A NEW MINLP MODEL FOR WORK AND HEAT EXCHANGE NETWORK SYNTHESIS AND OPTIMIZATION

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1. INTRODUCTION
1.1. Work and Heat Integration

Without work and heat integration

With work and heat integration
1.2. Work and Heat Exchange Network (WHEN)

- Network of heat exchangers, heaters, coolers, utility compressors and turbines, single-shaft-turbine-compressors, motors, electric generators, and valves;
- Performs demand for heating, cooling, compressing, and expanding;
- Minimum total annualized cost
Wechsung et al. (2011) presented a superstructure-based optimization model for HEN synthesis of streams that could compress and/or expand in pre-defined routes using Pinch Analysis and mathematical programming.

Onishi et al. (2014) introduced work integration; substituted Pinch Analysis to Yee and Grossmann (1990) HEN superstructure; changed objective function to TAC;

Huang & Karimi (2016) proposed a multi-stage WHEN superstructure for high-pressure, cold and low-pressure, hot streams;

Nair et al. (2018) modified that WHEN superstructure to deal with streams that are not pre-classified;

Pavão et al. (2019) proposed a new matrix-based formulation and implementation from Onishi et al. (2014) and solved with a two-level optimization approach using Simulated Annealing and Rocket Fireworks Optimization;
3. OBJECTIVE

- Present an MINLP model for WHEN synthesis and optimization;
- Develop a solution approach to this MINLP;
- Apply this framework to solve a small four-stream WHEN problem.
4. METHODOLOGY
4.1. Superstructure

Novelties:

- Process streams are not classified;
  - Idea of pseudo-identity
- Non-isothermal mixing consideration
4.2. MINLP model

- \( \text{min TAC} = \text{Capital cost} + \text{Operating cost} \)
- s.t. \( \begin{cases} \text{Mass and energy balance;} \\ \text{Thermodynamic constraints;} \\ \text{Design constraints;} \end{cases} \)
4.3. Decision Variables

Binary decision variables:
\( y(s, n, ss, nn, k), \)
\( y_w(s, n), \)
\( y_s(s, n), \)
\( e(s, n), \)
\( ue(s, n), \)
\( c(s, n), \)
\( uc(s, n), \)
\( v(s, n) \)

Continuous decision variables:
\( d(s, n), \)
\( Q(s, n, ss, nn, k), \)
\( dh(s, n, ss, nn, k), \)
\( dc(s, n, ss, nn, k), \)
\( Q_w(s, n), \)
\( Q_s(s, n), \)
\( P(s, n) \)
4.4. Solution Approach

- Initialize Topology \((y, y_w, y_s, e, ue, c, uc, v)\)
- Initialize Continuous \((d, Q, Q_w, Q_s, dh, dc, P)\)
- PSO of Continuous: \(\min \ TAC(d, Q, Q_w, Q_s, dh, dc, P)\)
- Topology Acceptance Criteria of SA
- Modify Topology \((y, y_w, y_s, e, ue, c, uc, v)\)
- SA Step and Termination Criteria
- Store Configuration, If Accepted \((y, y_w, y_s, e, ue, c, uc, v, d, Q, Q_w, Q_s, dh, dc, P)\)
- No
- Yes
- Return the Best Configuration Stored \((y, y_w, y_s, e, ue, c, uc, v, d, Q, Q_w, Q_s, dh, dc, P)\)
5. RESULTS AND DISCUSSION
5.1. Problem statement

Table 1 – Stream data (Huang & Karimi, 2016)

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5.2. Results

This work

TAC $172,031

Huang & Karimi (2016)

TAC $174,560
5.3. Discussion

Total annualized cost reduced

Features of superstructure did not show up at final solution such as:
- Pseudo-streams
- Non-isothermal consideration
6. CONCLUSIONS

- The new MINLP model for WHEN synthesis and optimization together with the two-level meta-heuristic optimization approach improved the TAC result of a literature problem;

- The concept of pseudo-stream and non-isothermal mixing consideration were not appreciated because:
  - the superstructure is unnecessarily complicated for small problems;
  - the optimization approach is incapable of dealing with large and complicated MINLP.
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REFERENCES


Thanks for your attention!