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A Data Acquisition with LabVIEW of Temperature of a water tank system: Comparative study with a Pseudo Bond graph Model

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***Abstract*— The paper presents the LabVIEW simulation of water temperature inside a plastic tank. This simulation is done in order to make a comparison in an open loop with a pseudo bond graph model, which is designed on 20sim software, and it allows varying the temperature, inside the tank, by acting on the temperatures and the mass flows of the hot and cold water, as well as on the output flow. The experimental results show the effectiveness of the bond graph model. However, it can't act against an abrupt disturbance which can exist during the real-time simulation.**

***Keywords*— Water tank system; Bond graph modeling; Thermal transfer; Hydraulic transfer;**

I. INTRODUCTION

The industrial processes are governed by the mutual interaction of several phenomena of diverse nature. That is why their modelling requires a unified and a structured approach capable of describing the physical nature and the location of the variables of state, which are associated with storage of energy and directly deducted from the graphic model.

The bond graph tool, in multidisciplinary vocation, seems then the best adapted for the knowledge and the modeling of such systems [1]. It focuses on power transfers, coupling between energy variables, losses and storage phenomena in several domains (electrical, thermal, hydraulic, chemical…) by satisfying energy conservation, power continuity… [2–3].

LabVIEW is a graphic programming environment very useful to develop sophisticated measurement, test, and control systems applying graphic icons and wires that resemble a flowchart or user graphical interface. It allows real time simulations on physical systems through data-acquisition modules [4].

In this paper, the potentialities of LabVIEW have been used to make a real-time simulation in an open loop of water temperature inside the tank of a level regulation system for different water mass flows. A comparative study was done with the pseudo bond graph model in order to validate it. It is already carried out in previous work [5], and this study presents its continuation.

During the experimentation, the acting on an automatic opening and closing valves allows to fill the tank. Thus, the temperature inside it depends on injected quantities of the hot and cold water (having constant temperatures) through the labVIEW graphical interface. While in the bond graph model, we make to vary both their mass flows and their temperatures to vary the water temperature inside the tank.

The paper is structured as follows: in Section II, we describe the water tank system. Section III presents the word bond graph model and then, the pseudo bond graph model; we explain the physical phenomena which draws attention. Section VI illustrates the real time simulation and the comparative study results. The last section is devoted to conclude this paper.

II. THE WATER TANK SYSTEM

The system to model (Fig.1) is constituted by a hot-water pipe, a cold-water pipe and an evacuation pipe. In addition, a tank, pressure blocks, a data-acquisition module and sensors of temperature and level.

It is used in the regulation of the level and temperature inside a plastic tank through the labVIEW software.

The dimensions of the pipes and tank are given in TABLE1:

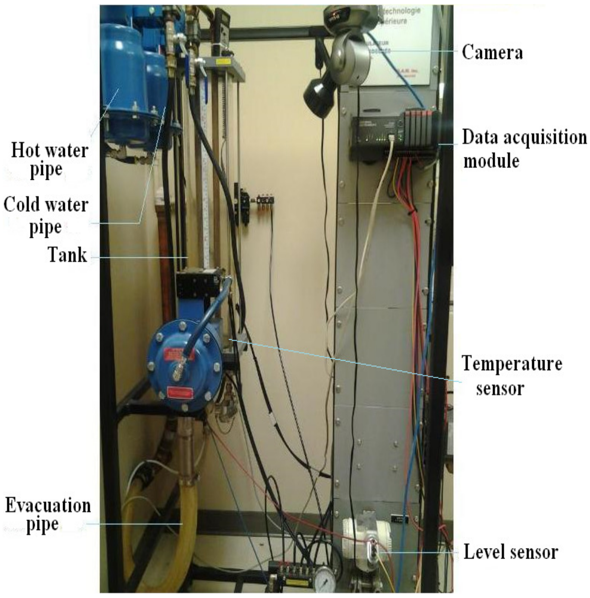

Fig. 1 The water tank system.

TABLE 1. The dimensions of the pipes and tank of the water tank system.

	Dimensions
Hot and cold water pipes	Length =75cm Ray=1cm Walls' thickness=0.4cm
Evacuation pipe	Length=80cm Ray=3cm Walls' thickness=0.5cm
Tank	Length=73cm Ray=10cm Walls' thickness=0.4cm

The closure and the opening of valves are automatically done thanks to a compressed air further to the activation of the pressure blocks by a signal sent through the labVIEW interface.

The hot and cold water's temperatures in the pipes are constants. However, in the bond graph model, we can vary them through its correspondent parameters.

The rate of closure and opening of valves determines the water quantities injected into the tank on which depends the water temperature inside. It is controlled through the labVIEW interface.

The temperature sensor is inside the tank. So, temperature measurements can be acquired and sent to the labVIEW program for treatment, through an acquisition block insuring the communication between the system and the labVIEW interface.

III. PSEUDO BOND GRAPH MODEL OF THE WATER TANK SYSTEM

The pseudo bond graph model [5] describes the thermal and hydraulic transfers inside the pipes and the tank. Besides, it draws attention to thermal and hydraulic losses at the level of the pipes' valves and the tank walls. These losses are modeled by R elements (for pipes, there are, respectively, R_cold, R_hot, R_evac for hydraulic losses and R_th_cold and R_th_hot for thermal losses).

The pseudo bond graph model was already carried out in [5].

The synoptic scheme of the water tank system, to be modeled, is illustrated by Fig. 2. It shows the thermal and hydraulic variables used in the pseudo bond graph model.

There are heat transfers by conduction at the level of pipes' walls and tank walls, and by convection inside the tank because the mixture of hot and cold water causes a coupling between thermal and hydraulic variables. Indeed, the temperature in the tank is determined by the water mass according to (1).

$$T_9 = \frac{H_9}{C_{th}} \tag{1}$$

With $C_{th} = C_V * m_9$ [6,7].

Where, C_V is the specific heat capacity of water in constant volume (C_V = 4177 J/kg.K at 35°C [5]) and m is the water mass.

H9 is the enthalpy [J]. It is computed by $H_9 = \int \dot{H}_9 dt$ [1].

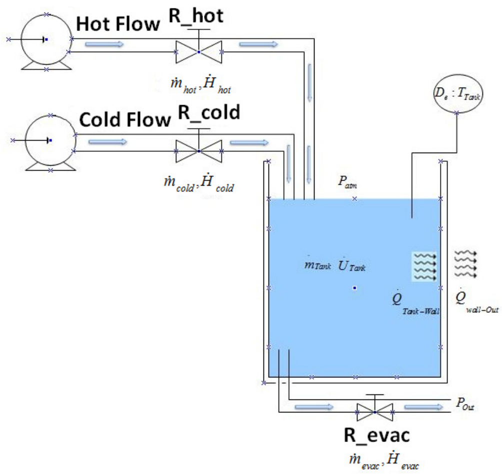

Fig. 2 Synoptic scheme of the water tank system [5].

A. *Word bond graph model*

The word bond graph model of the water tank system is presented in Fig. 3. The system components (pipes and tank) are interconnected by the thermo-hydraulic effort-flow variables' couple (Temperature and heat flow) and (Pressure and mass flow).

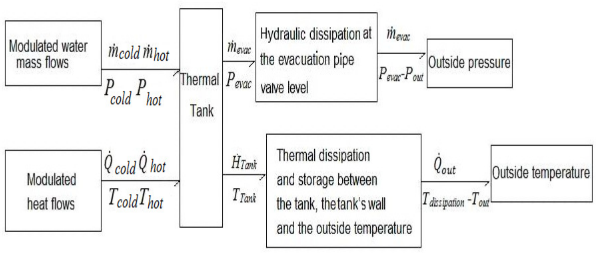

Fig. 3 Word bond graph model of the water tank system [5].

B. *Pseudo bond graph model*

The pseudo bond graph model of the water tank system is shown in Fig. 4.

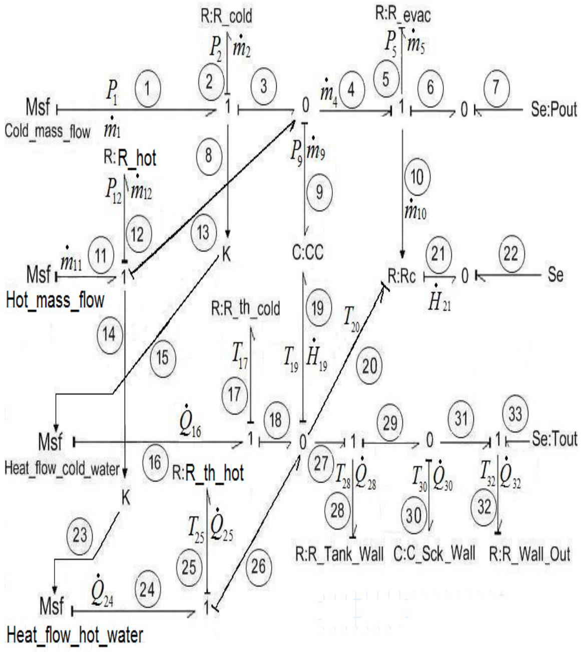

Fig. 4 Pseudo bond graph model of the water tank system [5].

When the hot and cold water mass flows change, it is necessary to adjust R_evac in (2) to obtain a better curve of water temperature inside the tank [5]:

$$\dot{m}_5 = (1/R\_evac) * sign(P_5) * \sqrt{|P_5|} \qquad (2)$$

Where $\dot{m}_5$ and P_5 are respectively the water mass flow [J/s] and the pressure [Pa] at the level of the evacuation pipe valve.

The water mass flows vary between 0 and 1Kg/s.

IV. Results and Discussion

A. *Data acquisition with labVIEW*

The real time simulation on the water tank system was made through the labVIEW software.

A labVIEW program activates and stops the system. It supplies a compressed air which allows opening the pipes' valves of hot and cold water in order to fill the tank.

The temperature measurements (in Celsius degrees) were taken in an open loop, in order to validate the pseudo bond graph model carried out on 20sim software.

A data-acquisition module is used to transmit sensors's measurements for treatment by labVIEW every 0.25s.

The valves's opening rate varies between 4 (totally closed) and 12 (completely opened). The Fig. 5 shows the labVIEW interface that starts up the system. It is described in French.

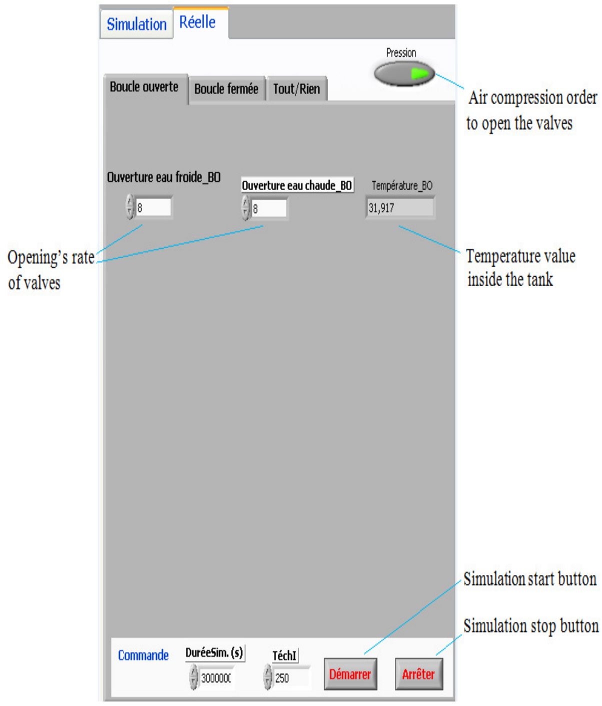

Fig. 5 Labview's graphical interface used to start up and stop the system.

B. *Comparative study*

For the simulation during 400s, we choose for each pipe the value "8" as a moderate opening.

For the bond graph model simulation, the mass flow sources were modulated by step signals in order to make the comparison between the real temperature measures and the model's simulation results.

The temperature is converted into degrees Celsius, and we choose □hot = □cold = 0.5kg/s. These values are equivalent to the valves' opening rate equal to 8 for each pipe. The hot and cold water's temperatures are respectively 50°C and 10°C. The initial water temperature inside the tank is 42.93°C. The simulation results are presented in Fig. 6.

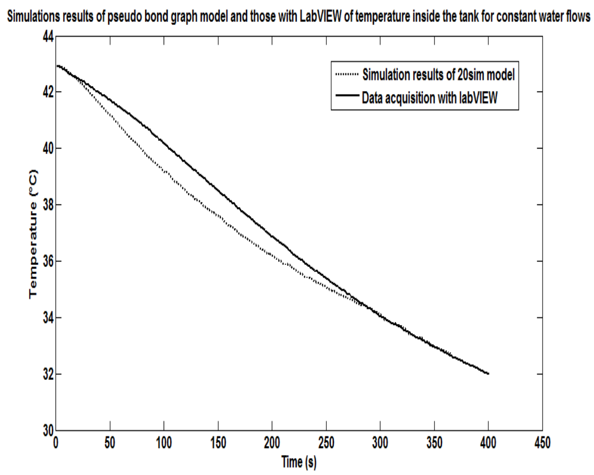

Fig. 6 Simulation results of pseudo bond graph model and those with labVIEW of water temperature inside the tank for constant and equal mass flows.

In both cases, we note that the temperature variation is almost similar. The difference of temperature is below 1°C. But only between the moment 95 and the moment 132s, it is about 1°C.

When we increase the rate of the cold-water mass flow to '10' for the same rate '8' of the hot-water mass flow, we obtain the following simulation results during 227s, which are shown in Fig. 7.

For the simulation of bond graph model on 20sim software, the cold-water mass flow is put to 1kg/s and the initial temperature value inside the tank is equal to 23.761°C (according to the real initial value at the startup moment of data acquisition with labVIEW).

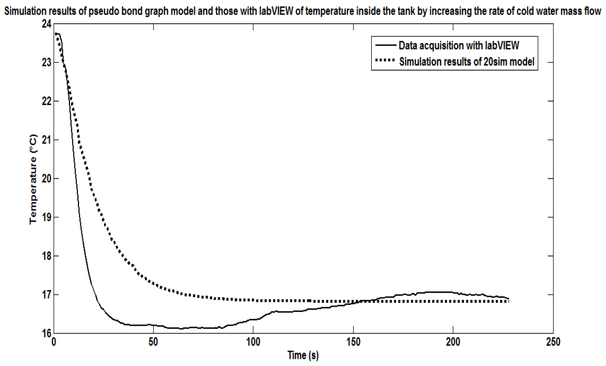

Fig. 7 Simulation results of pseudo bond graph model and those with labVIEW of water temperature inside the tank by increasing the rate of cold-water mass flow to '10'.

Inside the water tank system, we note a temperature drop of 3°C, which is shown in Fig. 7. It is between the moment 18s and the moment 46s. Disturbances on the system such as bad valves opening can be the cause. In fact, they conduce to discontinuous water falls. Besides after the moment 163s, we note that the temperature increases and the two curves become correspondent with a temperature difference about 0.14°C.

Table 2 contains thermo-hydraulic parametric values used in the bond graph model for each simulation.

TABLE 2. The thermo-hydraulic parametric values for each simulation.

	Simulation For equal water flows (rate of valves' opening is equal to '8')	**Simulation for different water flows (the rate of pipes' valves opening of cold and hot water is respectively equal to '10' and '8')**
The heat capacity inside the water tank	832.377 kJ/K	406.187 kJ/K
The hydraulic resistor at the evacuation pipe valve level (R_evac)	45.5 P.s/kg	15.5 P.s/kg

IV. Conclusions

A real data acquisition of temperature in an open loop is carried out on a water tank system using LabVIEW. It allows making a comparison with the pseudo bond graph model already realized on 20sim software. It describes the thermal and hydraulic transfers, the coupling energy, the hydraulic losses at the valves' level and the thermal losses at the tank walls level.

The obtained results show that the water temperature values, inside the tank, are matching for different cold and hot water mass flows.

In future works, we will try to introduce a non linear regulator in the pseudo bond graph model to ensure a good follow-up of a temperature set point inside the tank and avoid disturbances, which decrease the system performances.

V. References

[1] J. U Thoma, B. Ould Bouamama, "Modelling and Simulation in Thermal and Chemical Engineering. Bond Graph Approach", Springer Verlag, 2000.

[2] P. Breedveld, "Bond Graphs", Encyclopedia Life Support Systems contribution-preliminary version, Knowledge Foundation Area, Theme Control Systems, Robotics and Automation, Topic Modeling and Simulation, University of Twente, Bertinoro, Netherlands, pp. 1–27, 2003.

[3] P. J. Gawthrop, "Thermal modelling using mixed energy and pseudo bond graphs". Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering, pp. 201–215, 1999.

[4] Zhang Jian, Han Xinshen, Fang Xiaoxi, Cheng Xueqing, "LABVIEW Graphic Program and Sample Application," Beijing: China Railway Press, 2005, pp. 159–160.

[5] E. Aridhi, M. Abbes, A.Mami, *"Pseudo Bond graph Model of a Thermo-Hydraulic System",* the 5th IEEE International Conference on Modeling, Simulation and Applied Optimization, Tunisia, April 2013.

[6] B. Ould Bouamama, G. Dauphin-Tanguy, "Modélisation par Bond Graph. Eléments de Base pour l'énergétique", Techniques de l'Ingénieurs, pp. 1–16. BE8280, 2012.

[7] M. Vergé, D. Jaume, Modélisation structurée des systèmes avec les Bond Graphs, Technip, 2004.