Customer Success Brief

fe-safe/TURBOlife™

Accurately predicting thermo-mechanical fatigue in exhaust manifolds

Jaguar's VDV system using fe-safe/TURBOlife™ enables rapid development and deployment of high temperature components, accurately determining performance at the design stage, to minimise both component and material testing iterations

Jaguar Land Rover

Challenges

- Accurately predict fatigue life in thermo-mechanical situations
- Integrate with preferred commercial Finite Element (FEA) software and internal robust design (DOE) system
- Develop cost effective designs that meet higher efficiency (high temperature) requirements

Key fe-safe/TURBOlife™ capabilities

- Direct import and easy data manipulation with Abaqus and other commercial FEA software
- The appropriate fatigue technology for high temperature applications in which both structural and thermal loadings vary and inelastic effects (creep) can be accounted for
- Easy-to-use results visualisation and software integration as a part of a larger design system

Conclusions

- fe-safe/TURBOlife™ predicted the location and number of cycles to failure with good correlation to test results
- fe-safe/TURBOlife™ fatigue life predictions are now fully integrated into a robust design methodology
- fe-safe/TURBOlife™ plays a key role in accurately determining performance at the design stage, minimising both component and material testing iterations
- fe-safe/TURBOlife™ helps to reduce overall development costs and timescales, as well as providing insight into identifying lower cost materials for production

Advancing a tradition of excellence and performance

Jaguar Land Rover is built around two great British car brands that design, engineer and manufacture in the UK. Jaguar Land Rover is part of Tata Motors, India's largest automotive company.

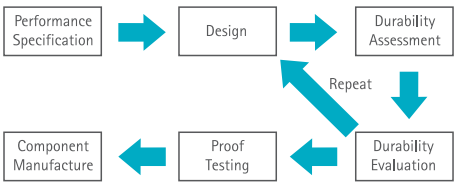
Always seeking to revolutionise their products and develop a class of vehicles around rigorous consumer expectations, from racing to safaris, Jaguar Land Rover continues to redesign and reinvent their vehicles.

In recent years the engine operating temperatures of cars, vans and heavy goods vehicles have been increasing because of European environmental legislation on emissions and the need to improve engine efficiency.

Recognising these demands, Jaguar developed a virtual design validation (VDV) process to streamline the manufacture and testing of prototypes by testing computer-modeled parts. Jaguar has achieved considerable success with a VDV approach for high temperature components in a new design of exhaust manifolds. This method of using standardised material data and computer-predicted performance of components provides a predictive design process which replaces a reliance on expensive and time-consuming component testing.

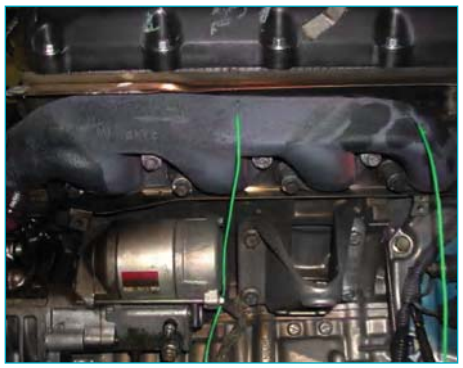
A more effective design and test process

The conventional design process involves repetitive prototype manufacture, testing and evaluation until a component can be manufactured. Jaguar's VDV process involves computer-based component performance specification, design, durability assessment and durability evaluation against the component performance specifications. A final single round of physical testing is then completed before the component goes into service.

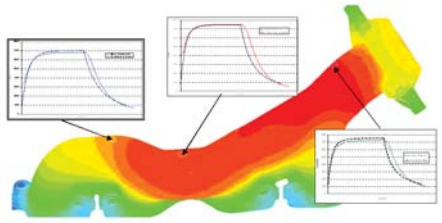


Real-world temperatures

Jaguar's VDV process starts by matching exhaust manifold metal temperatures on the test bed with those occurring during high speed running of actual vehicles. The aim is to simulate the test bed as an approximation of actual customer usage. Test bed temperature extremes, i.e. alternating maximum power and rapid cooling, are recorded in order to recreate the range of vehicle operation. Measured by multiple thermocouples, the heat generation feedback is used to select test bed engine speed, loadings and fuel consumption.



Advanced thermal imaging is also used to identify heat distribution to create a complex FEA model. Lab engineers predict the transient temperature distribution for the exhaust manifold over the test cycle and apply natural convection boundary conditions to the external surfaces of the manifold. Some modifications to the external heat coefficients are made to achieve a correlation between the predicted and measured temperature distributions. Finally, the transient temperature distribution is used as a loading condition for a transient structural FEA model of the manifold.



fe-safe/TURBOlife™ and FEA fatigue life prediction

A complex FEA model is required to correctly determine the stress distribution in the exhaust manifold, because joints are designed to slip in order to accommodate thermal expansion between the manifold and the cylinder head.

In this case, approximately 60 sets of incremental thermal load stress/strain data are applied through fe-safe/TURBOlife™. The predictive analysis process involves both FEA stress/strain analysis and durability assessment, accounting for fatigue, creep and corrosion.

The FEA is an elastic analysis, because the more complicated elastic-plastic-creep analysis would require rarely available material behaviour data. The material's inelastic aspects (plasticity and creep) are incorporated using algorithms developed by Serco Assurance from their experience in the nuclear industry. fe-safe/TURBOlife™ calculates inelastic strains and relaxed stresses from elastic analysis, and cyclic stress-strain hysteresis loops can be constructed to accommodate creep strain and also identify fatigue and creep damage.

Results

Jaguar's VDV process accurately correlated the physical prototype test with the software predictions, in both product life of the exhaust manifold (number of cycles to failure) and the location of the eventual failure.

Using fe-safe/TURBOlife™ for their design validation has enabled Jaguar to confirm an alternative material (high silicon molybdenum iron) for the exhaust manifold component, with advantages in cost and castability. Computer-based testing and analysis has provided a near-optimal design at an early stage in the design process, because Jaguar has been able to set up a design of experiments (DOE) where key parameters are varied and the impact on predicted manifold life can be assessed.

Summary

The Jaguar VDV system using fe-safe/TURBOlife™ enables a more rapid development and deployment of high temperature components, also helping to accurately determine performance at the design stage, minimising both component and material testing iterations. This in turn reduces overall development costs and timescales, as well as providing insight into identification of lower cost materials for production.

serco

fe-safe/TURBOlife™ has been developed in partnership with Serco Assurance. Serco Assurance has more than 40 years experience in collaborative research in thermo-mechanical and creep-fatigue damage mechanisms, supported by its world-class materials and component test laboratory and materials database.

safe technology limited

Safe Technology Limited is the technical leader in the design and development of durability software and is dedicated to meeting its customers' most demanding applications.

As a private company, Safe Technology is able to take a long-term view of software development and the research and industry collaboration needed to address real world, industrial applications. Its independence and focus enables quick response to customer feedback so that its software genuinely reflects the industrial and commercial requirements of engineers and designers.

In-depth knowledge of fatigue combined with expertise in software development allows Safe Technology to provide outstanding service - with standard and advanced training, software support, and consulting services provided by fatigue experts.

Safe Technology develops, markets and supports its software products directly from offices in the UK and USA, by a network of independent distributors worldwide and via the worldwide SIMULIA network.

To learn more, please visit our website where you can learn about our software products and related services, and register to download technical papers by our users on real world applications. You can also find the contact details for your local office or representative. If you would prefer to give us a call, please contact one of our main offices:

Worldwide: +44 (0) 114 268 6444
North America: +1 310 714 0792

safe technology

Safe Technology Limited
Willis House, Peel Street, Sheffield, S10 2PQ, UK

Tel: +44 (0) 114 268 6444 Fax: +44 (0) 114 303 0055
Email: info@safetechnology.com Website: www.safetechnology.com

safetechnology.com