FLUID DYNAMIC OPTIMIZATION OF A FORMULA SAE ENGINE

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Introduction

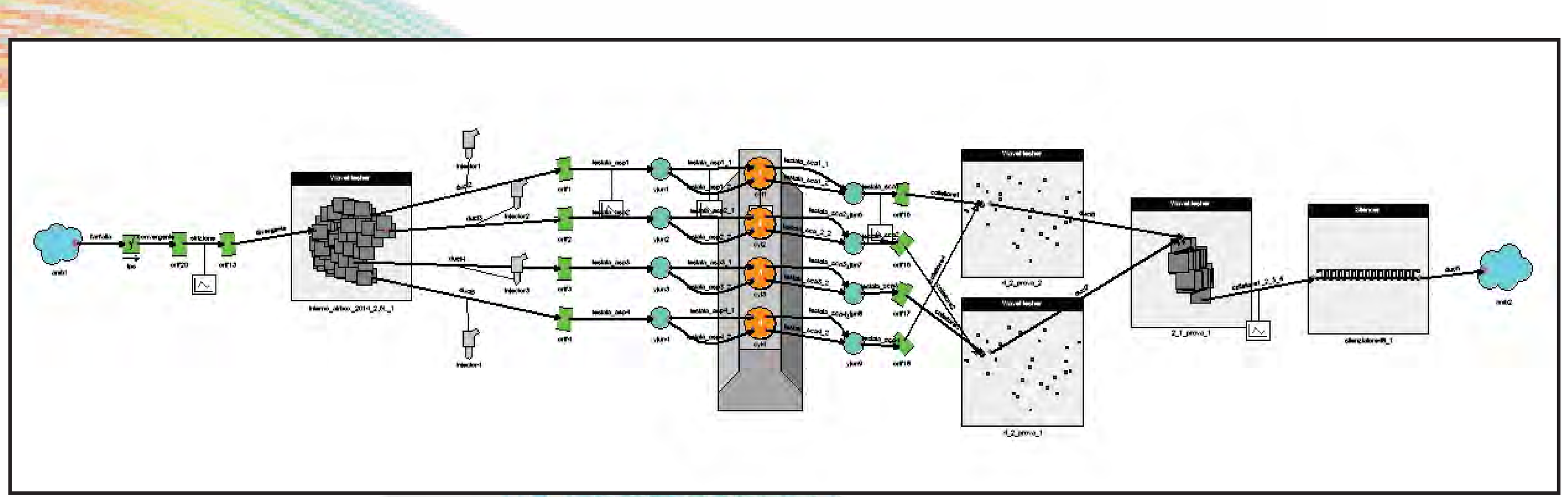
The Formula Student team of University of Padua designs every year a racing car to partecipate in many world wide competitions with other world University teams. CBR 600rr Honda 4 cylinder inline engine is adopted for the racecar.
Due to severe regulations and track necessities, the whole engine intake-exhaust system had to be changed and improved.

Targets

- Improve driveability through torque curve linearization and torque hole reduction.
- Improve performance through power curve rise at high rpm.

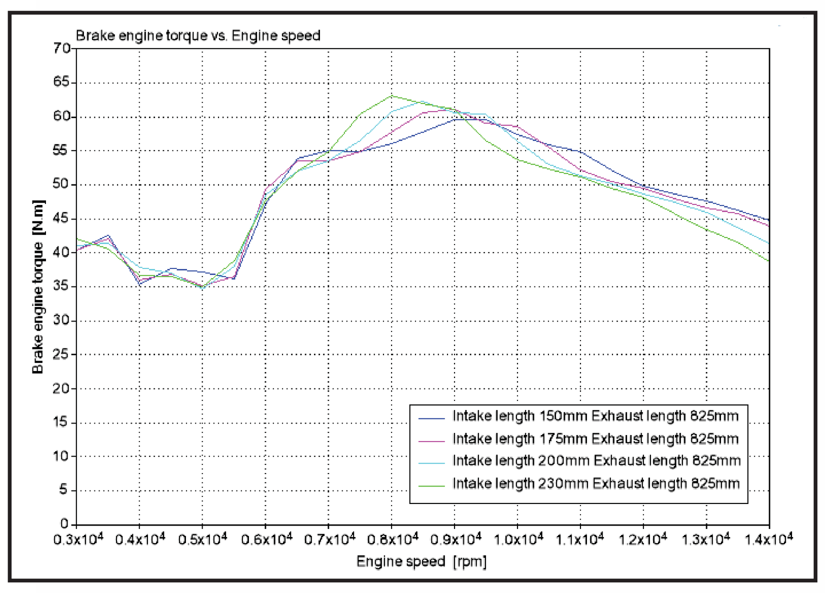
Methods

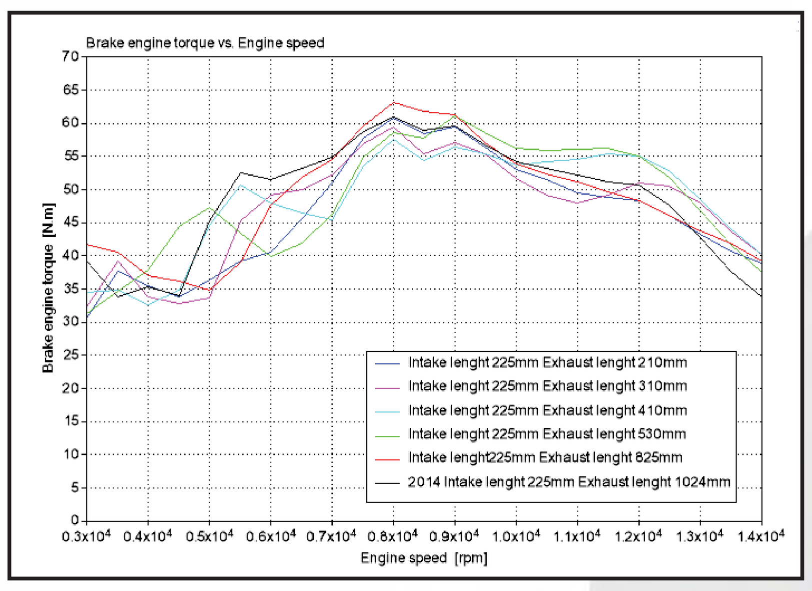
- 1-D engine gas dynamics simulations for engine performance optimization.
- 3-D CFD simulations of the intake system for pumping losses reduction.
- Matlab engine model for CFD solver transient control.
- 3-D Transient CFD simulations of the intake system for choking analysis, cylinders airflow balancing, turbulence reduction, plenum swirl and tumble control.
- Testbench and Dyno-testbench models validation and calibration.
- Track testing calibration.



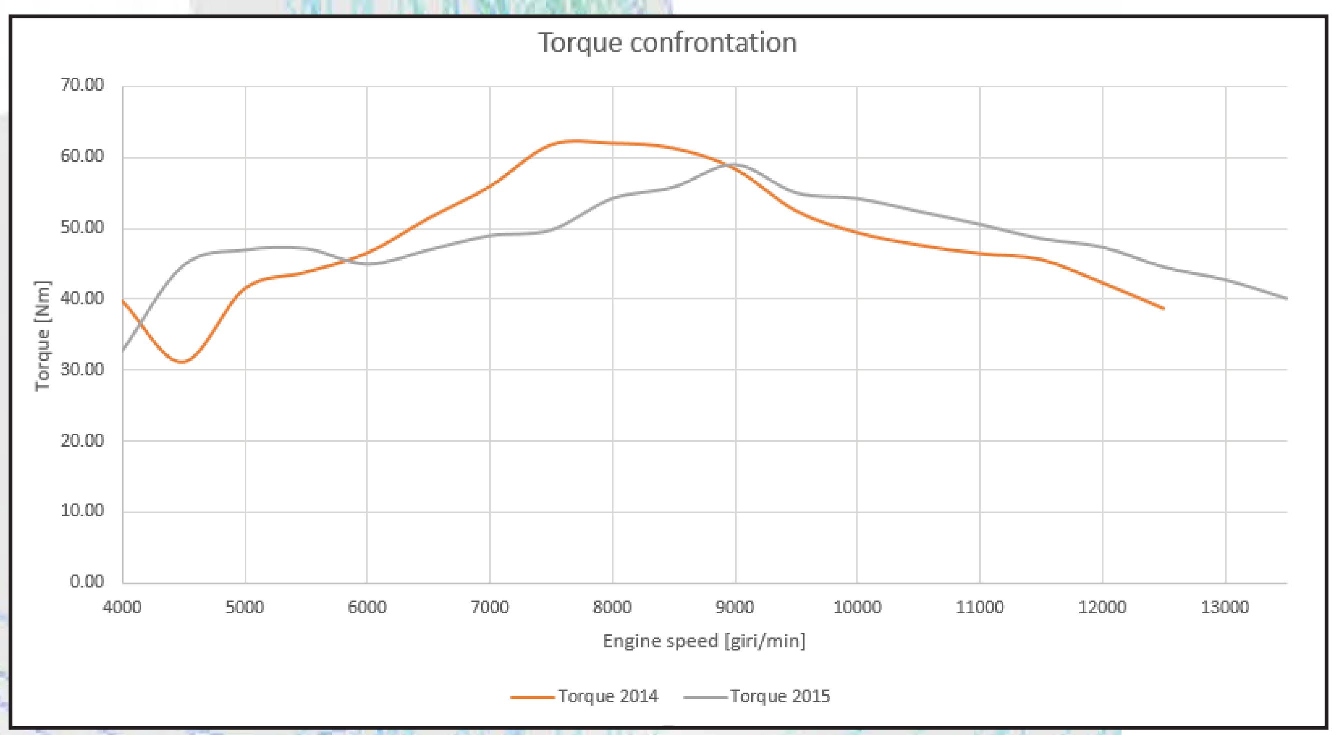
Results

Using the 1-D engine model, a sensitivity analysis of the intake and exhaust manifolds length, confluences, resonators, diameters, muffler geometries and camshaft timing was conducted.

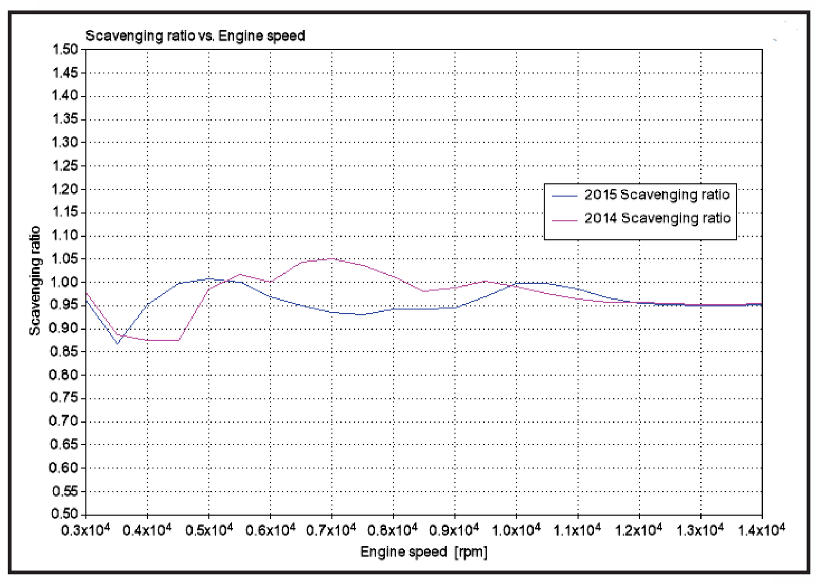


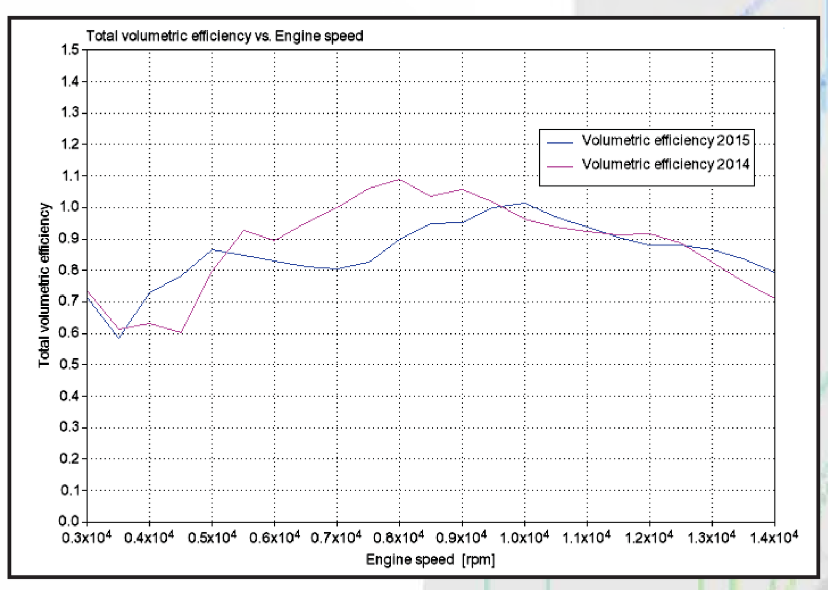


The optimization managed to linearize the torque curve and to rise power at high rpm.

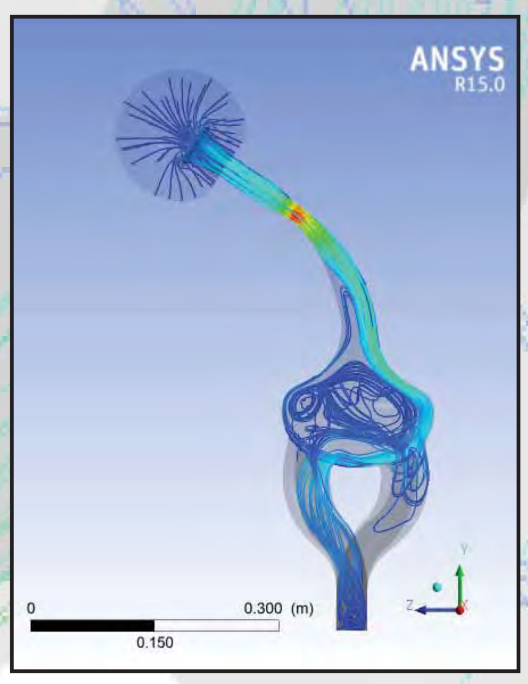


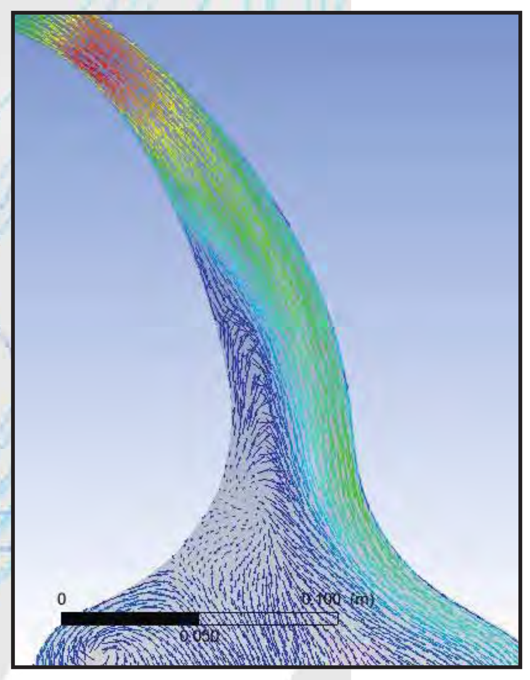
The results were used to optimize the volumetric efficiency curve using as control parameters the scavenging and trapping ratio.



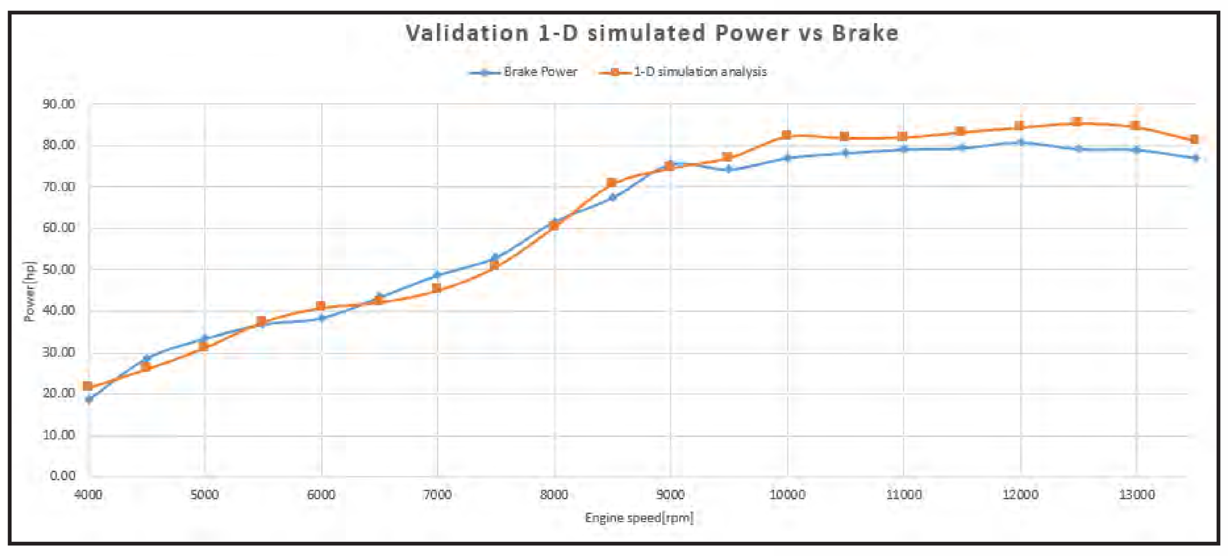


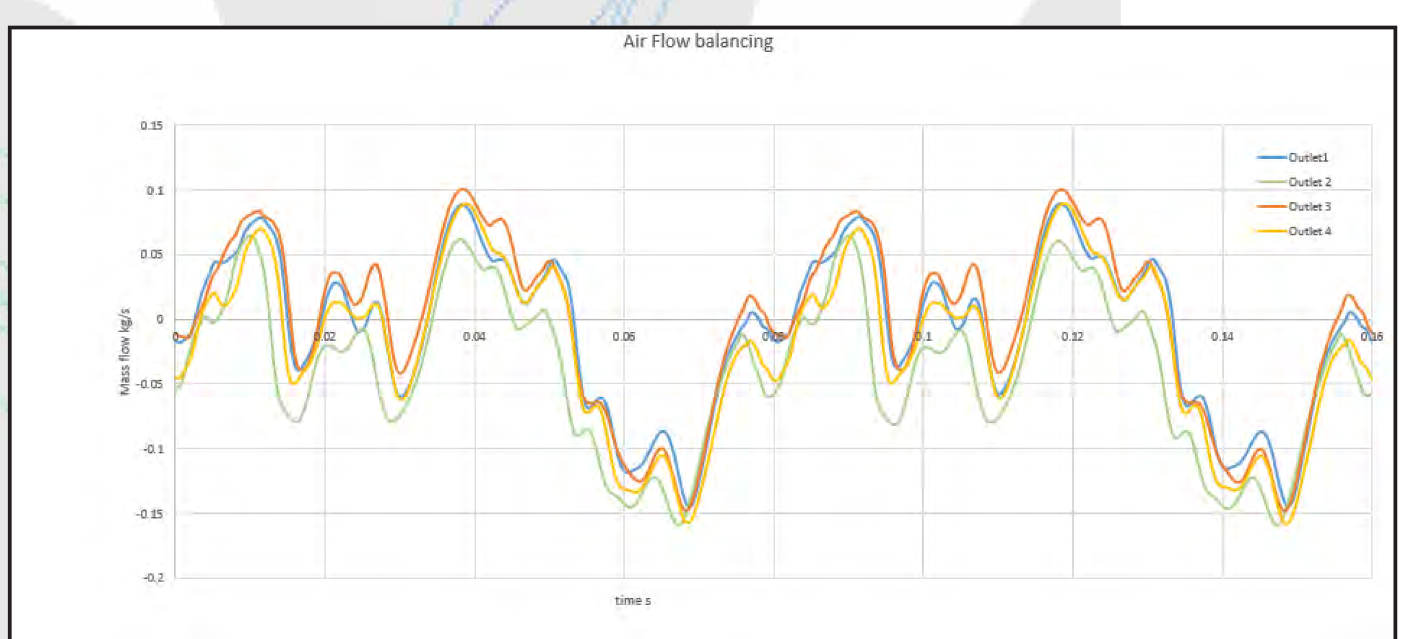
The Matlab engine model coupled with Fluent allowed us to analyse the shock supersonic wave spawned at high rpm in the restrictor body. Thus the choking engine speed was rised as the maximum power.
Trough the 3-D CFD model the pressure losses were localizated at certain location in the intake system.





The 1-D model was validated at the dyno testbench, with a mean error of 4.76% for the torque curve and 4.64% for the power curve.





Conclusions and future developments

A complete engine gas dynamic analysis and a 1-D optimization allowed to improve the engine behaviour in terms of both performance and driveability. In order to rise up the torque curve at middle rpm and rise further the power output at high engine speed, a new camshaft timing is under development