

MAE 3400 – Fluid Mechanics (Yu)

Final Project – Spring 2013

Computational Fluid Dynamics with
ANSYS

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While considering design aspects for a new model of semi-trucks, features that serve to increase the aerodynamic profile of the vehicle should be considered. Simple design steps can be taken such as decreasing the size of the gap between the semi cab and trailer, adding side skirts to decrease airflow under the trailer, and tapering the trailer. In order to demonstrate this, two models of semi-trucks with different cab styles are considered, a Peterbilt 579 and a Kenworth K100. The newer model Peterbilt features a much sleeker and streamlined cab design while the older model Kenworth maintains the older very cube like cab style.

The two models of semi-trucks first had to be modeled in SolidWorks and then imported into ANSYS for computational fluid analysis. It is assumed that both trucks are hauling a 40ft dry van trailer at a constant speed of 60 miles per hour. Given these parameters it is possible to compute and plot a range of associated variables within ANSYS. In Fig. A.6 and A.7 pressure contour plots are shown and in both models there is an obvious pocket of low pressure just behind the semi-truck. This is the region also associated with the drag force acting on the semi.

When examining the overall difference in efficiency between the two trucks the velocity contour plots shown in Fig. A.3 and A.4 are helpful. The areas where velocity is zero or negative relative to the airflow are indicative of drag caused by the trucks body. It is obvious that the older model Kenworth truck has a much larger region where this behavior occurs. By modifying the geometry of the very end of the trailer the drag can be greatly reduced. In fig. A.8 fluid analysis has been conducted on a truck model with a 'tear-drop' section attached to the end of the trailer.

A simple 1D model demonstrating the application of the Navier-Stokes equations has also been assembled and can be seen in appendix B. In order to accomplish this we considered a

simple fluid flow example, the propagation of a square wave. We then created a matlab program demonstrating this example. This program functions such as, first the initial wave form was defined giving the initial position and velocity profile of the wave. Next, using a for-loop the program advances one time-step forward in time. At this point the finite difference equation is applied at every point in x using a nested for-loop. The finite difference equation computes the wave form at the next time step using values corresponding to the current and previous time step. The program continues to advance forward in time, updating the wave form accordingly at each iteration. The three graphs produced by the simulation show the wave form at different times in the simulation. One thing to note is that as time moves forward some distortion occurs in the wave form as it goes from being perfectly square to more round. This is due to the nature of the calculations which occur at incremented, discrete values instead of occurring continuously. Given that this distortion was barely noticeable, we concluded that our simulation does a satisfactory job of representing the propagation of a square wave, giving us confidence in the methods used in CFD software.

Upon analyzing both the Peterbilt 579 and the Kenworth K100 trucks, the Peterbilt was found to have a more streamlined design thus leading to lower drag forces and better gas mileage. Better gas mileage has various social, political, and economic impacts in countries around the world.

Better gas mileage in today's environmentally conscious society has a great impact on how companies are viewed. A company that uses a Peterbilt instead of the less fuel efficient Kenworth design would have a smaller carbon footprint and could use this in advertising campaigns to get more business customers. Even though the trucks fuel, diesel, is cleaner to

burn than gasoline it still has an effect on the environment. A semi-truck on average produces 0.373 lbs of CO₂ per ton mile which is than both trains and sea freighters [1].

There are also various political impacts on using more fuel efficient trucks. The United States enacted the Emergency Highway Energy Conservation Act in 1973 in order to reduce the amount of fuel consumed. Various environmental foundations have also called for lower speed limits to reduce carbon emissions and improve air quality [2]. The process of emissions trading is commonly used to charge companies for the amount of pollution they emit. The Kyoto protocol was enacted by the United Nations in order to allow for emissions trading and is used by a total of one hundred ninety one countries. While the United States has signed the protocol, they have not enacted it [3].

The U.S economy will ultimately suffer if they continue to use less fuel efficient vehicles because of the move by the rest of the developed nations to reduce pollution. Even though it is acceptable to sell the inefficient vehicles in the country, when trying to sell their products elsewhere they have to abide by that countries guidelines. Companies outside the U.S. can sell their vehicles in their own country as well ours with no additional cost to them which gives them a comparative advantage. To compete in the national market, companies have to use more fuel efficient vehicles like the Peterbilt truck rather than the Kenworth truck.

References:

1. "Waterway Transportation Facts -." *Waterway Transportation Facts -*. N.p., n.d. Web. 09 May 2013. <<http://portofflorence.org/waterway-transportation-facts.html>>.
2. "Environmental Impact of Transport." *Wikipedia*. Wikimedia Foundation, 05 Jan. 2013. Web. 09 May 2013. <http://en.wikipedia.org/wiki/Environmental_impact_of_transport>.
3. "List of Parties to the Kyoto Protocol." *Wikipedia*. Wikimedia Foundation, 05 Mar. 2013. Web. 09 May 2013. <http://en.wikipedia.org/wiki/List_of_parties_to_the_Kyoto_Protocol>.

Appendices

Appendix A – Figures and Plots

Figure A.1 – Residual values for older model semi

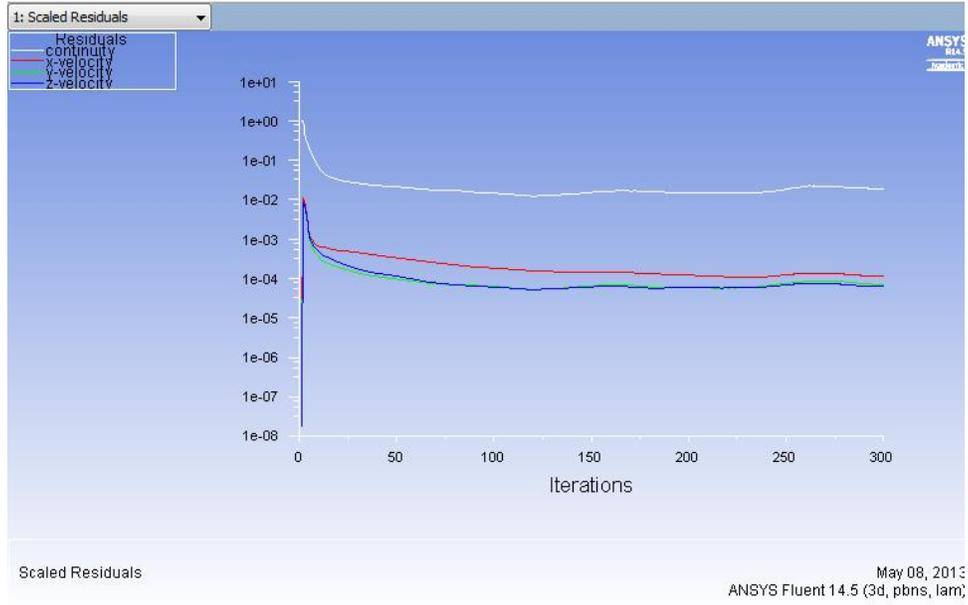


Figure A.2 – Residual values for newer model semi

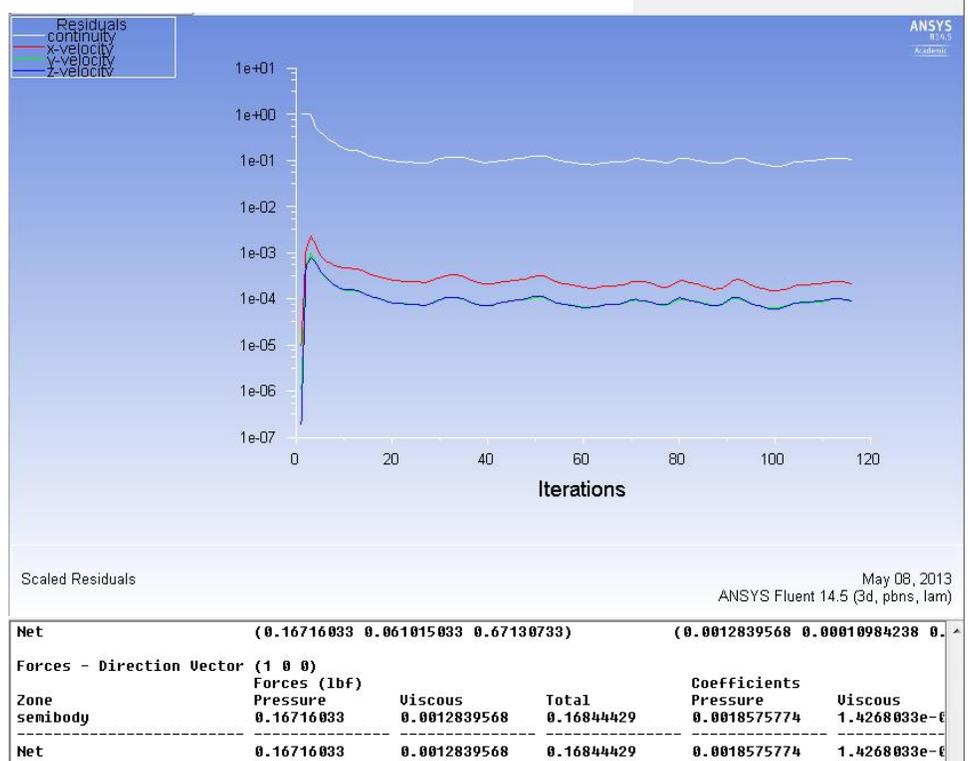


Figure A.3 – Velocity contour plot for older model semi

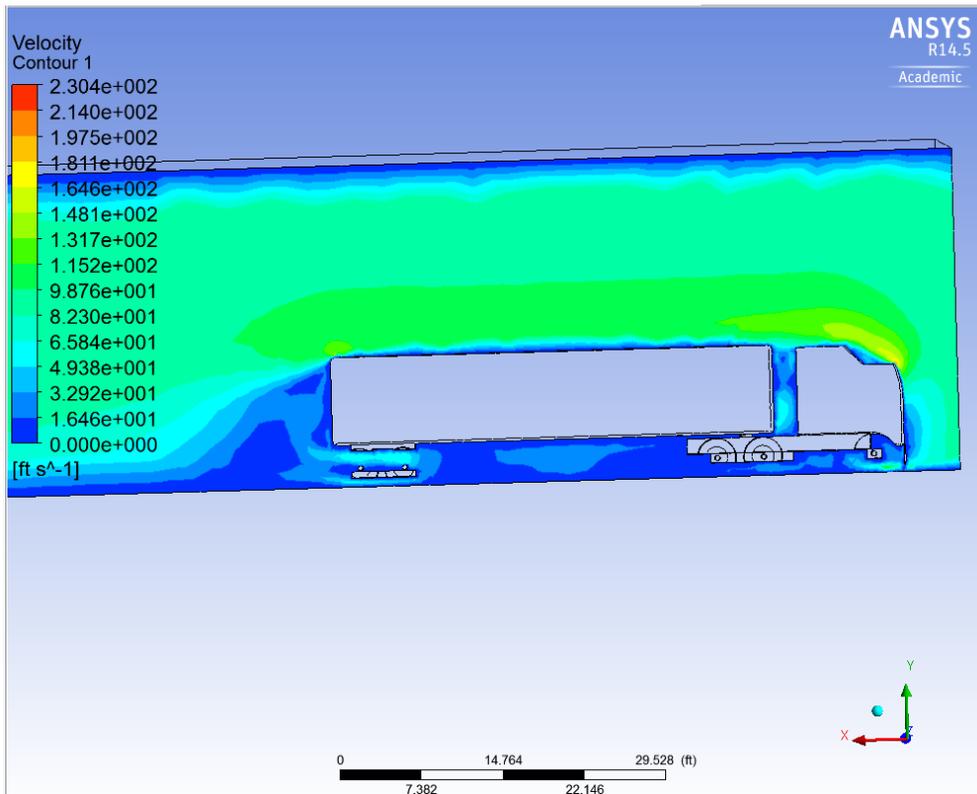


Figure A.4 – Velocity contour plot for newer model semi

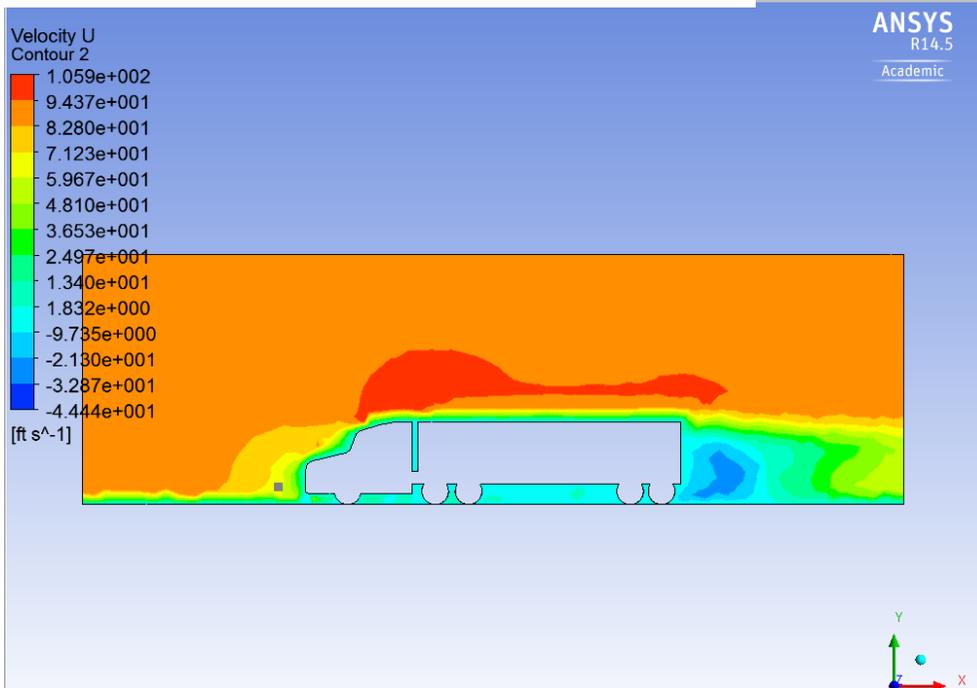


Figure A.5 – Pressure contour plot for older model semi

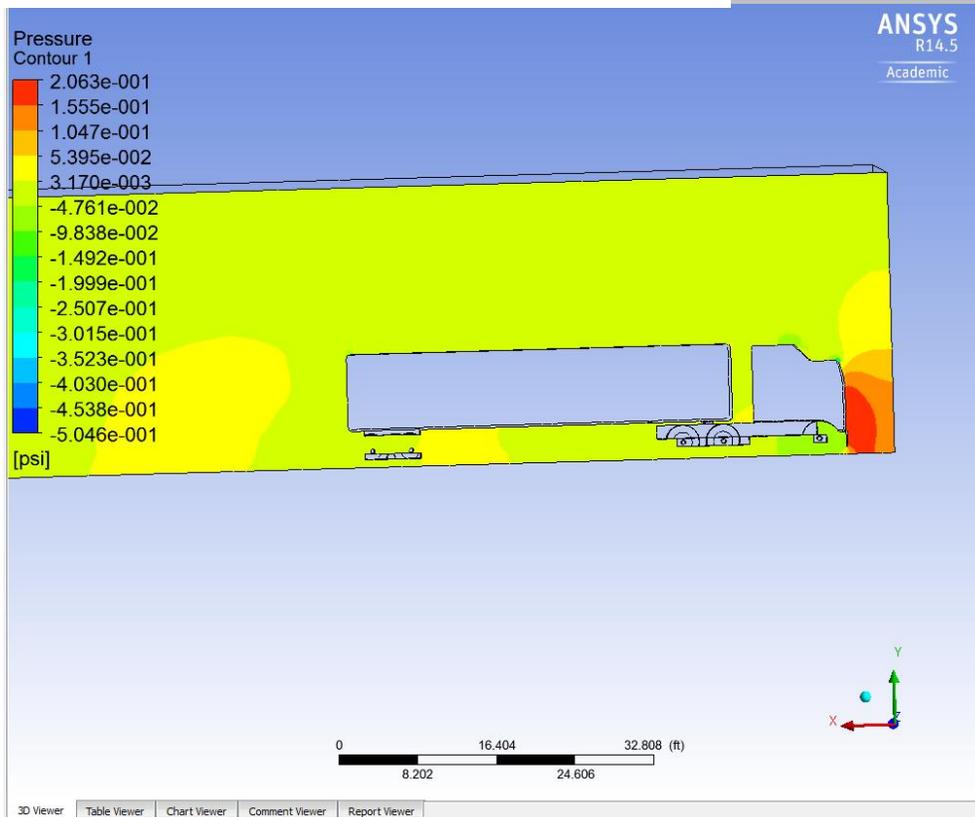


Figure A.6 – Pressure contour plot for newer model semi

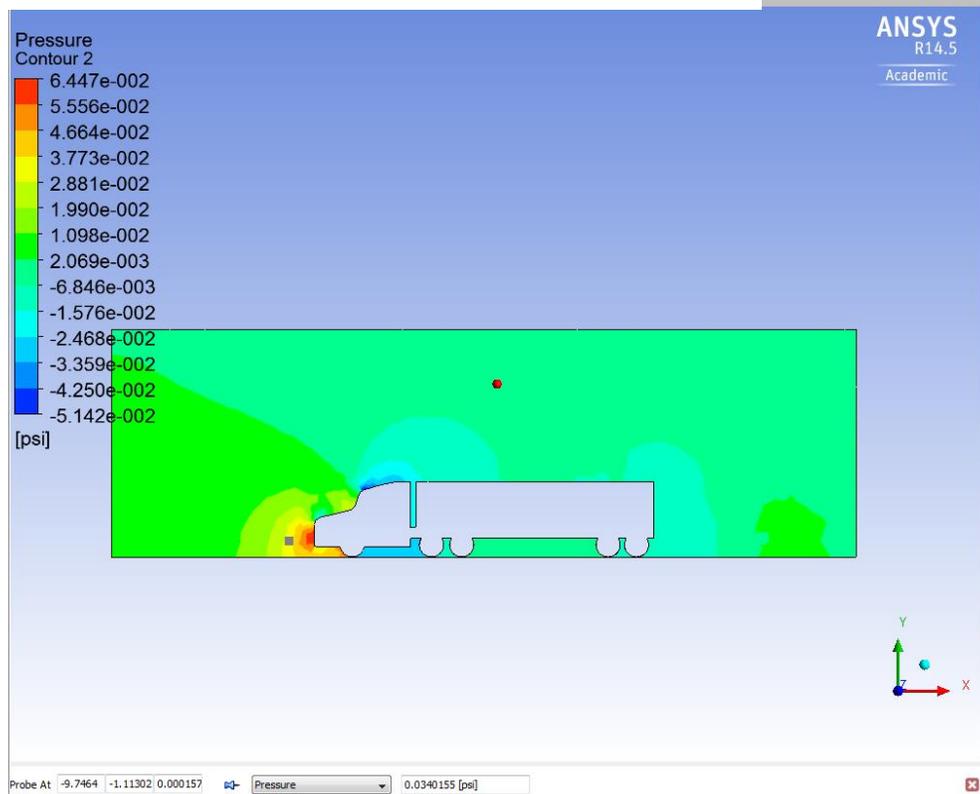
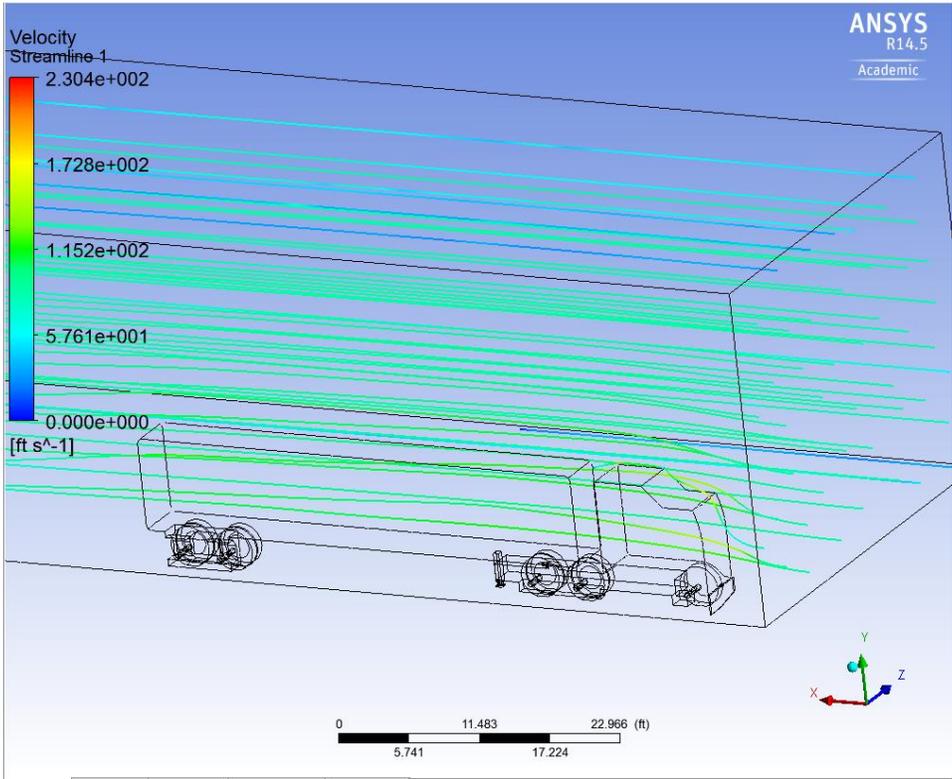
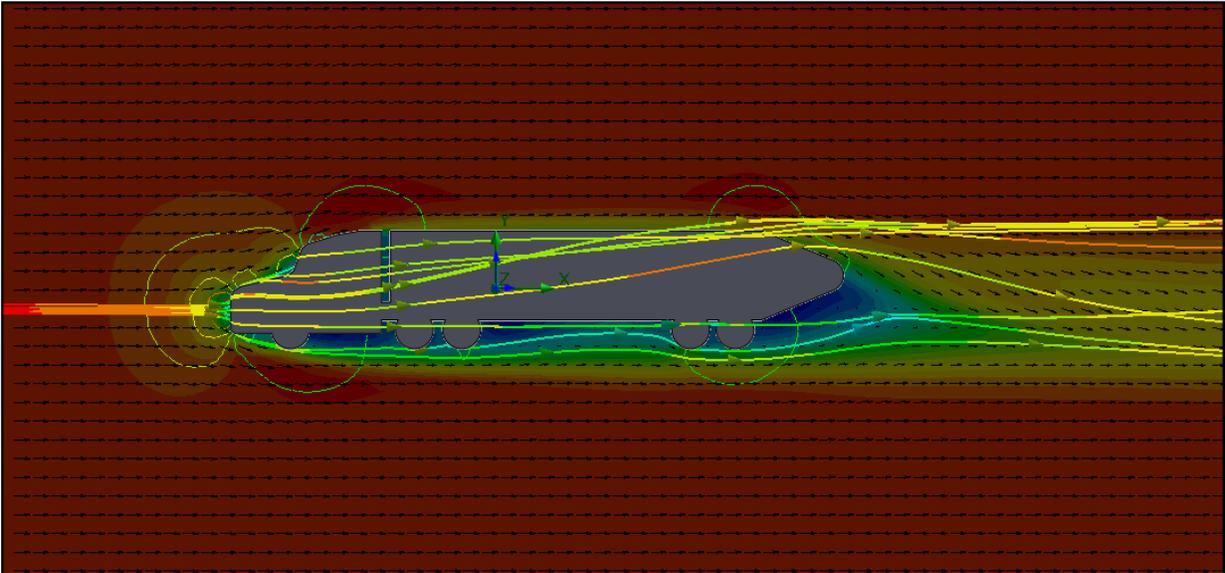


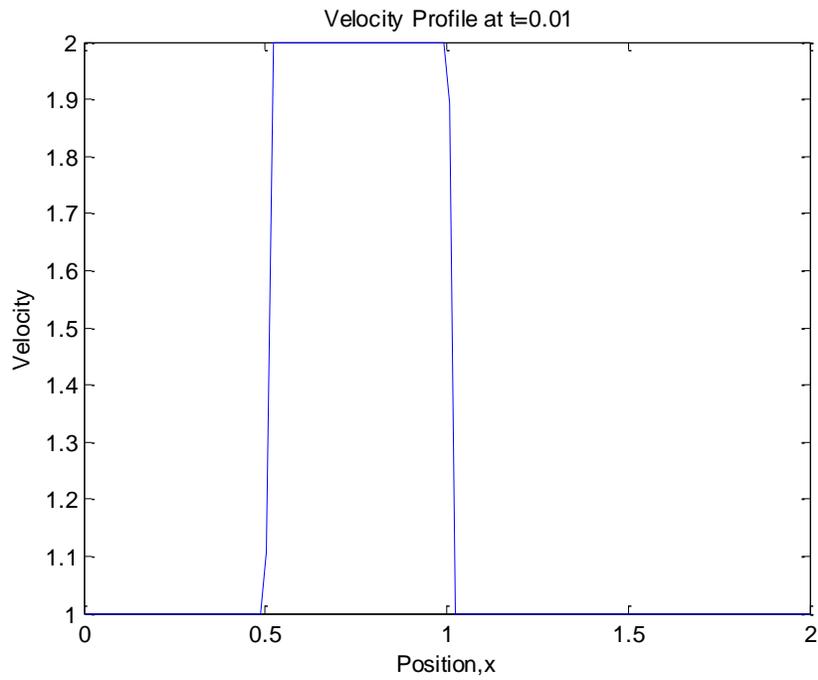
Figure A.7 – Velocity streamline plot for older model semi



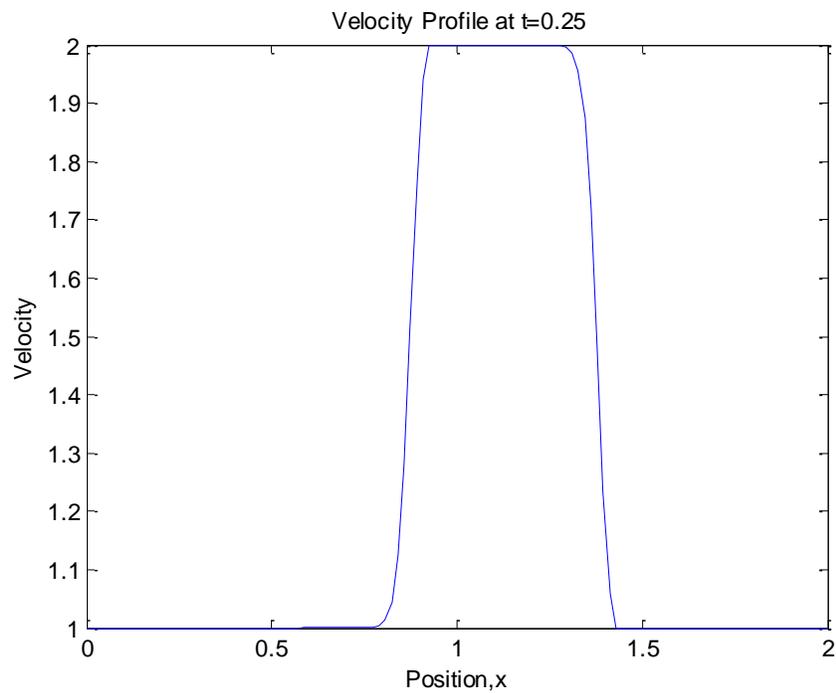
A.8 – Velocities and pressures over modified trailer



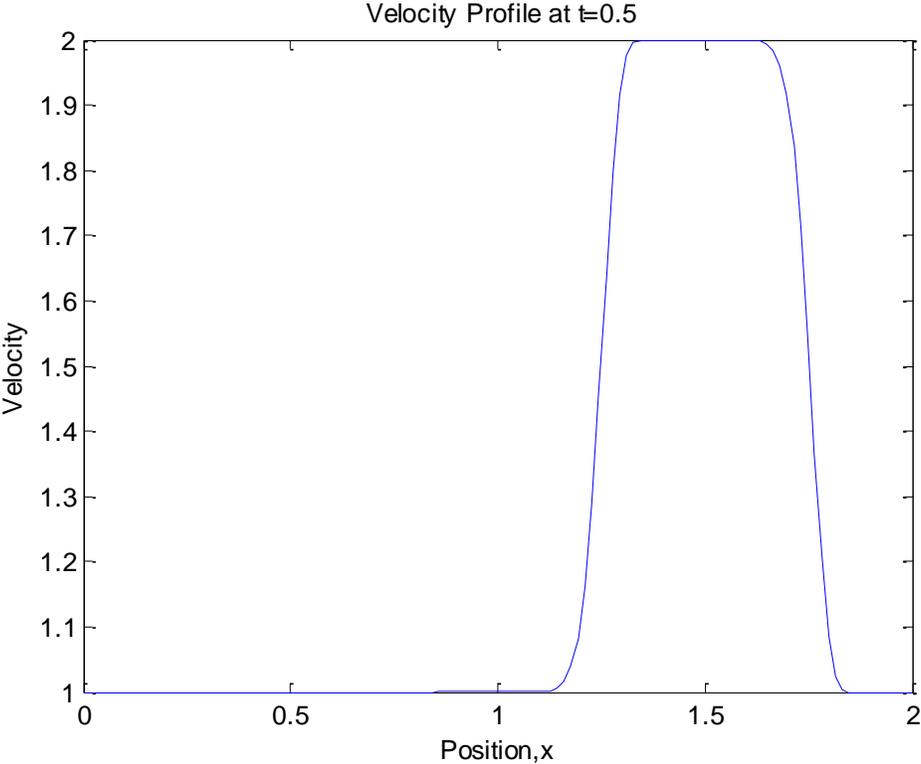
A.9- Matlab generated plot of velocity profile at $t = 0.01s$



A.10 - Matlab generated plot of velocity profile at $t = 0.25s$



A.11 - Matlab generated plot of velocity profile at t = 0.5s



Appendix B – Matlab code

```
%% Definition of variables
% nx = number of points in x
% nt = number of time steps
% dt = time step
% c = wave speed
% dx = delta x
%% set numerical values for variables
nx = 120;
nt = 50;
dt = 0.01;
c = 1.5;
dx = 2/(nx-1);
%% create array of x values
x=0:dx:2;
%% create initial wave form
for i = 1:nx
    if 0.5 <= x(i)&& x(i) <= 1
        u(i) = 2;
    else
        u(i) = 1;
    end
end
%% Calculations for moving forward in time
% Advances time forward and updates "un" accordingly
for it = 1:nt
    un = u;
    % finite difference equation at every point in x at current time step
    for i = 2:nx-1
        u(i) = un(i)-c.*dt./dx.*(un(i)-un(i-1));
    end
    % plots wave from at 3 distinct times
    switch it
        case {1}
            figure(it), plot(x,u)
            xlabel('Position,x')
            ylabel('Velocity')
            title('Velocity Profile at t=0.01')
        case {25}
            figure(it), plot(x,u)
            xlabel('Position,x')
            ylabel('Velocity')
            title('Velocity Profile at t=0.25')
        case {50}
            figure(it), plot(x,u)
            xlabel('Position,x')
            ylabel('Velocity')
            title('Velocity Profile at t=0.5')
    end
end
end
```

