Technical Report

®SIGRABOND-CC – Examples of use in the glass industry[1)]

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®SIGRABOND-CC is the trademark for the carbon fibre-reinforced carbon (CC) supplied by SGL CARBON AG. This material was developed in the Meitingen works at the beginning of the 1970s and has now been adopted in many industrial sectors, e.g. in pressure-sintering technology, furnace construction, high-temperature ceramics production, the hard metal industry, semiconductor technology, mould construction, reactor technology, the aerospace industry, the chemical industry and of course the glass industry. CC is a lightweight, high-strength, rigid and impact-resistant composite material consisting of carbon fibres as the reinforcement, together with graphite or carbon as the matrix.

For two-dimensional components, carbon fibre semi-finished materials (rovings, woven cloths, felts or staple fibres) are impregnated with resins or pitches, cured under pressure and then carbonized. The porosity which then exists is reduced by repeated alternate impregnation and carbonizing. Axially symmetrical components, such as pipes, are produced by winding resin-impregnated carbon fibre rovings.

Finishing operations, such as impregnation and coating, can be carried out afterwards to increase resistance to oxidation and abrasive wear, for example, and this is in fact usual practice. Such operations include phosphate, synthetic resin and metal-ceramic coatings, e. g. with SiC.

The wide variety of uses for CC results not only from the virtually unlimited possibilities for shaping this material but also its characteristic properties, some of which derive from the graphite and others from the reinforcing fibre:

- high strength parallel to the plane of the layers and alignment of the fibres
- low density
- thermal shock resistance
- thermal stability up to more than 2000 °C
- low thermal expansion
- electrical conductivity
- anisotropy, if roving cloth reinforcement is used
- high fatigue strength under bending stress (important for scoops)
- low thermal conductivity perpendicular to the laminate or fibre alignment
- corrosion resistance
- radiation resistance
- high chemical purity
- pseudoplastic failure behaviour, no brittle failure in CC with roving cloth reinforcement
- virtually creep elongation at up to 2000 °C

Although CC has long-term stability in air up to only 480 °C, it can cope well with the high temperatures of liquid glass. The gob distributor channels of the independent station plants used in container glass manufacture are one example of this. These channels used to be made only from grey cast iron or aluminium and had to be used with only short-lived coatings (pastes) and/or oil lubrication; but since 1989 SGL CARBON AG has been manufacturing them in ®SIGRABOND. The low mass of the channels (about 500 g), and the fact that they operate without a cooling circulation, coating or lubricants, have been the decisive reasons for their adoption, especially on independent station plants with high article output. With the continuous operation that then became possible, there were opportunities for a substantial reduction in maintenance expenditure. Although up to 150 gobs of glass at a temperature of some 1200 °C come into contact with the CC distributor channels each minute, the temperature of the channels can be reduced so much by spraying with water or cutting emulsions that no oxidation phenomena occur. This practice also ensures that the friction value is kept below the critical level, so that the gobs are not unacceptably decelerated in the channel. Depending on the article and the plant concerned, SIGRABOND channels can be kept in continuous use for more than a year. Service lifes of up to three years are being achieved. These are equivalent to 150 to 200 million gobs.

Another example, this time from lead crystal manufacture, illustrates the wide variety of uses for CC. The traditional moulds for high-quality drinking glasses are made of wood. The idea of using a carbon material comes to mind when one looks at the conventional shaping technique used in a lead crystal glassworks. The wooden moulds form a carbon coating on coming into contact with the hot glass. The trouble is that this carbon is not very stable. After a few hundred articles have been produced, the wooden moulds are no longer true to size.

Attempts to produce the moulds by lamination or winding of CC rovings led to unacceptably long production times or unduly high costs. Success was not achieved until the development of CC type 3001 G. Mould bases and rotary blow moulds were produced from thick sheet material and tested in close co-

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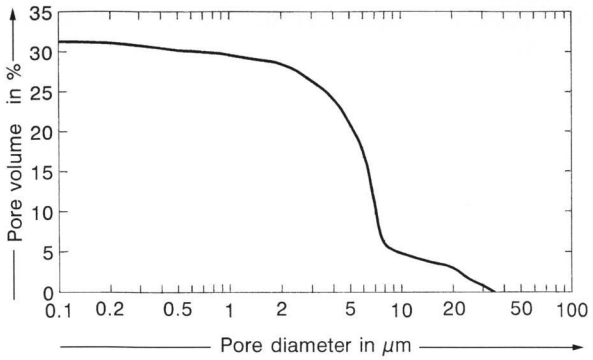

Figure 1. Pore size distribution of the mould material ®SIGRABOND 3001 G.

operation with the Nachtmann Bleikristallwerke, Weiden (Germany).

This was the first step in a series of tests lasting for more than a year. It was found that well over 24 000 articles could be produced by hand blowing with each mould. All the articles produced were of first quality and there were no rejects. The glass surfaces had a mirror finish. These very good results have been repeated time and again, and the material is in use at Riedlhütte for hand-blowing moulds for such articles as sparkling wine goblets, champagne flutes, liqueur glasses and carafes, which have smooth surfaces without much in the way of cut patterning.

For manual lead crystal manufacture, SIGRABOND 3001 G is available in two different densities in sizes up to (100 × 1 000 × 1 000) mm^3. Split moulds can be made in diameters of up to 200 mm. Larger moulds can be made by joining several sheets together.

The main reasons for the good results obtainable with this special material are to be found in the shape, size and distribution of the pores. Nearly all the pores are smaller than the diameter of the carbon fibre, which is 7 μm (illustration of pore size distribution see figure 1).

The starting materials used in making the CC components are special semifinished materials based on viscose or acrylic fibres, whose uniformity is subject to stringent control. Carbonization or graphitization at up to more than 2000 °C produces carbon fibre felts. These felts can be used to make CC with highly uniform porosity.

To summarize, there are four reasons for the good results obtained with this mould material:

a) First, the large proportion of small pores ensures that steam is formed uniformly over an extended period. This is an important requirement, especially with relatively long blowing times.

b) Secondly, any tendency of the mould to contaminate the glass is minimized by the mould material's structure, its high purity level (ash content of less than 0.01 %) and its high degree of graphitization. These properties of the mould material are also responsible for the uniform, high quality of the moulded glasses, which can be made in large numbers from a single mould. In addition, these properties allow the glasses to be freely rotated in the moulds.

c) Thirdly, the high compressive strength and abrasion resistance are jointly responsible for the high dimensional stability. As there are no hard or soft regions in the material, it is impossible for peaks and valleys to form in the mould during use (the proportion of matrix graphite is small, and it has little frictional contact with the glass).

d) Fourthly, the mould material can be cleaned with chemicals if the pores ever get blocked. Formic acid, for instance, has proved very effective for this purpose.

Examples of other uses of CC are the pincers used to remove the glass articles from the mould, heat-resistant dead-end plates to rest them on, pushers to push them out, deflectors, guide bars and, finally, staker bars to push the articles into the cooling kiln.

There are now around 20 insulating materials available on the market to prevent damage to articles by contact with unprotected metal. The range extends from brake-lining material to ceramics. All have their own particular advantages and drawbacks. CC is used when a good cost-performance ratio is attainable. This is generally the case on plants producing articles in medium to large numbers. Good results are obtained with fabric-reinforced CC materials on pushers and deflecting elements if the anisotropy of the material is borne in mind. If the surface of the fibre comes into contact with the glass article, it minimizes heat loss and ensures low wear (mechanical and oxidative), however, large the number of articles.

The thickness of the CC sheet material used can be reduced to 3.2 mm (1/8 inch). To meet the demands imposed on pincers and loading rods, a short-staple CC material has been developed with random fibre distribution, low thermal conductivity and high resistance to edge abrasion. The almost linear path of the thermal conductivity curve as a function of temperature ensures that no thermal shock cracks occur on the articles even during the start-up of production lines. When short-staple CC is used, this obviates not only the delamination observed in fabric-reinforced CC materials under edge-to-glass stress, but also cracking in the glass articles resulting from high dissipation along the fibre alignment in the plane of the sheet.

Depending on requirements, it is possible, whithin limits, to vary the material's hardness, thermal conductivity and resistance to oxidation. SIGRABOND 4012 DV and 4012 GA are now the standardized grades available.

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