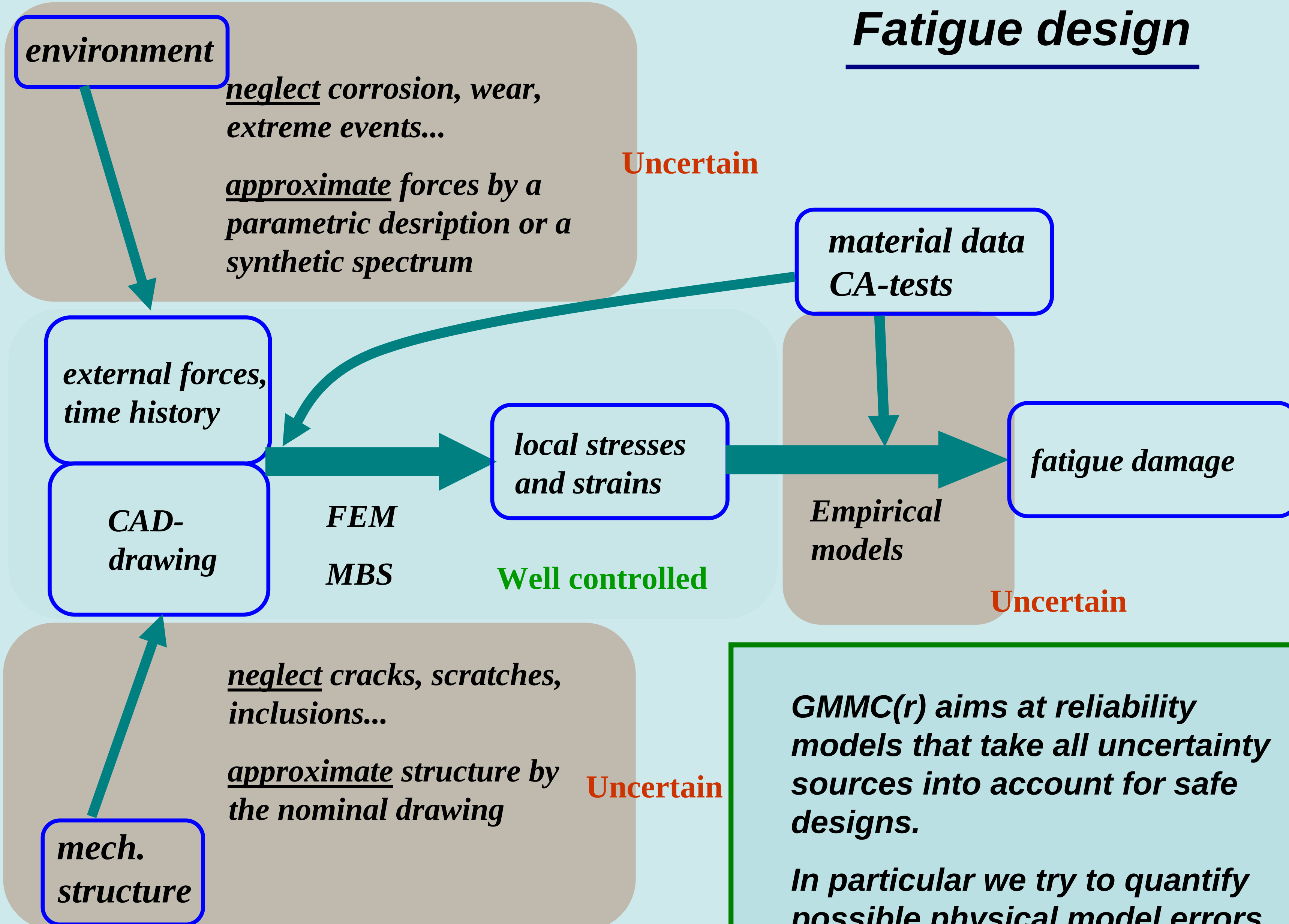
Fatigue design



GMMC(r) aims at reliability models that take all uncertainty sources into account for safe designs.

In particular we try to quantify possible physical model errors.

The round robin project Rödhake – A comparison of fatigue life prediction by computations

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Purpose:

To investigate the uncertainty of fatigue life predictions due to ***model errors***

Project:

Eight organisations performed in total eleven independent fatigue strength predictions of a cast component, based on a drawing and some material-, defect- and surface roughness specifications.

Result:

The ***coefficient of variation*** for the eleven resulting strengths was estimated at ***26%***

Organization

Participants

- Scania, Södertälje
- Volvo CE Wheel Loaders, Eskilstuna,
- Volvo CE Articulated Haulers, Braås,
- Siemens, Finspång,
- NTNU, Trondheim,
- Inspecta, Stockholm,
- Volvo Aero, Trollhättan and
- Atlas Copco Rock Drills, Örebro.

Three of the participants performed two different calculations each (the *S-N* approach and the d*a*/d*n approach*).

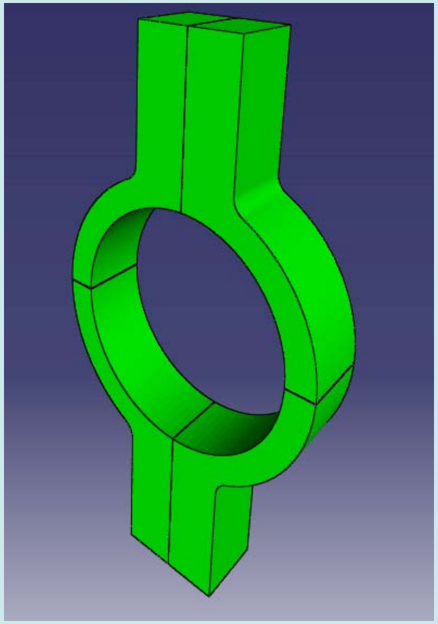
In addition one of the participants performed an internal comparison (CoV: 18%)

Project organizer:

The board of UTMIS (The Swedish Fatigue Network)

SP Building Technology&Mechanics

Problem formulation



Problem formulation

What is the fatigue strength of the given component at two million cycles?

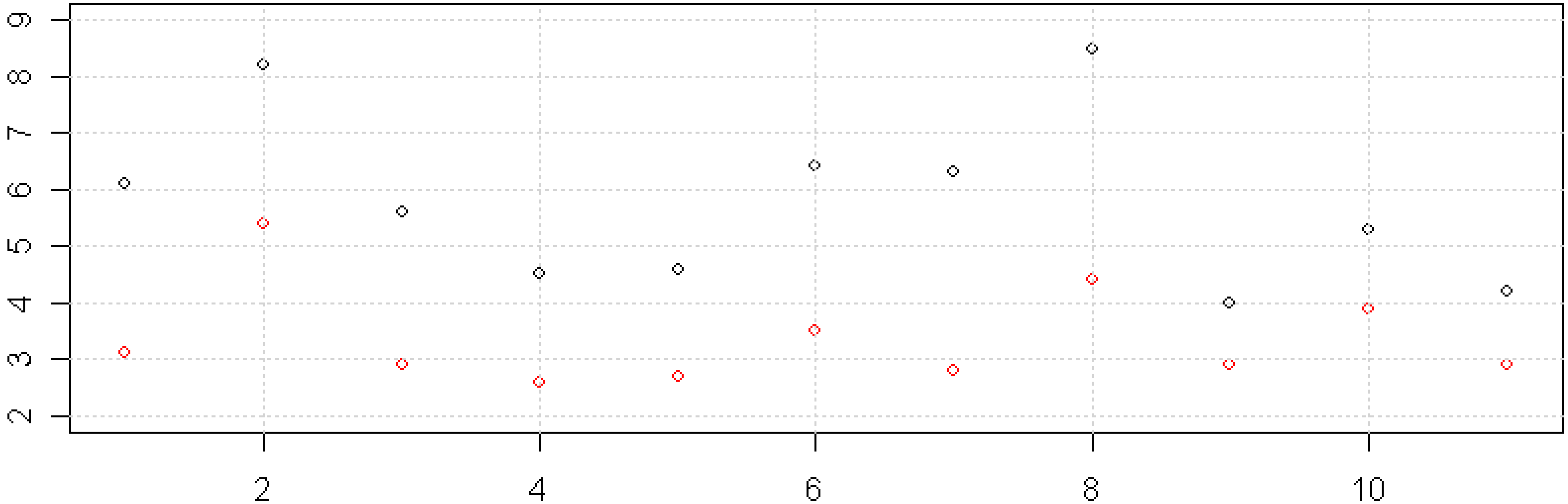
The strength is calculated both for the pull and the push load cases.

Method

Each participant is free to choose the method he regards most appropriate.

Result

The calculated fatigue strength from eleven independent calculations, pull (red) , push (black)

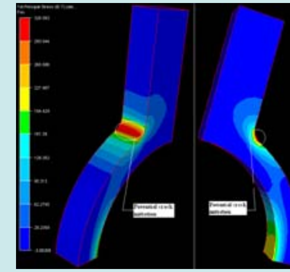


$$\overline{F}_t = 3.4\,\mathrm{kN} \qquad s_t = 0.9\,\mathrm{kN}$$

$$\overline{F}_d = 5.8\,\mathrm{kN} \qquad s_t = 1.5\,\mathrm{kN}$$

$$\frac{s_t}{\overline{F}_t} \approx \frac{s_d}{\overline{F}_d} \approx 0.26$$

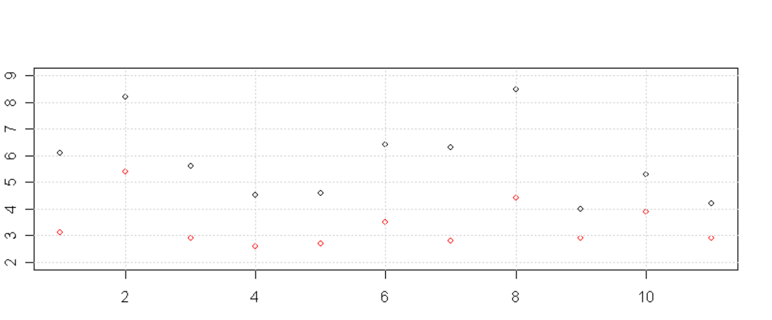
The calculation procedure, overview



- **Stress analysis (Finite Element Analysis)**
  - **Meshing (convergence)**
  - **Load cases (pull, push)**
- **Fatigue assessment 1: Initiation of a ‘technical’ crack based on *S-N* data or a fatigue limit**
  - **S-N Data: data adjustment (multiaxial stress, stress gradient, mean stress, size effect, surface condition)**
  - **Fatigue limit: Determine the smallest load cycle that initiates a ‘technical’ crack in $2 \cdot 10^6$ cycles (manually or by means of a post-processor)**
- **Fatigue assessment 2: Fatigue crack analysis based on d*a*/d*n* data**
  - **d*a*/d*n* data (adjustment for R ≠ 0)**
  - **Define initial and final crack sizes**
  - **Determine the smallest load cycle that propagates a crack from a_i to a_f in $2 \cdot 10^6$ cycles (manually or by means of a post-processor)**

What are the main causes of the variation?

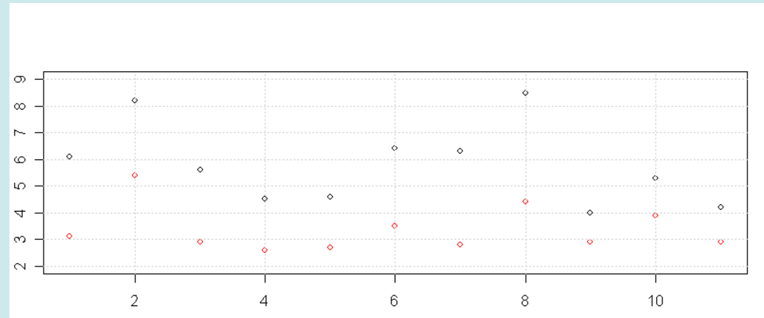
$$\frac{s_t}{\overline{\overline{F}}_t} \approx \frac{s_d}{\overline{\overline{F}}_d} \approx 0.26$$



Fatigue properties of the material	Only static strength and fatigue limit properties were available from specifications. Other properties must be found in literature.
Defect contents and role	Primarily the mean content is specified, while fatigue is governed from the worst case.
Choice of empirical corrections	The influence of multiaxial loads, surface roughness, stress gradients, mean stress or size are taken into account by non-unique empirical correction factors.

What can be done to diminish the variation?

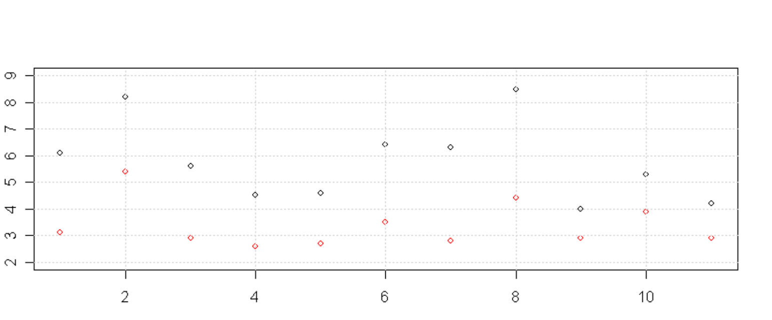
$$\frac{s_t}{\overline{\overline{F}}_t} \approx \frac{s_d}{\overline{\overline{F}}_d} \approx 0.26$$



Fatigue properties of the material	Only static strength and fatigue limit properties were available from specifications. Other properties must be found in literature.	Inhouse fatigue tests
Defect contents and role	Primarily the mean content is specified, while fatigue is governed from the worst case.	Advanced investigations
Choice of empirical corrections	The influence of multiaxial loads, surface roughness, stress gradients, mean stress or size are taken into account by non-unique empirical correction factors.	Book-keeping of experience

What to do if we can not reduce the variation enough?

$$\frac{s_t}{\overline{\overline{F}}_t} \approx \frac{s_d}{\overline{\overline{F}}_d} \approx 0.26$$



The possible model error must be taken into account when deciding safety factors.

This is at present usually made quite arbitrarily in industry.

GMMC(r) works with methods that can <u>include the model error</u> by means of its estimated <u>coefficient of variation</u> in a practical reliability measure, a safety index.

This make it possible to compare different sources of scatter and uncertainty in order to allocate investigation resources in a good and efficient way.