Visual Methods for Modeling Materials and Energy Balances

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ABSTRACT. *Materials and energy balances are some of the most important tools for analyzing processes for the food industry. In our paper we are trying to establish a connection path between mathematics, computer science and chemistry. The analysis using Petri nets has become a very common technique for modeling specifications and for the evaluation of systems' performances. Petri nets can offer an intuitive approach, use formal techniques and provide some graphical description methods.*
Key words: *Petri nets, gas absorber, net analysis*

1 Introduction

In the actual context of fast development of all sciences, the concept of interdisciplinarity becomes more necessary, namely the construction of a communication language between different domains of sciences.

The formalism of Petri nets offers a strong theoretical base, sustained by powerful mathematical methods for the purpose of modeling and analysis of operation-flow processes.

In this paper we are going to present the main advantages of such methods which are transfering the importance of conceptual modeling to material modeling. We intend to sustain this approach by introducing a Petri net model for an absorber with two inputs. We will begin with the presentation of the device from an engineer point of view, we will continue with the construction of the associated Petri net model and with the presentation of its elements and, finally, we will briefly enumerate the main properties of this model.

2 Absorber presentation

The absorber we are going to model here is characterised by two input streams: a vapor entry and a liquid entry. The absorber components are two simple separators and two mixers. A simple separator can be used to model processes with one input I_1 and two outputs: O_1 and O_2. In a graphic representation, the separator is shown in Figure 1.

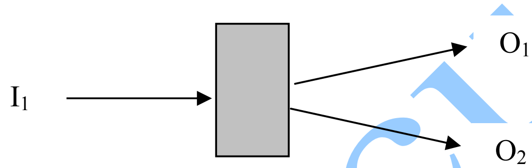

Figure 1. Simple separator

The other device used in this complex equipment is a mixer, characterised by at least two entries of different composition and the result is an unique uniform mixture as the output, as shown in Figure 2 for three entries.

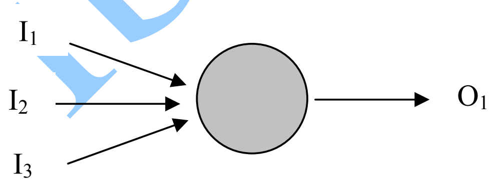

Figure 2. Mixer

The first separator is used for the vapor phase as follows: it separates the compound of interest V_1 from the input stream and the other output V_2 is the input stream from which we have removed the compound. Similarly, the second separator removes from the second entry in liquid phase another compound of interest L_1 and L_2 represent this input stream without the removed compound. V_1 and L_1 are transported to the first mixer that produces the mixture from the compounds of interest. The second mixer will produce a mixture with the vapor that were separated and the liquid.

This device can be used for flash drums, distillation columns and separation processes that do not need a separating agent.

3 Construction of the Petri net model

Our device is organized as a Petri net following the definition of such a structure.

Definition. *A Petri net structure is a four-tuple C=(P, T, I, O) with* $P=\{p_1, p_2,\dots,p_n\}$*, a finite set of places,* $T=\{t_1,t_2,\dots,t_m\}$ *a finite set of transitions, with the property that* $P \cap T = \emptyset$*. The mapping* $I : T \to P^\infty$ *is the input function and* $O : T \to P^\infty$ *is the output function and they are both mapping transitions to places.*

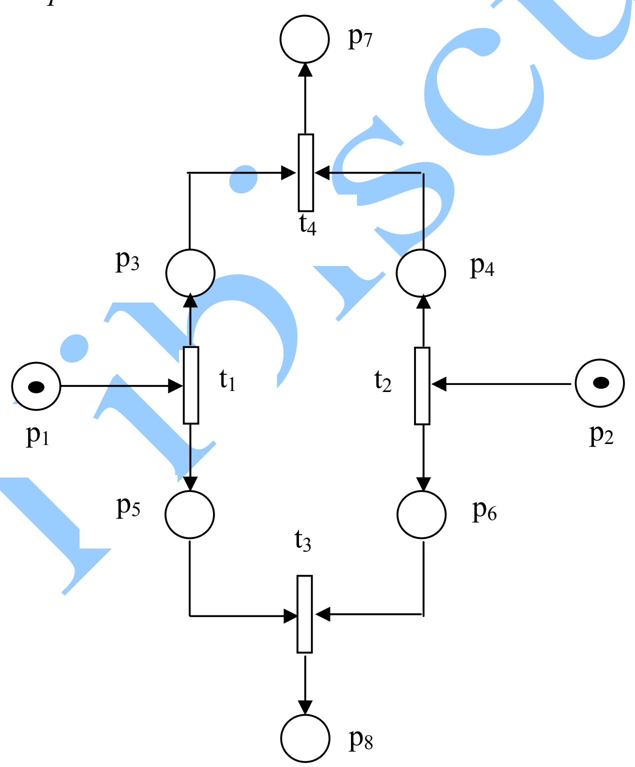

Figure 3. Petri net model for absorber

Figure 3 represents the Petri net model for our complex device in discussion.

In our case, the Petri net structure is *C=(P,T,I,O)*, with the places set containing 8 elements: $P = (p_1, p_2, p_3, p_4, p_5, p_6, p_7, p_8)$ and with 4 transitions: $T = (t_1, t_2, t_3, t_4)$. The input function $I : T \rightarrow P^{\infty}$ and the output function $O : T \rightarrow P^{\infty}$ are described as follows:

$$I(t_1) = (p_1) \quad O(t_1) = (p_3, p_5)$$
$$I(t_2) = (p_2) \quad O(t_2) = (p_4, p_6)$$
$$I(t_3) = (p_5, p_6) \quad O(t_3) = (p_8)$$
$$I(t_4) = (p_3, p_4) \quad O(t_4) = (p_7)$$

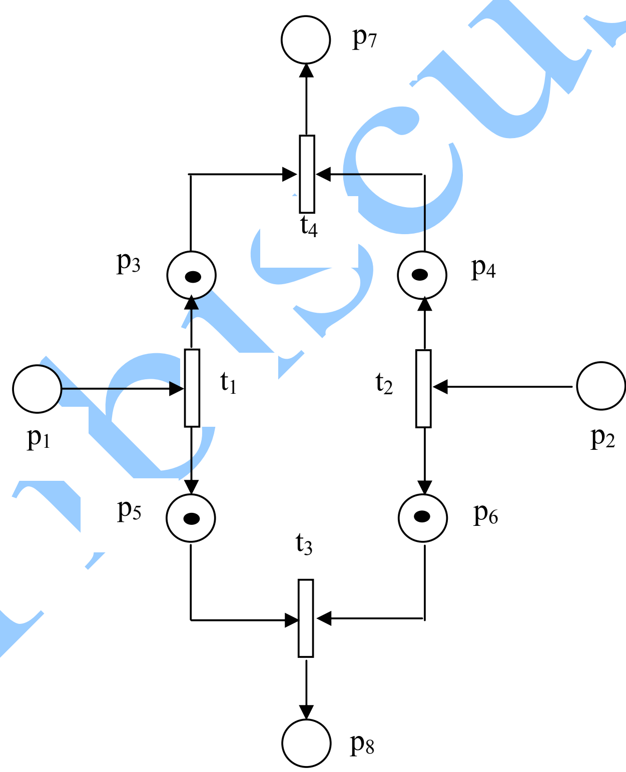

Figure 4. Petri net model for absorber after firing

Our example is a marked Petri net because of the tokens placed in positions p_1 and p_2 and the marking for this net is (1,1,0,0,0,0,0,0). Both t_1 and t_2 are enabled transitions because the number of tokens is equal to the number of arcs from the input places to the transitions. For the moment, transitions t_3 and t_4 are not enabled because their input places have no tokens. But, when t_1 fires, it is moving the token from the input place and it transforms it in two tokens, one for each output. So, the token from p_1 is removed and a token is placed in p_3 and another is placed in p_5. Similar, the token from p_2 is moved to p_4 and to p_6. Thus, t_3 and t_4 are now enabled and they can fire. The marking resulting from firing both transitions t_1 and t_2 is (0,0,1,1,1,1,0,0) and the net is represented in Figure 4.

After firing transitions t_3 and t_4, there will be no enabled transition, so the execution is stopped. When the process is continuous, with a permanent feeding flow in the inputs, the execution will be also continuous and an ending criteria could be the reach of a certain amount for the output quantities.

4 Analysis of the net properties

Safeness. Our Petri net model is safe because all its places are safe, i. e. the number of tokens for every place is either 0 or 1. The safeness property allows the introduction of a counter.

Boundedness. This is a general property from which safeness is derived and it establishes an upper limit for the counter. This maximal number is necessary in terms of computer allocation resources. In this example, the net is bounded, because it is covered by positive invariants, as shown in the next table.

Conservation. The device modeled here is tipical for the analysis of resource allocation and the tokens are representing the resources used in the process. In this case, the initial tokens are used to produce multiple tokens, by firing a transition with more outputs than inputs. We know that a Petri net is strictly conservative if it is conservative with respect to the weighting unit vector $w=(1,1,1,1,1,1,1,1)$. For this, we have to show that

$$\sum_{i=1}^{8} w_i \cdot \mu'(p_i) = \sum_{i=1}^{8} w_i \cdot \mu(p_i)$$

where μ' representing the marking after firing (0,0,1,1,1,1,0,0) and μ the initial marking (1,1,0,0,0,0,0,0). But

$$\sum_{i=1}^{8} w_i \cdot \mu'(p_i) = 4 \neq 2 = \sum_{i=1}^{8} w_i \cdot \mu(p_i)$$

Thus, our model is not strictly conservative. But, if we choose another weighting vector, $v=(0,0,0,0,0,0,1,1)$, the model is conservative with respect to v.

Liveness. For the model analysed here, all the transitions are live at level 1, i. e. every transition is potentially fireable.

Finally, we will present the **P-invariants** for this device. Those invariants are a set of places that do not change the tokens during firing. This invariants are obtained by solving an equation of the form

$$N^T \cdot x = 0$$

where N is the matrix corresponding to the net in Figure 3 and x denotes the P-invariant to be determined. At this moment we will only present this matrix and some of the P-invariants for the proposed model.

	t_1	t_2	t_3	t_4	i_1	i_2	i_3	i_4
p_1	-1				1	0	1	0
p_2		-1			0	1	0	1
p_3	1			-1	1	0	0	0
p_4		1		-1	0	1	0	0
p_5	1				0	0	1	0
p_6		1	-1		0	0	0	1
p_7			-1	1	1	1	0	0
p_8			1		0	0	1	1

In this table we have presented only the characteristic P-invariants, meaning those vectors consisting of components 0 or 1.

5 Conclusions

The main objective of our research was to create a model for the device, thinking of the audience whom we are adressing: a chemical engineer, with a little amount of knowledge in the field of mathematical modeling and to solve this problem we have choosen a visual model with Petri nets.

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