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Appendix A

A.1 Other Types of Graphs

The data collected was analyzed to see what types of behavior the breakwater exhibited during its period in motion. The primary method of evaluating the response of the breakwater was to produce and examine several types of graphs. The trajectory and normal velocity before impact vs. time plots were primarily used in this investigation. However, several other plots were produced during the investigation and typical examples of these will now be discussed. The additional plots include: x vs. time, y vs. time, and θ vs. time for time histories; $\dot{x}$ vs. x, $\dot{y}$ vs. y, and $\dot{\theta}$ vs. θ for phase diagrams; impact Poincaré plots; and total and kinetic energy vs. time plots. The following plots were produced from the standard conditions of the point-mass breakwater (PMBW) and rigid-body breakwater (RBBW) under free motions, as seen in Chapters 3 and 5, respectively.

The time histories describe the position of the breakwater during the time in which it moves about the region. A typical time history of the horizontal position x of the breakwater (Fig. 2.2) may be seen in Fig. A.1. In this plot it may be seen that the position is oscillating about the x=0 axis as expected from the geometrical configuration of the breakwater and it settles down to zero with time. Also, this plot is piecewise linear in nature because of the linear analytical solution developed in Chapter 2. A typical time history of the vertical position y of the breakwater may be seen in Fig. A.2. In this plot it may be seen that the position stays above the y=0 axis as required and settles to zero with time. Also, this plot is piecewise quadratic in nature because of the quadratic analytical solution developed in Chapter 2. Time history plots of the rotation angle θ of the breakwater may be seen in Chapters 5 and 6.

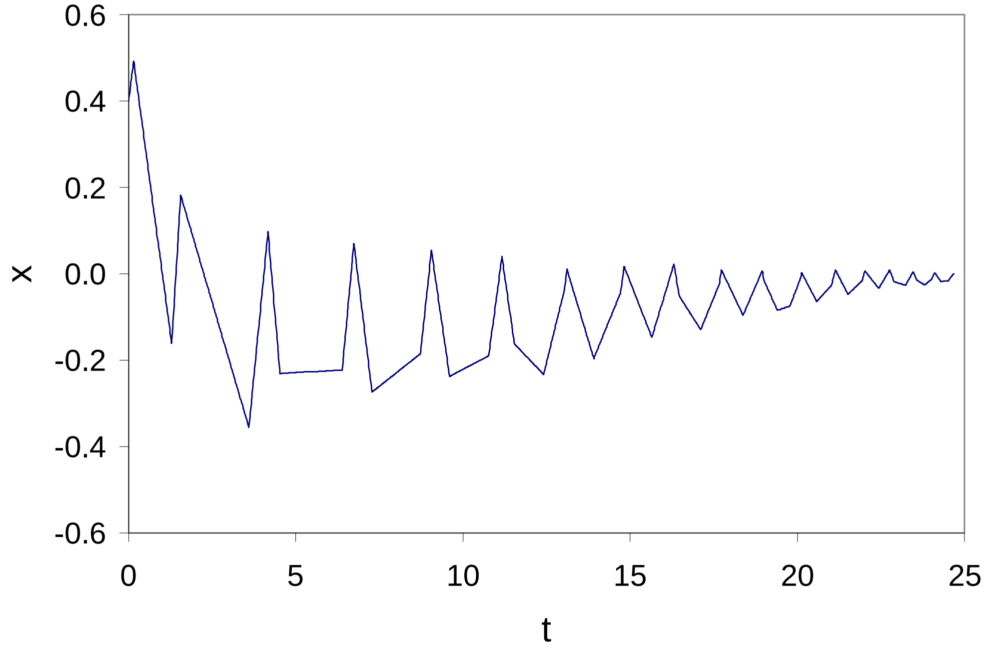

Fig. A.1. x vs. t, PMBW Standard Case

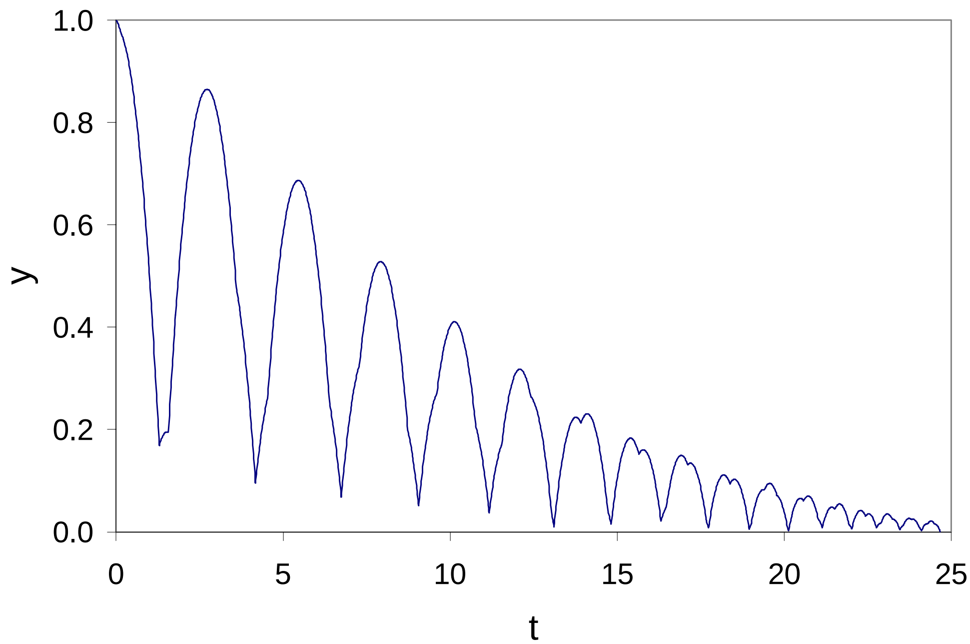

Fig. A.2. y vs. t, PMBW Standard Case

A phase plane plot is a plot where the velocity in one direction is plotted against the position in the same direction. These plots were produced for the x, y, and θ velocities and displacements. Figures A.3 and A.4 are the x and y phase plane plots for the standard case conditions of the PMBW under free motions from Chapter 3, respectively. Since rotations are not involved in the point-mass problem, Fig. A.5 was used to show a rotation phase plane plot and was produced from the standard case of the RBBW under free motions of Chapter 5.

The phase plane plot of the x velocity versus x position may be seen in Fig. A.3. It may be seen that in this plot the values of x and $\dot{x}$ are decreasing towards the middle of the plot which occurs when the breakwater settles its motions. This is because as time goes on, energy is dissipated and the position and velocity go to zero. The position and velocity in the x direction may be either positive or negative as defined by the problem formulation, which explains why the motions go towards the center of the graph. The abrupt vertical jumps in the graph indicate that the breakwater has impacted a boundary, and since it was assumed that the position of the PMBW does not change during an impact, the velocity changes sign and abrupt jumps appear. Between the jumps, the velocity $\dot{x}$ is constant because of the analytical solution in Chapter 2. Similar jumps may be seen in the $\dot{y}$ vs. y phase plane (Fig. A.4). In this case, though the velocity may be positive or negative, the position can only be positive because of the geometrical formulation of the problem, and thus the motion settles towards the center of the left side of the plot. The y position between impacts is quadratic with respect to the velocity $\dot{y}$ because of the analytical solution.

The phase plane plot of $\dot{\theta}$ versus θ (Fig. A.5) is similar to Fig. A.3. This plot should settle towards the center, but Fig. A.5 shows that the plot stops before it reaches the center of the plot where position and velocity both equal zero. This is because at this point $g_1=g_2=0$ but the breakwater is rotated and not settled to the equilibrium state. However, in the RBBW under free motions it was assumed that the breakwater would go into a rocking motion at this point and then settle to the bottom of the region. Again, the vertical jumps are caused by the position not changing during an impact and the velocity changing direction, and the analytical solution for θ is linear between impacts so that $\dot{\theta}$ is constant.

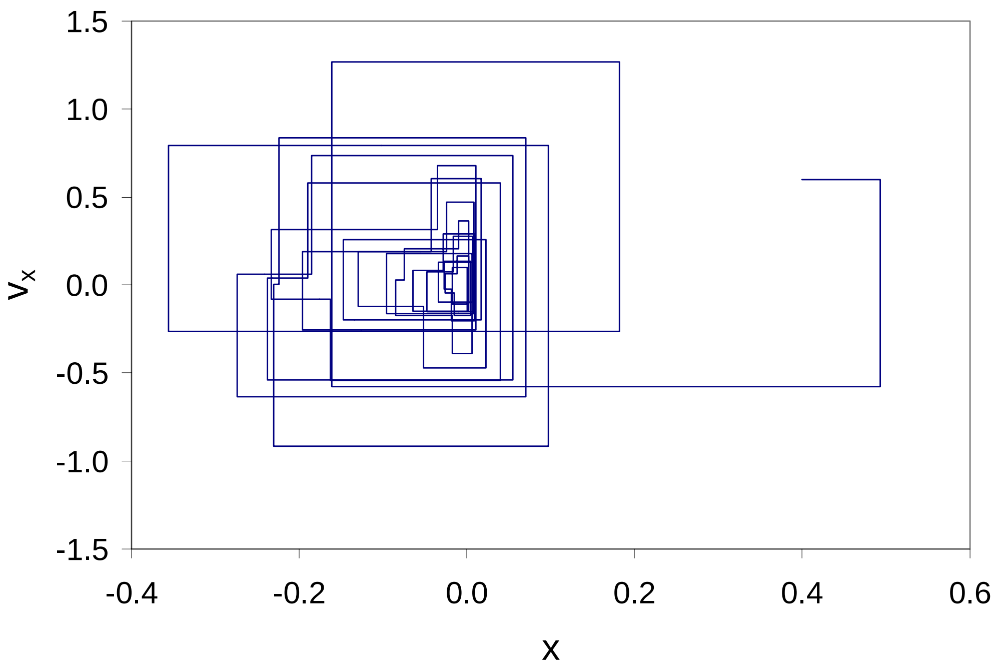

Fig. A.3. v_x vs. x, PMBW Standard Case

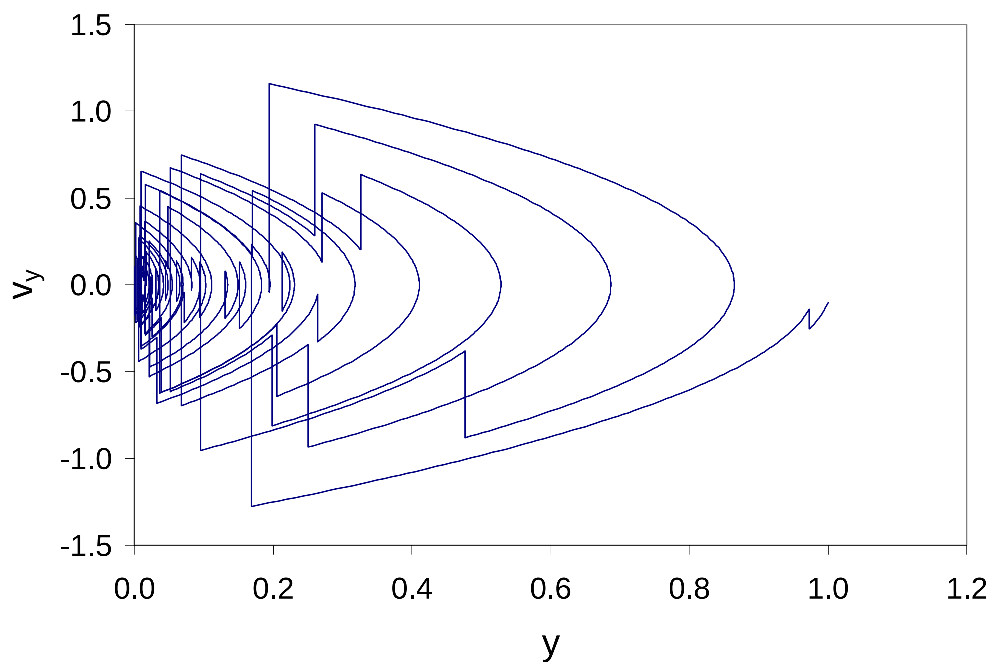

Fig. A.4. v_y vs. y, PMBW Standard Case

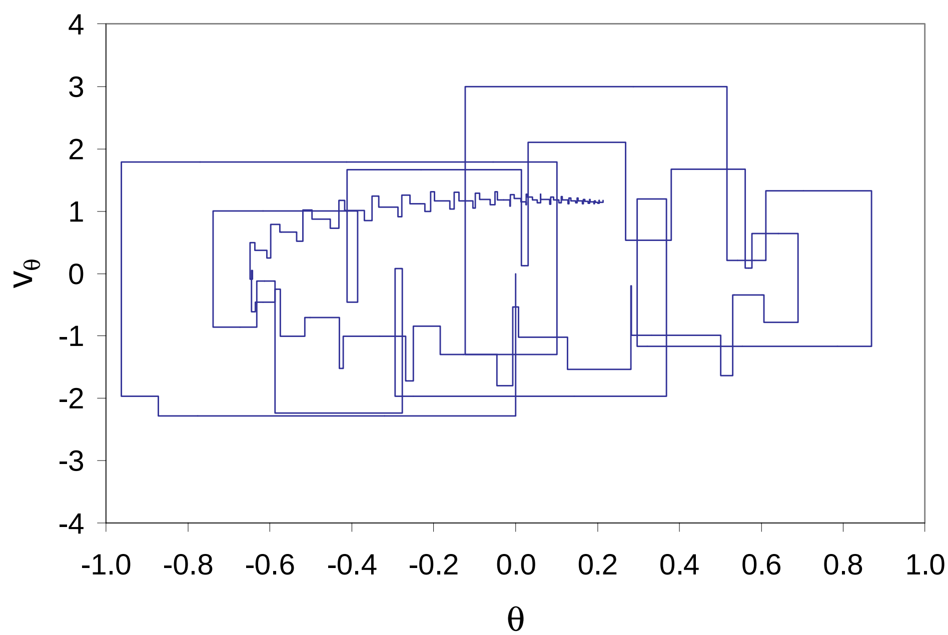

Fig. A.5. v_θ vs. θ, RBBW Standard Case

An impact Poincaré plot is a plot of the velocity just before impact versus the position at the time of impact. The impact Poincaré plot puts a dot corresponding to the impact velocity versus the position in the x, y, and θ directions. The x and y impact Poincaré plots for the free motion PMBW problem with standard conditions are shown in Figs. A.6 and A.7, respectively. The θ impact Poincaré plot for the free motion RBBW problem with standard conditions is shown in Fig. A.8. Corresponding to Fig. A.5, the dots do not converge to the point $(\theta, v_\theta)=(0,0)$. In the plots, as time goes on, the impact velocities tend to decrease in magnitude, and x and y approach zero. This is indicated by the dots clustering towards the zeros on the plots.

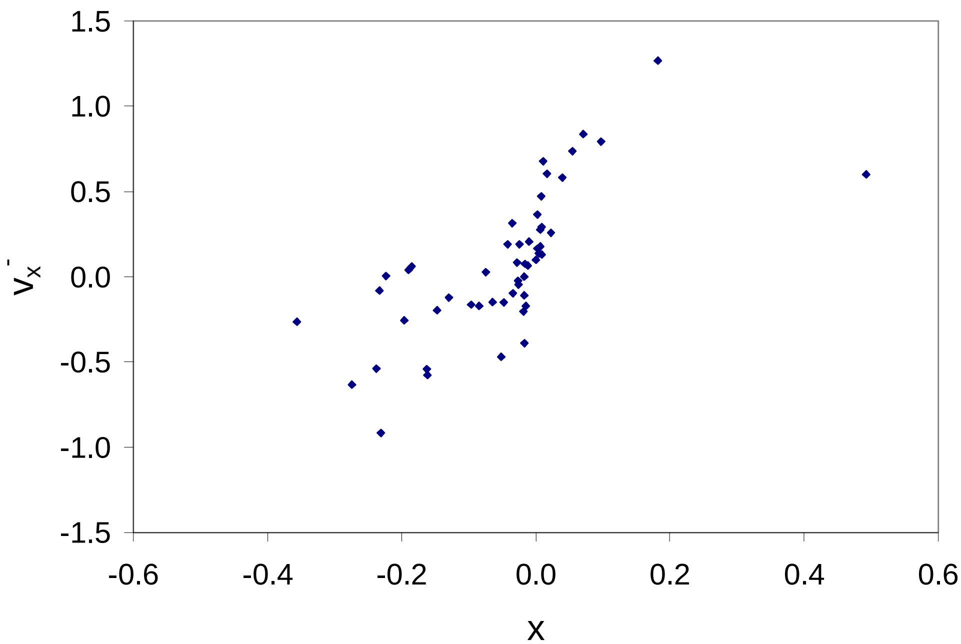

Fig. A.6. x Impact Poincaré Plot, PMBW Standard Case

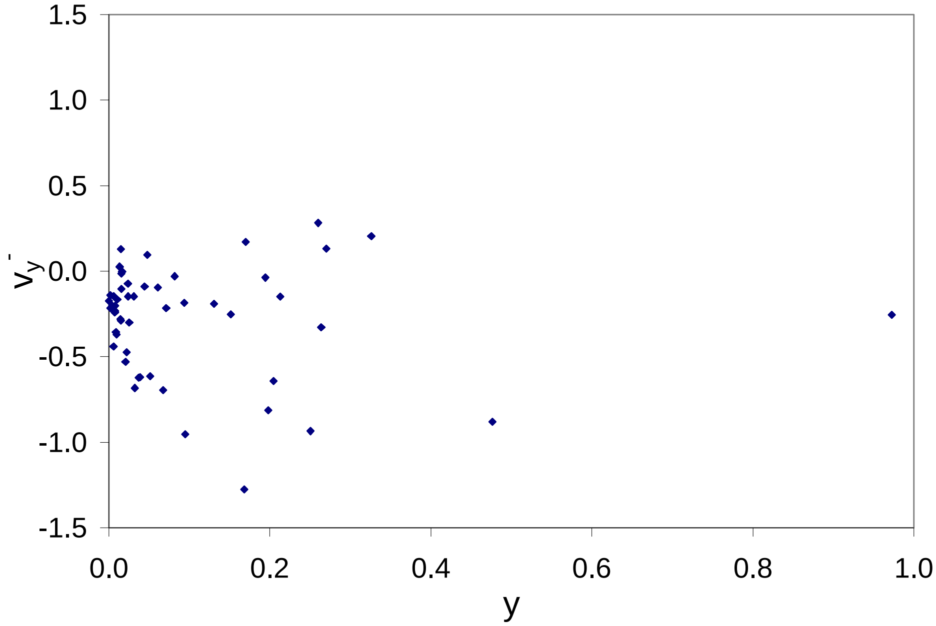

Fig. A.7. y Impact Poincaré Plot, PMBW Standard Case

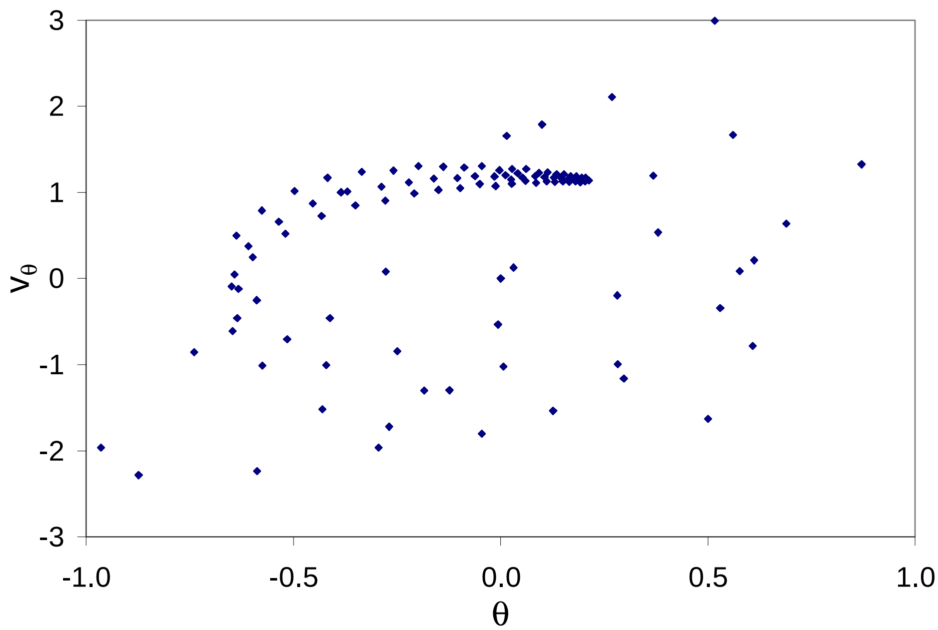

Fig. A.8. θ Impact Poincaré Plot, RBBW Standard Case

The total energy and the kinetic energy were both plotted against time for the cases analyzed in this investigation and are shown in Figs. A.9 and A.10, respectively. These are typical plots where the energy in the system is decreasing as the breakwater dissipates energy during impacts and starts to settle to the equilibrium state. Figures A.9 and A.10 were produced from the data collected from the free motion PMBW standard case and exhibit this decreasing nature.

The plots of the cases where forcing was introduced were very similar to the plots discussed here when the motions tended to settle. The motion between impacts is not linear or quadratic because of the introduced sinusoidal forcing. The plots discussed here show the typical nature of the response of the breakwater during its motions.

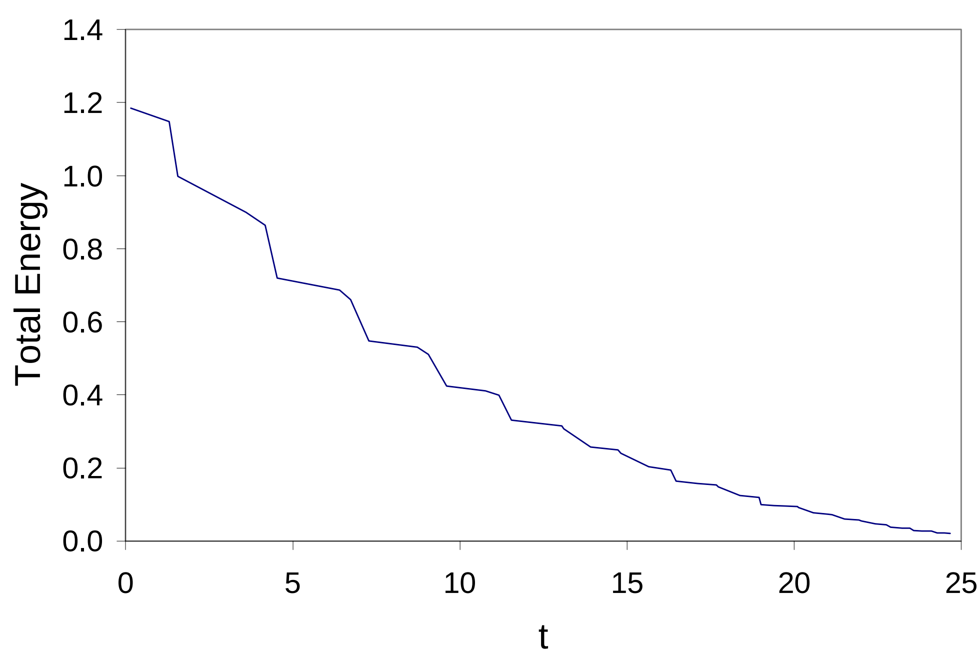

Fig. A.9. Total Energy vs. t, PMBW Standard Case

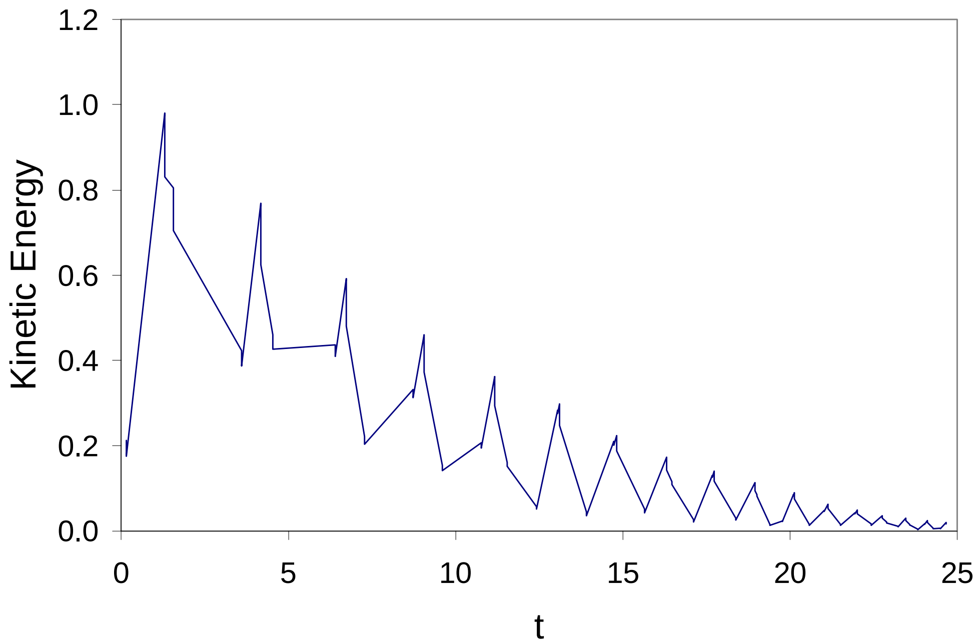

Fig. A.10. Kinetic Energy vs. t, PMBW Standard Case

Vita

Anthony Lee Farmer was born on December 5, 1975 in Portsmouth, Virginia. He lived in Chesapeake, Virginia, attending Western Branch High School, until 1991 and then moved to Orange County, Virginia. In June of 1994 he graduated from Orange County High School in Orange, Virginia. He attended Piedmont Virginia Community College in Charlottesville, Virginia until 1996 when he transferred to Virginia Polytechnic Institute and State University. While attending Virginia Tech, he completed his Bachelor of Science Degree in May of 1998. He continued his engineering education by receiving a Master of Science in Civil Engineering degree at Virginia Tech in December of 1999. Shortly after finishing his graduate studies, Anthony will begin working for the Naval Facilities Engineering Command in Norfolk, Virginia.

Anthony L. Farmer