The commercial break-through for Rheocasting.

Background/Summary

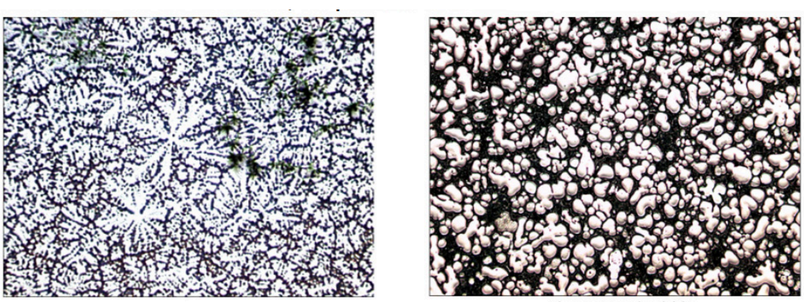
Since professor Flemings discovery of Thixotropy in 1971 semi solid casting has never really left the laboratories or technology provisioning offices around the world, until now.

The tipping point is EV´s and 5G telecom systems. 90% of all discussions, RFQ´s are based on the designers seeking for higher functionality to create low cost designs with lesser weight, higher strength, better thermal conductivity or leak free components.

Drawbacks have changed from lack of material properties data towards engineering capacity and to few suppliers that can offer the process, a problem already identified on the market and yet a concern to solve.

What is Rheocasting and semi solid casting?

Rheocasting is a member of the semi solid family of processes. The term semi solid means that the molten metal is transferred into a state where a portion of the melt is in solid phase. With a mixture of solid and liquid the phenomena of thixotropy occurs meaning that the faster we shear the melt the lesser force we need, se picture below.



HPDC: Dendritic
shear strength of about
200 kPa at fs=40%

Slurry: Non-dendritic
shear strength of about
0.2 kPa at fs=40%

Picture: The difference in microstructure between HPDC and semi solid melt structure

There are a number of different processes on the market today and they all have their benefit and could be hard to distinguish from each other. Two factors can be used to see the difference: solid fraction, quality of slurry (homogenius) and process cost. The explanations of these factors are:

- *Solid fraction, must be over a certain value to obtain a laminar flow*
- *Quality of slurry means oxide size and distribution and homogeneity of the slurry*
- *Process cost, is based on a low investment and a fast slurry preparation*

Semi solid casting and Rheocasting should be considered as melt preparation processes and not as a new process as they are to 80% similar to high pressure die casting (HPDC).

Why is the commercial break through happens now, after 40 years?

The amount of trials, R&D efforts and other development projects over the years has not resulted in any massive capacity build up and the most relevant question is Why? The answers to the why questions are:

Semi solids has been expensive and not given the quality needed

The speed of launching new systems has been to high. Time for proper R&D efforts and industrializations has not been present why many promising processes failed because of expensive solutions and low-quality slurries/melts. Due to efforts the last 10 years these problems have been solved why Rheocasting as example has the same cost as HPDC components today.

HPDC is god enough for yesterday´s products, not for EV´s

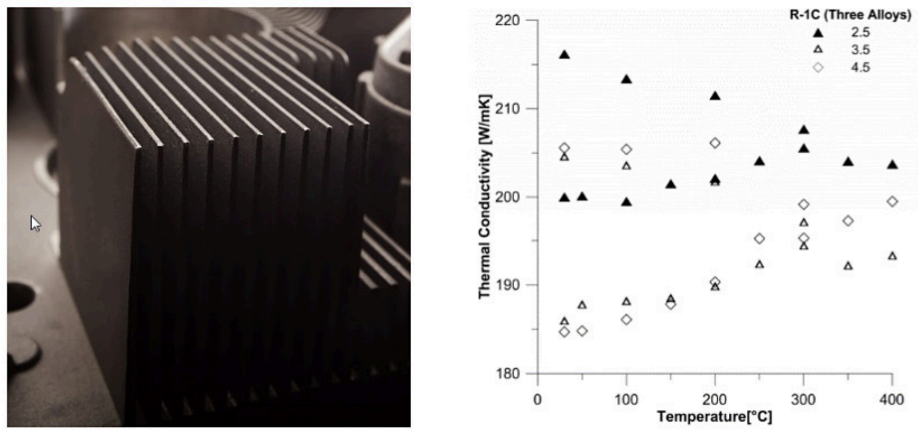
Basically, traditional engines with their drive trains and chassis structures has been designed in a safe and cost-effective way. But introduction of electrical cars and trucks as well as for hybrid vehicles are boosting the weight focus on a system level. Thus, the need of parts casted with other alloys that the eutectic alloys used in HPDC are not strong enough or does not offer the same heat treatment properties as Rheocasting does.

Basically, we see a lot of new applications as electrical engine, non-mechanical compressors, chassis with high requirement welds, battery systems and battery boxes. All these new systems at hand have some design drivers in common: light, leak free and strong, why alloy selection has become a great area for discussions

Picture: Elongation +9% using Rheocasting for aviation

Need of better thermal properties at low cost is growing fast

In 5G and EV´s there is a growing need of effective heating an cooling systems to take care of batteries, interior and also waste heat from electrical engines to optimize the work range of the vehicle. This is a new field for the automotive industry as range is becoming a very important USP in the competition of the customer.



Picture above: Heat sinks that are thin and weldable and the W/mK diagram results from Rheocasting. Picture from Comptech AB production and diagram from R&D project made by Comptech and Jönköpings university of technology.

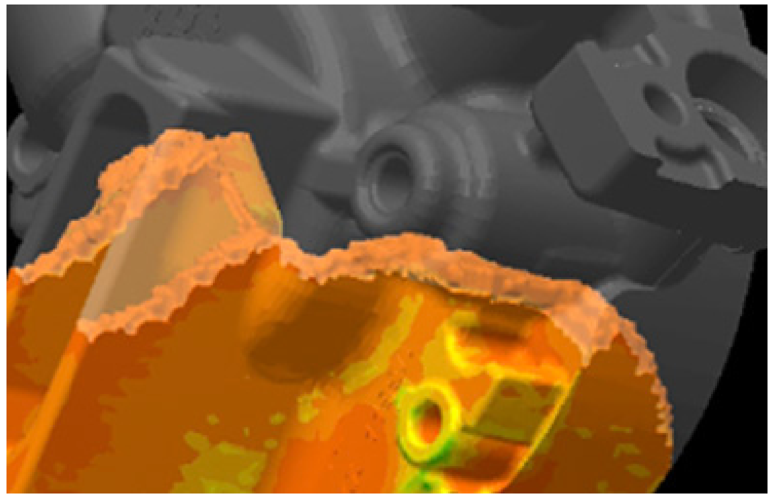
The use of heat sinks and other thermal management components has been around for a long time but if higher thermal conductivity, above 180-190 W/mK is a requirement, the problems arises. First problem is the typical values that can be obtained with HPDC. Not using HPDC most often results in a extruded component with a costly machining operation or other processes that often are costly. To the automotive sector low cost is a key

Porosity is a problem

The use of HPDC has he drawback of the turbulent flow of metal into the tool. The turbulence results in porosities that disables the component for several sub processing or after treatments that limits their use. Example of opportunities that are opened without these is a limitation are:

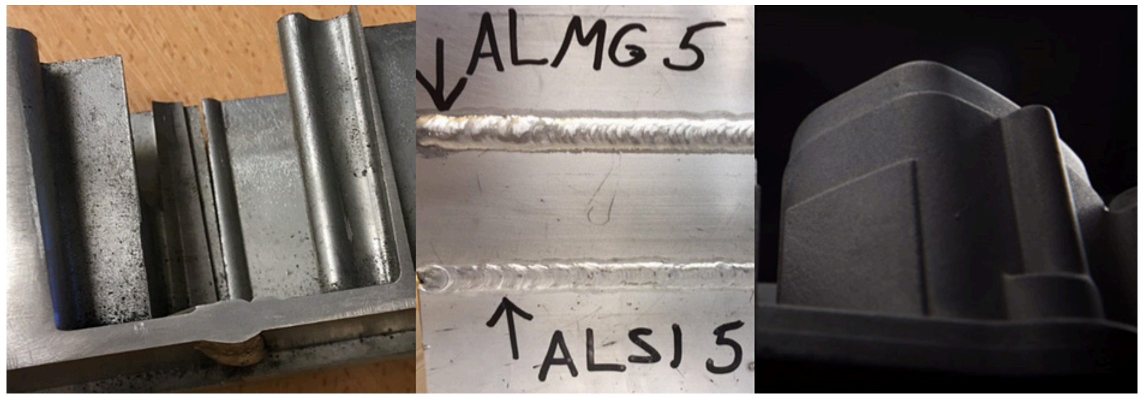
Stronger and lighter by heat treatment

Heat treatments to be well above 450 MPa requires a T6-T7 heat treatment. As these treatments are based on high temperatures the effect of entrapped air bubbles is a blistered surface, causing all sorts of problems from cosmetic to crack initializing spots.



Welded structures and chassis

There are welding of casted components as of today, but if the weight shall be decreased the part must be thinner and hence the quality of the weld must be better in terms of gas bubbles and other imperfections.



Pictures above: samples of welds made at Comptech AB in ongoing research projects

The hybrids require strong welds

The use of hybrids, meaning components built up of sheet metal, castings and extrusions requires a high-quality weld why the casting must be porosity free to a very high extent. But as hybrid components offers a great range of benefits this development is fast and we will probably see a lot of welded structures outside the chassis area.

The use of small machines (this is actually the most important one)
New applications are big, battery boxes, large chassi parts and extended antenna product are examples of those. The industries reply has been to invest in large machines with looking forces well above 4000 tons. However, a large tool in a large machine is causing new problems as metal flow length, tool wear due to extreme amounts of metal and it´s speed, not to mention practical problems. However, the sourcing problem might be larger than the technical issues for a big machine. First, the installed base is limited, and the market is growing fast giving a hard time to find capacity. Secondly the sourcing risk will be extreme as one tool break down will cause massive supply interruptions not to mention the negotiation power being eroded by a larger demand than installed capacity can fulfil.

The Rheocasting is offering two advantages to solve this: lower metal pressure, -40-50 %, that enables the use of smaller machines and the ability to weld parts made in smaller machines into a large complex part. Cost wise the final part will then be at a lower cost as small machines are effective and under competitions pressure.

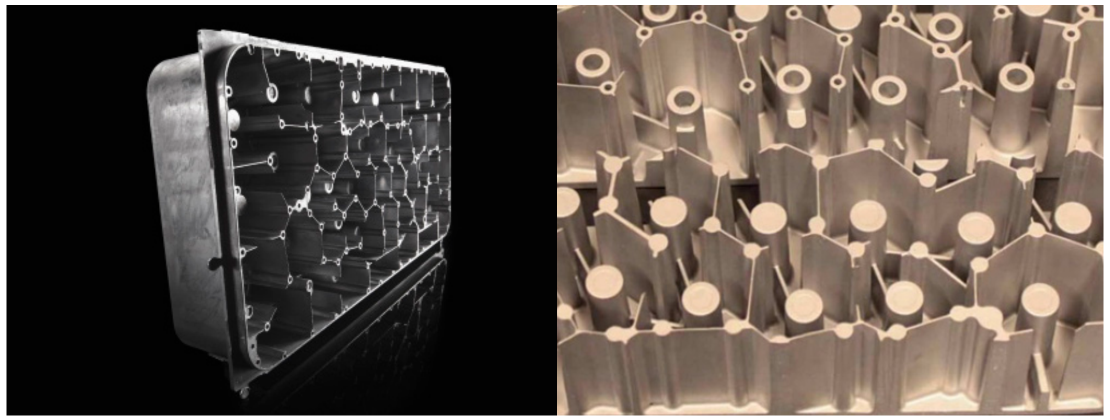
Benefits of Rheocasting

The benefits from using Rheocasting comes from three main advantages:

- *The solidification time in the tool that gives time for filling complex geometries*
- *laminar flow reducing porosity to very low levels*
- *alloy freedom that alloys that enables use of more effective alloys*

The solidification time in the tool

Due to a longer filling at slow speed and the solidification time the geometries designed can be thinner, thicker and allows pre-casted features as pre-casted holes (M2,5 with 100 depth), se picture below.



Picture above, telecom part and to the right detailed image of the 0,4 mm wall thickness.
Pictures taken at Comptech AB production.

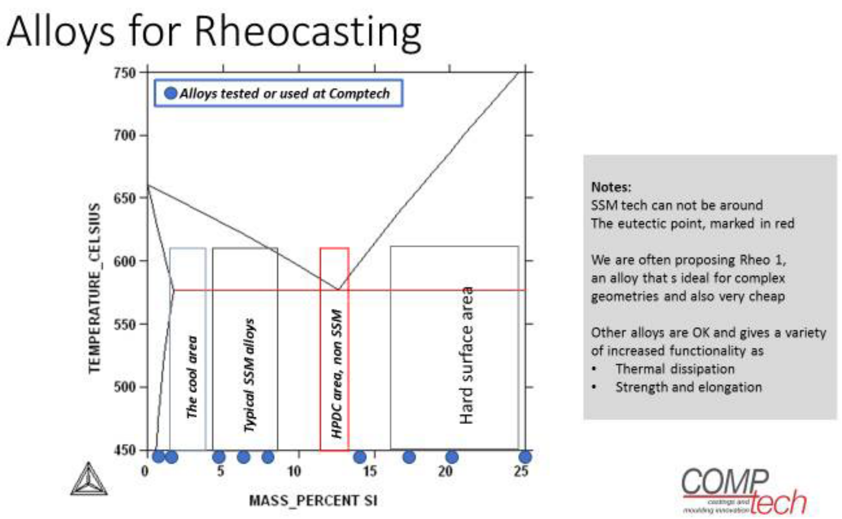
Laminar flow

It means that the melt is not sprayed into the tool or are behaving in a turbulent manner and this in combination with the ability of after feeding means that gas bubbles and shrinkage porosity can be minimized and, in many cases, avoided in full. The low level of porosity opens opportunities in safety parts, heat treatment, welding and leak free castings se picture of weld result below.

Alloy freedom

All alloys can be used, except eutectic alloys, se the picture below, and this gives opportunities for designers to increase functionalities as:

- *Heat transfer, with very low Si contents reaching +190 W/mK*
- *Stronger alloys after T6, as example A319 that gives 379 MPa average Yield stress*
- *Cheap alloys, approx. -0,1 EUR/kg compared with EN 46 000*
- *Hard alloys with Si content above 14-25%, to avoid surface erosion and cavitation damages*



Picture: Alloys available and used in Rheocastng

Market status of Rheocasting right now

The change over towards E-mobility is causing a strong pressure on development of new systems and components and as a result the number of parts with SOP 2019 are increasing. From smaller volumes in electrical busses the process is entering personal vehicles in the end of 2019 and the number of parts is then increased under 2020.

The number of development projects of parts and pre-development is also increasing strongly as there is a lock of proof of concept parts and also material data for example safety parts. The span in goals between the projects running is huge: from battery compartments to two stroke cylinders and from automotive to telecom, giving an interesting cross over as the world is going towards E mobility to save the climate.

Another evidence of commercial breakthrough is that the sales of Rheocasting equipment has started, even from a low number, the offers and discussions are increasing rapidly. This might be one of the strongest points as the es installations are initialized by the component buyng company in order to increase capacity and to safe guard engineering data and capabilities fr further developments. With the multiplication of sites the assumption is that the speed of the market development will grow during 2019.

The treats: engineering capacity and production capacity

The problems at hand has changed from technology and quality issues towards more structural and capacity drive problems. As many R&D efforts will be finalized in 2019 the data and findings will be used for the development of parts why new problems has been identified and discussed and the most important ones are:

Lack of suppliers that can support component development

Rheocasting or any high quality semi solid casting represents a new way of thinking in terms of simulations, tool design and also process parameters as speed, pressure and temperature. Due to this some partners are now concerned that the learning and duplication of foundry engineers will be a problem that can affect the industry´s ability to support product development.

Failure and long industrialization time

10 years ago, there was a lot of trials conducted, and they failed to 90%. The main reasons for failure was understanding of process parameters, ingate and tool design failures due to lack of simulation and low-quality melts. Implementation of a Rheocasting process is easy, but there must be a respect of the know how and the learning curve, otherwise we all will face the same failure that we saw 10 years ago.

Conclusions

The Rheocasting process has made it´s commercial breakthrough measured by the evidence in order for high volume production. The results so far is still a a production of +10 components but seen in the light of the number of RFQ´s there is clear evidence that high volume production is established during 2019.

The intense development pressure is still peaking both in terms of R&D projects for material data as pre-design work and as well for development of components and applications. The forecast is that this pressure will increase as new findings enters the market as every finding creates opportunities for more applications.

Probably the strongest capacity driver is yet to come and will most probably be about welding as this will enable lighter chassis and their parts as well as reduce the dependency of large machines hence ease up the upcoming sourcing problem.

The number of installations is forecasted to be double digits during 2019 and as this is happening the amount of people working, developing and selling parts made with Rheocasting is believed to reach the critical mass for creating a mass market.

Limiting factors are in capacity and capability, a problem that probably will be faced when the change over to EV´s as mass market is becoming larger as the competition where one main USP could be battery range between charging.

"Volvo Cars have a strong interest in SSM casting technology developing our next generation light weight components. The technology is very promising combining increased mechanical properties and functionality at reduced cost"

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