Virtual Flow Bench Test of a Two Stroke Engine

Preformed by:
Andrew Sugden

University of Wisconsin Platteville
Mechanical Engineering
ME: 4560, John Iselin
01.05.2011
**Introduction:** As an undergraduate of the University of Wisconsin Platteville, I took an introductory course in computational fluid dynamics for a personal interest I have in fluid dynamics. Near the conclusion of the semester we had to choose our own project of anything that interested us and model it using CD-adapco Star CCM+. I chose to model a two-stroke nitro methane model engine. My project was to compare the flow of air-fuel mixture into the cylinder of the engine of both an original and modified cylinder sleeve. Over the internet there have been a lot of debates as to why these particular modifications increase performance of the engines. It has been shown that modifying the sleeve does improve performance from physical tests that have been performed, but there has been no research or studies that provide evidence as to why it works. This project tested one of the core ideas, that the modification to the sleeve will increase air-fuel mixture into the engine and therefore create more power. Further understanding of how to increase performance on a scaled engine could expand the applications of the scaled engines and possibly improve on existing, larger two-stroke engines.

**Project Description:** The engine I chose to model is the HPI Star 25, since I own this engine and I was able to tear it down and draw dimensionally accurate parts to model. There is also a test that was performed on this engine several years ago, verifying that modifications can and do increase performance as shown by Steve Pond (A-1: 1). It is important to realize that just increasing the size of the intake ports (to allow more air-fuel in) will mess with the timing of the engine and actually decrease performance; with the exception of the exhaust port as described in the field test. The modifications that I made to my sleeve are similar to that describe by the field test (A-1: 2-3), figure a-b in appendix A-2 shows the difference between the original sleeve and the modified sleeve. The modifications were made on the exterior side of the sleeve. I increased the entrance angle on the front and side ports and
created a “fang” on the side port. I also increased the size of the exhaust port so that it is now open for 165 degrees.

**CFD Model Description:** Due to the complexity of a working engine and the limitations of my computational resources, some choices and simplifying assumptions had to be made. Even though this engine can fit in the palm of my hand, only half of the engine could be modeled due to the computation it would take to model it; with only modeling half of the engine it took nearly three quarters of a million cells to create. Figure c in appendix A-2 is the complete view of the model in solid works. The actual air-fuel flow rates are not the point of interest in this model since this is only a comparison of performance between the two sleeves. A lot of the internal parts of the engine (i.e. crankshaft, piston rod, bearings etc.) were removed, and the interior walls of the housing were extruded so the flow had time to develop before it reached the intake ports of the sleeve.

A surface wrapper, figure a-b in appendix A-3, was used to capture the geometry of the engine. Before the surface wrapper was used, all of the original feature curves were deleted so that none of the edges would get rounded off. A wrapper scale factor of 50 was used in order to capture the fine details of the intake ports and the interior walls of the engine while saving computational resources when surface and volume meshes were created. The surface repair tool was used to close off the openings in the engine like the intake, exhaust, and the symmetry (since only half of the engine was modeled). It was also used to create an interface for the intake ports so that the volume flow rates could be calculated through each port. Eleven contact preventions were used, varying the search floor from 0.1mm to 0.25mm depending on location.
After the wrapper, the surface remesher was selected. Since a relatively large base size was used, several custom surface sizes were used; eleven of the boundaries had a custom surface size with most of them having a target size of 0.5mm and a minimum size of 0.25mm.

A polyhedral volume mesh was selected with prism layers, as can be seen in figure a-b in appendix A-4. A total of ten prism layers were selected with a thickness layer ten percent of the base. Two volume controls were created, one in the center of the cylinder and one at the exhaust. The one at the center of the cylinder was a cylinder set up to match the same size as the custom surface size of the sleeve. The exhaust control volume was slightly finer, since there is a lot of movement going on there.

A total of nineteen different boundary conditions were created, most being created by splitting up the region by patch, and the others were created from the surface wrapper repair tool. Since this engine was modeled as symmetric, some of these boundaries were made into symmetry planes. Most others were made into walls but with different surface sizes. The exit/exhaust port was selected to be a pressure outlet with a negative pressure of ten Pascal and the turbulent intensity and turbulent viscosity ratios were left as their default values. Negative ten Pascal was chosen as the pressure because after running a couple of test simulation it gave a reasonable velocity and stable residuals. The pressure was negative because when modeling this engine the piston is at bottom dead center; this is the point in a two-stroke engine when the exhaust from the pervious explosion would be completely exiting the engine, creating a low pressure that would draw in fresh fuel and air from the intake ports.

As for the inlet, a stagnation inlet was created with no changes to the physics values. A stagnation inlet was chosen over a velocity inlet or pressure outlet because there is no specific velocity or pressure information available for air-fuel mixture to enter the engine.
Since there is a negative pressure at the outlet, it needed to draw only as much air-fuel mixture from the inlet as it desired. Two interfaces were created for the two intake ports; they were porous baffles with a porosity of one. This way the air-fuel mixture won’t be disrupted as it enters the cylinder, but there is still a median for calculating the flow rate through each port.

The physics models that were chosen were: Two-Layer All y+ Wall Treatment, Realizable K-Epsilon Two-Layer, K-Epsilon Turbulence, Reynolds-Averaged Navier-Stokes, Turbulent, Constant Density, Segregated Flow, Gas, Steady, and Three Dimensional. The Density and viscosity was changed to better represent a nitro-air mixture, with the assumption that an ideal mixture for combustion is 1.7:1 air to nitro (A-1: 5). Segregated flow was chosen over Coupled flow because for subsonic flow, like this model, it is a little more stable and it is computationally faster for the amount of cells that were used in this model.

Steady state was used for a couple of reasons. One: it simplifies the problem greatly; there is no need for internal moving parts, and it reduces the amount of time it takes to run the model. Two: it is not necessary to over complicate the problem. All that is needed is a comparison between the two sleeves at a given instant when the air-fuel flow rate is the greatest. K-Epsilon turbulence model was chosen because it provides a good compromise between stability, computation, and accuracy.

To save time and to make sure everything stayed the same between the two different simulations, an export surface was used. After the first simulation was completed, it was saved under a different name and a second simulation was created with all the same boundary names. The export surface was then used to bring in the modified sleeve without having to change any of the settings from the original sleeve.
**Results:** For the original sleeve, after about 350 iterations, the stopping criteria was met for both volume flow rates in each port with a sample size of 50 iterations and a standard deviation of 1.0E-8 m$^3$/s. A plot of the flow rate and the residuals are shown in graphs a and c in appendix A-5. All residuals were in between 0.1 and 1E-4 with the Tdr and Tke showing a saw tooth pattern hovering over their final values. A report was created using a custom field function to determine the volume flow rate through each of the ports. Port 1 had a volume flow rate of 13.2 cc/s and port 2 had a rate of 27.9 cc/s.

For the modified sleeve, after about 370 iterations, the same stopping criteria were met as the original sleeve. A plot of the flow rate and the residuals can be seen in graphs b and d in appendix A-5. All but one residual was in between 0.01 and 1E-5 with the y-momentum between 0.1 and 0.01. However, it appears that all the residual except the Tdr are dropping and had not reached their final value. The same report that was used for the original sleeve was used here.

Port 1 had a volume flow rate of 14.4 cc/s and port 2 had a rate of 30.7 cc/s. This means Port 1 will see 8.7% and port 2 will see 9.6% more fuel-air mixture with the modified sleeve over the original sleeve. In appendix A-6 figures a and b is a velocity scalar scene view looking at the exhaust and intake of port 2. When comparing between the two, it is visually evident that the modified port shows greater velocity throughout the entire port then it does on the original sleeve; which supports the outcomes of this simulation. The streamline scenes in appendix A-7, figures a and b, also show a better flow into the cylinder of the engine with the modified sleeve then it does with the original sleeve. With the original sleeve, the streamline is more jagged and disorganized but with the modified sleeve, the streamline is more fluent and structured.
**Conclusion:** The purpose of this simulation was to show that by making some modifications to the sleeve of these particular two-stroke nitro engines a gain of performance could very well be because of an increase of air-fuel mixture to the engine. As it was shown in the results of this virtual flow bench test, modifications to the sleeve does in fact increase air-fuel mixture to the cylinder of the engine as was expected to uphold the core ideas. This is only the first step towards making a better engine, with more time and resources more models and variations can be made to find the best combination for the best performance. With the power of the ever-improving simulation packages like CD-adapco, these first steps can be taken and can be used to open up new ideas for exiting products to improve the quality of our lives.
Appendix A-1:


Appendix A-2:

a) Original Sleeve

b) Modified Cylinder Sleeve

c) Engine Assembly

- Top Plate
- Sleeve
- Piston
- Housing
Appendix A-3:

a)

b)
Appendix A-4:
Appendix A-5:

a) 

b) 

c) 

d)
Appendix A-6:

Scalar Scene (Original Sleeve)

Scalar Scene (Modified Sleeve)
Appendix A-7: