CuproBraze®

EXECUTIVE Report

Diesel engine manufacturers agree that clean diesel engines will require more complex turbochargers and heat exchangers than in the past.

High-Temperature Strength of Charge Air Coolers is Crucial for Clean Diesel Engines

Governments around the world are pressuring the makers of diesel engines and heavy-duty trucks to meet increasingly stringent emissions requirements for particulate matter (PM), oxides of nitrogen (NO_x), nonmethane hydrocarbons (NMHC) and other pollutants.

The US EPA's standards for 2007 represent a 90 and 95 percent reduction in PM and NO_x, respectively. By comparison, the 2004 standards represent only a 50 percent reduction based on today's standards [Ref. 1, 2]. The 2007 emission standards include PM reduction to 0.01 grams per brake-horsepower-hour (g/bhp-hr), NO_x reduction to 0.20 g/bhp-hr and NMHC reduction to 0.14 g/bhp-hr. (Divide these numbers by 0.746 kW/hp to obtain emissions values in terms of grams per brake kilowatt-hour.)

Clean Engine Technology

According to the EPA, these emission standards are feasible using catalyzed diesel particulate traps, NO_x adsorbers and various other diesel technologies, some of which are discussed in Section III and in the Regulatory Impact Analysis (RIA) of the rule. Original equipment manufacturers are not limited to these technologies and they don't have to use these technologies; they just have to meet the emissions standards.

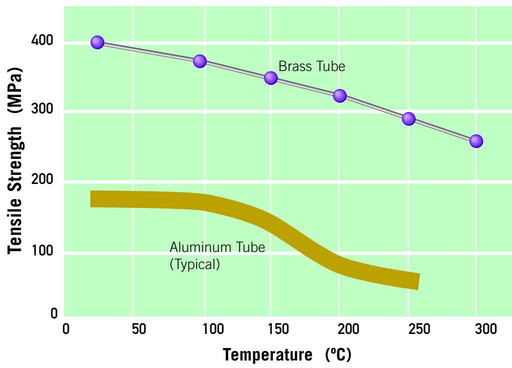
Most diesel engine manufacturers agree that clean diesel engines will require more complex turbochargers and heat exchangers than in the past. More heat at higher temperatures will need to be removed to gain control over the combustion processes.

One widely publicized technology, exhaust-gas recirculation (EGR), uses exhaust gas as an oxygen-depleted gas to be partially recirculated back to the intake manifold and into the combustion chamber. In this manner, NO_x emissions can be reduced because too much oxygen results in high combustion temperatures that produce oxides of nitrogen.

The exhaust gas needs to be cooled by an EGR cooler and then compressed by the turbocharger and perhaps cooled again. Meanwhile, the usual intake air is compressed by the turbocharger and cooled in the charge air cooler. At some stage, the exhaust gas and atmospheric air must be mixed.

Temperature Challenges

The aluminum tubes in current-generation charge air coolers are unreliable above 180 °C, and maximum specification temperatures



Brass tube retains much of its tensile strength at elevated temperatures. Aluminum tube experiences a severe drop in strength and is subject to fatigue cracking above 200 °C.

The International Copper Association, Ltd. (ICA)

is the leading organization for the promotion of the use of copper worldwide. The Association's twenty-nine members represent about 80 percent of the world's refined copper output, and its six associate members are among the world's largest copper and copper alloy fabricators. ICA is responsible for guiding policy, strategy and funding of international initiatives and promotional activities. With headquarters in New York City, ICA operates in 28 worldwide locations through a network of regional offices and copper development associations.

For additional information about the *Cu*proBraze process or ICA's *Cu*proBraze consulting services, please contact the International Copper Association at Alea@copper.org.

A *Cu*proBraze CAC withstands elevated temperatures better than an aluminum CAC, and the *Cu*proBraze design removes heat more efficiently.

for aluminum CACs typically are even lower. Serious problems occur at temperatures above 200 ºC at which the strength of aluminum drops 40 to 60 percent compared to its strength at 150 ºC.

As a conservative estimate, for example, aluminum tubes with a tensile strength of 150 mega-Pascals (MPa) at 150 ºC may experience a 40 percent drop in strength to 90 MPa at 200 ºC. As a result, aluminum CACs fail prematurely in the field when subjected to high temperatures. Tube cracking and tube-to-header joint failure are common failure modes of aluminum CACs. Temperature cycling and fatigue contribute to failure in both cases. These failures are well documented in the technical literature. [See, e.g., Ref. 3.] The failure modes of aluminum account for the main reasons why CAC operation has limited inlet air temperatures to below 190 ºC.

Brass to the Rescue

The introduction of *Cu*proBraze technology has greatly changed the design parameters for CACs and hence for turbochargers as well. A copper-brass CAC can withstand very high inlet temperatures, retaining much of its strength and avoiding metal fatigue.

Tensile strength for tube brass is more than 300 MPa at 200 ºC and still well above 250 MPa even at 300 ºC. Both tensile and yield strengths for tube brass and fin copper are provided in the "*Cu*proBraze Technical Manual" [Ref. 4]. The yield strength and the tensile strength represent the onset of plastic deformation and the maximum stress the tube can withstand, respectively. The tensile strength data for tube brass is reproduced here for 25, 100, 150, 200, 250 and 300 ºC because of its importance with respect to CAC design.

A useful interpretation of strength versus temperature data for brass versus aluminum is to calculate strength ratios at different temperatures. For example, brass tube is 1.75 times stronger than aluminum tube at room temperature, but it is 4 to 5 times stronger than aluminum at 250 ºC. Tube thickness should be specified using the high-temperature strength values. Clearly, the high-temperature strength of brass tube allows for more options in heat exchanger design.

High temperature performance is not the only reason to choose *Cu*proBraze for CACs. Another advantage is the lower airside pressure drop. It is estimated that a copper-brass heat exchanger will have a 20 to 30 percent lower air pressure drop compared to aluminum. Other heat exchanger applications in clean diesel engines may benefit from a same-sized copper-brass heat exchanger with higher heat rejection than an aluminum heat exchanger, or a smaller copper-brass heat exchanger with the same performance.

Conclusion

The good news is that clean-burning diesel engines will be nearly as clean as today's gasoline engines. If they can be made even cleaner, increased use of diesel engines in SUVs, minivans and light trucks can be expected. Consumers will also benefit from the greater fuel efficiency and durability of diesel engines compared to gasoline engines.

The bad news is that clean diesel engines will be more complex and hotter under the hood than ever before. Reducing both NO_x and PM emissions is complex because the typical approaches are contradictory. Lower combustion temperatures are needed to reduce NO_x emissions but higher combustion temperatures are required to reduce PM emissions.

Whatever type of clean diesel engines are developed in the next few years to meet the stringent reductions in emissions, *Cu*proBraze technology is likely to play a vital role as the material system of choice for advanced cooling systems and exhaust aftertreatment equipment. ■

References

1. The Environmental Protection Agency's proposal pertaining to diesel fuels and emission standards for heavy-duty vehicles is now a final rule, which was published January 18, 2001 in the Federal Register (pp. 5001-5193). The entire document is available in PDF or electronic-text format from the Federal Register Online via Government Printing Office (GPO) access (www.gpo.gov).

2. European Union, Japanese, California, Asian, Australian and South American diesel emission standards for various years are summarized on the Internet at www.dieselnet.com/standards.html.

3. "Long Life, Heavy Duty, Air-to-Air Charge Air Cooler," SAE Technical Paper Series 981974. Available online from Society of Automotive Engineers, www.sae.org, or order from SAE customer service at 1-877-606-7323 (North America) or 1-724-776-4970 (International) from 8 a.m. to 5 p.m. Eastern U.S. Time.

4. "*Cu*proBraze Technical Manual, Edition 3.1," available upon request from the International Copper Association.

COPPER International Copper Association, Ltd.

International Copper Association, Ltd.

260 Madison Avenue, 16th Floor, New York, NY 10016-2401

Tel: 212.251.7240, Fax: 212.251.7245