

Supplementary material

Design, Analysis, and Experimental Research of Integrated Operational Equipment for Hanging Column Installation

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Table S1. The end pose matrix

Joint variables	By equation (3)	By model in MATLAB
$(29^\circ, -30^\circ, 25^\circ, 4620, -40^\circ, 70^\circ)$	$\begin{bmatrix} -0.2440 & -0.7470 & -0.6184 & 53.74 \\ 0.9391 & -0.0230 & 0.3428 & 29.79 \\ 0.2418 & -0.6645 & 0.7071 & 6365 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} -0.2440 & -0.7470 & -0.6184 & 53.74 \\ 0.9391 & -0.0230 & 0.3428 & 29.79 \\ 0.2418 & -0.6645 & 0.7071 & 6365 \\ 0 & 0 & 0 & 1 \end{bmatrix}$
$(-15^\circ, -50^\circ, 13^\circ, 5810, -25^\circ, -23^\circ)$	$\begin{bmatrix} 0.3163 & 0.4154 & -0.8529 & -3508 \\ -0.4893 & 0.8417 & 0.2285 & 940 \\ 0.8128 & 0.3450 & 0.4695 & 6518 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 0.3163 & 0.4154 & -0.8529 & -3508 \\ -0.4893 & 0.8417 & 0.2285 & 940 \\ 0.8128 & 0.3450 & 0.4695 & 6518 \\ 0 & 0 & 0 & 1 \end{bmatrix}$
$(65^\circ, -65^\circ, -5^\circ, 6793, 10^\circ, 14^\circ)$	$\begin{bmatrix} -0.1480 & -0.8971 & -0.4162 & -2964 \\ 0.2549 & 0.3720 & -0.8925 & -6357 \\ 0.9556 & -0.2382 & 0.1736 & 4033 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} -0.1480 & -0.8971 & -0.4162 & -2964 \\ 0.2549 & 0.3720 & -0.8925 & -6357 \\ 0.9556 & -0.2382 & 0.1736 & 4033 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

Table S2. Weight of the end-effector

	name	weight(kg)
1	hinge clamping mechanism	89.7
2	alignment adjustment	50.3
3	tightening assembly	67.5
4	other accessories	15

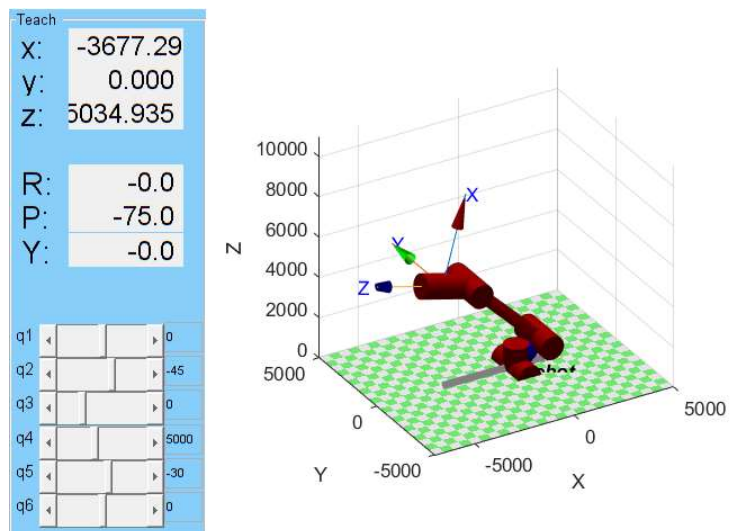


Figure S1. Simulation model of installation robot.

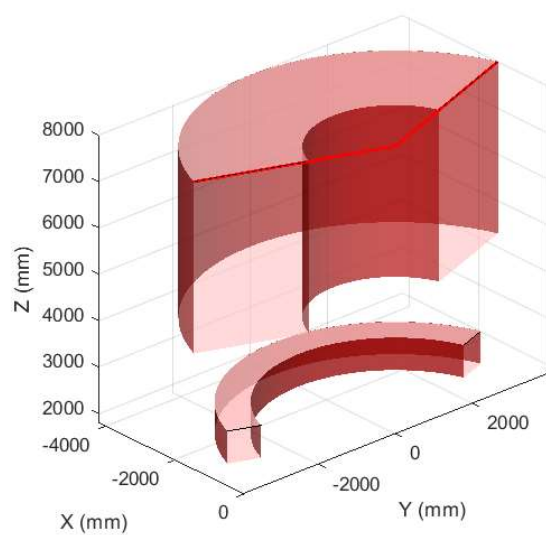


Figure S2. Working range requirement of installation robot

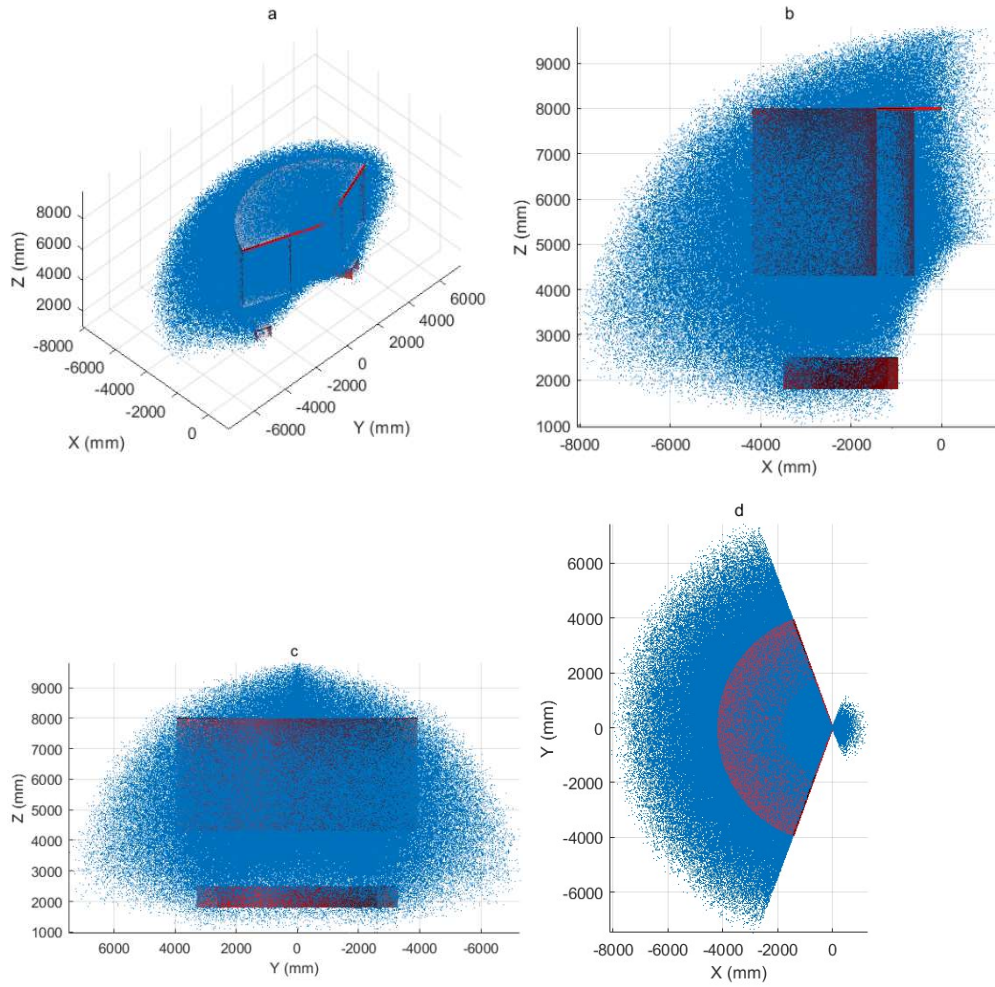


Figure S3. Workspace of installation robot. (a) Global Workspace; (b) X0Z Plane; (c) YOZ Plane; (d) X0Y Plane.

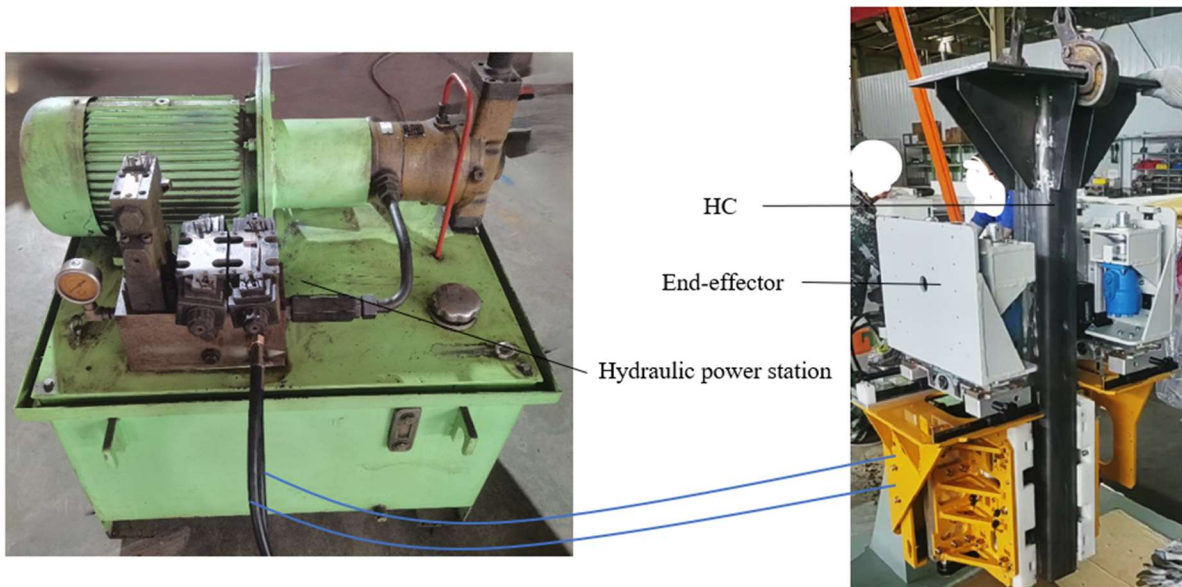


Figure S4. Picture of the end-effector testing.



(a)



(b)

Figure S5. Picture of installation robot testing. (a) Grabbing HC; (b) Transporting HC to installation position