SSAB OX
TechSupport

Information from
SSAB Oxelösund

#42

OUTLINE OF FATIGUE OF WELDED JOINTS OR SIX WAYS OF COUNTERACTING FATIGUE

What is fatigue?

Constant dripping wears away the stone.

Fatigue accounts for 80 - 90% of all breakdowns of engineering products. It causes the material to crack at various loads below the yield strength of the material. An analogy is that of water drops that can wear a cavity in stone over time.

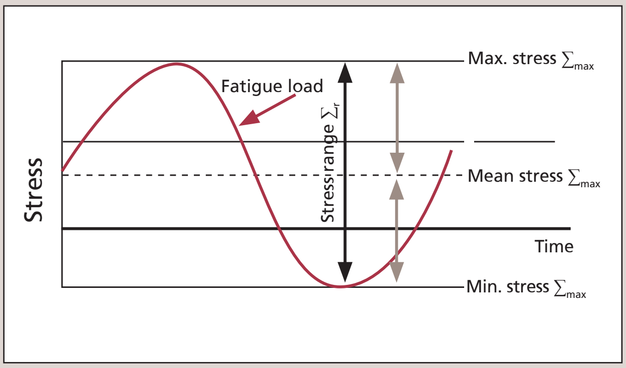
Varying loads may occur, for example, by

- a load that is repeatedly applied and relieved
- vibrations (when a vehicle is travelling)
- wind loads (tall masts that sway in the wind)

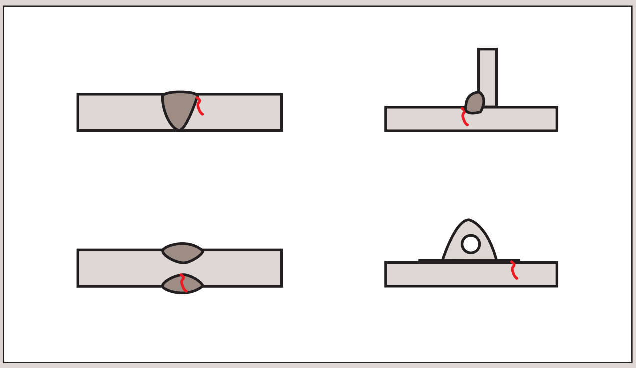
Why does fatigue occur?

All varying and repeated loads in a structure are known as fatigue loads. Fatigue loads can be regarded as the attacker. They attack the weakest points of a structure, which are generally the welds, thermally cut edges and other defects in the structure. Fatigue strength is the defence of the structure against fatigue loads.
If the fatigue load is higher than the fatigue strength, fatigue will occur.

Two parameters are needed for defining a fatigue load fully – the stress range Σ_r and the R value. The stress ratio R is the relationship between the maximum stress and the minimum stress to which a structure is subjected. The stress range is the difference between these two extremes, as shown in the figure below to the left.



Definitions of a simple fatigue load



Usual initiation points in different welded joints.

Where does fatigue occur?

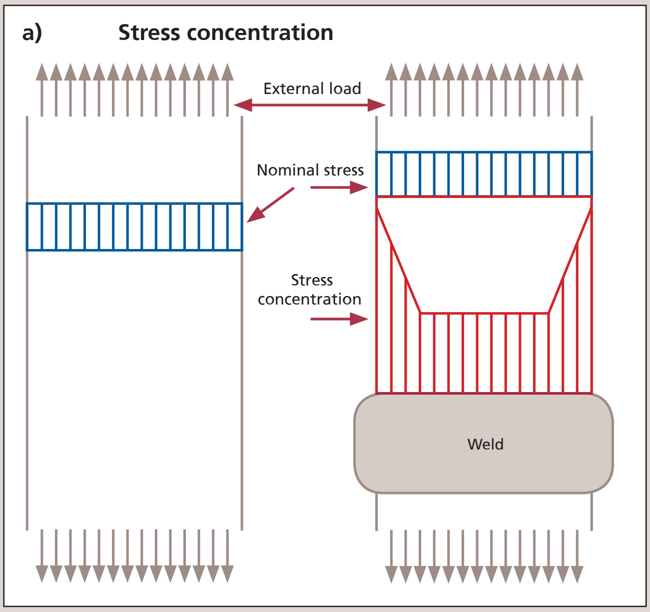
Welded joints generally have low fatigue strength. So it is welded joints that in practice determine the fatigue life of a structure. The figure above to the right shows typical areas in which fatigue cracks occur.

The fact that the fatigue strength of welded joints is low is due to three factors:

a) stress concentration

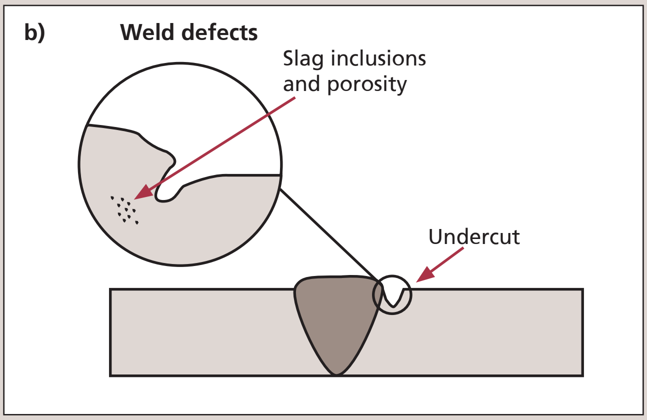
b) weld defects

c) internal tensile stresses



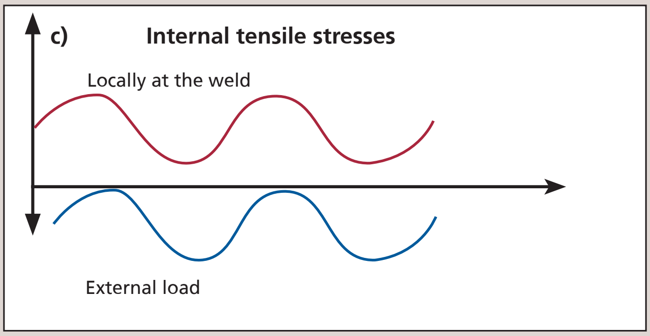
Stress concentration from a weld reinforcement

A weld represents a stress concentration. Adjacent to the weld, the stress is several times higher than the normal stress in the plate.



The weld as a defect

Weld defects, such as undercut and slag micro-inclusions, occur during welding. These facilitate the formation of fatigue cracks, since the defects act more or less as cracks.



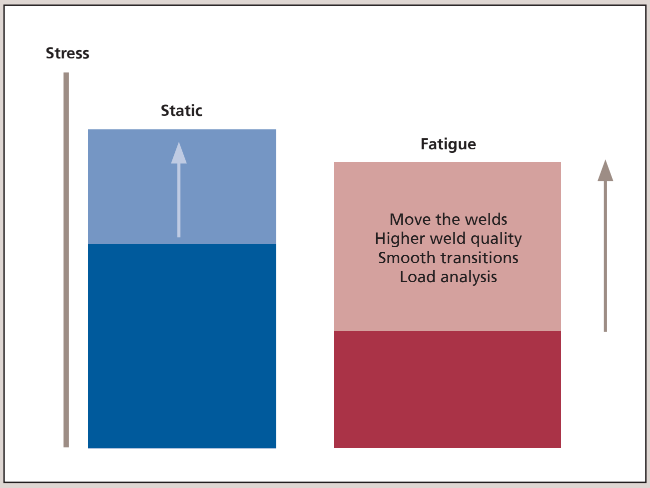
Internal Tensile Stresses

Welding gives rise to internal tensile stresses. As a result, the material adjacent to the weld is subjected to a higher stress than that corresponding to the applied load.

Difference between the stress to which the weld is subjected compared to that applied to the whole structure.

Six ways of reducing the risk of fatigue

Fatigue occurs when loads/attack are too high/ difficult for the strength/defence. This easily takes place, since the load applied to the structure is often increased when high strength steels are used. The problem is that the fatigue strength does not increase correspondingly with the static strength. In order to counteract fatigue, the fatigue strength can be increased by creative design. The figure to the right summarizes the various methods used for raising the fatigue strength.



To be able to increase the stress level, the fatigue strength must be improved

A number of methods and "ruses" can be used for increasing the fatigue strength of welds and to be able to put high strength steels to full use. The methods can be classified into two parts, the first of which consists of four procedures:

1 Create smooth force flows
2 Improve the weld quality
3 Apply the load along the weld
4 Locate the weld in a low-stress area

The second part is done to be able to put these methods and "ruses" to full use

5 Careful sizing
6 Load analysis

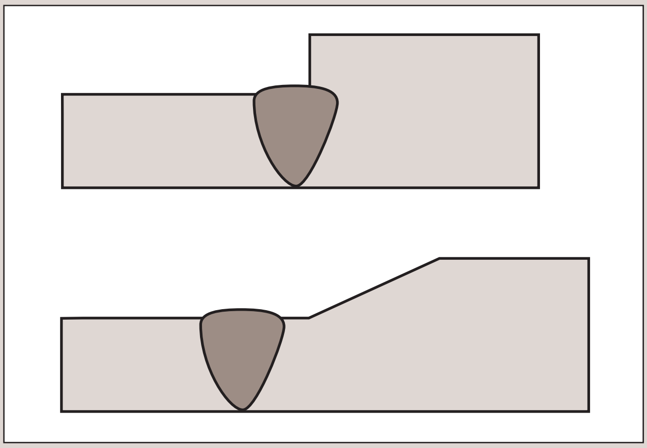
	Stress concentrations	**Weld defects**	**Internal tensile stresses**
Smooth force flows	X		
Higher weld quality	X	X	
Apply the load along the weld	X	X	X
Locate the weld in a low-stress area	X	X	X

Note that the methods, overlap one another

1 Smooth force flows

Smooth transitions around the weld are important, since they ensure a smooth force flow around the weld. Abrupt geometrical changes lead to stress concentrations in places that are unsuitable for locating welds. A good example of this is when two plates of different thicknesses are to be welded together. The figure to the right shows two such cases, the lower of which has higher fatigue strength.

1



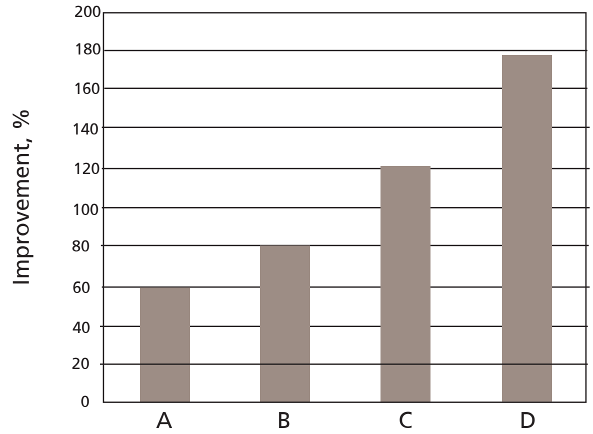
Smooth force flow in the vicinity of the weld improves the fatigue strength

2 Higher weld quality

The weld quality is important and is of major significance to the fatigue strength of the welded joint. It is also important to check that the weld quality is correct. This means, for example, the transition of the weld toe, and the number and sizes of defects at the weld. A smooth force flow at the weld is achieved by a smooth transition between the parent metal and the weld. In a butt weld, for example, the root side may lower the fatigue strength even if the top of the weld is of high quality. The figure to the right shows the improvements in fatigue strength compared to an ordinary, simple butt weld.

In this case too, the weld quality can be improved by various post-weld treatment methods, such as TIG dressing. TIG dressing produces a smoother transition, at the same time reducing the number of defects. On the other hand, a peening method affects the internal stress condition and the force flow around the weld toe can also be improved and certain defects are closed up.

2



A Non-destructive testing (NDT) or root backing
B Double V weld/root bead/ceramic root backing
C Double V weld/root bead, demands on weld transition
D Double V weld/root bead/ground-down weld + NDT

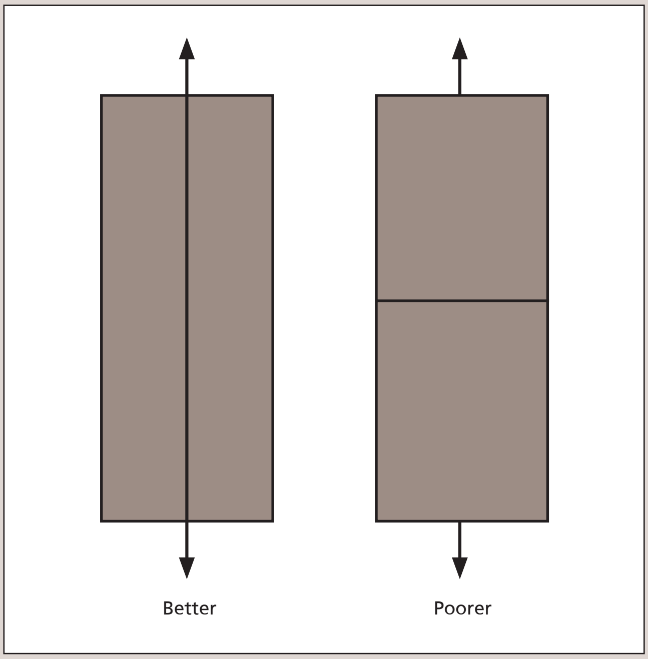
Influence of various measures on the weld quality

Various post-weld treatments can make certain defects close up.

3 Apply the load to the weld longitudinally instead of transversely

The fatigue strength of a weld that is subjected to a longitudinal load is about 1.25 higher than if the load had been applied transversely. This is because the internal stress condition along the weld is "milder" and the stress concentration is lower under this type of load.

3

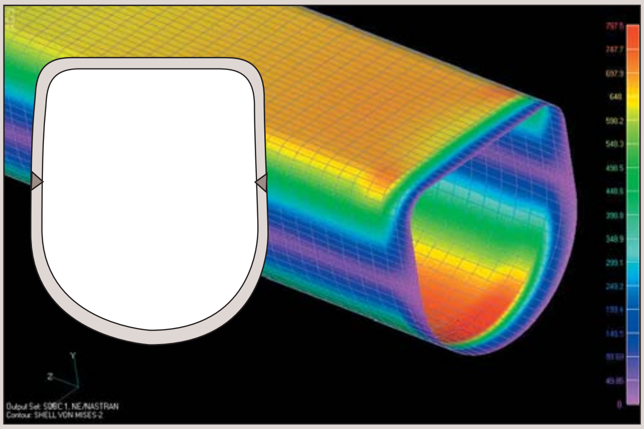


Locate the welds along the direction of loading instead of across it

4 Locate the welds in low-stress areas

The stress in a structure is not the same throughout the structure, and varies between different areas. One of the best examples of this is the web of a beam subjected to bending. The figure to the right shows where a mobile crane manufacturer has located the welds. In the middle of the web, the load fluctuations are low compared to those at the edges. It may also be advisable to locate parts that are not load-bearing in the centre of the web in beams that are subjected to bending.

4



Locate the welds in low-stress areas (violet colour)

These methods concern the fatigue strength. To determine whether these methods are needed and where they should be applied demands load analysis and sizing of the relevant structure.

5 Load analysis

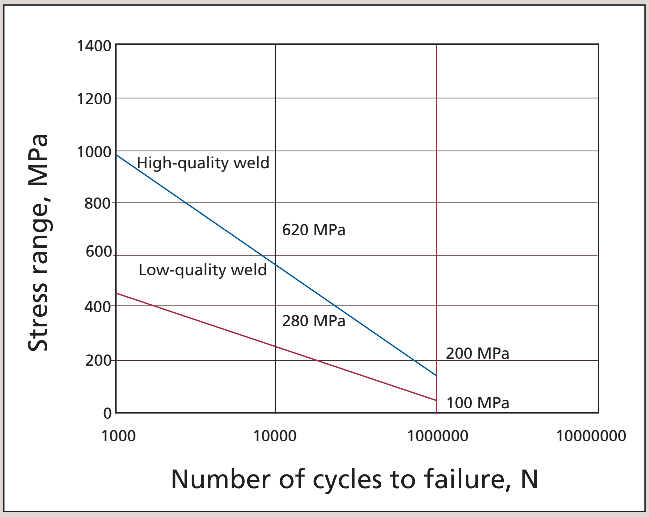
Load analysis involves investigating the loads to which the structure is subjected during its intended service life. An important matter to be determined is how many loading cycles (repeated loading and unloading) to which the structure will be subjected during its service life. Since many structures are not subjected to the maximum load in all cycles, it is also important to find out the distribution between the magnitudes of the individual loads. This distribution is known as the load spectrum. In summary, the important factors for load distribution are as follows:

- Number of loading cycles (number of times the load is applied and relieved)
- Load spectrum (load magnitude distribution)

Number of loading cycles

The number of loading cycles is of major importance to the magnitude of the load that can be allowed in a welded structure. A low quality weld in a structure with an assumed service life of 1 million cycles can be loaded to 100 MPa as shown by the red curve in the figure to the right. On the other hand, if the same structure is assumed to be subjected to 100 000 cycles, the weld can be loaded to 280 MPa. The blue curve in the figure shows the same condition, although for a high quality weld. The figure also shows the combination of the number of cycles and an improved weld quality.

5

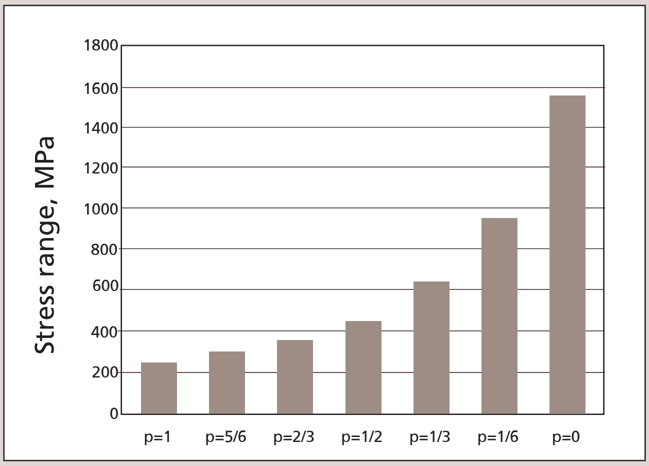


Fatigue strength as a function of the number of cycles for two different butt welds with different weld qualities

Load spectrum

Many fatigue assessments are made by considering the full load spectrum. Full load spectrum means that all loading cycles are of the same magnitude. In most cases in reality, a full loading spectrum does not apply. A good example is a comparison of a port crane with a mobile crane. The port crane almost always lifts fully-laden containers, which imposes a hard load spectrum. On the other hand, a mobile crane makes few lifts with maximum load and the boom fully extended, and is used for many small lifts. The magnitude of the load spectrum can be specified by the parameter p. For the port crane, the parameter is almost 1, which corresponds to a full load spectrum. The mobile crane has a lean load spectrum with a small number of maximum lifts, and p is then close to 0. The figure to the right shows the effect of different load spectra. The figure shows the highest permissible stress range at 100 000 cycles for different load spectra for a butt weld.

5



Influence from various load spectra for N=100 000 cycles.
The most important prerequisite when exploiting the full strength of extra high strength steel is to get the load spectra of the construction right.

6 Sizing

Sizing is generally the process in which the loads on the structure (attack) are compared with the strength of the material (defence). Accurate sizing is important if the stress level is to be raised. This is intended to find the strong and weak points in the structure. At the strong points, for example, the plate thickness can be reduced. The weak points, for example, can be redesigned or a weld improvement method can be applied.

HARDOX® WEAR PLATE

WELDOX® STRUCTURAL STEEL PLATE

HARDOX wear plate and WELDOX structural steel plate only from SSAB Oxelösund
HARDOX and WELDOX are registered trademarks of SSAB Oxelösund.

SSAB OXELÖSUND

SSAB Oxelösund AB
SE-613 80 Oxelösund
Sweden

Phone +46 155 25 40 00
Fax +46 155 25 40 73
www.ssabox.com
www.hardox.com

TS-42-fatigue-uk-v1-2004