winLIFE Multiaxial 2.3
Prerequisites

To perform the multiaxial calculations you need the module winLIFE MULTIAXIAL in addition to winLIFE BASIC.

Parts under the influence of a dynamic, multiaxial load

It is particularly problematic to calculate the fatigue life for parts where a dynamic load results in considerable changes in the principal stress direction. This is because it is much more complicated to find out the load spectrum and to calculate here, compared to when the direction of the principal stress remains the same.

This problem can be found in many areas of technology, however, such as in a bodywork structure, axle components, crankshafts, rotary blades for wind power stations etc.
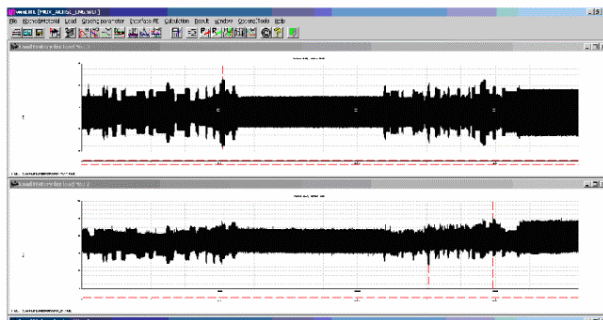

Figure 20: Load-time function of forces having an effect on the component

Figure 21 shows the example of steering under dynamic loading. It is influenced by horizontal and vertical force groups F_1 und F_2 . Because the forces are not proportional, a large change in the direction of the principal stress occurs. This is referred to as a multiaxial problem.

For the calculation, it is only necessary to take into account the stresses on the surface because a tear usually begins on the surface. The stresses on the surface form an even stress condition. This makes the analysis considerably easier.
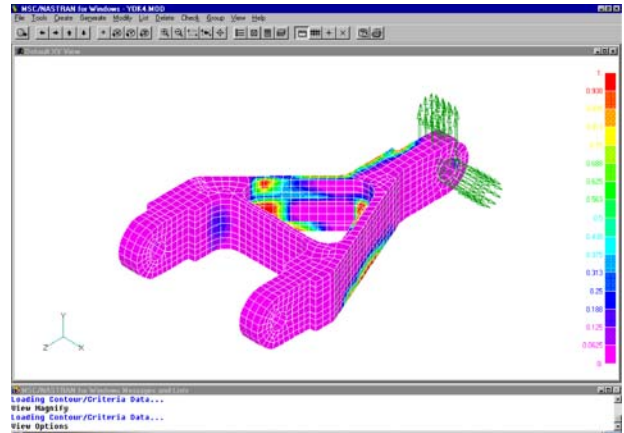

Figure 21: Part under the influence of several forces at the same time

Figure 22: Characteristics of a multiaxial case. The uniaxial and biaxial case can solved with winLIFE BASIC, the multiaxial case needs winLIFE MULTIAXIAL

The principal stress as a function of time decides whether a problem should be treated as a multiaxial problem.

If the angle ϕ or the ratio of the two principal stresses σ_2/σ_1 is variable over time, it means that we are dealing with a multiaxial case.) A Mohr's stress circle can also be used to decide.

Because it is possible to calculate a multiaxial problem in a simple way without disadvantages if the change of stress direction is only small, the grade of multiaxiality must be determined at the start. For this purpose winLIFE shows the angle ϕ and the principal stress ratio σ_2/σ_1 for characteristic time steps presented by a point). The location of the points helps to identify if a multiaxial problem really exists or if a simplified calculation by assuming biaxiality can be done.
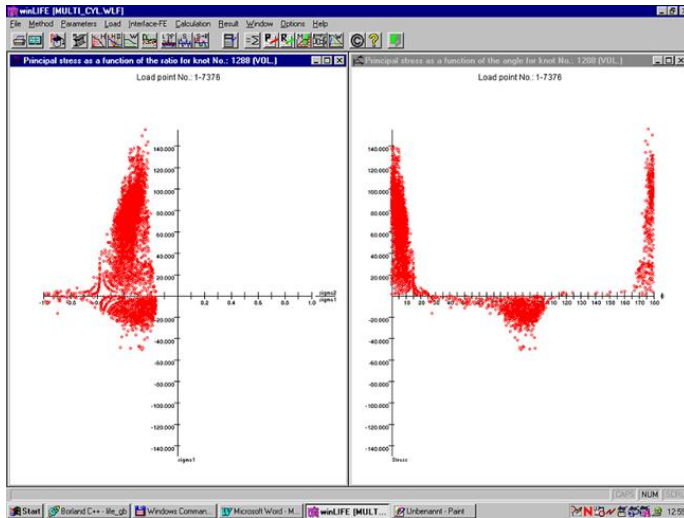
Figure 23: largest principal stress dependent on the principal stress ratio for a surface node

How a fatigue life calculation is carried out

Using FEA

The calculation is carried out in the following steps as can also be seen in a simplified manner.

- Firstly, a FE loading condition must be calculated for each effective load. This must be done with a "unit load".
- - A material S-N curve must be defined in the same way as a stress S-N curve for a uniaxial case. In the case of Local Strain Approach an e-N-curve must be created.
- The time needed for the calculation can be considerably reduced if critical nodes are pre-selected. This selection can either be made by the user entering node numbers, or winLIFE can perform an automatic analysis to find the nodes that are most likely to be the critical ones.
- If a hysteresis is carried out and if you only take into consideration the reversals in common, then the load-time function can be reduced to the events relevant to the damage. This considerably reduces the time needed for the calculation.
- The stress tensor for each selected node and each time step is calculated based on the unit load cases and the load-time functions.
- Then, according to the critical cutting plane method, the shear stress and the normal stress is calculated for each node and time step for every plane. With this data, an equivalent stress or a

damage parameter can be calculated. There are several hypothesis and damage parameters available, which the user has to select.

- The equivalent stress available for each node, time step and cutting plane is classed according to the rainflow method and a damage calculation is carried out. The plane with the greatest damage is the critical one. This result is taken as the damage for the node.
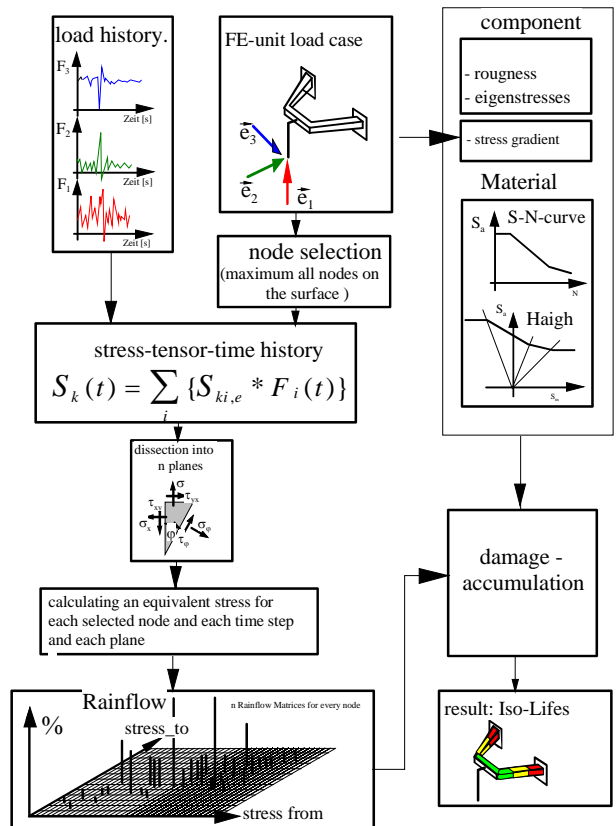

Figure 24: flow chart of a fatigue calculation for the multiaxial case in combination with FEA

Using Strain gauges

When strain rosettes are used and the strain is measured a fatigue calculation based on theses data can be carried out. The data can be read directly and a flexible read-in tool is available (Figure 25).

A fatigue prediction can be done for that point, where the measurement has been done.
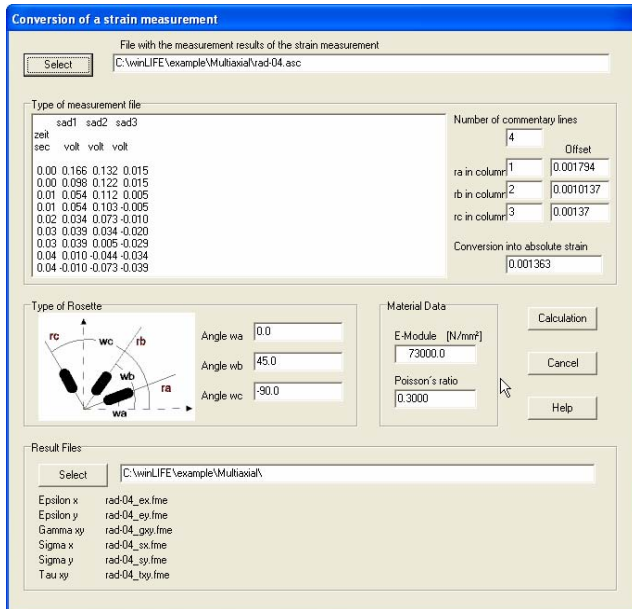
Figure 25: Mask to read in from strain rosette (Nearly all types of rosettes can be read in by entering the angle of gauge direction)

How to reduce the calculation time

If the load-time function is long, then the time needed for the calculation can be considerable. In order to reduce the load time function, the user should limit himself to the time steps where at least one load time function has a reversal. If a hysteresis is selected for each individual load-time function, the reversals can be reduced leading to a reduction in the number of time steps to be calculated.

The extensive possibilities for interactively processing the load-time function are also available in the multiaxial module. It is therefore possible to process the load-time function interactively.

Analysis of the results

In a multiaxial case it is possible to analyse the results in the following ways:

- Mohr's circle showing the critical cutting planes for each node and all considered time steps. The arising stress conditions can then be seen (diagram 6).

- largest principal stress vector for each node and all considered time steps

In addition there are numerous possibilities of showing the sum of damage with the FEA program post-processor.
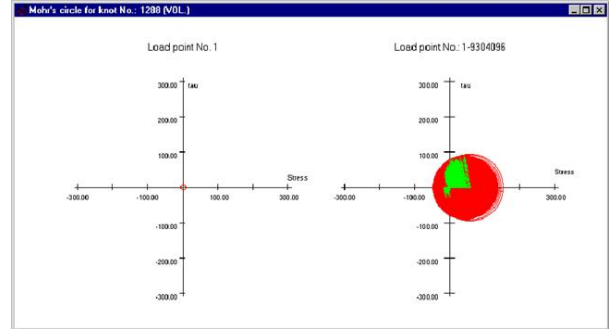

Figure 26: Mohr's circle on the hand left side for one time step on the right hand side for all time steps

The accuracy of the results for multiaxial problems will generally not be as good as those for uniaxial or biaxial problems. For this reason a conventional calculation should be carried out whenever possible in addition to the multiaxial calculation.

Reliable information can be ascertained regarding the critical places where a tear can be expected. Combining test results and the Relative Miner's Law, it is also possible to make helpful forecasts regarding the quantity.

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