Simulation and Modeling of Engineering System Using Bond Graphs

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Abstract:- **Bond graphs offer a domain-neutral graphical technique for representing power flows in a physical system. They are particularly powerful for representing systems that operate in multiple energy domains, such as thermal models of electronic circuits, mechanical vibrations in acoustic systems, etc. It is an explicit graphical tool for capturing common energy structure of systems. The Bond Graph is composed of the bonds which link together single or multi elements, each bond represents the instantaneous flow of energy or power. The flow in each bond is denoted a pair of variables called 'power variables' whose product is the instantaneous power of the bond. For example, the bond of an electrical system would represent the flow of electrical energy and the power variables would be voltage and current, whose product is power. Each domain's power variables are broken into two types: "effort" and "flow". Effort multiplied by flow produces power, thus the term power variables. Every domain has a pair of power variables with a corresponding effort and flow variable. Examples of effort include force, torque, voltage, or pressure; while flow examples include velocity, current, and volumetric flow.**

Modeling and simulation form an integral role in the engineering design process. In this paper it was try to elaborate basics of bond graph and try to figure out some common system using bond graph approach. The main aim is to prepare software of some engineering system using bond graph. The system shall have the interactive graphical user interface (GUI) and shall provide library of elements which the user can choose to build the composite systems from the provided elementary systems. The software shall be tested for some known systems by comparing the simulation results with the manual simulations. Further this simulation & modeling system will be used to model a few engineering systems by varying different parameters. These systems will be chosen from the real world. The different parameters of sub systems will be altered and the composite simulation results for each such combination will be obtained, these results will then be tested against the actual system composition. Such a comparison shall validate this modeling and simulation system. The software will be basically working on drag and drop principle and it will be created in Visual Basic and database software such as MS Access.

I. INTRODUCTION

In any System the variables are changing, flowing and it happens because elements of system interacting with each other. Suppose in an electrical circuit which consists of Resistance, Capacitance and inductance (which are known as elements) interact with each other, they interact with each other i.e. by exchanging Power and every element decides either the current in the circuit or the voltage at specific points. Bond Graph is the representation of these elements in a graphical way so that the power exchange amongst elements is represented and the governing equations can be established. To accomplish this the bond graph approach uses the basic fact that power=effort * flow and this fact is domain neutral. Bond Graphs are multi domain or domain neutral i.e. It is used to depict the energetic transfers between subsystems of different natures (Mechanical, electrical, hydraulic…….) It is today used in numerous important projects inside companies such as Renault, General Motors. Nowadays, engineering systems are becoming increasingly complex and, for design purposes, must be considered as multidisciplinary systems made up of components from different engineering disciplines. With regard to the systematic development and the analysis of models, interdisciplinary methodologies supported by software become more and more important. Bond graphs are a

graphical description formalism particularly suited for multidisciplinary systems and used by modelers across the world.

II. RESULTS AND DISCUSSION

The objective of entire project was to develop a GUI base software for modeling the bondgraph and developing the differential equation which will further be solved by giving the system variable as input. The state variables will be evaluated. The following examples shows the sequence of operations to be performed in order to get the desired differential equation and solution to that.

1. Click Generate Equation , the values which are saved in database are

	flow		effort
F1	-P2/M2	E1	f_t
F2	-P2/M2	E2	f_t+(R6*-P2/M2+V_t)+K7*Q7
F3	-P2/M2	E3	(R6*-P2/M2+V_t)+K7*Q7
F4	-P2/M2+V_t	E4	(R6*-P2/M2+V_t)+K7*Q7
F5	V_t	E5	(R6*-P2/M2+V_t)+K7*Q7
F6	-P2/M2+V_t	E6	(R6*-P2/M2+V_t)
F7	-P2/M2+V_t	E7	K7*Q7

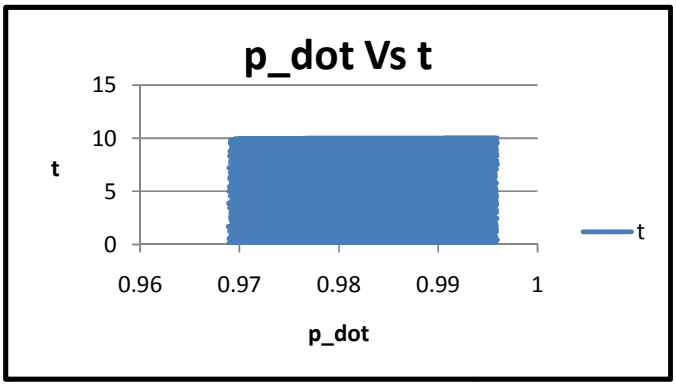
2. Input Values throughForm

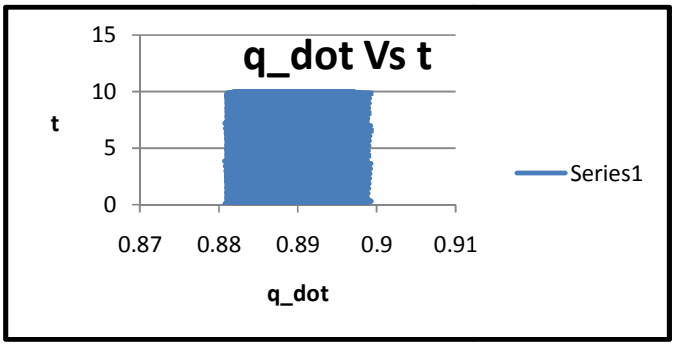
a	w	t	R6	P2	M2	b	K7	Q7
0.2	100	0.1	1	1	1	0.5	1	1

3. Results from Manual Calculation

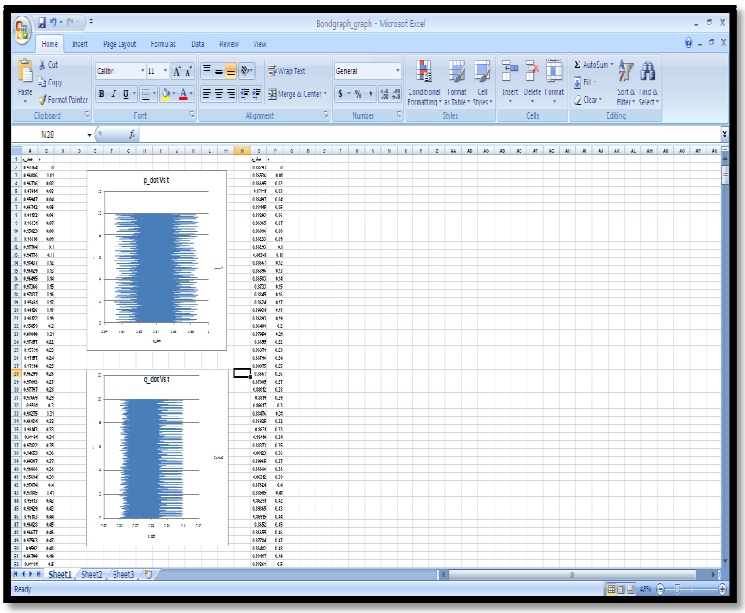
p_dot	t	q_dot	t
0.977639	0	0.882929	0
0.960865	0.01	0.865359	0.01
0.967357	0.02	0.866953	0.02
0.976141	0.03	0.878112	0.03
0.95947	0.04	0.864974	0.04
0.967424	0.05	0.884448	0.05
0.98132	0.06	0.882933	0.06
0.960308	0.07	0.869655	0.07
0.95823	0.08	0.860959	0.08
0.980159	0.09	0.882329	0.09
0.977639	0.1	0.882929	0.1
0.947785	0.11	0.863409	0.11
0.984373	0.12	0.886668	0.12
0.960294	0.13	0.868958	0.13
0.964948	0.14	0.865835	0.14
0.973663	0.15	0.873305	0.15
0.978375	0.16	0.8845	0.16
0.954608	0.17	0.862402	0.17
0.991264	0.18	0.899338	0.18
0.961218	0.19	0.86893	0.19
0.958595	0.2	0.864091	0.2
0.980492	0.21	0.879593	0.21
0.978571	0.22	0.885502	0.22
0.957911	0.23	0.863787	0.23
0.971575	0.24	0.887961	0.24
0.979135	0.25	0.880748	0.25
0.96299	0.26	0.866704	0.26
0.970931	0.27	0.870053	0.27
0.97797	0.28	0.880117	0.28
0.976688	0.29	0.881905	0.29
0.950103	0.3	0.866174	0.3
0.982752	0.31	0.884758	0.31
0.960341	0.32	0.869247	0.32

0.96143	0.33	0.863103	0.33
0.981912	0.34	0.884189	0.34
0.978221	0.35	0.883729	0.35
0.94653	0.36	0.861229	0.36
0.99307	0.37	0.899653	0.37
0.960885	0.38	0.86886	0.38
0.956943	0.39	0.863123	0.39
0.976742	0.4	0.876243	0.4
0.978854	0.41	0.885047	0.41
0.956134	0.42	0.862908	0.42
0.989289	0.43	0.898646	0.43
0.961833	0.44	0.86915	0.44
0.960277	0.45	0.865195	0.45
0.966768	0.46	0.866552	0.46
0.975633	0.47	0.877842	0.47
0.959202	0.48	0.864819	0.48





4. Software result is Shown in the following Screen Shot



The Result obtained by two software is successfully accepts the values and fixed differential equation which are further solved.

III. CONCLUSION

The results obtained discussed in previous chapters shows that the software has been succesfuly tested and it is capable of handling following elements for the analysis. Hence it can be concluded that the software developed for the analysis of bondgraph is giving correct results. The annexure attached shows some other examples and steps followed to support the conclusion drawn and hence the development of software has been satisfactory. However the software has not the capability to handle the Tf and Gy elements which can be the part of future development.

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