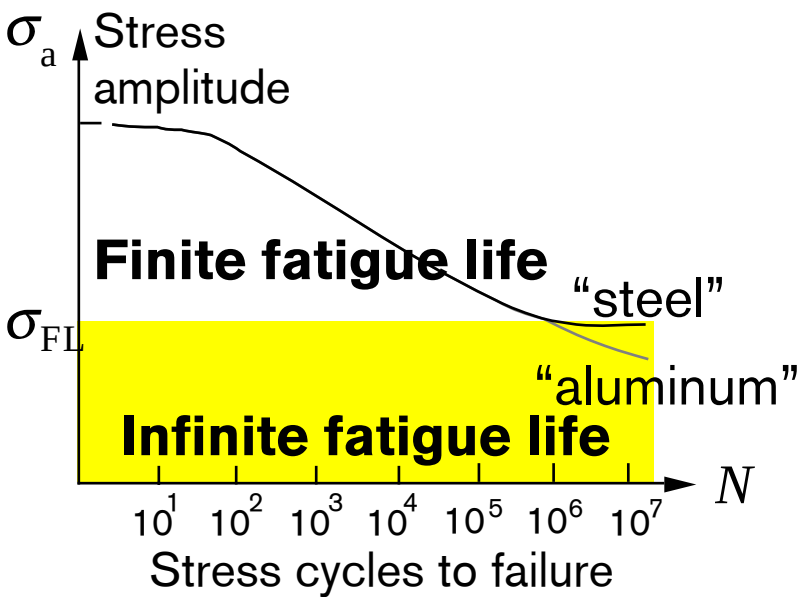
# High cycle fatigue – initiation

## Two primary causes

- From **stress concentrations**, such as pores, inclusions, initial cracks etc.
  - There will be a local increase of the stress levels
- Due to a **pile-up of dislocations**, which will form slip bands, which will grow to form cracks
  - Cracks form due to a local decrease in the fatigue strength

Which of this two mechanisms that will dominate depends on the purity of the material, the nature of the loading, etc.

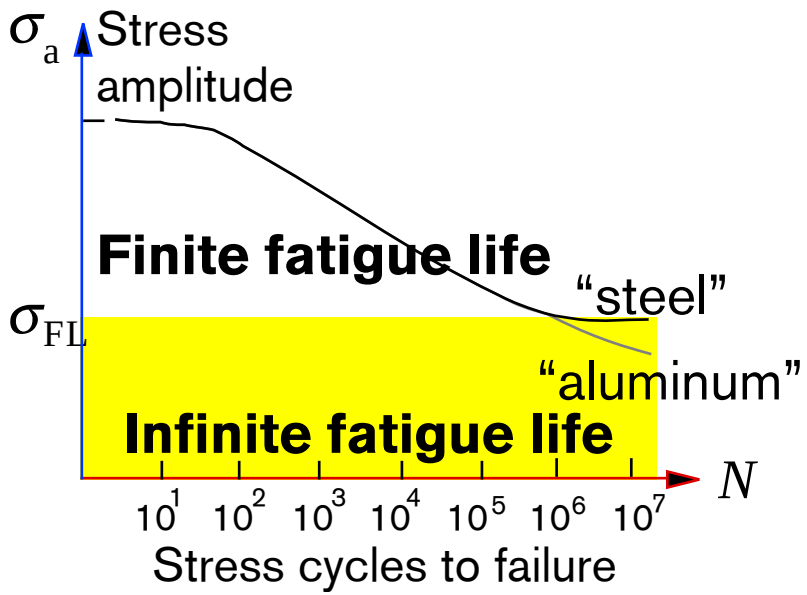
# Fatigue life at different stress levels




- For some materials, there is a stress amplitude below which no fatigue failures will occur
- This is called the **fatigue limit**
- The fatigue limit can be considered to be a **material parameter**

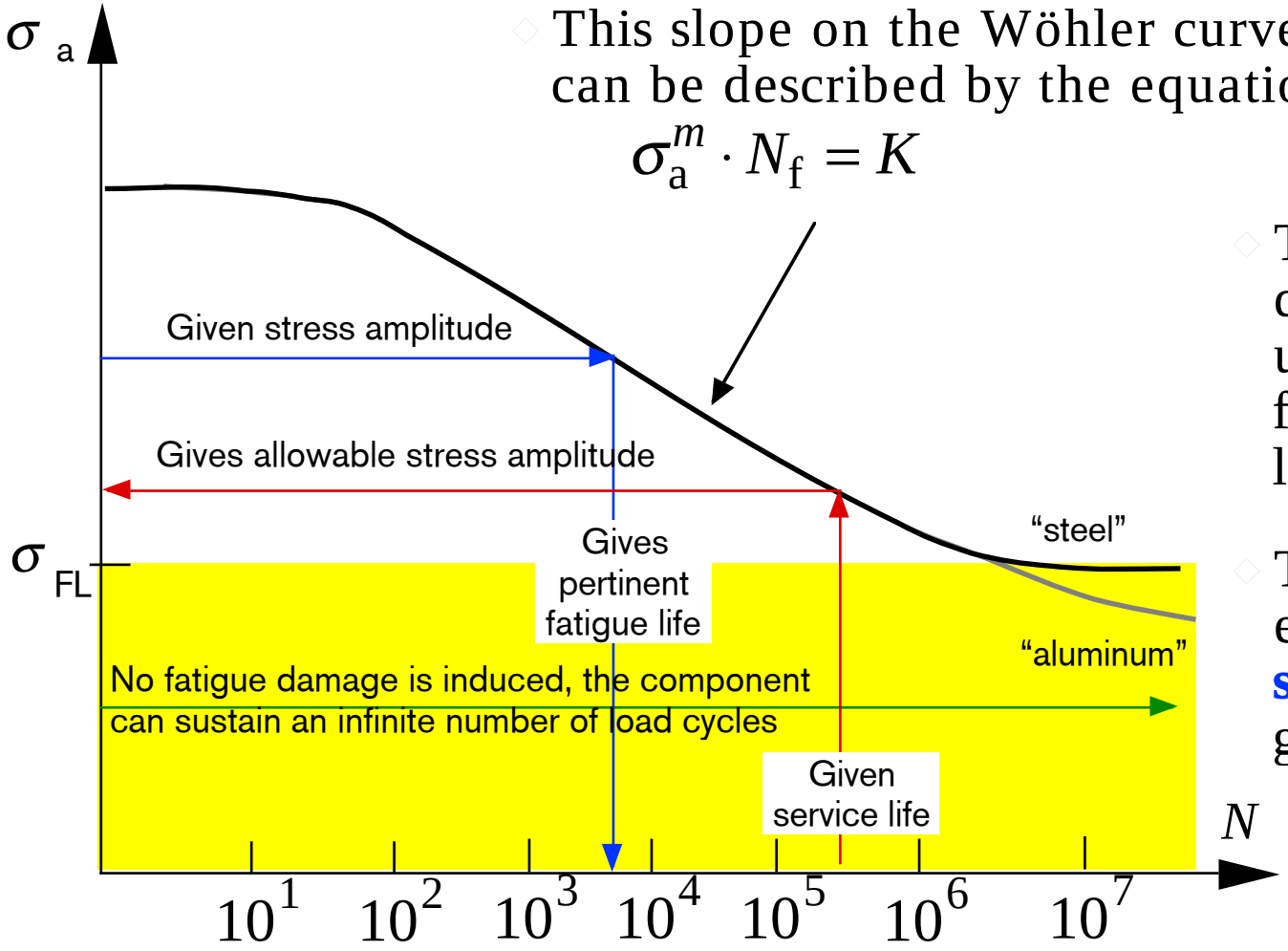
- Designing for infinite life is to assure that **no stress levels exceeds the fatigue limit**
- But how do we translate the fatigue limit to other types of loading?

# The Wöhler (S-N) curve




- The Wöhler curve shows **fatigue life** corresponding to a certain **stress amplitude**
- It is also called a *S*-*N*-curve
- The diagram is primarily valid for **uniaxial loading**
- The curve does not take into account any effects of the **mid value** of the stress during a stress cycle
- Consequently, the curve is only valid for loading with a certain *R*-ratio
- There are also Wöhler curves for entire components (*e.g.* chains, wheel axles). Then, fatigue life is normally plotted against applied load

# Using the Wöhler (S-N) curve

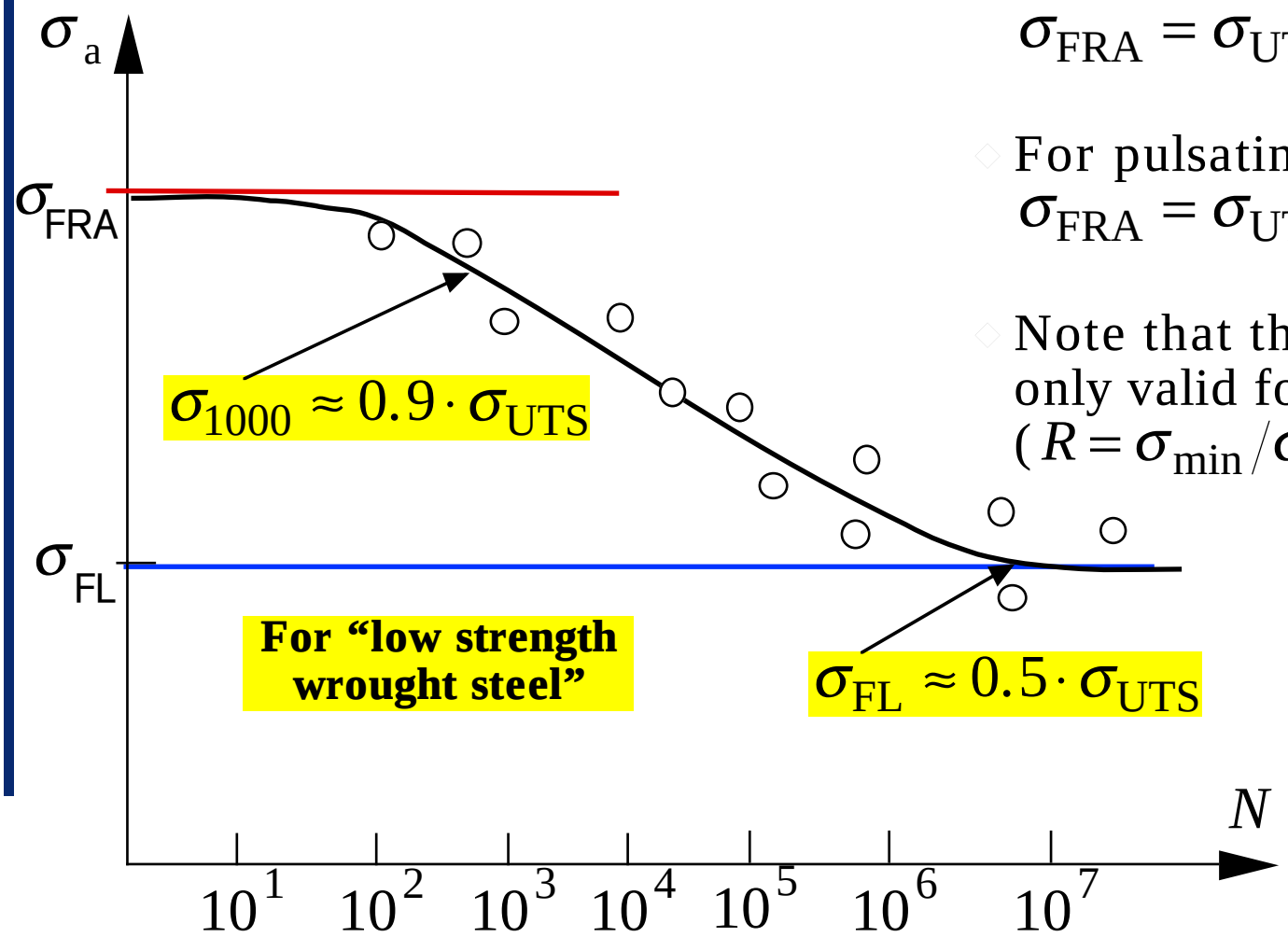



- This slope on the Wöhler curve can be described by the equation

$$\sigma_a^m \cdot N_f = K$$

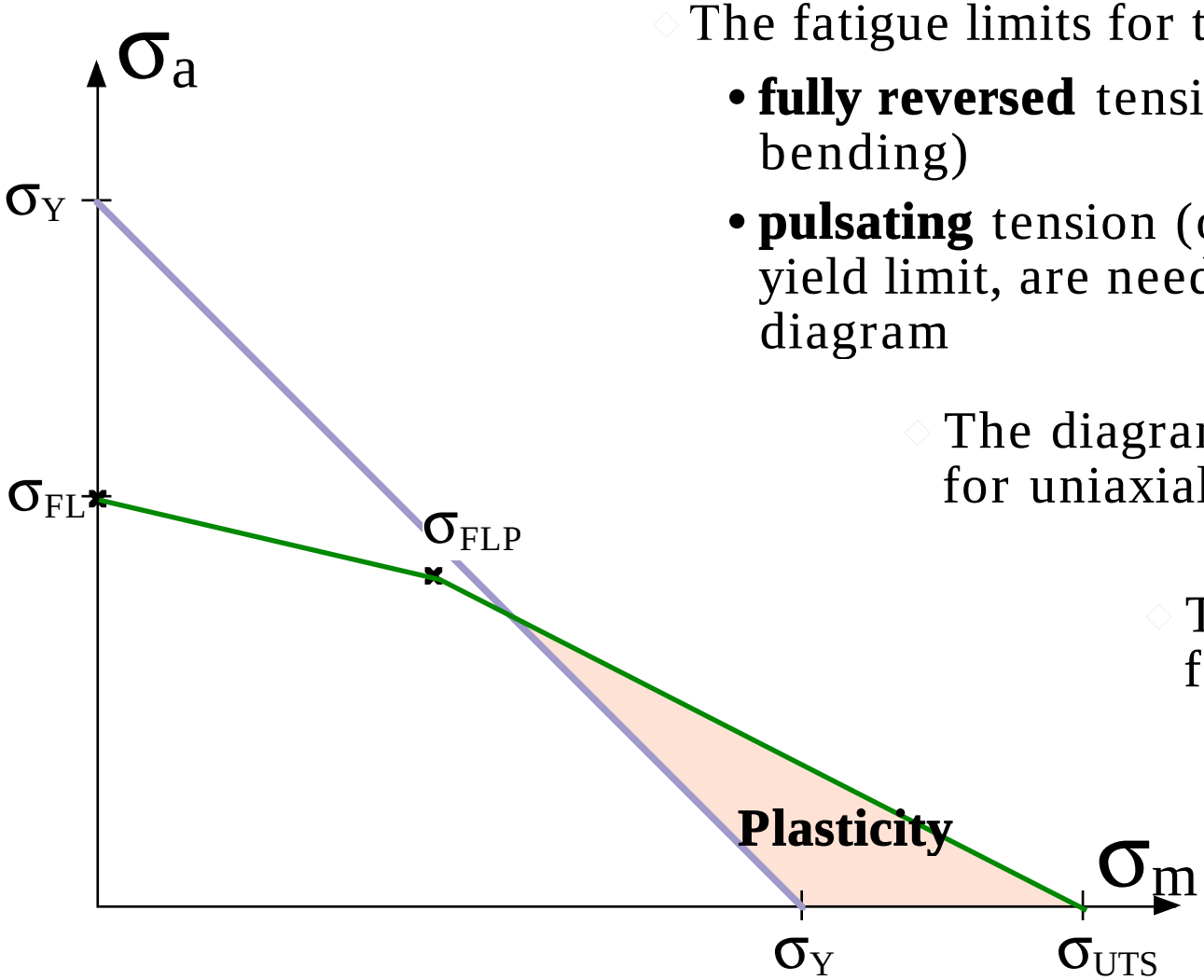
- The Wöhler diagram can be used to design for finite (and infinite) life
- This can be done either for a **given service loading** or a given **service life**

# How to Construct a Wöhler Diagram




- For alternating loading, $\sigma_{FRA} = \sigma_{UTS}$
- For pulsating loading $\sigma_{FRA} = \sigma_{UTS}/2$
- Note that the Wöhler curve is only valid for a certain ***R*-value** ($R = \sigma_{min}/\sigma_{max}$)
- For steel, the fatigue limit corresponds to $\mathbf{10^6 < N < 10^7}$

# The Haigh diagram




- The fatigue limits for two cases
  - **fully reversed** tension/compression (or bending)
  - **pulsating** tension (or bending) and the yield limit, are needed to create the diagram
- The diagram is only valid for uniaxial loading
- The diagram is valid for different *R*-ratios

# Reduction of the Haigh Diagram

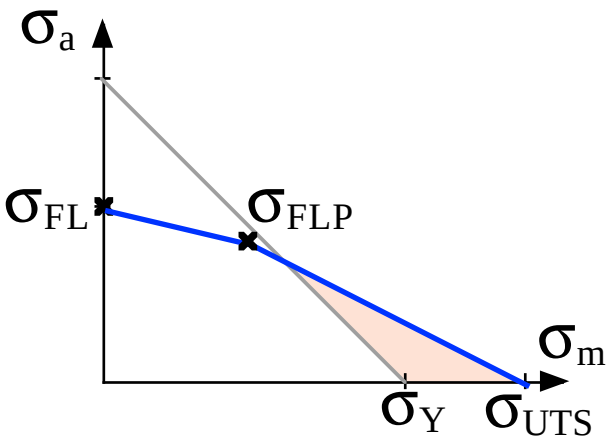
- **Reduction is made on the "amplitude axis"**
- Reduction is normally made with respect to
  - **Surface roughness** (taking also the effect of **corrosion** into account) – $\kappa$
  - **Size of the raw material** – $\lambda$
  - **Loaded volume** (no reduction in the case of a notch) –$\delta$
  - Fatigue **notch factor** – $K_f$
- The reduction factors are taken from diagrams (see *Material Fatigue*, p.9-12)
- The fatigue notch factor is determined from

$$K_f = 1 + q(K_t - 1)$$

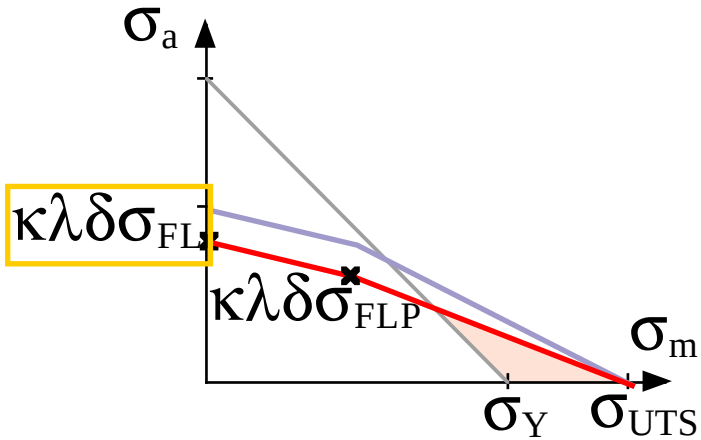
where $K_t$ is the stress concentration factor and $q$ depends on the notch radius ($q<1$, which gives $K_f < K_t$)

# Using the Haigh Diagram

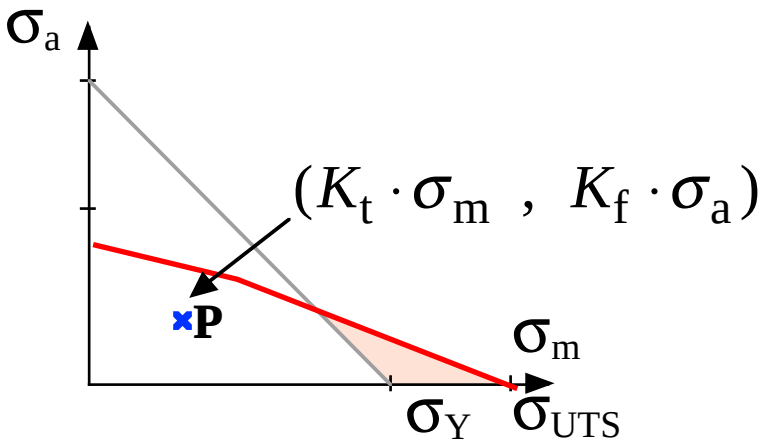
- Create the Haigh diagram




- Reduce the Haigh diagram




- Insert your service stress, **P**, in the reduced Haigh diagram




- Check if your in the “safe” area. Calculate safety factors