METHODOLOGY FOR BOND GRAPH REPRESENTATION OF NONLINEAR DISTRIBUTED PARAMETER SYSTEMS

Nasta Tanasescu
Dept. of Control Systems and Computers, „Dunarea de Jos" Univ., Galati
Nasta.Tanasescu@ugal.ro

Abstract This paper deals with the methodology for bond graph representation of nonlinear distributed parameter systems, which uses frequency response function as a basis in describing the required behavior. This methodology aids in the determination of control schemes, which are necessary to design the active element, such that the required frequency domain behavior is met.

Keywords: bond graph, frequency response function.

1. INTRODUCTION

Bond graphs were selected as the modeling tools from a number of reasons: the bond graph methodology yields a clear mapping of the topology of a system; there exists a straightforward method by which state equations can be extracted from the bond graphs; it allows for causality information to be contained in the system model; it easily handles the modeling of systems that involve multiple energy domains, and it easily allows for the modeling of system elements that exhibit nonlinear behavior.

2. NONLINEAR MODEL WITH DISTRIBUTED PARAMETERS

Such model is obtained by using the equations of continuity, momentum and energy. These partial differential equations (PDEs) correspond to the physical principles of mass conservation, Newton's second law and energy conservation. Under the assumptions that the fluid is compressible, viscous, isentropic, homogenous and one – dimensional they lead to a coupled nonlinear set of PDEs. They are linearized and written in a form using common notation. We perform a complex – plan curve fitting procedure in order to obtain the corresponding transfer function in analytical form, namely as a ratio of two polynomials. The results of the curve fitting procedure yields what we refer to in this case as the "data – based" transfer function.

3. TRANSFER FUNCTION MODEL

The derivation of a transfer function model for PDE follows the same steps as for the scalar case: apply the Laplace transformation with respect to time. This removes the time derivatives and turns the initial boundary value problem into a boundary value problem for the space variable; construct a suitable transformation for the space variable which removes the spatial derivatives and turns the boundary value problem into an algebraic equation; in order to obtain a multidimensional function, solve the algebraic equation for the transfer of the solution of the PDE;

As accurate as possible curve fit is desired, however the designer must exercise caution, since selecting too high a degree of polynomials can cause the curve - fitting algorithm to yield unstable transfer functions.

The bond graph structure that represents the system is obtained. A signal flow diagram was also developed, which provided information about the nature of the control system needed such that the system exhibited the desired frequency response behavior.

4. ALGORITHM FOR BOND GRAPH REPRESENTATION METHODOLOGY OF PDE

Step 1: obtain desired transfer function, given in analytical form, or determine from curve fit of experimental data; step 2: Determine theoretical transfer function; step 3: cast into bond graph framework – using primitive positive and negative elements bond graph; step 4: incorporate into system bond graph model; step 5: determine state equations from bond graph model, identify virtual state variables; step 6: identify separable bond graph elements, select hybrid or fully active system; step 7: select active devices physical realization, add idealized bond graph representation to model; step 8: determine control signal diagram, graphical representation of the differential equations of virtual state variable; step 9: perform simulations.

5. CONCLUSIONS

The use of the bond graph in representation distributed parameters systems (DPS) was shown. This methodology easily allows for simulations to be run for various physical systems and design parameters. The simulations results allow a systems designer to perform comparisons and make decisions regarding the system. Thus, the bond graph model of the DPS produces the desired response characteristics.

References

[1] Tanasescu, N. – *Identification of distributed parameter systems, applied at mass and heat exchanger processes*. Thesis, Univ. "Politehnica" Bucharest, 1995.

[2] Paynter, H. M., *Analysis and design of engineering systems bond graph methodology*, 1961.

[3] Karnopp, D. C., Rosenberg, R. C., *System dynamics,* New York, 1974.

[4] N, Tanasescu, A, Filipescu, O. Tanasescu, Mathematical modeling of the technological processes treated as distributed parameter dynamic systems, Vienna, 3^{rd} Mathmod, 2000.