Maximizing Ceramic Furnace Roll Performance

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Session 7

Abstract

While ceramic roller properties and dimensional specifications are critical to the glass tempering process, many product and process variables influence roller performance and glass quality. The manufactured quality of the roller is essential, but the environment in which the rollers operate and the processes and procedures practiced before and during tempering directly influence the life and performance of the rollers. The combined influences of the roller quality, the environmental effects on the rollers and the roller-to-glass interface, and the methods and frequency of cleaning the rollers directly relate to the life and cost effectiveness of the rollers. These influences ultimately effect the productivity and profitability of the glass tempering operation. Additionally, scientific identification of microscopic defects in tempered glass is essential to isolating the cause and resolution of such defects.

Introduction

Maximizing ceramic furnace roll performance requires an understanding of the total tempering system. This presentation addresses the critical properties and specifications that are required of fused silica ceramic rollers and the influences of the glass tempering plant environment on the rollers. Roller maintenance and cleaning methods are discussed along with methods for identifying microscopic defects in glass using optical microscopes, scanning electron microscopy, and energy dispersive spectroscopy.

A comprehensive understanding of the fused silica rollers, the glass tempering environment, the glass tempering furnace, and the interaction of each of these systems will improve roller performance and the productivity of the glass tempering operation.

Ceramic Furnace Rollers

The History: The first fused silica rollers were introduced to horizontal tempering furnaces in 1972. Since their introduction, Vesuvius Zyarock™ brand fused silica roller applications have expanded into float glass annealing lehr applications. Roller manufacturing and size capabilities have increased from the original 32mm (1.25in.) diameter to over 305 mm (12in.) today. Length capabilities also increased from 1.14 meters (45in.) in 1972 to over 6.25 meters (246in.) today. Zyarock™ rollers have effectively replaced asbestos and steel rollers in horizontal glass tempering furnaces.

The Material: Fused silica is uniquely qualified for tempering roller applications due to its physical and chemical properties. It has a non-crystalline, amorphous structure with very low thermal expansion, low thermal conductivity, and a very high resistance to thermal shock. It is compositionally a glass (SiO_2) which is inert and resistant to corrosion, making it very compatible with tempered glass.

Manufacturing: There are many critical steps in the manufacturing process that can and will effect the performance of the fused silica tempering rollers. The process requires tight controls from the raw materials through the casting and firing processes to produce a homogenous and thermally stable blank.

The blank quality will directly effect the surface finish, the strength, and the hot TIR of the finished roller. TIR is very critical especially when the rollers are at operating temperatures. An inferior roller blank may have a higher thermal expansion

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resulting in bow or warp at tempering temperatures. The blanks are machined with diamond tooling to achieve the tight tolerances of the finished roller.

Surface finishes are critical to the roller-to-glass interface and effect the heat transfer from the rollers to the glass. Rollers may be polished, textured, or spiral machined. The surface finish specification may vary with each furnace manufacturer. Be certain that replacement rollers meet the OEM specifications.

A variety of end cap designs are available depending upon the application temperature, furnace design, and drive system. These include popular RTV silicon bonded caps, custom designs, patented high temperature caps for use up to 750°C (1380°F), and for certain furnace designs, rollers without end caps. The end caps should not induce mechanical stress on the ceramic. They must be concentric to the roller to assure good TIR and the attachment method must be carefully considered.

The Quality: To assure the quality of your rollers, all Vesuvius manufacturing locations are Quality Assured ISO 9001. We recommend that all specifications be confirmed in writing and preferably with a detailed drawing. Certified quality inspection reports for each roller are available. It is suggested that incoming inspection be conducted on rollers if they are not purchased from an ISO certified supplier.

The Environment

The manufacturing environment and production practices influence the tempering operation, specifically the roller life and performance. Plant cleanliness is of highest importance. Dirt and dust that is on the glass or that passes into the furnace cavity will deposit on the rollers. This debris can result in bottom surface mechanical damage or it can be picked up and re-deposited onto the glass. The sources of this dust seem endless.

Glass Seaming & Fabricating: While glass seaming and fabricating can be significant sources for dust, the quality of these operations is also critical. Edge work must always be complete, smooth, and free of chips or small shards protruding from the glass, as they will break away during the heat treating process. These particles may stick to the rollers and result in bottom surface defects. When viewed by scanning electron microscopes (SEM), the defects are bottom surface break outs or chips in the glass *"Figure 1"* and deposits on the glass surface *"Figure 2"*. Always check the quality of the edge work, seaming, and drilled holes, and be certain that the glass is clean.

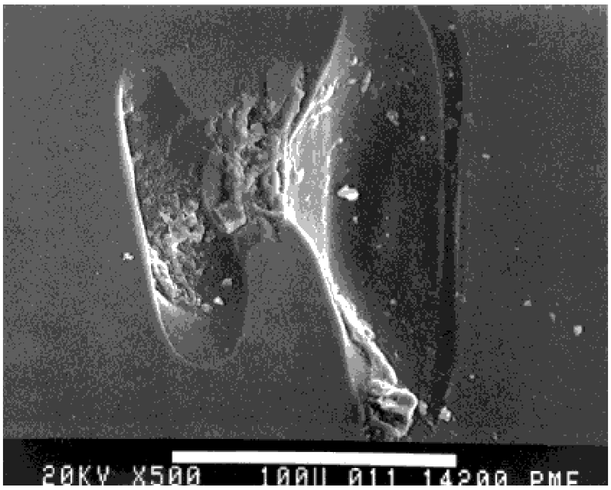

Figure 1. SEM image at 500X of bottom surface mechanical damage from glass debris on rollers.

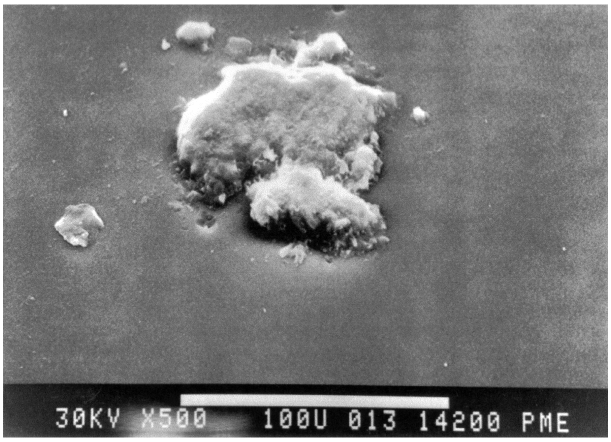

Figure 2. SEM image at 500X of bottom surface glass deposit.

Plant Dust Control: Debris and airborne dust in the tempering plant will cause defects in the glass and limit the effectiveness of the rollers. Debris may be carried into the furnace from different operations such as silk-screening, painting operations, and fabricating. Paint that is on the edge of the glass may drip on the rollers. Airborne paint can deposit on the rubber rollers in front of the furnace and track into the furnace cavity. Ceramic based frit paint bonds to the fused silica rollers and can not be washed from the roller surface. Paint defects on glass may appear as white haze or scuff marks while it is typically a deposit that can be viewed by SEM *"Figure 3"*. Energy dispersive spectroscopy (EDS) reveals the unique components of the paint including lead and chromium.

The Glass Washer: Effective use of the glass washer is critical to every tempering operation. The glass should be washed just prior to tempering. Washing the glass and staging it for extended periods of time before tempering is ineffective. Dust collecting on the glass will be carried into the furnace. The glass washer must

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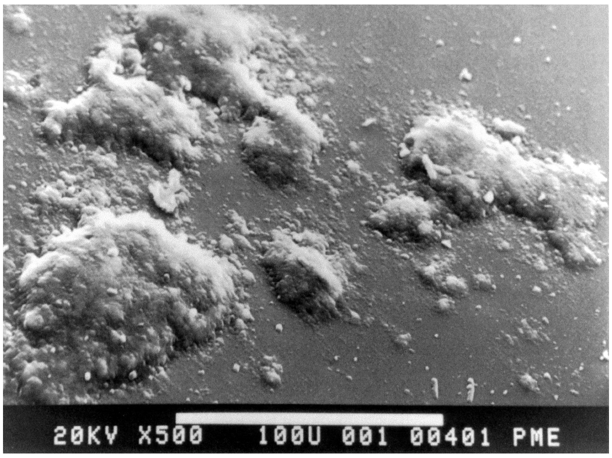

Figure 3. SEM image at 500X of paint deposit on glass.

be operating properly with the detergents, brushes, and rinse water at the manufacturer's recommended settings. Maintenance of the glass washer is equally important to ensure that the glass is clean and without residue or debris that will be carried into the furnace. Certain materials used to separate the glass are difficult to remove if the washer settings are not correct. These defects may appear as chips under an optical microscope but under SEM they are deposits *"Figure 4"*. Energy dispersive spectroscopy (EDS) shows the spectrum of a high carbon component

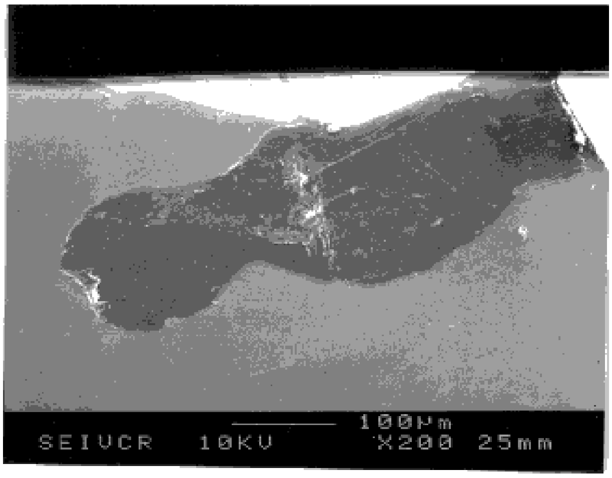

Figure 4. SEM image at 200X of glass defect from separation media that was not washed off of the glass prior to tempering.

typical of Lucor™ "*Figure 5"*. Proper settings and strict adherence to the maintenance schedules of the glass washer will minimize certain glass defects and protect the rollers from contamination.

The Tempering Furnace

Cleanliness continues as the fundamental theme for optimizing the life and performance of the Zyarock™ fused silica tempering rollers. Several sources of contamination can be generated within the furnace. Glass tempering

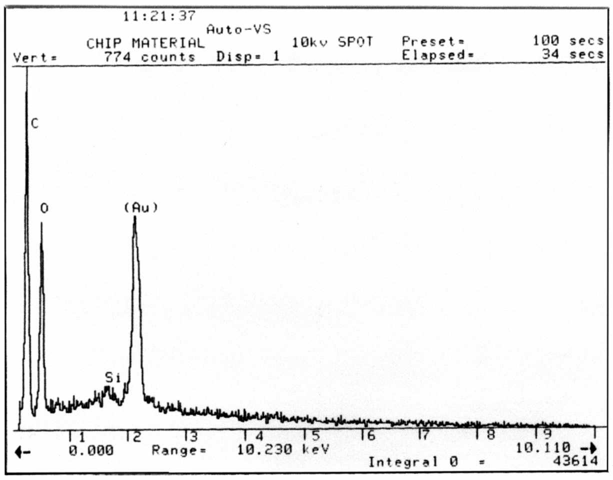

Figure 5. EDS spectrum of deposit shown in figure 4.

furnace operators are encouraged to consult with the furnace manufacturer for maintenance schedules and the proper methods for handling refractory insulation, roll seals, heating elements, and Sulfur dioxide.

The Fiber Insulation: This is one of most common and prolific sources for glass defects *"Figures 6 & 7"*. The furnace cavity must be kept

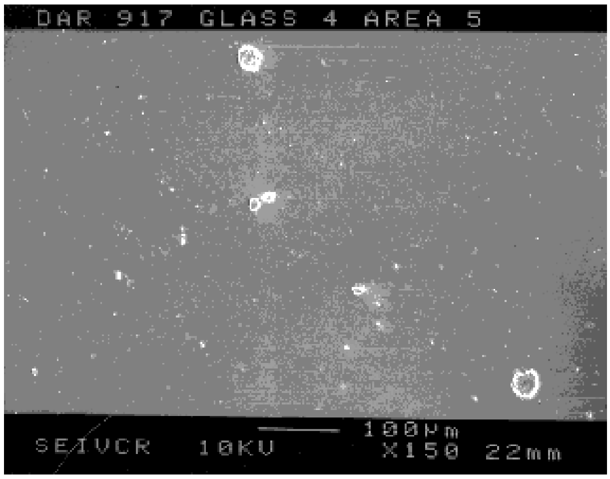

Figure 6. SEM image at 150X of refractory dust on glass.

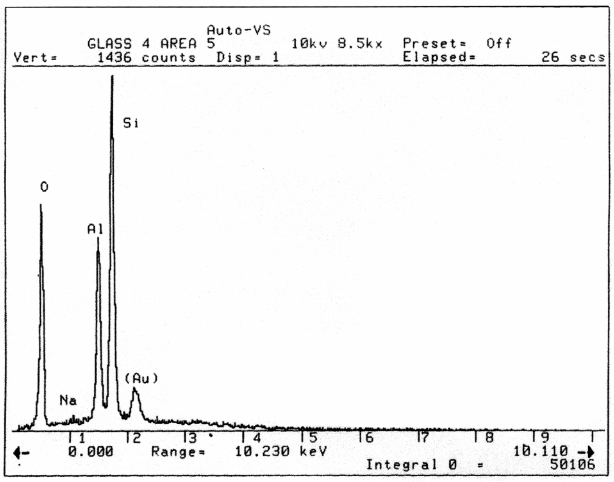

Figure 7. EDS spectrum of alumino-silicate refractory dust from fiber insulation on the glass as seen in figure 6.

free of refractory fiber dust. This dust is often created when furnace maintenance is performed, although it may also develop as the fiber degrades with time and temperature. The detrimental effects of refractory fiber contamination are compounded in the presence of aspiration and forced air convection, which stirs up the dust.

The Roll Seals: The roll seals are important to maintain heat balance in the furnace, energy conservation, and to protect the roller end caps, furnace drive, and bearings. Many roll seals are manufactured with refractory fiber insulation that is surface hardened. The roll seals may produce dust if they are broken, damaged, or worn. Any dust should be vacuumed away and broken roll seals immediately replaced. Plugging gaps or holes in the roll seals with bulk fiber insulation is not recommended, as it may introduce dust into the furnace cavity. Alternative seal materials are available including Zyarock Mousse™, a low density, hard fused silica refractory offering excellent thermal insulation, matched thermal expansion to the rollers, and elimination of the alumino-silicate fiber contaminants.

The Heating Elements: Maintaining the heating elements and other metallic components, and following the OEM furnace builder's specifications for replacements may prevent metallic contamination in the furnace cavity and on the rollers. Certain metal alloys or failure to properly install or maintain the heating elements may result in metal contamination on the rollers and on the glass *"Figures 8 & 9"*.

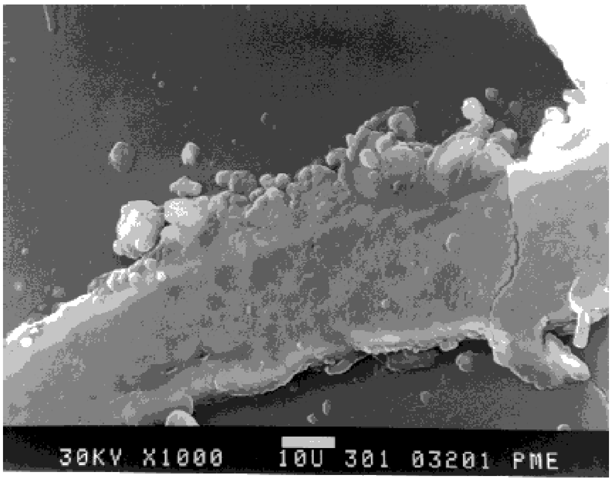

Figure 8. SEM image in the compositional mode at 1000X of a metallic deposit on glass.

The Sulfur dioxide: SO_2 is useful as a dry lubricant to form a coating on the glass and a barrier between the glass and the rollers. Often build up or debris on the roller surface will leave an impression or defect in the glass surface. The SO_2 provides the barrier to prevent or minimize

CHEMICAL ANALYSIS

SEM - EDS

FLAKES		CHATTER	
Fe	95.8%	Fe	75%
Si	1.3%	Cr	16%
Pb	1.2%	Ni	9%
Cu	0.6%		
Cr	.2%		
Zn	.2%		
Sb	.2%		

Figure 9. Chemical analysis by EDS of metallic contamination on glass. "Chatter" chemistry is from figure 8.

defects. However, sulfur dioxide reacts with the sodium ions in the glass at elevated temperatures to form sodium sulfate (Na_2SO_4). Excess usage of SO_2 leads to the formation of sodium sulfate deposits or nodules on the rollers. While these deposits are water soluble, the nodules may pull out grains of fused silica from the roll surface leaving pits in roller. The pits have more surface area and become the sites for more build up on the roller surface. Sodium sulfate nodules can transfer from the rollers to the glass surface resulting in defects *"Figures 10 & 11"*. Limited use of SO_2 or dosing the gas often reduces the frequency and the concentration of sodium sulfate nodules.

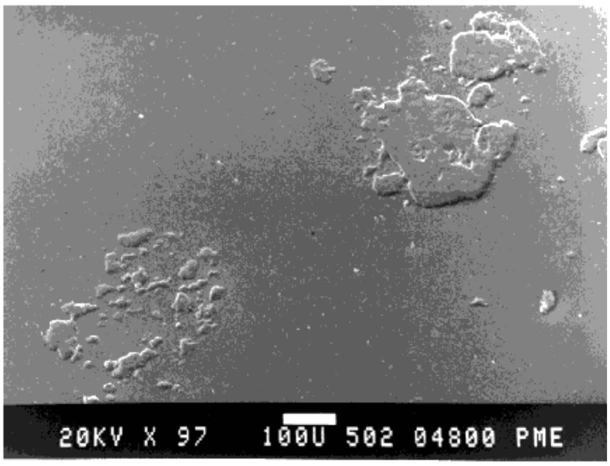

Figure 10. SEM image at 97X of sodium sulfate deposit on glass.

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CHEMICAL ANALYSIS

SEM - EDS

	SAMPLE 1	SAMPLE 2
S	48.51%	38.65%
Na	34.62%	25.84%
Si	3.59%	19.11%
Ca	4.25%	6.55%
P	4.43%	3.49%
Al	1.02%	2.65%
Cr	2.27%	0.44%
Fe	0.82%	1.19%
K	0.44%	1.18%
Ti	0.00%	0.90%

Figure 11. Chemical analysis by EDS of sodium sulfate deposit as seen in figure 10.

Roller Cleaning and Maintenance

The ceramic rollers should only be washed with water, never use detergents! Detergents will chemically react with the rollers, resulting in devitrification and roller failure. Due to the extremely low thermal expansion, the rollers can be washed hot. Glass debris on the roller surface can be thermal shocked off of the rollers when cold water is properly applied to a hot roller. Precautions should be taken to prevent the end caps from getting hot during the cleaning process. Rollers can also be effectively cleaned at room temperature. Lint free towels and certain abrasive pads such as 3M's Scotch Brite™ are effective. The rollers should be dried following cleaning. If the rollers are soaked with water and heated too quickly, steam may develop in the roller and cause it to fail.

Other cleaning methods include the use of tack cloth to remove surface dust. Sandpaper can be used, but should be avoided if possible. Sanding may induce waves or an out-of –round condition to the roller surface. On certain rollers, the surface specification requires a textured finish. Sanding the rollers may remove the finish and polish the surface. If sanding is required, take great care and be absolutely certain to avoid introducing the dust into the furnace environment.

The frequency of how often rollers should be cleaned varies greatly and is usually determined by the cleanliness of the tempering environment. As discussed throughout this presentation, the plant environment, furnace cleanliness, fabricating practices, glass cleanliness, SO_2 usage, etc. will influence the roller cleanliness. There are methods and measures for determining the cleaning frequency for each furnace.

Refurbishing may also be performed on rollers that have excessive surface build up and a moderate amount of surface damage. Usually this involves re-machining the rollers and removing up to 0.13mm (.005 in.) from the diameter. Before proceeding, consider the TIR of the rollers, wear, and end cap condition. A roller with excessive TIR may look better after refurbishing, but it may not perform better. Refurbishing should include 100% inspection of the rollers, surface reconditioning to the OEM specification, end cap replacement if necessary, and final inspection. It is recommended that rollers be re-machined only one time to avoid significant diameter changes.

Summary

Maximizing the performance of ceramic furnace rollers requires a total systems approach. Roller quality and stability are essential as are the cleanliness of the factory and the furnace, the operating practices, and glass cleanliness. Defects in tempered glass can usually be identified, isolated, and resolved through the use of optical microscopy, scanning electron microscopy, and energy dispersive spectroscopy.

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