and that carbon dioxide injection could account for 30% of that amount.

Nitrogen-based Carburization

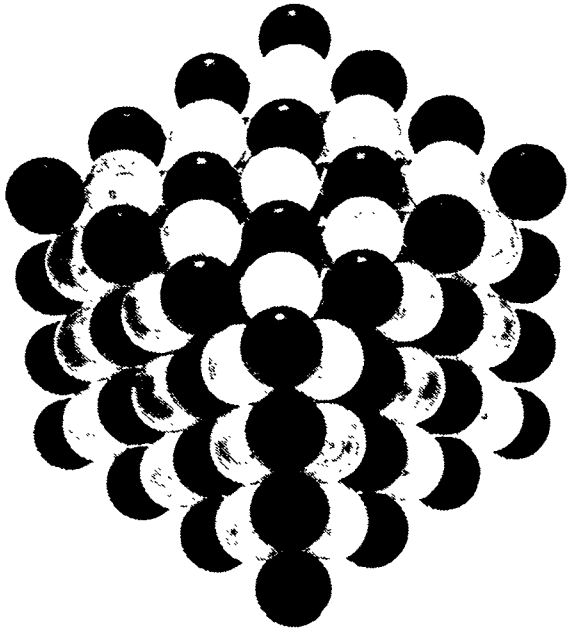
Carburization is a method of heat-treating steel parts in a carbon-containing atmosphere to give them improved strength, hardness, and resistance to wear. The conventional carburizing furnace atmosphere contains 20% carbon monoxide, 40% hydrogen, and 40% nitrogen. With DOE funding, a more energy-efficient nitrogen/methanol carburization process was developed and tested by Air Products and Chemicals. The process improves energy efficiency by increasing the carbon monoxide concentration in the furnace. This accelerates the rate of carburization and allows a reduction in the cycle time, thus saving energy. The advanced process is now operating in 2419 furnaces, saving 1.1 trillion Btus annually. Savings in 2010 are estimated at 2.3 trillion Btus annually.

High-Performance Slot-Forge Furnace

Conventional slot-forge furnaces, which are used to heat metal stock to about 2300°F prior to forging, are highly inefficient. Thermal losses can amount to about 90% of their energy consumption. These losses occur as a result of hot combustion gases escaping through the exhaust system and heat loss through the furnace walls, roof, and slot.

Under a DOE cost-shared project, Hague International developed a high-performance slot-forge furnace that minimizes these and other heat losses. The furnace incorporates certain design features that offer energy savings of 50% or more, while retaining the simplicity of a conventional slot furnace. The key feature is a ceramic recuperator that preheats incoming combustion air to 1500°F with furnace exhaust gases. Other energy-saving modifications include new recirculation burners, improved temperature and air/fuel ratio controls, slot closure doors that open only for metal stock insertion or removal, and lightweight furnace wall insulation.

As a result of this project, other manufacturers have developed similar furnaces that are even more energy efficient. Seven of the Hague-designed units were in operation during 1989, saving an estimated 0.4 trillion Btus. Projected savings in 2010 are 88 trillion Btus per year.



Nickel aluminide, the first ductile-ordered alloy that can withstand high temperatures, provides an alternative to ceramics in advanced, energy-conserving technologies.

Ductile-ordered Alloys

The development of advanced, energy-conserving technologies is constrained by the lack of materials capable of withstanding high temperatures, high pressures, and highly corrosive environments. However, development of metallic materials of ordered crystal structure with high-temperature capabilities has provided an alternative to ceramics in overcoming these material limitations. In particular, intermetallic compounds offer the advantages of excellent high-temperature strength, good response to work hardening, superior creep properties, and excellent oxidation and corrosion resistance for certain intermetallics (e.g., aluminides). However, using aluminides as structural materials results in poor ductility and fabricability, which are major problems.

Developed at the Oak Ridge National Laboratory through research supported by DOE, nickel aluminide is the first truly ductile-ordered intermetallic alloy that can withstand high temperatures. The new high-temperature alloy is moving rapidly toward commercialization, with five licensing agreements to date: Cummins Engine Company, for use in large diesel engine applications; Armco, Inc., one of the five largest steelmakers in the United States, for commercial