Research Article
The Static Stiffness Linear Regression of Parallel Mechanism Based on the Orthogonal Experiment

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Abstract: Using the orthogonal experimental method, we can get the linear regression model of about parallel mechanism stiffness. Selecting four factors three levels of orthogonal experiment method, in ANSYS-workbench to space in third rotation 3-SPS/S parallel mechanism for static stiffness analysis, we have won nine of the data of the experiments, the application of the MATLAB software to experimental data is linear regression, which can get the static stiffness linear regression of parallel mechanism, under the influence of the stiffness, the regression function can be predicted in the different factors of parallel mechanism, we provide a new basis and reference for the following static stiffness analysis.

Keywords: Linear regression, orthogonal experiment, parallel mechanism, static stiffness

INTRODUCTION

Because of the big stiffness, the small accumulated error, large carrying capacity and the good dynamic performance, the parallel mechanism is easy to control, which is widely used in engineering. In recent years, the space of three degree freedom parallel mechanism is synthetically, is reverse motion analysis, is instantaneous motion characteristics and motion sensitivity, is scale parameter optimization and performance comparison between different configuration problems give a full research.

The stiffness of parallel mechanism is determined to the moving platform by external force in production after a displacement and the displacement will affect the positioning accuracy of parallel mechanism and dynamic characteristic, in a variety of organizations configuration, the structure parameters, the branched chain type and branched chain in a different attitude, the changed stiffness, which decided stiffness factor is very complicated, so trying to increase the stiffness of parallel mechanism is an important research subject.

In view of the mechanical structure geometry and the complexity of boundary conditions, which usually need to the method of finite element stiffness model and the calculation (Xu and Sun, 2002; Li *et al.*, 2001; Jiang *et al.*, 2003; Bai, 2004), Considering the parallel configuration equipped machine rigidity is a form of function, the application of orthogonal experimental method and the MATLAB polynomial regression for the linear regression function of stiffness (John athews and Kurtis, 2005; Su *et al.*, 2004; Gerald, 2004), so as avoid

the need for different configuration to the finite element model for grid redraw the settlement calculation save a lot of time and manpower, improve the design efficiency. The regression model for the research and analysis of parallel mechanism stiffness, which provides a new platform and basis.

The introduction of parallel mechanism model: Parallel mechanism 3-SPS/S contains three scalable supporting, an intermediate fixed link, upper and lower two platforms together. As shown in Fig. 1, the telescopic rod and the platform (y), respectively
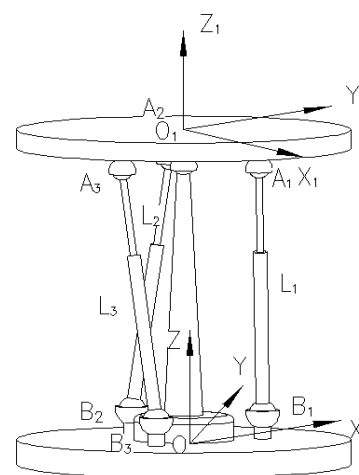

Fig. 1: The sketch of 3-SPS/S parallel mechanism

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between ball is A1, A2, A3 connection and platform (y) were throwing a B1, B2, B3 connection. Intermediate fixed link and platform (Y) fixed and the platform (Y) ball vice connection. Respectively in up and down the platform establish coordinate system O1-X1Y1Z1 and O-XYZ as shown in Fig. 1.

Three support bar and up or down the platform connect the ball more distribution in two round the edge of the platform and the platform and the radius of the ball, which is different to the distribution, ensure the telescopic rod that is a certain the angle, thus realize the parallel mechanism 3-SPS/S with rotational degrees of freedom.

THE ORTHOGONAL EXPERIMENTAL DESIGN

Introduction: The orthogonal experimental design is the study of multi-factor and the level of design method, which is according to the orthogonal property from the comprehensive that test select part of the representative point test, with the "uniform dispersion and neat comparable "of the representative point, orthogonal test design is a fractional factorial design of the main method, it is a kind of high efficiency, rapid and economic experiment design method (Zhong and Yu, 2003; Huang, 2004; Montgomery, 1998).

The data of orthogonal design test: Selected and platform radius, branched chain length, branched chain fluctuation period of radius for factors, the level of 1-3, one of the factors limit three factors on behalf of the lower and on behalf of the lower limit, 2 for intermediate value. According to the three factors, levels of orthogonal design table L9 (34) and its

ShiYong Biao arrangement experiment, so the orthogonal test design variables and their range is shown in Table 1, the parallel mechanism 3-SPS/S static stiffness test data such as shown in Table 2.

The ANSYS-workbench analysis: According to the data in Table 1 and 2 of the arrangement, the Pro-E establishes respectively in nine experimental data of the model, the model in ANSYS-workebnech, respectively statics analysis, respectively get nine model of the strain for the Table 2 data. Figure 2 shows the experiment 1 analysis results:

- **Applied constraint:** The platform and ground is connected with the Fix, up and down the platform and the ball is connected with Spherical (n = 7), branched chain fluctuation period of translational with vice connection (n = 3).
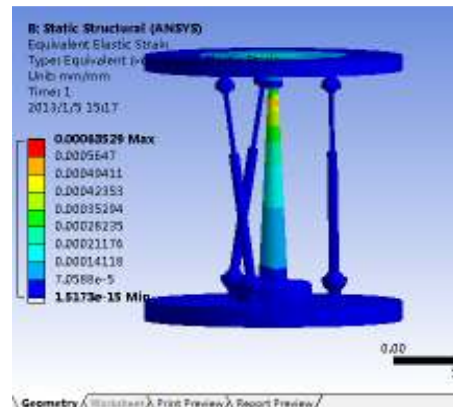

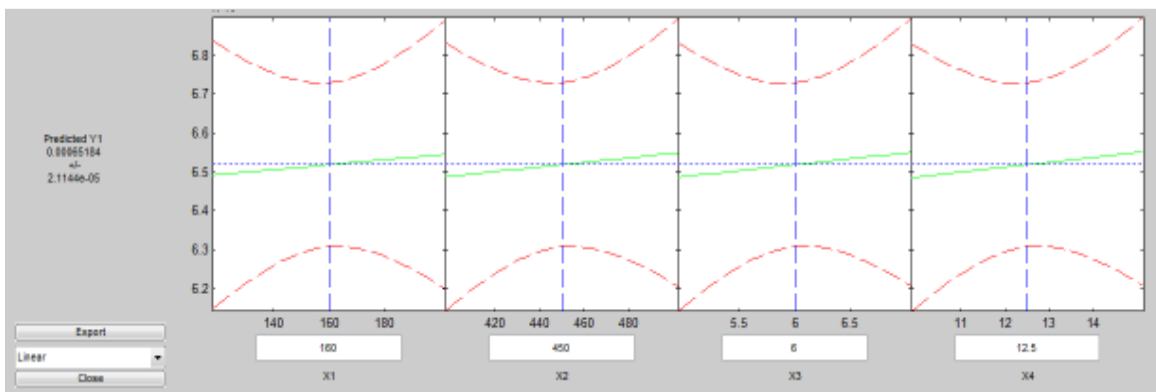Fig. 2: First experiment statics analysis

Fig. 3: Linear model predicted table

Table 1: Design variables and their range

Design variable physical meaning	Design variable decoding		Design variable coding	
	Decoder form	Measure data (mm)	Encoder form	Range
Platform radius	R	120-200	X1	1-3
Platform height	H	400-500	X2	1-3
Branched chain top radius	r1	5-7	X3	1-3
Branched chain bottom radius	r2	10-15	X4	1-3

Table 2: Parallel mechanism 3-SPS/S static stiffness test data

X1	X2	X3	X4	Y (mm) e-04
1	1	1	1	6.3529
1	2	2	2	6.6785
1	3	3	3	6.5363
2	1	2	3	6.4611
2	2	3	1	6.4609
2	3	1	2	6.4601
3	1	3	2	6.5740
3	2	1	3	6.5740
3	3	2	1	6.5676

Table 3: Mechanics analysis of ANSYS-workbench meshing parameters

Physical priority option	Automatic setting of the following			
	Entity unit nodes in default	Association center the default value	Smooth	Transition
Mechanics analysis	Retain	Rough	Medium	Fast

- **Mesh generation:** The mechanics analysis of network set as shown in Table 3.
- **The applied load:** In the next platform and based on between fixed Support connection, three drive rods were loading Joint-Displacement connection, the Displacement is zero mm, applied Pressure on the platform, its size set to 0.2 Mpa.
- **The results of the analysis:** Analysis of cloud and data is shown in Fig. 2, with the Solution of the Elastic Strain selection, this chooses the maximum value as a reference and test of the Y value.

REGRESSION ANALYSIS

Introduction of regression analysis: Based on the mathematical statistics theory, a large amount of statistical data is processed with the mathematical, determined the parallel mechanism stiffness and some correlative has relationship between the independent variables, which establish a good relationship in the regression equation, it can be used to predict the push, parallel mechanism is different in variables stiffness analysis.

In the regression analysis, if there are two or more independent variables, which is called multiple regression. In fact, a phenomenon is often associated with multiple factors, the more arguments and the best combination of common to predict or estimated the dependent variable, than use only one argument to predict or estimate more effective and more actual. So the multiple linear regressions have more than a linear regression of practical of meaning (Table 4).

The coefficients in the model solution: According to the theoretical analysis and the law of single factor experiment results determine the form of regression model:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4$$

Using MATLAB multiple binomial regression command: rstool (x y, "model", alpha), get the coefficients in the regression model (Song and Xu, 2005; Su *et al*., 2005; Wang, 2005).
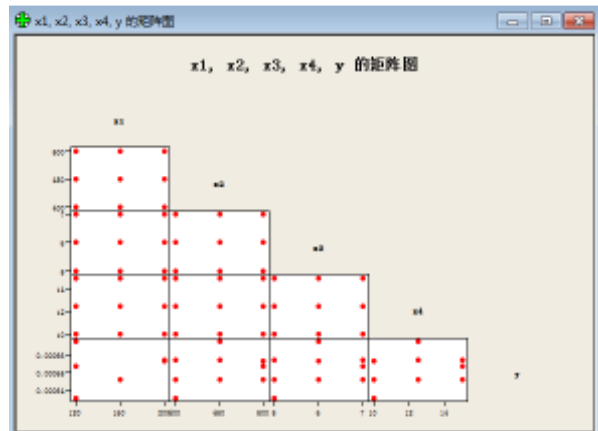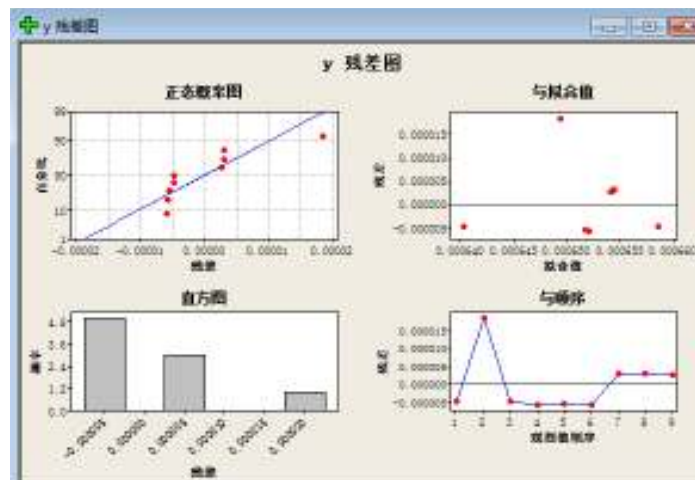

Fig. 4: The plot of matrix analysis

Fig. 5: The plot of residual

Table 4: Regression effect analysis of variance table

Variance source	S.S. e-10	df	Mean square e-10	Mean square than
Regression	U = 2.04800	M = 4	U/M = 5.12000	F = 3.40
Residual	Q = 5.14544	N-M-1 = 4	Q/ (N-M-1) = 12.8636	
Sum	L = 7.19345	N-1 = 8		

S.S.: Sum of square

Including: X said n 'm matrix; Y said n columns; Alpha is significance level (default is 0.05); Model said regression model in the form of here is linear equation.

We write a program and in the MATLAB operation, get the regression equation:

$$Y = 0.5813 + 0.0001x_1 + 0.0001x_2 + 0.0031x_3 + 0.0013x_4$$

We can get residual standard deviation that is 11342e-05, which is small, the regression function and actual situation has more anastomosis.

Get the prediction curve form, as shown in Fig. 3. the four factors of in Fig. 3, the Predicted place will predict parallel mechanism in static stiffness of the four factors, in this diagram you can predict to get parallel mechanism with static stiffness of the different model, which is concrete numerical value, to avoid the four factors, in this diagram you can predict to get parallel mechanism with static stiffness of the different model, which is concrete numerical value, to avoid the different model, to order to get the red tape of the static stiffness, to has modeling and complicated process.

Minitab regression test: The experiment data to excel way input form of the Mintab Matrix chart analysis, as shown in Fig. 3, the residual map analysis, as shown in Fig. 4 and 5.

CONCLUSION

- Static stiffness of four factors three levels, which is experimental scientific collocation, arrangement a Use the orthogonal experimental method and then the nine data is put in ANSYS-workbench, respectively in statics analysis.
- Orthogonal experiment to get experimental data regression analysis, get the regression model. Through this model can know static stiffness of the parallel mechanism, which has different factors, has concrete data, save for different model and repeat modeling time, greatly improve the efficiency.

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