Ceramic Heat Shields

Precision-Made Protection

Ceramics protect gas turbines from scorching combustion gases. By developing protective materials and production processes, Siemens has gained a competitive advantage.

At the center of a candle flame, where the soot particles glow most brightly, the temperature reaches 1,000 to 1,200 degrees Celsius. However, for a Siemens Ceramic Heat Shield (CHS), the singing heat of a candle’s flame would be little more than a cool breeze. Such heat shields must be capable of withstanding temperatures of 1,500 degrees Celsius. That’s the temperature reached in the interior of the annular combustion chamber of a gas turbine — and therefore, on the hot side of the ceramic cladding, which consists of up to 500 individual CHS tiles.

On the “cold” reverse side, in contrast, the temperature falls to approximately 600 degrees. “Therefore, the insulating effect provided by this four-centimeter-thick ceramic insulation amounts to around 900 degrees,” explains Vasilios Papadopoulos, Production Manager CHS at Siemens Power Generation (PG) in Berlin. “Without this protection, the metal walls of the combustion chamber would rapidly melt, and the machine would be destroyed instantly.”

In addition to the heat, the mechanical stresses inside a gas turbine combustion chamber are also extreme. The gas, rushing by at speeds of up to 100 meters per second and resembling a category F4 tornado — the second strongest — howls through the combustion chamber, constantly attacking the ceramic. However, a CHS can withstand it all — even though its operating conditions are tougher than those faced by a space shuttle. “The ceramic heat shields of a space shuttle are extensively inspected following every launch and landing,” says Dr. Holger Grote, materials expert and team leader CHS at PG in Mülheim an der Ruhr. “In contrast, our machines have to undergo many thousands of operating hours before their components can be inspected.”

**In-house Production.** Over the years, gas turbine performance and efficiency has increased continuously (p. 50). This has been primarily achieved by notching up combustion chamber temperatures. As a general rule, the higher the temperature, the higher the performance and efficiency of the turbine. For the same electrical power, less natural gas is required and consequently, less carbon dioxide is produced. “Of course, as a result, the requirements for the heat shield also increase,” says Papadopoulos. “Before 2006, we were still purchasing all our CHS units from external companies. However, our suppliers’ development times were rather long. They were not able to keep up with the speed of innovation of our gas turbines.” That was also one of the results of the “Value Generation Program,” launched by PG in 2002. “Back then, we compared our own competitiveness with that of companies such as General Electric and, unlike our competitors, decided to get involved in the entire value chain associated with the fully ceramic components,” says Grote.

Plans called for the ceramic heat shields to be produced and optimized in-house. To realize this aim, Siemens set up a materials testing center in Mülheim. “The heart of the facility is the special test rigs for thermal and thermomechanical characterization of the ceramics. From 2003 to 2005 we studied a very wide variety of different material combinations,” says Grote. “We tested how well the ceramic material performed at 1,500 degrees Celsius, for example. After two years of research, one material clearly emerged as the top candidate. It’s more robust than the ceramics that were originally used, and holds up better under the stresses of temperature changes — while also having a longer service life. Those are all very attractive characteristics for the customer, because a CHS..."
Unmatched Efficiency

The world’s largest turbine, with an output of 340 megawatts, will enter trial service in November 2007. In combination with a downstream steam turbine, it will help ensure that a new combined cycle power plant achieves a record-breaking efficiency of more than 60 percent when it goes into operation in 2011.

that remains intact longer also doesn’t have to be replaced as often, which reduces plant maintenance costs.”

But the CHS wasn’t all that was newly developed. The entire production process also was revamped. Production at the Berlin facility began in March 2006, after a record-setting construction period of only 12 months. “We’re using a process that’s unique worldwide. It includes producing the CHS material from raw materials in quantities precise to the gram, processing the material using special forming equipment, and firing the ceramic heat shields. The result is a precision-crafted CHS — with maximum variances in length and width of four-tenths of a millimeter,” says Papadopoulos. “That’s a key advantage because the external suppliers use a different process to produce their heat shields, which then require reworking — and anyone who has ever reworked a ceramic knows how much work is involved.” Each individual heat shield is painstakingly inspected prior to delivery, and a shield that displays even the tiniest of fissures, for example, will be rejected. “Siemens also created a Total Quality Management System for this production line, which further improves the availability and safety of our gas turbines,” reports Grote.

**Tailored Production.** If a CHS displays damage, the cause can quickly be found. That’s because each heat shield bears a number that designates its production process, in addition to ensuring the shield’s traceability. Later, each individual heat shield is also documented at PG in Berlin during “stoning,” which is what specialists call the process used to painstakingly fit the CHS into the annular combustion chamber. The specified clearance between the two is about 1.4 millimeters, with a maximum tolerance of one-tenth of a millimeter. “Here we clearly see the benefits of the high-precision production process,” says production chief Papadopoulos. But the greatest advantage of the new heat shield — innovative CHS geometries — is still to come.

“In contrast to external suppliers, we can cast the CHS in an extremely wide variety of forms. This means they will be suitable for applications not only in the area of the combustion chamber but also in other gas turbine components,” says Grote. And the material itself also will be further improved to meet requirements in future generations of power generation plants. By the end of this year, the ceramic heat shields are to be enhanced with a corrosion protection layer, which will also be ceramic. As a result, the shields will be even more resistant to howling gases and scorching temperatures.

— Ulrike Zechbauer