face to face with

Pietro Del Negro

Senior CAE engineer at Ricardo

How Ricardo predicts the life of motorcycle components

by Pietro Del Negro
Ricardo

Pietro Del Negro is a senior CAE engineer at Ricardo's Rimini Technical Centre in Italy, specialising in motorcycle and light mobility applications, including simulation, analysis, and systems integration for global OEMs and tier-one suppliers. In this article, Del Negro explains how Ricardo is developing solutions to support its customers to predict the lifecycle of motorcycle components, using finite element analysis (FEA) and fatigue analysis.

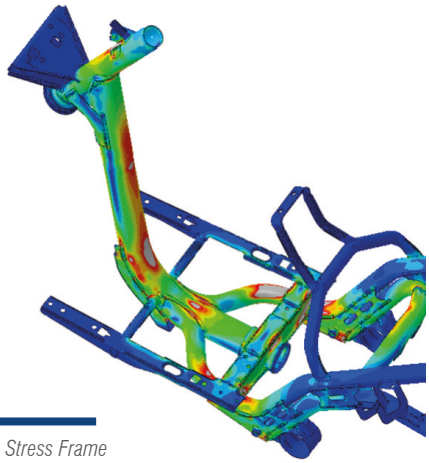
How important is load cases evaluation?

Ricardo has developed a methodology to calculate analytically dedicated load cases for a range of motorcycle and light mobility applications. The target is to optimise stiffness, stress distribution and fatigue resistance, minimising the weight, and allowing for an expected target, or infinite life, for each motorcycle component.

These calculations enable our customers to accurately determine how different components will perform in any given situation by representing, via FEA, all the critical events that a vehicle may encounter during its life cycle. FE model calibration through comparison of results and road test data from strain gauges allows numerical models and hypothesised load cases to be validated, reducing the gap between the virtual and the real worlds. This instils confidence in all stages of design and results in shorter product time to market.

How do FEA and fatigue analysis work?

FEA and Fatigue Analysis is used to understand structural behaviour during the design phase of a project to determine safety and identify where improvements can be made. There are several types of analysis, including static linear and non-linear, dynamic, topology and fatigue analysis. Each plays a key role in the development of a motorcycle or light mobility vehicle. Tools such as Nastran, Abaqus,



Stress Frame

OptiStruct, HyperWorks, Femap and FEMFAT are all used by Ricardo to support analysis processes. Each analysis plays an important role in motorcycle development. For example, stiffness analysis has an impact on several aspects of a motorcycle, including:

- Drivability – stiffness determines the vehicle's response to all dynamic events (curves, bumps, potholes, etc.)
- Comfort – the stiffness is directly linked with vibration in the vehicle's frame.
- Safety – the stiffness has a big impact on safety because it influences the capability of the frame to absorb the energy in the case of a dynamic event.
- Sensitivity – the stiffness influences the sensitivities of the rider to recognise the dynamic behaviour of the vehicle and anticipated reaction to dynamic events. This enables the rider to better preserve safe conditions. Frames that are too stiff can be dangerous as they are less likely to alert the rider to a dynamic event, or a sudden change of wheel grip.

The optimal stiffness value guarantees and respect all the above conditions.

Correct evaluation of vehicle rigidity is fundamental. Evaluated stiffness can often be error prone, e.g. torsional stiffness can be affected by lateral stiffness and vice versa. Ricardo has developed a method to properly calculate pure stiffness values (i.e. bending, torsion).

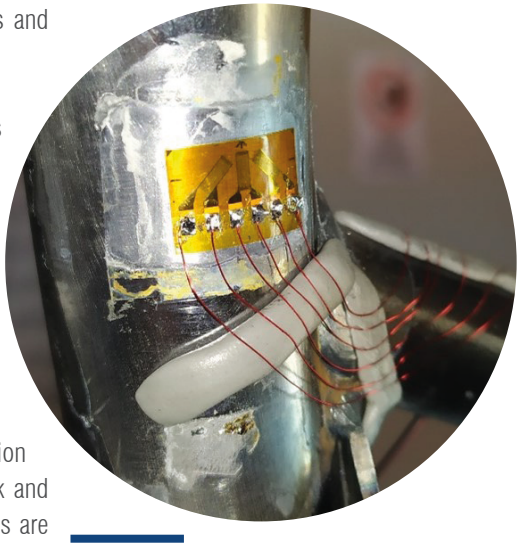
In most cases, the rigidity calculation involves the main frame, the front fork and the swingarm, however, stiffness values are also important to obtain a suitable overall correlation to ensure the correct behaviour of the whole vehicle.

Ricardo continues to compare and analyse different brands of motorbike and light mobility vehicle to ensure adequate benchmarks.

What is fatigue analysis?

Fatigue analysis makes it possible to assess the deterioration of structures subject to cyclic loads. Sometimes, it is difficult to predict and avoid problems and improve critical areas.

Often a fatigue phenomenon begins with nucleation and increases continually before leading to a definitive failure of the component. This is largely due to the progressive reduction of its cross section.
Ricardo uses a holistic approach in developing a motorcycle or light mobility vehicle, starting with concept and styling, and progressing on to the evaluation of specific load cases, component engineering, FEA and Fatigue analyses. Providing good results are obtained, the road tests follow, until the start of production.



Strain Gauge Application

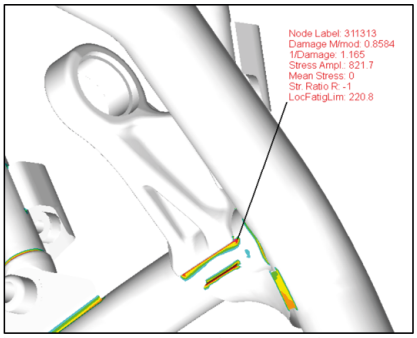
Fatigue analysis is integral to the normal development design of a motorcycle, reducing development time.

Why is fatigue analysis important?

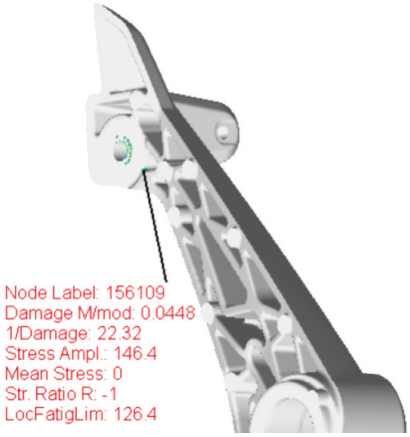
Fatigue evaluations based purely on static FE analyses sometimes do not align with the results obtained from fatigue tests. In fact, in a structure subject to cyclic loading, the critical areas affected by fatigue phenomena can generally be different to those given by a simple static FE analysis. These differences can be more pronounced in welded structures, in which the welds are often the most fatigued areas.

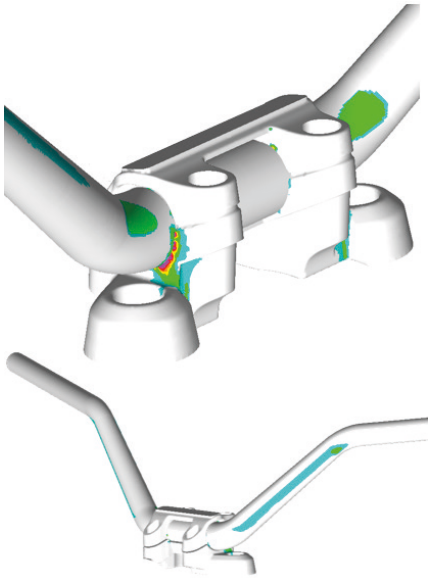
Often the welds are modelled in FEA using shell elements. An important consideration in this scenario is that only stresses in the shell plan are provided by FEA. Therefore, if shell elements meet in two places, i.e. T-joints, one element will deliver an FEA stress, whilst the other element can only deliver zero value in the same place. When evaluating the total entity, the post processor generally averages the stresses at the neighbouring elements for every node. Therefore, the stress result displayed at any mutual node of these two elements will only be half of the actual stress.

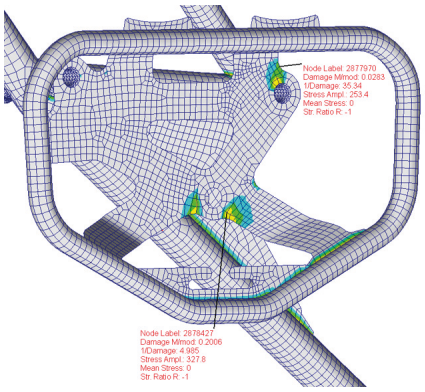
RICARDO – Dyno Roller Bench Test



Cycles considered in the analysis	100000
Damage	0,858
Number of cycles reached	116496







Fatigue result examples for motorcycle components obtained using FEMFAT

In FEA models, generally, the welded areas can produce unrealistic stress results, stress concentrations and singularities. The shape and size of elements near to the welded seams also have an influence on FEA results and can be affected by the geometry simplifications introduced in the transition areas and the replacements of radii with edges.

Difficulties can be correlated, based on necessity, by using specific standards to perform fatigue evaluation on a welded structure.
For example in the Eurocode 3 standard it is not easy to use the results provided by the FEA to evaluate the fatigue of welded seams for several reasons, including:

- finding the normal and transverse tangential stresses along all welding paths that are irregular.
- the coefficients to increase stress considering the details of the welds on both weld toe and weld root.
- the complex history loads
- choosing the right category representative to each welded seam.

Dedicated, powerful and reliable software is essential to perform fatigue analysis. Ricardo mainly uses FEMFAT to perform these types of assessments, which helps to reduce risks in the process.

How does FEMFAT support fatigue analysis?

FEMFAT provides several resources to generate reliable fatigue analysis results through a series of modules, including:

FEMFAT Visualizer:

- Easily and effectively defines welds in the model according to one of the available standards. For example, Eurocode 3 for steel structures, Eurocode 9 for aluminium structures, BS7608 DVS952 and the ECS standard (FEMFAT 4.7), which is the best suited for motorcycles.
- Recognises the welds in the global FEA model even if they are complex in shape.
- Identifies the various joint types, weld types, and weld executions.

FEMFAT Weld:

- Evaluates structural stresses on the local welded areas of a component.
- Considers the “local stress approach” and the “structural stress method or hot spot method”, in the case of Eurocode 3, which is more suitable for the welded components of motorcycle and light mobility vehicles modelled using shell elements.
- Offers an “Automatic Stress Correction” option to minimize the effect of the size and quality of elements close to welded elements.
- Includes a “Compressive Stress Reduction” option to consider eventual stress reductions due to stress relief treatments applied to the welded structure after welding.
- Performs a fatigue assessment on the local weld regions, considering the relevant weld notch stresses at the root and toe of welds. Welded ends are treated separately due to their high notch effects.

FEMFAT allows users to consider all possible fatigue factors and perform a simultaneous evaluation of welds and the surrounding base material in a single analysis. The software creates the main outputs for fatigue analysis, including S-N graphs, Haigh diagrams, damage values and R (stress ratio).
Using FEMFAT enables Ricardo to determine the most relevant issues related to fatigue evaluations. For example, a factor of 3 or 5 (meaning an error between 200% and 400%) on the life estimation of a component could be considered in any case as a good correlation between fatigue simulation results and fatigue test results.

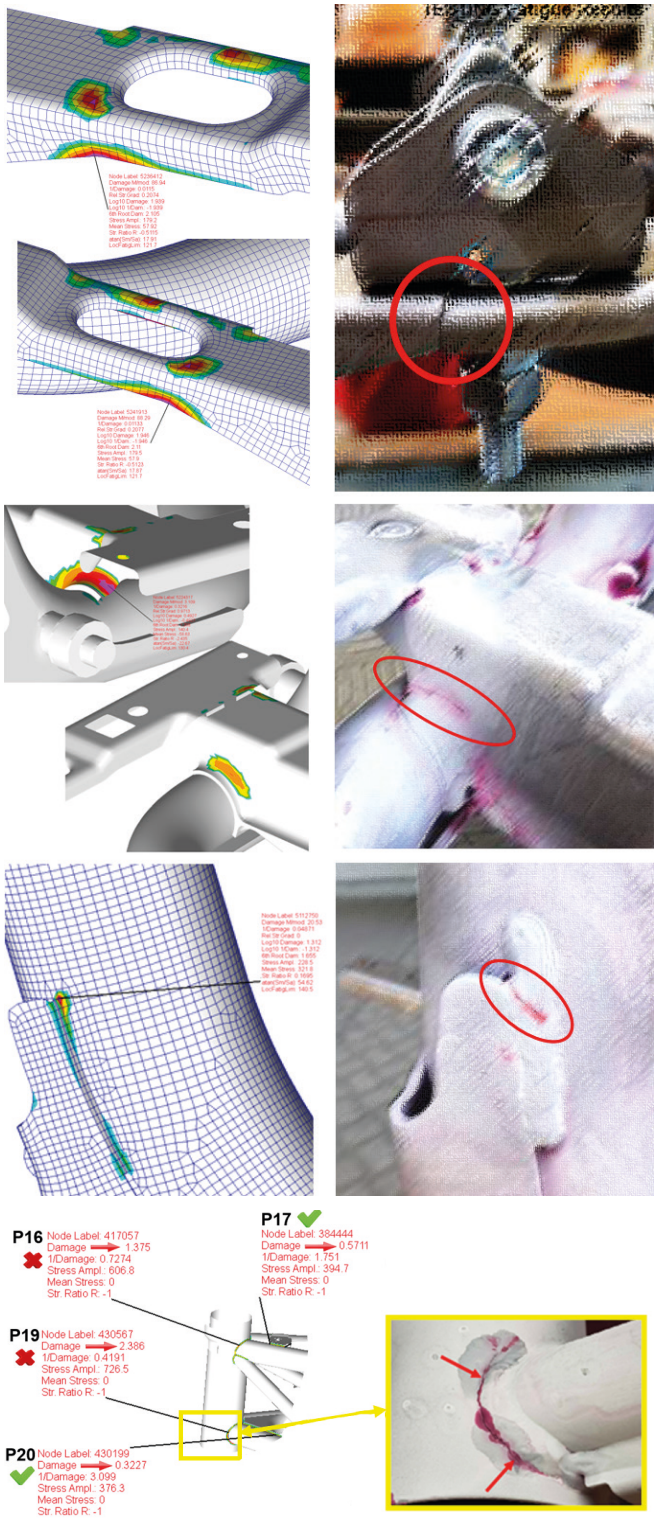
Conclusion

Ricardo uses FEA and fatigue analysis simulations combined with dedicated test bench and road tests to predict critical events. This helps the company to better support its clients in their goal of reducing project development time and go-to-market while maintaining the safety, quality, and confidence in each component.

About Ricardo

Ricardo is a global strategy, environmental and engineering consultancy listed on the London Stock Exchange. With over 100 years of engineering excellence and employing close to 3,000 people in more than 20 countries, we provide exceptional levels of expertise in delivering innovative and sustainable cross-sector outcomes to support energy transition and scarce resources, environmental services along with safe and smart mobility. Our global team of consultants, environmental specialists, engineers, and scientists supports our customers in solving the most complex and dynamic challenges to help achieve a safe and sustainable world. Visit ricardo.com

For further information on the motorcycle and light mobility services and solutions offered by Ricardo, get in touch with one of our experts info@ricardo.com



Example of comparisons between fatigue results obtained using FEMFAT and testing results for some motorcycle components

For more information about the software FEMFAT:

Paolo Bortolato - EnginSoft
p.bortolato@enginsoft.com