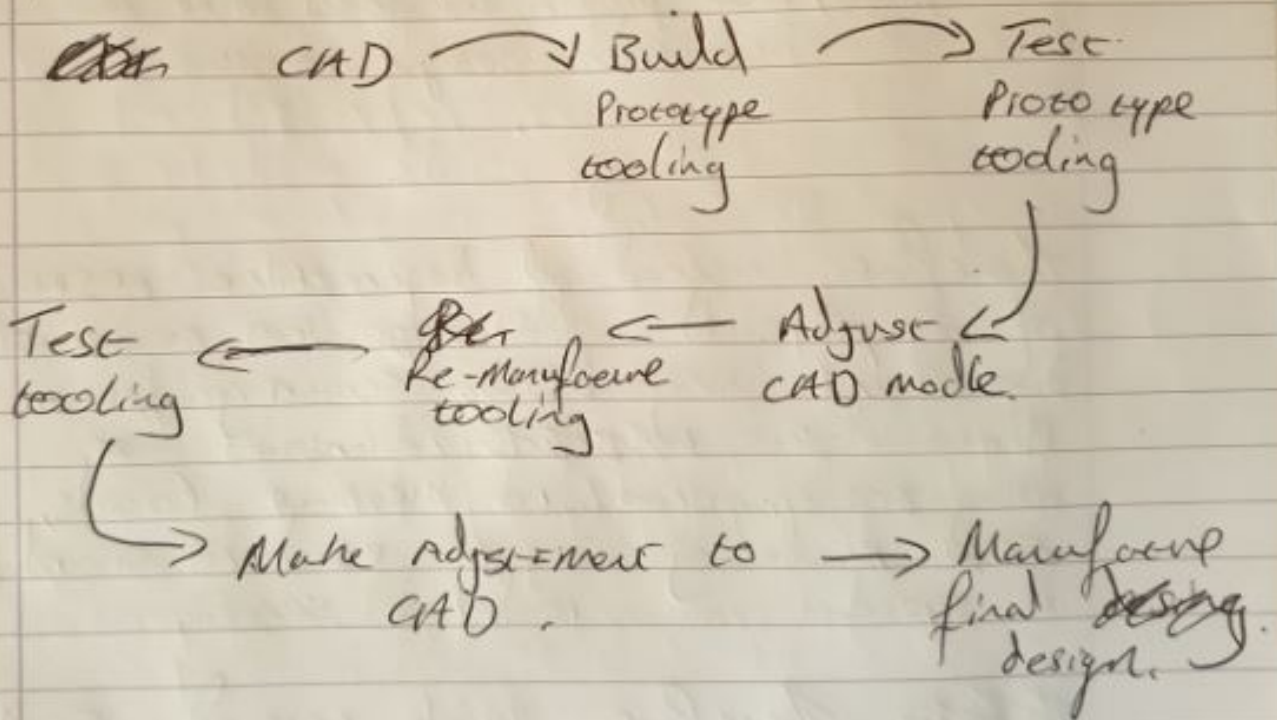


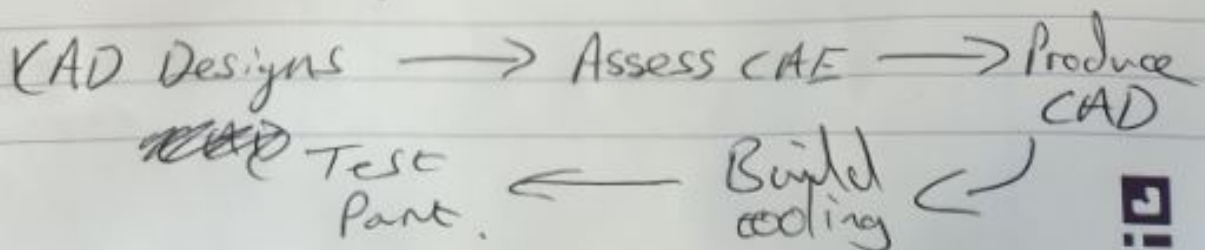
Q1)
a)

~~In CAD led designs~~ in CAD led designs FEA... Historically, ~~FEA~~ was used as a verification tool, to understand stiffness, fatigue life, max stress, etc... so, for example an assessment of existing designs where additional CAD model changes would be made post testing.

~~Before~~ Before CAD led designs, the design process would follow the following cycle:



Where as the optimisation led design use CAE/FE up front to drive the CAD where the cycle would follow.



It is important to note that generally historic physical prototype lead designs would always lead to failed initial prototypes thus, wasting.....

- 1) Time in development
- 2) Money due to additional resources (including labour + materials)
- 3) Less profit window due to increased design to market.

Therefore, instead of destructive testing of a physical prototype to measure displacement, using DTS, strain gauges or Photo-elastic ~~techniques~~ techniques or using accelerometers to measure loads, FEA Modeling can be used to simulate a system in a real life scenario.

~~Therefore~~ Therefore, with trusted FEA results, displacement, fatigue stress and other criteria can be found without the need for destructive testing.

- 1 b) Depending on the industry, physical proto types may be needed due to regulations and governing bodies that mandate proof of physical tests.
ie) Auto motive and crash testing.

Also, to gain confidence in an fea model, where the can be correlated to confirm the FEA. Hand Calculations and physical models can ~~also~~ be used, but it's important to understand their aims and objectives. ie) Cantilever beam in simple bending could easily be hand calculated or physically modelled.

Even though the FEA element quality ~~quality~~ can be assessed via analytical methods (Jacobian, stress, etc...) a physical comparison to trials will show if results are highly different to these physical tests and yet the element quality is good, we can consider ~~of~~ problems in other areas, such as boundary conditions.

1c) Correlation between FEA, hand calcs and physical modes can be ~~assess~~ essential to assess the capability, accuracy and ~~reliability~~ confidence.

Variables such as Material properties ~~which~~ in consistent young's modulus, stiffness and material voids can occur in real life. An assessment / comparison of these properties is essential.

Also comparing physical properties, as tolerances between material batches and manufacturers vary, so accurate properties in the FEA is essential.

Confidence in a model can be achieved by...

1) Performing a subjective check to understand how stress changes from one element to the next. Drastic stress changes indicate stress gradients to not be accurately captured, where element size could be too large. ~~the mesh~~ FEA mesh should show a ~~smooth~~ smooth contour plot. Hence, emphasising how dangerous it can be showing node stresses instead of elemental stresses.

2) ~~Quantifiable~~ Quantifiable checks can be performed by plotting a convergence... PRO

graph is where ~~results~~ we would continue processing until results converge and the difference is very small. We would then know that we may have a reasonable element size.

However, convergence may not occur due to unrealistic boundary conditions, where stress tends towards infinity.

Also, the element quality can be checked. Where in an ideal world we would use perfectly shaped elements. However, if the geometry deviates from this perfect shape the formulation breaks down giving less accurate results.

So quality of elements will quantify the quality to ensure to have good the stress/strain estimations are.

Therefore, checking...

- Element Normals
- Solver type (Static or Non-Linear)
- Using average element stress instead of individual elements
- checking node locations within certain tolerances, where close nodes could indicate duplication
- Skewness, to see how out of perfect shape elements are.

Samuel da Rosa (05/02/2021 - 14:00)

MX00420 - Advanced Stress + FEH (PT)

Page 6 of 14

- Aspect ratio and warpage
- Element length
- Free edges that could lead to non connecting elements.

Q2)

a)

- Understand aims + objectives, what are we trying to measure?
ie) deflection, stress, fatigue life, thermal stress, more we ask for, the more processing time required.
- Choose solver type, Linear or Non-linear.
(A linear analysis will expect a static state)
- Choose element type, which would be dictated by geometry. Elements can be 0D, 1D, 2D or 3D.
Ideally we select simplest element that is appropriate to reduce ~~run~~ time.
- Choose element order, where 1st order 2nd order could be used. It is important to understand, for example solid elements with only 3 Dof will have translational stiffness only in X, Y + Z, with no rotational stiffness. So if constrained where solid edge of the node is held, an error could be propagated due to twisting and thus no final resting state.
- Mesh size where both subjective checks using, ~~arbitrary~~ arbitrary element size (Default) could be used for a rough estimate of stress concentrations and then use finer mesh where needed more accurate results needed. Also, quantitative check of 'error norm' ~~check~~ and associated skewness, quality checks.

- 25)
- Material information and properties shall be checked (Isotropic vs non-isotropic materials).
 - Loading and boundary conditions.

- 26) The processing stage is the physical computer calculation stage where the stiffness matrices will be created.

This is the analysis of the model where direct matrix algebra, simultaneous equations, Node analysis takes place.

Pre-processing will determine the amount of analysis, time and accuracy. Where smaller meshing will lead to longer solve time.

It is important to understand material physical CPU + Hardware power prior to the analysis, so that your PC is capable of computing the FEA.

2c) The post processing
is the evaluation of results
where the FEA can be correlated
to test or hand calculations.

We evaluate with the understanding
of how pre-processing could
affect the results

Assess computational accuracy to
understand how accurate results are
before we can make crucial
recommendations to modify the CAD.

This reviews the results, stress/strain,
displacement, fatigue life

where 2D/3D graphs can be created
to analyse the results.

4)

- a) An S/N curve is formed on experimental data where, $S = \text{Stress } (\sigma, y \text{ axis})$
 $N_f = N^\circ \text{ of cycles to failure } (x \text{ axis})$

A line of best fit would be used for the curve, where this is based on probability and is limited to the experiment equivalent.

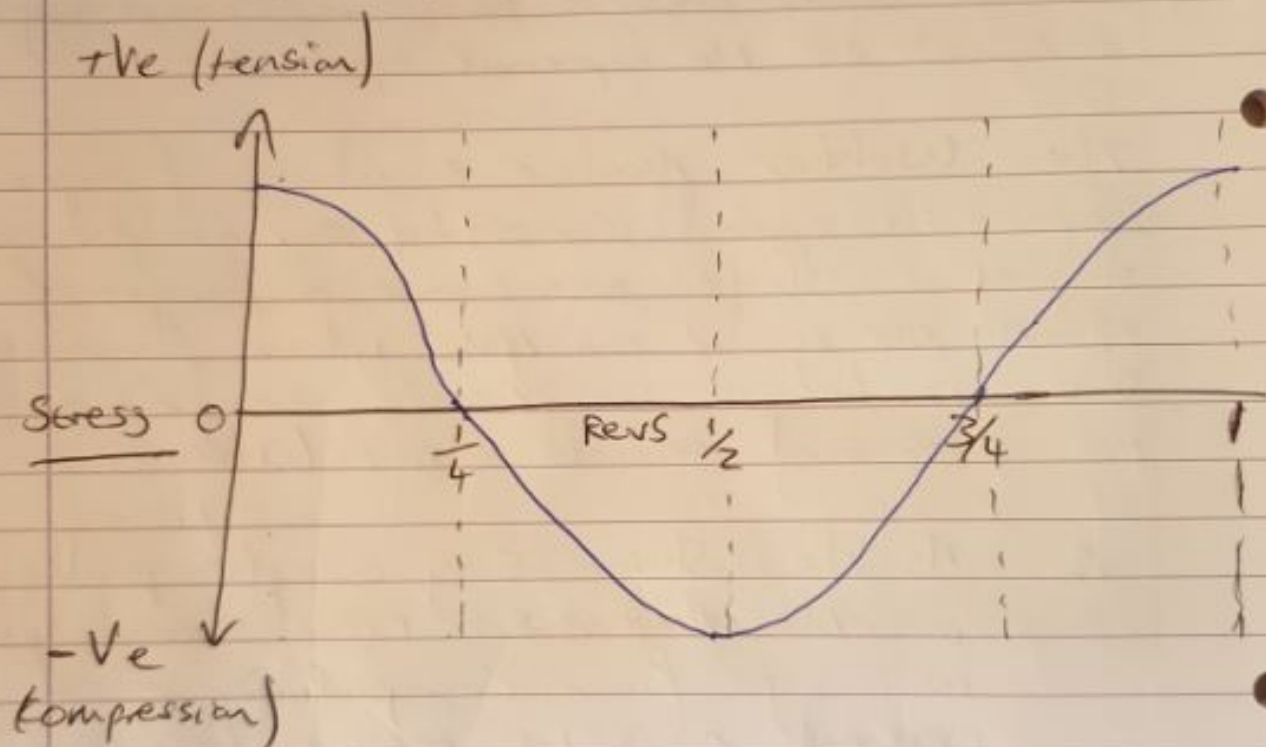
The Wohler machine simulates fatigue where the applied stress by a weight at end of a shaft will cause a fatigue failure after ~~an~~ under conditions where fluctuating stress is below the tensile strength of the material or the elastic limit.

- ∴ As the shaft spins, weight pulls down on the shaft, so cross section point will go from compression to neutral axis to tension. Thus producing a sine wave.

Define:

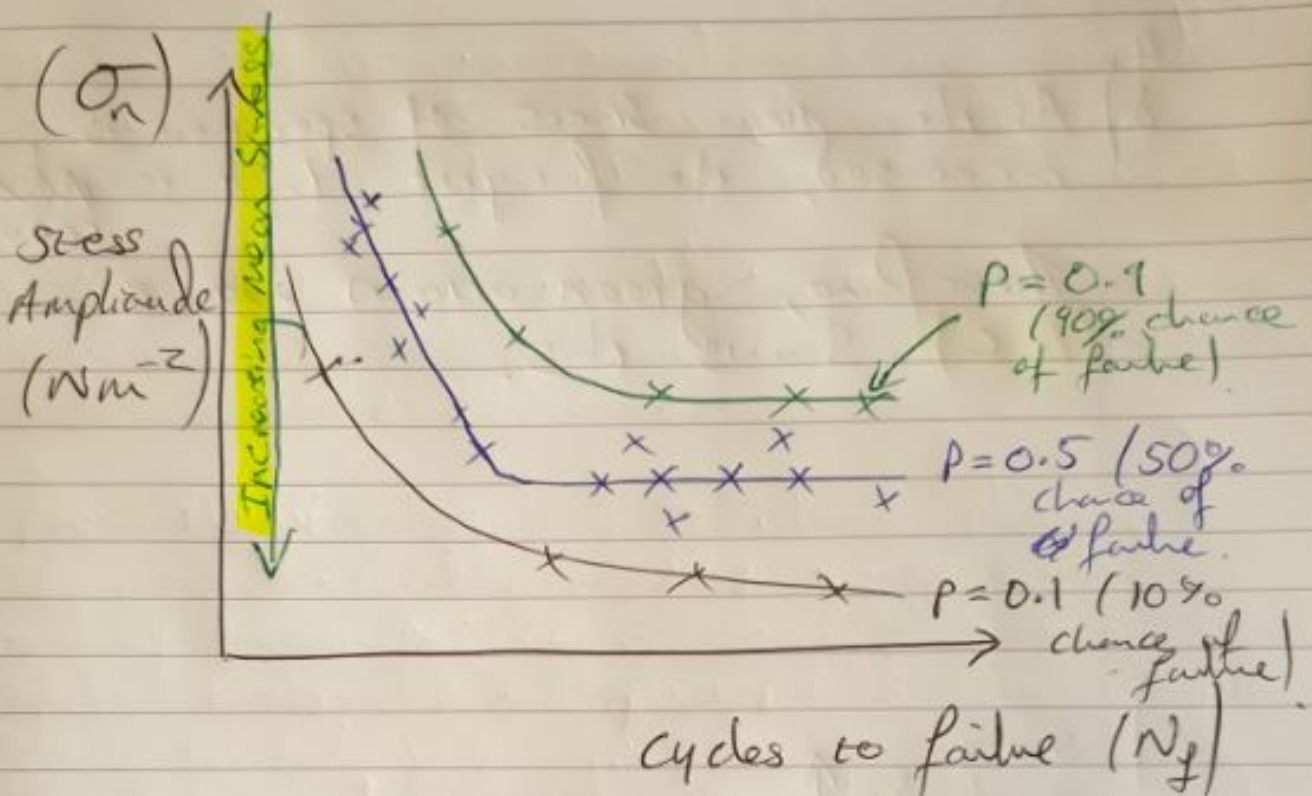
A single such test would produce one point on an S/N curve. Where repeat tests with varying ~~different~~ stress amplitude could thus be plotted/compared and a line of best fit overlaid on top of these points. How the line of best fit is fitted to these experimental results would relate to the probability of failure.

- 4)
b) The cycle of the cross section going from compression, neutral axis to tension. will produce a sine wave.
(Top Surface in tension + bottom surface in compression)



Therefore a single test would produce one point on an S/N curve. Where repeat test with varying stress amplitude could thus be plotted/completed.

4C)

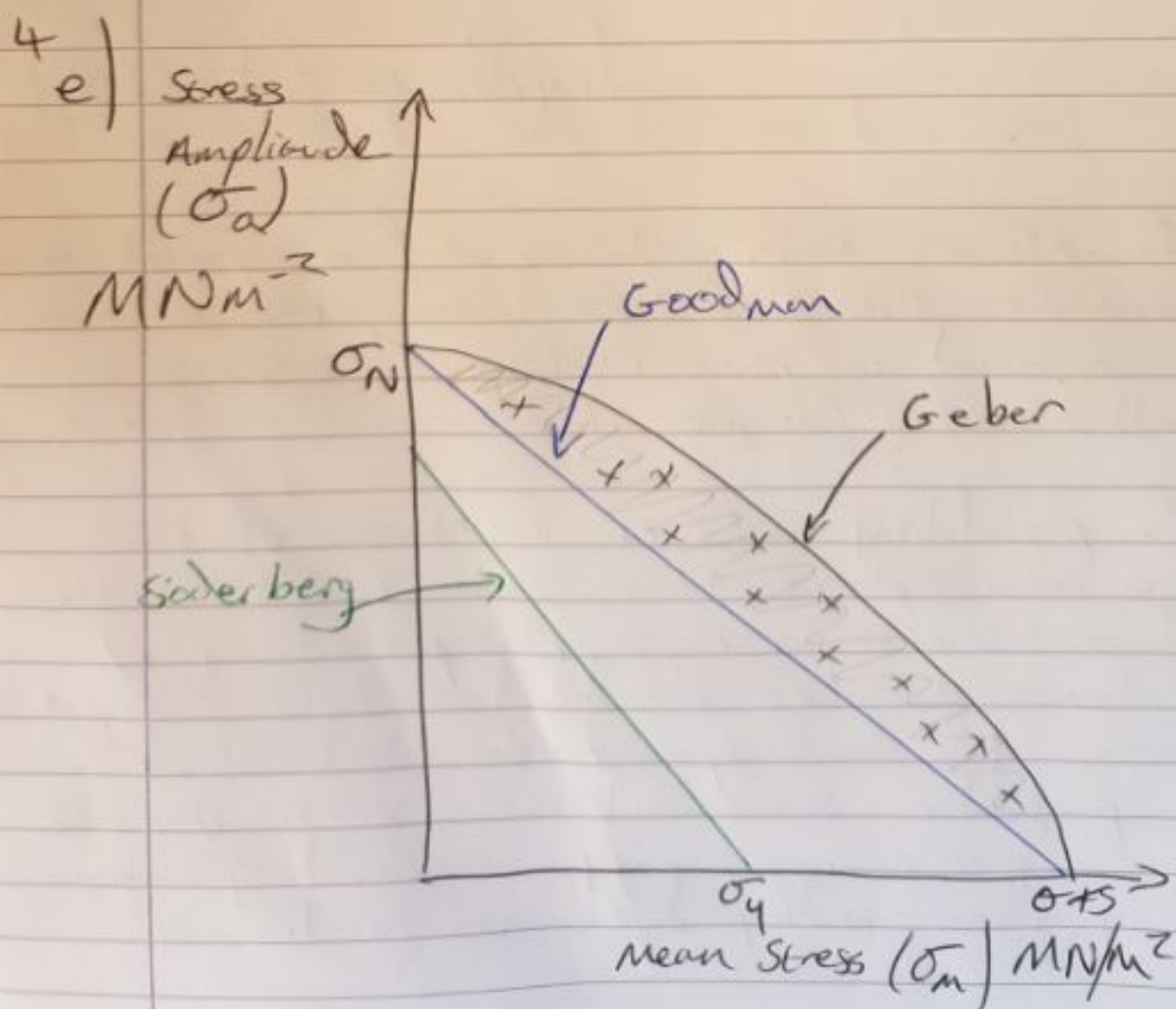


The above example shows a fatigue limit where gradient close to zero would result in a theoretical infinite cycles. This stress is called the fatigue limit.

The probability looks at a number of test specimens/pieces which are tested at the same stress so that the probability of failure can be calculated. None fatigue life of a component is determined at a particular stress level is a very variable quantity so that seemingly identical specimens may give widely different results.

- 4) d) As the mean stress of specimen is increased, the fatigue life is ~~reduced~~ reduced.

Therefore, green arrows ~~are~~ within (4c) shows this.



Samuel da Rosa (05/02/21) 14:00
Advanced Stress + FEA (PT) - MCX00420

Page 14 of 14

Shaded area in between Goodman and Geber shows where most experimental results land./are plotted.

Soderberg is the most conservative theory Goodman is more optimistic and Geber is most optimistic.

Goodman, Geber and Soderberg created relationships linking the stress amplitude and mean stress for certain samples ~~that~~ subjected to a certain N° of cycles.

This relationship can be seen in the graph.

In general, experimental results are found to lie between predictions of Goodman and Geber. As such Soderberg is most often used as it is the most conservative theory.