Global Journal of Researches in Engineering
Electrical and Electronics Engineering
Volume 12 Issue 7 Version 1.0 July 2012
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Matrix Laboratory (MATLAB) as an Efficient Pedagogical Tool for Engineering Education, Teaching and Research

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Abstract - Matrix laboratory can assist the teaching and research of engineering and science education. This paper mirrors how the tedious analytical method of arriving at a solution of mechanical systems and electrical transients can be made less burdensome using MATLAB. The simulated results show that velocity changes with displacement and time. It also highlighted the frictional force or air viscosity inherent in the system as a result of acceleration or retardation and further exhibited the effect of transients on circuit charge and current respectively. The values of this pedagogical tool will enhance a better comprehension of mechanical and electrical systems.

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GJRE-F Classification: FOR Code : 090602,090609

MATRIX LABORATORY MATLAB AS AN EFFICIENT PEDAGOGICAL TOOL FOR ENGINEERING EDUCATION, TEACHING AND RESEARCH

Strictly as per the compliance and regulations of:

Matrix Laboratory (MATLAB) as an Efficient Pedagogical Tool for Engineering Education, Teaching and Research

B.J. Robert [α], O.I.Okoro [σ], E.I. Igweonu [α] & C.V. Eguzo [α]

Abstract - Matrix laboratory can assist the teaching and research of engineering and science education. This paper mirrors how the tedious analytical method of arriving at a solution of mechanical systems and electrical transients can be made less burdensome using MATLAB. The simulated results show that velocity changes with displacement and time. It also highlighted the frictional force or air viscosity inherent in the system as a result of acceleration or retardation and further exhibited the effect of transients on circuit charge and current respectively. The values of this pedagogical tool will enhance a better comprehension of mechanical and electrical systems.

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I. Introduction

The application of science in the design, planning, construction and maintenance of manufactured entity is called Engineering. Engineering education is the training of engineers for the purposes of initiating, facilitating and implementing the technological development of a nation. In Nigeria, the training of engineers has witnessed formidable challenges ranging from poor funding to inadequate facilities, loss of qualified human capacity due to the brain drain syndrome and poor staff training and retention profiles. Other challenges include an almost non-existence of university/industry partnership, defective curricula, traditional approach to teaching, poorly equipped laboratories, and poorly developed local codes and monitoring standards for the training of prospective engineers as well as inadequate ICT environment[1].

Technological advancement serves as a major key to a nation's development. On the other hand, proper engineering knowledge (acquired through appropriate structures) plays a major role in the attainment of a high level of technological advancement. Most developing countries find it difficult to impact adequate knowledge and training to engineers at different levels of training [2].

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Today technology has permeated every aspect of social life and virtually everything revolves around it. For a developing country like Nigeria, engineering education thus assumes vital importance in the development of relevant technology for societal growth. This kind of education is obtained by attendance of a tertiary institution, a university, college or polytechnic. Since technology is constantly being updated and improved in other parts of the world, the challenge of this millennium for engineering education in Nigeria requires our learning systems to undergo changes so that engineering graduates will be equipped to cope with these global changes and societal needs [3].

As part of the changes in the learning system, matrix laboratory (MATLAB) was introduced as it plays an important role in the design, analysis and evaluation of engineering and sciences problems.

MATLAB was designed and developed for engineering and science applications by Math Works Inc and is a widely used simulator. The combination of analysis capabilities, flexibilities, reliability and powerful graphics makes MATLAB the premier software package for engineers and scientists .The most important feature of MATLAB is its programming capability, which is very easy to learn and to use, and which allows user-developed functions.

In the light of the above, MATLAB was applied in steady and transient states thermal analysis of induction machine at blocked rotor operation [4], software simulation techniques for teaching communication systems [5] etc.

The authors hence applied MATLAB as a pedagogical tool in analysis of electrical transients and mechanical systems.

II. Analysis of Mechanical Systems

MATLAB program for handling and improving mechanical systems was developed using the state variable equations which describe the spring-mass system shown in figure 1 and can be written in vector-matrix form as in equation (1).

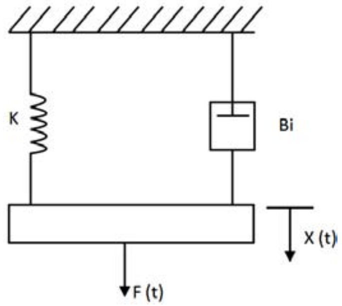

Figure 1 : Spring-Mass System

$$\begin{bmatrix}\dot{X}_1(t)\\ \dot{X}_2(t)\end{bmatrix} = \begin{bmatrix}0 & 1\\ \frac{-K}{M} & \frac{-B_1}{M}\end{bmatrix}\begin{bmatrix}X_1(t)\\ X_2(t)\end{bmatrix} + \begin{bmatrix}0\\ \frac{1}{M}\end{bmatrix}F(t) \quad (1)$$

III. Analysis of Electrical Transients

The most important mathematical operations in electrical transients which gives rise to differential equation is the investigation of when the transient state has passed, giving way to a steady state. MATLAB was applied in figure 2 to solve transient problems in R-L-C electrical circuit. The MATLAB program was developed using the developed equations.

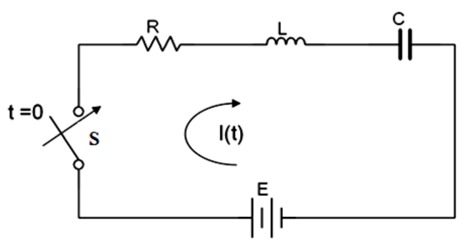

Figure 2 : R-L-C Circuit

$$R_i + L\frac{di}{dt} + \frac{1}{C}\int idt = V(t) \quad (2)$$

With $V(t) = E$ (a DC Voltage) and

Substituting $i = \frac{dQ}{dt}$ and dividing by L,

We can rewrite equation (2) in terms of charge Q as

$$\frac{d^2Q}{dt^2} + \frac{RdQ}{Ldt} + \frac{1}{LC}Q = \frac{E}{L} \quad (3)$$

First, we reduce the given expression:

$$\frac{d^2Q}{dt^2} + \frac{2dQ}{dt} + Q = 0.375 \quad (4)$$

into two first order differential equations:

Let us define $X_1 = Q$

$X_2 = \dot{Q}$

$$\dot{X}_2 = \ddot{Q}$$

$$\therefore \dot{X}_1 = \dot{Q} = X_2 \quad (5)$$

The given expression becomes:

$$\dot{X}_2 = 0.375 - X_1 - 2X_2 \quad (6)$$

Where $X_1 = charge$

$X_2 = current$

We now use equations (5) and (6) to develop the MATLAB function program.

IV. Development of Matlab Scripts

Mechanical system and Electrical transient algorithm of a spring-mass system and R-L-C circuit respectively has been developed using the MATLAB package version 7.5.

a) Tutorial 1- Mechanical Systems

MATLAB was applied to the spring-mass system in Figure 1 initially at rest, a force of 40 Newtons is applied at time t=0. Assume that the mass M=2kg, frictional coefficient B1= 2.5N/m/sec and the spring constant K=10N/m. A MATLAB test program to computes the displacement (X1) and velocity(X2) of the system at t=0(0.02) 15.0 with the initial conditions at X1(0) = X2(0) = 0 was developed and shown in Table 1 and Table 2.

Table 1 : MATLAB Function Program

```
%Function file that defines the given function
%save as example 1.m
%represent the function as xDot=Ax+Bu
function xDot=example1(t,x)
xDot=zeros(2,1);
x1=[x(1); x(2)];
B1=2.5;
k=10;
F=40;
M=2;
A=[0 1;-k/M -B1/M];
B=[0; 1/M];
U=F;
xDot=A*x1+B*U;
```

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Table 2 : MATLAB Calling Program

```
%calling program that evaluates the function
from t=0 to t=3.0 save as
%example 1a.m
t0=0;
tf=15;
tinterval=0.02;
x0=[0 0];
tspan=t0:tinterval:tf;
[T,x]= ode23('example1',tspan,x0);
% we now generate the first graph
figure(1)
plot(T,x(:,1),'k')
grid on
xlabel('Time[s]')
ylabel('Displacement,Velocity')
hold on
plot(T,x(:,2),'ok')
legend('Displacement','Velocity')
figure(2)
plot(x(:,1),x(:,2),'k')
grid on
xlabel('Displacement')
ylabel('Velocity')
title('Graph of Velocity against Displacement')
```

b) Tutorial 2- Transients in R-L-C Circuit

MATLAB was applied to a series R-L-C circuit in Figure 2 in which both the charge Q and the current are initially zero and contains the elements R=8Ω, L=4H, C=0.25F. If a constant voltage E=1.5V is suddenly switched into the circuit current and charge against time at t=0(0.01)10. A MATLAB program to perform this was developed and also shown in Table 3 and Table 4.

Table 3 : MATLAB Function Program

```
%function file that defines equations ( 5)
and (6)
%save as exaple2.m
function dx = example2(t,x);
dx = zeros(2,1);
dx(1) = x(2);
dx(2) = 0.375-x(1)-2*x(2);
dx = [dx(1);dx(2)];
```

Table 4 : MATLAB Calling Program

```
%calling program that evaluates the functions to
save as 2a.m
t0 = 0;
tf = 10;
tinterval = 0.01;
tspan=t0:0.01:tf;
x0 = [0 0];
[t,x] = ode45('example2',tspan,x0);
% we now plot the graphs
Q = x(:,1); % charge
I = x(:,2); % current
figure (1)
plot (t,Q,'k')
grid on
xlabel('Time[s]')
ylabel ('Charge[c]')
figure (2)
plot(t,I,'k')
grid on
xlabel('Time[s]')
ylabel('Current[A]')
```

V. Simulated Results and Discussions

The system output for spring-mass system and electrical transients are shown in figures 1, 2, 3 and 4 respectively.

Figure 1 shows velocity-displacement graph for the spring-mass system. It is seen that the mass is displaced from zero metre till it attains its full velocity at 2s. The spring-mass system finally decelerates to zero at 4s. Furthermore, in figure 2 the velocity changes as well as displacement after one second and two seconds respectively followed by a deceleration and a struggle for stability due to external or built-in influences until stability is maintained after seven seconds. Considering figure 3, it is seen that the circuit charge rises steadily from zero second and remains constant after six seconds. Likewise current rises steadily from zero second to one second after which there is a sharp fall due to transients and remains constant after eight seconds.

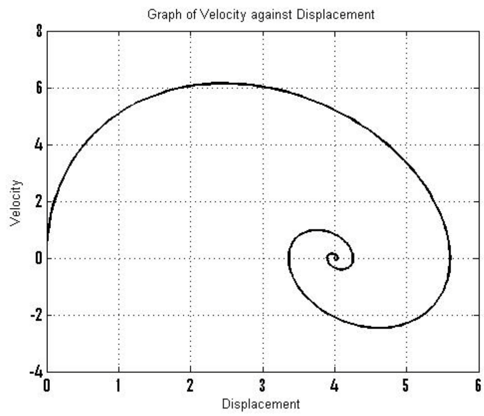

Figure 1 : System Response for Spring-Mass System

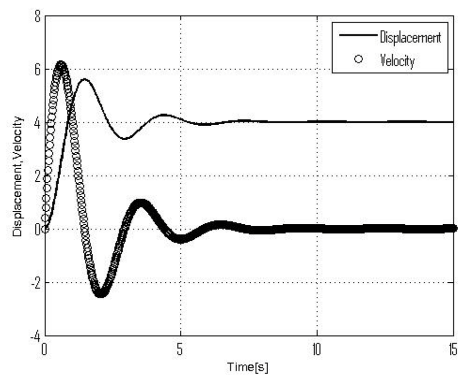

Figure 2 : System Response for Spring-Mass System

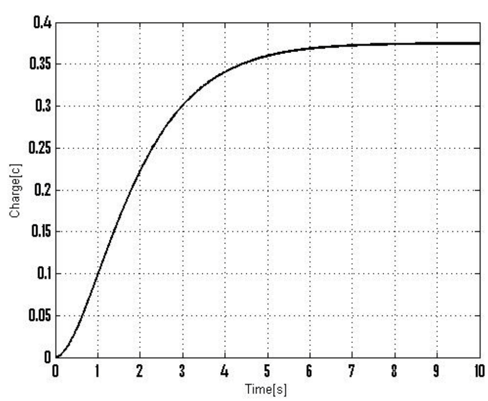

Figure 3 : System Response for Electrical Transients

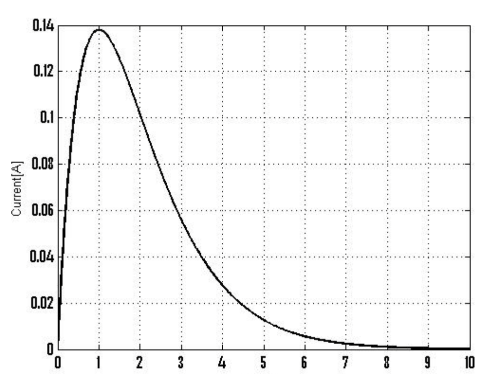

Figure 4 : System Response for Electrical Transients

VI. Conclusion and Recommendations

The potentials of MATLAB in teaching and research have been explored and certified very efficient in solving wide range of engineering and science problems. It has been shown that the use of MATLAB software package in mechanical systems and electrical transients could make their analysis less tedious, more accurate and more speedily.

Therefore, in order to encourage the use of this all-important software by students and staff in Nigerian higher institutions, the following recommendations are considered inevitable:

1. MATLAB should be introduced in the nation's engineering faculties and made compulsory for all engineering students.
2. Postgraduate engineering students should be made to carry out one or two projects on MATLAB before embarking on their final thesis.
3. MATLAB groups among students should be encouraged in all the nation's universities. These groups should be involved in discussions about problems encountered and successes made while solving a particular problem.
4. Engineering faculties should encourage their teaching staff to attend workshops/seminars on the recent versions of MATLAB.
5. Calculations and analysis done using MATLAB should be well documented for future references.
6. Inter-university and inter-departmental competitions among students on MATLAB and its programming application should be encouraged to stimulate interest in the use of the software.
7. MATLAB just like any other engineering software, is very expensive for a department to purchase it, therefore Deans of Faculties should be made to bear the financial burden-especially in securing the necessary software toolboxes.
8. COREN and NSE can ensure that recommendation number one is achieved through appropriate legislation.

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