Creep testing of steel
- Assessing remnant lifetime

Creep in high temperature systems may have catastrophic consequences

Creep testing ensures operation and a sound economy
High temperature systems make up part of the core of production systems within the petrochemical industry, the gas industry and in power plants.

Standard operation and maintenance ensuring high operating safety and a sound economy often require major investments. Thus it is critical to possess knowledge about the system condition at all times.

Such knowledge may be achieved and ensured by localising and assessing the importance of faults or non-favourable operational loads before they become critical to the safety or the operation.

Creep in system components may have catastrophic consequences, but by use of test methods we are capable of determining the condition and development of creep at an early and non-critical stage, at benefit to both personnel and supply reliability.

Use of remnant lifetime assessment
Extrapolation of results from creep testing enables determination of remnant lifetime on most creep-loaded high-temperature systems. As mentioned above, this increases the security level and improves the possibility of exchanging components in due time in connection with pre-planned operational stops.

Remnant lifetime assessment may be applied in cases as listed below:

- Thermally loaded superheater pipes/tubes

- Long-term operating stressed high pressure steam tubes
- Heavily and unevenly loaded headers
- Hot parts of turbine systems
- Reformer tubes in refineries
- High-temperature components receipt check.

What is creep?

When a material is loaded statically below the yield stress point for a long period of time, the temperature impact may incur plastic deformation. One say that the material creeps.

When the material is stretched below the static load at increased temperatures creep will develop over several stages. In the last stages, micro-cavities will form in the material. In time these micro-cavities will grow in number and develop into micro cracks, after which fractures may easily occur.

The temperature level at which creep will initiate depends on the alloy. For aluminium creep may start at approximately 200°C and for low alloying steel at approximately 370°C.

Determining creep strength and remnant lifetime by creep testing

If you load materials in a temperature range where creep may occur, it is important to know the material creep strength in regard to dimensioning, safety and components lifetime. However, as the material deteriorates in time by creep a test formula with abbreviated testing time is needed. In practice, it is not interesting to conduct creep testing in a time scale at full length. Therefore, methods have been developed which by use of extrapolation may assess or estimate the number of hours for materials' remnant lifetime.

Creep testing methods

FORCE Technology apply the ISO-stress and/or the ISO-therm-methods which are both fast and attractive as regards pricing. When applying the ISO-stress-method the temperature is varied and the load is kept constant. When applying the ISO-therm-method the load is varied and the temperature is kept constant. The creep testing method is selected based on a number of factors such as e.g. how the material acts metallurgically in the temperature range and the access to creep data on the material.

The actual creep data is conducted on miniature test samples, made from material samples from the component in question. Under normal circumstances five samples are sufficient to make a complete lifetime determination on a given position in the plant. The test time is determined by performing the creep test at temperatures above the operational temperatures and at stresses that are fixed based on the components working stress. Fracture times are often between 10 and 1000 hours. During creep testing the samples are protected against oxidation, as testing takes place in a closed chamber with argon atmosphere.

Equipment for performing creep testing up to 1200°C exists at the creep laboratory with FORCE Technology in Brøndby.

Creep testing is documented by a technical report.

Remnant lifetime at extrapolation

When determining remnant lifetime by applying the ISO-stress-method a linearly extrapolation at the actual operating temperature is performed in a figure showing the connection between the temperature and the fracture-time. The remnant lifetime at any future given operational temperature can then be read from the diagram.

If, in future, the system shall be running at alternating operating temperatures, the extrapolation curve may be included when calculating the used lifetime and the corresponding remnant lifetime at any given point in time.

Selecting material for creep testing

Remnant lifetime determination is based on detecting critical positions in a system, which are often in places where large thermal and mechanical loads occur. When detecting such critical positions, strength calculations subsequently supported by traditional NDT-methods - including replica examination- are applied.

Due to the size of the applied miniature samples most system components will supply sufficient volume material. If, for instance, testing is performed on a thin walled pipe/tube, a 10 mm ring sample will be adequate.

Alternatively, in thick-walled steam tubes a plug sample may be made of the full material thickness or a boat shaped sample of the surface. The subsequent welding repair will in any event be simple or even unnecessary and the sample-taking will not weaken the component. Under any circumstance sample-taking shall be performed according to the subsequent repair procedure.

Fabricating miniature creep samples

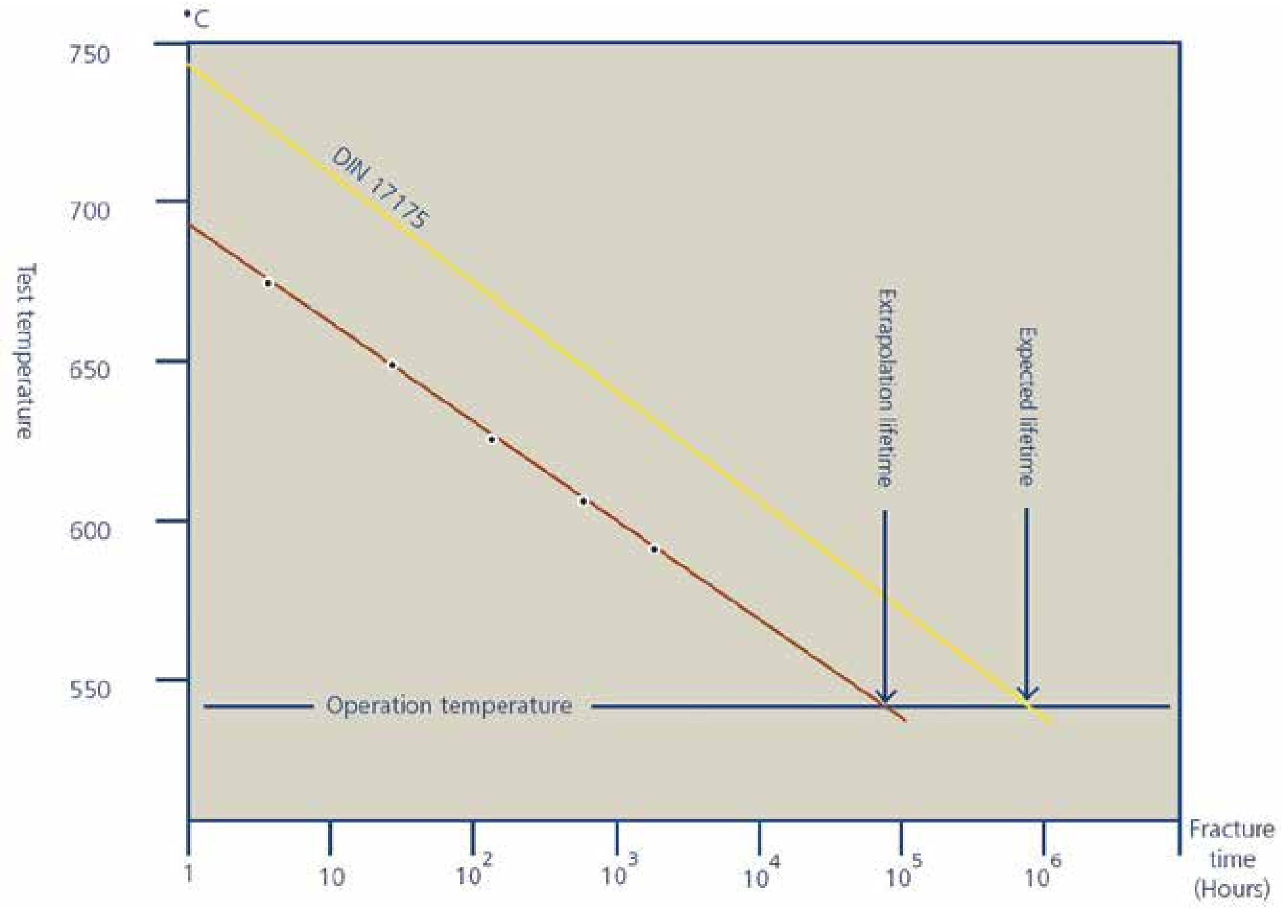
The dimension for creep samples follows the guidelines in ASTM E139 section 7. Most often we use the dimension: Ø3 x 30 mm.

Which components and operating information is important?

When creep testing has been completed the material's creep resistance and the plant's remnant lifetime may be determined according to the mentioned methods, however in order to do so the below listed information must be available:

- Material specification
- Brief description of plant including e.g.:
  - Outer pipe/tube diameter
  - Inner tube/pipe diameter
  - Material thickness
  - Input pressure - design pressure and operation pressure
  - Tube/pipe temperature
  - Output temperature
  - Operation history.

Isostress-extrapolation of fracture times achieved in 12% Cr-steel with unexpectedly low creep strength. In this case the remnant lifetime is only 10 % of the expected life time.



FORCE Technology holds many years experience within creep testing

FORCE Technology possesses several types of equipment for creep testing, where creep testing may be performed by use of miniature samples.

Simultaneously, the creep laboratory is an integrated part of the Corrosion and Metallurgy department, employing experienced metallurgists and technicians and manage a special work shop for the cutting out and preparation of miniature test samples.

FORCE Technology therefore offers creep testing and remnant life determination combined with a full metallurgical examination of the materials.

On-site metallurgy in creep loaded components

In addition to material examinations in one of FORCE Technology´s metallurgical laboratories, we have many years' experience in performing on-site material examination.

E.g. it is possible to examine material microstructures and cracks by use of the replica method which includes examination of damages caused by creep.

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