Furnace is key to CADI solutions

Arron Rimmer, ADI Treatments Ltd, says that many in the industry are familiar with the austempering process used to create ADI. Not so widely appreciated is the niché material CADI (carbidic austempered ductile iron), which was developed to improve the wear durability of conventional ADI.

Ductile irons are treated with magnesium and/or rare earths to produce spheroidal graphite. The same irons can be induced to form a carbidic microstructure in a number of ways including alloying with carbide stabilisers such as chromium, molybdenum and titanium, controlling inoculation, or controlling the cooling during solidification. The carbides so produced can also be 'dissolved' in a subsequent heat treatment.

When austempering cast irons, careful control of parameters is essential to achieve optimal material properties and consistency. The solution can be found in purpose-designed furnaces supported by process know how.

Specialist contractor ADI Treatments Ltd has established such a facility to carry out work for castings suppliers and users. A typical customer is SIMBA International, a manufacturer of cultivation and drilling machines. SIMBA's application resulted from a co-operation to identify the properties and benefits of CADI for ground engaging components.

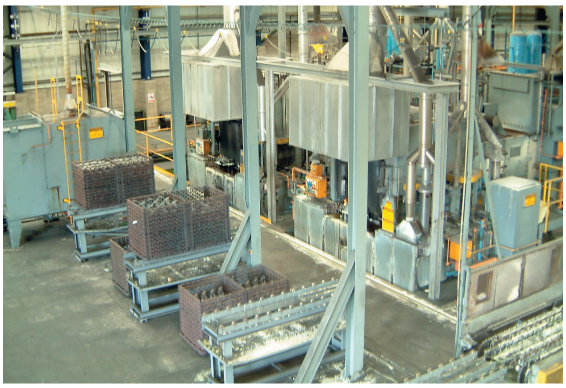

Fig. Ia. Purpose built furnaces for production of ADI and CADI. This facility at ADI Treatments Ltd operates the largest furnace of its kind in commercial use, accommodating parts up to 1.8m diameter

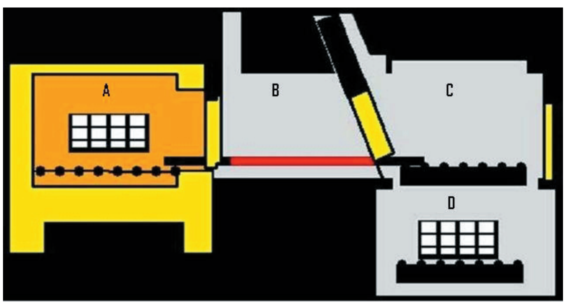

Fig. Ib. Schematic layout of the furnace system

Furnace capability and process

The furnace systems at ADI Treatments (figs 1a/b) use a controlled atmosphere austenitising batch furnace (A) with integral re-circulating roof fans and radiant tubes to ensure rapid heat up of heavy loads and high uniformity. An intermediate purge transfer chamber (B) and an enclosed vestibule (C) continue to protect the work from oxidation as it is transferred to a salt quenching station (D). The vestibule also isolates the furnace from salt ingress.

The quench medium is a nitrate/nitrite mix that is held at temperatures in the range 230-400°C. To ensure the homogeneity of the process and final material properties, the salt is forcibly circulated through the load. By inoculating the salt bath with water, quenching rates are enhanced to allow treatment of larger section parts without adjustment of cast composition. The salt is managed and recycled to obviate environmental damage.

Furnace system and process are driven via a state-of-the-art Human Machine Interface, which also provides access to the heat treatment programmes. Fig. 2 illustrates a typical two-stage thermal process carried out at ADI Treatments on carbidic irons. The first stage austenitisation cycle is followed by a controlled quench and an austemper of typically one to two hours duration. The traditional quench media, oil and water, are not used so that the load does not reach the Ms temperature and brittle martensite cannot develop. Instead the microstructure is transformed to an ausferritic matrix with a controlled carbide dispersion (fig. 3), an arrangement that confers excellent wear-resistance with adequate toughness.

Flexibility in the furnace and controller configurations allows the austempering process to be tailored to the part in question. The controlled atmosphere features eliminate oxide scale formation, while the austempering process introduces minimal distortion and stresses.

Parts may be designed to account for dimensional changes during the heat treatment so that little or no finishing is required. In the following case study, ADI Treatments worked with foundry partners Hulvershorn GmbH to develop the ADI and CADI cast compositions. The heat treatment programs were established with reference to Applied Process Inc, ADI Treatments' original process licensors, who have built a substantial database over 20 years in the field.

A CADI case study

SIMBA's engineers, aware of earlier success with ADI and CADI in the USA, wished to explore both materials for use in high wear parts on their new development soil aerator, the Solo Subsoiler. ADI Treatments was able to assist in the design and supply of heat treated ADI and CADI castings.

Initially, the Solo's tip parts were produced in these and three other wear-resistant materials for laboratory soil abrasion tests. The results of the trials carried out by SIMBA are compared in table 1. ABRO 500 is a steel plate with minimum hardness 500HB. The NiHard abrasion resistance level has been normalised to 1.0.

Live field trials were also performed on the CADI and 22%CrFe parts. Over the lifecycle the white iron proved to be more energy efficient and wear-resistant and was therefore selected for the tip application.

Attention then turned to the adjacent Solo component, the 'shin' (fig. 4). Based on the results of the tip trials, the designers chose CADI for this part. The heat-treated casting, which also bears the company logo, is low cost relative to alternative materials and fabrication.

Wear life is compatible with the tip, enabling convenient change at the same interval, and impact resistance is fully satisfactory. SIMBA has enjoyed several seasons of success with the shin, believed to be the first European application of CADI.

In the USA John Deere has introduced CADI for threshing elements on rotary combines, and for ripper points used in deep tillage. Manufacturers in continental Europe are currently developing similar applications and examining the potential for material containing crushed iron carbide, added mechanically during casting.

CADI compared

Following the success of the SIMBA application, ADI Treatments

NiHard	ADI	ABRO 500	CADI	22%CrFe
1.0	0.76	0.4	1.15	2.0

Table 1: Relative soil abrasion resistance. (SIMBA International Ltd., www.simba.co.uk)

Material	HB	HRC	Weight loss mg	Source
CADI			43.7	1
17%Cr Fe			9.45	1
ADI Grade 2	321	32	76.7	3
ADI Grade 4	415	43.2	70.3	3
Quenched ductile iron		59	52.8	3
Q&T steel (0.8%C)		63	59	3
ASTM A514-T1A steel	269		139	2
NiHard 1			35-45	2

Table 2 Compilation of abrasive wear data. Sources: 1This study; 2 Climax Research Services reference materials; 3 R Gundlach and J Janowak, 2nd International Conference on austempered ductile iron: your means to improved performance, productivity and cost, Ann Arbor, MI., 17-19 March 1986, 23-30

Material	Impact energy (J)
CADI	13
Carburized 8620 Steel	17
Pearlitic Malleable Iron	17
7003 Ductile Iron	49
Grade 5 ADI	52
5506 Ductile Iron	58
Grade 3 ADI	91
Grade 1 ADI	117
4512 Ductile Iron	123

Table 3: Typical un-notched Charpy impact values (Joules) tested at 22°C. Source Applied Process Inc

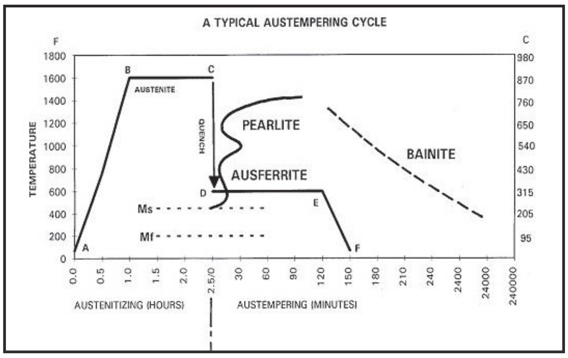

Fig. 2. A schematic representation of the CADI heat treatment cycle

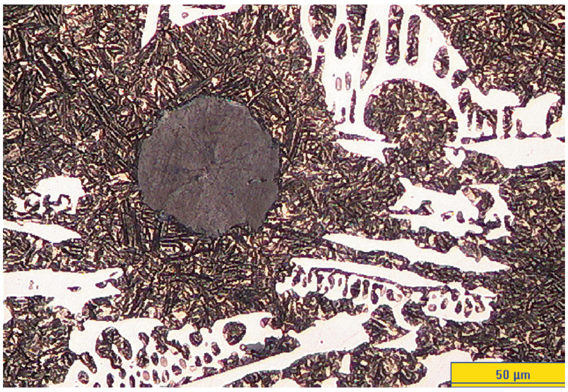

Fig. 3. A typical CADI microstructure showing carbide and spheroidal graphite, dispersed in an ausferrite matrix and austempered at 370°C

commissioned a further study on the abrasive wear characteristics of the same CADI material and a heat-treated 17% white iron. The work, carried out with the University of Birmingham is summarised in table 2. The table also lists comparative data from tests on a selection of other reference materials. For wider comparison, results previously reported on a range of ADI and wear resistant steels and irons are also included.

The data indicates that CADI offers significantly greater wear resistance than standard ADI materials, martensitic ductile iron, and some wear resistant steels. While similar to that of NiHard 1, CADI is less wear resistant than high chromium irons.

CADI's wear performance increases with increasing carbide volume. This is accompanied by a corresponding reduction in impact properties. Un-notched Charpy test data for a typical CADI alloy containing 30-45% carbide and a range of traditional materials are compared in table 3.

The CADI figure of 13J exceeds that of as cast white iron, which has been reported as low as 3J. *(Reference K Hayrenan, Transactions of the American Foundry Society V 111 Paper No 03-088 P 845-850, 2003).*

Wider market potential

CADI's properties present some intriguing market opportunities, potential applications in vehicles including camshafts and cam followers. Agricultural applications may include rippers, teeth, plough points, wear plates and harvester, picker and baler components. In construction and mining, potential applications include digger teeth and scarifiers, cutters, mill hammers, flails, guards, covers, chutes, plates, housings, transport tubes and elbows, rollers and crusher rollers.

General industrial applications could include pump components, wear housings and plates, conveyor wear parts, skids and skid rails, rollers and blast parts. Market entry is eased because no capital investment is required for the ductile iron producer to add the material as a new product line.

Summary and acknowledgements

Carbidic austempered ductile iron offers cost savings and a useful mix of properties that position the material alongside established wear resistant steels and irons. Furnace capability is key to achieving component performance and batch to batch consistency. Expert contract services have been established to assist the caster and end-user to design for solutions in CADI and many other austempered materials.

The author acknowledges SIMBA International Ltd and Dr Richard Harding, IRC in Materials Processing, University of Birmingham for their help and contributions.

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Fig. 4. Ground engaging components on the SIMBA Solo subsoiler. The CADI shin part bearing the company logo is appositely positioned behind the white iron tip. Courtesy SIMBA International, www.simba.co.uk