RENAULT F1 Team

Firing Order on a Formula 1 V10

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2005 WORLD CHAMPIONS

Brief presentation of our 2005 World Champion F1 Engine

V10

3 liters displacement

Naturally aspirated

4 valves per cylinder

Variable trumpets

Max Speed : 19250 RPM

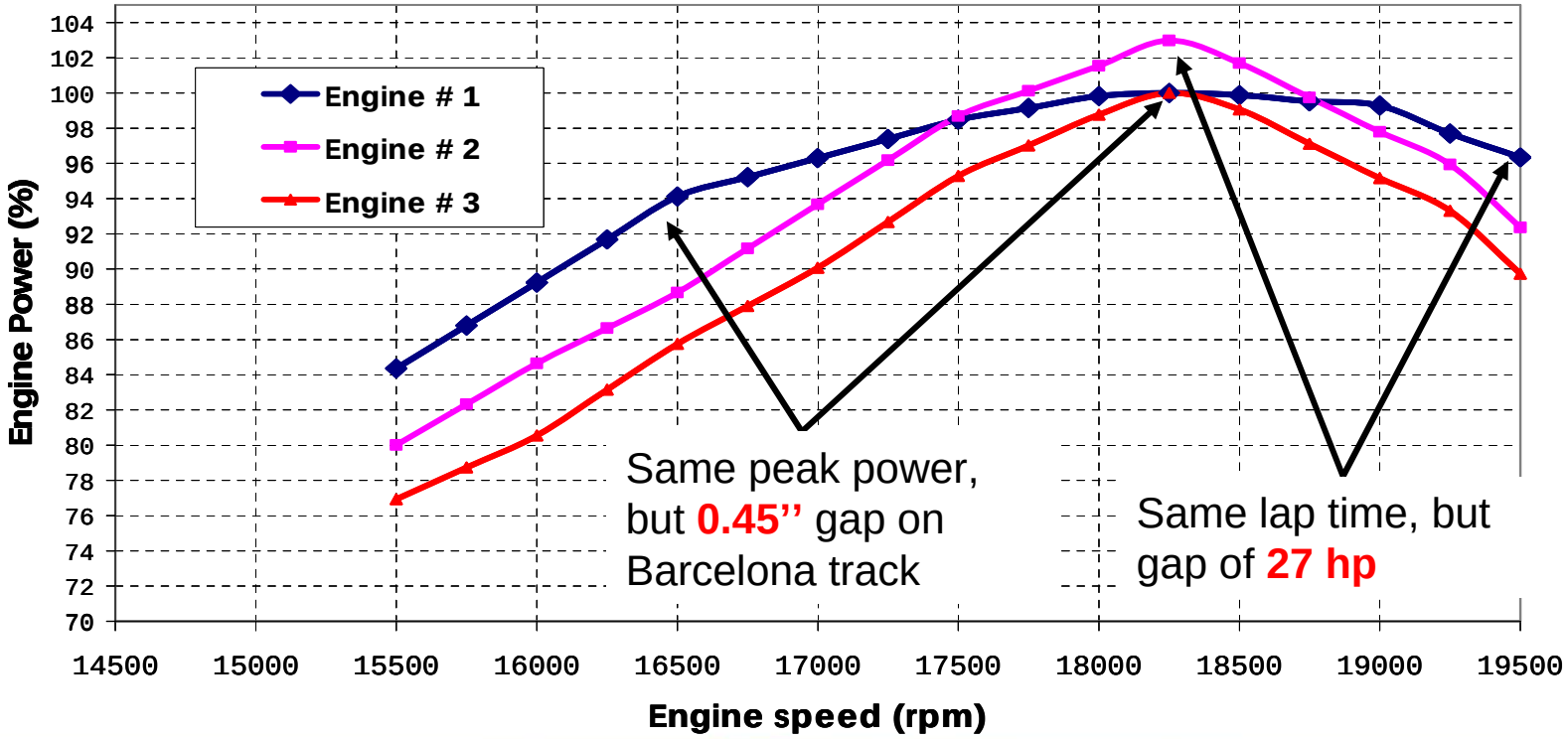
Max power : ~900 hp

Weight : ~107 kg

Engine Performance

A good engine has to help get good lap times : peak power is not sufficient, therefore we created a lap time performance index.

Lap Time - Effect of power curve shape



Role of firing order

Parameters of firing sequence :

- Crankshaft design (→sequence between each cylinder on 1 bank)
- Ve angle (→sequence between 2 cylinders on 1 Ve)
- Camshaft design (→choice between firing or scavenging TDC)

The firing order impacts :

- Reliability (dynamics)
- Performance, because of :
  - "Free" acoustic couplings between intake ports
  - Acoustic coupling between ports and plenum

Therefore, it is important to understand:

- Eigen modes of the plenum
- Excitability of these modes
- Influence of these couplings on volumetric efficiency

Simulation

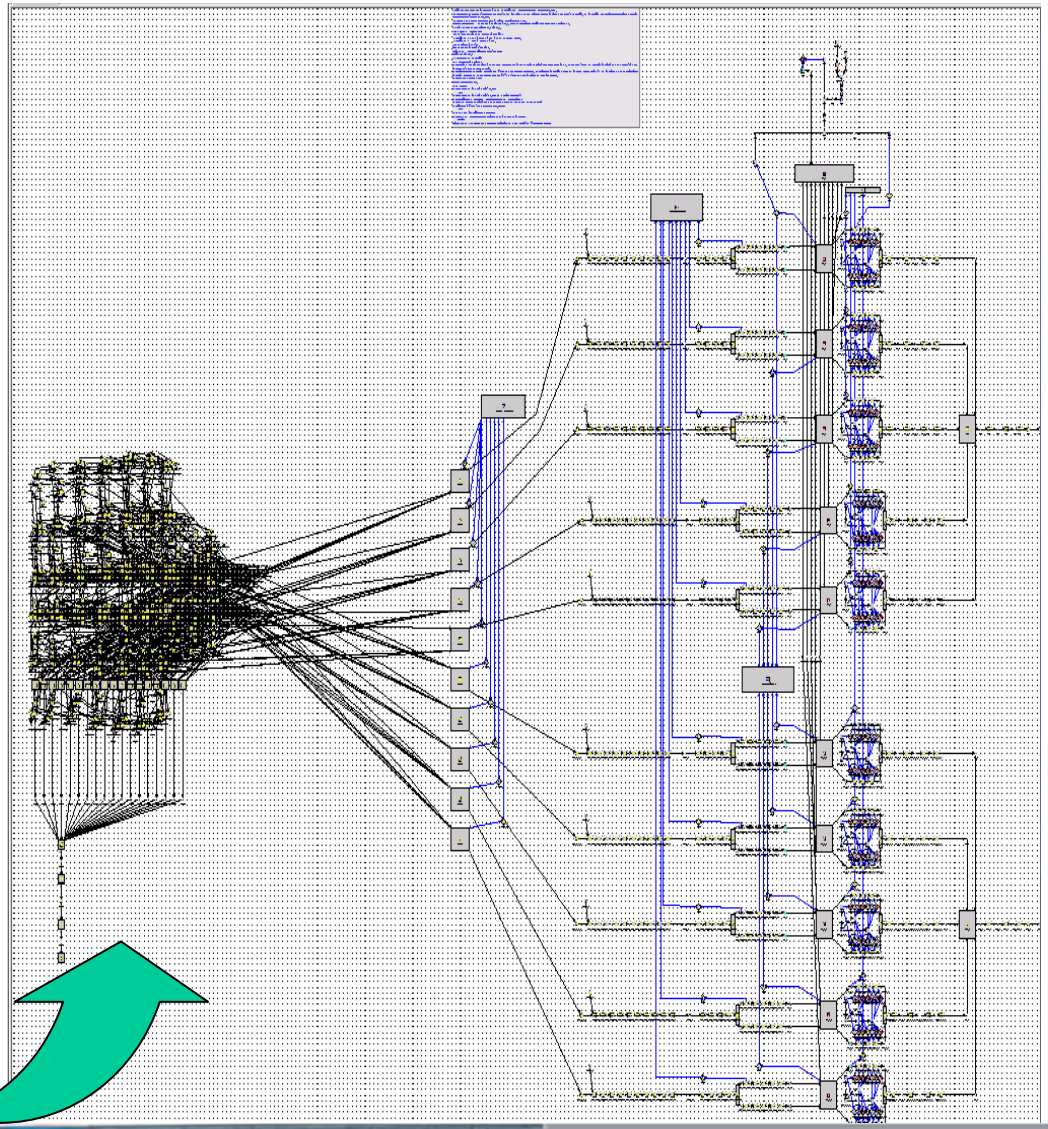
Functional specification:

- Being able to characterize firing order and plenum design on a whole performance curve within 1 day
- Reactive design : ability to guide new evolution designs from the analysis of 3D acoustic phenomenon

Simulation tools :

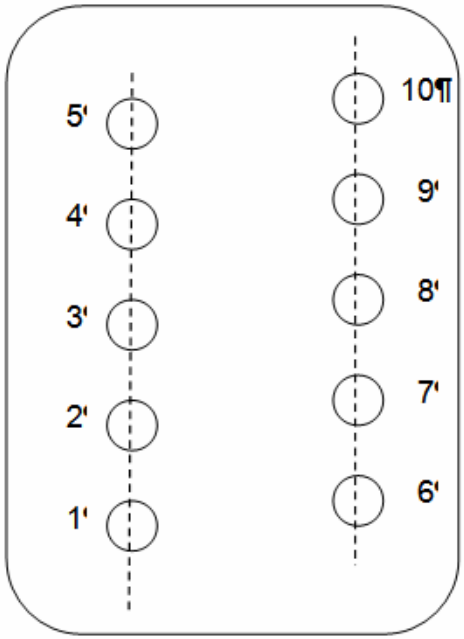
- Since 2000, we have been designing and evolving a specific software “GT-Mesh” able to translate a plenum CAD into a GT-Power model. It can also help the post-treatment with 3D visualizations and animations from the gp files.
- GT-mesh allows the building of specific meshes to be used on 3D linear acoustic softwares (Plenum Eigen modes and frequency responses) or Star-CD
- Fine analysis work with Star-CD / GT-Power coupled simulations
- Plenum design DOE and optimization using morphing tools

GT-Mesh



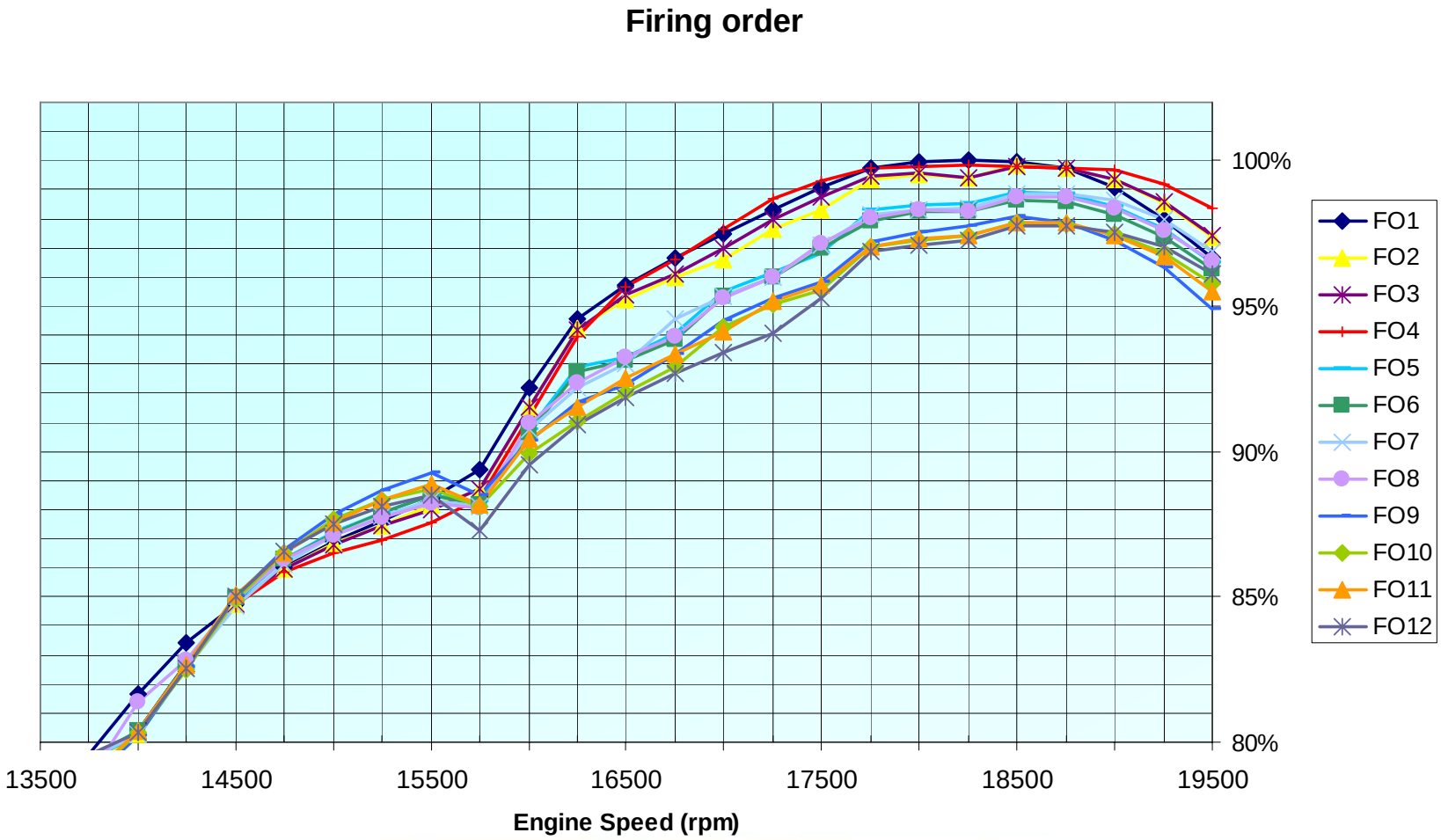
Basic firing orders

There are 24 « basic » firing orders divided into 2 symmetric groups of 12 Firing Orders:



	Firing Sequence									
Firing order	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1	7	2	9	4	10	5	8	3	6
2	1	7	2	8	3	10	5	9	4	6
3	1	7	2	10	5	9	4	8	3	6
4	1	7	2	8	3	9	4	10	5	6
5	1	7	2	10	5	8	3	9	4	6
6	1	8	3	7	2	10	5	9	4	6
7	1	7	2	9	4	8	3	10	5	6
8	1	8	3	7	2	9	4	10	5	6
9	1	8	3	10	5	7	2	9	4	6
10	1	8	3	9	4	7	2	10	5	6
11	1	9	4	7	2	8	3	10	5	6
12	1	9	4	8	3	7	2	10	5	6
13	1	8	3	10	5	9	4	7	2	6
14	1	9	4	10	5	8	3	7	2	6
15	1	8	3	9	4	10	5	7	2	6
16	1	10	5	9	4	8	3	7	2	6
17	1	9	4	8	3	10	5	7	2	6
18	1	9	4	10	5	7	2	8	3	6
19	1	10	5	8	3	9	4	7	2	6
20	1	10	5	9	4	7	2	8	3	6
21	1	9	4	7	2	10	5	8	3	6
22	1	10	5	7	2	9	4	8	3	6
23	1	10	5	8	3	7	2	9	4	6
24	1	10	5	7	2	8	3	9	4	6

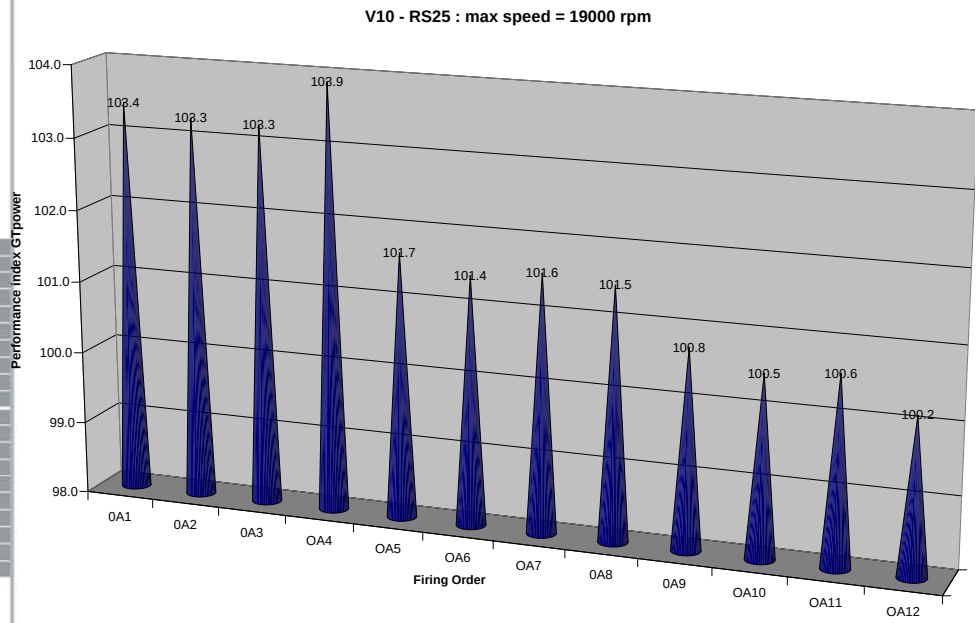
Simulated Power Curves

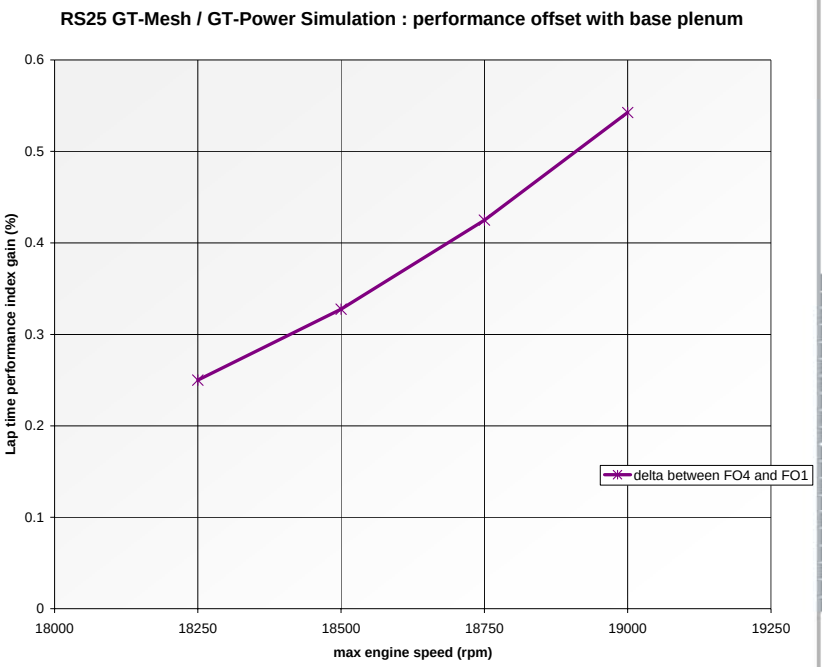


Simulated performance index

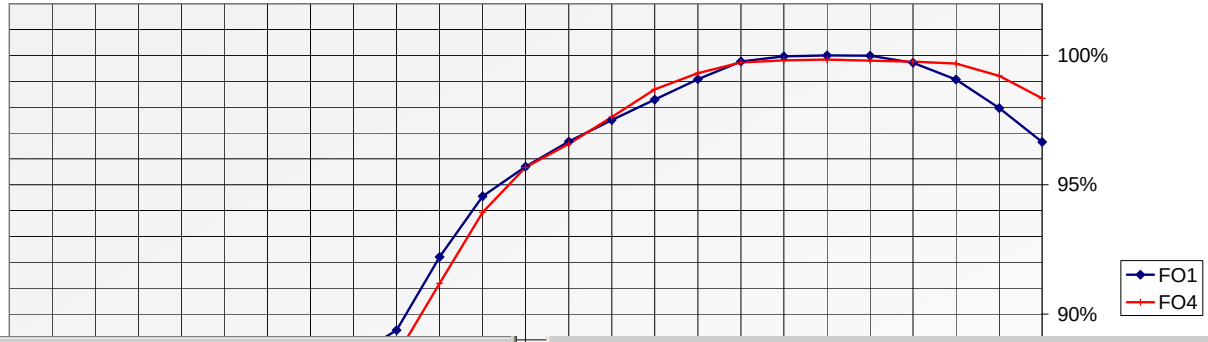
As expected from high speed power figures, lap time performance index shows 3 groups of firing orders.

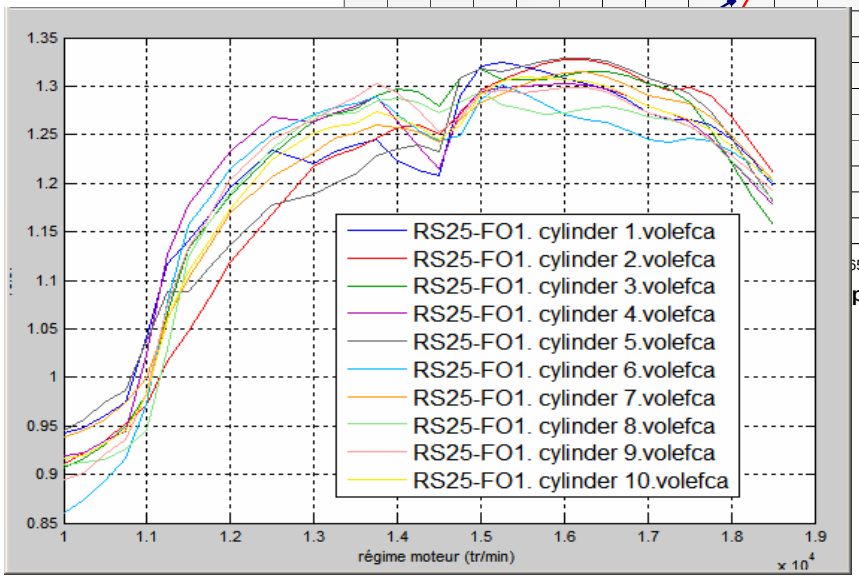
In the first group N°4 gives the best results: compared with RS24 firing order (N°1), the performance gain increases with max speed.

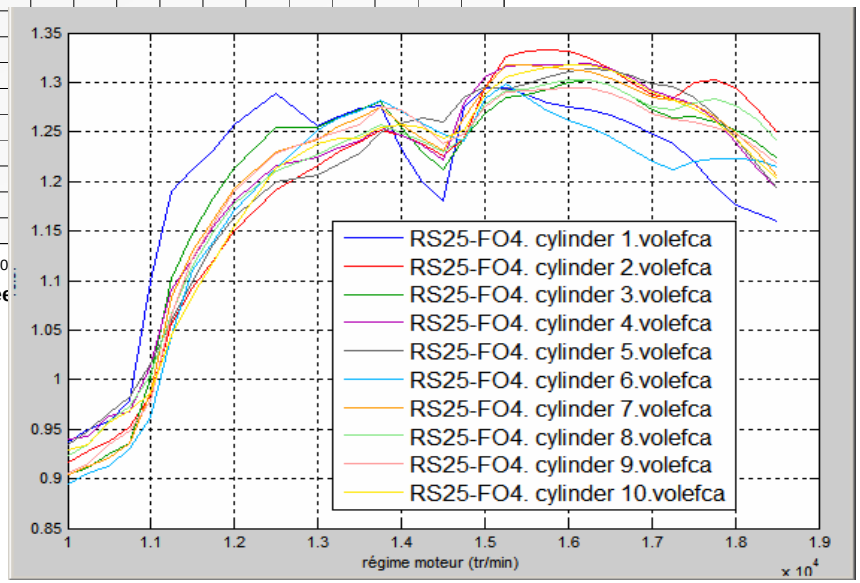




Volumetric efficiency cyl. to cyl. FO4 vs. F01



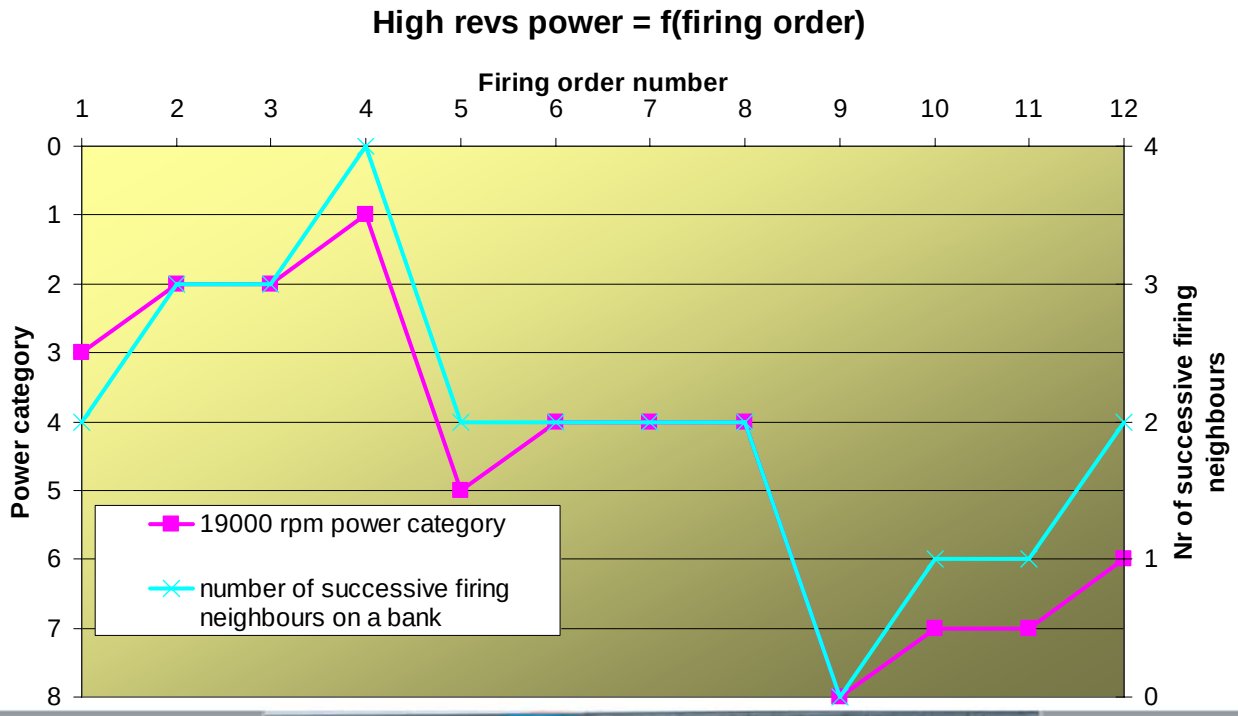




Analysis

Correlation between performance at high revs and number of consecutive firing neighbors on 1 bank (free acoustic couplings).

For example, FO9 (1-3-5-2-4) is the worst whereas the ideal one is FO4 (1-2-3-4-5).

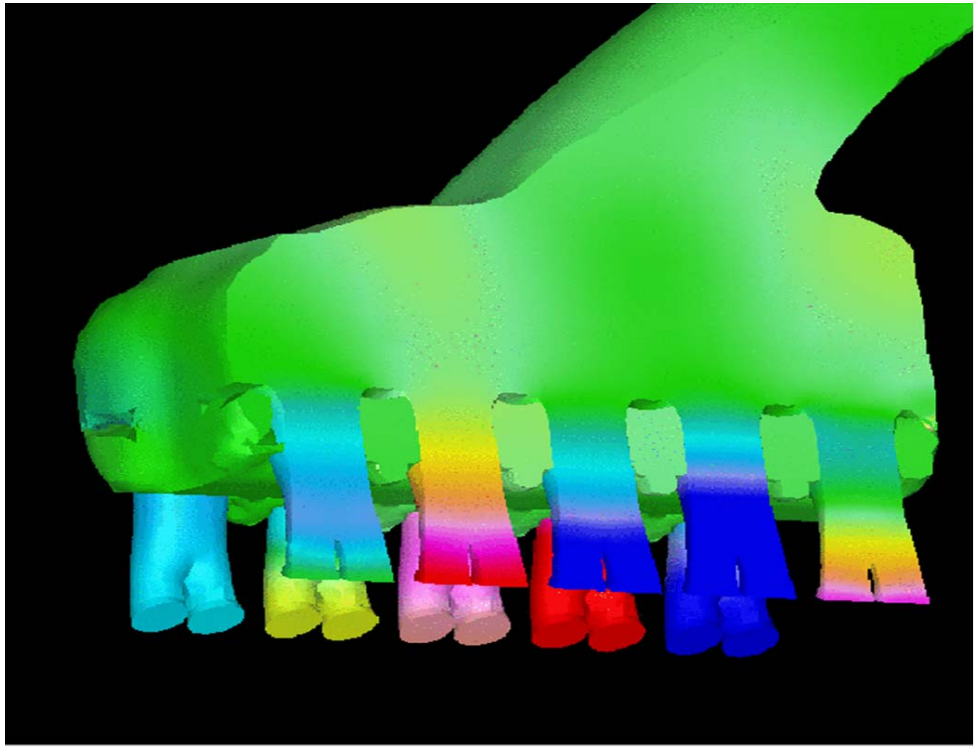


Analysis

Nevertheless, the correlation is not perfect: free acoustic couplings between ports do not explain all!

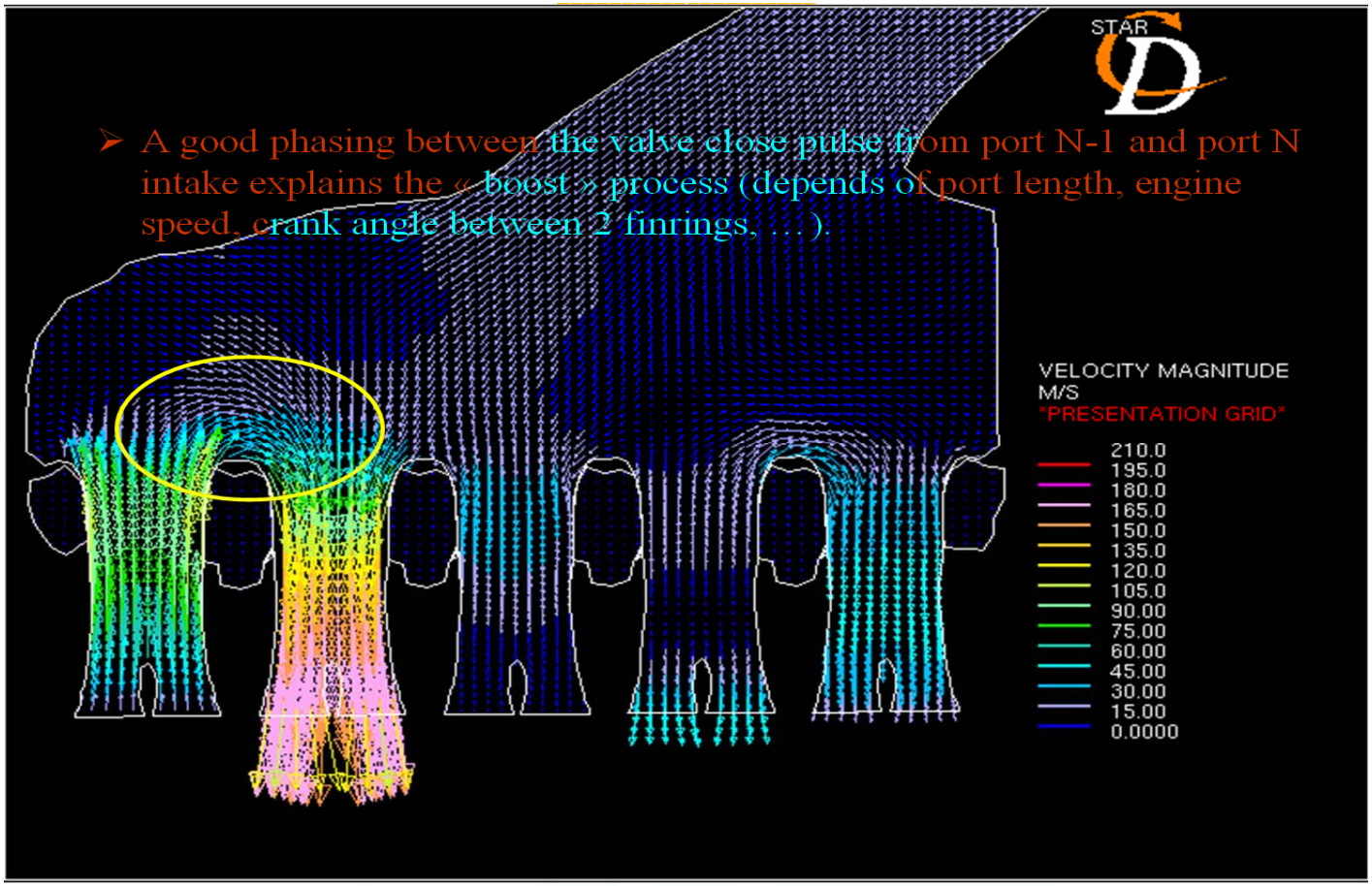
For example, firing order N°12 (1-4-3-2-5) and N°1 (1-2-4-5-3) have very different performance whereas they both have 2 consecutive firing neighbors.

This is due to other acoustic couplings between ports and plenum.



Analysis

Coupled Star-CD / GT-Power simulation allows to confirm that a port can help the volumetric efficiency of his neighbor when the later fires next



- A good phasing between the valve close pulse from port N-1 and port N intake explains the « boost » process (depends of port length, engine speed, crank angle between 2 finrings, …).

Conclusion

The simulations were confirmed on the dyno, with a good power and performance index improvement.

Therefore, despite increased external vibrations, Firing Order N°4 was adopted on the RS25, which was a little step (among many others) towards the world championship…

Thank you for your attention

Pierre-Jean Tardy

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