**SinterCast Interview – Forge Fonderie April 2017**

Unofficial English translation

**Introduction**

SinterCast is the world's leading supplier of process control technology for the reliable high volume production of Compacted Graphite Iron (CGI). The SinterCast technology, with 44 installations in 13 countries, is primarily used for the production of petrol and diesel engine cylinder blocks and exhaust components for passenger vehicles, medium-duty and heavy-duty cylinder blocks and heads for commercial vehicles, and industrial power engine components for marine, rail, off-road and stationary engine applications. SinterCast formally launched its new Ladle Tracker™ technology in 2016. The SinterCast Ladle Tracker™ technology monitors and records the presence and status of each ladle as it progresses through the foundry. The technology provides a new opportunity for foundry managers to measure, control and improve process flow and productivity within the foundry.

**Steve Dawson, President and CEO**

1. **Can you briefly recap some of the history of Compacted Graphite Iron (CGI) and SinterCast's involvement with the market development?**

Starting from the beginning, Compacted Graphite Iron (CGI) was first observed and documented in 1948. At that time, researchers were trying to improve the strength of grey iron. They found that adding 0.030-0.070% magnesium transformed the graphite flakes into spheroidal particles – that was the discovery of ductile iron. The researchers also found that, when the magnesium addition was in the range of approximately 0.008-0.015%, the graphite grew in a compacted or vermicular shape – that was the discovery of CGI. The researchers filed patents for both CGI and ductile iron on the same date in 1948.

It is understandable that the initial development focused on ductile iron – the stable production range was bigger and the strength was higher. But there were some attempts to industrialise CGI, particularly in the 1970's and early-1980's, when the automotive OEMs showed interest in the material. Unfortunately, because of the narrow stable range for CGI, these attempts were unsuccessful. By the time that SinterCast entered the market in 1990, there was a healthy skepticism toward CGI – the prevailing wisdom was that CGI was not suited for series production.

SinterCast was officially incorporated in 1983. At that time, a professor at the University of Stockholm filed a patent on a measurement and control technology for CGI. In parallel, he registered the company "SinterCast" (because of his research interests in sintering and casting) and assigned the patent to the company. The R&D continued with the professor and his graduate students during the 1980's, and the business activities started around 1990. At that time, the professor secured initial funding and recruited a small team of foundry engineers, engine engineers and managers. A head office was established in Detroit and a former Chief Engineer from General Motors was appointed president. I was recruited in 1991 as the Technical Director.

From 1990 to 1995, we introduced our control technology to the foundries and discussed material properties and engine benefits with the OEMs. Some of the early OEM work started with racing applications and today all NASCAR engines are CGI. From 1996 to 1999, we focused on developing machining solutions to cope with the higher strength of CGI. And, in 1999, we had our first series production breakthrough, with the start of production of the Audi 3.3 litre V8 diesel engine cylinder block. Volumes were only about 10,000 per year, but we had our first engine running successfully on the road. The next breakthrough was the high-volume production commitments from both Ford and Audi for 2.7 and 3.0 litre V6 diesel engine cylinder blocks. Programme approval was granted in 2001 with SOP in 2003. These engines are still in production, with a combined volume of approximately 400,000 engines per year. The first commercial vehicle references started with the introduction of Euro 4 emissions in 2005, and more OEMs have adopted CGI with each new engine generation and new emissions legislation. Our latest breakthrough, in 2014, was with the start of production of the high volume Ford 2.7 and 3.0 litre petrol engines used in six different Ford and Lincoln vehicles. The 3.0 litre V6 provides 400 ps. On the foundry side, we have installed our CGI process control technology on 44 production lines at foundries in 13 different countries, so the production base is quite broad.

Overall, the development cycle for CGI needed 50 years, from 1948 to 1999. Since then, the running engines on the road have provided confidence and competitive benchmarks, and that has fueled the growth. More than one million CGI engines will be produced this year. We would have liked it to be bigger and faster, but it’s a good story.

2. **What are the primary applications for CGI?**

Our series production components range from 2.7 kg to 9 tonnes, so there is a lot of variety. The smallest components are turbocharger housings for passenger vehicles and the largest component is an engine frame for Allen Diesels (formerly Rolls Royce) for stationary power applications.

If we consider the microstructure of cast irons, we can define the opportunity for CGI. The long graphite flakes in grey cast iron provide good heat transfer while the spheroidal particles in ductile iron provide good strength and stiffness. The vermicular graphite in CGI is intermediate to flakes and nodules and therefore CGI is good for applications that have simultaneous thermal and mechanical loading. If you only need strength, like in a crankshaft or a suspension application, use ductile iron. But if you need to withstand both thermal and mechanical loads, CGI can be the best solution.

The most obvious application for CGI is in cylinder blocks and heads. In cylinder blocks, we routinely realise 10-15% weight reduction compared to grey iron while providing improved durability. We also have diesel blocks in series production up to 9.0 litre displacement without separate cylinder liners due to the better wear resistance of CGI compared to grey iron. An extension of this is that CGI can be used for mid-range and heavy-duty diesel cylinder liners. For cylinder heads, we have series production references from 5 litres to 95 litres, for utility trucks, tractors, commercial vehicles, mining trucks, stationary power and rail applications.

Other production components include turbocharger housings and exhaust manifolds. These components, produced in SiMo CGI, provide better castability than ductile iron, are better at distributing thermal loads, and are strong enough to support exhaust components. We also support the production of CGI piston rings for large stationary engines from 200 to 980 mm bore diameter for 2-stroke marine applications. Initially, the top ring was CGI to withstand the high thermal and compression loads while the lower three rings were made of grey iron. But today, there are ring packs with three CGI rings that replace the former 1+3 ring packs, providing better durability at a lower total cost. Our piston ring experience has also led to the development of 350 to 980 mm bore diameter cylinder liners and we have many test liners successfully running in the field with individual piece weights ranging from 2.5 tonnes to 10 tonnes.

## 3. What have been the main market drivers that have contributed to the growth of CGI? What are the new casting opportunities and growth markets?

Compacted Graphite Iron has grown in both tonnage and number of applications in recent years. The inherent strength and performance of CGI is very beneficial for engine designers. Compared to gray iron, CGI is 75% stronger, 45% stiffer and provides double the fatigue strength. This increase in strength allows for increased peak firing pressure ($P_{max}$) and improved specific performance – horsepower per litre. In off-road applications, CGI is used to increase performance while ensuring durability, for example, to increase the power of an existing engine or, in a new design, to get the performance of a 15 litre engine from a 12 or 13 litre package. Most engines operate near the durability limit, so it isn't possible to make significant performance upgrades without resorting to stronger materials.

We have several commercial vehicle engine programmes in Europe and Asia where grey iron is used for the 'base engine' and CGI is used for the cylinder block and head of the high power versions of the engine. The OEM uses the same foundry tooling and the same machining line, but substitutes CGI to improve performance and durability. In the standardised thermal fatigue bench test developed by AVL in Austria, CGI provides approximately double the fatigue life of grey iron. This improvement translates directly to field experience with heavily loaded cylinder heads in commercial vehicle and marine applications.

Another main growth driver is downsizing and power-up while ensuring durability. In passenger vehicle applications, CGI provides 20-30% less bore distortion. This improved dimensional integrity allows for reduced ring tension and reduced friction losses (particularly at cold start); less oil consumption; and, less low-by. Engine designers can also expect 1.0-1.5 dB reduced noise due to the higher stiffness. If you give engine designers a free hand to choose materials, they will always choose the stronger material.

We are at the stage where there are credible high volume references in every market sector, and these references provide competitive benchmarks that help CGI to secure additional applications. The fact that we are most proud of is that no OEM has made one SinterCast-CGI engine and then stopped. If we remember back to the scepticism of the 1990's, there were many reasons why CGI couldn't be used: too difficult in the foundry; too difficult to machine; too expensive. But, when an OEM produces its first CGI engine, the engineers see the benefits and they apply CGI in more engines. For example, Ford has nine CGI engines while Audi and Hyundai both have six. Our challenge is to get the first engine – if we can get one, there is a strong probability that the growth will be self-fulfilling.

**4. What are the main competitive technologies to CGI in the next ten years?**

On the passenger vehicle side, aluminum is an obvious competitor. But iron has a good story and we just need to get better at telling the story. Legislation has understandably focused on $CO_2$ tailpipe emissions and this has prompted some passenger vehicle OEMs to adopt aluminum cylinder blocks in order to reduce weight. But the production of aluminum is significantly more energy intensive than iron. The production of each kilogram of aluminium generates 9-12 kilograms of $CO_2$, depending on the energy source. The weight reduction achieved by aluminium is about 10 kg for a typical 1.6 litre passenger vehicle aluminum engine. Life cycle studies consistently show that the driving breakeven distance to payback the up-front $CO_2$ generation is more than ten years of driving. Iron is stronger, less expensive and more environmentally friendly – we just need to get better at telling our story.

On the commercial vehicle side, CGI has been well embraced as the 'next' material and we don't see anything else in the pipe. The higher peak firing pressures (250 bar for heavy duty vs. 175 bar for passenger vehicle diesels) and the larger bore diameters (130 mm for heavy duty vs. 90 mm for passenger vehicles) mean that aluminium simply isn't strong enough for the durability requirements.

**Arnaud Denis, Chief Engineer, Tracking Technologies**

**5. How does the SinterCast technology assist foundries with CGI production?**

The SinterCast process control technology is based on a two-step measure-and-correct control strategy. The process begins by base treating the iron with magnesium and inoculant, either by cored wire injection or by the sandwich method. After the base treatment, a sample of the base-treated iron is obtained by immersing the SinterCast thermal analysis Sampling Cup into the liquid iron. When the analysis is completed, corrective additions of magnesium and inoculant cored wire are added, and the ladle is released for pouring. During series production, the average addition of magnesium is only 30 grams per tonne. This accuracy ensures that the iron remains within the narrow 0-20% CGI nodularity window from the start until the end of casting.

During the calibration phase for each new foundry and each new CGI component, SinterCast works with the foundry engineers to define the optimal ranges for Modification and Inoculation— under treatment will lead to flake graphite, resulting in low strength and premature failure. Overtreatment with either magnesium or inoculant results in high nodularity and porosity defects in complex components such as cylinder blocks and heads. Even when the base treatment is performed by wirefeeding, and optimised with automatic inputs for sulphur, iron weight and temperature and the results of previous ladles, the Modification variation after base treatment is too large to remain within the narrow CGI window. A correction step is needed to deliver consistency to the moulding line.

**6. SinterCast has recently launched the Ladle Tracker™ technology. Can you explain how this technology works and how the foundry can benefit from it?**

The Ladle Tracker™ technology provides a unique solution to correctly identify, trace, and document the movement of ladles throughout the foundry process. Ladle Tracker™ can be configured to suit the layout, process flow, and production volume of any foundry. The system can also interface with peripheral devices such as temperature measurement, weight, chemistry and wirefeeding data to ensure that every ladle receives all critical treatments and every ladle completes all process steps within pre-set limits. The Ladle Tracker™ technology allows the foundry managers to set rules and automate the process, instead of being dependent on the behaviour of the operators. Ladle Tracker™ uses either Radio Frequency Identification (RFID) or optical identification of each ladle to detect the arrival and departure of the ladle at any process-critical step in the process. The system provides precision monitoring, improved process adherence, improved traceability, and documents where ladles fall-out of the process. SinterCast has installed the first Ladle Tracker™ system in a high volume cast iron foundry in North America and it has been running successfully for more than two years now, with over 75,000 ladles tracked. It is an exciting technology for foundries to control the casting process and improve quality and productivity.

**7. How do SinterCast process engineers provide support to their foundry customers?**

Before the installation of a new CGI control system, the customer engineers are invited to our Technical Centre in Sweden to receive training. After the training, we ship the equipment to the foundry and we provide on-site installation and training support to the engineers and the operators. Our ambition with our equipment has been to make it as simple as possible – the initial goal was one green button and one red button. We didn't quite achieve that goal, but the equipment is very user friendly and the interface is always in the local language. During series production, the SinterCast engineers regularly log in to the system to review the production and provide feedback. And, at the end of every month, a formal summary of the production is provided to every customer, summarising the production statistics for the month and comparing the production to the most efficient SinterCast customer in every measurement category. We provide these benchmark reports – together with written recommendations for improvement – to our CGI customers and our Ladle Tracker™ customers. Finally, we also provide on-site visits and Annual Service Visits for the hardware maintenance. This close and ongoing collaboration between SinterCast and the customer leads to good friendships with the customer engineers. Most of the SinterCast engineers will be on the road about 75 days per year.

**Steve Dawson**

**8. Can the Ladle Tracker™ technology be applied to other metalcasting operations other than CGI foundries? Are there other initiatives within SinterCast to help metalcasting companies measure and improve their processes?**

At present, Ladle Tracker™ installation discussions are ongoing with our current CGI customers, with grey iron and ductile iron foundries, and with metallurgical plants beyond the cast iron foundry industry. Our initial goal is to establish the first handful of reference installations and we are making good progress with that. We believe that measurement, control and automation are the pathway to improved efficiency in the foundry industry and we believe that the end-users of castings will continue to demand increased documentation and traceability. These beliefs guide our development. The founding mantra of SinterCast is that "you can't control what you can't measure". Our goal is to bring these novel measurement capabilities to the foundry industry to help foundries improve quality, efficiency, productivity and profitability. We don't want to be a second source for ordinary products – our ambition is to bring new ideas and new technologies.

**Photos:**

*Ladle Tracker™ RFID Tags affixed to ladles*


*Ladle Tracker™ RFID Antennae located at key positions in the foundry*

*The patented SinterCast Sampling Cup is the only thermal analysis device in the world that uses a high accuracy steel vessel and reusable thermocouples*

*Fully automated System 3000 with two Sampling Modules. The SinterCast process control technology has been installed on 44 foundry production lines in 13 different countries. CGI can be produced in existing cylinder block and head foundries using the same melting and moulding techniques.*

*System 3000 Plus base treatment and correction station. The System 3000 Plus provides automated base treatment with the inputs of ladle weight, temperature, and historical SinterCast results thereby reducing the variation of the base treatment process.*