# Modeling a production system based on flow-shop electrical system

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***Abstract*— Improving the competitiveness of a company amounts to control its workflow. The purpose of industries is to provide customer satisfaction and maximum production with a minimal cost, which requires the provision of a scientific model applied to production systems to control their behavior**

**The contribution conducted by this work focuses on the problem of flow management, we propose an analogy between the production system and electrical circuits. The modeling approach proposed is based on elementary electrical components which are intended to draw the various parameters that change the characteristics of production system.**

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***Keywords-component; modeling, flow, production systems, electrical system***

## I. INTRODUCTION

Currently, manufacturers are confronted by a strong global competition, which is manifested by uncertain demand and customers increasingly demanding vis-à-vis cost, quality and even the delivery conditions. These constraints automatically impose the rapid adaptation of the productive capacity of systems to changes in demand and the vagaries of internal production. This requires both a permanent improvement in productivity and increased flexibility of the production system. The pilot and mastering workflow solutions become key to the success of this mission.

To achieve the best, firms need to respond appropriately during manufacture. Among the possible solutions, eliminate bottlenecks and address the sticking points that stand the test of the product stream.

So far, it is unrealistic to say that we are able to master the entire production. For this, specialists in the field have proposed several short-time models for production systems. These models can be considered as limited to present the complexity of real systems (Integrating NC machines, wire-guided carts, robots ...). For the same production system, there may be several models. The difference between them is in the process and issue we want to snuff prior assumptions on its structure, its dynamics and its environment. A model can not handle all the problems of a production system. We can summarize that a model can only processes a given purpose.The mean aim of this research is the use of modeling of the electrical, which is generally not a tool for modeling production systems manufacturer, but rather the design of electronic and electrical schemes. This analogy helps to reduce the problem to the field of electronics, the process and find adequate solutions. Then return to the manufacturing field and application of these solutions on a production system.

This paper is organized as follows:

- In section 2 we will develop the critical state of art in which we present the limitations of some models.

- In Section 3 we present an approach of analogy between the production system with a circuit of electrical components.

## II. STATE OF THE ART

Modeling a production system is a complex problem (number of parameters, its interaction with the environment, significant production volume, large variety of products, etc...). Several methods have been proposed in the literature to obtain models close to reality, able to reflect the dynamics of its operation. Despite these many proposals, the majority still difficult to put into practice. In the same context, the models based on the physics of fluids have been used by several authors. As an example we cite the work of Balduzzi [1] which proposes an approach to modeling and simulation of complex manufacturing systems in which he combines hybrid Petri nets with fluid approximation model workflows. In [2], he connects the transportation problems of products circulating in production facilities by a continuous model; it considers the dynamic phenomena specific to road traffic as analogous to the workflow. While Khaled ALKASSEM [3], draws an analogy between fluid mechanics and traffic theory to study the behavior of flow manufacturing. Based on the tetrahedron of Paynter Bond Graph method, and then sets the variable generalized flow manufacturing. Also, Karim Tamani [4], focuses on the modeling problems of the production system with high density. such in the paper industry, food processing and semiconductors….The advantage of modeling this type of production system "large volumes" are their inputs and outputs can be considered as continuous "fluid".

In our approach, we will be inspired by the electrical field to model the workflow. What we present in the next section.

## III. ANALOGY BETWEEN THE MANUFACTURING SYSTEM AND THE ELECTRICAL SYSTEM

For reasons of simplicity, our study will focus on the study of a production line flow shop. The line is composed of modules connecting the flow. Each module consists of two parts: Stock and machinery. The inputs and outputs of each module are taken into account because the internal operation is highly dependent on available technology and control policies. The observation points are a station of stock entry and exit of the machine.

The proposed approach to formulate our approach is summarized in two main stages: the first step is to define the flow variables (flow, velocity, acceleration and density), and establish an analogy between the workflow and the flow of electricity based on the similarity of the dynamics of the two streams to determine subsequently the flow variables, load and effort. The second step is to define the relationships between the three flow variables (current, voltage and load).

*III.1.Flow variables:*

The description of the overall behavior of the product stream uses so-called macroscopic variables (load, velocity, flow and density ...). We detail below the definition for each of these variables.

*III. 1.a.Load:*

In a conductor, we consider a set of particles of charge q, density moved in a set of velocity v. In manufacturing production system, the charge q represents the quantity of items passing through a machine, stored in a storage area, positioned on a transfer element (conveyor, electrical ...) or positioned on the entire surface of the line production. By analogy with electrical circuits, the production line of length L, acts as the conductive channel, the width of each part of the line represents the number of parts that can be treated in parallel or stoker in a machine at the same time.

The relationship of these parameters can be expressed as:

$$dq = \sigma . dt . \vec{v} . d\vec{L} \quad (1)$$

And $\sigma = [\frac{C}{m^2}]$ (2)

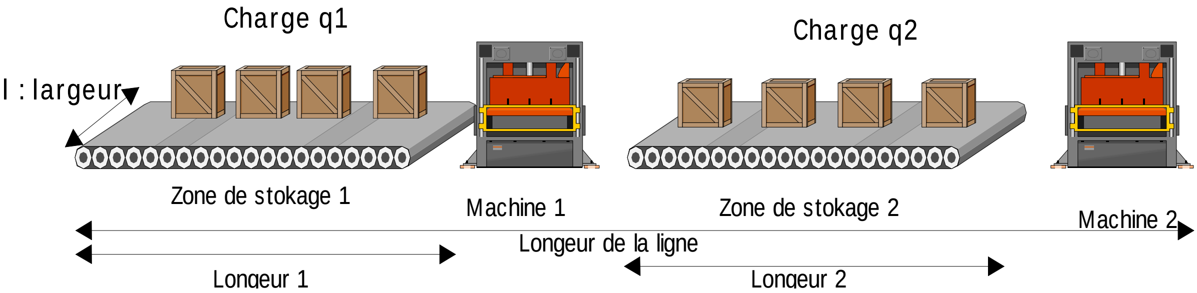


Figure 1: Example of a production line in two stock-machine modules

In our study, we consider that the parts manufactured are homogeneous. They have the same dimensions. We also consider the storage areas are flat areas (the parts are stored on the ground).

*III.1.b. density:*

Density is the number of items occupying a zone between two given areas A and A + ΔA in a production line at time t.

$$\sigma(t, A, A+\Delta A) = \frac{q(A, A+\Delta A, t)}{A+\Delta A} \quad (3)$$

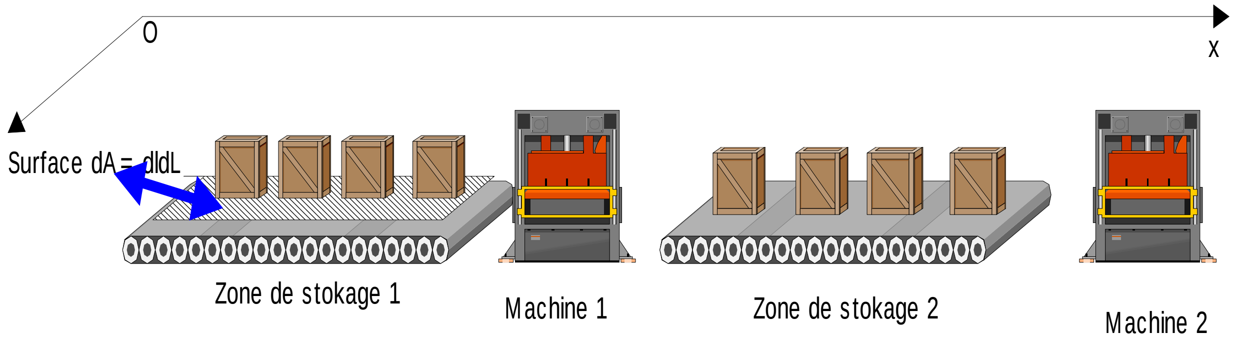


Figure 2: The density of the storage area

*III.1.c. Flow I:*

The flow is the quantity q of the product passing through a given area A of the production line between t and t + t (number of parts that passes along a conveyor, a machine ...).

$$I(x, t, t+\Delta t) = \frac{q(A, t, t+\Delta t)}{\Delta t} \quad (4)$$

The current is the electric charge through a conductor cross section per unit of time. Section is equal to the area A times the height of the room, the current is then written as follows:

$$I_e = \frac{q(A, t, t+\Delta t)}{\Delta t} \quad (5)$$

The flow value is calculated at a specific area in the production line (at the source, at the end of production line, outside the machine, or on a conveyor). In our study we measure the flow from the machines output,

*III.1.d. Average velocity:*

We always consider in our study that the production is in flow shop. All parts follow the same production process, the speed of the parts is then calculated over time by the following formula:

$$\vec{v} = \frac{1}{n}\sum_{i=1}^{n} v_i \quad (6)$$

We calculate the velocity at the exit of each module stock-machine. The number n represents the number of parts manufactured by the machine at the instant t i.

*III.1.e. The instant acceleration:*

The acceleration of a mobile characterizes its velocity variation over time. This variable is obtained from the velocity profile by differentiation. The average acceleration over a distance in the interval T is defined from instantaneous accelerations as follows [5]:

$$a_m = \frac{1}{T}\int_0^T a_i(t)dt = \frac{v_i(T) - v_i(0)}{T} \quad (7)$$

Variables are deduced instantaneous acceleration after smoothing successive differences speeds in a defined time interval [5].

*III.1.f. Work:*

By analogy, the work is the dot product of the force F required to move an item from one location j to a location k by the traverses distance between these two locations,

The force F is given by the following formula:

$$F = q.m.a_m \quad (8)$$

$m$: The mass of each part, we consider that the parts that pass through the line have the same mass value.

*III.1.i. The potential:*

The potential difference U between two locations of the line j and k is the work that must be to move a quantity of parts between these two locations divided by the amount of charge:

$$U_{jk} = \frac{W_{j\to k}}{q} \quad (9)$$

$$\text{The unit is: } \left[\frac{kg.m.\frac{m}{s^2}}{C} = \frac{J}{C}\right] \quad (10)$$

$$U = V_k - V_r \quad (11)$$

To set the potential at a location k of the production line. We choose O as the source location (where the potential is zero) as we call it as reference point is the start of the production line such that the potential is zero. The potential at a point B is equal for example:

$$V_O = 0$$

$$V_B - V_O = \frac{W_B}{q} - 0 = \frac{W_B}{q} \quad (11)$$

The potential value is calculated at a specific location (at the source, at the end of production line, in the machinery, to a point between the source and the end of the line) for a period of time Δt.

*III.2. Proposed relationships between variables in the model:*

After defining the generalized variables and their measurement units, the next step is to define the relationships between these variables, defining capacity and resistance. Again we rely on the basic equations of electricity.

*III.2.a. Manufacturing capacity:*

In the Electricity, the capacitor has the role of the electric charge storage. Similarly, the storage area in a production system has the role to store the pieces. The maximum capacity of zone i equal $q_i^{\max}$ .

The flow in the two components, a stock and capacity can then be written as:

$$I_c = I_{in-} I_{out} \quad (12)$$

With the flow is in stock, and the capacity are respectively the inflow and outflow in its components,

*III.2.a.1.Capacity:*

The capacity $C_e$ is the amount of electric charge stored for a given electric potential [6]. It is defined as the sum of the electrical loads of an element divided by the potential of this element:

$$C_e = Capacity = \frac{Load}{\text{Potentiel difference}} = \frac{q}{\Delta V} \quad (13)$$

By analogy, manufacturing capacity $C_{man}$ is defined as the ratio between the quantity of parts in an area of the production line (eg a storage area or in a conveyor) divided by the potential of this area.

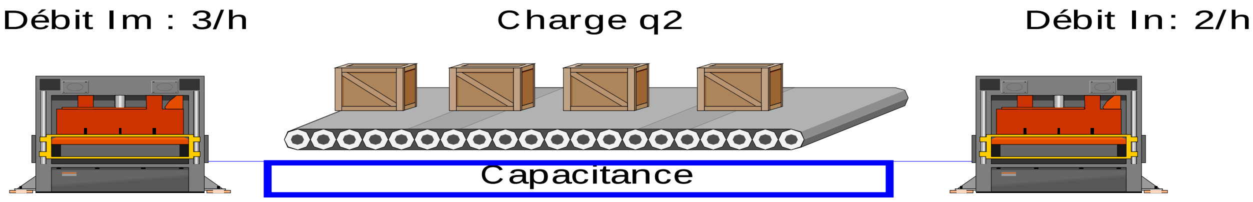


Figure3: The capacitive effect between the two machines

The unit of measurement is then:

$$C_{man} = Capacity = \frac{Load}{\text{Potentiel difference}} = \frac{q}{\Delta V} \quad (14)$$

$$C.\left[\frac{kg.m.\frac{m}{s^2}}{C}\right]^{-1} = \left[\frac{C^2}{kg.m.\frac{m}{s^2}}\right] \quad (15)$$

$$produit.\left[\frac{kg.m.\frac{m}{s^2}}{pièce}\right]^{-1} = \left[\frac{pièce^2}{kg.m.\frac{m}{s^2}}\right] \quad (16)$$

*III.2.b. Resistance:*

The resistance R of a body refers to the property thereof to prevent the propagation of a phenomenon. A body with a high resistance is called insolent. By cons, a body with a low resistance is called conductor. By analogy, the resistance $R_{man}$ in the production system is an "elements" that decrease the production flow. This means that any decrease in the flow of production generates a resistive effect to the workflow (a machine fails, control phase, unbalanced production line ...). This resulted in the generation of stocks at the feet of the machines.

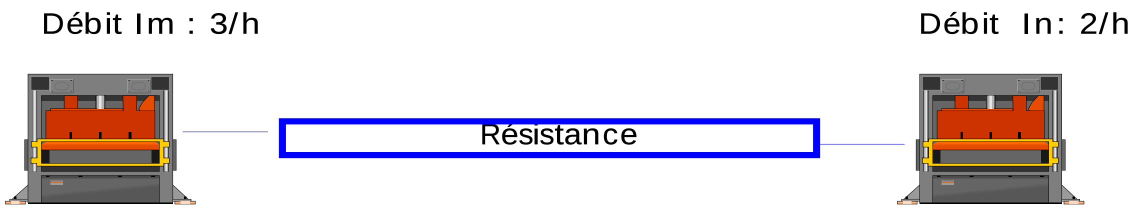


Figure 4: resistive effect between the two machines

$$R_{man} = \frac{U_{manufacturier}}{I_{manufzcturier}} : \left[\frac{kg.m.\frac{m}{s^2}}{pièce}\right].\left[\frac{s}{pièce}\right] = \left[\frac{kg.m^2}{pièce^2.s}\right] \quad (17)$$

The study of resistance, leads us to talk about the resistivity and find the relationship between these two terms.

*III.2.c. resistivity:*

The resistivity of a material, usually symbolized ρ, is its ability to oppose the flow of electricity. It is given by the following formula:

$$\rho = R.\frac{S}{L} \quad (18)$$

S is the section of the line is equal to the line width times the height of the room.

By analogy, the resistivity of the production system is the ability of the line to oppose the movement of parts. S is the section of the production line that equal the width of the line times the height of the part.

$$\rho = R_{man}.\frac{S}{L} \quad (19)$$

The unit of measurement of the resistivity is:

$$\left[\frac{kg.m^2}{pièce^2.s}\right][\frac{m^2}{m}] = \left[\frac{kg.m^3}{pièce^2.s}\right] \quad (20)$$

*III.2.d. The node:*

A node is a junction of several conductors. By analogy, a node in the production line represents a dispatching point.

*III.2.e. The branch:*

We consider our production line as a branch composed of a set of capacities-resistance.

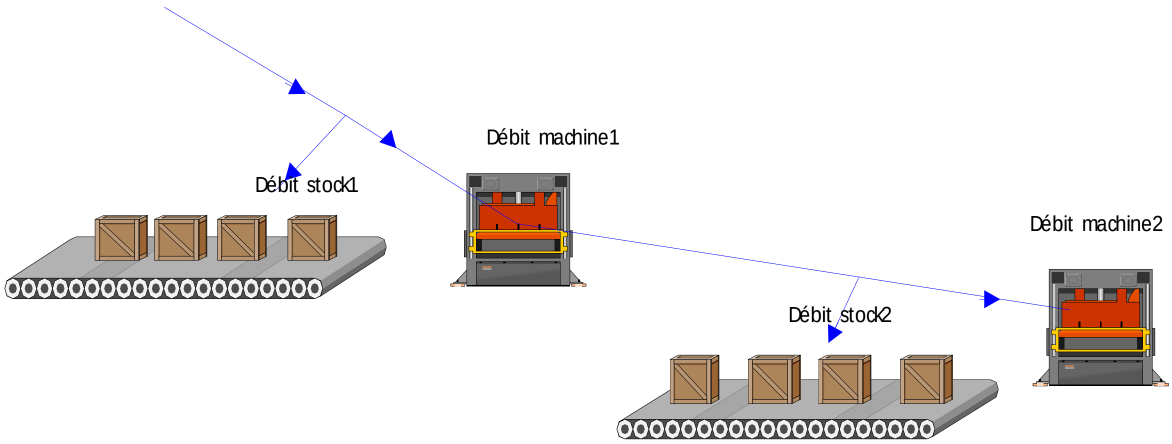


Figure 4 : schéma de circulation de flux de pièce

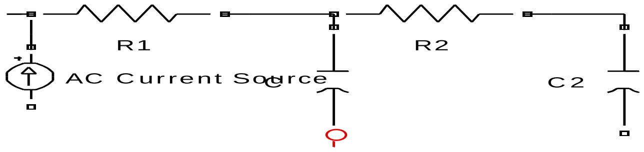


Figure 5: equivalent circuit diagram for traffic flow room

*III.2.f. Generalized Kirchhoff networks:*

Electrical circuits are often modeled by Kirchhoff networks. This type of network is also used in other areas [7]. In this case, they are often called generalized Kirchhoff networks, and the model produced is the equivalent electrical circuit of a component [8]. Modeling a system using these networks based principally on the manipulation of flow quantities [9].

By analogy, we can apply Kirchhoff's networks on the flow generation manufacturing. We consider that our production line is a branch. Nodes are the points of interconnection stock-machine and the dipoles are either resistance from of low flow between the two machines and the subsequent storage capacity is from parts in inventory.

The table below summarizes the analogy between the two flows.

TABLE 1: The table of summarizes the analogy between the two flows.

| system physical | Effort | flow | load | resistance | capacity |
|---|---|---|---|---|---|
| electric system | electric potential [V=J/C] | electric current [A=C/s] | load electric [C] | electrical Resistance [V/A] | capacity Electric [C/V] |
| manufacturing system | manufacturing potential [J/pièce] | Production rate [pièce/s] | Quantity of parts [pièce] | Resistance manufacturing $\left[\frac{kg.m^2}{pièce^2.s}\right]$ | manufacturing capacity $\left[\frac{pièce^2}{kg.m.\frac{m}{s^2}}\right]$ |

## IV. CONCLUSION

In this section we have been able to establish an analogy between the flow manufacturing and the electric current flowing in a conductor, and then define the model variables and their relationships characterizing the manufacturing flow. The concepts of capacitance, resistance can be considered as potential indicators to compare the flow behavior in various traffic conditions.

After setting these variables, the next step is to use them to model the physical flows in manufacturing systems. These variables are the parameters that control the flow changes and to assess its future state.

We have described our model by analogy with a continuous flow. This logic considers the flow from a "macroscopic" point of view, which facilitates the study compared to a purely discrete representation. From our model, we will offer perspective as an extension for the automated assembly lines.

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