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Optimization of the equipment positioning in manufacture of Tissue Paper

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Abstract

Optimization is a tool to find the best solution from a set of feasible solutions for a problem. Many processes can be benefited by an optimized allocation of resources. These resources, which may include capital, equipment, tasks and time, must carefully be placed in the correct amounts, the correct times, and the correct sequence for the best possible result to be attained. These are usually complex problems, many times of difficult solution, and they may result in significant reductions of costs, improvements of times of processes, or better allocation of resources in activities. Mathematical models can be used to get the more economical layout of a process, subject to restrictions that make possible the operation, maintenance and security. Therefore, the model is set to minimize the total cost, provided that they satisfy the restrictions of free space of components. The category of Tissue papers encloses the toilet paper, that make up 80% of the production, the towels (16%) and napkins (4%), most for attendance of consumers such as nets of fast-food, hospitals, offices, industries, etc. Brazil contributes with 2.8% of the world-wide production, participation that comes if keeping since 1990. Moreover, the Country is 9th producing world-wide of toilet paper. This work had as objective a study of the optimization of the localization of equipment in the manufacture of Tissue paper. We use for this work a mathematical model formulated as a mixed integer program model (MILP) solved with GAMS/CPLEX. The original problem, with 15 components, was regrouped to a 10 components problem in order to solve the model to optimality (zero gap in the branch-and-bound procedure). This grouping was not arbitrary, but it was based on requirements of some components to be placed close to others, as for example, bombs to the side of tanks. The resulting layout was solve in an acceptable computational time.

Keywords: Optimization,GAMS, MILP

1. Introduction

The layout development of a chemical plant is part of a more general process, i.e., the global design of the plant. This one comprises six steps [12]:

1. Problem definition and conception. In which basic aspects and hypothesis should be well known, as well as plant capacity and time distribution. In this stage the objectives of the plant, its economical viability and flexibility to eventual changes are investigated.
2. Development of the process fluxograms. It allows for the process familiarization, reduces the process complexibility and identifies the missing information.
3. Equipment design. At least a preliminary design is required to produce info for economical assessment. Beyond that, equipment manufactures and vendors need more detailed information, such as material to be used and tank wall thickness.
4. Economical analysis. "How much money will be earned for the investment made?" The answer requires determination of raw materials, equipment, labor and processing costs, as well as knowledge about inflation rates, taxes, etc., which affects the industry profitability as a whole.
5. Optimization. A balance between engineering and economics. The optimum is searched considering all factors involved. The factory components placement is regarded here, which is the topic of this work.
6. Report publication. The previous work is presented in a clear and organized way, to guarantee absence of doubts.

The The ideal layout achievement may be hampered by space limitations, available time and absence of qualified personnel. Nevertheless, the ideal layout sets a guideline for any modification. An adapted layout is the way to go then. The objective of this work was to optimize, using mathematical modeling, specifically GAMS/CPLEX version 7.5 with the equation proposed by [7], the layout of a tissue manufacturing plan.

2. Mathematical Model

A mathematical model for a specific situation is a set of mathematical elations, i.e., equations, inequations and logical conditions, which represent virtually the real system. To optimizing modeling involves a problem regarding choices[17]. It uses decision variables, and search for values that maximize or minimize a target function, regarding restrictions imposed to the choices. A mathematical model consists of four basic elements: variables, parameters, constants and mathematical relations. The variables may assume different values and their specifications define different states for a system. A model may have continuous variables, integer variables or a set composed of a mixture of them. The parameters are determined by one or multiple values, and each value defines a new model. The constants contain one value, and are declared in the model. The mathematical relations may be classified as equations, inequations or logical conditions.

3. Modeling and Simulation

Modeling and simulation are powerful tools to analyze and synthesize a system. A model describes objects and related processes, which allows dealing with complex problems in an efficient and systematic way. The model may be physical, graphical or mathematical. The model purpose determines its selection and building. Simulation allows previewing the behavior of a system by using the developed model.

The steps involved to develop a model are:

1. Deciding about the type of model to be used and considerations related;
2. Defining the equations according to considerations and simplifying hypothesis;
3. Obtaining the required data and parameters for the model;
4. Choosing the solution method and building the computer programs;
5. Testing and refining the model.

The objectives of process simulation are:

1. Preview the effects of changes on operating conditions, physical layout and operating capacity;
2. Perform fast heat and mass energy balances useful in design and to study monthly production of an existing plant;
3. Optimize operation quickly and efficiently;
4. Detect and eliminate operating flaws;
5. Promote a deep understanding of the whole system;
6. Improve controlling and assess new control strategies;
7. Ease cost calculation and operation planning;
8. Train engineers and operators.

3.1. Case study

To optimize the tissue manufacturing plant, the model proposed by [4] was employed (figure 01). It consists of a model encompassing a linear and integer mix programming, in which the target function to be minimized includes:

- plant ground cost;
- cost of each equipment support;
- cost of piping

and is subjected to the following restrictions:

- do not superpose pieces of equipment;
- keep safe distance among pieces of equipment;
- provide room for equipment rotation,

to guarantee safety and easy access to plant components.

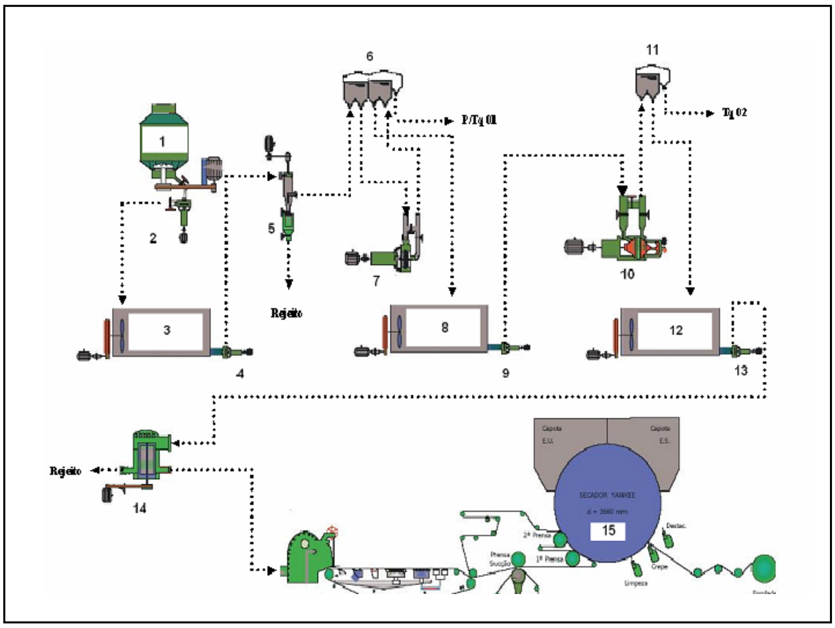

Figure 01 – Tissue plant fluxogram
Components: (1) Pulper, (2) Pump 01, (3) Tank 01, (4) Pump 03, (5) Setter, (6) Dosage Box 01, (7) First Refiner, (8) Tank 04, (9) Pump 04, (10) Refiner, (11) Dosage Box 02, (12) Dilution Tank, (13) Pump 08, (14) Vertical Refiner, (15) Paper Machine

3.2. Results and discussions

The model proposed by Guirardello was implemented with GAMS/CPLEX 7.5, and solved by a Sun Enterprise E250 400 MHz workstation. Initially the model was tested with its original structure, and the algorithm was allowed to reach the best solution. Initially tests had been carried through where if it decided the model in its original form with 15 components, allowing that the algorithm found the best solution. To solve this problem, it was decided to the reduce the amount of components from 15 to 10, through the grouping of some equipment. This grouping was not arbitrary, but it was based on the requirement of some components to be necessarily together to other components, as for example, bombs to the side of tanks. In table 01, we present the number of equations and variable gotten with the optimization.

Table 01 - Number of equations and variables employed

Blocks of Equations	25
Blocks of variables	24
Non zero Elements	3.349
Single Equations	783
Single Variables	738

Table 02 - Results for costs for study of two strategies "best bound" and "depht first"

Costs	
best bound e depth first	
Ground	17,583.00
Support	58,207.72
Pipines	4,984.86
Z Optimal	80,739.35

Table 03 presents the demanded computing times, as well as the number of iterations necessary and the amount of required knots.

Table 03 - Results for "best bound" stategies.

best bound	
Time	38278 s
Number of iterations	46
Knots	6235023

In table 04, the values in the directions of x, y and z are demonstrated after the optimization.

Table 04 – Directions

	Directions x,y and z	
1	3.00	3.00
2	4.00	6.50
3	0.50	0.45
4	0.50	1.90
5	4.50	3.00
6	3.30	1.20
7	0.50	1.10
8	2.50	2.00
9	1.60	2.00
10	21.50	3.30

4. Conclusions

The objective of this work was successfully obtained with the best placing of the pieces of equipment for a tissue manufacturing plant. Ground, equipment support and piping costs were minimized. The algorithm employed was very efficient. The requeried computing time was accetable, despite the great amount variables. The lower the amount of fixed position variables, the higher the computing time. High computing times are not interesting, even if values of optimal Z are obtained.

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References

1. BUSH, M. J. and WELLS, G. L . Optimum plant layout scores on maintenance, operation, safety. Process Engineering, 53 (9), pp. 135-137, 1972.
2. DRUMMOND, Daniela Medeiros Devienne; GUIRARDELLO, Reginaldo. Optimization of Tissue paper equipment layout using MILP. In: ICHEAP 7, 2005, TAORMINA. 2005.
3. FRANCIS, R.L. and WHITE, J. A. Facility layout and location: an analytical approach. New Jersey: Prentice Hall, 1974.
4. GUIRARDELLO, R. Optimization of Process Plant Layout. Ph.D. Thesis, University of Wisconsin, Madison, USA, 1993.
5. GUIRARDELLO, R., Ross E.Swaney, Optimization of process plant layout with pipe routing, Comp.And Chemical Eng, 30 (2005) 99-114.
6. HOUNSELL,MARCELO DA SILVA., Plant Layout,1999
7. KAURA, M. L. Plot plans include safety. Hydrocarbon Processing, 59 (7), pp. 183-194, 1980.
8. KERN, R. How to manage plant design to obtain minimum cost. Chemical Engineering, 84 (11), pp. 130-136, 1977.
9. KERN, R. Arranging the housed chemical process plant. Chemical Engineering, 85 (16), pp. 123-130, 1978.