Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

A comparison of sensitivity indices for tolerance design of a transmission mechanism

Zhen-yu LIU

Cite this as: Zhen-yu LIU, Han-chao XU, Guo-dong SA, Yu-feng LYU, Jian-rong TAN, 2022. A comparison of sensitivity indices for tolerance design of a transmission mechanism. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 23(7):527-542. https://doi.org/10.1631/jzus.A2100461

浙江大学 ZHEJIANG UNIVERSITY

01 Background





The kinematic and dynamic performances of the transmission mechanism are significantly affected by the geometric errors of its parts. To ensure the comprehensive performance of the mechanism, tolerance design is necessary, which can reasonably control part geometric errors with low cost.

Transmission mechanism

Difficulties

- Make a reasonable tolerance allocation.
- Quickly and accurately obtain sample data for sensitivity analysis.
- Determine the sensitivity analysis method applicable to the transmission mechanism.

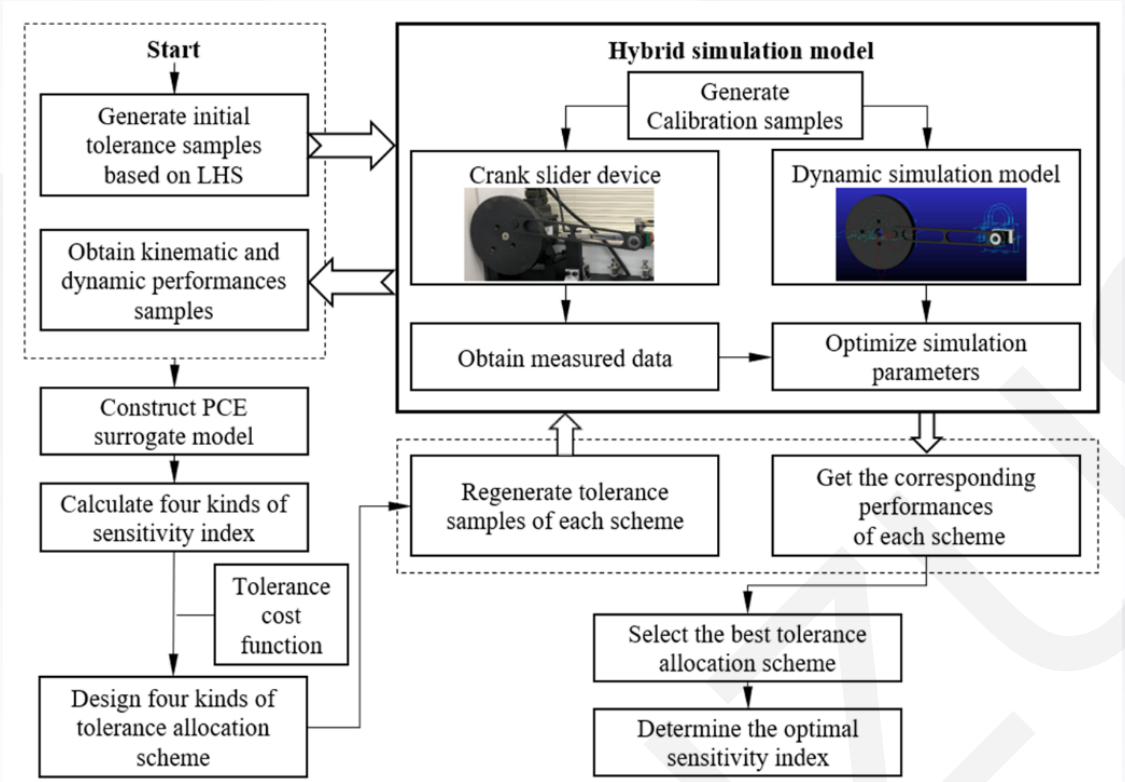


Fig. 1 Approach framework for comparing sensitivity indices based on the hybrid simulation model

We proposed a comparison method of the sensitivity indices based on hybrid simulation, so as to determine the optimal sensitivity index that accurately reflects the impact of geometric errors on the kinematic and dynamic performances of the transmission mechanism as shown in Fig.1.

A hybrid simulation model was established based on the experimental data of the crank-slider experiment platform. The accuracy and reliability of simulation data are ensured when the experiment cost is reduced and the input variables are freely controlled.

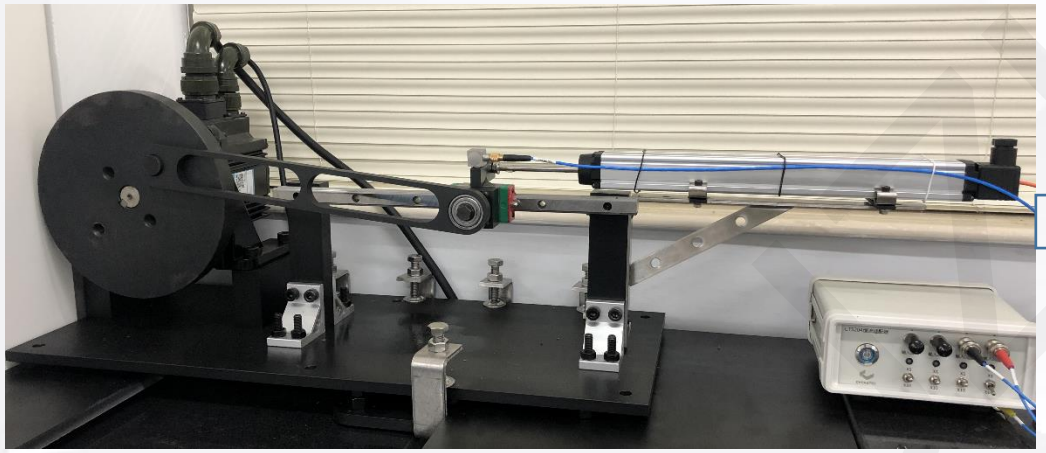


Fig. 2 Crank-slider experiment platform

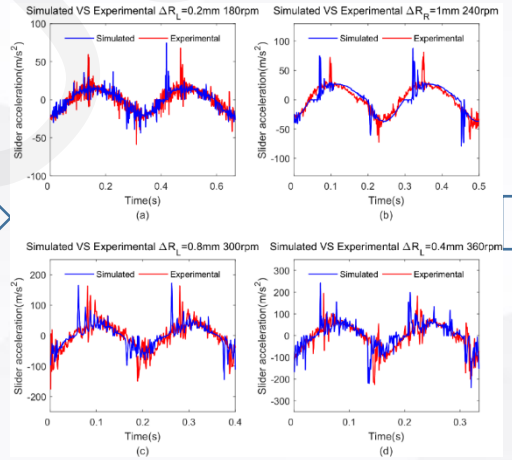


Fig. 3 Comparison of simulation and experimental data on slider acceleration

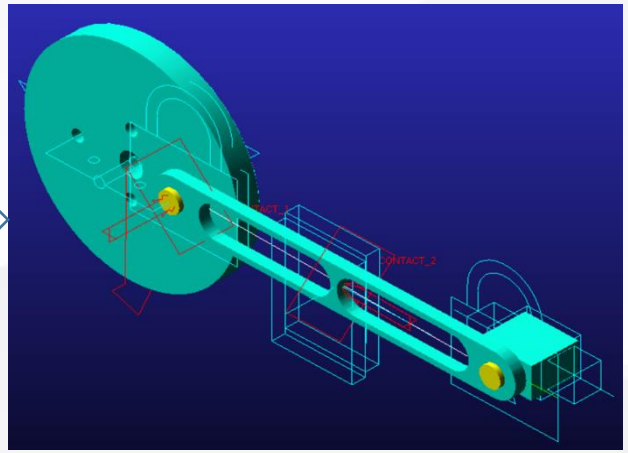
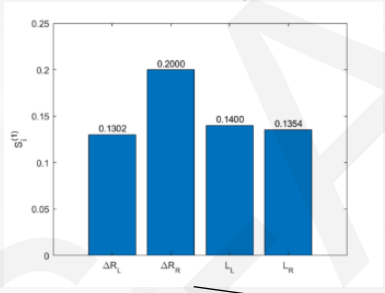


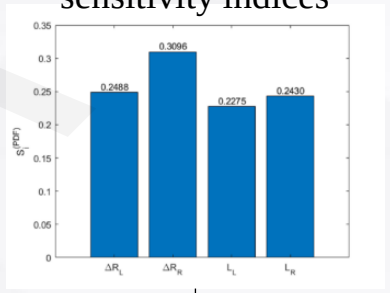
Fig. 4 Hybrid simulation model of the crank-slider mechanism

Sensitivity and cost-tolerance functions are combined to allocate tolerance. Given a total cost value, the cost was allocated according to the proportional rela-tionship between the sensitivity of the input variables. Then the tolerance range of each mechanism part size corresponding to the input variable was calculated by combining the cost-tolerance functions. The tolerance allocation scheme corresponding to each sensitivity index was obtained.

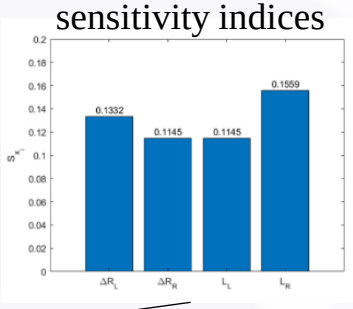
Sobol sensitivity indices



Moment-Independent sensitivity indices



Information-Entropy sensitivity indices



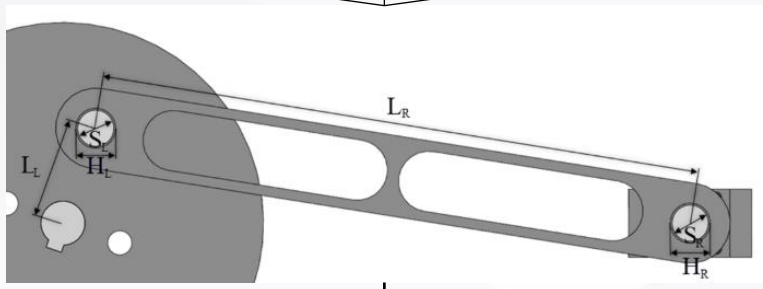


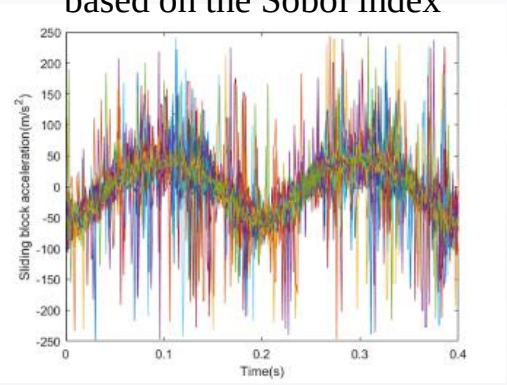
Table 1 Tolerance cost and tolerance range of each mechanism part size

		S_L	S_R	L_L	L_R
Tolerance cost	Sobol method	1.0751	1.6515	1.1557	1.1177
	Moment-Independence method	1.2090	1.5043	1.1057	1.1810
	Information-Entropy method	1.2855	1.1051	1.1048	1.5045
Tolerance range (mm)	Sobol method	0.2100	0.0721	0.1075	0.1146
	Moment-Independence method	0.1000	0.0781	0.1173	0.1036
	Information-Entropy method	0.0919	0.3505	0.1175	0.0765

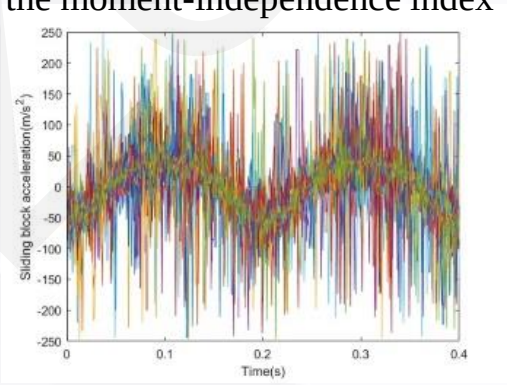
03 Discussion

Compared with the other sensitivity analysis methods in this study, the Sobol sensitivity analysis method can better optimize the kinematic and dy-namic performances of the crank-slider mechanism for tolerance allocation because the first-order Sobol index can effectively extract the main effect of each input variable in the nonlinear model on the response, but not the total effect. This is very important for sensitivity analysis of complex models such as transmission mechanisms because the total effect of each input variable on the response includes redun-dancy. The more complex the model is, the more attention should be paid to the redundancy, which will enlarge the effects of some input variables on the model response.

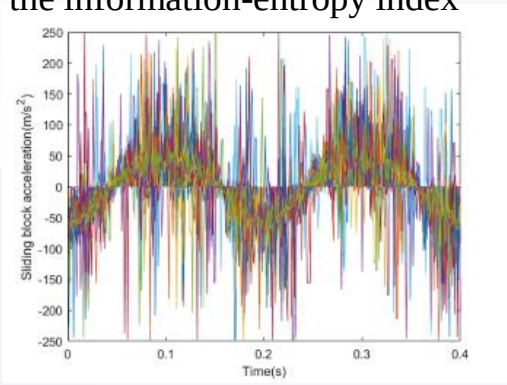
Slider acceleration data based on the Sobol index



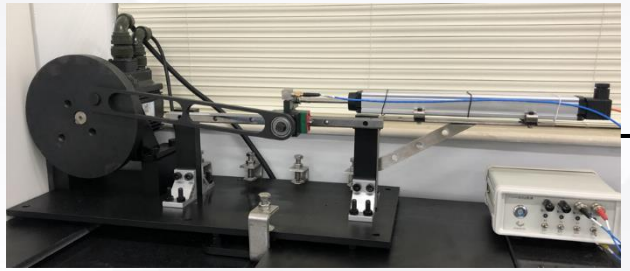
Slider acceleration data based on the moment-independence index

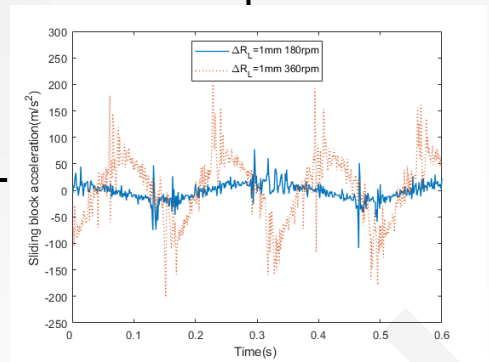


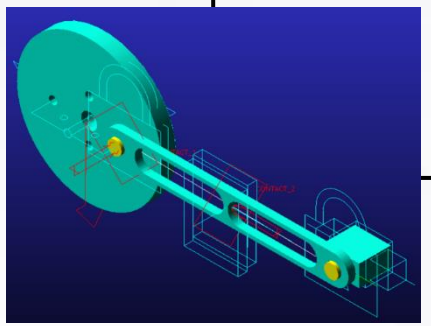
Slider acceleration data based on the information-entropy index

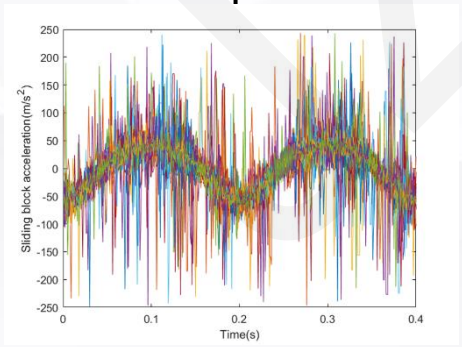


03 Conclusions









01

A hybrid simulation model was established based on the experimental data of the crank-slider experiment platform. The accuracy and reliability of simulation data are ensured when the experiment cost is reduced and the input variables are freely con-trolled.

02

Based on the experimental data of the hybrid simulation model, a surrogate model based on the PCE method was established for the sensitivity cal-culation. It simplifies that calculation significantly.

03

The tolerance was allocated based on the sensitivity and cost-tolerance function, and the tol-erance scheme corresponding to each sensitivity index was obtained. Based on the kinematic and dynamic performances of the mechanism of each tolerance scheme, a new sensitivity evaluation method with engineering value is proposed.