High-pressure fuel rails

As legislation for cleaner energy and lower exhaust emissions becomes more strict demand for high-pressure fuel systems is steadily increasing

All over the world, legislation is being introduced that sets tougher regulations on emissions. In January 2015, China implemented China IV (NS 4) standard, which is equivalent to the Euro 4 emission standards. India is planning to implement Bharat Stage IV (BS 4) standard in April 2017, which is also equivalent to Euro 4. Although both of these countries lag behind other parts of the world, it is obvious that all nations are moving toward cleaner air, which continues to put the onus on suppliers of fuel systems to increase overall pressures and reduce costs. It also becomes increasingly important to build the fuel system in the local market. Globalization continues to create new opportunities while increasing the field of competitors.

Demanding engine applications need robust fuel rails that can withstand the strain – without costs spiralling out of control

In such a complex environment, successful manufacturers must be able to adapt quickly to stay ahead. The competitive edge resides in the manufacturer's ability to understand the customer and to take ownership of market drivers. With more than 100 years of experience in delivering innovative solutions, Senior Flexonics continues to demonstrate its ability to align resources and apply sound engineering to support fuel rail technologies in the automotive and diesel market.

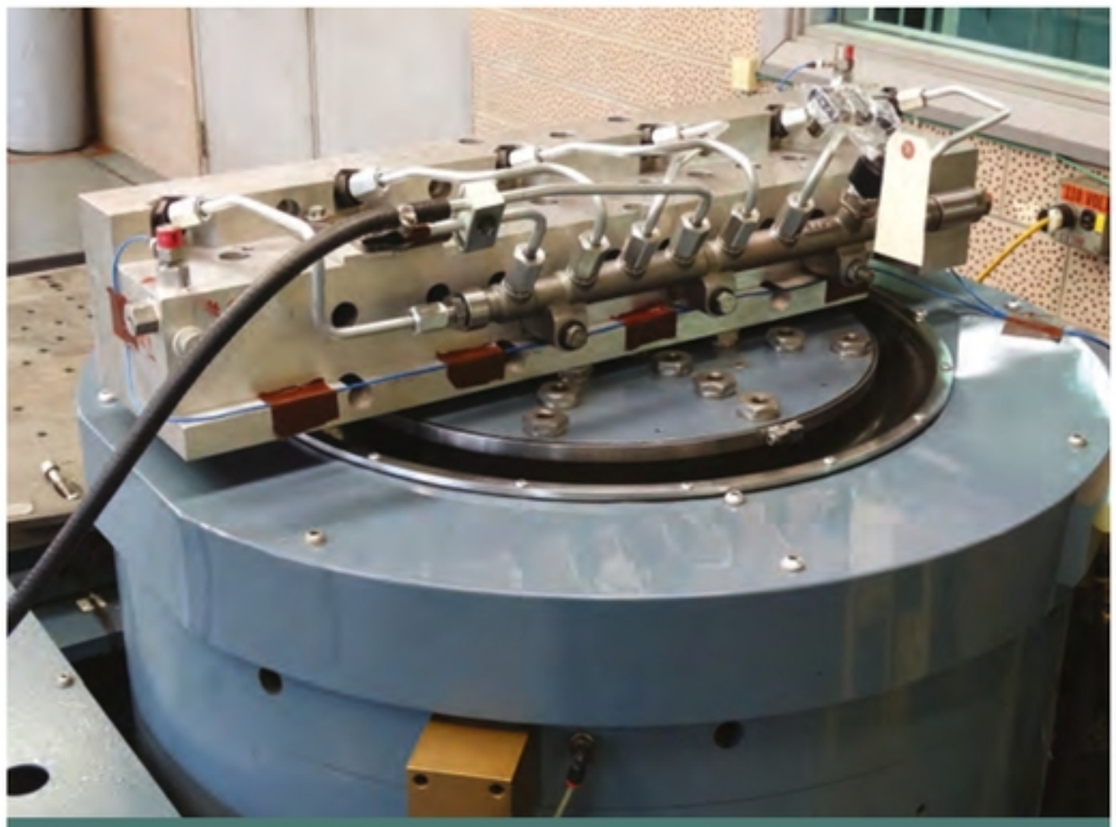
Heavy-duty diesel engine manufacturers typically require common rails that can operate between 1,800 and 3,000 bar, while the automotive manufacturers require gas direct-injection fuel rails, which need to operate in the 200 bar to 350 bar range. At these pressures, both material selection and fuel rail construction method are important to achieve the required durability. This is paramount to manufacturers of engines, but cost must not be ignored. Suppliers must take into consideration both of these key factors when developing fuel rails.

Senior has been developing and manufacturing fuel rails for more than a decade, and has manufactured welded, forged and brazed fuel rails for many different applications, which include heavy-duty and mid-range diesel engines, automotive engines, even natural gas engines.

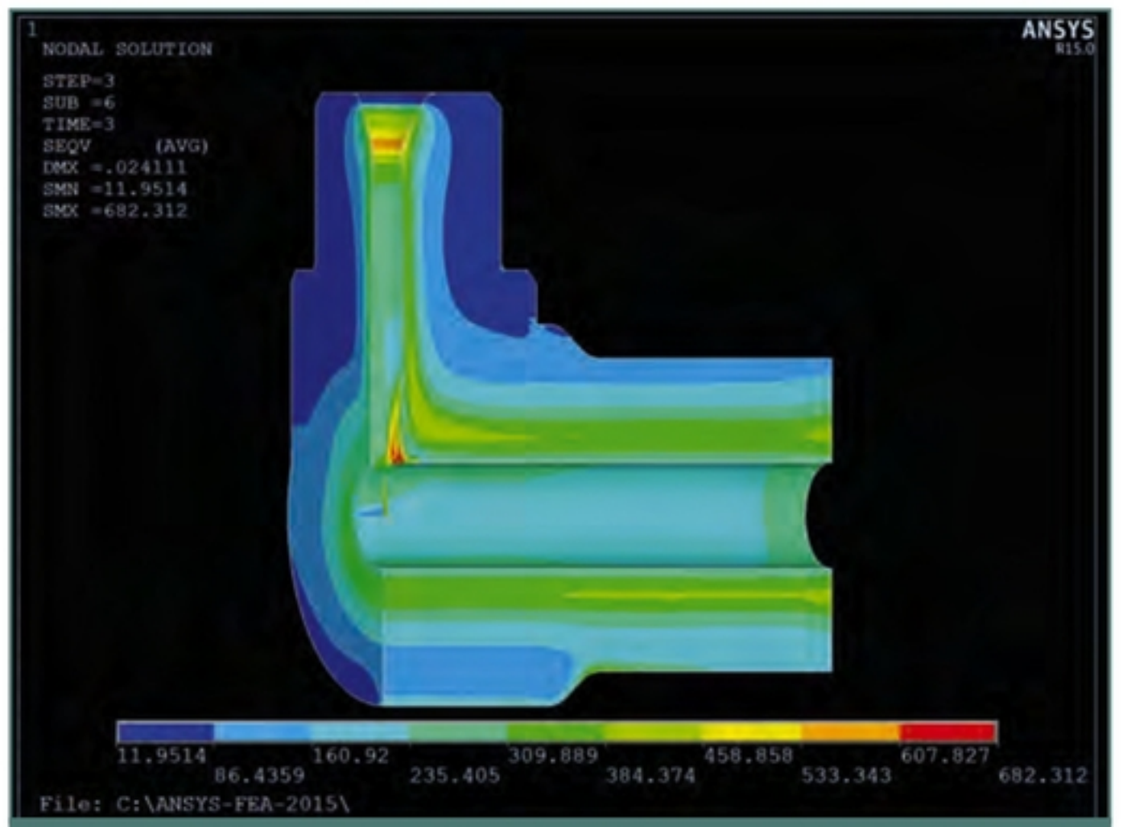
Laboratory testing of pressure fatigue on a forged rail. Senior Flexonics balances computer simulation and physical testing of actual parts to get optimum results

Senior Flexonics uses an effective customer-based approach through each phase of product design, development and realization. In-depth design reviews ensure all requirements and variables are considered and vetted. CAD models are used to validate design intent and interactions within the fuel system. Advanced FEA techniques are employed to evaluate rail designs against fatigue, loading, vibration and other environmental conditions.

In its designs, Senior Flexonics balances theoretical analysis and simulation with physical laboratory analysis and prototype builds to deliver cutting-edge solutions for rail technology. Engineers and technicians draw from their extensive knowledge of the automotive and diesel industries, and new ideas and concepts for fuel rails play out in versatile prototype labs. Within these facilities, new designs must meet rigorous pressure pulsation evaluations and multi-axis vibration testing that simulate the engine environment. Tensile, bending and



Lab setup for vibration effects on a forged rail simulates the engine environment



Results of non-linear finite element analysis of a typical cross hole on a forged rail

torque evaluations simulate forces from other components, as well as installation forces. Fuel rails must withstand these demands, and sealability must be maintained as leak tests are performed to maintain fuel system performance. A fully equipped prototype lab and metallurgy lab support fuel rail development, whether it be welded, brazed or forged.

Senior recently completed advanced development of a new forged rail. Typical forged rails currently in production do not see pressures in excess of 2,100 bar. The foundation of a high-performing fuel rail is good material selection. Senior developed a proprietary material specification to ensure that the characteristics of the as-forged rail exceeded typical forged rails. Senior considered the following material characteristics during material selection: cleanliness, toughness, hardness and machinability. Cleanliness is important to eliminate the potential for inclusions that may cause premature failure of the rail due to local stress risers. Toughness determines the overall strength of the rail and its ability to withstand high pressure. Hardness is important to ensure sealability between the fuel lines and the rail. It is also important to develop a material that does not require special heat treatment after forging. Finally, machinability is important to maintain surface finish requirements and improve equipment utilization.

The forging process itself is also important – fuel rails are typically long and slender, and this type of geometry is susceptible to warping during the cooling process. Warping cannot be tolerated due to gun drill requirements and overall fuel rail tolerance requirements. It is also important to consider the parting lines, which affect the flow of material during the forging and can ultimately affect the durability of the rail. Senior's design team worked countless hours along with the company's selected forging supplier to develop a design and process that could meet these demands.

Finally, methodologies to control internal radiuses and surface finishes along with autofrettage cannot be forgotten. Although these process are common across many manufacturers of fuel systems, the control of the processes is critical. Senior Flexonics has developed robust controls for these process, which translates into zero fatigue failures in the field. Taking all of this into consideration, Senior has made a breakthrough and recently designed and manufactured a forged rail capable of being used in a fuel system rated at 2,600 bar. This rail has undergone full durability testing and is rated to have less than a 1ppm failure rate.

Addressing complex problems and developing solutions requires an approach where all aspects of the business are innovative and driven by success. Creating this environment is what Senior Flexonics has been doing for the past century. Guiding principles focused on technology and human capital will propel advancements. Innovative fuel rail designs must also be flexible in order to support a variety of engine configurations. By integrating flexibility into the design and manufacturing process, design and prototype phases are more efficient, and result in a responsive structure that the customer can readily tap into. This approach also leverages the supply chain, providing improved cost benefits for the customer.

The company's flexible designs and responsive production cells reflect the commitment of Senior Flexonics' to lean manufacturing principles. Lean is not only a process that is used to improve efficiency on the manufacturing floor; it is a mindset that flows through the entire organization, from product development and through to manufacturing. The result is a team driven by continuous improvement that fosters and cultivates lean manufacturing and delivers exceptional products.