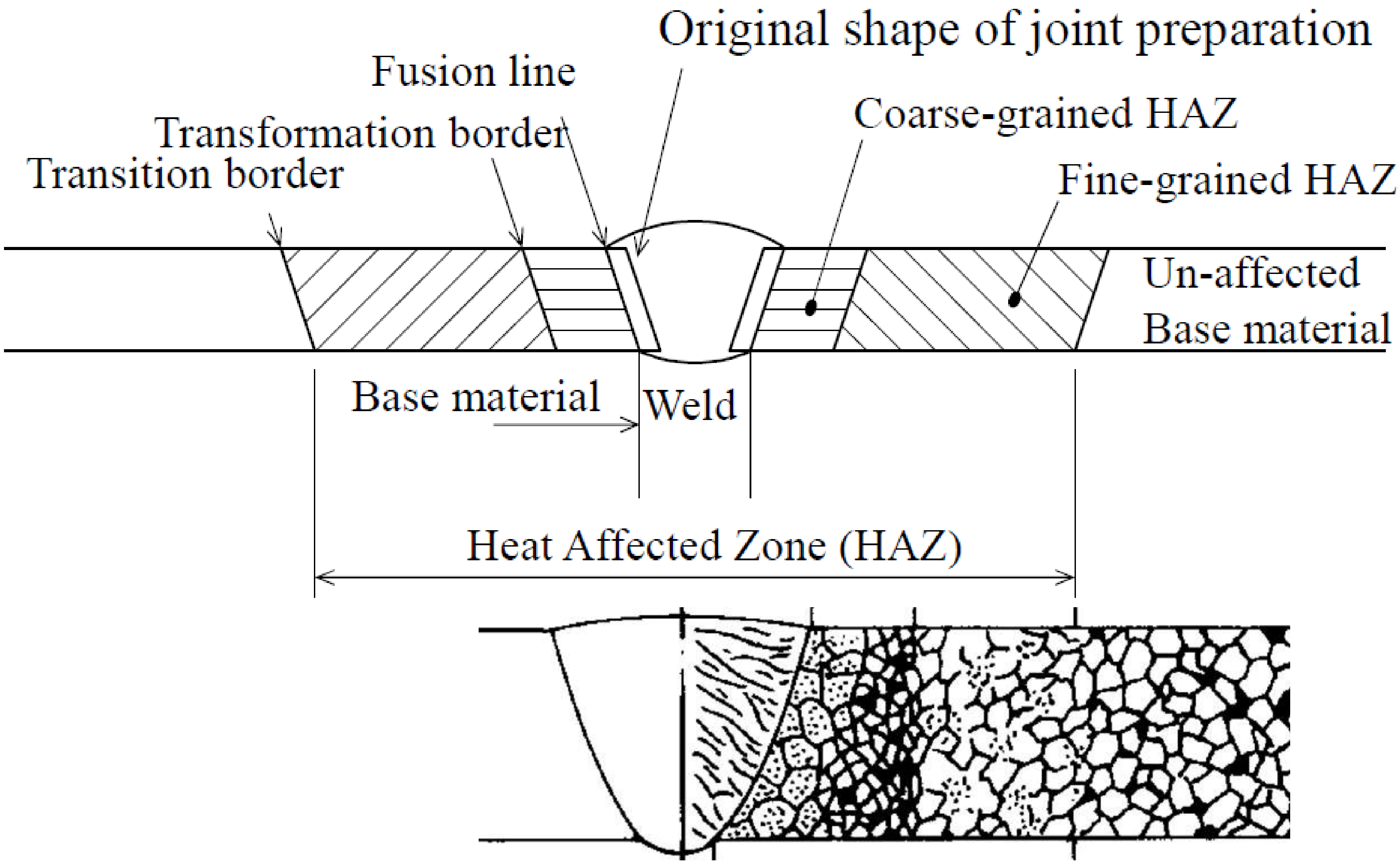
Weld on Sweden
MAKES INDUSTRY GROW

# Fusion-welded joints
## Quality levels for imperfections, ISO 5817

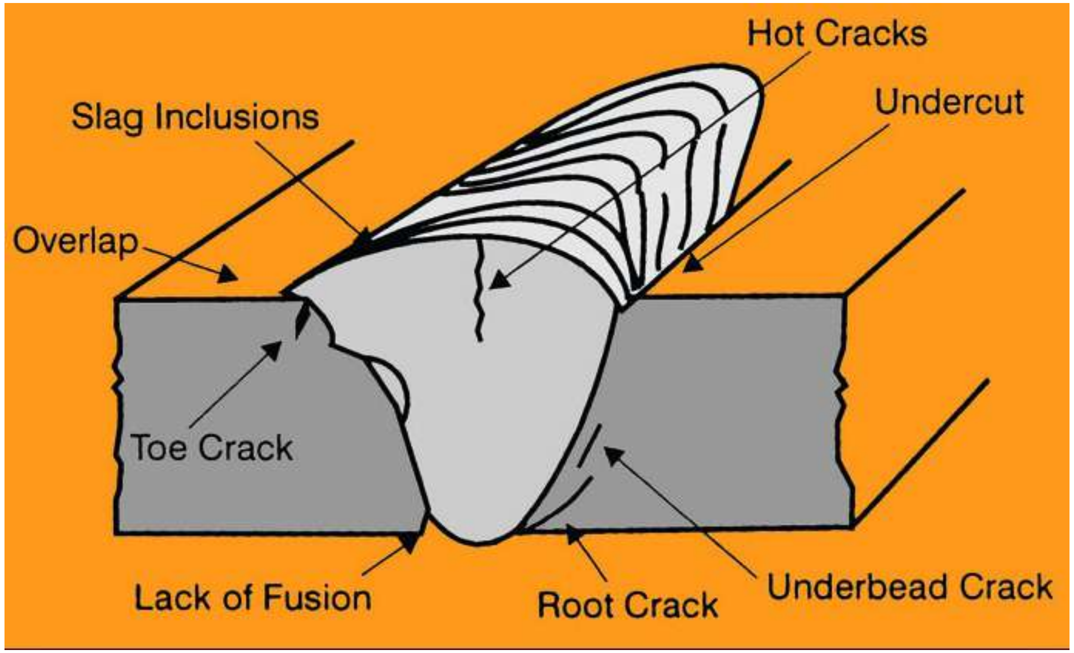
(+ one slide about Classification of geometric imperfections, ISO 6520)

Funded by the Erasmus+ Programme of the European Union


Original shape of joint preparation
Fusion line
Transformation border
Transition border
Coarse-grained HAZ
Fine-grained HAZ
Un-affected
Base material
Base material
Weld
Heat Affected Zone (HAZ)

## Material-dependent

- Lamellar tearing
- Low toughness in the HAZ
- Cracks in the HAZ
- Solidification cracking
- Hydrogen cracking
- Reheat cracking, brittleness at stress reliving
- Segregation of contaminants to the centre of plate thickness




## Operator-dependent

- Slag inclusions
- Lack of fusion
- Undercut (5011, 5012)
- Overlap - cold lap (506)
- Porosity (2017)
- Incomplete root penetration (4021)
- Incorrect weld toe (505)
- Excess penetration (504)
- Root concavity (515)
- Excess weld metal (502)
- Non filled weld (509, 511)
- Crater crack (104)
- Stray arc (601)
- Spatter (602)
- Linear misalignment (507)

## SS-EN ISO 5817:2014

**Welding – Fusion welded joints in steel, nickel ,titanium and their alloys**

**– Quality levels for imperfections (inner and surface)**

Three quality levels (classes):

- B (high) strictest, for welded joints subject to fatigue and risk for brittle fracture
- C (medium) normal workshop practice, subject to static load
- D (moderate) for welded joints carrying no load

- Valid from 0.5 mm and up
- Short discontinuities and shape deviations are a total of a maximum of 25 mm if the length of the weld is 100 mm or longer. If shorter welds 25% of the weld length.

## SS-EN ISO 6520-1:2007

**Welding and allied processes**

**- Classification of geometric imperfections in metallic materials**

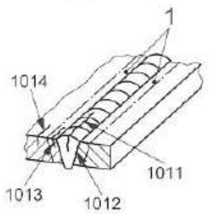
**Part 1: Fusion welding**

Example**: L**ongitudinal cracks (101)  in the weld metal (1011) are denoted

**ISO 6520-1-101** and **ISO 6520-1-1011** respectively

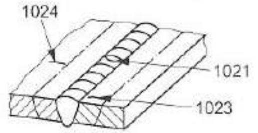
# Classification of geometric imperfections, ISO 6520

| | | | |
|---|---|---|---|
| 101 | **longitudinal crack**<br>crack essentially parallel to the axis of the weld | **fissure longitudinale**<br>fissure sensiblement paral-lèle à l'axe de la soudure | **Längsriss**<br>Riss, der im Wesentlichen parallel zur Schweißnaht-achse verläuft |
| | It can be situated | Elle peut se situer | Er kann liegen |
| 1011 | — in the weld metal, | — dans le métal fondu, | — im Schweißgut, |
| 1012 | — at the weld junction, | — dans la zone de liaison, | — in der Bindezone, |
| 1013 | — in the heat-affected zone, | — dans la zone thermiquement affectée, | — in der Wärmeeinflusszone, |
| 1014 | — in the parent material. | — dans le matériau de base. | — im Grundwerkstoff. |

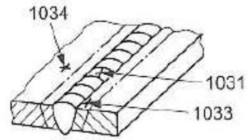



1 heat-affected zone
1 zone affectée thermiquement
1 Wärmeeinflusszone

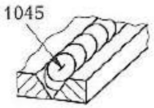
| | | | |
|---|---|---|---|
| 102 | **transverse crack**<br>crack essentially transverse to the axis of the weld | **fissure transversale**<br>fissure sensiblement transversale à l'axe de la soudure | **Querriss**<br>Riss, der im Wesentlichen quer zur Schweißnahtachse verläuft |
| | It can be situated | Elle peut se situer | Er kann liegen |
| 1021 | — in the weld metal, | — dans le métal fondu, | — im Schweißgut, |
| 1023 | — in the heat-affected zone, | — dans la zone thermiquement affectée, | — in der Wärmeeinflusszone, |
| 1024 | — in the parent material. | — dans le matériau de base. | — im Grundwerkstoff. |

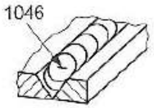


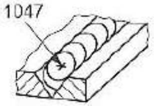

| | | | |
|---|---|---|---|
| 103 | **radiating cracks**<br>cracks radiating from a common point | **fissures rayonnantes**<br>groupe de fissures issues d'un même point | **sternförmige Risse**<br>sternförmig von einer Stelle ausgehende Risse |
| | They can be situated | Elles peuvent se situer | Sie können liegen |
| 1031 | — in the weld metal, | — dans le métal fondu, | — im Schweißgut, |
| 1033 | — in the heat-affected zone, | — dans la zone thermiquement affectée, | — in der Wärmeeinflusszone, |
| 1034 | — in the parent material. | — dans le matériau de base. | — im Grundwerkstoff. |
| | NOTE Small radiation cracks are also called "star cracks". | NOTE En anglais, les fissures rayonnantes de faibles dimensions s'appellent «star cracks» (fissures en étoile). | ANMERKUNG Im Englischen werden kleine Risse dieses Typs „star cracks" (Sternrisse) genannt. |




| | | | |
|---|---|---|---|
| 104 | **crater crack**<br>crack in the crater at the end of a weld which can be | **fissure de cratère**<br>fissure située dans un cratère de fin de cordon et qui peut être | **Endkraterriss**<br>Riss im Endkrater der Schweißnaht. Er kann auftreten |
| 1045 | — longitudinal, | — longitudinale, | — längs, |
| 1046 | — transverse, | — transversale, | — quer, |
| 1047 | — radiating (star cracking). | — rayonnante. | — sternförmig. |

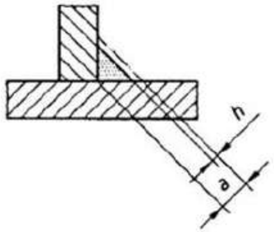
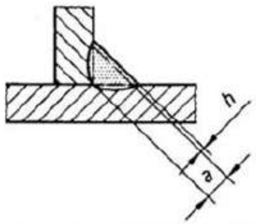




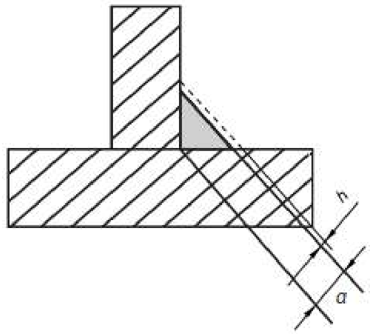


# Surface discontinuities such as Insufficient (5213) and Excessive (5124) throat Thickness, Stray arc (601) and Spatter (602)

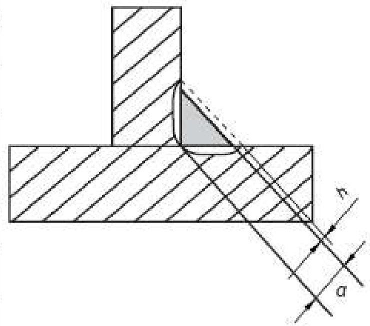
**Tabell 1** (fortsättning)

| Nr. | ISO 6520-1 referens | Benämning | Anmärkningar | $t$ mm | Acceptansgränser för diskontinuiteter och formavvikelser för kvalitetsnivåer | | |
|---|---|---|---|---|---|---|---|
| | | | | | D | C | B |
| 1.19 | 517 | Startfel | – | ≥ 0,5 | Tillåten<br>Acceptansgränsen beror på vilken typ av diskontinuitet som uppträder vid återstart. | Ej tillåten | Ej tillåten |
| 1.20 | 5213 | För litet a-mått | Inte tillämpligt vid metoder med visad större inträngning.<br><br> | 0,5 till 3 | Korta diskontinuiteter:<br>$h \leq 0{,}2$ mm + 0,1 $a$ | Korta diskontinuiteter:<br>$h \leq 0{,}2$ mm | Ej tillåten |
| | | | | > 3 | Korta diskontinuiteter:<br>$h \leq 0{,}3$ mm + 0,1 $a$,<br>men max. 2 mm | Korta diskontinuiteter:<br>$h \leq 0{,}3$ mm + 0,1 $a$,<br>men max. 1 mm | Ej tillåten |
| 1.21 | 5214 | För stort a-mått | Kälsvetsens verkliga a-mått är för stort.<br><br> | ≥ 0,5 | Obegränsat. | $h \leq 1$ mm + 0,2 $a$,<br>men max. 4 mm | $h \leq 1$ mm + 0,15 $a$,<br>men max. 3 mm |
| 1.22 | 601 | Tändmärke | – | ≥ 0,5 | Tillåten om grundmaterialets egenskaper inte påverkas. | Ej tillåten | Ej tillåten |
| 1.23 | 602 | Svetssprut | – | ≥ 0,5 | Godkännande beror på tillämpning, t ex material, korrosionsskydd | | |

| För litet a-mått/ Insufficient throat thickness Ref. ISO 6520-1 No: 5213 | Acceptansgränser för diskontinuiteter och formavvikelser Limits for imperfections for quality levels | | | Anmärkning/Remarks: Inte tillämpligt vid metoder med visad större inträngning/Not applicable to processes with proof of greater depth of penetration *Gäller endast korta diskontinuiteter/ applies only to short imperfections |
|---|---|---|---|---|
| | D | C | B | |
| Acceptansgräns t ≥ 0,5 - 3 mm | h ≤ 0,2 mm + 0,1x a* | h ≤ 0,2 mm* | Ej tillåten Not permitted | |
| a = 2 mm* | 0,4 mm* | h ≤ 0,2 mm* | | |
| Acceptansgräns t > 3 mm | h ≤ 0,3 mm + 0,1 x a (men max 2mm)* | h ≤ 0,3 mm + 0,1 x a (men max 1mm)* | | |
| a = 4 mm | 0,7 mm* | 0,7 mm* | | |
| a = 5 mm | 0,8 mm* | 0,8 mm* | | |
| a = 6 mm | 0,9 mm* | 0,9 mm* | | |
| a = 8 mm | 1,1 mm* | 1,0 mm* | | |
| a = 10 mm | 1,3 mm* | 1,0 mm* | | |
| a = 12 mm | 1,5 mm* | 1,0 mm* | | |




| För stora a-mått/ Excessive throat thickness Ref. ISO 6520-1 No: 5214 | Acceptansgränser för diskontinuiteter och formavvikelser Limits for imperfections for quality levels | | | Anmärkning/Remarks: Kälsvetsens verkliga a-mått är för stort./The actual throat thickness of the fillet weld is too large |
|---|---|---|---|---|
| | D | C | B | |
| Acceptansgräns ≤ 0,5 mm | Obegränsat Unlimited | h ≤ 1,0 mm + 0,2 x a (men max 4 mm) | h ≤ 1,0 mm + 0,15 x a (men max 3 mm) | |
| a = 2 mm | | 1,4 mm | 1,3 mm | |
| a = 4 mm | | 1,8 mm | 1,6 mm | |
| a = 5 mm | | 2,0 mm | 1,75 mm | |
| a = 6 mm | | 2,2 mm | 1,9 mm | |
| a = 8 mm | | 2,6 mm | 2,2 mm | |
| a = 10 mm | | 3,0 mm | 2,5 mm | |
| a = 12 mm | | 3,4 mm | 2,8 mm | |



# Hot cracking (Solidification cracking)

## Characteristic

- Usually in the middle of weld and runs along the weld
- Usually reaches to the surface and can be seen visually but can also be hidden under surface
- Can be detected by VT, PT, UT and RT

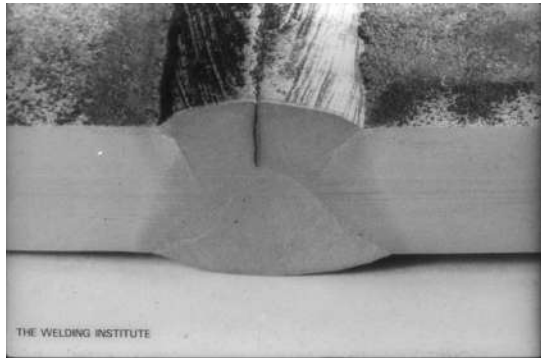
## Origin

- Chemical composition of the weld metal: High amount of C, S, P and Nb. (UCS=230C+190S+75P+45Nb-12,3Si-5,4Mn-1)
  UCS = Unit of Crack Sensitivity (<10 -> low risk, >30 -> high risk)
- Welding process which give large weld pool as method 121
- Depth of the weld is greater than the width

## How to avoid solidification cracks

- The weld geometry, less depth and root gap. (Width / Depth)>1,0
- Welding sequence to reduce stresses
- Cleaner steel and basic flux
- Weld metal containing 2-9% ferrite for stainless steel


Solidification crack in a fillet weld




Solidification crack in a butt weld

Solidification crack. Depth of the weld is greater than the width

# Hydrogen cracking (Cold / Hardening / Hydrogen / delayed cracking)

## Characteristic

- Formed when the temperature is below about 150 °C
- Can often be delayed and NDT should take place first after a few days
- Localized in HAZ along the weld, but can also occur transverse in the weld
- Do not always reach the surface and the crack is sharp
- Can be detected in most cases with VT, PT, UT or RT

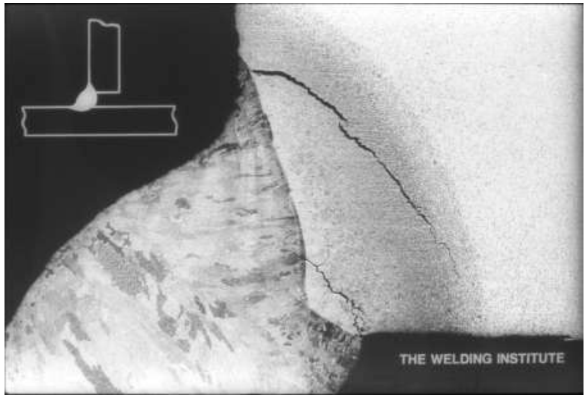
## Origin

Three things has to be precent at the same time

- Hydrogen (as H) – Choice of electrode , storage of consumables, humidity etc
- Tensile stresses – weld stresses and rigidity
- Brittle micro structure mainly martensite / high hardness in HAZ –which duo to
  - Carbon equivalent $CEV = C+Mn/6+Ni/15+Cu/15+Cr/5+Mo/5+V/5$ ($CEV \leq 0,4 – 0,41$)
  - Cooling rate: depends on type of section, preheat and working temperature

## How to avoid hydrogen cracking?

- Good joint preparation, weld sequence
- Good connection between weld and base material
- Dry consumables, clean and dry joint surfaces
- Preheat and high working temperature
- Suitable heat Input
- Soaking immediate after welding




**Hydrogen crack in a fillet weld <**

# Incomplete root penetration (4021)

## Characteristic

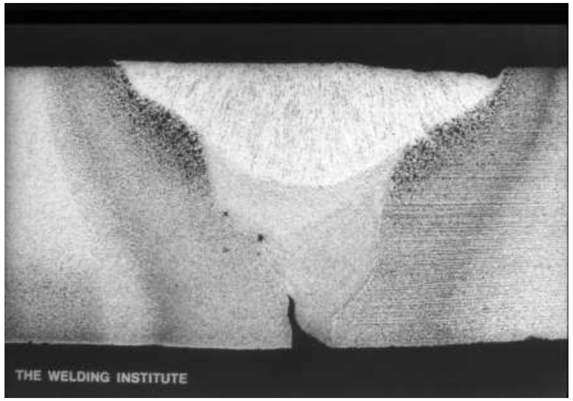
- Incomplete weld through
- Goes along the weld

## Origin

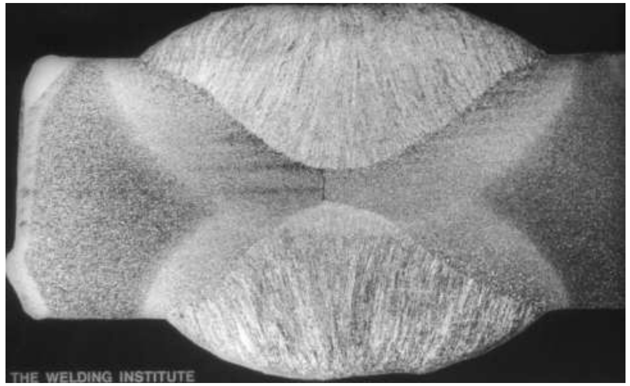
- Too Small joint angle
- Too small gap
- Too big root face
- To large electrode diameter
- Too low current
- Unsuitable welding technique
- Incomplete root cleaning
- Poor control of the electrode in submerged arc welding

## How to avoid?

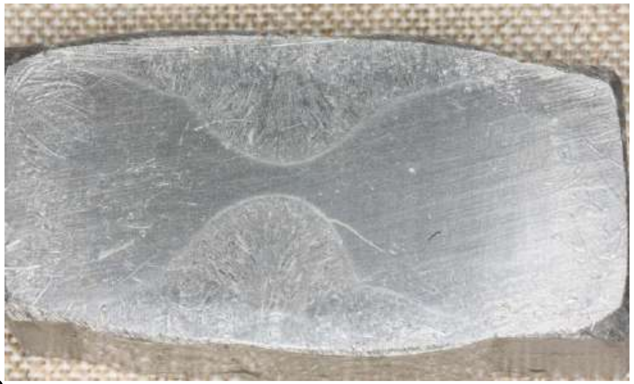
- Method 111: Use small electrode diameter for the root pass with
- Method 131/135: Sufficient welding current and adjusted voltage to keep the arc length short.
- Method 141: Use short root face and adjust the welding current




Incomplete root penetration




Incomplete root penetration welds do not meet



Submerged arc welded duplex stainless steel containing incomplete root penetration


Incomplete root penetration were welds do not meet. Argon rich shielding gas

## Characteristic

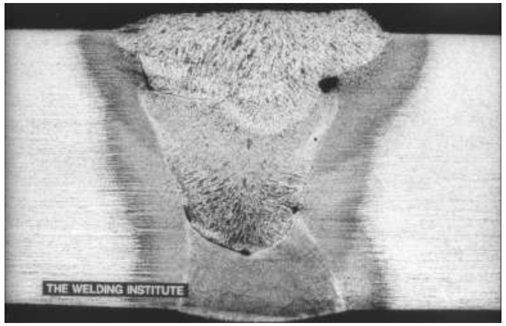
- The joint surfaces has not melted.
- Is oriented along the weld
- Occur mainly at MIG/MAG with solid wire and gas welding 311
- Best detected by UT, worse with RT

## Origin

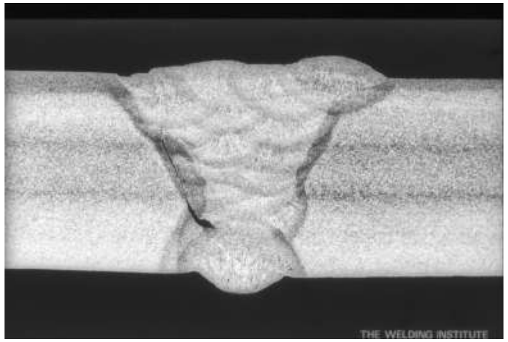
- Improper tilting of the welding gun across the weld
- Large weld pool were that flows ahead
- Too long stick-out
- Low heat input
- Small joint angle
- Sharp transition between weld passes
- Magnetic arc blow

## How to avoid?

- Good accessibility
- Short stick-out
- Grind undercuts
- Enough joint angle
- Avoid large welds, better using more smaller welds




**in root and in  the edge of weld**



**In the side of the joint**

**Big difference in thickness**

**When welding reinforcement bar**

# Lamellar tearing

## Characteristic

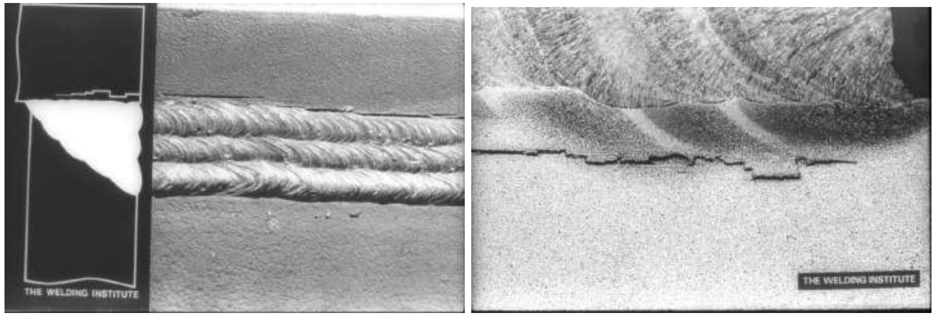
- High stresses in the thickness direction and the weld parallel to plate surface
- Fracture between rolled out inclusions in the steel, which gives stepped appearance
- The material can be inspected by UT

## Origin

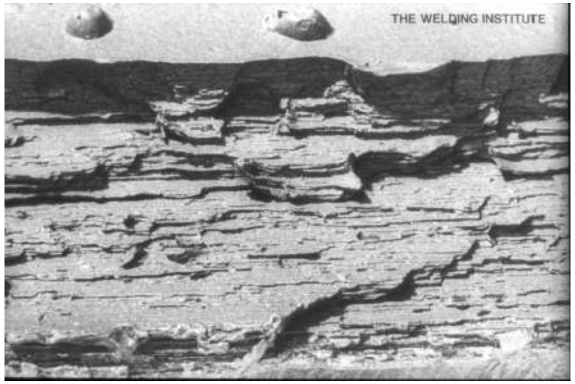
- Rolled out slag inclusions (sheet)
- Tensional forces in the thickness direction
- Insufficient material properties in the thickness direction

## How to avoid?

- Choose material with required through thickness properties in the thickness direction (Z-value)
- Materials with rare earth metals to give harder slag inclusions
- Design in purpose to reduce the stresses in the thickness direction
- Use of so called Z-plate
- Butter ( clad weld) with soft weld metal



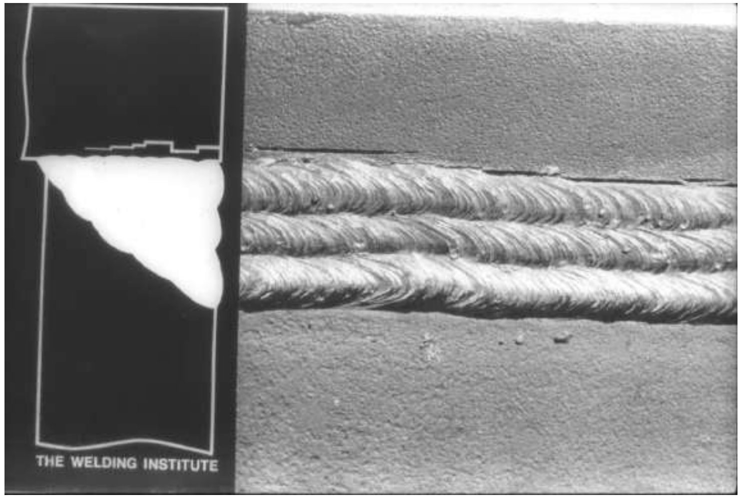

**Lamellar tearing in material with low strength in the thickness direction**

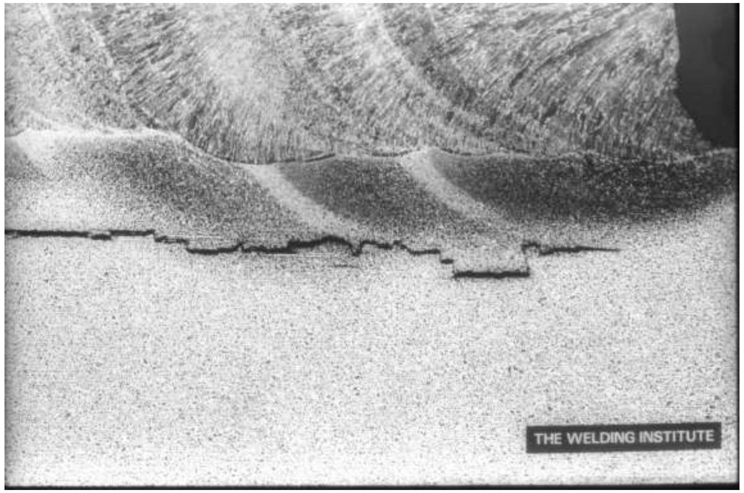



**Typical stepped appearance**


**Fractured lifting devise**

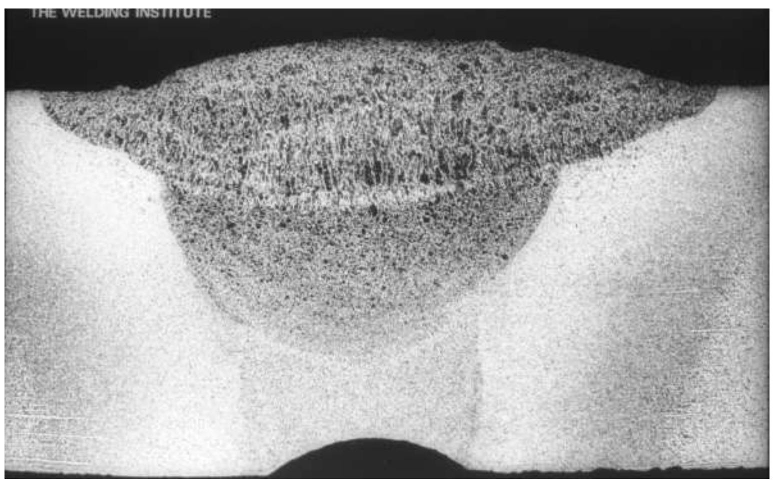
## Lamellar tearing



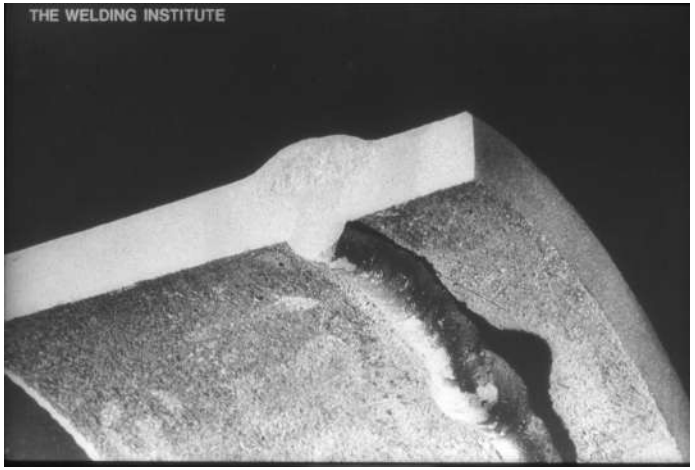



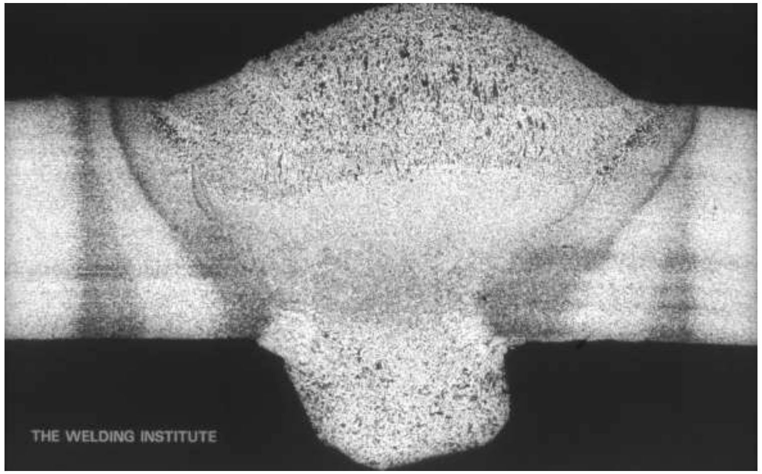

Lamellar tearing with typical stepped appearance in material with low strength in the thickness direction

## Root concavity (515)

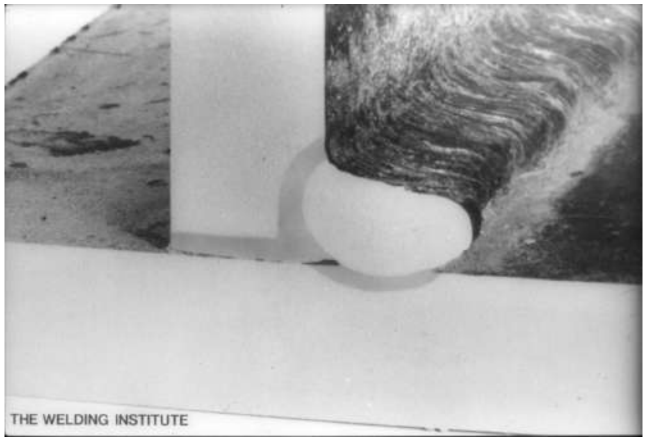



## Excess penetration (504



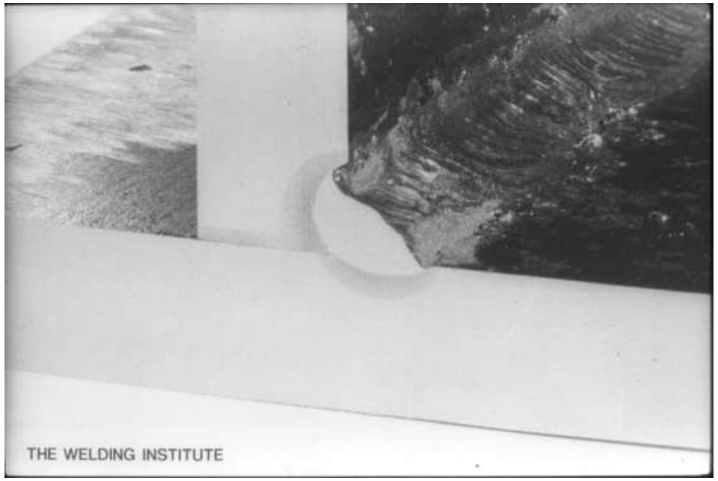

## Incorrect weld toe (505), Overlap (506)




Overlap - cold lap (506)

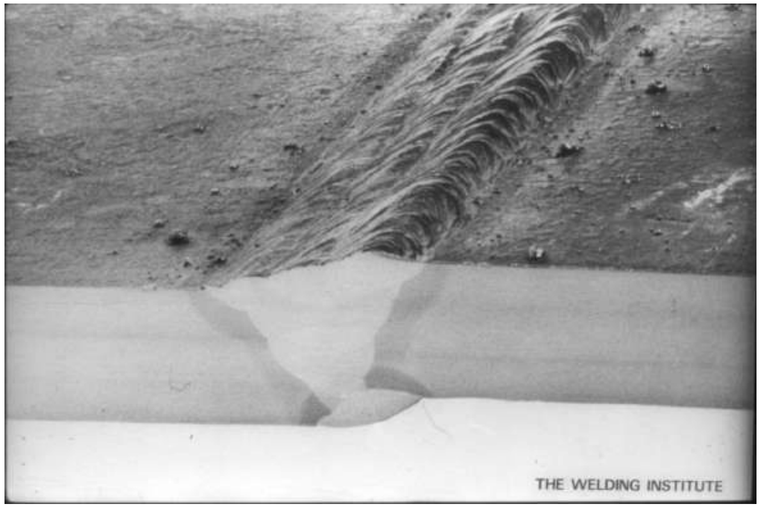

Incorrect weld toe (505)

## Undercut (5011, 5012

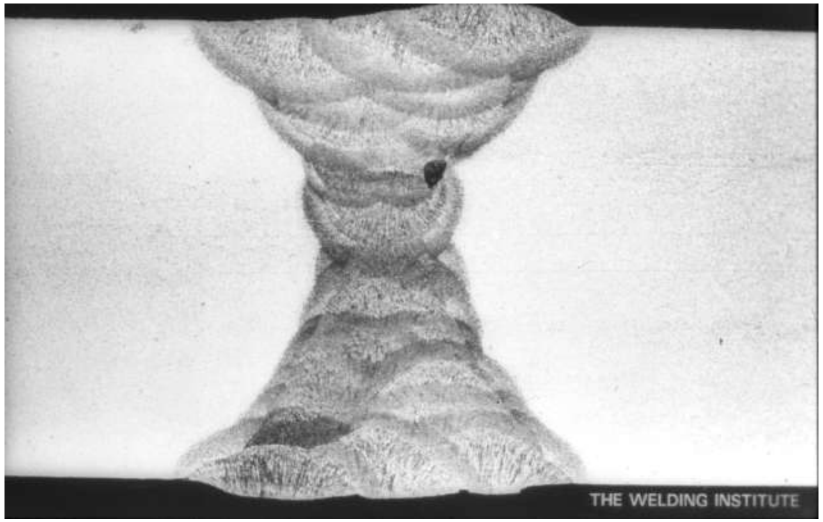




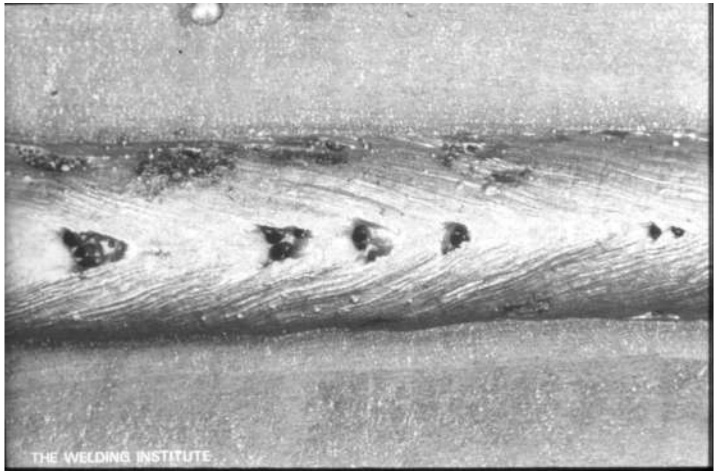
## Linear misalignment (507)




## Slag inclusions

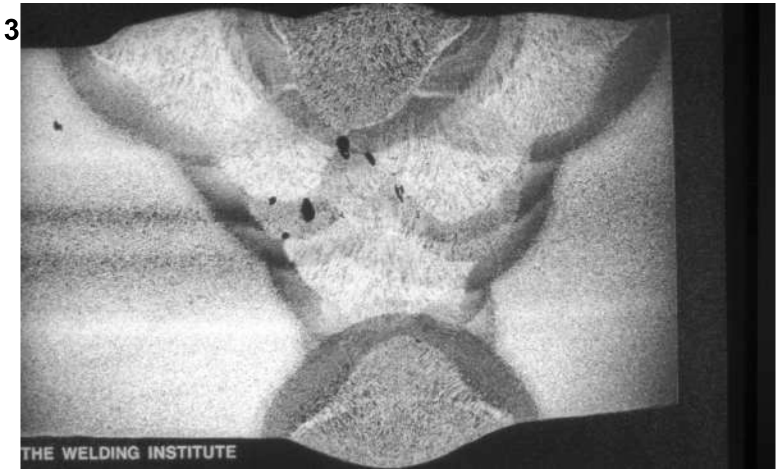


## Pore (2017)



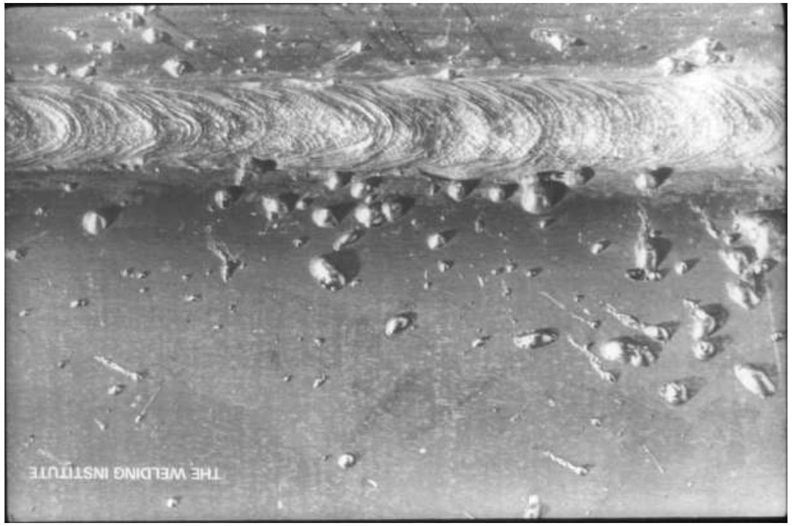

Surface pores (2017)

3




Pores inside the weld

## Spatter (602)



## Stray arc (601)