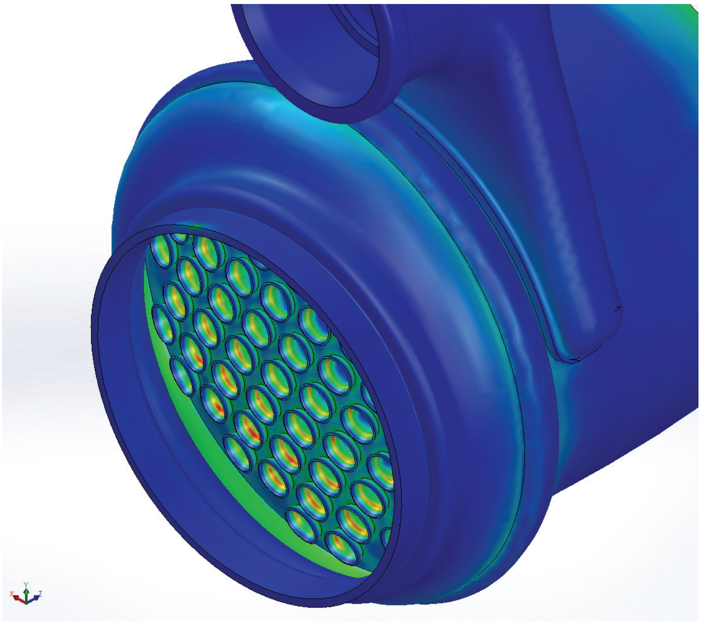
Alternative powertrain needs

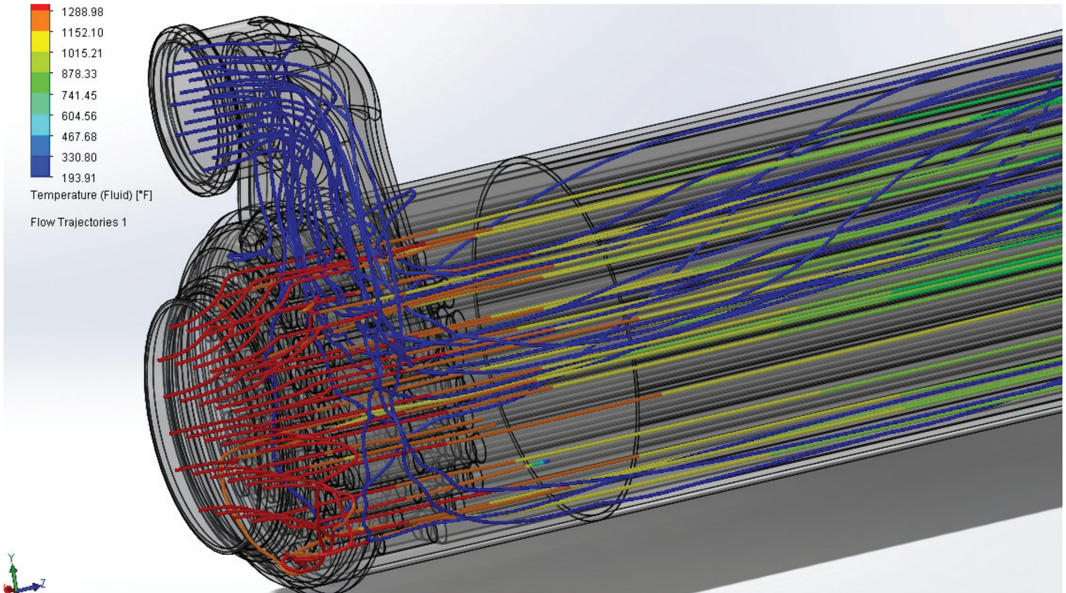
EGR coolers need to be even more durable in a world of natural gas engine development

Whether you believe that hydraulic fracking is a truly pioneering breakthrough or something that will create more bad than good, there is no denying that natural gas is becoming a highly abundant energy source. The expected dropping of prices, coupled with a relatively clean burn, make natural gas an attractive alternative for both accountants and environmentalists alike. It should therefore comes as no surprise that interest in natural gas engines for stationary as well as mobile applications has increased considerably in recent years.

Natural gas engines, just like other engines, have operating points where they are most efficient and operating points where they have the lowest emissions.



High stress areas on ID of tubes indicate area of thermal fatigue failure



CFD showing how exhaust and coolant change temperature as they travel through the EGR cooler

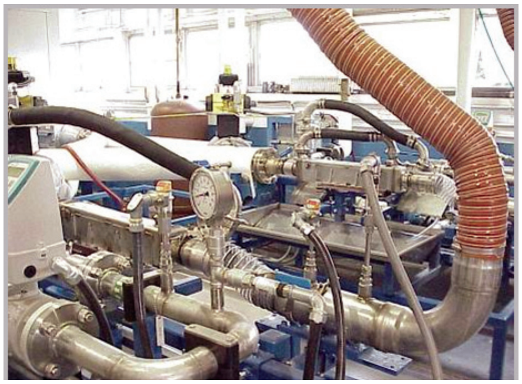
Unfortunately, just like any other typical engine, these points do not align. Over the past few years, engine manufacturers have been able to show that by using strategies that include cooled EGR, it is possible for both points to be brought closer together.

Natural gas engines that use these strategies represent a step up in the requirements for EGR coolers. The exhaust entering EGR coolers in diesel engines usually tops out at a very hot 650°C. Natural gas engines typically operate at a level that is 100°C higher. Because high exhaust gas temperatures are a major consideration in EGR cooler durability, raising the temperature by 100°C is a big deal.

As a company, Senior Flexonics believes that there are a number of things that are needed to successfully develop a natural gas EGR cooler that will operate in a harsher environment compared to its diesel counterpart.

A free flow of information and thoughts between the engine manufacturer and the cooler manufacturer is essential in cooler development. Each of these parties brings in their own expertise and capabilities, and by working together it is possible to realize the full potential of developing a cooler in an accelerated time. Either party working in a vacuum is susceptible to developmental hiccups.

Natural gas EGR coolers experience a great deal of thermal cycling during their life. Not only do they heat up and cool down during key-on and key-off stages, they also



Bench thermal fatigue testing

experience measurable thermal cycling events during operation. It is these transient thermal cycle events that ultimately lead to cooler failure. Steady state CFD and FEA results may not always relate to the transient events, but they do help to provide direction for the design. Through comparison, items such as coolant distribution, thermal hot spots and high stress regions can be greatly improved.

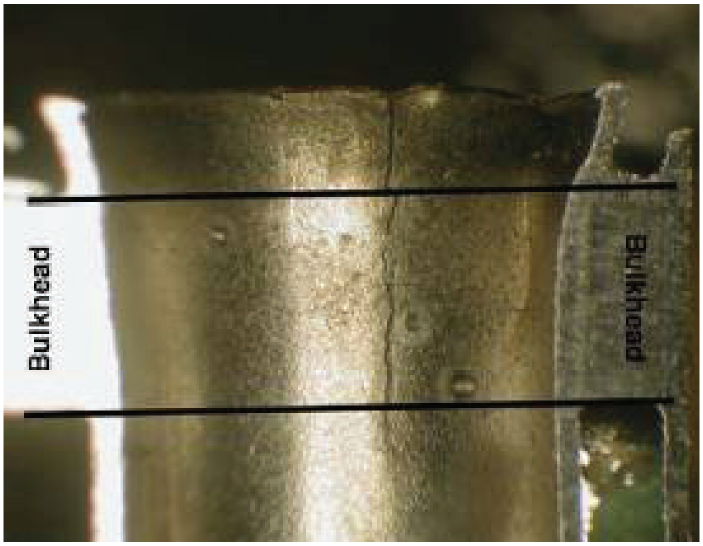
To determine real-world durability, the testing of natural gas EGR coolers on engine dynamometers, thermal cycle test benches and field trucks has to be undertaken. Thermocouples, pressure gauges and strain gauges can be mounted to the test sample to learn more about the design and the environment that the component finds itself in. Additionally, failed as well as surviving parts should be thoroughly examined to discover actual failure points, potential failure points and possible causes. As valuable as this testing is, the amount of time needed to perform durability testing is measured in weeks and months, making it difficult to evaluate more than just a small handful of designs.

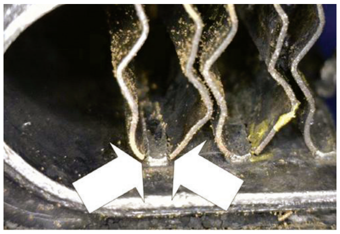
A more compressed method for evaluating durability is transient analysis, in which a time-dependent CFD is run with a cycle representing the worst the real world can offer. Metal temperatures at each time step are then transferred to an FEA package. Stresses, strains and other such phenomenon are then solved at each time step. All FEA results are given to an appropriate fatigue solver to discover the maximum alternating stress for each element over the entire time domain. Life is then calculated for each element based on its own maximum alternating stress.

Bringing design by analysis into play enables more designs to be evaluated in a much shorter time than physical testing would allow. In addition, this process also allows engineers to assess the possibility of secondary failure modes. Design by analysis cannot replace physical testing, but it can reduce the number of designs that need to be tested to just one or two.

The application of a solid method for evaluating designs for natural gas EGR coolers is important. Analysis shows that the 100°C increase in gas inlet temperature over a typical diesel engine can produce an 18% increase in the amount of stress that the natural gas EGR cooler experiences. Roughly speaking, this increased stress could cause the natural gas EGR cooler to fail at least two times earlier than its diesel equivalent.

Exploration and drilling techniques such as fracking are set to bring about an abundance of natural gas. In the end, natural gas engines represent an opportunity to have an efficient powerplant that uses this low-cost fuel. EGR coolers are part of an overall strategy to use natural gas efficiently and in an environmentally friendly manner.





Close ups of a fatigue crack in a tube (above) and fin tube fatigue (left)

However, the increase in exhaust gas temperatures brings with it an 18% increase in EGR cooler stress. As a company, Senior Flexonics understands that cooperation between engine manufacturers and their EGR cooler supplier along with testing and design by analysis are key in overcoming this high stress environment. Natural Gas EGR coolers require a thorough development effort, especially because temperature levels are extremely high.

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