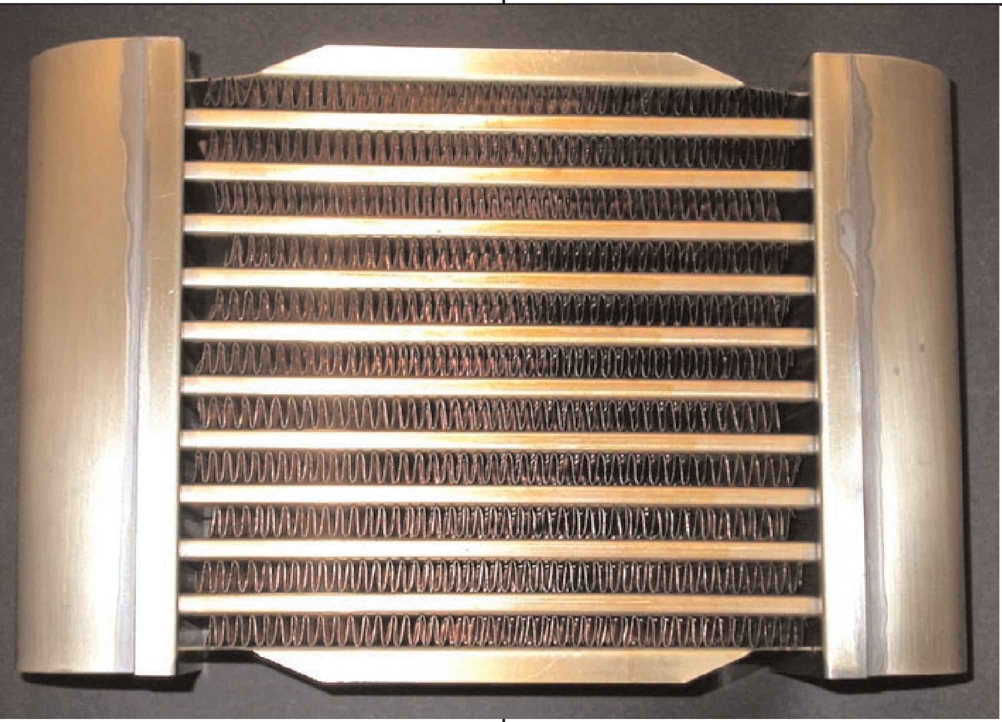
A CAC with extra header width reduces the maximum stress at the tube-to-header joint significantly.

New Concepts for Charge Air Cooler Designs

New materials technologies are sometimes slow to be adopted when existing materials are good enough. In other words, the new technology may be better than the existing technology, but the existing technology is so entrenched that it becomes difficult to change over to the new technology.



New charge air cooler design has one-shot brazed tanks.

As a result of legislation to reduce diesel emissions from heavy trucks, however, diesel engine makers are carefully reviewing the performance of the cooling systems within truck engines and, in many cases, an overhaul of the design is already happening or imminent.

Already, it is clear that *Cu*proBraze CACs are likely to come out on top in terms of elevated-temperature performance gains. Elimination of the pre-cooler clearly would result in a less complicated engine and a smaller footprint for the cooling system, compared to the alternatives. However, it would result in higher operating temperatures for the CAC, which would require the replacement of aluminum CACs with copper-brass CACs.

Diesel manufacturers are evaluating a variety of approaches to curtail emissions. A common solution is to carefully monitor and control the combustion process, maximizing hydrocarbon burning (thus reducing particulate matter), while minimizing the production of NO_x (oxides of nitrogen).

More about EGR

Exhaust gas recirculation (EGR) was established as an integral part of the effort to reduce NO_x emissions to meet the October 2002 levels required of some engine makers. Recently, hundreds of EGR systems as well as diesel-particulate filters were successfully installed on existing Swedish urban buses, giving 50 percent NO_x reductions and more than 90 percent particulate-matter (PM) reductions. While EGR is not the only technology available, it is certainly one of the technologies that will be used to reduce emissions this decade.

The principle of EGR is that the exhaust gas can be used as an oxygen-depleted gas to be mixed with the fresh, oxygen-rich air and re-circulated into the combustion chamber. As much as 30 percent of the new charge in the combustion chamber may be exhaust gas. In this manner, EGR allows for oxygen levels in the combustion chamber to be carefully controlled. Too much oxygen results in high combustion temperatures that produce oxides of nitrogen. Optimizing the conditions of combustion can greatly reduce NO_x formation, while still efficiently burning the diesel fuel.

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.

The 2007 EPA emission standards represent a 90 to 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.

The overall effects of the new emissions standards on diesel-engine design will be that more heat has to be rejected in the radiator, the boost pressures will be higher, and the charge-air temperatures at the inlet to the CAC probably also will be significantly higher.

Trouble Spots

An extensive study performed on aluminum CACs reported that they mainly fail from fatigue cracking at the joints between the header and the tubes. The high coefficient of thermal expansion of aluminum (23.6 µm/m °C compared to 19.9 µm/m °C for brass) exacerbates these strains due to thermal cycling. Nonetheless, the steep drop in tensile strength at high temperatures is the underlying reason.

New Copper-Brass CACs

Recent research on new designs of CACs has been directed at strengthening the tube-to-header joint. This research confirms that stresses on any CAC are most intense at the joints between the tubes and headers, regardless of the material systems.

The research simulated stresses that are due to thermal elongation, internal pressure, and bending torque from the inlet hose. Stress intensification was estimated using computer simulation with finite element technique.

The simulations show that stress gradients are most severe at the joints where the tubes enter the header. These stress gradients can be greatly reduced by changing the width of the header. A CAC with extra header width reduces the maximum stress at the tube-to-header joint significantly.

CACs with the extra header were then fabricated using the *Cu*proBraze process. In this new design, the tanks surrounding the headers were made of brass rather than cast aluminum.

The complete CAC, including the extra header and brass tanks, was fabricated using one pass through the *Cu*proBraze furnace.

Conclusion

Recent advances in materials, design and fabrication technology have demonstrated that copper-brass is a superior technology for mobile heat exchangers.

The development of new diesel engines to meet more stringent emissions standards has brought *Cu*proBraze into the spotlight as an alternative to brazed aluminum. CACs based on *Cu*proBraze have at least two major advantages over their aluminum counterparts. The first advantage is the smaller drop in air pressure for a CAC that otherwise offers the same cooling performance as an aluminum CAC. This feature can result in lower temperatures under the hood because more airflow is available for cooling downstream from the CAC. In this case, the better-performing copper-brass CAC can be directly substituted into the same footprint as the aluminum CAC.

Moreover, completely new cooling systems, designed to operate at elevated temperatures, are being investigated. Here, the strength of copper-brass at elevated temperatures and the deterioration of aluminum at those temperatures make copper-brass the only choice for a materials system. This decided advantage is expected to accelerate the adoption of copper-brass as the materials system of choice for mobile heat exchangers. ■

Stress at the tube-header joints can be reduced using new header designs. Stresses due to (a) narrow header width can be reduced with (b) extra header width and (c) an exta header.

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