing	plane sub
Crank shaft	spur gear	stationary sub
Swivel arm bearing	Crank shaft	rotating disk
Cycloidal wheel	Swivel arm bearing	rotating disk

Needle tooth pin	ground	stationary sub

3.2 Dynamic model drive and load settings

By checking the product specification of 2K-V110E reducer, it is known that its transmission ratio is 111, and the output flange output speed is 15r/min and the output torque is 1078Nm under the rated output condition, according to the above basic operating parameters under the rated operating condition, the drive and load are added and parameterized in RecurDyn.

First of all, as shown in Figure 3, add the "rotary drive" on the preset input shaft rotating vice, in the definition of the use of "function drive" edit function for STEP (time, 0,0,0,0.2,9990d), click "apply". Click "apply" to apply. In this way, the rated operating conditions, the time 0.2s smooth acceleration of the input shaft to the rated speed, 0.2s after the input speed of the input shaft to 1165r/min speed smooth operation.

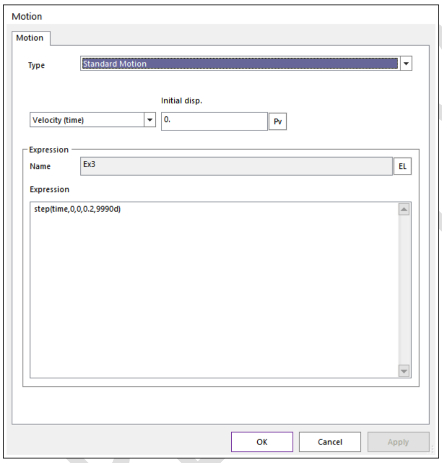
Motion
Type: Standard Motion
Velocity (time)
Initial disp.: 0.
Name: Ex3
Expression: step(time,0,0,0.2,9990d)

Fig. 3. Adding a driver

Finally, as shown in Fig. 4, a fixed moment is applied to the output flange rotating sub as a load to realize the output simulation at rated operating conditions, and the editing function is STEP(time,0.2,0,0.5,1.078e+6), which starts applying the load smoothly from the beginning of the virtual machine after 0.2s, and finishes applying the load at 0.5s at the same time as the completion of the input acceleration, and subsequent loads will be maintained at 1078Nm without further change.

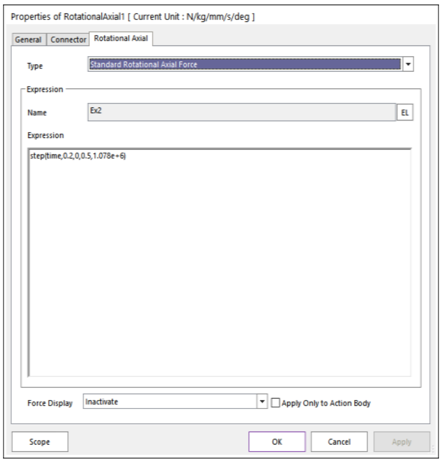
Properties of RotationalAxial1 [Current Unit : N/kg/mm/s/deg]
Type: Standard Rotational Axial Force
Name: Ex2
Expression: step(time,0.2,0,0.5,1.078e+6)
Force Display: Inactivate
☐ Apply Only to Action Body

Fig. 4. Adding a load

4. SIMULATION ANALYSIS RESULTS

4.1 Verification of the simulation results of 2K-V110E reducer

In order to verify the correctness and reasonableness of the constraints and model motion added in the previous section, it is necessary to simulate the established model and analyze its motion form. According to the settings in the previous subsection, the input rotational speed of the input shaft is 174.34 rad/s, and the simulation time is set to 4.5s, because it takes 4s for the output of 2K-V110E gearhead to be one week, so it is simulated by the dynamics software and the simulation is terminated with the time set to 4.5s. The input shaft rotational speed is 174.34 rad/s, as shown in Figure 5. The rotational speed of the input shaft is 174.34 rad/s, as shown in Fig. 5. The rotational speed of the output flange fluctuates around 1.57 rad/s, as shown in Fig. 6. Therefore, it can be concluded that the dynamic simulation modeling is correct.

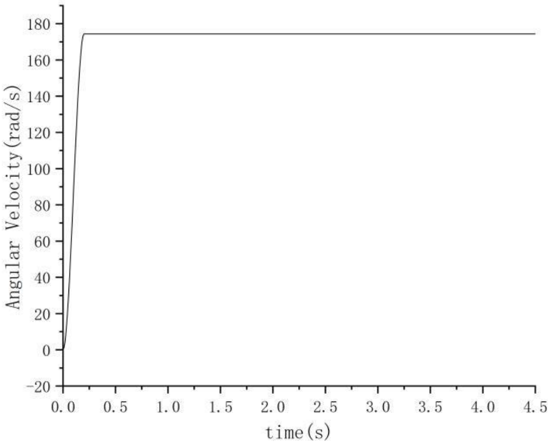

Fig. 5. Input Axis Angular Velocity

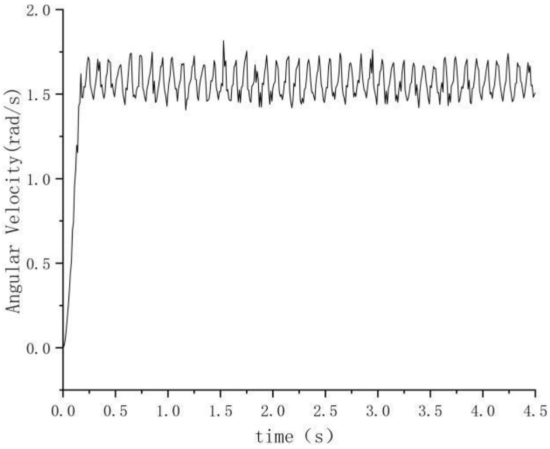

Fig. 6. Output Axis Angular Velocity

4.2 Dynamic response analysis of related components

Given the input shaft speed of 174.34rad/s under rated condition and the rated load of 1078N/m, the total reduction ratio is 111, and the theoretical output speed is 1.57rad/s[4]. Figure 7 shows the crankshaft angular speed change, and the amplitude fluctuates up and down around 61.26rad/s. The crankshaft angular speed change after 0.2 seconds tends to stabilize, and the amplitude fluctuates around the theoretical value of 1.57rad/s. Figure 8 shows the crankshaft angular speed change after 0.2 seconds. Figure 8 shows the change in angular velocity of the balance wheel in 0.2 seconds after the balance wheel rotation stabilizes, the amplitude fluctuates near the theoretical value of 1.57rad/s, the situation occurs due to the engagement is used geo surface contact, the impact between the rigid body generated. Figure 9 shows the output flange angular velocity, amplitude in the theoretical value of 1.57rad/s fluctuations in the vicinity of the reason for the generation of the wheel tooth meshing impact contact and other factors, in line with expectations[5].

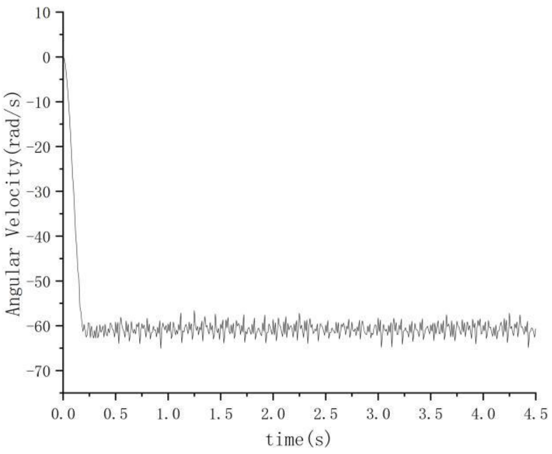

Fig. 7. Crankshaft angular velocity

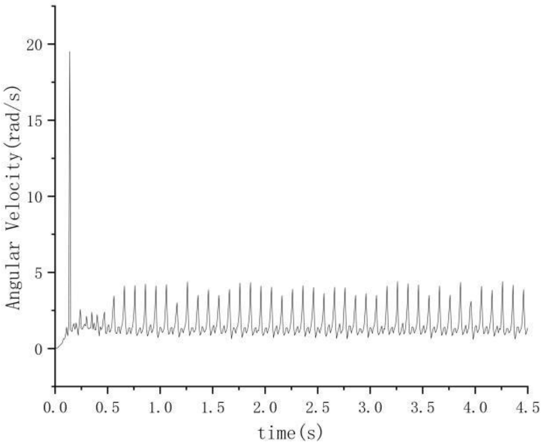

Fig. 8. angular velocity of the cycloid

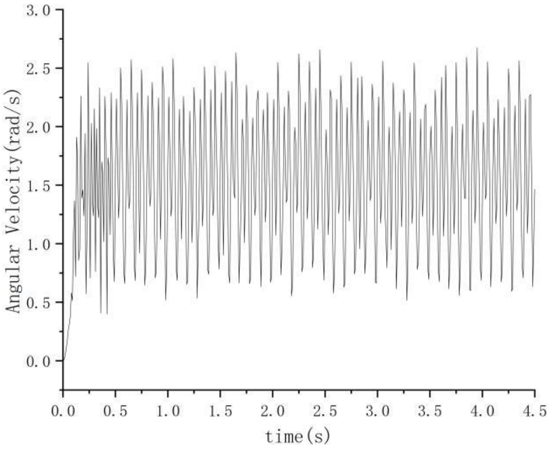

Fig. 9. Output flange angular velocity

4.3 Transmission Error Analysis

Transmission error as one of the important indicators of the size of the 2K-V reducer transmission accuracy, which represents the meaning of the input shaft unidirectional rotation of any moment of the output shaft at the same moment the difference between the actual value of the angle and the theoretical value[2]. In this paper, the transmission error is calculated by the following formula in the case of fixed needle gear housing, input shaft input and planetary carrier output movement:

$$\theta_{er} = \frac{\theta_{in}}{i} - \theta_{out}$$

Where, θ_{er} is the transmission error, $\frac{\theta_{in}}{i}$ is the theoretical turning angle of the output end, and θ_{out} is the actual turning angle of the output end.

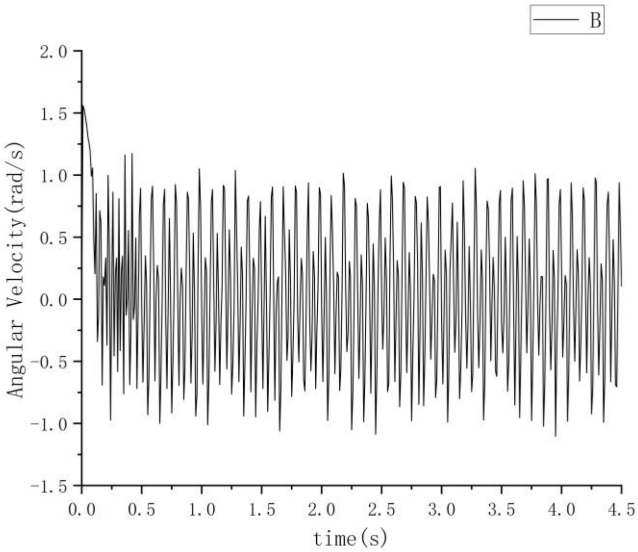

Fig. 10. Transmission error at rated load

The discrete point of angular velocity change obtained by post-processing can be converted to angular displacement through relevant processing, and then the transmission error change from 0. 2~4.5s in the stabilization stage is obtained, as shown in Fig. 10[6]. That is, the transmission error under the rated condition is about 69.13%. In this paper, we consider the parts are rigid body without considering the flexible body, so it is within the range of error under rated condition. Relative error = (theoretical calculated value - simulation calculated value) / theoretical calculated value.

CONCLUSION

(1) The 2K-V110E three-dimensional model was established using SolidWorks. The dynamic simulation model was established by RecurDyn software, which provides ideas for the subsequent study of predicting the life of key components based on rigid-flexible coupling.
(2) Through simulation analysis, the correctness of the dynamics simulation model was verified, the dynamic response curve of the speed of the key parts was obtained, and the transmission error of the rigid 2K-V110E reducer was analyzed, providing a basis for the subsequent consideration of the necessity of elastic variation of parts.

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