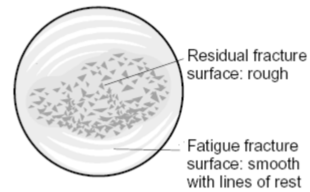
Fatigue Test

Objective:

To investigate the failure of metals due to fatigue loading.

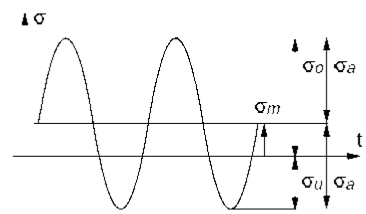
Theory



Appearance of the fracture surface of a sample

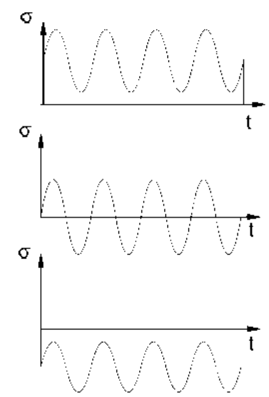
Oscillating stresses are far more dangerous for structural parts and components than a static force applied once.

In the event of frequent repetition of a static load which is in itself permissible, a machine part may rupture as a result of **material fatigue**. As the number of load cycles increases, the permissible stress level declines.



Even stresses which are below the yield point of the material in the elastic range may lead to minor plastic deformations as a result of local peak stresses inside the part. This effect gradually destroys the material due to the constant repetition and eventually results in rupture. The absolute **number of load cycles** is a more decisive factor for failure than the frequency.

<u>Alternating cyclic stress</u>

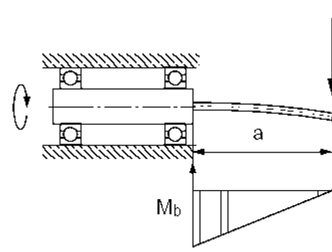


The cyclic stress is composed of a constant part, the mean stress σ_m caused by an initial load, and a superimposed cyclic part with the alternating stress amplitude σ_a.

The largest stress occurring is termed maximum stress $\sigma_o = \sigma_m + \sigma_a$, and the smallest stress is termed minimum stress $\sigma_u = \sigma_m - \sigma_a$. Three ranges are distinguished in alternating cyclic stress:

1. **Range of pulsating stresses (tensile force)** Mean stress larger than the alternating stress amplitude $\sigma_m > \sigma_a$
2. **Range of alternating stresses** Mean stress is smaller in total than the alternating stress amplitude $|\sigma_m| > \sigma_a$
3. **Range of pulsating stresses (compression)** Mean stress is smaller than the negative alternating stress amplitude $\sigma_m < (-\sigma_a)$

<u>Loading of the sample</u>



Loading of the sample corresponds to a clamped bending bar under a **concentrated force F**. This induces a triangular **bending moment Mb** in the sample.

As the bending moment is fixed but the sample is rotating, it is loaded by an alternating, sine-shaped bending stress. The highest bending stress occurs on the shoulder of the sample.

This is a pure reversed bending stress without mean stress. For this reason, it is only possible to determine fatigue strength under complete stress reversal σ_D with a revolving fatigue testing machine. It represents a special case of fatigue strength σ_D. The bending moment is calculated with the load and the lever arm as follows:

$$M_b = F.a$$

By using the section modulus of the sample

$$W_b = \frac{\pi d^3}{32}$$

It is possible to calculate the alternating stress amplitude.

$$\sigma_a = \frac{M_b}{W_b} = \frac{32.a}{\pi.d^3}.F = \frac{32*100.5mm}{\pi*8^3mm^3}.F = 2.0(1/mm^2).F$$

Fatigue Life:

It is the number of cycles to cause failure at a specific stress taken from S-N curve

Fatigue strength:

It is the stress at which failure will occur for a specified number of cycles e.g. 10^6.

Fatigue Endurance Limit:

It is the stress level at which fatigue will never occur, that is the largest value of fluctuating stress that will not cause failure for infinite number of cycles.

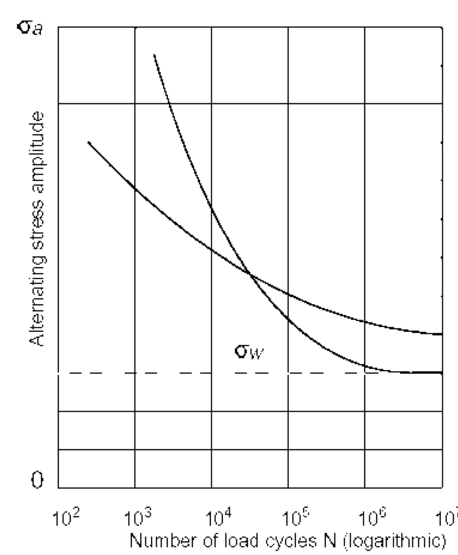
Endurance

Endurance refers to the number N of load cycles until rupture at a certain load.

Stress-number diagram

The stress-number diagram (S-N diagram) portrays the correlation between the number of load cycles until rupture and the corresponding load stress in graph form.

When plotting a stress-number curve, it is important that with alternating stress, the mean stress, or with pulsating stress, the ratio of maximum or minimum stress to mean stress, is kept constant for the various loads. As the mean stress is zero in the revolving fatigue testing machine, this condition is automatically fulfilled.

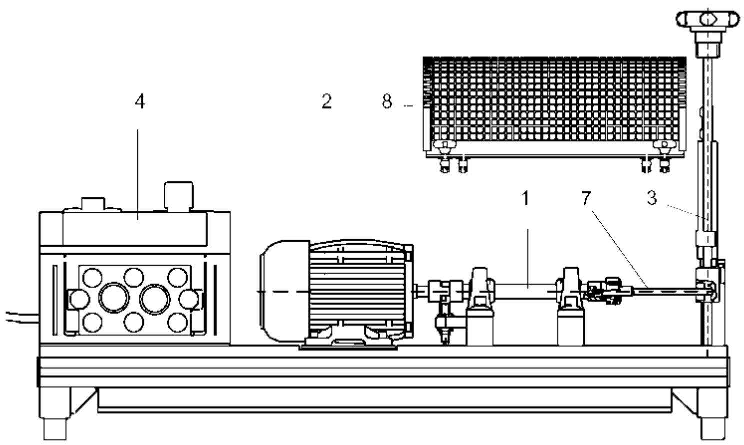


Stress-number diagram for two different materials

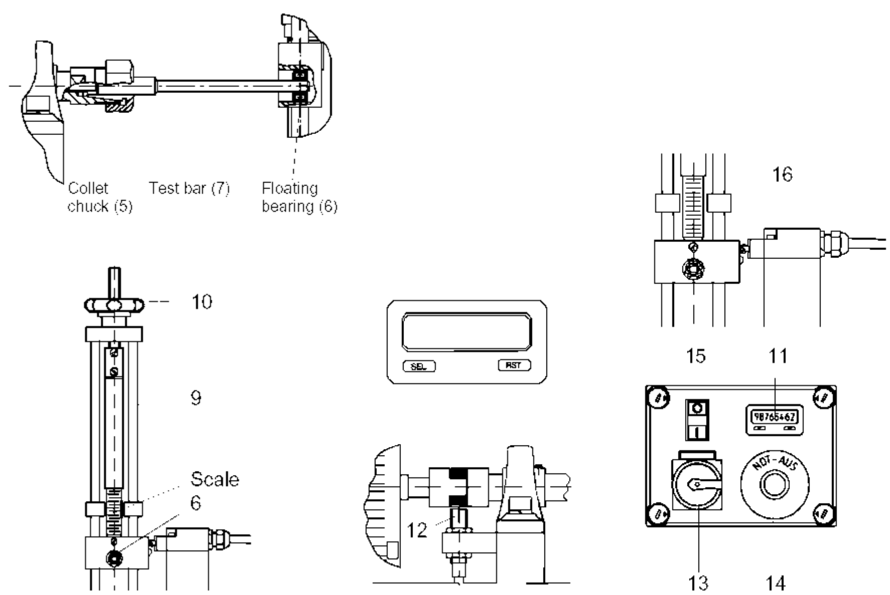
Apparatus:

In the revolving fatigue testing machine, a rotating sample which is clamped on one side is loaded with a concentrated force. As a result, an alternating bending stress is created in the cylindrical sample. Following a certain number of load cycles, the sample will rupture as a result of material fatigue. The revolving fatigue testing machine essentially consists of:

- Spindle with sample receptacle (1)
- Drive motor (2)
- Load device (3)
- Switch box with the electrical control and counter (4)
- Protective hood (8)



The spindle is mounted on two amply dimensioned rolling-contact bearings. The spindle is driven by a smooth running a.c. motor with a speed of approximately 2880 RPM.



The **test bar** (7) is clamped in the spindle on one side by a collet chuck (5) and guided on the other side in a floating bearing (6).

Loading of the sample is performed using a **spring balance** (9) and the floating bearing (6). Pre-stressing of the spring balance and hence adjustment of the load is performed via a threaded spindle with a hand wheel (10). The set load can be read from a scale on the spring balance.

A digital, 8-digit **counter** (11) records the number of load cycles. The counter may also be switched to **rotational speed measurement**. The rotational speed is then displayed in revolutions/minute.

The pulses for the counter are supplied by an **inductive proximity sensor** (12) on the motor coupling.

If the sample ruptures, the motor and the counter are halted automatically via the **stop switch** (16).

The master switch (13), emergency off switch (14), motor control switch (15) and counter (11) are housed in the **switch box** (4).

Procedure:

1. Relieve the load device using the hand wheel (the floating bearing must be at the height of the spindle).
2. First insert the test bar in the floating bearing of the load device.
3. Then insert the test bar in the collet chuck and push in as far as the end stop
4. Check concentricity of the sample by rotating the spindle by hand (correctly seated in the collet chuck, sample not deformed).
5. Mount the protective hood and lock with the knobs
6. Switch on the motor.
7. Swiftly apply the required load by rotating the hand wheel. Read off the load from the scale on the spring balance.
8. Reset the counter using the RST button in order to begin counting.
9. The motor halts automatically when the sample ruptures. Read off the number of load cycles from the counter and make a note of the number

Results & Analysis:

Number of load cycles for test bar under different loads			
No.	**Load F (N)**	**Endurance N (rpm)**	**Stress σ_a (N/mm^2)**
1	200	14030	
2	170	48800	
3	150	167000	
4	130	455000	
5	120	1280800	

1. Calculate the bending stress.
2. Plot stress against number of cycles (endurance).
3. Find the endurance limit and compare with the theoretical values.
4. Estimate the fatigue strength corresponding to $4*10^5$ cycles.
5. Estimate the expected fatigue life corresponding to a bending stress of 250 MPa.