Metallurgical investigation

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September 2021

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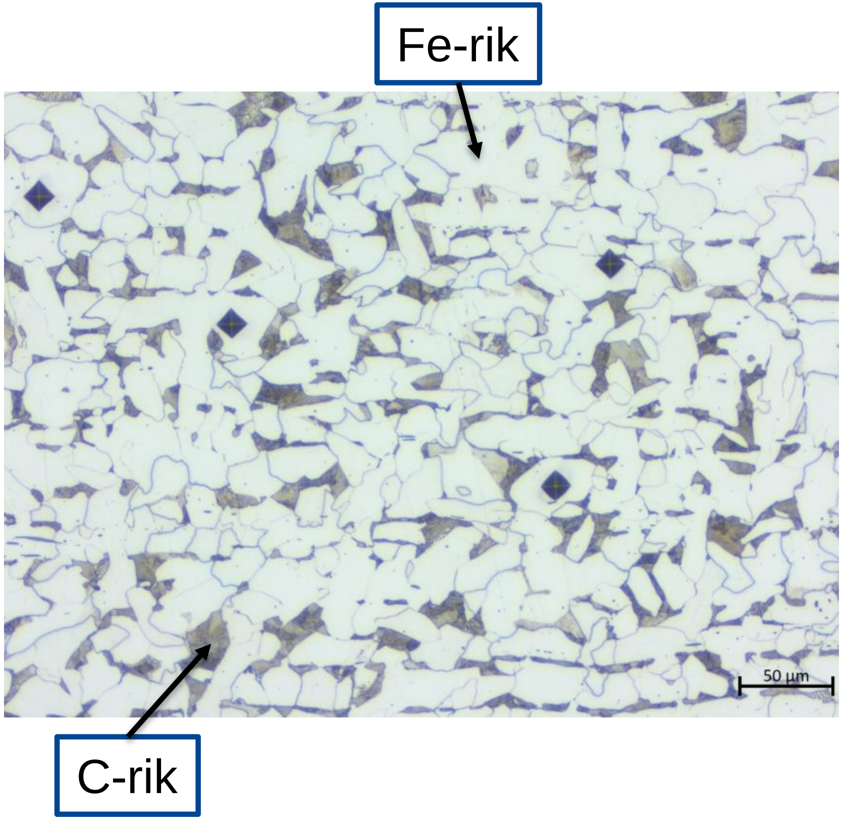
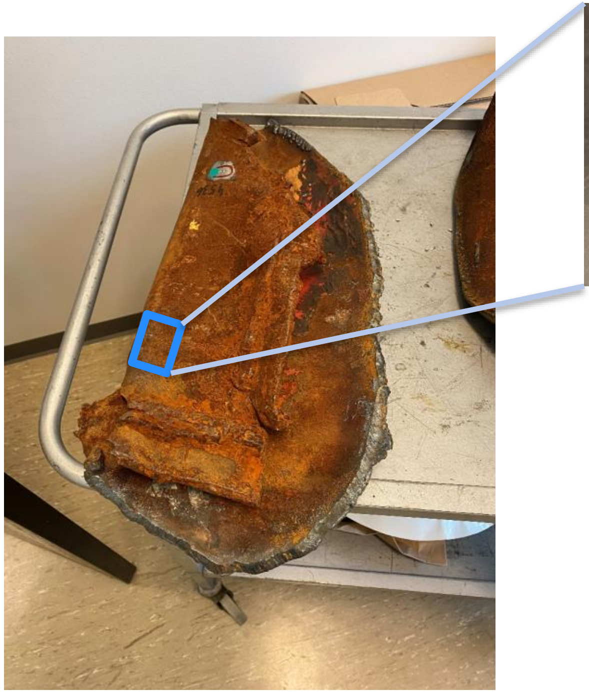
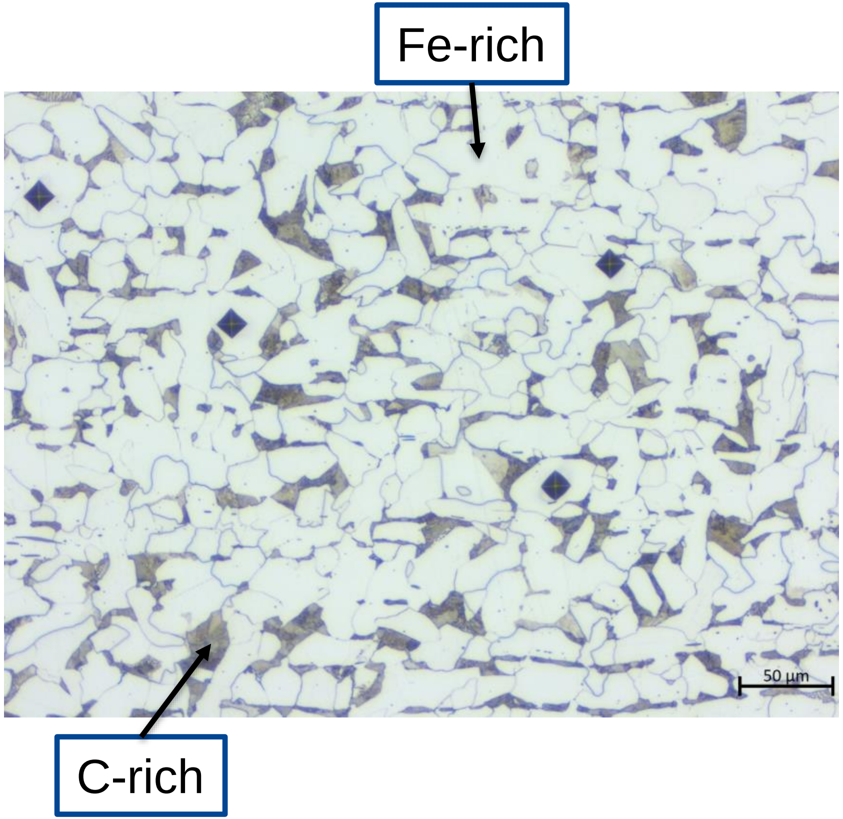
Plate # 4536 from the bow door

Visual inspection

- 10 mm thick steel plate
- Large deformations
- 180^{o} bend

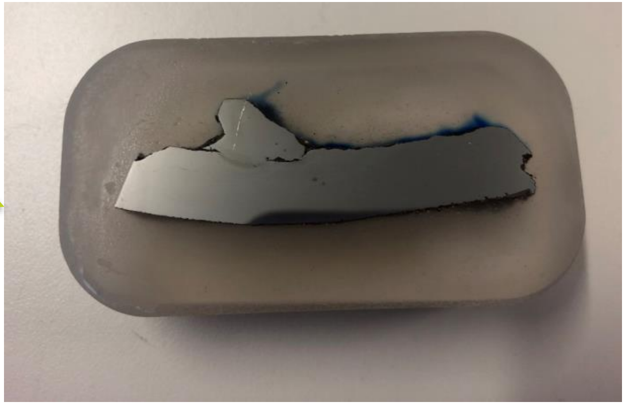

Fe-rik
C-rik
50 µm





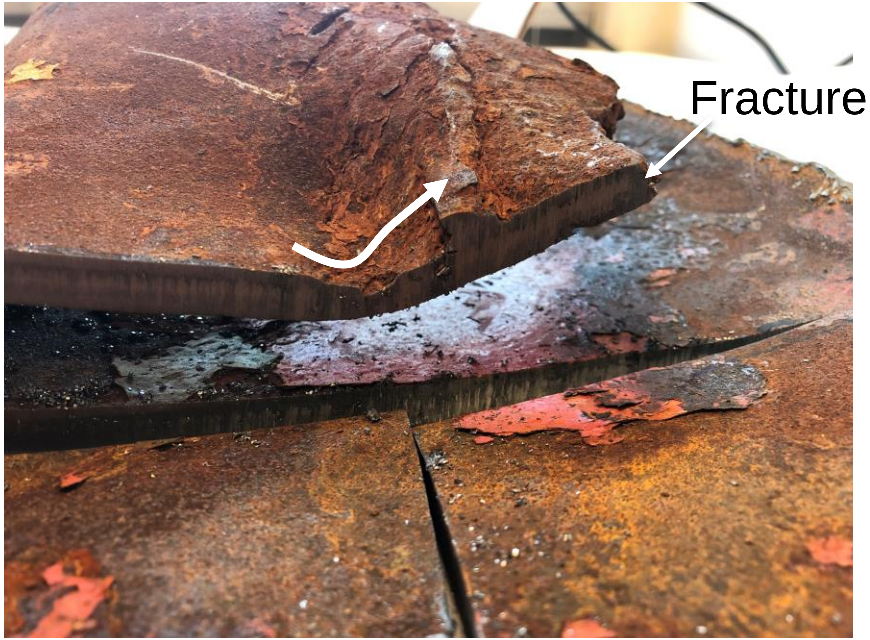
Expected microstructure for this steel
Stable up to 769°C
Above 769°C the steel starts to transform and forms new grains
Above ~850°C the entire structure it transformed

2



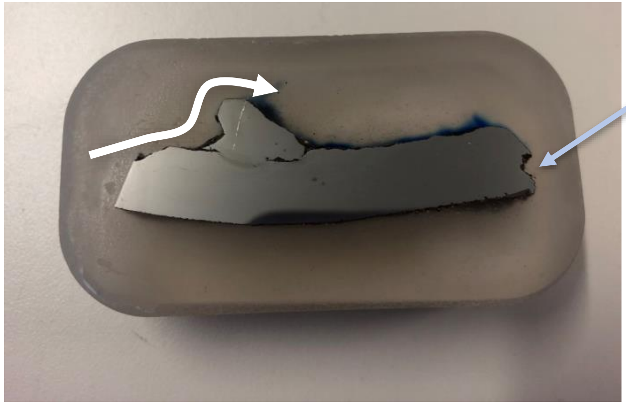
1

Region 1

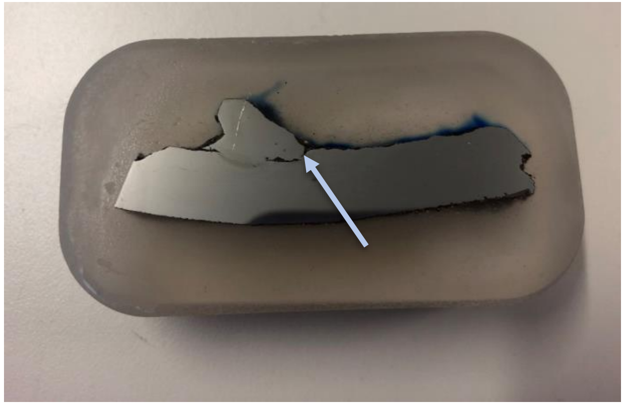


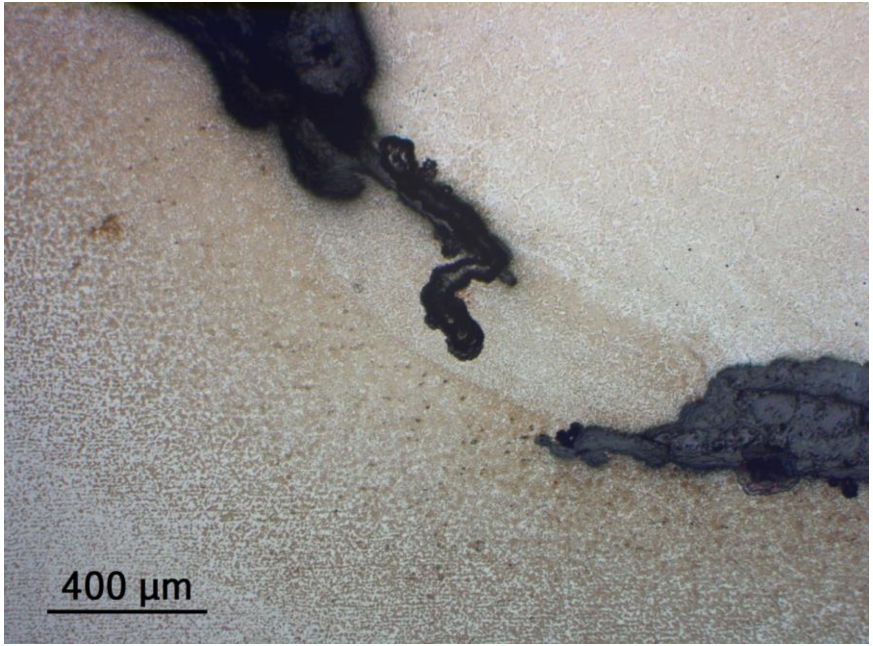
- Thinning of the plate
- Material has shifted into a ridge
- Ridge is of mm height
- Fracture in a distance from the ridge
- No sign of contact deformation

Metallographic investigation

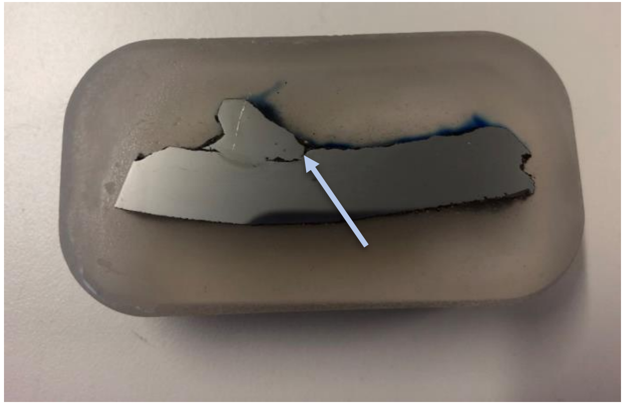


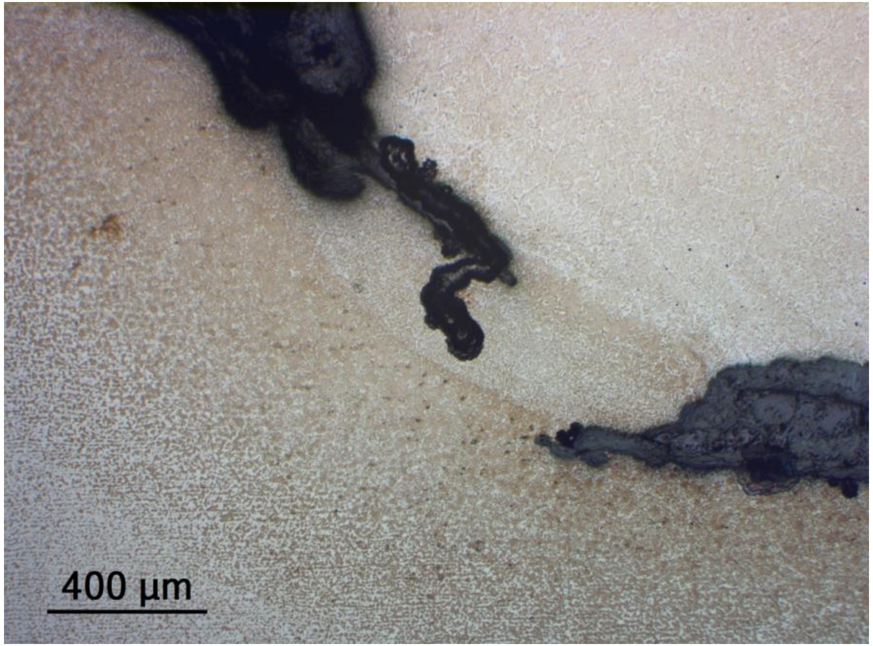
Fracture

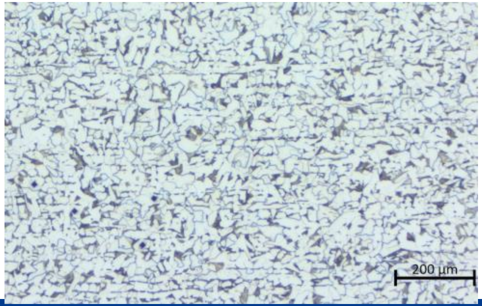


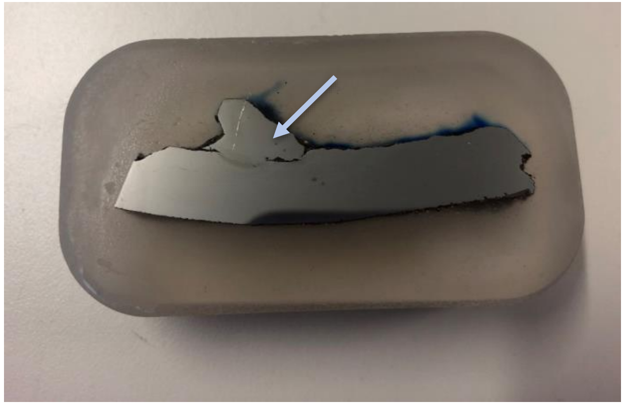


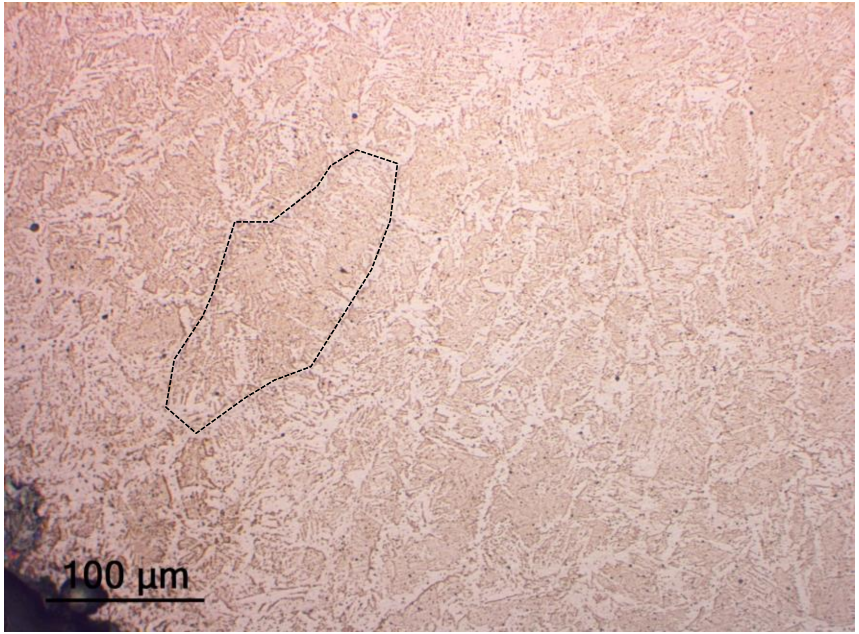
- Large differences in microstructure
- Welded together
- Requires high temperature and pressure
- This formations has similarities to explosion welding



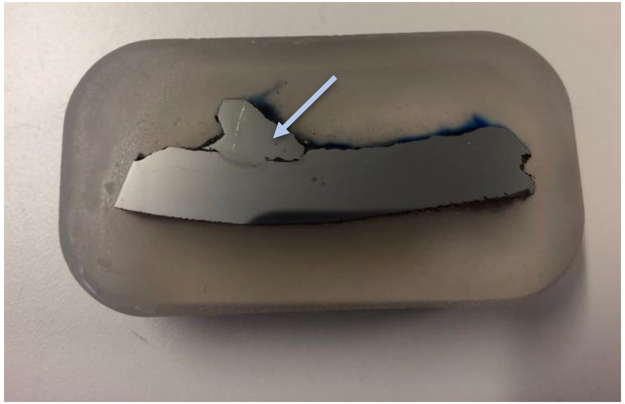

400 µm

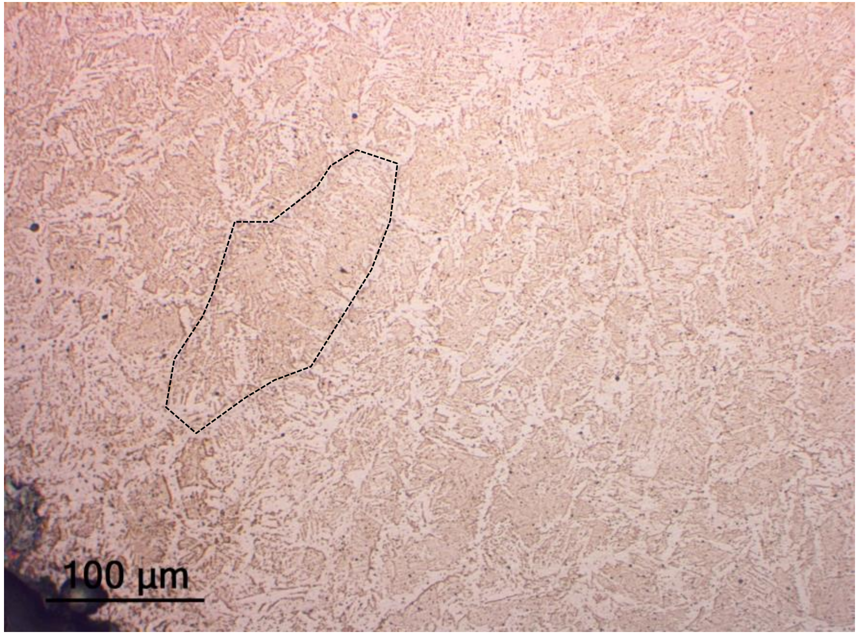

200 µm





- Contours of large grains
- Structure occurs above ~850^{o}C
- Appr. 10 times larger than original structure
- Requires temperature and time

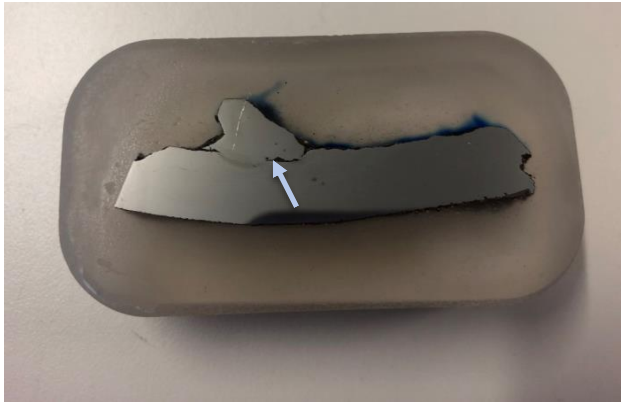


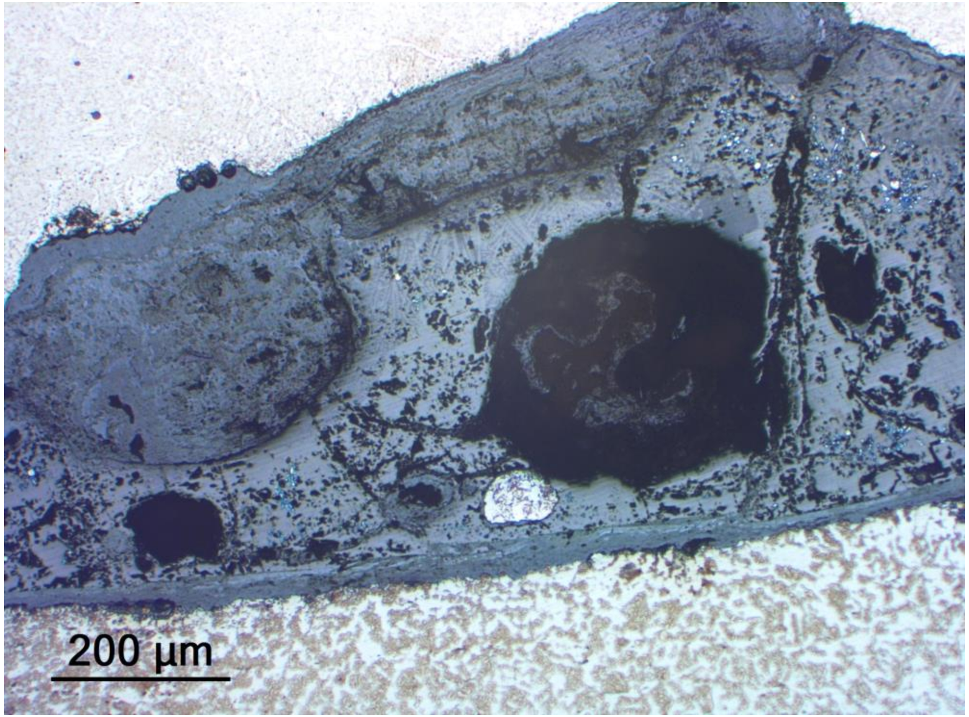


- Contours of large grains
- Structure occurs above ~900^{o}C
- Appr. 10 times larger than original structure
- Requires time and temperature

Similar hardness as original structure

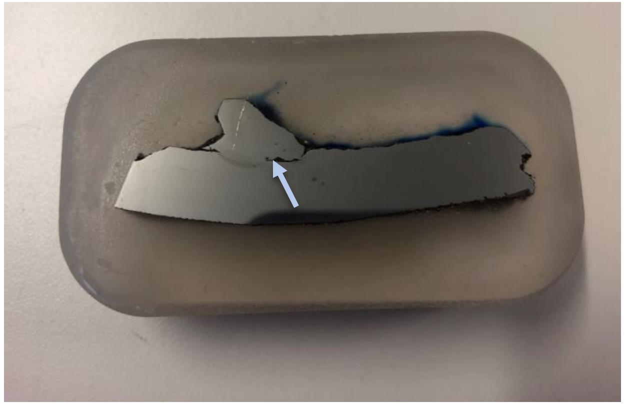
Black area

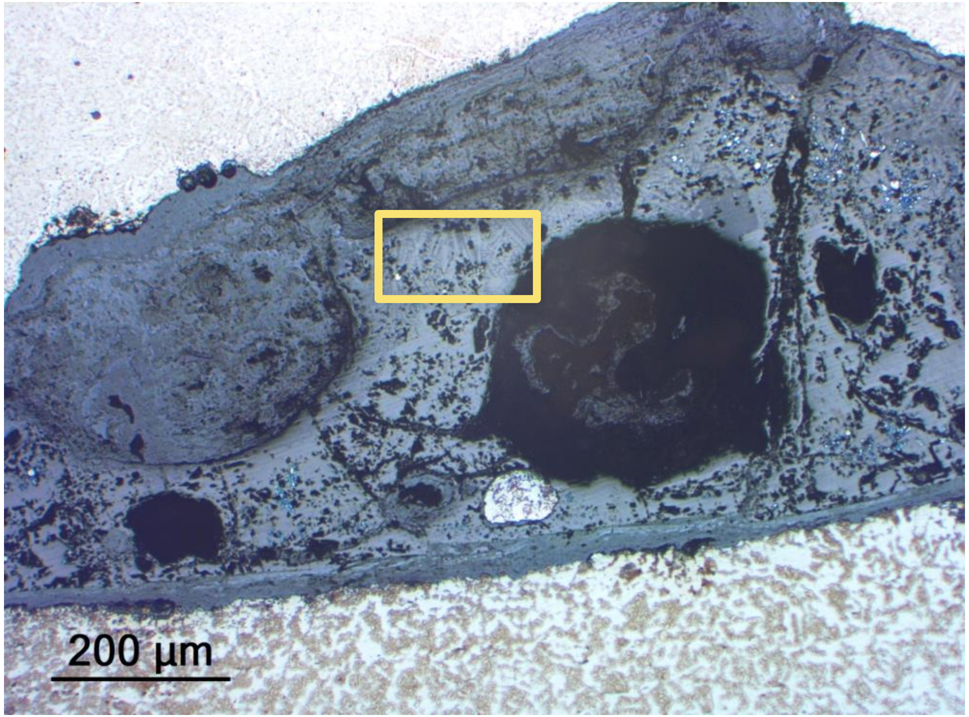




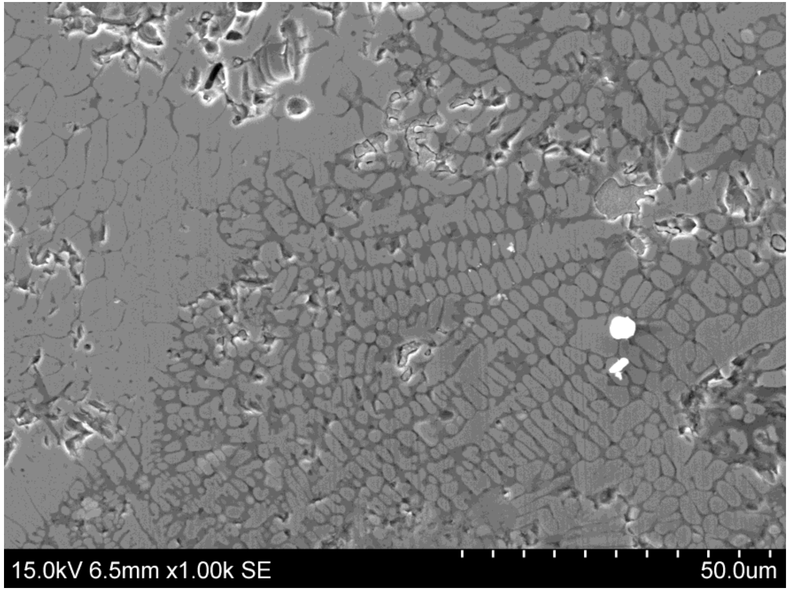
- Intermetallic phase

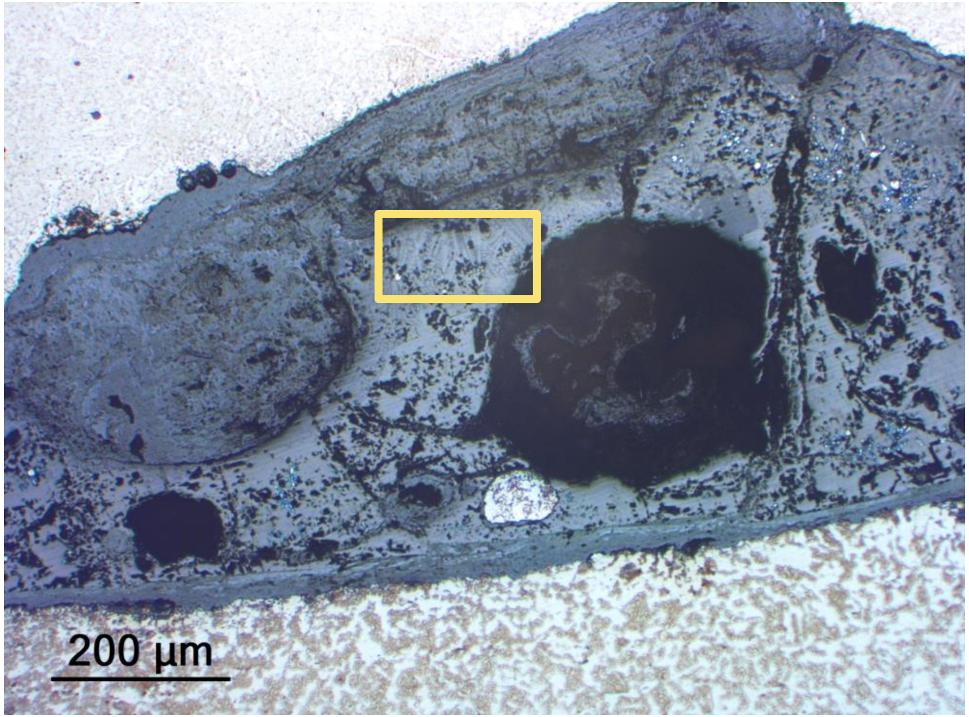
Black area



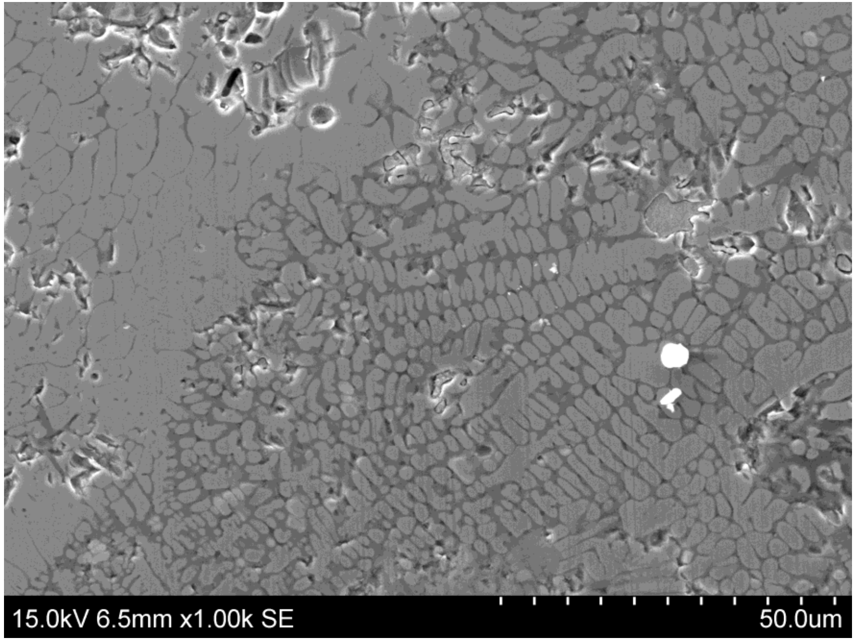


Intermetallic phase





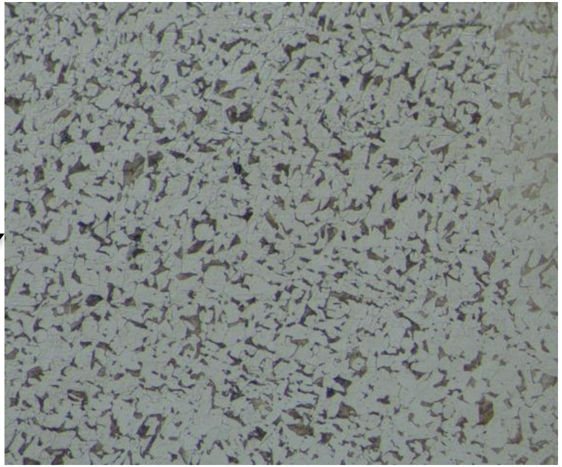
Intermetallic phase



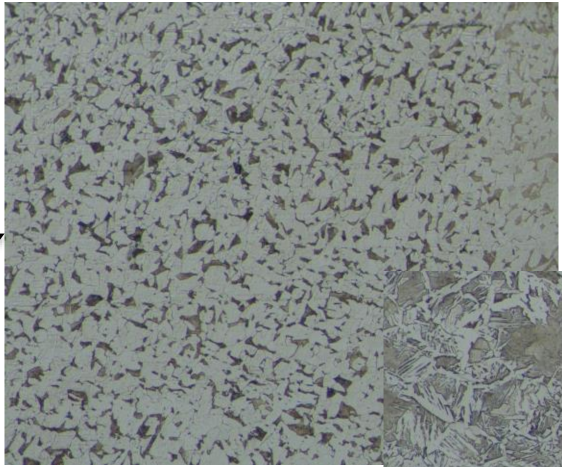
- Solidification structure
- Oxide (rust and paint)
- Has been melted under the given conditions
- Estimated temperature: above 1200^{o}C

Region 2

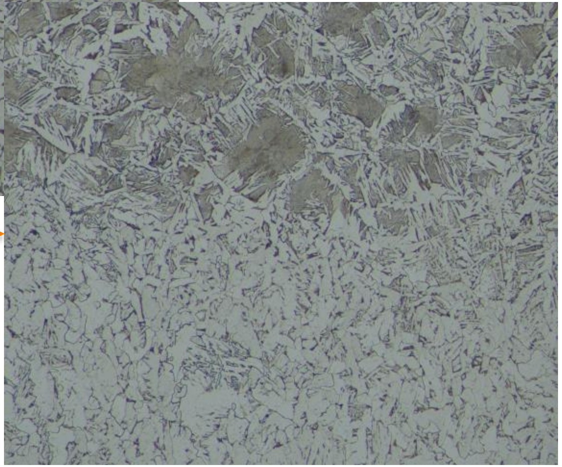
- Thick section: 16 mm
- Rough fracture
- Fracture occurs in 2 steps
- No sign of contact deformation



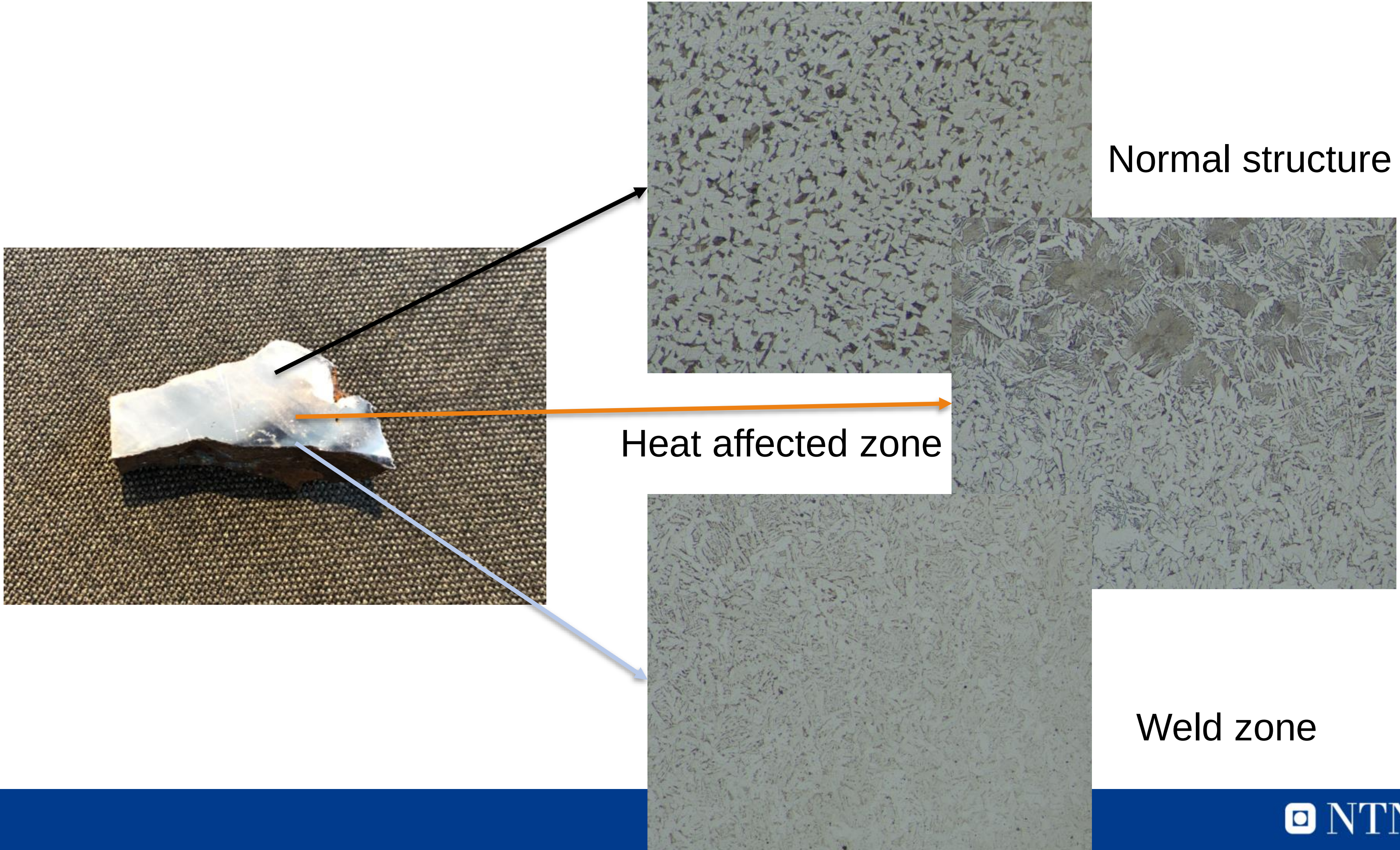
Normal structure



Normal structure

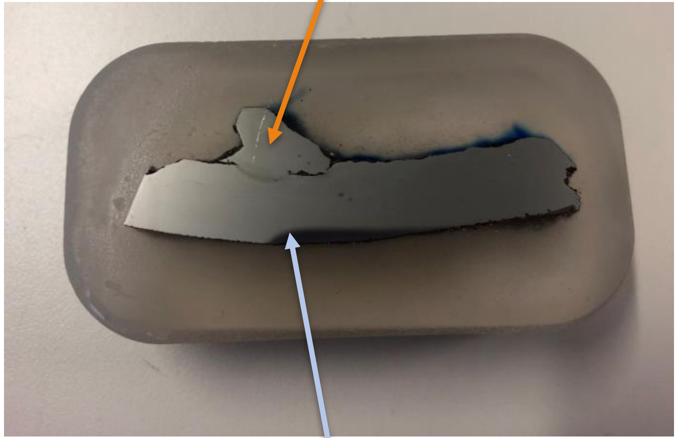


Heat affected zone


Normal structure
Heat affected zone
Weld zone

Compare regions 10 cm apart

Heat affected zone



Unaffected microstructure

Unaffected microstructure

Heat affected zone

Conclusion

- We see very large deformation
- No sign of physical contact
- Looked at three different regions: 1 unaffected, 2 near fracture regions
- High energy impact
- Locally very high temperature
- Two heat sources – one on each side of the plate
- The observed microstructure cannot be explained by mechanical deformation and friction