Compacted graphite iron for high performance piston rings

Per Samuelsson and Peter Vomacka discuss the improvements in material quality and consistency of production output using the SinterCast process.

THE piston ring is a key component in a marine diesel combustion engine. It functions in a very demanding environment represented by high mechanical loads, relatively high temperatures and corrosive gases and liquids. Nevertheless, the piston ring has to contribute, together with other combustion chamber components, to the high performance and the reliability of the engine in terms of minimising the wear of the cylinder liner and the ring itself without jeopardising the sealing ability. At the same time, the piston ring must fulfil the requirement of a predictable overhauling interval as one of the most important aspects in the operation of diesel engines, especially large bore diesel engines [1].

Over the years cast iron has proven its suitability as the piston ring material for marine diesel engines due to its relatively high mechanical strength, satisfactory tribological properties and heat conductivity. In fact to date, cast iron is the only existing engineering material with the perfect match of properties and production cost efficiency needed. This is not to say that there are not any other choices but in a search for another material one has to compromise with at least one important property. As an example, steel piston rings, having higher mechanical strength but also lower heat conductivity and less satisfying tribological properties, are used in diesel engines for trucks. Selecting any other material than the traditional cast iron creates major challenges for the designers of the engines in order to ensure its performance.

The mechanical and physical properties of two main groups of cast iron usually used as piston ring material, lamellar grey and ductile irons with a pearlitic matrix, are governed by the morphology and distribution of the graphite in the microstructure. Therefore, a considerable amount of research and development has been undertaken to study the cast iron graphite during recent years. A large number of investigations showed that generally grey irons (lamellar graphite) possess higher thermal conductivity, better tribological properties and lower mechanical strength compared to ductile irons (spheroidical graphite) [2]. Consequently, there was a need to create a cast iron with properties in between grey and ductile iron aiming at almost as high thermal conductivity and tribological properties as the grey irons but at the same time a relatively high mechanical strength compared to the ductile irons. Therefore, Compacted Graphite Iron (CGI), also called vermicular iron, has been developed during the last 40 years.

Figure 1

Figure 2

Figure 3

Figure 4

Top to bottom: Figure 1: Daros Piston Rings facilities at Molnlycke near Gothenburg; Figure 2: Graphite shape in Darcast manufactured by the Foot Mineral method; Figure 3: SinterCast control system at Daros Piston Rings foundry; Figure 4: Graphite shape in Darcast manufactured by the SinterCast method.

Generally, CGI has higher tensile strength, higher stiffness and approximately double the fatigue strength of conventional grey cast iron [3]. The thermal conductivity lies between grey and ductile iron [4]. Daros Piston Rings has been producing compacted graphite iron for piston rings for almost 20 years. The production process is complicated due to a very small process window.

Compacted graphite production

Fig. 1 shows the new facilities of Daros Piston Rings AB in Molnlycke, where two different grades of CGI have been developed. These are the Darcast and RVK irons with 95 percent vermicularity. At the early stages of the development a large number of different treatments were tested to establish a sustainable CGI microstructure, with shorter and thicker graphite particles compared to the grey iron grades with rounded edges. These features govern the mechanical and physical properties of the material as mentioned above. The Foot Mineral treatment method was then chosen as the most suitable one to proceed with in order to optimise the production process and to ensure a high and consistent quality of the material. Fig. 2 shows the graphite shape in the microstructure of Darcast compacted graphite iron manufactured by the Foot Mineral method. However, using the Foot Mineral treatment consisting of the addition of elements such as magnesium and titanium to the base cast iron was a great challenge. It is a procedure with an extremely small process window in terms of addition of magnesium and other elements (magnesium content in the melt must be in an interval of 0.01 to 0.03 weight percent). In addition, factors such as the operator's experience and skills are of importance and also variables which the foundry personnel are not always in control of, such as humidity in the foundry. The treatment also created difficulties when machining the compacted graphite due to very hard particles of titanium carbonitrides present in the microstructure. Therefore, an increasing need for a computer aided process control system (thermal analysis) together with a new treatment have emerged. Such systems for controlling the production of compacted graphite became commercially available three years ago.

The SinterCast process

At the beginning of 2001 Daros Piston Rings installed the SinterCast process control system (Fig. 3). Simultaneously, the Foot Mineral treatment process was replaced by the SinterCast treatment using only magnesium. After some development efforts and adjustments, the production of Darcast and RVK compacted graphite irons using the new treatment and the SinterCast control system started in August 2001. Fig. 4 shows the graphite shape in the microstructure of Darcast compacted graphite manufactured by the SinterCast method. Results of more than one year of production with the SinterCast process are very satisfactory. The material quality and the consistency of the production outcome have improved to a great extent. As an example, the bending strength of the Darcast material has increased by 15 percent. At the same time, other required material properties have been maintained or improved.

The introduction of the SinterCast equipment to the production of piston rings is a very important step to increase the quality of high performance piston rings manufactured from compacted graphite iron. Daros Piston Rings AB in co-operation with the Swedish based company SinterCast will lead the way in the effort to establish compacted graphite iron as the cast iron grade of future piston rings. ■

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