AUTOMATIC DRAG COEFFICIENT RANKING FOR THE EFFICIENT FAIRINGS DESIGN PROCESS OF A RACING SPORT MOTORBIKE USING OPENFOAM AND HPC CLUSTERS WITH A ZERO EURO BUDGET

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PolimiMotorcycleFactory - PMF *(http://www.polimimotorcyclefactory.it)* is an academic team of **Politecnico di Milano**, formed by 75 people, divided in 5 different department, with the objective to participate to an i**nternational university competition** called **MotoStudent** *(http://www.motostudent.com/)* in wich we partecipate for the second time.
The competition take place every **two years** and to participate every team must **design and manufacture** all the motorbike components, excluding the engine, the wheels and the braking system that are provided by the MotoStudent organization itself. As university team, we have a very limited budget, so we must look for many sponsorship in order to obtain all needed component. The limited budget and the relevant costs of every motorbike component, we decided to heavily invest on **computational simulations** to improve every aspects of our design process.

This poster regards fairing department's work where our main purpose was therefore to improve, within a time period of two years, the **external aerodynamic efficiency** by reducing the global aerodynamics-drag force of our motor bike.
We were starting from the 2016 motorbike design, defined as C0 design in the forthcoming, and for sake of zero Euro budget and time constraints we decided to adopt an **open-source based computational fluid dynamics (CFD) workflow** to rank all the designs in terms of **drag coefficient value (Cd)**.
The drag coefficient is a dimensionless parameter defined as:

$$C_d = \frac{2F}{\rho * S * v^2}$$

and is a common driving parameter for external aerodynamics efficiency measure. Our study case was a **3D flow tunnel:** 20m long, with 10m high and 10m large; the motorbike was placed at 6 meters from inlet surface; this was set in order to **reduce border effect** that could affect the results.

More in details, we worked by changing the C0 design into a rich set of new designs (thirty-six) changing the front and the rear height and length within reasonable bounds.
The front and rear shape were studied and designed seeking a reduction of the drag coefficient. In addition to the numerical data, it is possible to see the improvement in drag reduction from streamline renderings that show a decrease in turbulence and a higher speed of the contrail in the last version than the others.
The **automatic workflow**, design together with **CINECA** personnel, was implemented to efficiently take advantage of state-of-the-art high performance computing systems (**HPC**) requiring as external inputs only the new CAD design file as stereolithography format and the velocity value of interest. The drag coefficient value was monitored along the overall simulation by means of standard function objects and the convergence value was extracted at the end of each new configuration simulation together with 2D sampling planes and 3D pressure distribution on the motorbike.

All the visualization process and comparisons were then performed off-line.
In the forthcoming, we will present the results obtained for three main design milestones: **the starting design (C0), the intermediate design (CL2A2) and the end design (BM000)** showing also by means of different views the design procedure and decision making process adopted to evolve from one design to the other not only by suing the Cd value for ranking but also using meaningful fluid dynamics evaluations of the flow patterns.

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The studies have been concentred principally on 3 fundamental parts of the fairings, we also used to the **three principal views** of the model: **Front, Side, Top** to analyse in deep the fluid dynamics patterns and structure present on each selected design.

Design Analysis start-point name: C0 - 2016

C0: has a Cd of 0.535 at 50 m/s.

Design Analysis intermediate name: CL2A2 - 2017

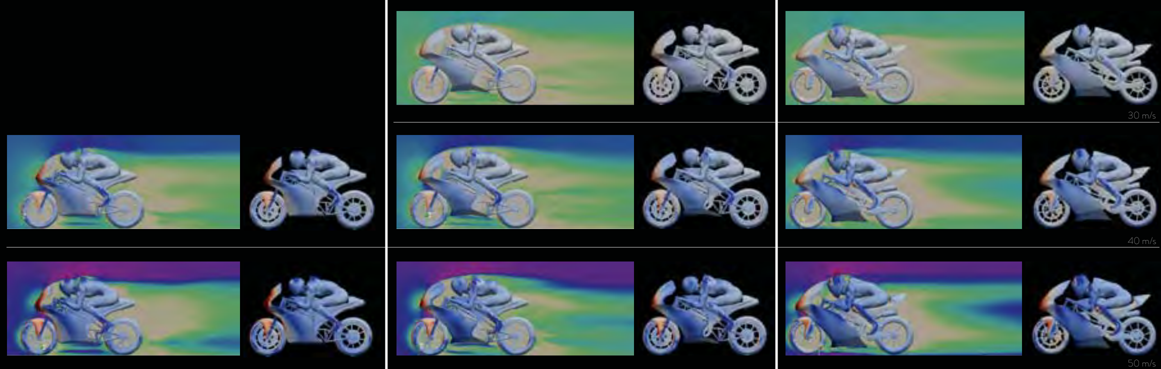
CL2A2: starting from a principle fairing shape(CL0A0) **nine combinations** of length and height were studied. CL2A2 has a Cd of 0.493 at 50 m/s, with a global average reduction of 7.37% on all 5 speeds analysed compared to the C0 design.

Design Analysis end-point name: BM000 - 2018

BM000: this model represents the initial configuration of length, height and width. From this shape we made **twenty-seven different configurations** and the initial shape provided the best results. BM000 has a Cd of 0.479 at 50 m/s, with a global average reduction of 10% on all 5 speeds compared to C0 design.

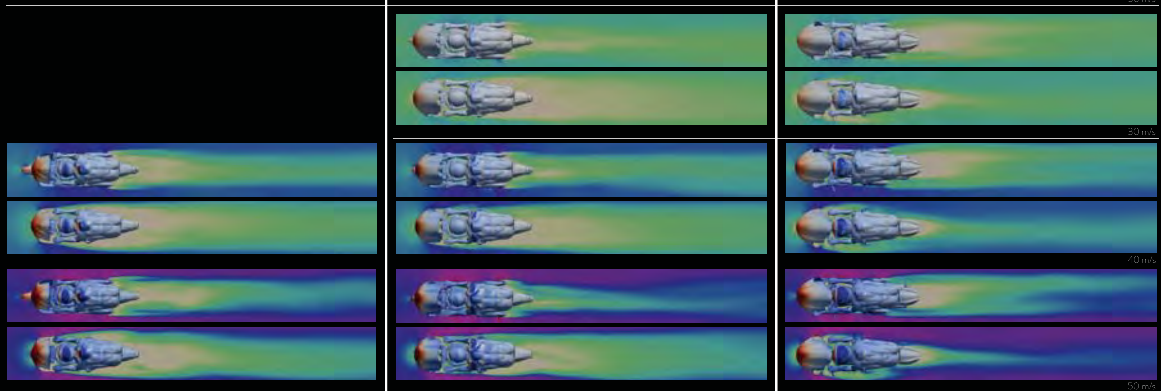
SIDE VIEW

Side view shows the **principal shape** we focused on: we tried many different configurations of length and height. We finally developed the BM000 curve passing through CL2A2. BM000 curve is longer with a lower angle than CL2A2 in order to increase flow stability and reduce turbulent dissipation after helmet impact. Appreciable improvement on this view have been done also on the tail shape that helps contrail's compacting.



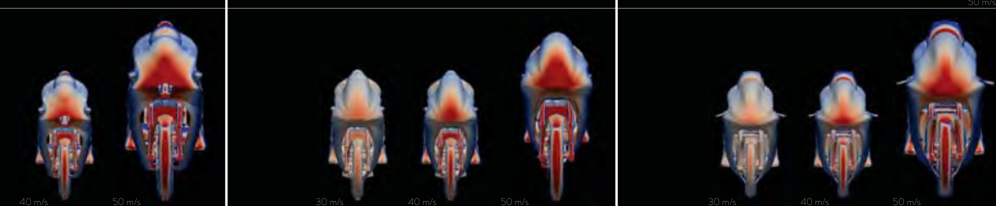
TOP VIEW

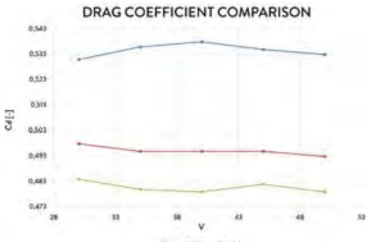
From Top view are appreciable the modify made on **lateral fairings**: in BM000 they are longer and narrower to increase flow stability.



FRONT VIEW

As is possible to see we have developed the **leading edge** with the aim of reducing the area exposed to maximum pressure. We developed a shape with this capacity and also with the ability to direct the flow away from the pilot's shoulders.





Velocity [m/s]	C0	CL2A2	BM000
30	0,531	0,498	0,484
35	0,536	0,495	0,480
40	0,538	0,495	0,479
45	0,535	0,495	0,482
50	0,533	0,493	0,479
Average	0,534	0,495	0,480

Three main designs are compared at different velocity values. The drag coefficient value averaged over all the five velocity values considered is also shown on the last line for each design.

CFD AUTOMATIC WORKFLOW DETAILS

With CINECA we develop a set of **smart utility text user interface (TUI)** commands to **semi-automate** the simulation process in order to to reduce the simulation preparation time and bypass the inner complexity of using HPC infrastructures in an efficient way. The TUI allows to enable different kind of **mesh and boundary sheets**. The standard working procedure requires just the uploading of the motorbike CAD design on the platform and setting the desired velocity parameter by calling an intuitive utility function. The utility is able to: check if there are already the desired simulation on the user database and if there return a summary of past simulations; create a mesh, set up boundary and launch simulation; return summary of already existing simulation if required.

DISCUSSION

Thanks to the achieved collaboration with CINECA, that provided us access to HPC infrastructure and co-design the automatic CFD workflow we were able to take advantage of the required computing power that highlight the beauty of the license-free computational engine (OpenFOAM- *https://openfoam.com/*).
This possibility made us able to analyse many different shape configurations every month with actually a zero euro budget since the core hours budget has been obtained by participating to standard calls for proposal (see *http://www.hpc.cineca.it/services/iscra*). As shown, for instance for CL2A2 design we studied nine different configurations of frontal length and couple angle and from data we choose the one with best results.
For BM000 we made twenty-seven different concepts, that were a combination of three different length of leading edge, three different angle of upper part and three different width.