Vacuum furnace hot zone upgrade and improvement

by Jez Higham

The Schunk Carbon Technology division is the first major supplier of materials for the vacuum heat treat industry to offer complete overhaul and upgrade of vacuum furnace hot zones. Using existing, and developing new CC profiles and products to protect hot zones and increase lifespan for any make or model of vacuum furnace, the company uses years of experience in supplying materials to improve the performance of hot zones.

By developing new CC profiles and products for hot zone edge and hot face protection the manufacturer increases the lifespan of the hot zone between relines (Fig. 1). The extensive use of CC plate for hot face protection, CC profiles for edge protection, replacing molybdenum fixings with CC fixings and replacing graphite gas grids with CC has seen the development of a complete CC hot zone offering and extremely hard wearing surface designed to withstand gas erosion and accidental operator damage and offering complete protection to the hot zone insulation board.

Insulation protection within a hot zone is paramount to the longevity of the hot zone and by protecting the insulation by using CC hot face and edge protection the performance and longevity of the hot zone can be improved by many years.

Offering a complete ‘turn-key’ package from hot zone removal, up-grade / reline, re-install and commission the company relines existing hot zone cages (including repairs to the outer cage) or supplies complete ‘all new’ hot zones (inclusive of new fabricated outer cage) as a plug and play option.

The plug and play option being invaluable to customers where furnace downtime is a major issue where a reline to an existing outer cage could see the furnace out of production for up to 2 to 3 weeks a ‘plug and play’ hot zone can see the furnace only out of production for 2 to 3 days.

Offering a complete after sales package including hot zone and heater set assembly drawings listing all graphite heater and hearth set spare parts item numbers.

One of the biggest pitfalls in existing hot zone design is the use of molybdenum and its inherent problems with embrittlement once having been up to temperature and fragility when conducting repairs or replacement. Molybdenum has been used for many years in insulation board fixings, element support assemblies, elements, heat shields and edge protection, by replacing wherever possible all molybdenum products with CC products to reduce hot zone maintenance and repair.

CC ‘TEE BOLT’ BOARD FIXINGS

Molybdenum insulation board fixings with molybdenum ‘butterfly clips’ have been the industry standard for many years within the high temperature furnace industry and have all suffered with the butterfly clips breaking and then the actual board fixing breaking leaving an extremely hard
& brittle stud in the fixing nut making replacement difficult. The breaking of these fixings resulted in many cases of the hot zone having to be removed from the furnace vessel to access the fixing from the outside of the hot zone cage, sometimes resulting in 2 to 3 days furnace downtime. The alternative options were to remove a plug of insulation to enable removal from the inside of the hot zone, damaging the hot face, or, to not replace the board fixing at all. By not replacing the board fixing the board moved and vibrated under quench conditions causing extensive & expensive damage to the furnace insulation.

Following extensive trials with respected customers these molybdenum fixings have now been replaced on all hot zone relines using M10 CC ‘Tee bolt’ fixings. Should breakage occur due to accidental damage or operator error the CC fixings are easily replaced from inside the hot zone within a matter of minutes. Any CC stud left inside the fixing nut is very simply ‘tapped’ out and a new fixing inserted.

The CC board fixings are used with a CC washer to prevent damage to the ‘hot face’ when tightening up (Fig. 2).

This approach has seen a major improvement in furnace downtime and saved many maintenance hours in replacing broken molybdenum fixings. It is recommended that checking the tightness of the fixings is included in the operator daily, weekly, monthly maintenance tasks.

CC ELEMENT SUPPORT FIXINGS

Following on from the success in replacing molybdenum insulation board fixings with CC the same approach has been adopted for element support fixings seeing all molybdenum fixings replaced with CC. The fixings are available in sizes from M10, M16 & M20. When looking at improved element support design the existing OEM design is looked at for obvious weakness or maintenance issues and whenever possible a simplified re-designed system is offered. By using a mixture of standard ceramic parts and CC fixings an easily replaced low maintenance element support system can usually be offered.

Existing molybdenum ‘eyebolt’ element support hangers as used by many OEMs are now replaced with CC ‘eyebolt’ fixings. The above element support assemblies have the obvious advantage of ease of replacement from inside the furnace hot zone.

CC DOUBLE L-PROFILE

Many Original Equipment Manufacturers (OEMs) use a raised face on the hot zone door assembly to provide better insulation properties and prevent ‘line of sight’ radiation to the outside of the hot zone. This raised face also provides a sealing edge for the door to seal onto the leading edge of the hot zone. The edges of this raised face have for many years suffered from damage due to gas erosion and thermocouple positioning damage. The sacrificial skin fitted to the door insulation has also suffered from coming loose due to vibration during furnace quench, resulting in the skin ‘slipping’ down and then causing damage to the insulation around the hot zone door aperture. The raised face on the door assembly is usually either 20 or 40 mm thick.

The development of a patent approved CC double L-profile to ‘picture frame’ the door insulation, has created a unique system that will protect all edges of insulation from gas erosion, completely captive the sacrificial skin on the hot zone door and keep all fixings inside the sealing edges.

The double L-profile provides complete door edge protection against operator accidental damage (Fig. 3) and also a hard wearing sealing face between the door and the hot zone leading edge.
This double L-profile can be used for both CC plate and Graphite foil sacrificial skin and is available to suit both 20 and 40 mm raised faces.

**CC GAS GRIDS**
Machined graphite gas grids have been used for many years within the heat treat industry and are usually very heavy, quite fragile and susceptible to base grids getting damaged by parts falling onto them. Replacement gas grids are usually a long lead time item due to the size of the plate required prior to manufacture and extensive machining required. The graphite gas grids are usually quite bulky items and are usually fitted in the roof, base and sides of the hot zone, this large bulk of graphite has to be heated up along with the furnace load every time the furnace is operated and obviously has extra power usage implications.

The development of using gas grids water jet cut from standard CC plate offers a lighter, stronger, easier to handle gas grid. These lighter CC gas grids are much easier to install and when coupled with CC profiles protecting the aperture offer an extremely long lasting system with the obvious advantage of being less susceptible to gas erosion. With less machining and readily available plate means these CC grids can be offered on much shorter lead time than conventional graphite gas grids. Replacing graphite gas grids with CC gas grids has had no effect on furnace temperature surveys or cooling parameters.

**CC SACRIFICIAL SKIN**
The use of 2 mm thick graphite perforated foil sacrificial skin is used throughout the industry to protect the hot face of the insulation board from gas erosion and accidental damage. The nature of the product being heavy and difficult to handle makes it labour intensive to fit.

Once the foil face is damaged or torn gas pressure can get behind the foil causing damage the protective barrier very quickly. Once the sacrificial skin / barrier has been broken extensive damage to the insulation board from gas erosion can occur. Once the integrity of the insulation board is compromised problems can occur with temperature survey and damage to the hot zone outer cage likely.

The extensive use of CC plate (usually 1.5 mm thick) as a sacrificial skin / barrier has seen labour times in fitting reduced improving hot zone reline time.

A very hard wearing face is achieved offering protection from gas erosion and accidental damage and the use of CC strips covering the joints of the sacrificial skin offer a major improvement in hot zone longevity. With CC plate sizes available in sheets of 3,000 mm x 2,000 mm most sides of the hot zone can be covered in one sheet preventing any unnecessary joints.

Should the hot face get coated by chrome build up this can be lightly scraped off and vacuumed out. Build-up of chrome can result in arching and shorting between elements and fixings.

CC plate sacrificial skin coupled with CC profile edge protection can add many years onto the lifespan of the hot zone and keep hot zone maintenance to a minimum.

**CC L- & U-PROFILES**
CC profiles are used extensively to protect all apertures of the hot zone including bung and gas grid apertures and also door front leading edges. The combination of L- & U-profiles can be used to replace most molybdenum edge shield protection. The use of profiles greatly reduces damage by gas erosion and accidental damage and provides a hard wearing sealing face.

Any round apertures (bung or bull’s eye) in the hot zone are converted to flat sided to enable the use of U- or L-profiles to hold sacrificial skin in place and to prevent gas erosion.

Any round doors are converted to flat sided so CC edge profiles can be used. This approach helps to protect the edge of the door from accidental damage or gas erosion and gives a hard wearing sealing face.

With L- and U-profiles being readily available in longer lengths aperture edge protection is made simpler by the use of one piece edges. With increased widths available to accommodate sacrificial skins all round protection can be added to any leading edge or application.

The use of CC profiles for edge protection coupled with CC sacrificial skin has seen hot zone life increased considerably.

**THERMOCOUPLE FEED THROUGH**
All survey and load thermocouple ports are protected by removable plugs manufactured from CC or graphite products to prevent damage to the insulation by the constant inserting and removing of the load and survey thermocouples. The overtemp and control thermocouple ports are always protected by graphite bushes.

Once the plug becomes damaged these can be readily replaced preventing on-going damage to the insulation. Therefore not the complete insulation, front edge protection of the base and sealing face has to be re-newed (Fig. 4).

Another option is to have different designed plugs for different applications available. For example one for the standard temperature monitoring during normal production, and another with more feed through possibilities for monthly general functionality checking.

**GRAPHITE PAINT**
All edges of insulation board (even edges protected by profiles) are painted and cured with graphite paint to prevent damage and wear by gas erosion. The curing of the paint has proven to reduce pump down times on bake-out
due to outgassing. All joints in barrel stave construction hot zones are also painted and cured.

**FABRICATED OUTER CAGES**

With most companies trying to keep furnace downtime to an absolute minimum, a complete all new manufactured hot zone outer cage can be supplied fully insulated allowing the existing hot zone to be removed and the new one installed within a few days. This approach sees the furnace downtime reduced from some 2 to 3 weeks for a reline to an existing outer cage to that of 2 to 3 days whilst the new one is installed and baked-out.

One of the main advantages to manufacturing a new outer cage is that the existing outer cage can be repaired and even relined and stored as a spare should anything happen to the installed hot zone. This approach is useful for customers with only 1 or 2 furnaces where they cannot afford to lose a furnace for up to 3 weeks for reline.

**GRAPHITE HEATER AND HEARTH SETS**

All relines are offered with complete top quality graphite heater and hearth set assemblies. Arrangement drawings of the heater and hearth sets are supplied with the hot zone documentation listing individual spare parts numbers for ease of replacement of spare parts. Complete traceability of all materials fitted within the hot zone is available.

**SAFETY AND HEALTH**

When disassembling a worn out hot zone, lots of dust from the dissolving insulation occurs containing deposits from every heat treated material. For a skilled disposal and to secure the health of every involved person, a converted spray booth extracts the particles in addition to the personal protective equipment (Fig. 5).

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Fig. 4: “Thermocouple feed through”-plug  
Fig. 5: Stripping booth

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