Air flow through an engine intake manifold on Microsoft Azure

An UberCloud Experiment

With Support From

UberCloud Case Study 185:

Air flow through an engine intake manifold on Microsoft Azure

http://www.TheUberCloud.com

December 13, 2015

Welcome!

The UberCloud* Experiment started in July 2012, with a discussion about cloud adoption in technical computing and a list of technical and cloud computing challenges and potential solutions. We decided to explore these challenges further, hands-on, and the idea of the UberCloud Experiment was born, also due to the excellent support from INTEL generously sponsoring these experiments!

We found that especially small and medium enterprises in digital manufacturing would strongly benefit from technical computing in HPC centers and in the cloud. By gaining access on demand from their desktop workstations to additional compute resources, their major benefits are: the agility gained by shortening product design cycles through shorter simulation times; the superior quality achieved by simulating more sophisticated geometries and physics and by running many more iterations to look for the best product design; and the cost benefit by only paying for what is really used. These are benefits that increase a company's innovation and competitiveness.

Tangible benefits like these make technical computing - and more specifically technical computing as a service in the cloud - very attractive. But how far away are we from an ideal cloud model for engineers and scientists? In the beginning, we didn't know. We were just facing challenges like security, privacy, and trust; conservative software licensing models; slow data transfer; uncertain cost & ROI; availability of best suited resources; and lack of standardization, transparency, and cloud expertise. However, in the course of this experiment, as we followed each of the 175 teams closely and monitored their challenges and progress, we've got an excellent insight into these roadblocks, how our teams have tackled them, and how we are now able to reduce or even fully resolve them.

This case study is about air-fuel flow through an engine intake manifold. Increasingly stringent legislation aimed at reducing pollutant emissions from vehicles has intensified efforts to gain better understanding of the various processes involved in internal combustion (IC) engines. In the case of spark ignition engines one of the most important processes is to prepare air-fuel mixture. This mixture circulates to the intake port through a complicated path including air cleaner, intake pipe, and intake manifold. The main objective of this project is to understand the flow characteristics in an intake manifold. The simulation framework is developed and executed on Azure Cloud resources running the ANSYS Fluent UberCloud container.

We want to thank the team members for their continuous commitment and voluntary contribution to this experiment, and thus to our technical computing community. And we want to thank our main Compendium sponsor **INTEL** for generously supporting the 185 UberCloud experiments.

Now, enjoy reading!

Praveen Bhat, Wolfgang Gentzsch & Burak Yenier
The UberCloud, December 2015

**) UberCloud is the online community and marketplace where engineers and scientists discover, try, and buy Computing Power as a Service, on demand. Engineers and scientists can explore and discuss how to use this computing power to solve their demanding problems, and to identify the roadblocks and solutions, with a crowd-sourcing approach, jointly with our engineering and scientific community. Learn more about the UberCloud at: http://www.TheUberCloud.com.*

Team 185:

Air flow through an engine intake manifold on Microsoft Azure

"Combination of Microsoft Azure with UberCloud's HPC having ANSYS FLUENT provided a strong platform to develop accurate virtual simulation model that involved complex geometries.

MEET THE TEAM

End-User/CFD Expert: Praveen Bhat, Technology Consultant, INDIA
Software Provider: ANSYS INC., Fluent, and UberCloud Fluent Container
Resource Provider: Microsoft Azure
HPC Expert: Burak Yenier, Co-Founder, CEO, UberCloud

USE CASE

Increasingly stringent legislation aimed at reducing pollutant emissions from vehicles has intensified efforts to gain better understanding of the various processes involved in internal combustion (IC) engines. In the case of spark ignition engines one of the most important processes is to prepare air-fuel mixture. This mixture circulates to the intake port through a very complicated path including air cleaner, intake pipe, and intake manifold. Hence the design of the intake manifold is an important factor which determines engine performance.

The main objective of this project is to understand the flow characteristics in an intake manifold. The simulation framework is developed and executed on Azure Cloud resources running the ANSYS Fluent UberCloud container to achieve good accuracy in result prediction and also with respect to the solution time and resource utilization.

PROCESS OVERVIEW

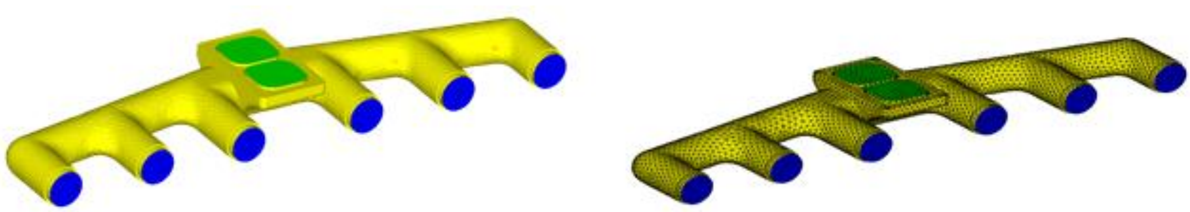

Figure 1: Geometry & Mesh model for air intake manifold

1. The internal volume is extracted which represents the flow path for the intake manifold. A finite volume mesh is generated which is followed by the Fluid properties definition. The entire internal volume of the intake manifold is defined as air.
2. The fluid properties are defined under Newtonian fluids which posts a linear relationship between the shear stress (due to internal friction forces) and the rate of strain of the fluid.
3. The air enters into the manifold with a certain flow rate and then moves into different hose at the exit of the intake manifold.
4. The next section in the model setup is defining the model boundary conditions and assigning the pressure and velocity initial values. The wall boundary conditions are assigned on the outer surface of the air volume. The top surface of the intake manifold where air enters is defined as inlet and the cylindrical faces are defined outlet.
5. The solution algorithm and the convergence criteria are defined for the simulation to solve and find out the accuracy of the results.
6. The model is solved in parallel. The final result is used to view the output of air flow inside the intake manifold and the respective result components are captured using the post-processing software tool in ANSYS.

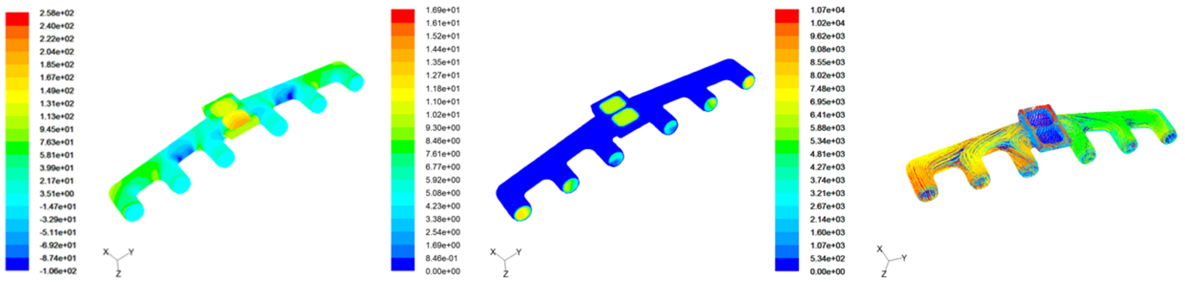

Figure 2: a) Contour plot of pressure distribution b) Contour plot of velocity distribution c) streamline plot of air flow velocity

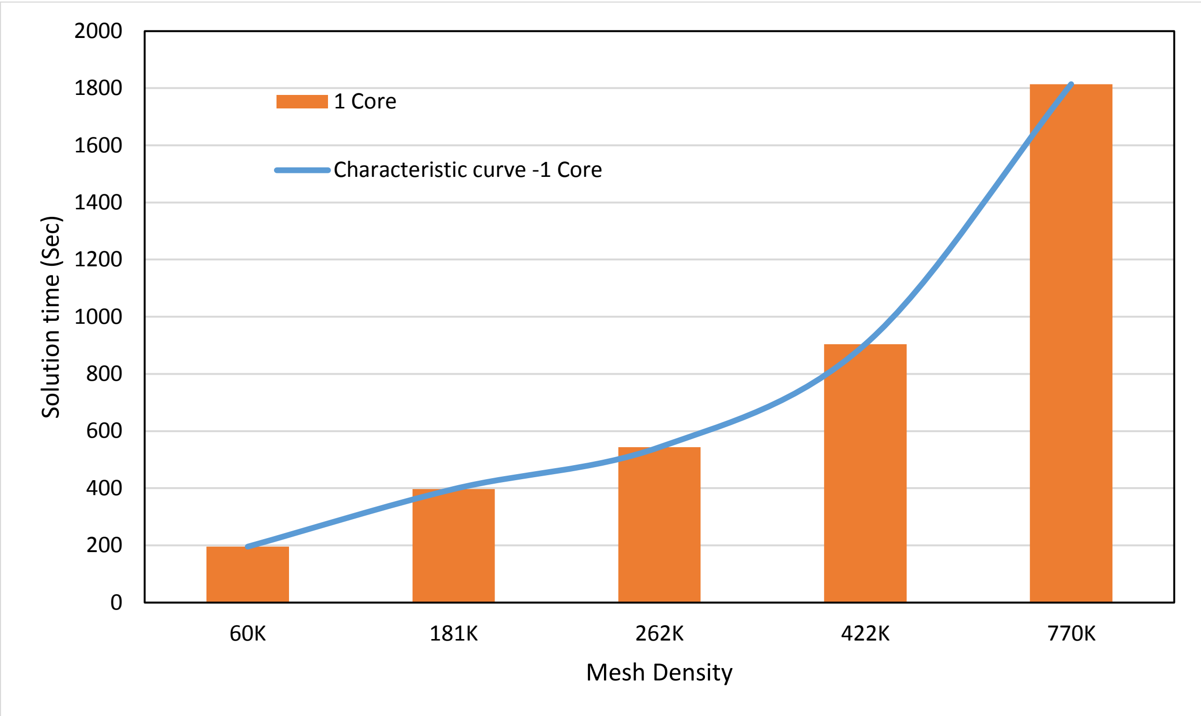

Figure 3: Solution time required for different mesh density with single CPU Core

HPC PERFORMANCE BENCHMARKING

The HPC system is a Microsoft Azure GS5 Instance: 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 is ANSYS Workbench with FLUENT in an UberCloud HPC container, which is integrated with the Microsoft Azure cloud platform. The model is evaluated for the accuracy of predicting air circulation within the intake and also determines if there is any recirculation which results in blockage / smoother flow of air. Different finite volume models are developed for fine and coarse mesh. The time required for solving the model with different mesh intensity is then captured to benchmark the HPC performance in solving high density mesh models. Boundary conditions, solution algorithm, solver setup and convergence criteria remain same for all models.

Figures 4 & 5 provide the comparison of the solution time required for different mesh densities with and without parallel processing. The comparison of the solution time with single core and 8 cores shows that the time for the parallel run is significantly less when compared with running the same simulations with single core.

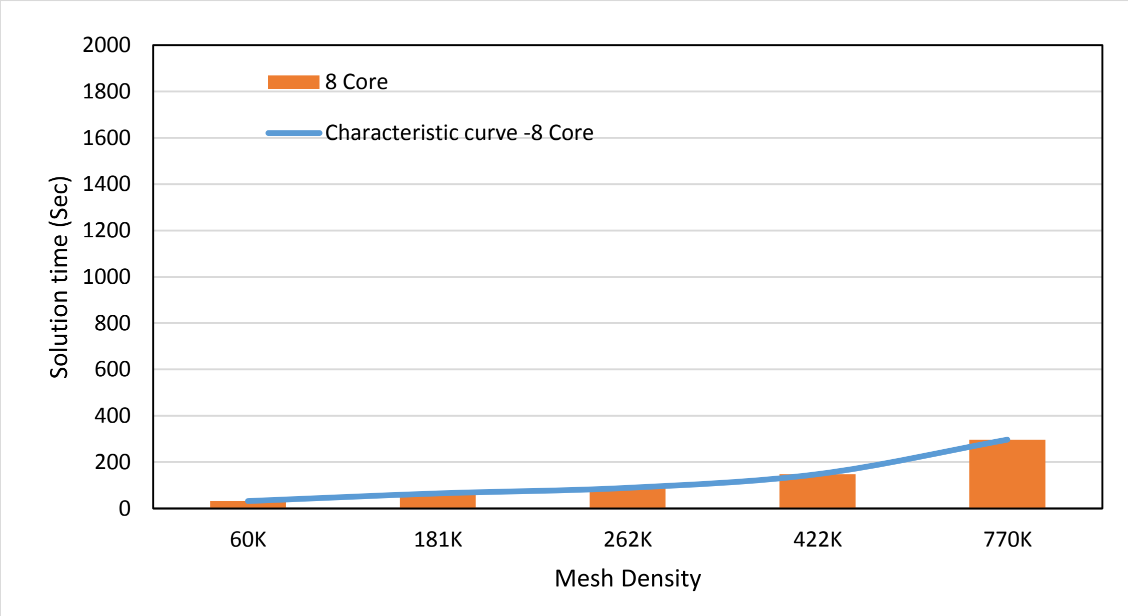

Figure 4: Solution time required for different mesh density using 8 CPU Core

EFFORT INVESTED

End user/Team Expert: 10 hours for simulation setup, technical support, reporting and overall management of the project.

UberCloud support: 1 hours for monitoring & administration of the performance in the host server.

Resources: ~600 core hours were used for performing various iterations in the simulation experiments**.**

CHALLENGES

The project challenges faced were related to technical complexity. This involves use of appropriate mesh model and solution algorithm which will capture accurately, the flow behaviour. Hence it was necessary to perform trials with different mesh density model. The finer the mesh better is the flow behaviour captured, but higher is the simulation runtime required and hence the challenge was to perform the simulation within the stipulated timeline. Getting exposure to the azure cloud platform and using its features consumed some time as this required going through, learning and following written instructions provided in Azure.

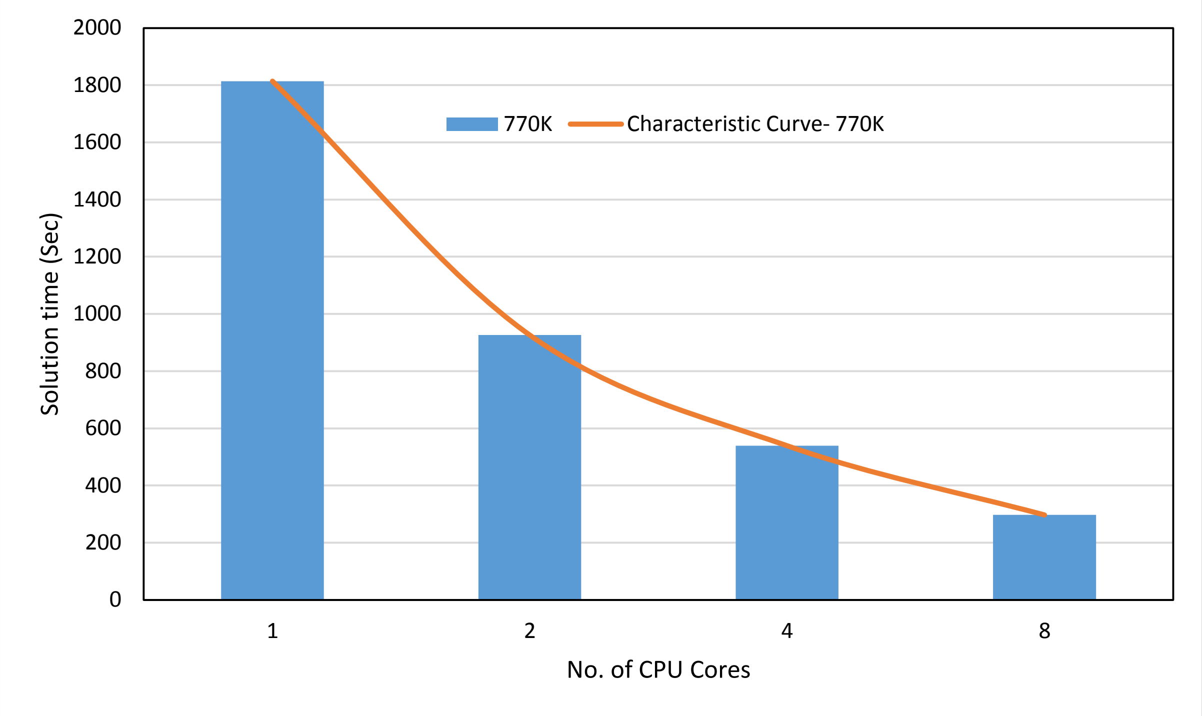

Figure 5: Solution time for a model with 770K elements solved using different HPC Core configuration

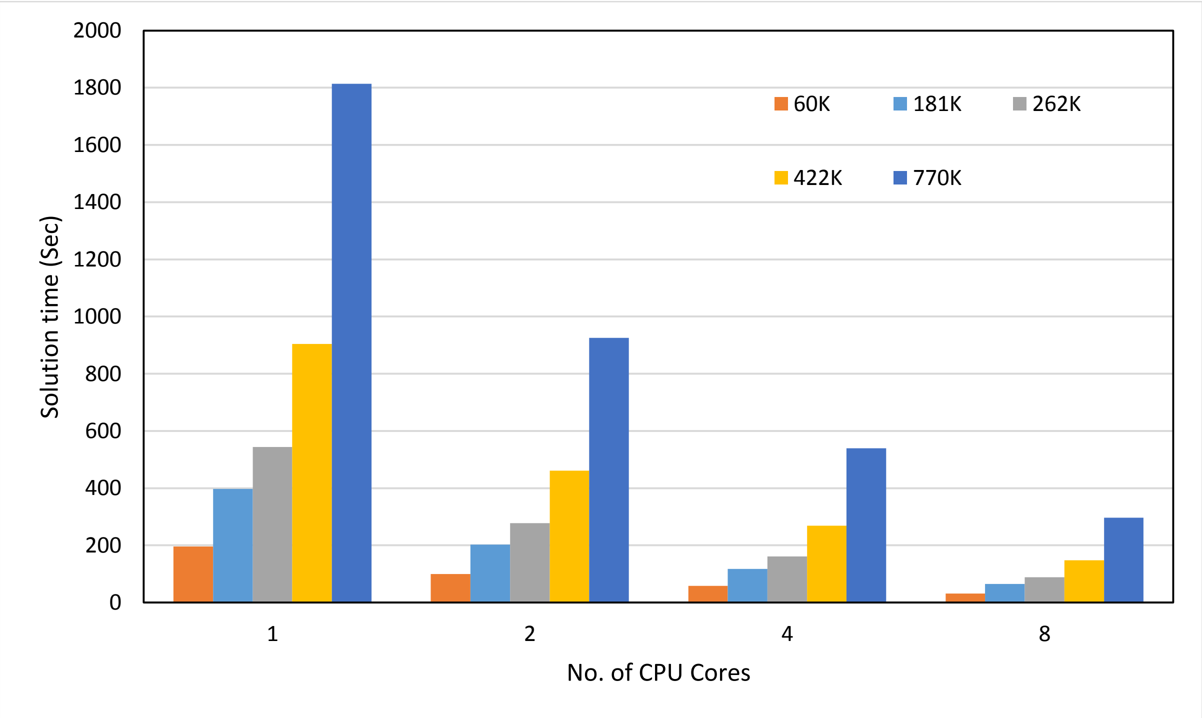

Figure 6: Comparison in solution time for different mesh densities models solved using different HPC core configuration

BENEFITS

1. The HPC cloud computing environment with ANSYS workbench & FLUENT made the process of model generation easier with process time reduced drastically along with result viewing & post-processing because of the HPC resource.
2. The mesh models were generated for different cell numbers with experiments performed for coarse – to – fine to highly fine mesh models. The HPC resource helped in achieving smooth completion of the simulation runs without re-trails or resubmission of the same simulation runs thereby helping the user to achieve highly accurate simulation results.
3. The computation requirement for fine meshes (~770K cells) is high, which is near to impossible to achieve on a normal workstation. The HPC cloud provided the feasibility to solve highly fine mesh models and the simulation time drastically reduced thereby providing an advantage of getting the simulation results within acceptable run time (~5 min).
4. The experiments performed in the HPC Cloud environment showed the possibility and provided extra confidence to setup and run the simulations remotely in the cloud. The different simulation setup tools required were pre-installed in the HPC container and this enabled the user to access the tools without any prior installations.
5. With the use of VNC Controls in the Web browser, The HPC Cloud access was very easy with minimal or no installation of any pre-requisite software. The whole user experience was similar to accessing a website through the browser.
6. The UberCloud containers helped with smooth execution with easy access to the server resources. UberCloud environment integrated with the Microsoft Azure platform proved to be powerful as it facilitates running parallel UberCloud containers, with a dashboard in the Azure environment which helped in viewing the system performance and usage.

CONCLUSION & RECOMMENDATIONS

1. Microsoft Azure with UberCloud HPC resources was a very good fit for performing advanced computational experiments that involve high technical challenges with complex geometries and cannot be solved on a normal workstation.
2. The combination of Microsoft Azure, HPC Cloud resources, UberCloud Containers, and ANSYS Workbench with FLUENT helped in speeding up the simulation trials and also completed the project within the stipulated time frame.

Case Study Author – Praveen Bhat, Technology Consultant, INDIA

Thank you for your interest in the free and voluntary UberCloud Experiment.

If you, as an end-user, would like to participate in this Experiment to explore hands-on the end-to-end process of on-demand Technical Computing as a Service, in the Cloud, for your business then please register at: http://www.theubercloud.com/hpc-experiment/

If you, as a service provider, are interested in promoting your services on the UberCloud Marketplace then please send us a message at https://www.theubercloud.com/help/

1st Compendium of case studies, 2013: https://www.theubercloud.com/ubercloud-compendium-2013/
2nd Compendium of case studies 2014: https://www.theubercloud.com/ubercloud-compendium-2014/
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HPCwire Readers Choice Award 2013: http://www.hpcwire.com/off-the-wire/ubercloud-receives-top-honors-2013-hpcwire-readers-choice-awards/
HPCwire Readers Choice Award 2014: https://www.theubercloud.com/ubercloud-receives-top-honors-2014-hpcwire-readers-choice-award/

In any case, if you wish to be informed about the latest developments in technical computing in the cloud, then please register at http://www.theubercloud.com/. It's free.