

Major Project Questions

Project Title: Tumble-Flow Development Through Port Geometry Optimisation and the Influence of Turbulence on GDI Engines Efficiency and Emissions.

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Question 1

Were there any substantial issues that Covid-19 played in the completion of your project? If not what aspects of the project had taken longer than planned and why?

Question 1 Response (maximum 200 words)

Yes, as mentioned in the conclusion, the CNC machined prototype which has been manufacture few days prior workshop shutdown, was planned to be bench flowed to measure mass flow rate of the optimised model. This would have been further validated the CFD results related to the minimum decrease of mass flow reduction (2.3%) between the base and optimised cylinder-head.

Within the project development planning there were multiple phases, which have been critically discussed in the methodology section. The last phase of the project (CFD Analyses) took longer time than the other once, because I have faced multiple learning challenges including:

- The utilisation of ICE-Ansys software.
- Understanding the physics of turbulence model equations, and which once can be used to solve the internal-combustion flow turbulent.
- And also learning the advanced techniques of CFD-post processing for better presentation of the flow-characteristic and turbulent behaviour.

However, this didn't cause me any delay on finishing my project in the designated timeline, as I was investing many hours (12 hours a day) to speed up the learning process, and also due to the early start of my project which commenced in July-2019.

Question 2

From your methodology section, could you explain why EGR tolerance is improved owing to better burn rate due to turbulence kinetic energy (TKE) enhancement?

Question 2 Response (maximum 200 words)

To answer this question, it is vital to explain the EGR system.

When EGR valve allows some of the exhaust gases to enter the combustion chamber, it creates two zones within the cylinder, one occupied by the air/fuel mixture, and second occupier by the gas induced from EGR valve as explained by Xu et al, 2000. The authors also pointed that, the mixing of the gas and the mixture is inevitable.

Knowing that, and as described by Singh et al. 2019, during the late compression stroke, the well structure tumble motion tends to collapse producing a high turbulent intensity and consequently turbulent kinetic energy. As consequence, the EGR gas will be well destroyed due to the high TKE (Xu et al, 2000), which is what I referred to as EGR tolerance.

Another point to highlight is, due to the coherent movement of both gas and mixture, and the conservative angular momentum created by the increased tumble ratio, will cause the two zones to readjust. This indeed, will lead to a better breakup and therefore, achieving what I highlighted in the study as a better burn rate due to EGR tolerance improvement.

Xu, M., Chen, G., Daniels, C, and Dong, M. (2000) 'Numerical Study on Swirl-Type High-Dilution Stratified EGR Combustion System', *SAE International Journal*. DOI: 10.4271/2000-01-1949.

Singh, A., Poonia, S., Jalan, A., Singh, J., and Kumar, N. (2019) 'Intake and Exhaust Ports Design for Tumble and Mass Flow Rate Improvements in Gasoline Engine', *SAE International Journal*. DOI: 10.4271/2019-01-0763.

Question 3

Throughout your report you mention the term higher thermal efficiencies as an advantage in many scenarios. However, are there any limitations to heightening this efficiency and if yes what are the limitations?

Question 3 Response (maximum 200 words)

It is well known that Petrol thermal efficiency range between 20 to 35% in most conventional cars say Carney, while some other car manufacturer like Toyota lately unveiled a new petrol engine with 40% maximum thermal efficiency (Carney, 2018). Currently the most thermally efficient IC engine belong to Mercedes-AMG formula 1 team, with an efficiency of 50%. Thus, yes internal combustion engines are very limited in term of their thermal potentials and that is due to the following reason or limiting factors which were highlighted by Caton 2017 in his investigation regarding the thermodynamic limitation of ICE as followed:

- Heat losses: cylinder heat transfer was identified to be one of the greatest influences on high efficiency.
- Mechanical frictions: high mechanical friction reduces thermal efficiency, and even though frictions can be reduced to a certain extent, but they cannot be eliminated which is another limiting factor.
- burn durations and lean operation: a short burn duration is also considered to be ideal for higher ICE thermal efficiency, however, this can only be adjusted to a certain extent because hitting the limit on that factor, may as well decrease other once such as lean operation, resulting to an uncomplete burn.

Caton, J. (2017) 'Maximum efficiencies for internal combustion engines: Thermodynamic limitations', *SAGE Journals*. DOI: 10.1177/1468087417737700.

Carney, D. (2018) 'Toyota unveils more new gasoline ICEs with 40% thermal efficiency' *SAE International Journal*. 04 April. Available at: <https://www.sae.org/news/2018/04/toyota-unveils-more-new-gasoline-ices-with-40-thermal-efficiency>.

Question 4

What other features within the combustion chamber would also have an influence on your charge motion other than port design and the introduction of fuel spray dynamics for a DI system would that have had an impact on your final designs?

Question 4 Response (maximum 200 words)

Other features that would have altered the charge motion of my final design are: Piston bowl design, variable compression ratio, and variable valve timing.

Piston design: the shape of the piston bowl is paramount to the flow distribution inside the cylinder, Lippert et al, 2004, as an example, critically discussed and compared different piston shapes by means of CFD calculations, to see the difference in flow distribution and fuel-air mixture formation.

Variable compression ratio, and variable valve timing: changing the cylinder/piston displacement will change the compression ratio, and therefore, influence the flow motion inside the combustion chamber. Variable valve timing also has a great influence on the charge motion and mixture formation. Both these phenomena have been widely investigated by multiple researchers (Milovanovic et al, 2004).

Lippert, A., El Tahry, S., Huebler, M., Parrish, S., Inoue, H, and Noyori, T. (2004) 'Development and Optimization of a Small-Displacement Spark-Ignition Direct-Injection Engine – Full-Load Operation', *SAE International Journal*. DOI: 10.4271/2004-01-0034.

Milovanovic, N., Chen, R, and Turner, J. (2004) 'Influence of the Variable Valve Timing Strategy on the Control of a Homogeneous Charge Compression (HCCI) Engine', *SAE International Journal*. DOI: 10.4271/2004-01-1899.

Question 5

What further areas would you liked to have investigated if you were to expand your aims?

Question 5 Response (maximum 200 words)

The Influence of engine rpm on tumble and turbulent has been substantially investigated by various researchers, and as previously mentioned in the main report, Cameretti et al, 2017, critically investigated the effect of engine speed on the development of tumble ratio. If I were to expand my aims, I would have certainly considered engine speed as a variable parameter, instead of only studying the tumble development at 2000 rpm. However, it is hoped that future research will further investigate the optimised port-design at wide rpm range.

It is also interesting to foresee the effect of higher or lower boost pressure on tumble development and turbulent intensity, which can be altered experimentally by either ECU calibration or/and Turbocharger upgrade. Boost pressure can be simulated within a 3d CFD domain, by increasing or decreasing the intake flow pressure at the Inlet plenum.

Other area of interest if I were to expand my aims, is to complete the simulation of the remaining engine strokes (compression, power, and exhaust strokes), to investigate the influence and the development of turbulent characteristics, which were induced during the intake stroke.

Cameretti, M., Bellis, V., Romagnuolo, L., Iorio, A., and Maresca, L. (2017) '3D CFD analyses of intake duct geometry impact on tumble motion and turbulence production in SI engines', *SAE International Journal*. DOI: 10.4271/2017-01-2199