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

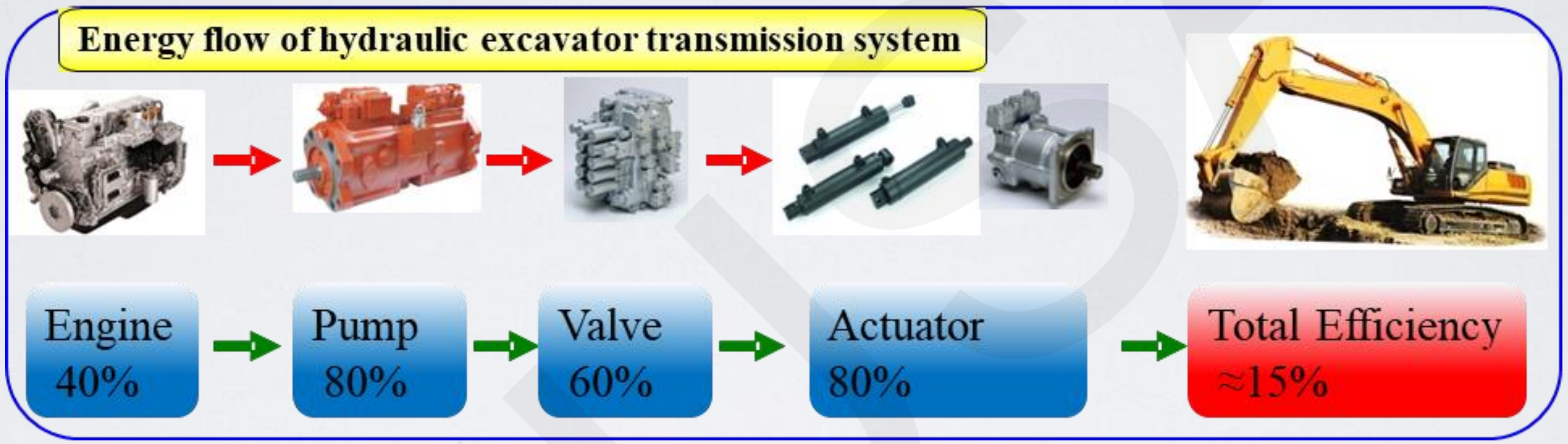
Cite this as: Chao SHEN, Jianxin ZHU, Jian CHEN, Saibai LI, Lixin YI, 2025. Parameter matching and optimization of hybrid excavator swing system. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 26(2):138-150. https://doi.org/10.1631/jzus.A2400040

Parameter matching and optimization of hybrid excavator swing system

Key words:
Hybrid system;
Energy regeneration;
Swing braking energy;
Parameter optimization;
MOPSO;
Adaptive grid

Energy -saving background

- Excavators are one of the most common forms of machinery in the construction and mining industries. However, conventional hydraulic excavators suffer from the problems of high energy consumption, low energy utilization, and poor emissions.



- Increasing environmental pollution and energy costs promote the development of novel energy-saving technology for hydraulic excavators.

One excavator emits as much exhaust as 30 cars.

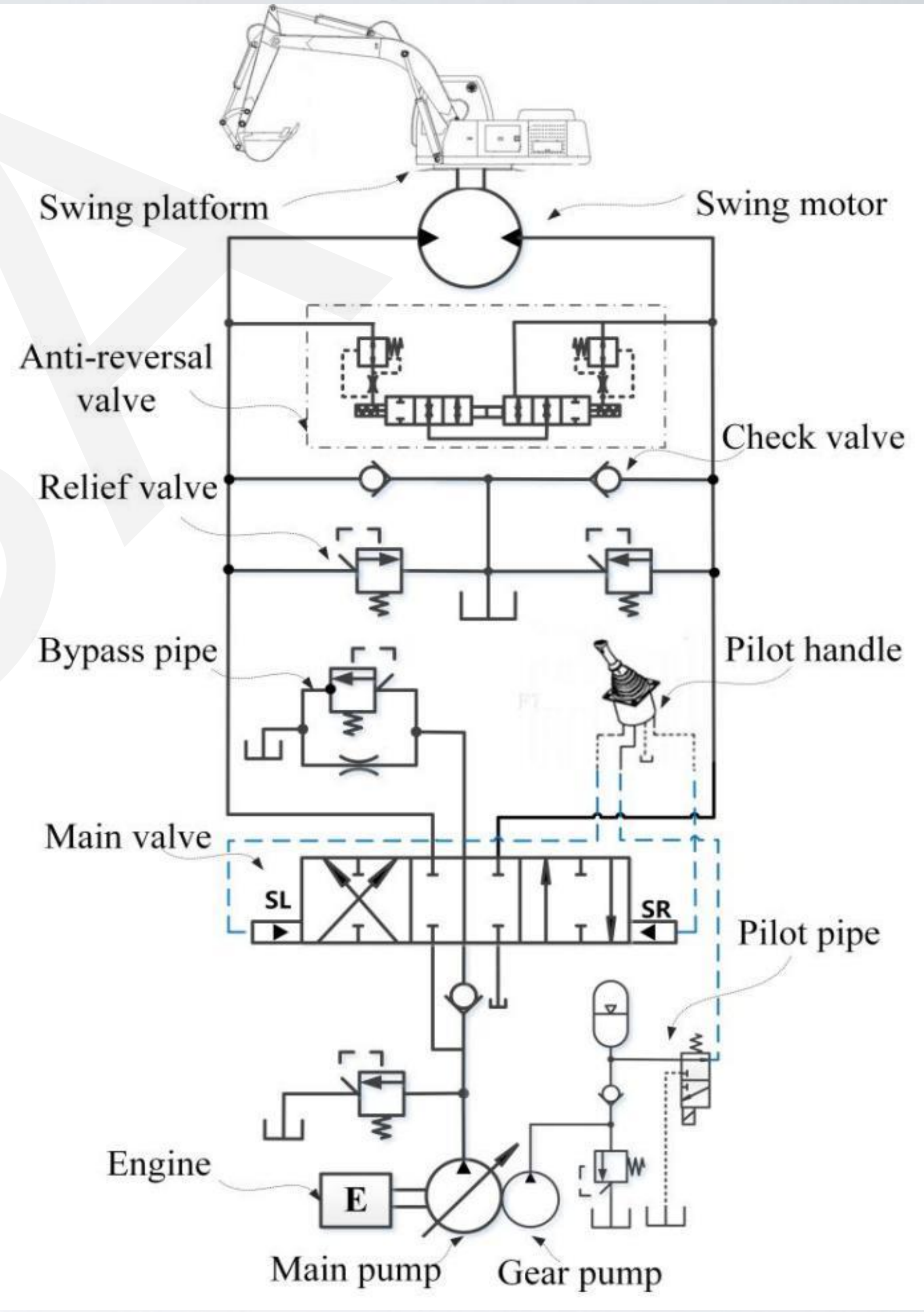
System configuration

There are four motion states of a slewing platform:

- Stationary
- Accelerated swing
- Uniform swing
- Braking

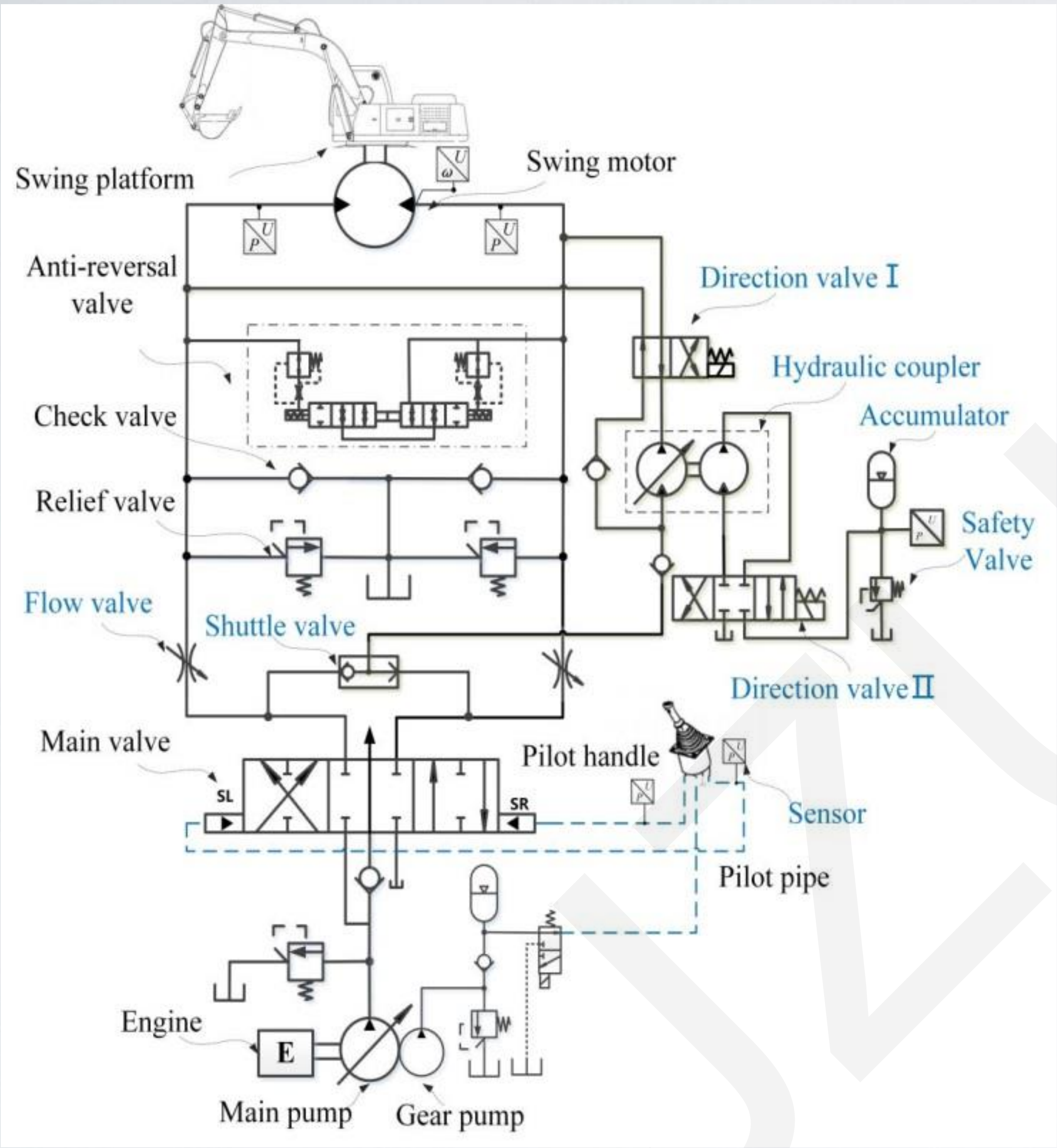
Energy loss of a swing system comes mainly from four sources:

- Brake overflow loss in the relief valve;
- Acceleration overflow loss in the relief valve;
- Throttle loss in the main valve;
- mechanical loss in the swing mechanism.



Conventional swing system of excavators

System configuration



Synergistic swing energy-regenerative hybrid system (**SSEHS**)

- The SSEHS is mainly composed of an **HT**, **hydraulic energy storage unit**, **pilot handle control system**, **hydraulic pump**, **necessary control valves**.

- In the hydraulic energy storage unit, the hydraulic accumulator serves as an energy storage element to store the recovered swing energy. The HT plays a role in regulating flow without throttling loss.

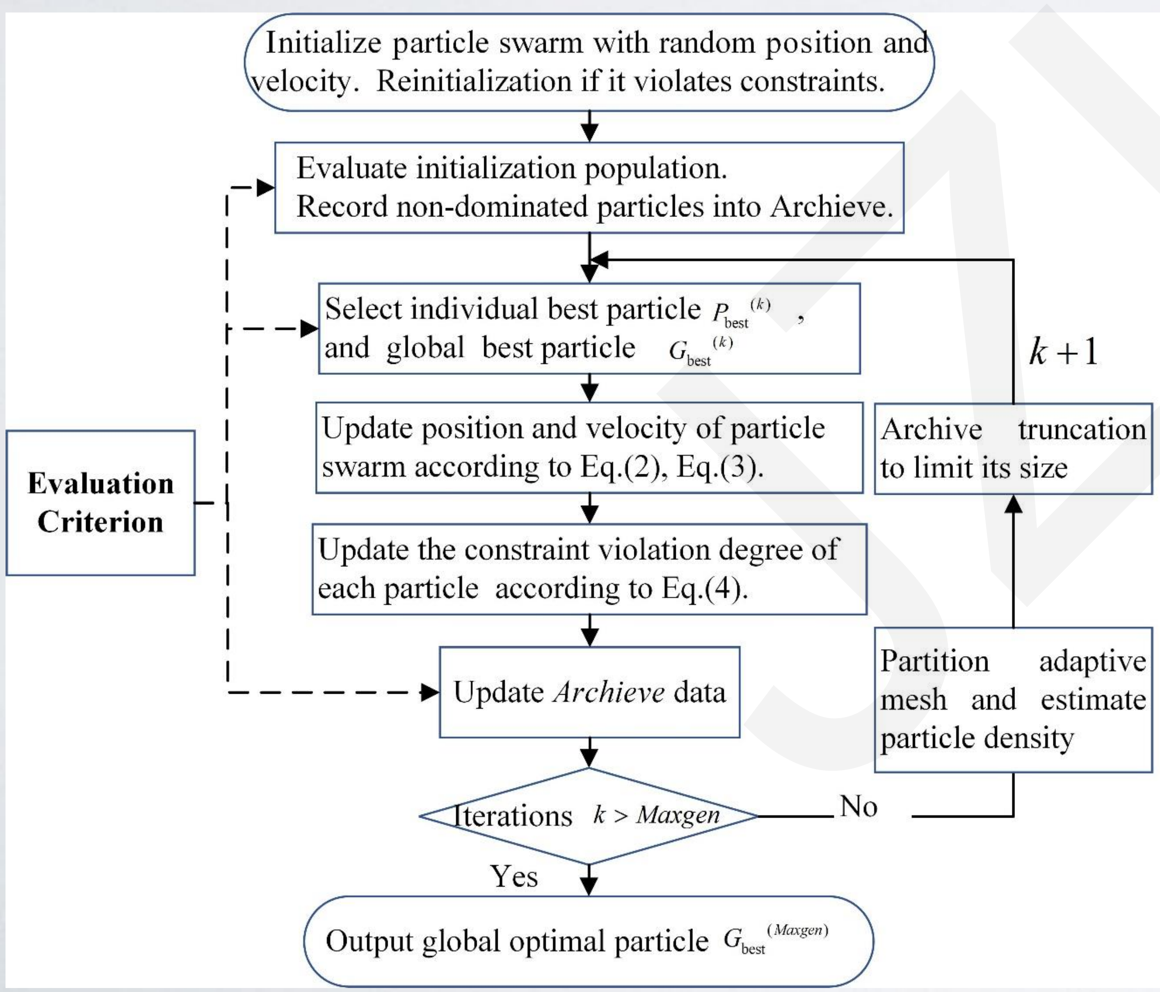
Parameter matching and optimization

An improved multi-objective particle swarm optimization (IMOPSO) combined with an adaptive grid is proposed for parameter optimization of the SSEHS.

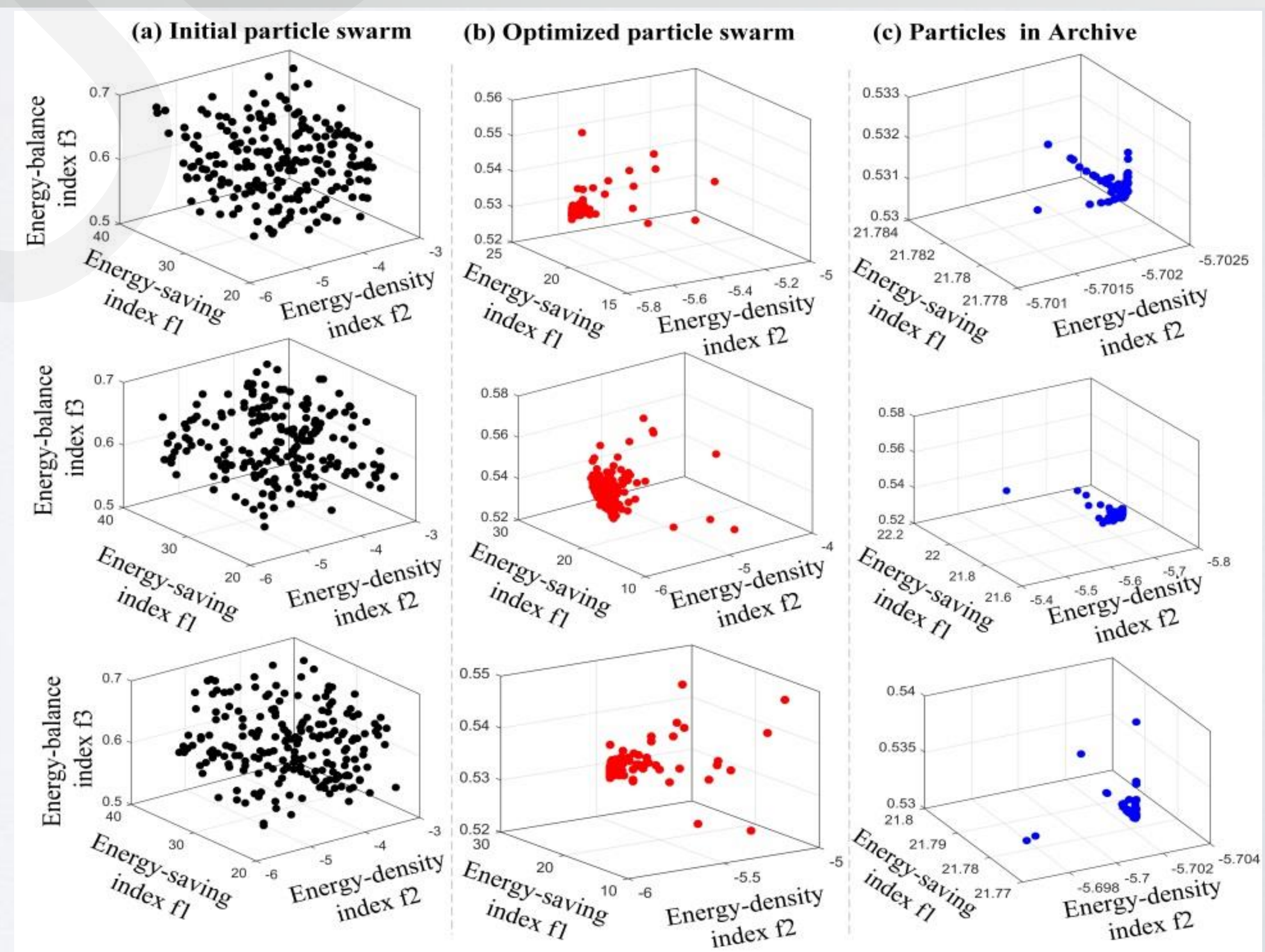
$$\min F(\boldsymbol{X}) = (f_1(\boldsymbol{X}), f_2(\boldsymbol{X}), \ldots, f_m(\boldsymbol{X}))^T,$$
$$\boldsymbol{X} = (x_1, x_2, \ldots, x_n)^T, \boldsymbol{X} \in R^n$$
$$s.t \begin{cases} g_\varphi(\boldsymbol{X}) \le 0 & \varphi = 1, 2, \ldots, p \\ h_\psi(\boldsymbol{X}) = 0 & \psi = 1, 2, \ldots, q \\ \lambda \le x_i \le \gamma & i = 1, 2, \ldots, n \end{cases} \quad \text{(Eq.1)}$$

$$\boldsymbol{X}^{(k+1)} = \boldsymbol{X}^{(k)} + \boldsymbol{V}^{(k+1)} \quad \text{(Eq.2)}$$

$$\boldsymbol{V}^{(k+1)} = \omega^{(k)}\boldsymbol{V}^{(k)} + c_1 r_1 (\boldsymbol{P}_{\text{best}}{}^{(k)} - \boldsymbol{X}^{(k)}) + c_2 r_2 (G_{\text{best}}{}^{(k)} - \boldsymbol{X}^{(k)}) \quad \text{(Eq.3)}$$

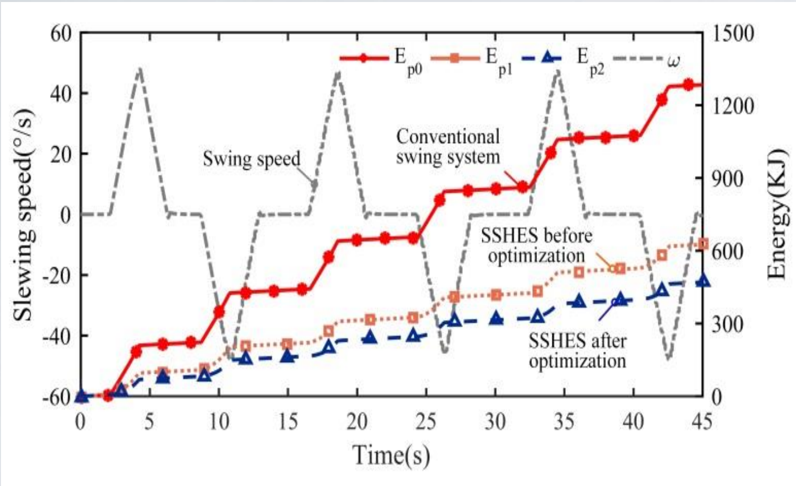


Calculation step of the IMOPSO



Results of three-parameter optimization

Energy-saving efficiency results



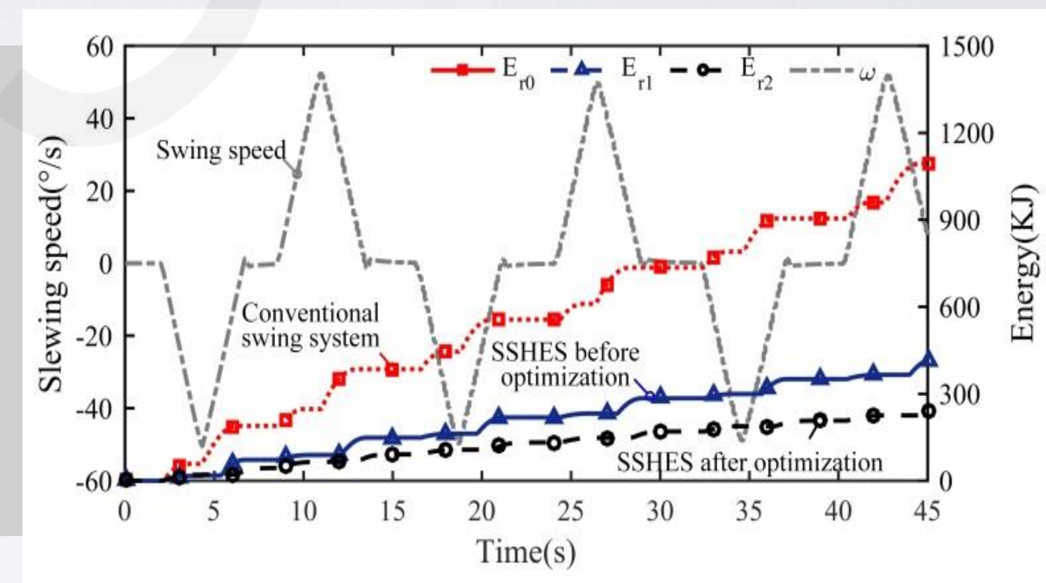
Energy output of main pump

The output energy of the main pump
(six slew acceleration-braking motion cycles)

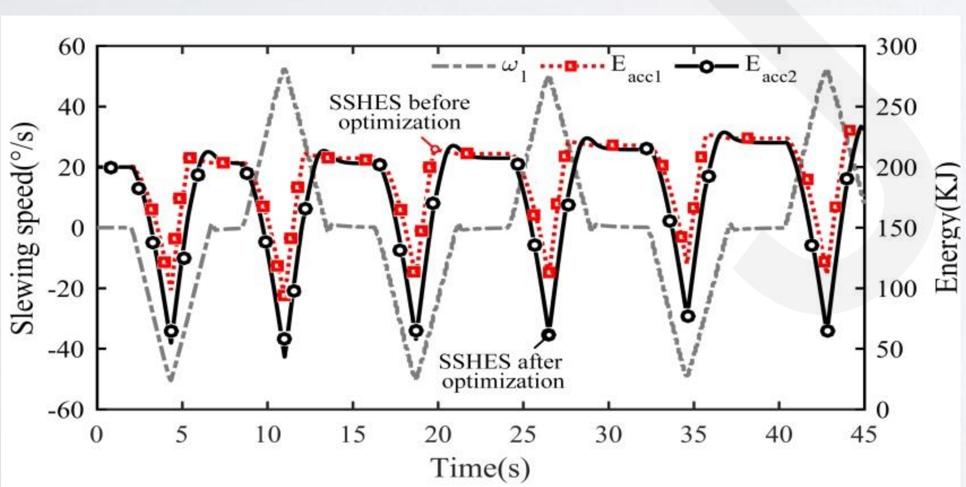
- Conventional swing system： 1284.0 KJ
- SSEHS without parameter optimization: 625.6 KJ
- SSEHS with parameter optimization: 470.4 KJ

The Overflow energy loss

- Conventional swing system：1094 KJ
- SSEHS without parameter optimization: 677 KJ
- SSEHS with parameter optimization: 237 KJ



Overflow energy loss



Accumulator energy change

In terms of swing energy consumption, the proposed SSEHS achieves the recovery and reuse of swing braking energy.

Conclusions

- Compared with traditional swing systems, the proposed SSEHS reduces the output pressure required by the main pump during the swing acceleration process;
- After the parameter optimization of the SSEHS system based on the adaptive grid constrained multi-objective particle swarm (AG-MOPSO) algorithm, the energy saving efficiency of the system is improved by 13.2%.
- Compared with traditional swing systems, the SSEHS can reduce 78.3% of overflow energy loss.

The designed SSEHS is also suitable for construction machinery with large inertia slewing platforms, such as rotary drilling rigs and cranes, and the proposed IMOPSO algorithm can be used for parameter matching and optimization of hydraulic hybrid systems.