CRP Motorsport Case study

New ULTRARapid Casting and Windform® PS: the TRUE RAPID MANUFACTURING Technology

INTRODUCTION

CRP Technology

CRP has been instrumental in the success of many winning racing teams. From F1, to MotoGP, World Rally Championship, American Le Mans Series and Rally Raid CRP offers a high level of support throughout the entire project, including the manufacturing process.
What makes this company different are the partnerships they have formed with the different teams. CRP is involved at the earliest design and development stages and their innovative approach to the use of new materials and technology is widely recognised by the race car industry.
CRP Technology is therefore considered a unique service point for several different technologies and engineering activities:

- HQ & HSM CNC (high speed and high quality machining with 3, 4 and 5 axis)
- Rapid Casting (lost wax casting with RP patterns) in Titanium, Aluminium, Steel alloys or Superalloys
- New ULTRArapid Casting
- Rapid Manufacturing and Rapid Prototyping services
- Rapid Manufacturing & Rapid Prototyping composite materials production and sales
- R&D: continuous research on materials like metallic alloys, plastic materials and new manufacturing processes development
- Reverse Engineering

R&D Development

CRP is again a pioneer in hi-tech casting.
CRP is in fact still the only one in the world able to deliver such high quality Titanium Rapid Cast parts. The same technology was then developed for special steel alloys and aluminium alloys as well, allowing exceptional reliability, fatigue resistance, lightness and high mechanical performance.

Today they have moreover developed a casting procedure that allows to deliver a full dense and free-shape casting within 2 WEEKS. The technology has been developed by the CRP R&D Staff, starting from the CRP's rapid casting process, shortening the procedures and improving the quality.

The quality of the parts is incredibly close to a CNC machined part, but with the ISOTROPY BY COMPENSATION typical of casting structure. It is therefore possible to speak of "really near net shape" technology!
Moreover, comparing it to all the direct metal sintering technologies available nowadays, all their compromises and limits are finally over passed:

- Less dimensional limits (less volume limits)
- No quality limits or problems (NO deformations, porosity, holes…)
- No shape limits, no supports, complete geometrical freedom, like only in selective laser sintering of PA powders

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- Really lower cost

It is optimized for Aluminium alloys, whilst everybody knows the difficulty to cast or direct sinter Aluminium alloys.

Sidebar

Titanium Rapid Casting and Windform® PS

The CRP R&D department is involved in the Rapid Casting technology since 1997.

In 1998, CRP began to optimize the engineering process and the manufacturing process, studying titanium rapid casting, which is based on the combination of rapid prototyping (RP) technology, to manufacture the disposable pattern, and investment casting technology (lost wax casting) with titanium alloys.

The casting structure is formed of an aggregate of grains or polyhedral crystallites which produce isotropy compensation, while in a solid metal they are anisotropic: it is obvious that isotropy has great advantages, for instance, FEM calculations are very close to the real behaviour of the part.

The RP pattern is made by selective laser sintering technology, through a consecutive overlapping of layers. The system doesn't require any support because the piece is held up by the non-sintered powders, therefore giving complete freedom of shape: thus reducing undercut and tool path problems during CNC machining and perfect optimization of the project to the working conditions.

It's therefore possible to create the product along its mechanical stress axes, and to obtain a perfect reproduction of all details of the RP pattern, with tolerances and surface finishing of a very high quality (such as fully machined parts).

Rapid Casting procedure is composed of various steps:

- A disposable pattern is made through RP technique and Windform® PS
- The pattern undergoes wax infiltrations (immersion and capillarity) to increase its strength (to avoid handling breaks);
- The pattern is immersed in a ceramic bath:
- Slurries and stuccoing and exsiccation;
- The lost pattern is evacuated: dewaxing with flash firing or in an autoclave and subsequent sintering of the ceramic shell
- Alloy casting with inductor or voltaic arc;
- pouring, cooling, reduction of the shell, shot peening, gate cutting, heat treatments

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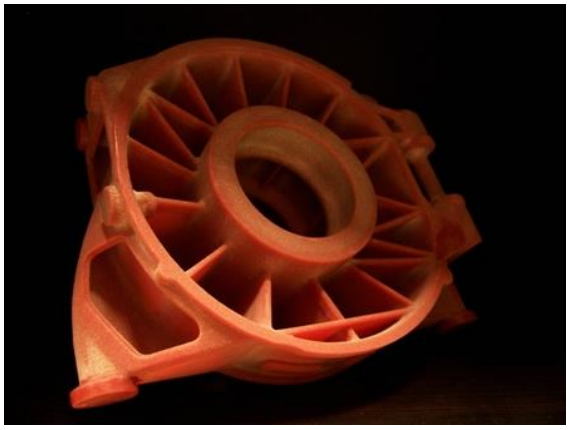

Picture 1: Disposable pattern: laser sintering and red wax infiltration

The Ti-6Al6V is the most widely used alloy in motorsport and aerospace markets, particularly the one used by CRP. It contains 6% aluminium and 4% vanadium, an excellent combination of stress resistance and toughness, with optimal wear resistance.

Positive aspects of Ti-6Al4V are:

- lightness (density 4,43 g/cm3)
- high specific Ultimate Tensile Strength (225,73 MPa/(g/cm3)) (UTS 1000 Mpa)
- bio-compatibility
- low thermal and electrical conductivity
- corrosion and stress-corrosion resistance (SCC)

Advantages given by heat treatment of the casting are:

- stress reduction
- ductility
- workability
- dimensional and structural stability

Titanium casting has a really high reactivity and that's the reason why it needs in addition:

- Chemical milling, to remove the alpha case created when the metal touches the ceramic shell;
- HIP: Hot Isostatic Pressure applied in an inert atmosphere (argon) to eliminate micro-porosity and shortage of material inside the casting;
- TIG Weld repair in inert atmosphere to fill in porosity or HIP hollows, tested with real time RX inspections;
- Shot peening: under-control shot peening to reduce stress and increase fatigue resistance.

This technology was immediately highly appreciated by customers: it provided durability and reliability of the part (a casting is naturally isotropic for compensation), fewer design limitation to lightener (pockets) and get stiffer (adding ribs) the part during the racing season.

CRP decided to continue to improve the Rapid Casting process because they know what their customers need: at 300kmh quality isn't optional, it's your life.

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In 1997, CRP began to study laser sintering technology to manufacture disposable patterns, using Polycarbonate and Trueform materials; these materials were not suitable for titanium alloys' pouring, however they seemed to be perfect for steel and aluminium alloys.
This led to CRP and DTM creating a new material (Castform) developed for Titanium alloys casting. CRP's goal was to use rapid casting for very high-performance parts—primarily for F1 with very complicated shapes and geometries—and using the best alloy available for the casting procedure: Ti-6Al4V.
For many years CRP utilized Castform®, from DTM Corp. for the sintered disposable patterns.
In an effort to solve issues CRP R&D department built on the knowledge and experience in rapid prototyping, casting, and machining to become experts in the Rapid Casting process. This work has led to CRP being recognized as a leader in the use of Rapid Casting for motorsport applications throughout the world. These efforts have now yielded a breakthrough in this arena.

Today the result is Windform® PS.

Windform® PS is a new polystyrene based material, suited to produce complex investment casting patterns. The sintered patterns are enough porous in order to allow the convenient wax infiltration, and therefore becoming easy to handle and to finish.
Improved properties, compared to other polystyrene materials already available on the market, and that make the difference, are:

- Improved surface quality and details reproduction
- Less "curling" effect on the first layers
- Very low ash content, therefore perfect suitable for highly reactive alloys, such as Titanium alloys too, besides aluminium, magnesium, steel and nichel base alloys.

It's particular suited for the foundry and RP market since the main applications are:

- Complex investment casting patterns
- Casting with highly reactive alloys, in addition to typical cast alloys.

The application: 125cc 2 STROKES ENGINE CYLINDER

CRP Racing, the young new racing division of CRP Technology, born last December 2006, has been having one sole goal during the last 10 months: the Honda 2 strokes 125cc engine development.

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Picture 2: Riccardo Moretti in action

Its first goal was in fact to bring its innovative way of working into a very conservative world: the Motorcycling Racing World. With this new department, CRP Technology wanted to create an independent and dedicated R&D facility, whose real goal is to reach as soon as possible all international racing areas, even if now it is focused on two wheels only.
The competitive spirit of this new reality started with the 2007 Road Racing Italian Championship (CIV). The bikes have been tested and set up on the CIV tracks first and on RS 125GP Honda Trophy tracks later, with two Honda RS 125GP bikes.
Today there are 2 bikes, one for the CIV and one for the Honda Trophy. The main goal was and still is to develop an higher performance engine.

Picture 3: Riccardo Moretti won the Honda Trophy RS 125GP in 2007

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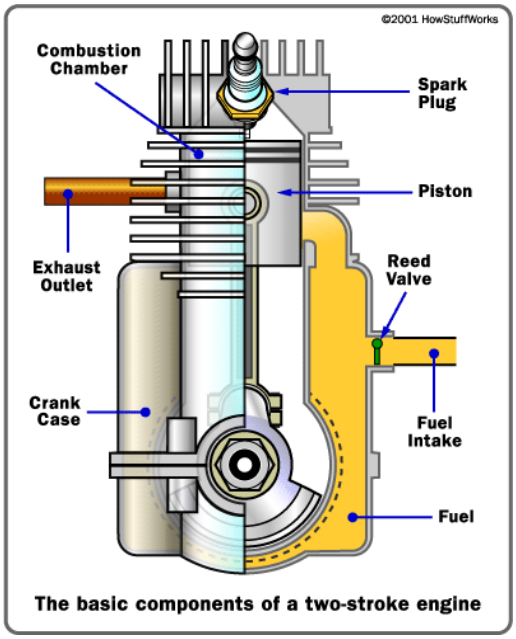
What was the last great step forward that CRP R&D Dept suggested to CRP Racing?
The new ULTRArapid casting technology to manufacture the last cylinder evolution together with the new Windform® PS, polystyrene based material, suited to produce complex investment casting patterns.

REQUIRED PERFORMANCE



Picture 4: The basic components of a two-stroke engine

The engine cylinder runs always at high temperatures with some short transients at even 600°C!
Being a 2 strokes engine running at 14000 rpm, it stands 14000 ignitions each minute. Just to make a comparison, a F1 4 stroke engine running at 19000 rpm (max rpms) stands 9500 ignitions each minute: it means that the 2 stroke cylinder has to face so many ignitions as a F1 4 stroke engine running at 28000 rpm, that's impossible!

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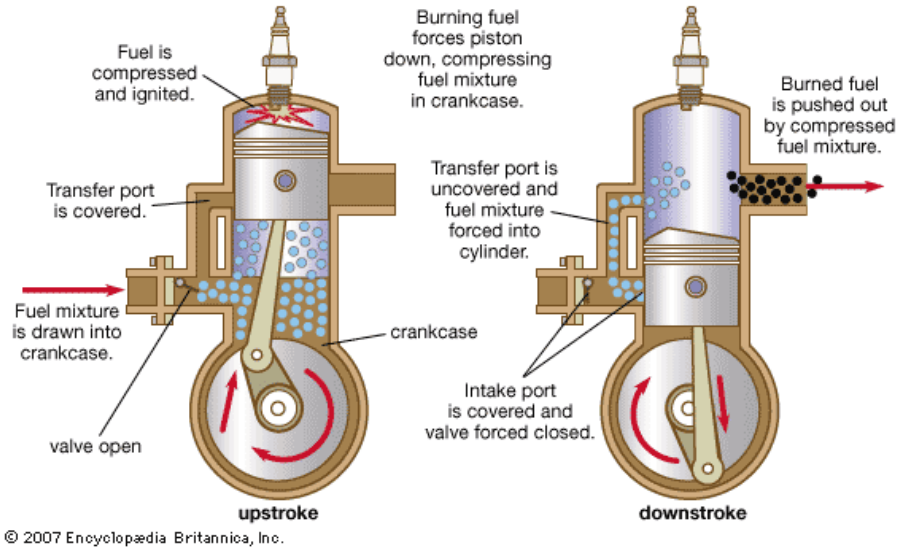
HOW TO OBTAIN IT



Picture 5: The performances of a two-stroke engine

Performance of a 2 strokes engine is mainly due to the 5 intake ports and the exhaust port that are integrated inside the cylinder. Their geometry is therefore the main reason for the engine power release, and it's not possible to CNC machine them, besides the last portion of the exhaust port, due to their very complex shape and undercuts, that give an impossible and unreachable tool path. It means that their shape and surface definition are the rough casting ones and they can't be finished or adjusted by CNC milling.
Following this, it's quite clear the importance of a perfect casting, where the shape and geometry have to be perfect and the inside surface definition has to be as smooth as possible.

Picture 6: Cylinder shape and geometry

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Moreover the exhaust valve that CRP Racing defined as the best is located in a pocket inside the cylinder that can not be reached even by hand, so impossible to machine of course.
The standard manufacturing procedure is the sand casting and it is possible to obtain very good results with the right feeding study and the right tools. By the way, this technology doesn't fit the racing world needs. Tools are expensive and need a long time to be manufactured. The process has therefore too high costs and first of all too long delivery times.
CRP Racing is studying a new engine and needs a continuous updating of the drawing and of course of the cylinder casting as well. With the ULTRArapid casting technology and Windform® PS they have been able to test and validate 7 different drawings and castings in only 10 months. It's not possible even to imagine the waste of money and the waste of time of the same production with sand casting process.

Picture 7: The new ULTRArapid casting aluminum engine cylinder

The process has therefore no limits from Rapid Manufacturing point of view. Of course there's no comparison to sand casting when the request is a very large manufacturing lot. When the design is definitive and therefore the tools can be used for many castings, if the scheduled time allows it, the cost of the tools is spread on the production lot and the sand casting becomes more convenient.

INFLUENCE OF THE ANALYSED PART ON THE PROJECT

The motorbike performance is based mainly on the engine performance. Aerodynamics are almost useless, since the rider is never completely behind the firing and each movement thereby changes the aerodynamic shape of the bike.
The engine performance is based on the cylinder performance and therefore on the ports as above described.

THE PROCEDURE

The ULTRArapid casting is an evolution on the rapid casting process that was already developed by CRP Technology.

There are several common steps between the 2 processes:

- A disposable pattern is made through RP technique and Windform® PS

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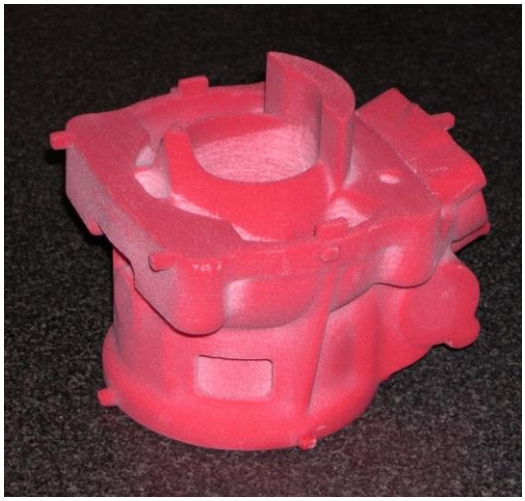
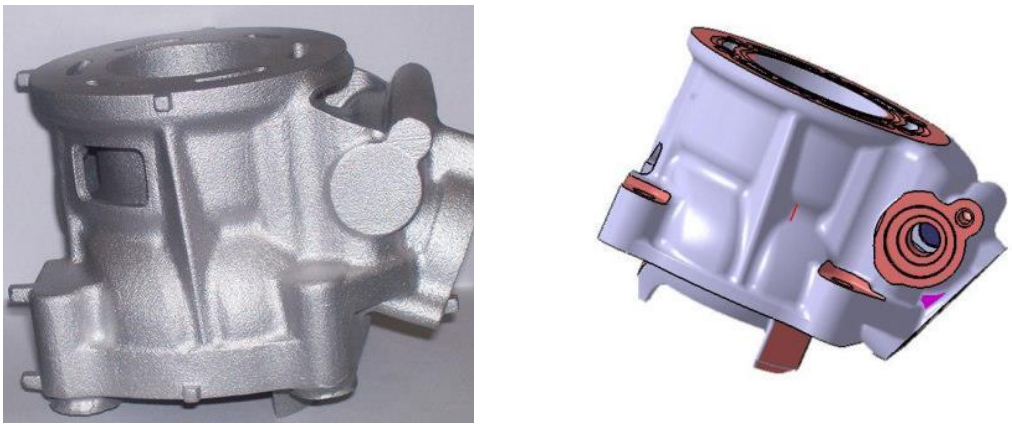


Picture 8: A disposable pattern of the cylinder is made through RP techniques and the new Windform® PS.

- The pattern undergoes wax infiltrations (immersion and capillarity) to increase its strength (to avoid handling breaks)
- The pattern is immersed in a plaster-like bath
- The lost pattern is evacuated: dewaxing inside a oven
- Alloy casting in a low-pressure environment
- Pouring, cooling, reduction of the mould, gate cutting
- When needed: shot peening, heat treatments

The process has been optimized for Aluminium special alloys so far but the CRP's R&D staff is already working on other alloys.



Picture 9: The new ULTRArapid casting aluminum engine cylinder

The real novelty is that being a low-pressure casting the melted alloy flows in the mould really smoothly and there are no bubbles or porosity inside the casting at the end. The structure is therefore perfectly isotropic for compensation and full dense with a brilliant details' reproduction.
There is almost no need for any weld repair.

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As a consequence, this new technology has all rapid casting positive characteristics, but it's much quicker and precise.

Again, from a comparison between the direct metal sintering technology and the ultra rapid casting, the sintering compromises and limits are finally over passed:

- Less dimensional limits (less volume limits)
- No quality limits or problems (NO deformations, porosity, holes…)
- No shape limits, no supports, complete geometrical freedom, like only in selective laser sintering of PA powders
- Really lower cost

Of course the real secret to have such a great casting is to have a great disposable pattern, so that the mould created by the pattern can be almost perfect and give a perfect near net-shape part.

Windform® PS new polystyrene-based material is perfect to produce complex investment casting patterns. The sintered patterns are porous in order to allow wax infiltration, making them easy to handle and finish.
Compared to other polystyrene materials available on the market, Windform® has:

- Improved surface quality and details reproduction
- Less "curling" effect on the first layers
- Very low ash content suitable for highly reactive alloys, such as Titanium, aluminium, magnesium, steel and nickel-based alloys.

Finally CRP machines the component and fully inspect it, supplying a "turnkey" part ready to be used.
What do you need more to speak of true rapid manufacturing?

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