Case study WINDFORM® FX: Racing Motorbike reed valve

TITLE:
RM application on racing engine: reed valve made by flexible Windform® FX and SLS Technology

CRP Technology is constantly active in researching and studying new solutions and materials, exploiting the laser sintering technology, aimed at RP and RM.
Let's talk about the **new project developed** (right now being in a testing and improving phase) **by CRP Technology's RP Department** in collaboration with **CRP Racing**: a **125cc bike reed valve made by the new flexible material Windform® FX and SLS technology.**

The **reed valve frame made in Windform® FX** represents a great example of an excellent union between CRP Technology's R&D Department and the applications on track carried out by CRP Racing.
The most innovative aspects about this application are the **material used** and the **results obtained,** such as a better performance of the reed valve, a better repeatability and production speed and its lower cost.

The material used is the newly created **Windform® FX**, the latest material from the Windform® family, invented by CRP Technology in 1996. Windform® FX was launched in **June 2007** and is a new generation polyamide based material, in which mechanical and repeatable characteristics make it particularly suitable for Rapid Manufacturing applications.

Application made in WINDFORM® FX and SLS Technology: a flexible ball

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Windform® FX is characterized by **exceptional resistance and resilience to repeated bending and torsion effects and by an excellent impact resistance.**
In fact, this is a material particularly suitable for the creation of RM components with a complex shape or with thin walls, but overall flexible, especially in the aerospace and motorsport areas.

Properties Windform® FX	Test Method	SI Unity	WindForm® FX
General Properties			
Density (20° C)		g/cm3	1,027
Color			WHITE
Termal Properties			
Melting Point	ASTM D 3418	°C	180,70
HDT, 1.82 Mpa	ASTM D 648	°C	47,10
Vicat 10N	ASTM D 1252	°C	186,70
Mechanical Properties			
Tensile Strength	UNI EN ISO 527-1(97) UNI EN ISO 527-2(97)	Mpa	48,96
Tensile Modulus	UNI EN ISO 527-1(97) UNI EN ISO 527-2(97)	Mpa	1357,00
Elogation at break	UNI EN ISO 527-1(97) UNI EN ISO 527-2(97)	%	43,90
Flexural Stregth	UNI EN ISO 14125 2000	Mpa	45,00
Flexural Modulus	UNI EN ISO 14125 2000	Mpa	952,20
Impact Stength - Charpy Unnotched (23°C)	UNI EN ISO 179-1 2002/1eU	KJ/m2	31,72
Impact Stength - Charpy Notched (23°C)	UNI EN ISO 179-1 2002/1eB	KJ/m2	3,25
Surface Finish			
After SLS Process		Ra µm	6
After finishing		Ra µm	2
Properties per Density Unit			
UTS per Density Unit		Mpa g/cm3	47,67
Tensile modulus per Density Unit		Mpa g/cm3	1321,32
Electrical Properties			
Resistivity, Volume	ASTM D257	ohm	$2.3x10^{14}$
Resistivity, Surface	ASTM D257	ohm cm	$0.9x10^{14}$

Notes: these are all indicative values, data was generated from the testing of parts produced with the Windform® FX materials under typical processing conditions.
STD Tolerance:
For parts up to 6" (150 mm) the standard tolerance is: +/- 0.012 inch (0.3 mm)
For parts more then 6" (150 mm) the standard tolerance is: +/- 0.002 inch per inch (0.05 mm ogni 25 mm)

Technical data Sheet Windform® FX

Thanks to these structural properties, Windform® FX was chosen to manufacture the frame of the reed valve, a component that has to be stiff and overall resistant to shocks and vibrations.

To better understand why Windform® FX was chosen for the realization of the reed valve it's necessary to give a short description of this component and its characteristics.

The Reed valves restrict flow of gases to a single direction and consist of thin flexible metal, fiberglass or carbonfiber strips fixed on one end that open and close upon changing pressures across opposite sides of the valve.

The reed valve frame is wedge-shaped; the base is completely open and is the intake side area, while on the side faces which are bigger there are windows which are the passage area on the crankcase side.

Elastic thin reeds called "blades" are applied above such windows completely covering them. These blades raise up and allow the transit of the flow (mix of air and fuel) when the difference of the pressure between the inside of the crankcase and the outside is bigger.
The dimensions and the shape of the frame and the windows determine the flow of the fuel when the blades are at maximum opening position.
Therefore the dimensions depend on the engine characteristics and the shape is studied to reduce as much as possible the fluid dynamic loss.
The blade is the component that determines the system functionality, and the valve opening and closing rule does actually depend on its characteristics.

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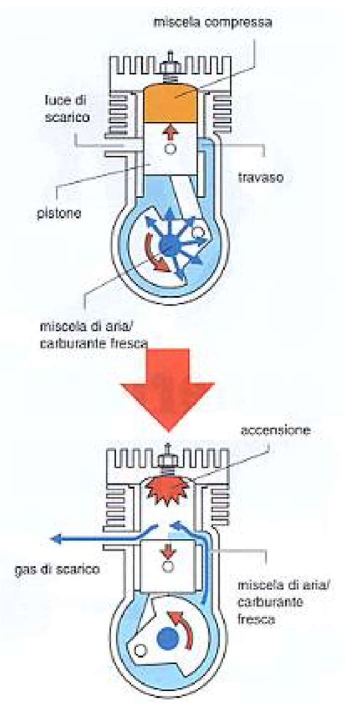
The reed valve function is to regulate the fresh gas intake in the crankcase and/or combustion chamber of a 2 stroke engine.
The reed valve is therefore a key component for the bike's performance: the fuel supply of a 2 stroke engine gives in fact the power and torque's output values.

The two-stroke cycle



1. **Compression/intake**: The air/fuel/oil mixture has entered the cylinder, and the piston begins to move up. This compresses the charge in the cylinder and draws a vacuum in the crankcase, pulling in more air, fuel, and oil from the carburetor. The compressed charge is ignited by the spark plug, and the cycle begins again.

2. **Power/exhaust**: This stroke occurs immediately after the ignition of the charge. The piston is forced down. After a certain point, the top of the piston passes the exhaust port, and most of the pressurized exhaust gases escape. As the piston continues down, it compresses the air/fuel/oil mixture in the crankcase. Once the top of the piston passes the transfer port, the compressed charge enters the cylinder from the crankcase and any remaining exhaust is forced out.

Without a valve, the gas would exit from the intake manifold and there wouldn't be enough pressure to allow the combustion chamber wash. This explains the importance of the continuous opening and closing of the reeds during each cycle: in this way, if a two-stroke racing engine reaches **14,000 rpm**, **the reeds will do more or less 230 oscillations per second**.

Compared to the rotary valves distribution and to the piston port, the reed valve distribution allows versatility for the engine set up; it also allows asymmetrical engine phases compared to the top dead point of the engine. Meanwhile an inconvenience is that the reed valve distribution doesn't allow high rotation revs and the expressed performances are slightly lower compared to a rotary valve distribution. On the other side, talking about low and medium revs, the reed valve is more advantageous.

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The reed valve critical issues

The main stresses to be faced usually are the **big vibrations** (at every rpm the carbon reed valve blades hit the reed valve wall) and **the fuel transit**.
The most critical problems to keep in mind during the design of the parts are therefore the **breaking problems** due to the **big depression** that has to be faced, combined to the **vibrations** caused by the repeated hit of the carbon reed blades against the reed valve walls.
The **manufacturing material of the reeds** is important because they have to face a big stress besides having a range of different stiffness' values. Therefore, their thickness, and consequently their stiffness, determines high differences in the valve behaviour.

In the past, aluminium with a rubber coating was used to manufacture the reed valve.
With this technology there were no particular limits for the performance of the reed valve (without diffuser) but the cost of a typical production for motorsport (not mass production) was really high. At the same time, the delivery times and the lack of "freedom" of design and customization were absolutely unsuitable for the sports applications. Moreover, the inserts (diffusers) were developed and manually manufactured, with many repeatability issues and without any scientific base: they were made through plastering and further manual manufacturing (hand crafted).

For all these reasons, **CRP Racing, in collaboration with CRP Technology's R&D and RP Department has chosen to test new and different solutions to obtain a scientific method and an exact repeatability** after having found, as the result of experimental testing, the best configuration to guarantee the best functionality of the components, actually <u>a balance between flexibility and stiffness</u>.

Two solutions were considered and created. In both cases we started from the component engineering and CAD study.

<u>The first solution</u>

The first solution was to manufacture the **reed valve with its own diffuser made from the Windform® FX material, in one piece.**

The aim was to obtain more stiffness of the whole system.

This solution allowed the **creation of an extremely compact "group" (Frame + Diffuser), and also to optimize the aerodynamic air flows through the frame and the diffuser**, which were then integrated in a single object.

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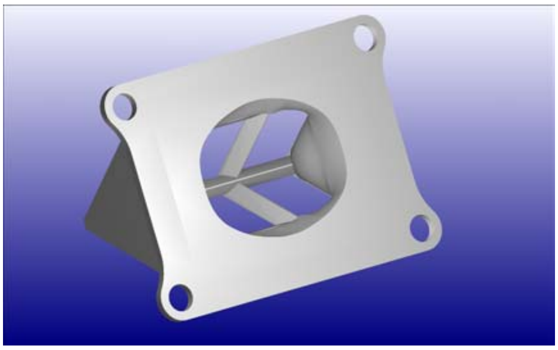
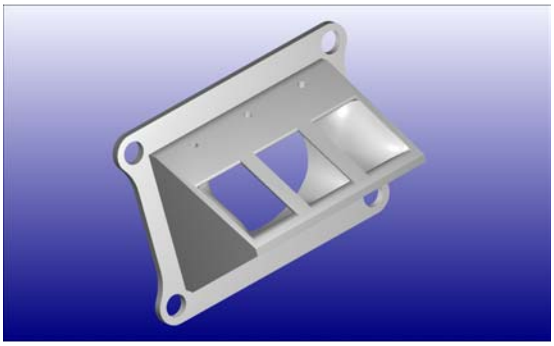


Back side of the reed valve



Front side of the reed valve

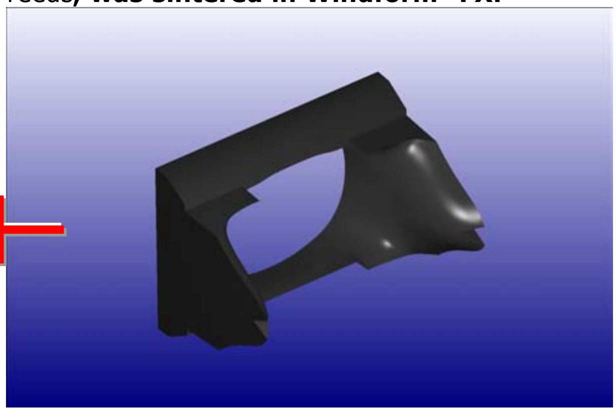
<u>The second solution</u>

The second solution concerned the creation of the **reed valve (see picture below) in two parts, the frame and the diffuser, using two different materials:**

- **The diffuser was sintered using Windform® XT, carbon fibre filled.**

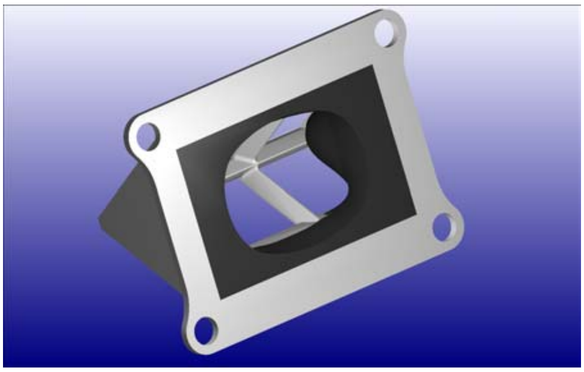
- **The frame**, that had to be resistant to the hits of the reeds**, was sintered in Windform® FX.**

Frame in Windform® FX



Diffuser in Windform® XT, carbon filled

The whole reed valve



This solution guaranteed a good versatility during the development phase and allows better set up of the reed valves.
It allowed us to:

- change some properties of the engine, manufacturing <u>several kinds of diffusers</u>, each of these

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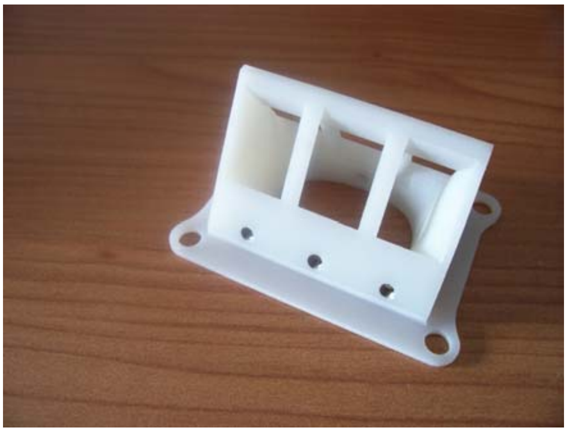
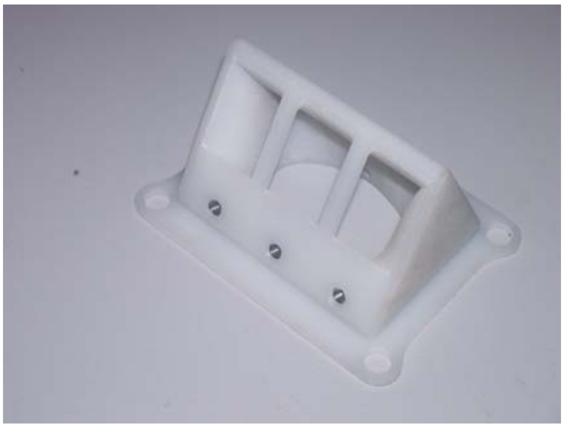
exchangeable on the same frame. They can be easily substituted during a test on track or on the dyno, without having to move the reeds from a frame to the other. In this way, the test results are perfectly comparable and allow to validate the best geometry for the diffuser. The substitution of only the diffuser brings direct advantages also from an economical point of view, allowing some cost-saving.

- fully exploit the elasticity of Windform® FX for the frame, where the blades violently "hit" at a very high frequency.



CRP Reed valve – front side

CRP Reed valve – back side



The initial results of the dyno tests, in spite of the early difficulties which are usually encountered with every development project**, showed a good development margin and in the future further tests will be useful to improve and develop this project**, that surely will open a new path in the study of the two-stroke engine supply.

The potential is huge and the aim is to reach the following goal: **the reed valves we have produced were made to reach at least the same performance obtained with the traditional valves and that's why these are similar to a sample part realized in aluminium.**
It is then possible to study **many new ideas** about reed valves, without having any shape limits thanks to the new manufacturing technology and with a great repeatability of the component but at a lowest cost, **therefore improving the standard performance and the engine power**.