This case study was created as part of
the free and voluntary UberCloud Experiment

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Modeling Airflow Through an Engine Intake Manifold with ANSYS FLUENT on Microsoft Azure

Key Findings

- The HPC cloud computing environment with ANSYS workbench and FLUENT made model generation much easier and dramatically reduced process time, result view and post processing.
- For fine meshes (>770K cells) the normal workstation was not a good fit. The HPC cloud solved these fine mesh models with ease at very fast run times (~5 min).
- The engineer did not need to install or configure any software or hardware. The complete simulation environment was accessed just as one would access a regular website.

This document is based on one of the more than 200 technical case studies that have been generated by engineering teams participating in the UberCloud Experiment. You will benefit from the candid descriptions of the problems the teams encountered, how they solved them, and lessons learned.

It seems hard to imagine, but there was once a time in the U.S. when you could buy a car without emission controls.

Research conducted by federal, state and local governments in the 1950s and 1960s changed all that – the California Air Resources Board was created in 1967 and the federal Environmental Protection Agency in 1970. A flood of legislation followed and has only intensified since.

As a result, today's automotive manufacturers in the U.S. and around the world are faced with ever changing, increasing complex government mandates designed to reduce vehicular pollutant emissions. Technology is the key. In particular, high performance computing (HPC) is helping manufacturers intensity their efforts to understand the processes involved in the operation of modern internal combustion engines. A recent UberCloud Experiment is part of that effort.

One of the most important processes taking place inside these spark ignition engines is the preparation of the air-fuel mixture. The mixture circulates to the engine's intake port following a very complicated path that includes an air cleaner, intake pipe, and intake manifold.

The design of the intake manifold is one of the key factors determining engine performance and this is where the UberCloud team focused their efforts.

In order to understand the flow characteristics of the manifold, the UberCloud team created a complex simulation framework. This allowed them to generate highly accurate results predictions in a short period of time with the optimal use of the allocated HPC resources.

Meeting the time constraints for the experiment was not easy. When the team performed trials with different mesh density models, they discovered that the finer mesh allowed them to capture more accurate flow behavior data. However, the finer the mesh, the longer the simulation runtime. The team used the power of HPC in the cloud to determine the optimal tradeoffs.

Another challenge was learning how to use the Azure Cloud platform following written instructions provided by Azure.

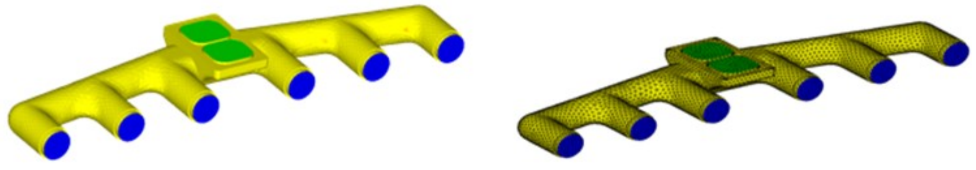

Figure 1: Geometry and mesh model for air intake manifold.

SOLVING THE MODEL STEP BY STEP

Below are the key steps the team took to get the desired results within the project's time limitations.

First, they extracted the internal volume representing the flow path for the intake manifold.

A finite volume mesh was generated, followed by the fluid properties definition. The entire internal volume of the intake manifold was defined as air. The fluid properties were defined as Newtonian fluids and described a linear relationship between the shear stress (due to internal friction forces) and the rate of strain of the fluid. The air entered the manifold at a specified flow rate and then moved into a different hose at the exit of the intake manifold.

The next step in the model setup was to define the model boundary conditions and assigning pressure and velocity initial values. The wall boundary conditions were assigned on the outer surface of the air volume. The top surface of the intake manifold where air enters was defined as inlet, and the cylindrical faces were defined as outlet.

The solution algorithm and the convergence criteria were defined – this allowed the simulation to solve the problem and determine the accuracy of the results.

The model was solved in parallel. The final result was used to view the output of air flow inside the intake manifold. The respective result components were captured using the post-processing software tool in ANSYS.

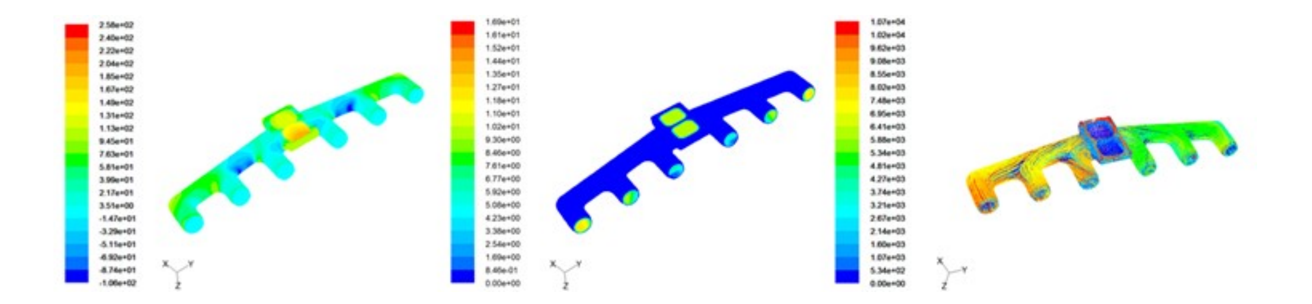

Figure 2: a) Contour plot of pressure distribution b) Contour plot of velocity distribution c) streamline plot of air flow velocity.

HPC PERFORMANCE PAYS OFF

The HPC system used for this project was a Microsoft Azure GS5 Instance with 32 cores, 448 GB RAM, Max Disk size OS = 1023 GB and local SSD = 896 GB, Cache size 4224, and Linux operating system. The software used to develop the air flow modelling for intake manifold was ANSYS Workbench with FLUENT in an UberCloud HPC container. The container was integrated with the Microsoft Azure cloud platform.

The team evaluated the model based on how accurately it predicted air circulation within the intake . They also determined if there was any recirculation that resulted either in a blockage or a smoother flow of air. Different finite volume models were developed for fine and coarse mesh.

In order to benchmark the HPC system's performance in solving high-density mesh models, the team captured the time required to solve the model with different mesh intensities, and with and without parallel processiing. Boundary conditions, solution algorithm, solver setup and convergence criteria remained the same for all models.

Comparison of solution times with single core vs. 8 cores indicated that the time for the parallel run was significantly less when compared with running the same simulations using a single core. (see Figure 3)

~600 core hours were used to perform various iterations in the simulation experiments.

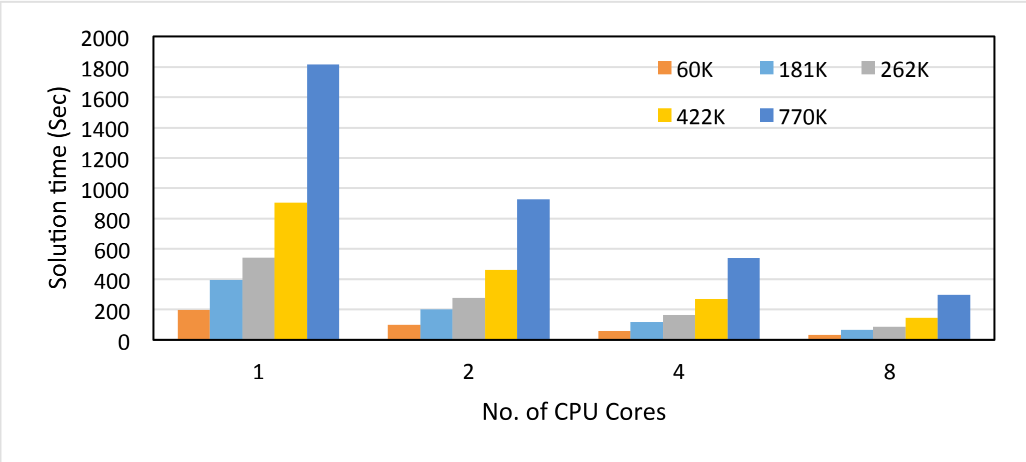

Figure 3: Comparison in solution time for different mesh densities models solved using different HPC core configurations.

RUNNING COMPLEX MESH MODELS IS EASIER IN THE CLOUD

The HPC cloud computing environment with ANSYS workbench and FLUENT made the process of model generation much easier. In addition, process time, result view and post processing were all reduced dramatically.

The different simulation setup tools were pre-installed in the HPC container for easy access and operation. For example, the team was able to generate mesh models for different cell numbers, with experiments performed for coarse–to–fine to highly-fine models.

The computation requirement for fine meshes (~770K cells) was high and next to impossible to achieve on a normal workstation. The HPC cloud provided ample resources to solve these highly-fine mesh models. Also, the simulation time was drastically reduced, producing results within an acceptable run time (~5 min).

VNC Controls in the Web browser provided easy access to the HPC cloud and no software had to be pre-installed. In fact, the whole user experience was similar to accessing a convential website.

The UberCloud containers helped with smooth execution of the project by providing easy access to server resources. TheUberCloud environment, integrated with the Azure platform, allowed the team to run parallel UberCloud containers.

A dashboard in the Azure environment provided the team with a clear view into HPC system performance and resource usage.

For performing advanced computational experiments that involved major technical challenges with complex geometries, the combination of Microsoft Azure, HPC Cloud resources, UberCloud Containers, and ANSYS Workbench with FLUENT proved to be an excellent choice. These experiments could not have been solved on a normal workstation.

ABOUT UBERCLOUD

UberCloud makes it easy to run your simulations on powerful cloud infrastructure.

No more compromises on mesh quality or model fidelity because of hardware limitations. With UberCloud's flexible software platform and network of cloud partners, you get on-demand access to major providers such as Microsoft Azure, HPE and others. Choose from a variety of secure data centers, and hardware options such as InfiniBand, GPUs etc.

Unleash the full power of your analysis software and boost confidence in your results.

With over 200 technical-computing-as-a-service case studies, UberCloud has the experience, software platform and partnerships required for your success.

Engineers and scientists rely on UberCloud to manage the complexity of cloud and software operations, so they can focus on their analysis.

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