Closure

Prof. André Hemerly Costa

State University of Rio de Janeiro (UERJ)

December 6, 2019

Introduction

The objective of this presentation is to offer an overview of some of the results obtained by our research group recently

Rationale

Focus on the state-of-the-art

Our research group is focused on contributing to the state-of-the art of Process Systems Engineering, providing new tools for the design of chemical process equipment and flowsheets.

Rationale

<u>Research activities are “Result-Oriented”</u>

All students are assigned to a research theme directly linked to a publication from the start.

Rationale

Research activities are "Result-Oriented"

Example: Caroline Gonçalves (Former DSc student)

AIChE

Shell and Tube Heat Exchanger Design Using Mixed-Integer Linear Programming

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DOI 10.1002/aic.15556
Published online November 15, 2016 in Wiley Online Library (wileyonlinelibrary.com)

The design of heat exchangers, especially shell and tube heat exchangers was originally proposed as a trial and error procedure where guesses of the heat transfer coefficient were made and then verified after the design was finished. This traditional approach is highly dependent of the experience of a skilled engineer and it usually results in oversizing. Later, optimization techniques were proposed for the automatic generation of the best design alternative. Among these methods, there are heuristic and stochastic approaches as well as mathematical programming. In all cases, the models are mixed integer non-linear and non-convex. In the case of mathematical programming solution procedures, all the solution approaches were likely to be trapped in a local optimum solution, unless global optimization is used. In addition, it is very well-known that local solvers need good initial values or sometimes they do not even find a feasible solution. In this article, we propose to use a robust mixed integer global optimization procedure to obtain the optimal design. Our model is linear thanks to the use of standardized and discrete geometric values of the heat exchanger main mechanical components and a reformulation of integer nonlinear expressions without losing any rigor. © 2016 American Institute of Chemical Engineers *AIChE J*, 63: 1907–1922, 2017

Keywords: optimization, design

I&EC research
Industrial & Engineering Chemistry Research
Article
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Alternative Mixed-Integer Linear Programming Formulations for Shell and Tube Heat Exchanger Optimal Design

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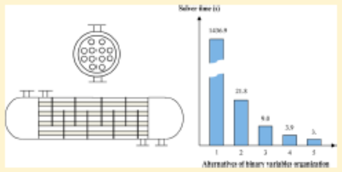
Supporting Information

ABSTRACT: In a recent article (Gonçalves et al., *AIChE J.* 2017. DOI: 10.1002/aic.15556), we presented a mixed-integer linear programming formulation for the detailed design of shell and tube heat exchangers based on the Kern approach (Kern, D. Q. *Process Heat Transfer*; McGraw Hill, 1950). The formulation relies on the use of standardized values for several mechanical parts, which we express in terms of discrete choices. Because we aim at having this model used as part of more complex models (i.e., heat exchanger networks synthesis), we identified a need to improve its computational efficiency. In this article, we explore several different modeling options to speed up solutions. These options are based on different alternatives of aggregation of the discrete values in relation to the set of binary variables. Numerical results show that these procedures allow large computational effort reductions.



Received: 5 November 2018 | Revised: 1 March 2019 | Accepted: 15 March 2019
DOI: 10.1002/aic.16602
PROCESS SYSTEMS ENGINEERING
AIChE JOURNAL

Linear method for the design of shell and tube heat exchangers using the Bell–Delaware method

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Abstract
In this article, we present a rigorous reformulation of the Bell–Delaware model for the design optimization of shell and tube heat exchanger to obtain a linear model. We extend a previously presented methodology1,2 of rigorously reformulate the mixed-integer nonlinear programing Kern model and we add disjunctions to automatically choose the different correlations to calculate heat transfer coefficients and pressure drop under different flow regimes. The linear character of the formulation allows the identification of the global optimum, even using conventional optimization algorithms. The proposed mixed-integer linear programming formulation with the Bell–Delaware method is able to identify feasible solutions for the design of heat exchangers at a lower cost than those obtained through conventional design formulations in the literature. Comparisons with the Kern method also indicate an average 22% difference (usually lower) in area.

KEYWORDS
design (process simulation), optimization

Rationale

Research activities are “Result-Oriented”

Example: Julia Lemos (Former DSc student)

Applied Thermal Engineering 125 (2017) 1345–1353

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Research Paper

Linear method for the design of shell and tube heat exchangers including fouling modeling

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HIGHLIGHTS

- A fouling model is inserted into the design optimization of heat exchangers.
- The mathematical problem consists in a mixed-integer linear programming (MILP).
- The results indicate a better performance when compared to conventional approaches.

ARTICLE INFO

Article history:
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Revised 7 June 2017
Accepted 9 July 2017
Available online 11 July 2017

ABSTRACT

Typical heat exchanger design procedures are based on the use of fixed values of fouling factors, mostly based on estimates coming from practice. However, fouling depends on thermofluidynamic conditions (e.g. flow velocity) which values are consequence of the selection of design variables (e.g. baffle spacing). Therefore, the inclusion of fouling models into an optimal design procedure may yield better solutions. In this article, we extend a recent globally optimal linear formulation for the design of shell and tube heat exchangers (Gonçalves et al., 2017). Our extension leads to a linear model and consists on adding velocity dependent fouling factors. A comparison with design examples based on fixed fouling factors indicates that the linear problem can identify better design solutions, without involving any external convergence loop.

AIChE

Globally Optimal Linear Approach to the Design of Heat Exchangers Using Threshold Fouling Modeling

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DOI 10.1002/aic.16083
Published online January 22, 2018 in Wiley Online Library (wileyonlinelibrary.com)

This article presents a method for the mathematical optimization of the design of heat exchangers including fouling rate modeling for the tube-side. The description of the fouling rate in crude preheat trains of petroleum distillation units is commonly based on threshold models (Ebert-Panchal model and its variants). Our formulation of the design problem employs a mixed-integer linear programing approach; therefore the solution is the global optimum and common non-convergence drawbacks of mixed-integer nonlinear programming models are totally avoided. Three different examples are employed to compare the proposed approach with an optimization procedure using fixed fouling resistances. The results indicate that in two problems was possible to obtain design solutions associated to smaller heat exchangers. Additionally, three case studies are also explored to discuss how fouling is related to crude types, pressure drop manipulation, and energy integration. © 2018 American Institute of Chemical Engineers *AIChE J*, 64: 2089–2102, 2018

Keywords: optimization, design, heat transfer

Rationale

Research activities are “Result-Oriented”

Example: Ana Levy (Current DSc student)

I&EC research
Industrial & Engineering Chemistry Research
Article
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pubs.acs.org/IECR

Globally Optimal Design Optimization of Cooling Water Systems

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[‡]LEPABE, Department of Chemical Engineering, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, s/n, 4200-465 Porto, Portugal

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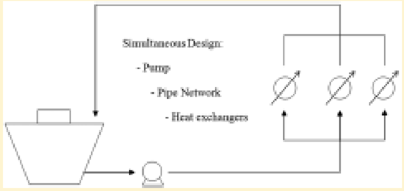
Supporting Information

ABSTRACT: This study presents a globally optimal linear procedure for the simultaneous design of cooling water systems. The optimization entails obtaining optimal pipe diameters, pump selection, and detailed cooler design. For the latter, the Kern model and the linear formulation proposed by Gonçalves et al. (Ind. Eng. Chem. Res. 2017, 56, 5970) were used. The proposed linear model is compared with conventional design procedures, such as optimizing the design of each exchanger first, through area minimization or through area and pressure drop costs. The results illustrate in one of the examples the advantage of using the proposed simultaneous design approach.



Cooling Water Systems Featuring Heat Exchanger Design and Variable Outlet Temperature

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(+) Rio de Janeiro State University (UERJ), Rua São Francisco Xavier, 524, Maracanã, CEP 20550-900, Rio de Janeiro, RJ, Brazil

Rationale

Research activities are "Result-Oriented"

Example: Aline Raybolt (Current DSc student)

Globally Optimal Mechanical Design of Sieve Trays in Distillation Columns

*Aline R. da Cruz Souza[a], Miguel J. Bagajewicz[b], André Luiz Hemerly Costa[a] **

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[b] School of Chemical, Biological and Materials Engineering, University of Oklahoma, Norman, Oklahoma USA 73019

Rationale

Research activities are "Result-Oriented"

Example: Marco Thiago (Current DSc student)

Globally Optimal Design of Air Coolers Using Distributed Model. Part I- Fixed Air Flowrate

Marco Thiago da C. Santos [‡], Argimiro Resende Secchi[+], Miguel J. Bagajewicz[†] and André L. H. Costa,[‡]*

Rationale

Research activities are "Result-Oriented"

Example: Priscila de Souza (Former MSc student)

AIChE

Globally Optimal Linear Approach for the Design of Process Equipment: The Case of Air Coolers

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DOI 10.1002/aic.15977
Published online October 20, 2017 in Wiley Online Library (wileyonlinelibrary.com)

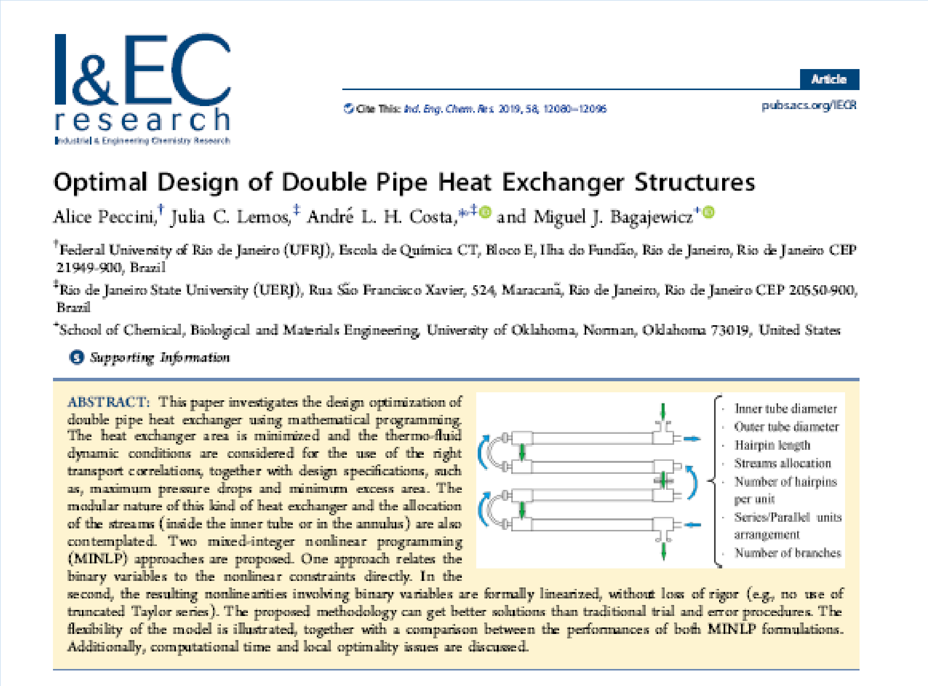
In a recent article, Gonçalves et al., introduced a linear and rigorous methodology for equipment design, in particular shell-and-tube heat exchanger. Here, we explore its application to air coolers, a problem that we solve globally for the first time. Because the approach is linear, results are globally optimal. The objective function is the total annualized cost. The constraints include the thermal and hydraulic modeling of the process stream flow in the tube bundle and the air flow through the finned surface. In addition, we worked on reducing computing time, through an analysis of different alternatives for the description of the original discrete variables organized in sets of binary variables. The performance of the proposed approach is illustrated through its comparison with an air cooler described in the literature. © 2017 American Institute of Chemical Engineers *AIChE J*, 64: 886–903, 2018

Keywords: heat transfer, optimization

Rationale

Research activities are "Result-Oriented"

Example: Alice Peccini (Former MSc student)



I&EC research Industrial & Engineering Chemistry Research

Article

Cite This: Ind. Eng. Chem. Res. 2019, 58, 12080−12096

pubs.acs.org/IECR

Optimal Design of Double Pipe Heat Exchanger Structures

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[‡]Rio de Janeiro State University (UERJ), Rua São Francisco Xavier, 524, Maracanã, Rio de Janeiro, Rio de Janeiro CEP 20550-900, Brazil

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Supporting Information

ABSTRACT: This paper investigates the design optimization of double pipe heat exchanger using mathematical programming. The heat exchanger area is minimized and the thermo-fluid dynamic conditions are considered for the use of the right transport correlations, together with design specifications, such as, maximum pressure drops and minimum excess area. The modular nature of this kind of heat exchanger and the allocation of the streams (inside the inner tube or in the annulus) are also contemplated. Two mixed-integer nonlinear programming (MINLP) approaches are proposed. One approach relates the binary variables to the nonlinear constraints directly. In the second, the resulting nonlinearities involving binary variables are formally linearized, without loss of rigor (e.g., no use of truncated Taylor series). The proposed methodology can get better solutions than traditional trial and error procedures. The flexibility of the model is illustrated, together with a comparison between the performances of both MINLP formulations. Additionally, computational time and local optimality issues are discussed.

Rationale

Research activities are "Result-Oriented"

Example: André Nahes (Current undergraduate student)

Design of Gasketed-Plate Heat Exchangers Using Different Deterministic Optimization Techniques

André L. M. Nahes[a], Natalia R. Martins[a], Gustavo C. Alves[a], Miguel J. Bagajewicz[b], André L. H. Costa[a,*]

[a]*Institute of Chemistry, Rio de Janeiro State University (UERJ), Rua São Francisco Xavier, 524, Maracanã, Rio de Janeiro, RJ, CEP 20550-900 Brazil*

[b]*School of Chemical, Biological and Materials Engineering, University of Oklahoma, Norman Oklahoma 73019*

Rationale

<u>Research activities are "Result-Oriented"</u>

Example: João Pedro (Current undergraduate student)

Globally Optimal Horizontal Condenser Design

João Pedro Domingues[†], *Igor .....* [†], *Miguel J. Bagajewicz*[+] *and André L. H. Costa*[†,*]

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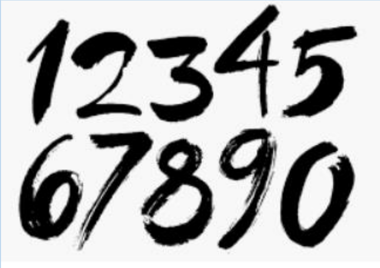
Results

Let´s talk about numbers…

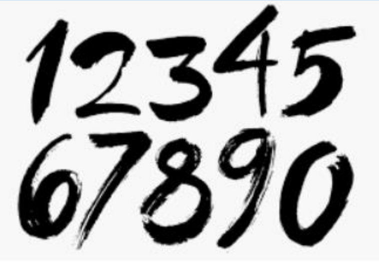


Papers in international journals (2015 - 2019): 11

- AIChE Journal
- Industrial & Engineering Chemistry Research
- Applied Thermal Engineering

Results

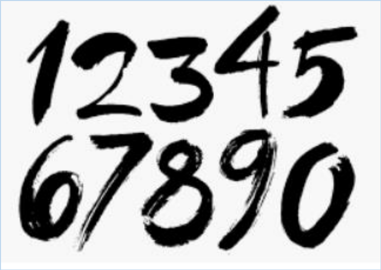
Let´s talk about numbers…



Conference Papers: 11

- XXI Congresso Brasileiro de Engenharia Química – COBEQ 2016 (1)
- 27th European Symposium on Computer Aided Chemical Engineering – ESCAPE 2017 (1)
- International Symposium on Process Systems Engineering – PSE 2018 (1)
- XXII Congresso Brasileiro de Engenharia Química – COBEQ 2018 (1)
- 29th European Symposium on Computer Aided Chemical Engineering – ESCAPE 2019 (2)
- 5th International Conference on Sustainable Chemical Product and Process Engineering (1)
- AAIQ - X Congreso Argentino de Ingeniería Química CAIQ2019 (1)
- I Congresso Brasileiro em Engenharia de Sistemas em Processos (PSE Brazil), Rio de Janeiro , May 2019. (2)
- Process Systems Engineering Asia(1)

Results



<u>Let´s talk about numbers...</u>

MSc Dissertations: 2

DSc Thesis: 2

Current group

Women and men at work

Undergraduate students:	4
Graduate students:	5
Post doc:	1

Opportunities

We are hiring…

The research group is expanding, addressing new problems and seeking new students.

Opportunities

We offer…

"You will be famous"