Introduction to fe-safe®

Durability analysis software for FE models

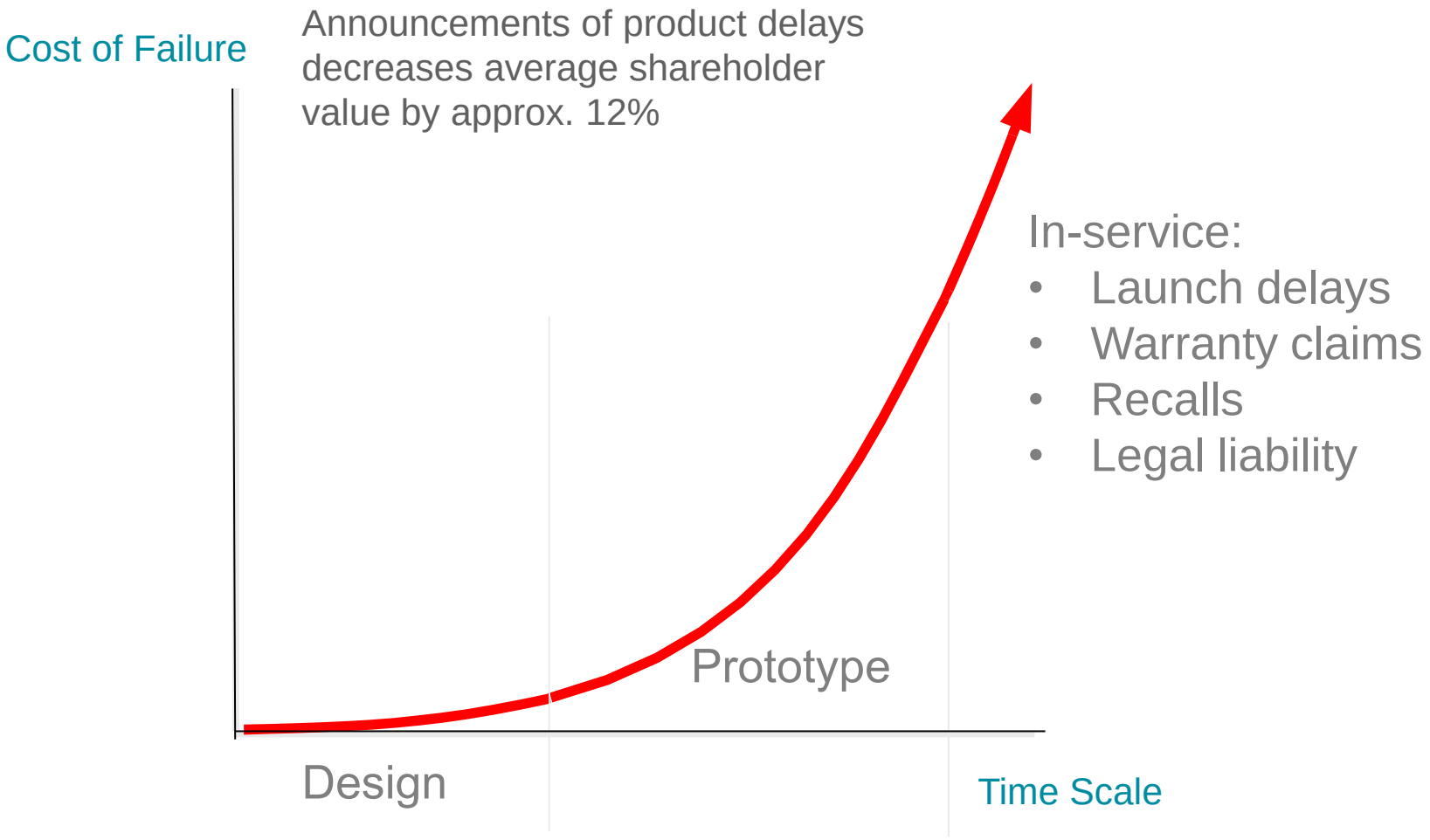
Jan Granlund

Technical Sales Expert, Simulia EuroNordics

Agenda

- Why do fatigue analysis?
- Why do I need intelligent fatigue analysis software such as fe-safe?
- But isn’t all fatigue software the same?
- Do I have to choose between speed and accuracy?
- Do I need to be a fatigue expert?

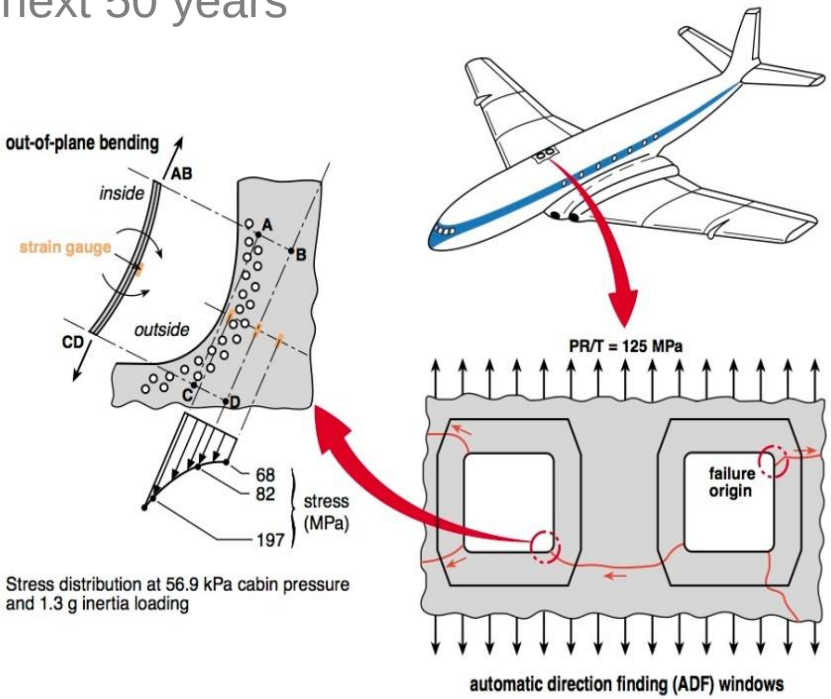
Why do fatigue analysis?



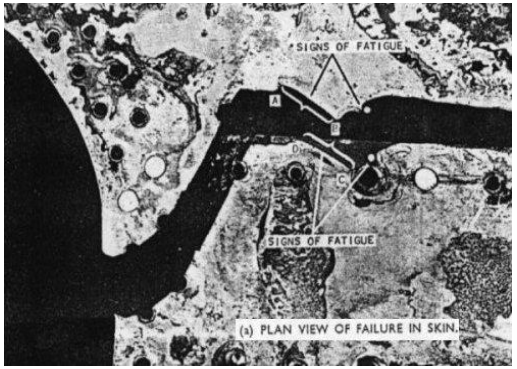
Why do fatigue analysis…?

The 1950's Comet de Havilland Air Disasters: The cost of fatigue failure

- Three lost aircraft with many lost lives
- Europe lost of the lead in the jet airline industry to the USA for the next 50 years



Stress distribution at 56.9 kPa cabin pressure and 1.3 g inertia loading

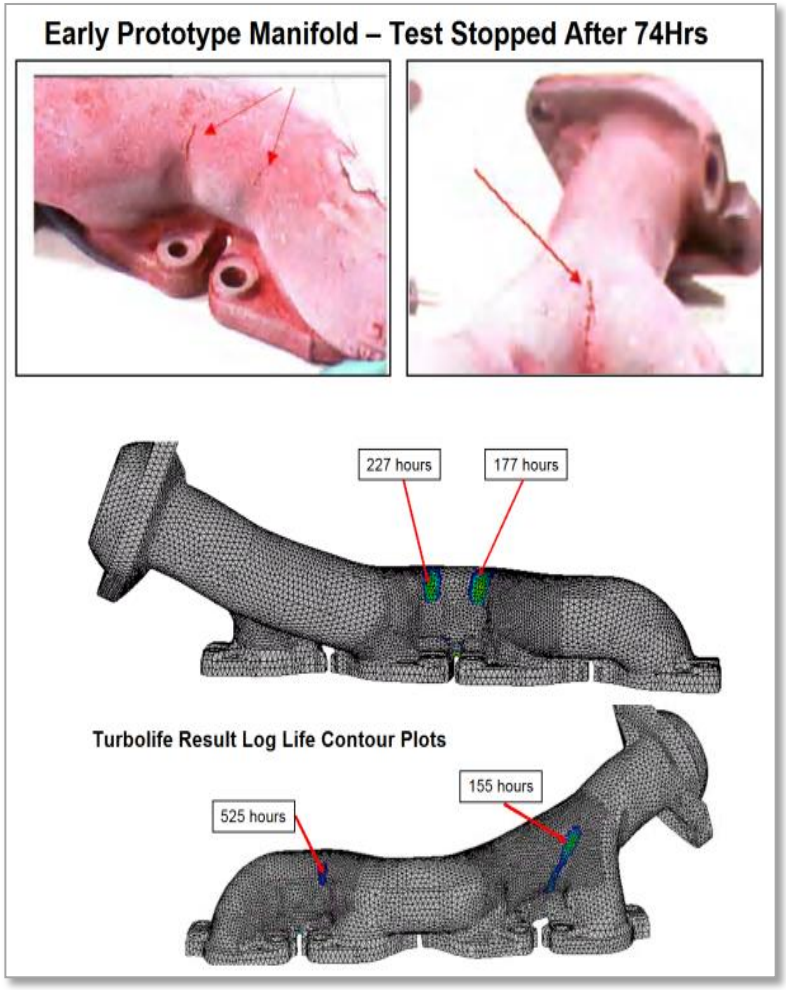


Why do fatigue analysis?

Jaguar Land Rover Virtual Design Validation Process using fe-safe/TURBOlife

Project Conclusions

- **Identified a lower cost alternative material** with improved castability leading to *"a multi-million £GBP per annum cost benefit"*
- **Provided a *near-optimal design* at an early stage** in the design process by creating a DOE where key parameters were varied and the impact on the manifold life could be assessed
- Confirmed that Jaguar's own target to **reduce the number of engine tests from 5 to 1** was realistic and achievable



"High Temperature Fatigue of Engine Components - Virtual Design Validation of Exhaust Manifold", fe-safe UGM 2010, FESI 2009

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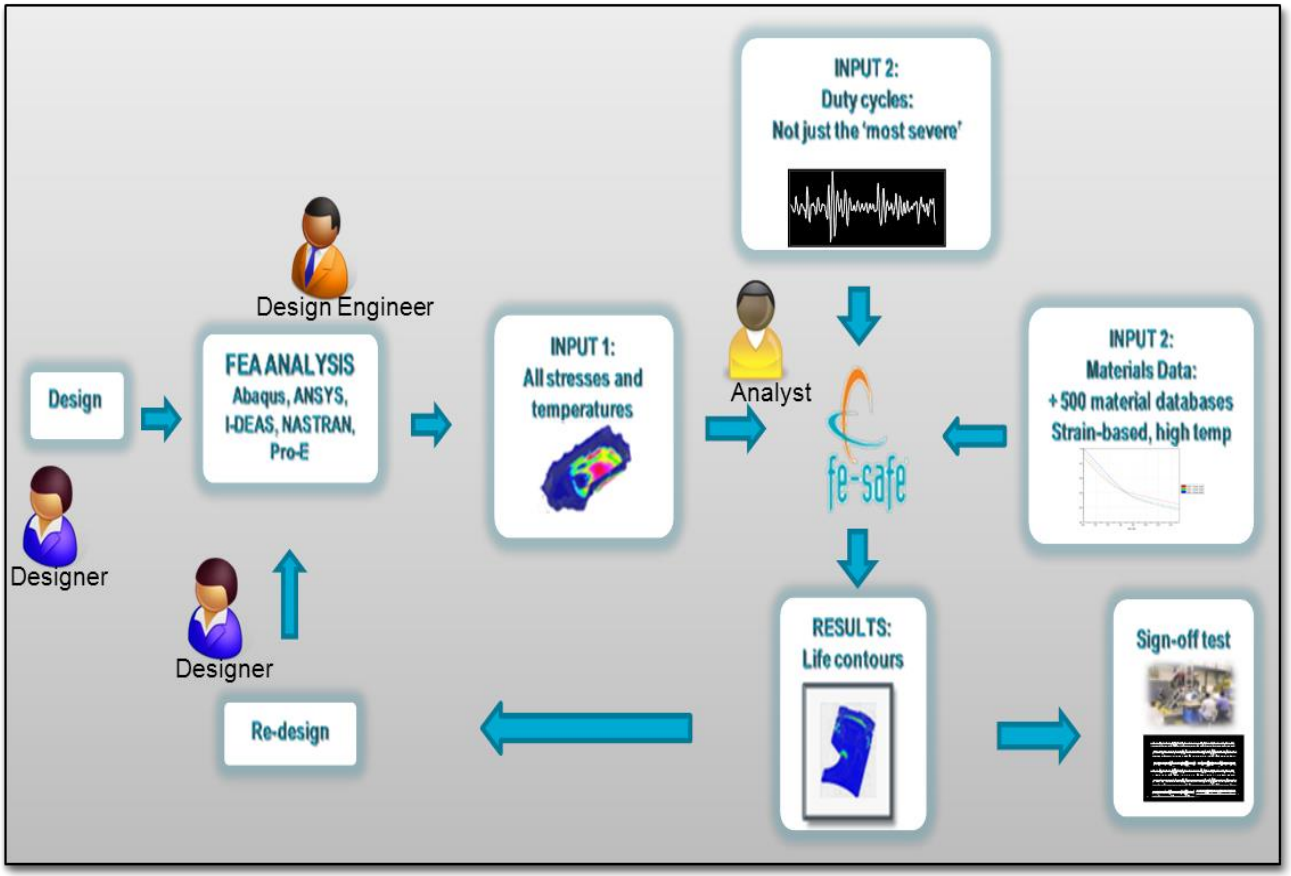
The fatigue analysis process



fe-safe

Supported Input & Outputs

- Abaqus
- ANSYS
- I-DEAS
- NASTRAN
  (NEi, NX, MSC, Optistruct)
- Pro/M:
  Wildfire & Creo
- General .csv

Other Supported Outputs

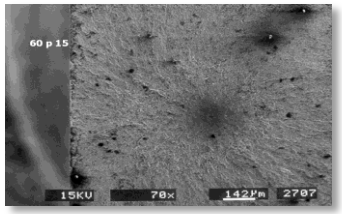
- Hypermesh
- PATRAN
- FEMVIEW
- CADFIX
- FEMAP

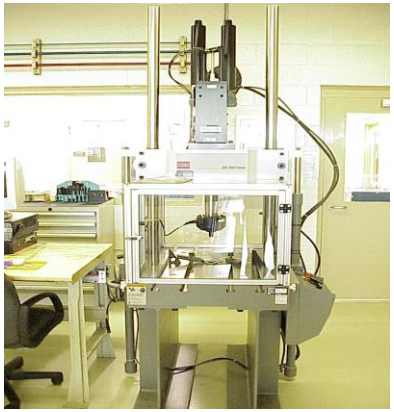
We need intelligent fatigue software

Physical tests are required, but should be done once, at the final stage for validation

Fatigue testing a premature prototype design is:

- Time consuming
- Project time-scales are unpredictable
- Impossible to account for all conditions
- Expensive

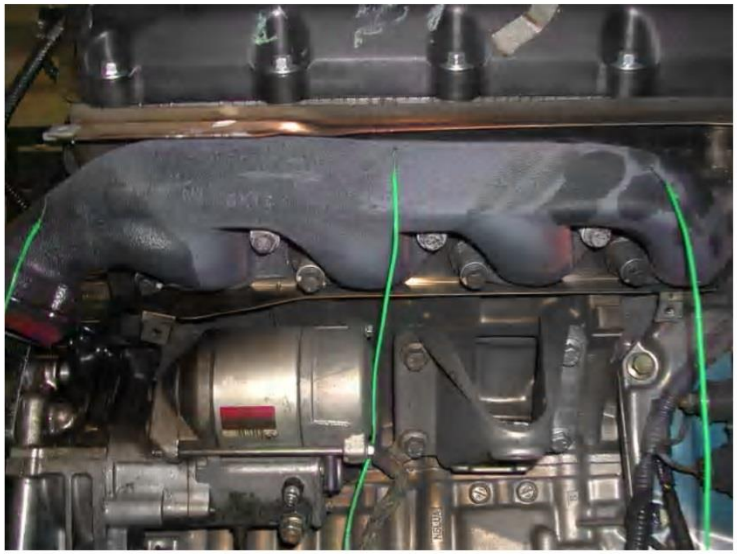




Jaguar Land Rover

- Single engine test cost = + £30,000
- Cost benefit of reducing 5 engine tests to 1:

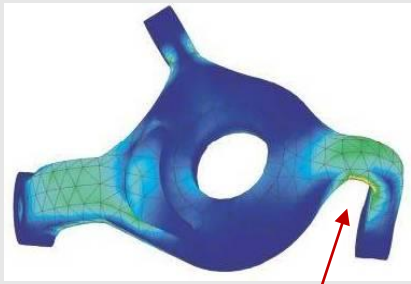
  + £120,000
- Less fuel used = Reduced environmental impact & emissions



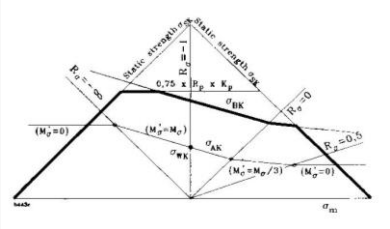
We need intelligent fatigue software

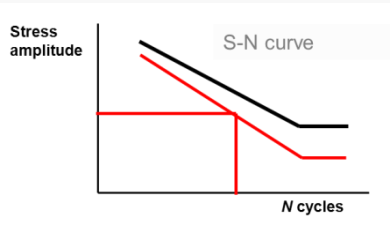
Traditional stress based fatigue methods and hand calculations

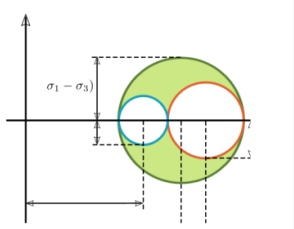
- Unreliable
- Easy to miss failure locations
- Can't cope with complex loadings and structures
- Very few real fatigue scenarios are simple uniaxial cases



max stress





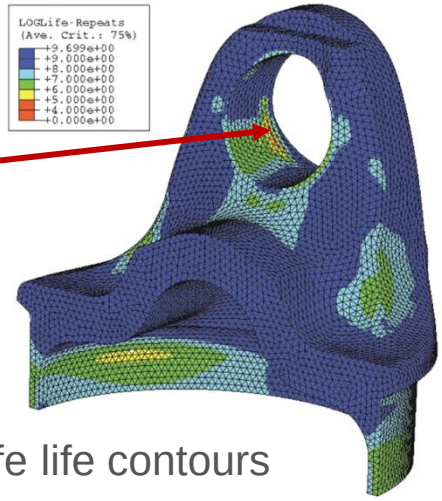


We need intelligent fatigue software

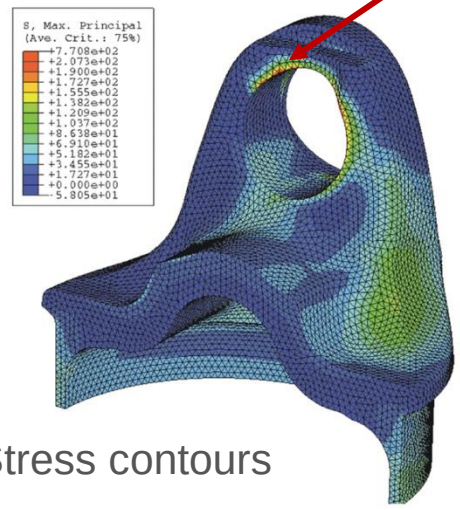
- Cracks may not start from the points of maximum FEA stress

Max principal stress

Shortest life



fe-safe life contours



Stress contours

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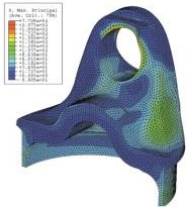
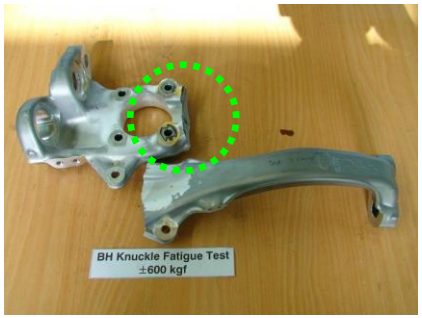
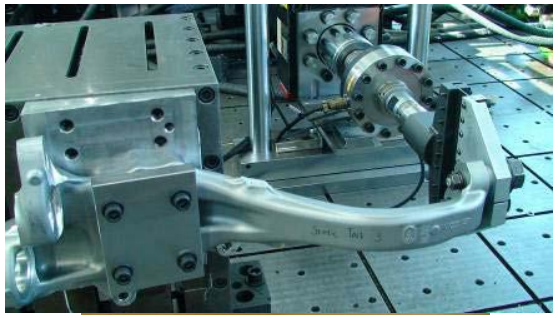


We need intelligent fatigue software

- Crack initiation site may depend on the loading sequence

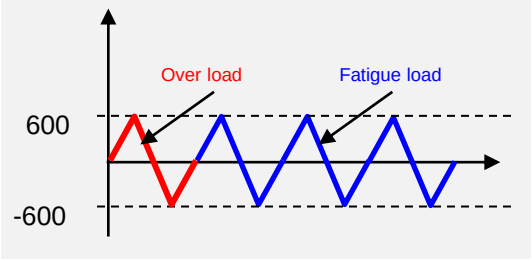


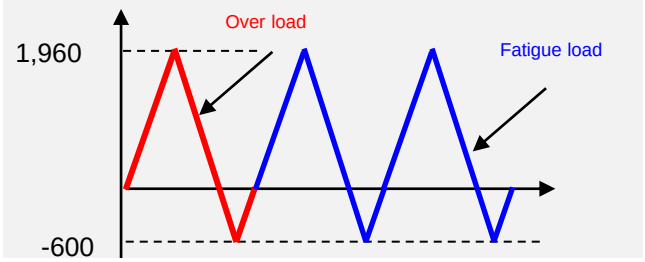
< only low level fatigue loading >

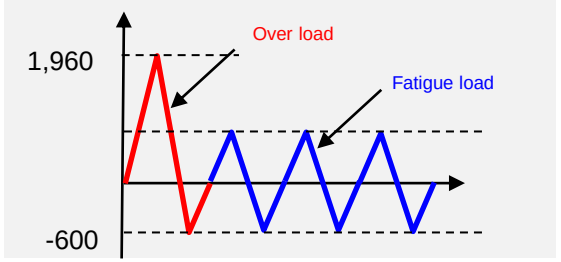


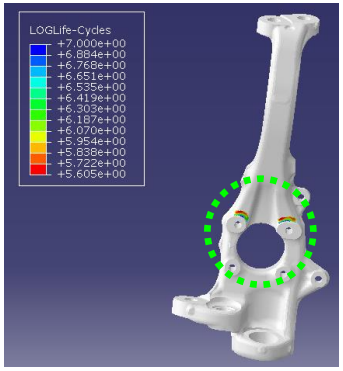
< only high level fatigue loading >

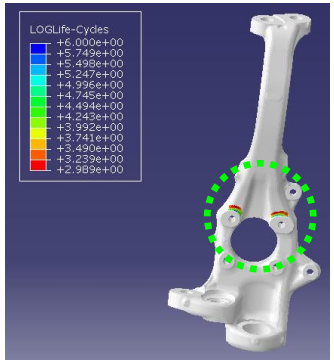
< High level + low level fatigue loading >

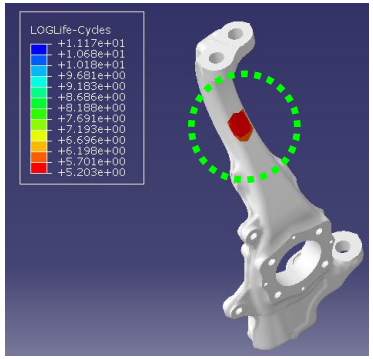












We need intelligent fatigue software

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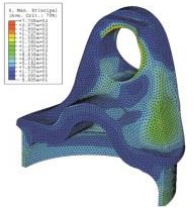

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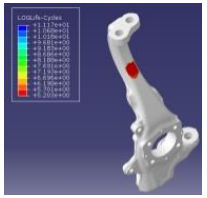
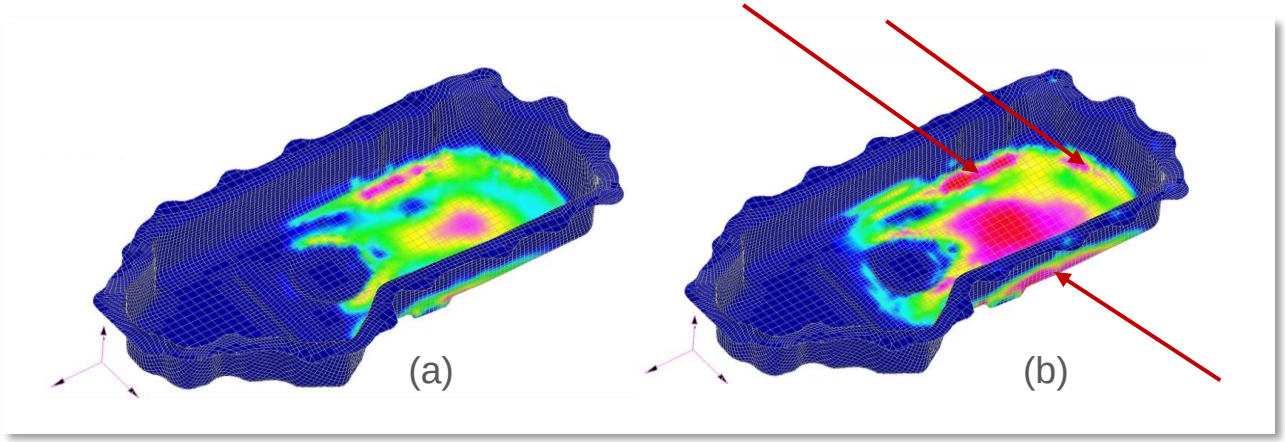


We need intelligent fatigue software

Simulating Forming Processes in an Oil Pan



Fatigue life contours for a Ford oil-pan
(a) excluding and (b) including effects of forming process

The effects of stamping a sheet metal part may reduce the life by a factor of 30 – from 15 years to 6 months

Fatigue Assessment Of An Oilpan Incorporating Manufacturing Effects
Hughes A, Draper J, Kemp M
'Engineering Integrity', The Journal of the Engineering Integrity Society, January 2002

We need intelligent fatigue software

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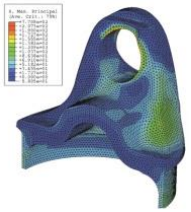

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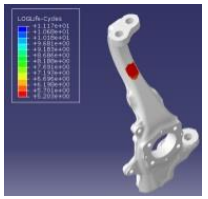
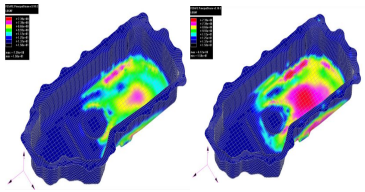


- Manufacturing effects need to be taken into account



We need intelligent fatigue software

With fe-safe you can…

- Optimise design for minimum weight or cost
- Save time and money with ‘right first time’ prototype testing
- Evaluate different material options
- Study the influence of load uncertainty on fatigue life
- Examine the effect of assembly and manufacturing processes
- Design and validate fatigue test programmes
- Reduce product recalls and warranty costs
- Predict accurate fatigue life quickly and reliably

Agenda

- Why do fatigue analysis?
- Why do I need intelligent fatigue analysis software such as fe-safe?
- But isn't all fatigue software the same?
  - Trust the EXPERTS
  - Comprehensive
  - Accurate
  - Fast
  - Ease of use & flexibility
- Do I have to choose between speed and accuracy?
- Do I need to be a fatigue expert?

You can trust *fe-safe*® because you can trust the experts in fatigue

- **Fatigue is all we do:** we specialise in fatigue analysis software and related services and consultancy
- Technical leader in durability: pioneers in modern multiaxial strain based methods
- Technology driven
- Highly qualified, specialist support team
- 60% PhD in technical team
- Over 100 man-years of industrial fatigue experience

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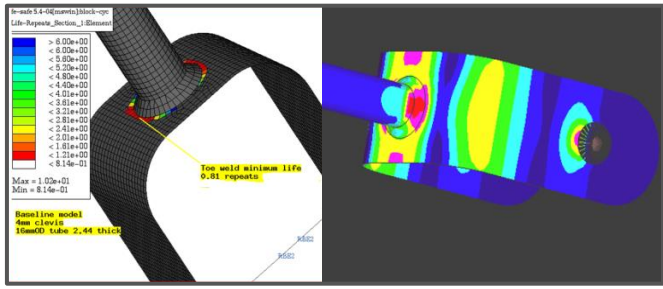
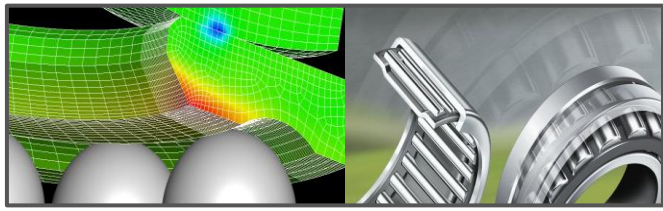
Ford Motor Company

- Test results to crack initiation: 0.83 repeats of proving ground test
- *Verity*® *in fe-safe* fatigue life prediction to crack initiation 0.81 repeats



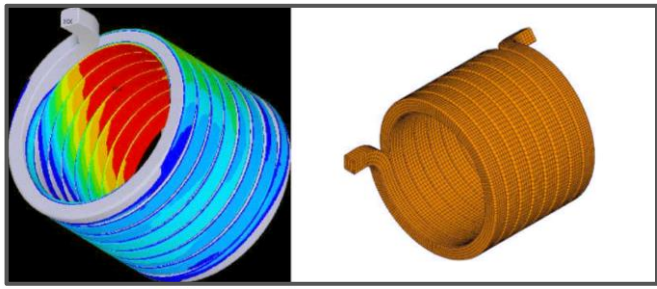
Schaeffler Inc.

- Test results to crack initiation: 110K cycles
- *fe-safe* fatigue life prediction to crack initiation: 92K cycles



Eaton Automotive

- Test results to crack initiation: 60K cycles
- *fe-safe* fatigue life prediction to crack initiation: 67K cycles



References:
1. Verity in fe-safe Seam Weld Fatigue, Ford Motor Company, fe-safe UGM 2010
2. Fatigue Considerations of High Strength Rolling Bearing Steels, Schaeffler Inc, fe-safe UGM 2006
3. Predicting Fatigue Life for a Supercharger Torsional Isolator Spring, Eaton Automotive, fe-safe UGM 2008

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safe technology

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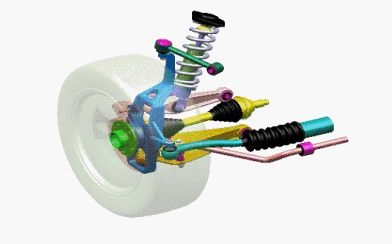
All fatigue software is *not* the same

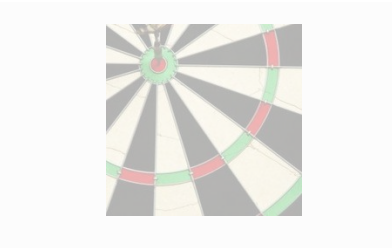
Comprehensive

- Advanced, feature-full technology with many unique, leading edge capabilities
- Specialist add-on modules
- 3 year restructuring plan



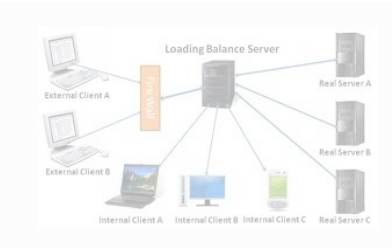
Accuracy

- Advanced strain based, multiaxial algorithms are at the core of fe-safe®
- Consistent customer feedback reports excellent correlation with test results



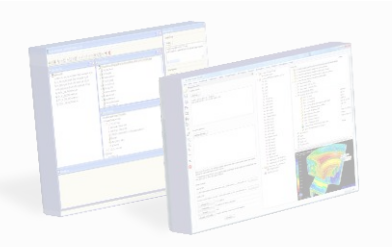
Speed

- fe-safe is computationally efficient
- Distributed and Parallel Processing



Ease of Use & Flexibility

- Many default settings and custom settings
- Standard analyses can be saved, batch analysis easily set up
- CMF (Custom Module Framework)



fe-safe® is comprehensive

Some capabilities in **standard** version of *fe-safe*

- Strain-Life (multi-axial)
- Stress-Life (S-N curve analysis)
- Infinite life (Dang Van)
- Fatigue of cast irons
- Property mapping
- Fatigue of welded joints using BS5400/7608
- Vibration fatigue
- Test programme validation
- Materials database
- Critical Distance Methods
- Automatic hot-spot formation
- Manufacturing effects
- Automatic surface detection
- Automatic surface contact detection
- Vector plots
- Warranty curve
- Signal processing
- Parallel processing
- Component for SIMULIA Isight

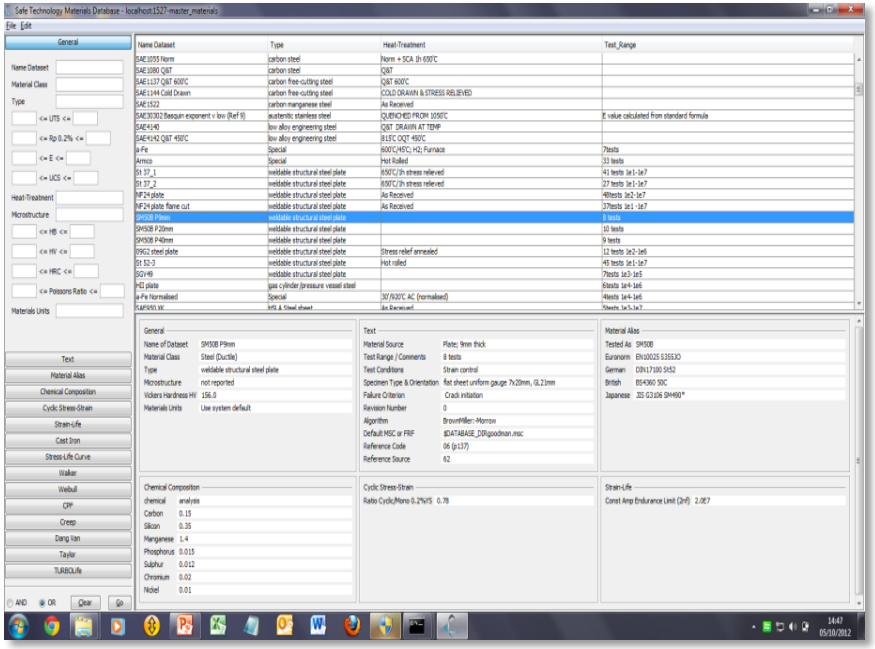
fe-safe® is comprehensive

We have completed a 3-year software restructuring program:

- New underlying file structure – for future developments
- Code re-structured to include parallel and distributed processing
- Custom Module Framework (CMF) ‘Plug-in’ allows users to add proprietary analysis methods
- Result
  - The code is now easier to develop
  - Some dramatic reduction in analysis times

New materials database

- Database of + 350 materials shipped with *fe-safe* – **possibly the largest commercial strain-based and stress-based fatigue database**
- Public domain data, fully validated, referenced and re-analysed by Safe Technology **– a unique data collection**
- Equivalent specifications allow searching on US, European, Japanese and Chinese standards - **unique**
- Users can add their own materials and material parameters
- Includes material properties, chemical composition, fatigue properties
- Includes creep fatigue data for fe-safe/TURBOlife
- Includes AFS database of strain-life fatigue properties for cast iron – **unique**
- Includes elastomer material data for fe-safe/Rubber **- unique**

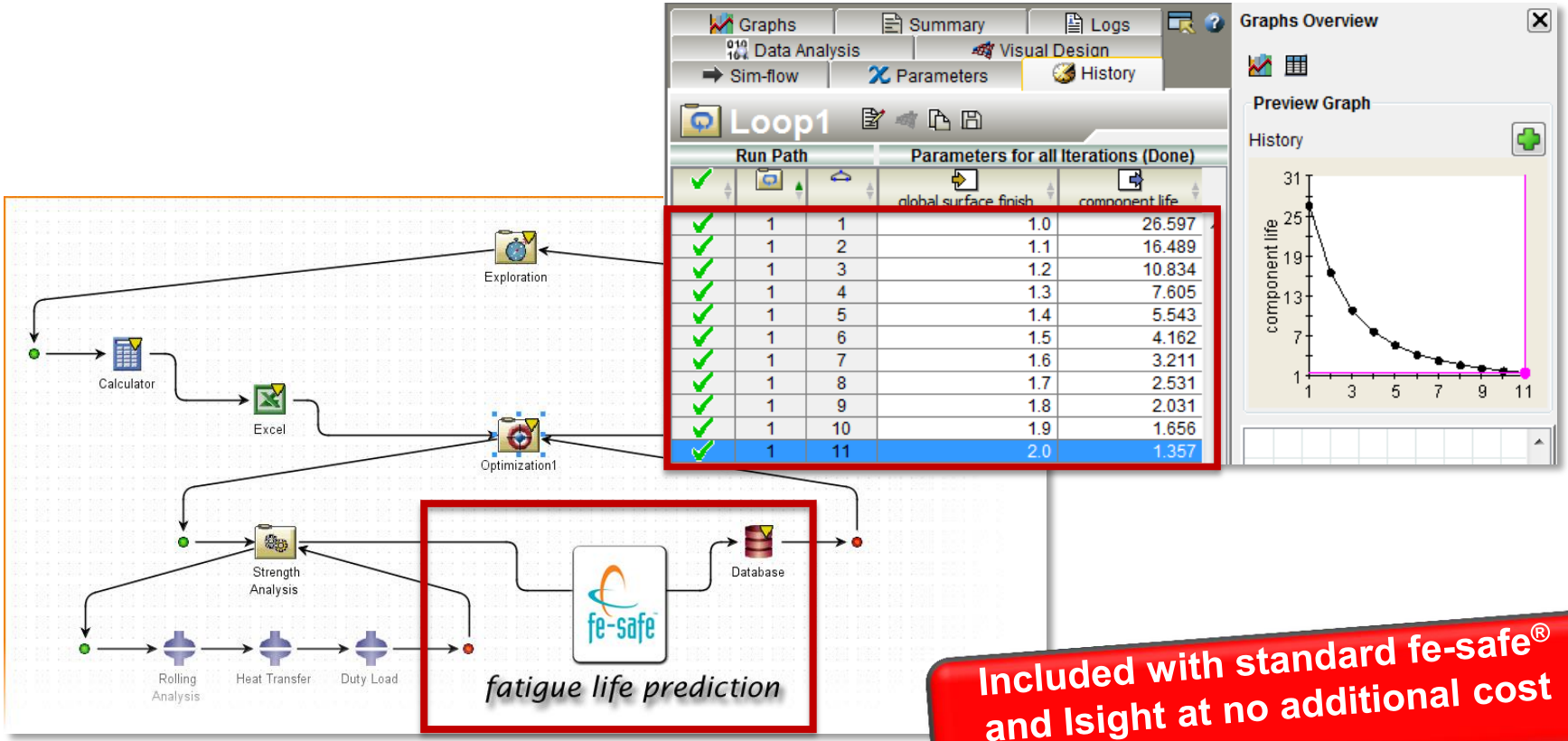


Included with standard fe-safe® at no additional cost

fe-safe® - software integration

Design optimisation using Isight

- A dedicated fe-safe component in Isight allows fe-safe to participate in the simulation process workflow



Included with standard fe-safe® and Isight at no additional cost

All fatigue software is *not* the same

Comprehensive

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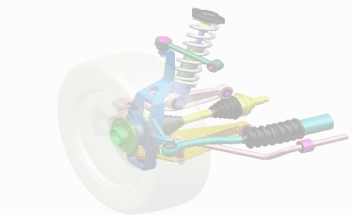
- Specialist add-on modules
- 3 year development plan to future-proof fe-safe



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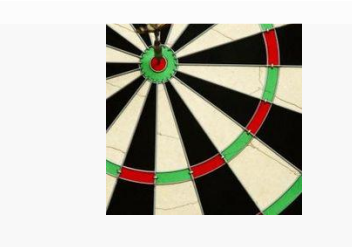

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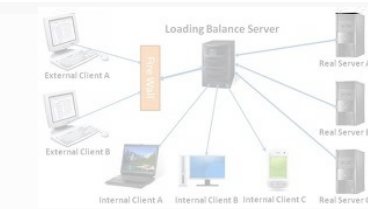

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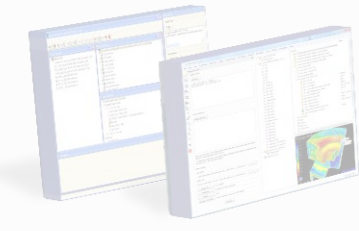

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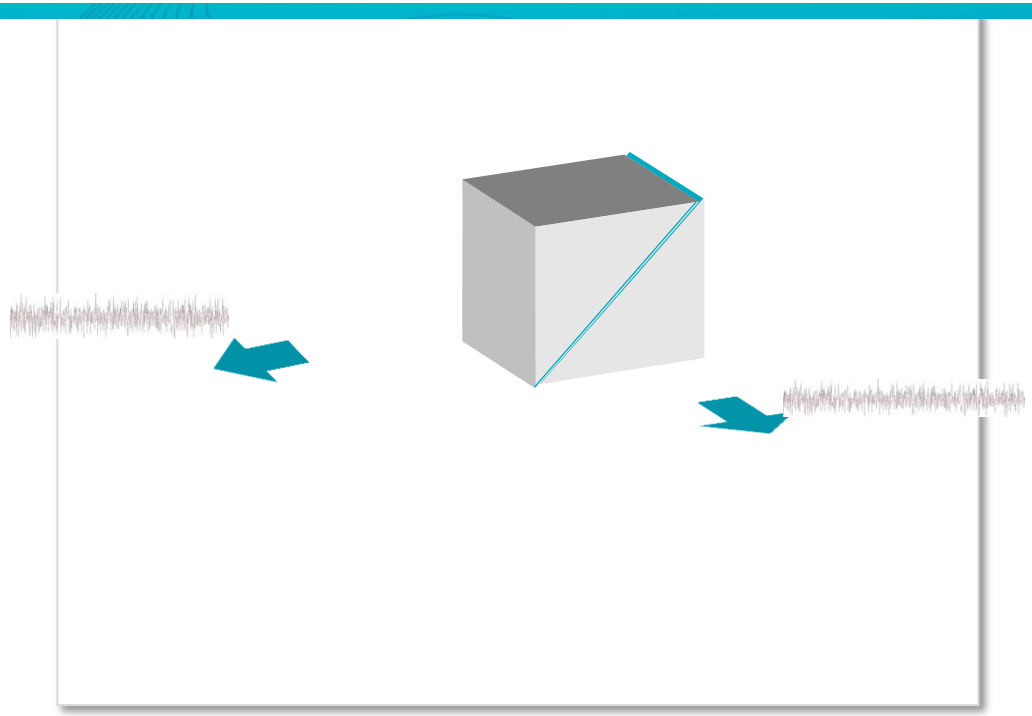
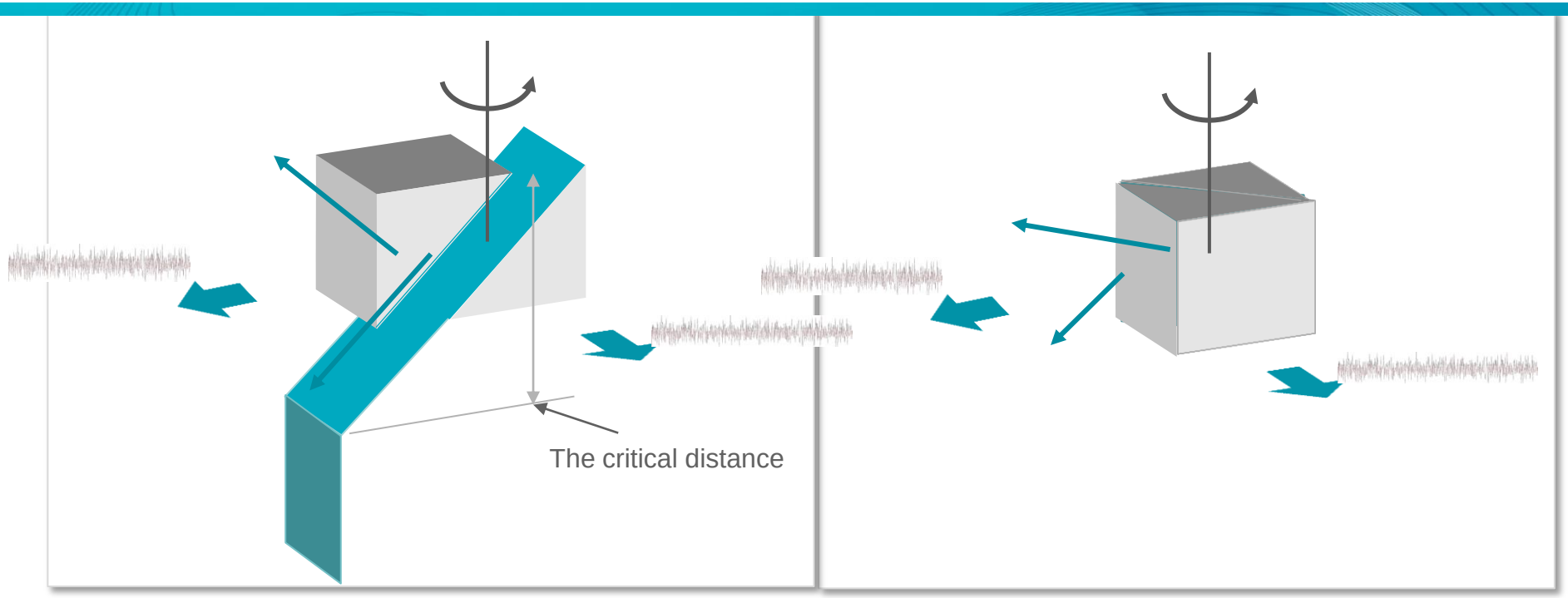


All fatigue software is *not* the same



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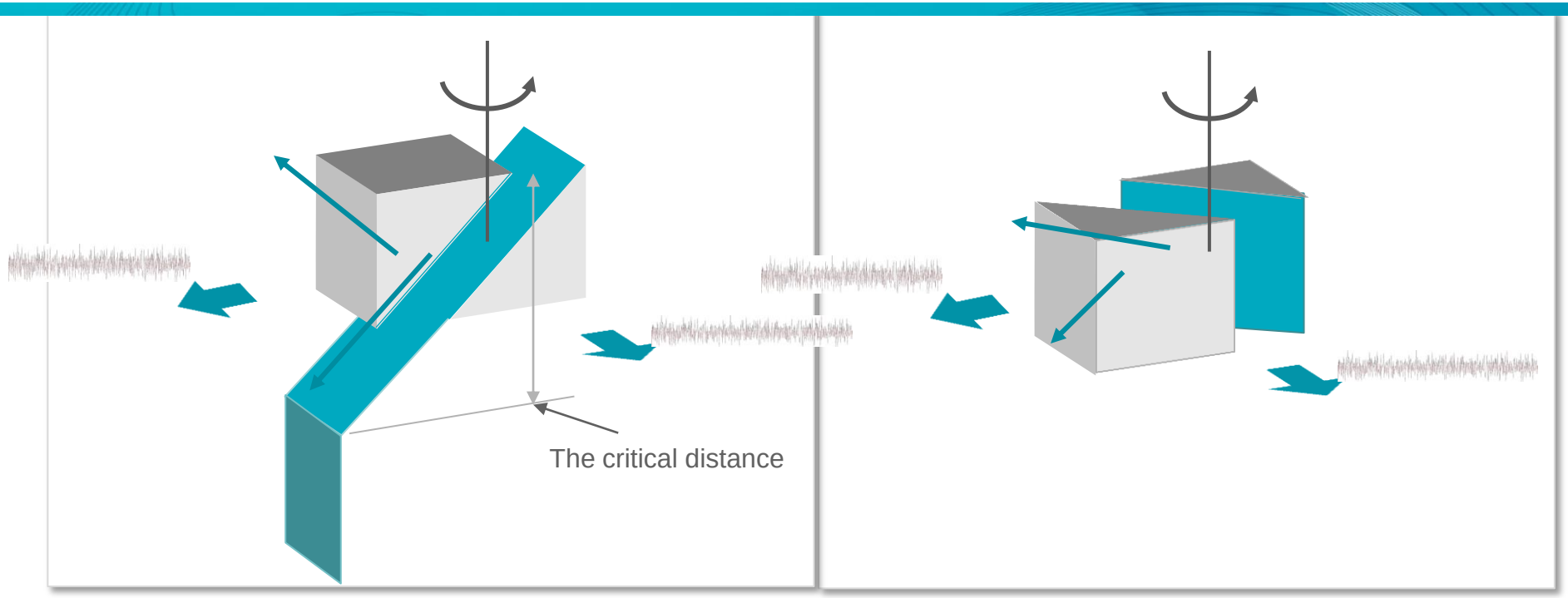

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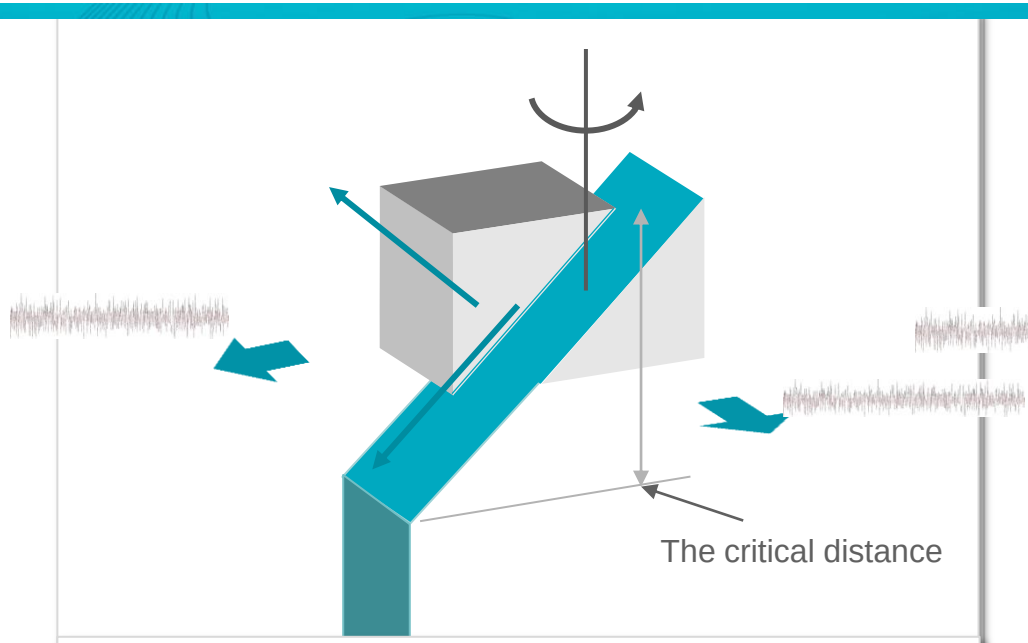
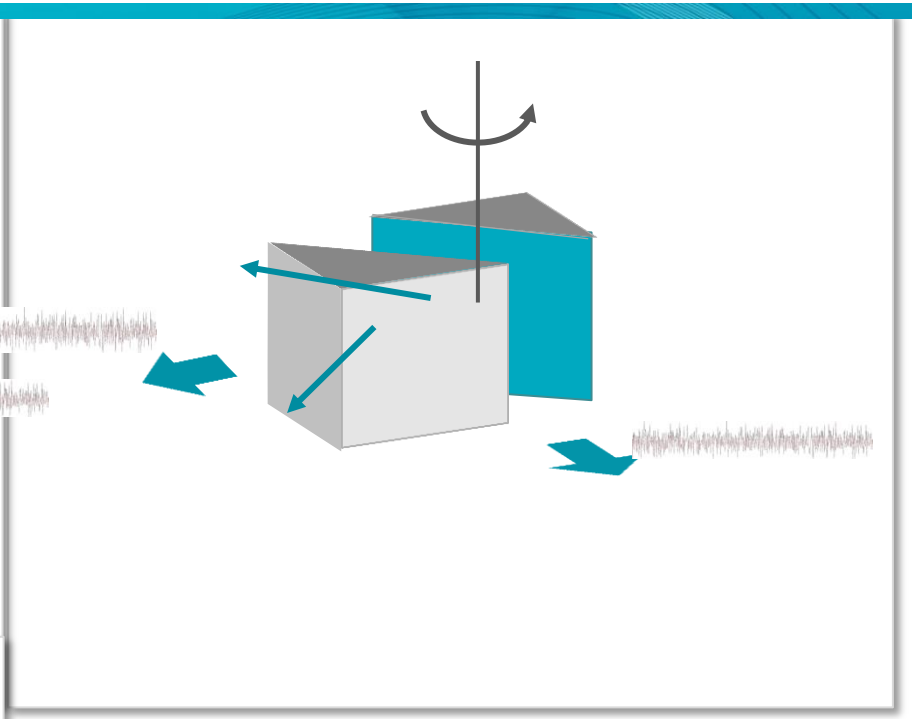
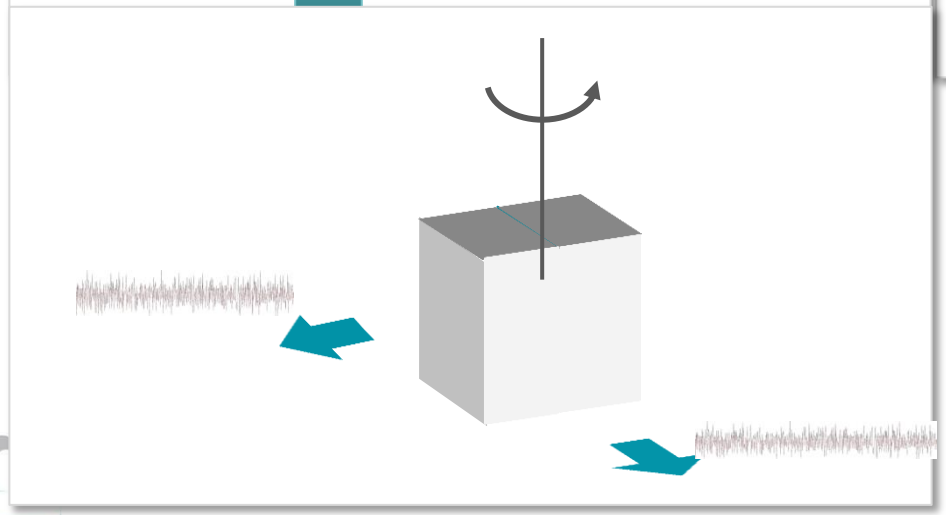
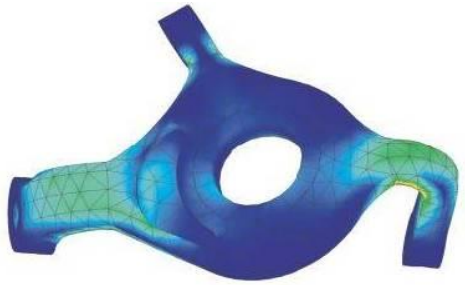








Why is accuracy so important?

Inaccurate results are unreliable results

- **Methods based on assumptions and approximations will produce unreliable results: you never know when they will be wrong**

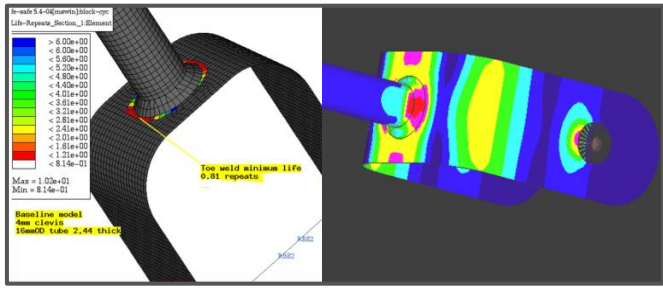
Accurate results allow you to:

- **Find the correct fatigue 'hot spots'.** If these are not identified correctly, you end up adding material in the wrong places, which results in a heavier component that still isn't designed for optimum durability!
- **Optimize your design for fatigue**: you will know how much the design is over-strength or under-strength at each node, giving you the confidence that you are adding material only where necessary to achieve optimum fatigue life
- **Increased confidence that your component will pass tests as "right-first-time"** gained from good correlation with test results

You can trust *fe-safe*® because you can trust the experts in fatigue

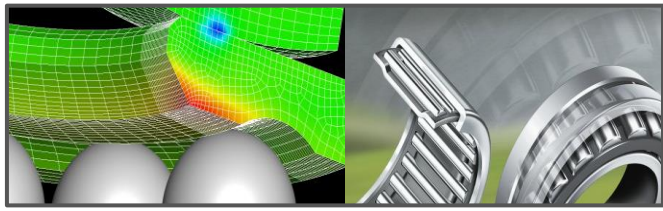
Ford Motor Company

- Test results to crack initiation: 0.83 repeats of proving ground test
- *Verity*® *in fe-safe* fatigue life prediction to crack initiation 0.81 repeats



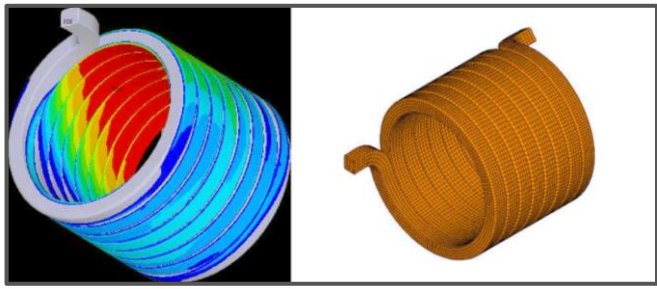
Schaeffler Inc.

- Test results to crack initiation: 110K cycles
- *fe-safe* fatigue life prediction to crack initiation: 92K cycles



Eaton Automotive

- Test results to crack initiation: 60K cycles
- *fe-safe* fatigue life prediction to crack initiation: 67K cycles

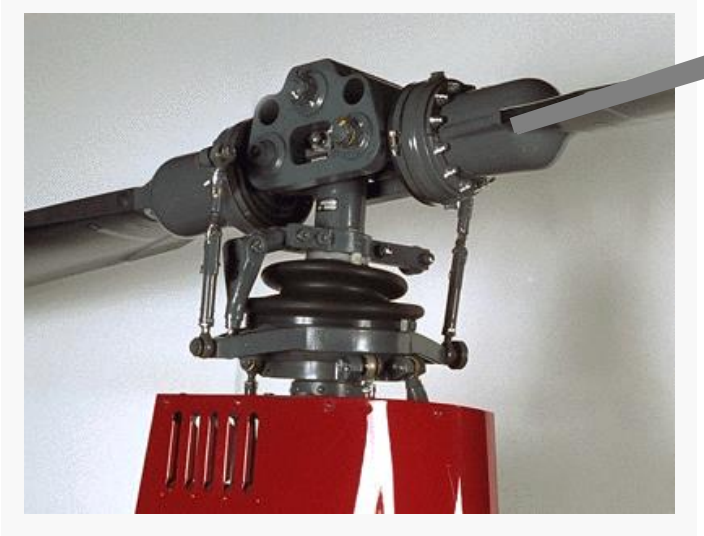


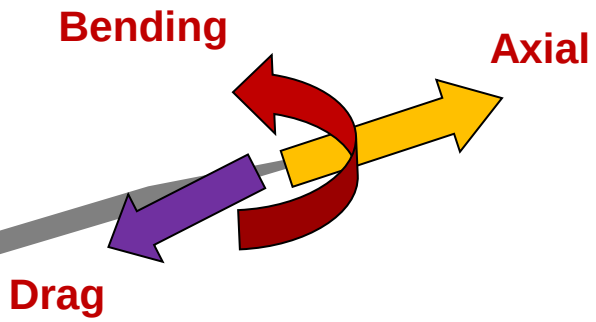
References:
1. Verity in fe-safe Seam Weld Fatigue, Ford Motor Company, fe-safe UGM 2010
2. Fatigue Considerations of High Strength Rolling Bearing Steels, Schaeffler Inc, fe-safe UGM 2006
3. Predicting Fatigue Life for a Supercharger Torsional Isolator Spring, Eaton Automotive, fe-safe UGM 2008

You can trust *fe-safe*® to give ACCURATE results

Analysis of the rotor hub of a pilot-less helicopter

Reference: fe-safe UGM 2007





Nianzhao Jiang[1], Hui Chen[1], Yong Dai[1], Zhiqing Zhang[1], Kexuan Wang[1], Hongbo Wu[1]

Jinping Tao[2]

[1]The Research Institute of Simulation Technology of Nanjing, No. 2 Huangpu Street, Nanjing,210016, P. R. China; [2]Ansys-China Shanghai Office. Room 801, Aurora International Building 99 Fucheng Rd. Shanghai,200120, P. R. China

You can trust *fe-safe*® to give ACCURATE results

"The conventional uniaxial model can't satisfy the real load applied to the rotor hub.

On the other hand, the expense of testing is high, and the load spectrum of the hub is random.

Testing to all flight conditions is impossible.

For this reason, it is necessary to develop a new way to calculate the fatigue life of the hub".

The 'new way' is to use fe-safe

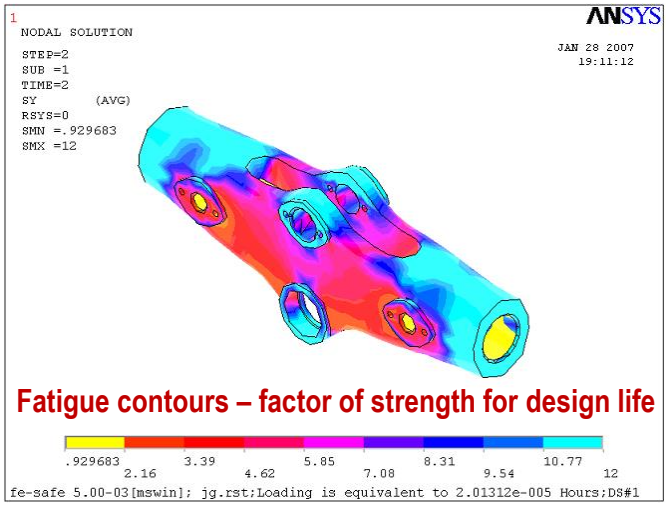
You can trust *fe-safe*® to give ACCURATE results

- Uniaxial analysis is not valid
- Duty cycle and loading is very complex
- Testing is very expensive and cannot cover all possible usage
- fe-safe gave an accurate life calculation

With the fatigue test and flight-testing of the helicopter the final fatigue life of the rotor hub is

985 hours.

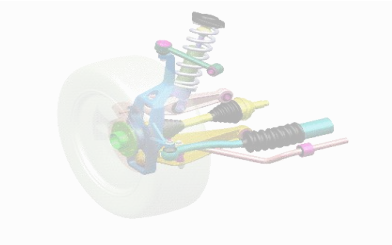
The result of calculating in fe-safe is **934 hours.**



You can trust *fe-safe*® to give FAST results

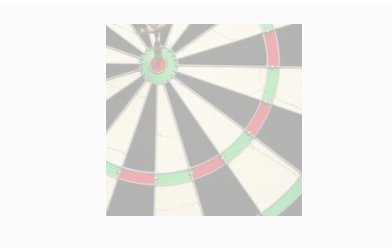
Comprehensive

- Advanced, feature full technology with many unique, leading edge capabilities
- Specialist add-on modules
- 3 year development plan to future-proof fe-safe



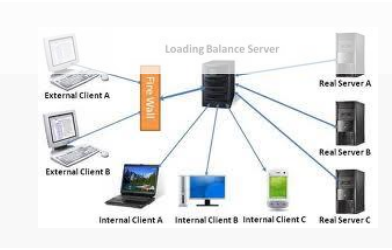
Accuracy

- Advanced strain based, multiaxial algorithms are at the core of fe-safe®
- Consistent customer feedback reports excellent correlation with test results



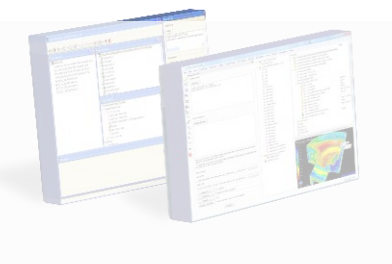
Speed

- fe-safe is computationally efficient
- Distributed and Parallel Processing



Ease of Use & Flexibility

- Many default settings and custom settings
- Standard analyses can be saved, batch analysis easily set up
- CMF (Custom Module Framework)



You can trust *fe-safe*® to give FAST results

- Assemblies of different parts, surface finishes and materials can be analysed in a single run
- Contour plots showing the fatigue life at each node, the factor of strength and probabilities of survival can all be calculated in the same run
- Automatic hotspot formation: for rapid design-change studies and design sensitivity analysis
- Native 64 bit code on Windows & Linux
- Parallel Processing (SMP)
  - Threading on multi-core processors
  - Support for multiple cores on a single machine at no additional cost
  - 4 cores typically give 2.5× speed-up
- Distributed Processing (DMP)
  - Distribution of analyses across an HPC or ad-hoc network cluster
  - Scalability is linear

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Agenda

- Why do fatigue analysis?
- Why do I need intelligent fatigue analysis software such as fe-safe?
- But isn’t all fatigue software the same?
- Do I have to choose between speed and accuracy?
- Do I need to be a fatigue expert?

ACCURATE results FAST

- No ‘trade-off’ between speed and accuracy!
- Unique nodal elimination methods in fe-safe ensure that you get your result quickly and correctly - regardless of the complexity of the analysis
- Parallel processing is automatic. Distributed processing is available
- Speed examples shown are using fe-safe ‘out-of-the-box’ – no settings required to force the user to choose between speed of analysis or accuracy of results
- This is not the case with all fatigue software!

Agenda

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fe-safe® is easy to use

No, you can leave that to us…

- We are not going to tell you that fatigue is simple: there is rarely a ‘simple’ fatigue scenario
- Most real-life fatigue issues are multi-axial: there are multiple variables which cannot be disregarded if you want truly accurate results
- fe-safe is developed by fatigue experts: it is intelligent
- fe-safe is configured to take into account all the variables that will affect the accuracy of your results ***automatically***
- fe-safe GUI is intuitive and easy to use without being ‘dumbed down’ or over-simplified to the extent that results are simply not accurate and therefore useless
- fe-safe is easy to use for designers and analysts

Not all fatigue software is the same!

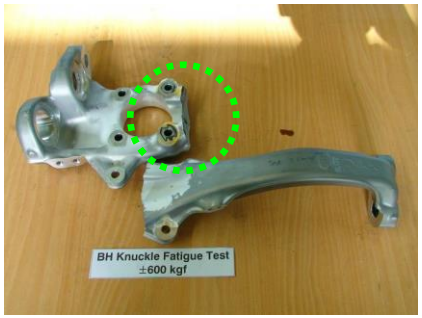
fe-safe® is easy to use

- *fe-safe* works ‘out-of-the-box’
- Many default settings and intuitive interface
- Automatic selection of the most appropriate algorithm based on the selected material – **unique**
- Standard analyses can be saved, batch analysis easily set up
- *fe-safe* automatically detects complex scenarios such as contact fatigue and changes the fatigue algorithm without user intervention
- Intuitive GUI
- fe-safe is not a “black-box”

“We have found fe-safe® to be *very fast, very solid and very easy to use*…”

Mercury Marine

Testimonial: Hyundai Motor Company



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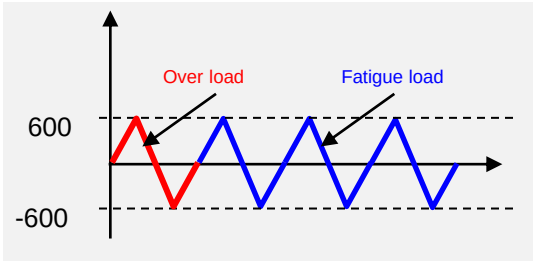

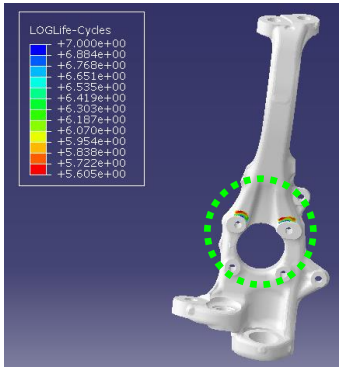

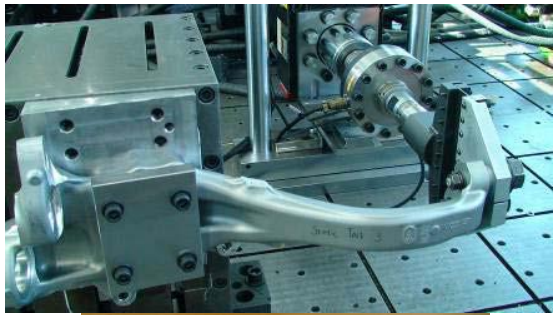

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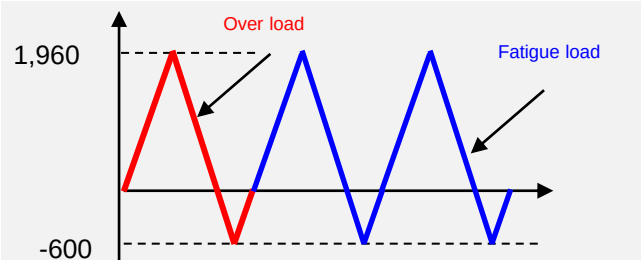

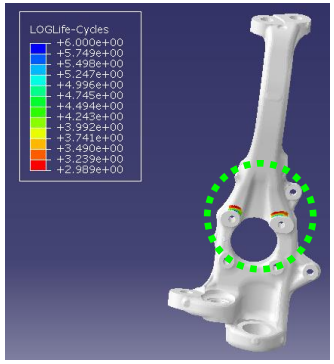

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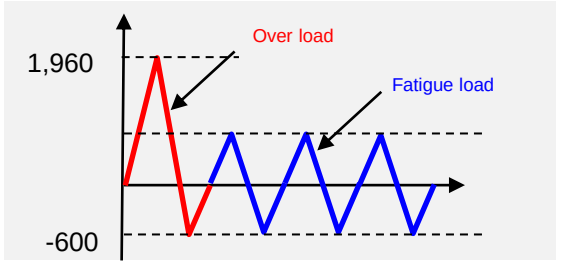
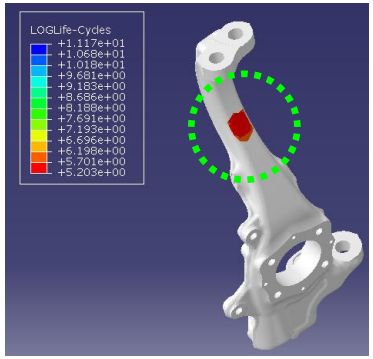
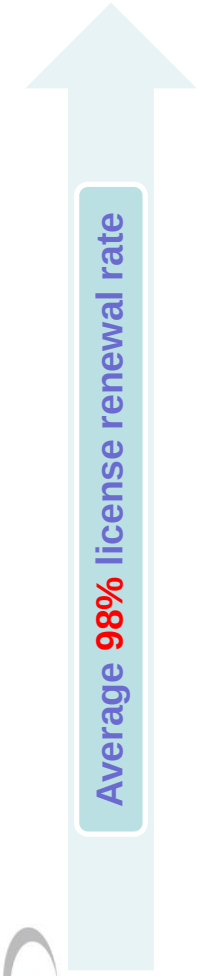




Confidence in *fe-safe*®



- ***Expertise*** **with Specialisation**

  Fatigue analysis is what we do

- ***Reliability*** **with Accuracy**

  fe-safe® is accurate – we have many case studies from our customers

- ***Innovation*** **with Continuous Development**

  Driven by the needs of the customers and strong customer and partnership integration

- ***Confidence*** **with Quality of Service**

  We are happy to share our user feedback, success stories and references