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Catalogue of metallography results

This catalogue reports the examination of Iron samples from excavations at SJM 3 Posthustorvet, Ribe using a metallurgical reflected-light microscope (Zeiss AX10, Observer A1m with magnifying 100x/0.8 HD, housed at the School of Engineering, NAVITAS/Aarhus University). Images of the microstructures observed were recorded as optical micrographs using the Zen software. The results are summarized with detailed descriptions of individual samples.

Term	Definition
Eutectoid	Decomposition from a solid phase into two finely dispersed solid phases creates a structure called a eutectoid. May resemble the eutectic.
Eutectic	The composition of the lowest melting point of binary alloys.
Hyper-eutectoid	Containing a greater amount of carbon than that needed to form a completely eutectoid structure.
Hypo-eutectoid	Containing a lesser amount of carbon (<0.80%) than that needed to form the eutectoid.
Widmannstätten	A needle-like structure that appears when a new solid phase is produced from a parent solid phase.
Equiaxed	Grains of equal dimensions or properties in all directions. Equi-axed grains are hexagonal in form.
Ferrite	Also known as iron.
Pearlite	A needle-like structure consisting of layers of ferrite and cementite. The proportion of pearlite rises with the amount of carbon.
Cementite (FeC3)	A hard and brittle phase that increases hardness in high-carbon steels.
Martensite	A hard needle-like structure formed during quick cooling (quenching). It is often found in low-carbon steels.
Steels	Low-carbon steel: 0.09–0.20% carbon content. Mid-carbon steel: 0.20–0.40% carbon content. High-carbon steel: 0.40–0.80% carbon content.
Carburization	Increasing the carbon content of a metal by heating the metal below its melting point with charcoal and/or another carbon-rich agent. A whole piece of iron can be carburized slowly in a forge.
Case-hardening	Represented with a high content of carbon encasing the object. Case-hardening can also be performed before folding the object and hence introducing carbon deeper into the stock.
Cold-working	Forming a metal at a low temperature, which will cause strain-hardening.
Welding	The joining of two or more stocks of metals by heating and joining the constituent parts. A welding agent, such as sand, may be used.
Annealing	Heat treating, often used to soften the material to allow further deformation. Heat treating is performed up to the normalizing temperature of iron (750–980°C).
Smelting	The process ore undergoes when transformed to bloomery iron.
Reduction	The condition of the reducing atmosphere in the furnace when iron oxides are reduced to metallic irons.
Stock of iron	Pieces of iron before transformation/forging, used when referring to weld lines of raw iron such as bars.

X1294

Macrostructure: The microstructure of this sample consists of two phases; in the topmost part is a weld line, which is visible to the naked eye (Fig. 11.12).

Microstructure: The microstructure consists of a hypoeutectoid low-carbon steel with small ferritic grains in between. The pearlite, however, has not had time to form completely and was stopped by quenching (Fig. 11.13).

X1210

Macrostructure: Well-preserved nail. The head and the neck of the nail have been sampled to better investigate the construction of the nail. The changes in the metal structure are visible to the naked eye. The left side of the nail seems more ferritic than the right, which could indicate that the nail was made from two stocks of iron.

Microstructure: The microstructure of this nail alternates from being ferritic to pearlitic, with intersecting bands of pearlite, (Fig. 11.14) indicating steel. The ferritic grains are large and phosphoric. The slag inclusions are slightly elongated, running from top to bottom (Fig. 11.15).

X1036

Macrostructure: Nail and rivet. This nail and rivet combination was constructed from very well-constructed steel. The nail was most likely constructed from two pieces of iron, which is also visible to the naked eye.

Microstructure: The microstructure is predominantly pearlitic, with Widmanstätten structures spanning the surface (Fig. 11.17). Running through the nail is a weld line, indicating that this object was constructed from two stocks of iron (Fig. 11.16). The rivet seems to consist of the same ultra-high-carbon steel, although the iron becomes more ferritic towards the one of the sides.

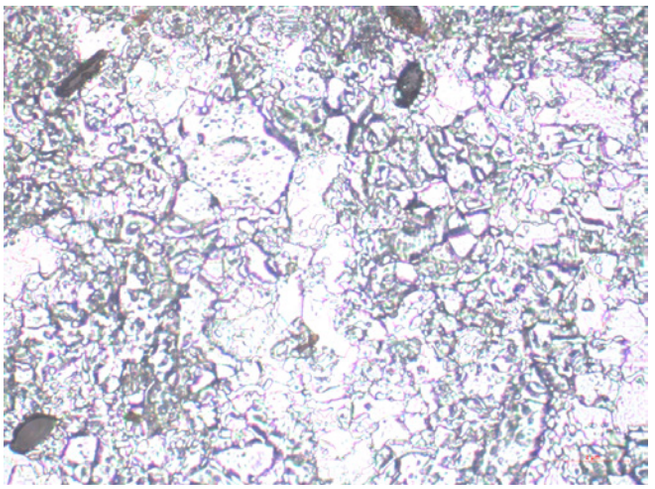

Figure 11.12. *X1294 microstructure.*

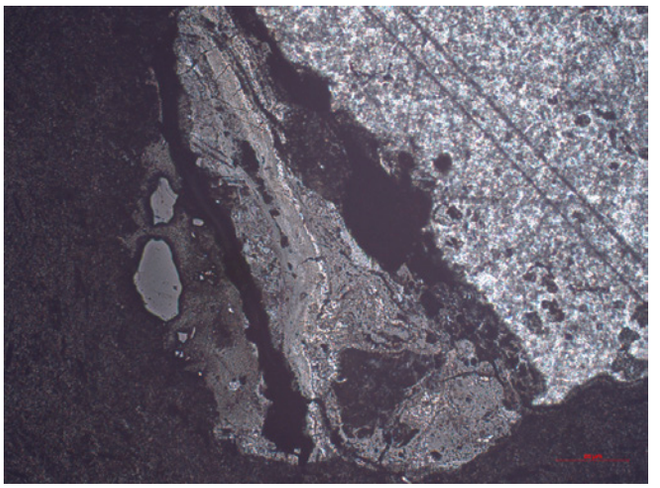

Figure 11.13. *X1294 microstructure.*

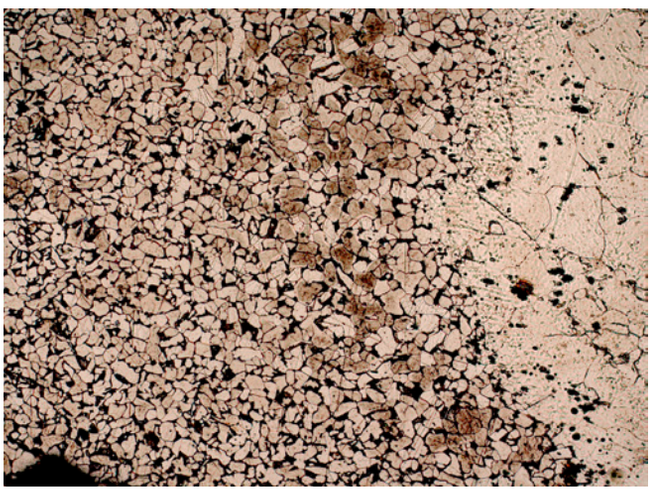

Figure 11.14. *X1210 microstructure.*

Figure 11.15. *X1210 microstructure.*

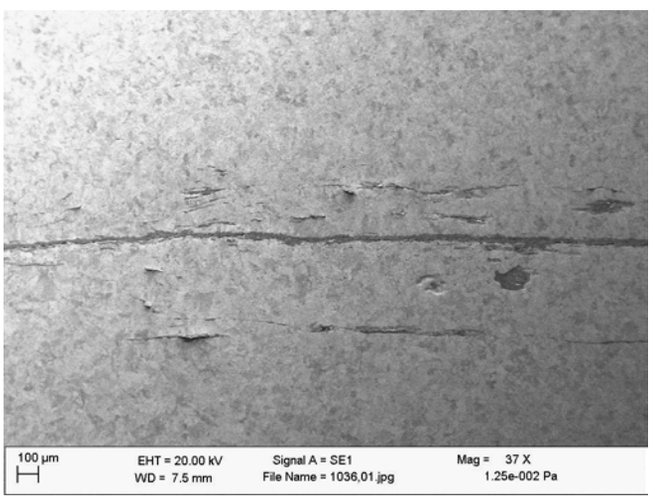

Figure 11.16. *X1036 microstructure.*

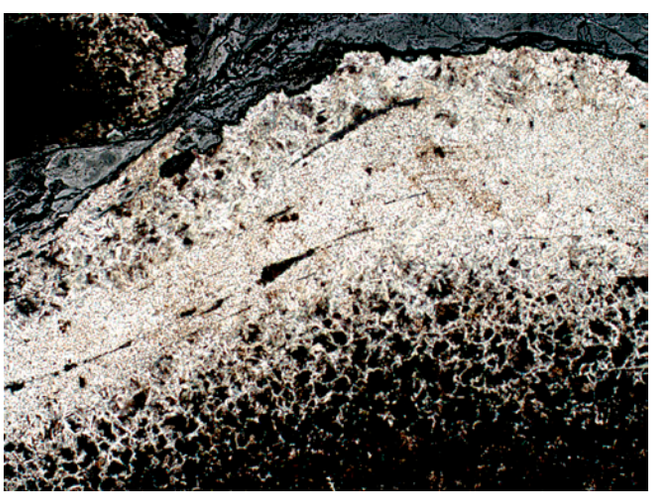

Figure 11.17. *X1036 microstructure.*

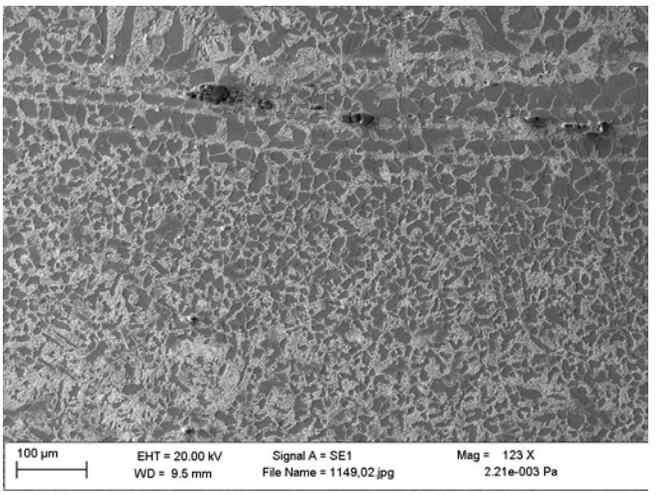

Figure 11.18. *X1149-1 microstructure.*

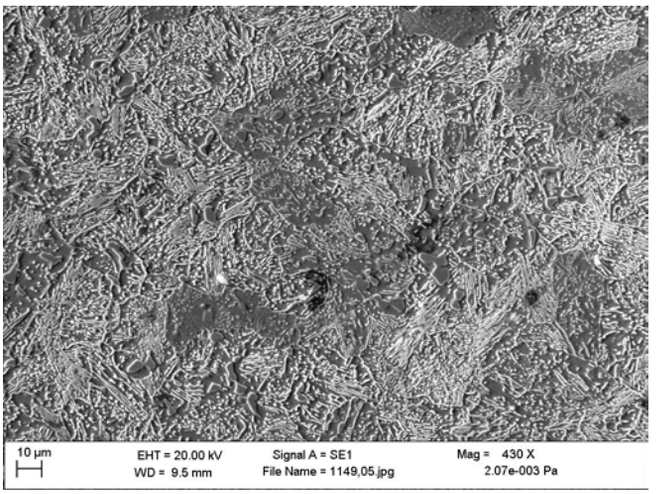

Figure 11.19. *X1149-1 microstructure.*

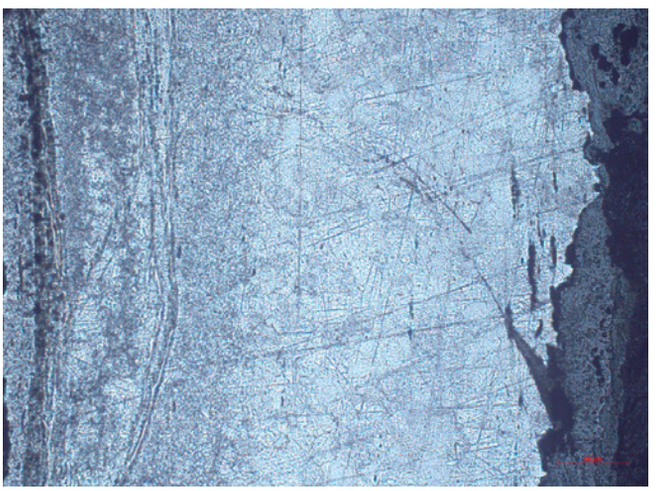

Figure 11.20. *X1149-2 microstructure.*

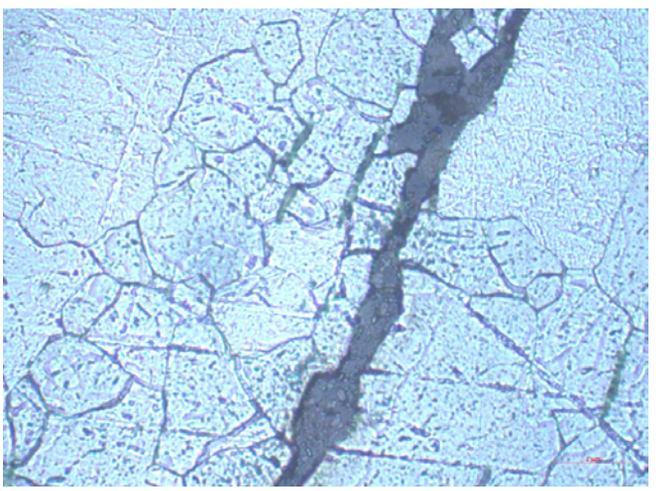

Figure 11.21. *X1149-2 microstructure.*

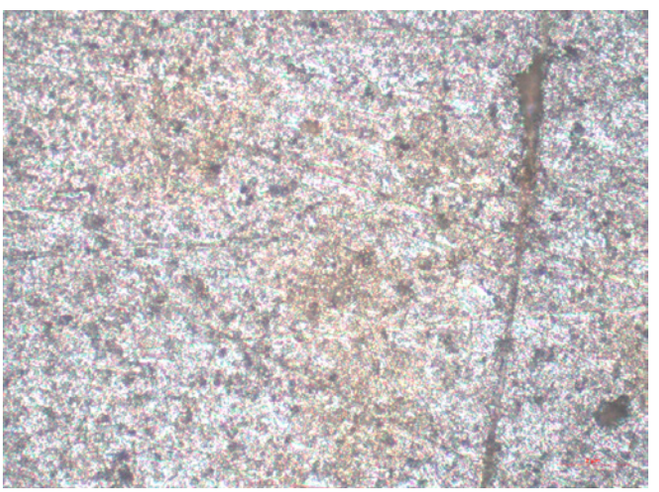

Figure 11.22. *X1149-3 microstructure.*

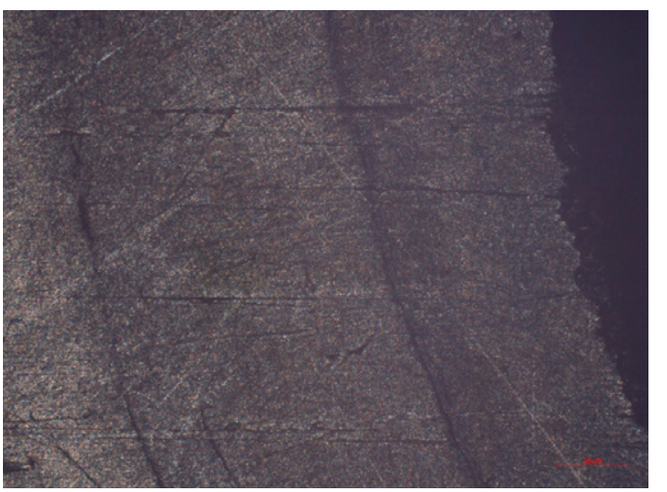

Figure 11.23. *X1149-3 microstructure.*

X1149-1

Macrostructure: Nail, cut below the head, with a bit of body remaining. One side is better preserved than the other, forming a rectangular shape. The highest content of carbon seems to be on the side of the nail. The change of structure is visible to the naked eye.

Microstructure: The structure of this nail is composed of hypo-eutectoid structures with interstitial coarse pearlite (Fig. 11.18), which is more dominant in bands throughout the nail, indicating an ultra-high-carbon steel. Ferrite seems more dominant towards one side. Towards the topmost part of the nail, Widmanstätten ferrite with coarse pearlite is also observed (Fig. 11.19).

X1149-2

Macrostructure: This sample was cut from a nail or a small rod, and the sample showed that it was composed of low-carbon steel and ferrite. Due to possible weld lines, it is most likely that it was made from two stocks of iron. The sample has two phases: a pearlitic and a ferritic phase.

Microstructure: The microstructure of this nail is dominated by large hexaglomerate, heterogeneous ferritic grains (Fig. 11.20) along with smaller hypo-eutectoid grains running along the sample in bands with carbon forming inside the grains. The sample contains many elongated slags and possibly a weld line (Fig. 11.21). The carbon content is higher towards the lower middle.

X1149-3

Macrostructure: This sample is a small, half-moon-shaped iron rod made from ultra-high-carbon steel, and it was most likely made from two stocks of iron or else folded during working.

Microstructure: The most obvious features are the carbon banding throughout the section and two major welding seams with martensite structures (Fig. 11.22), which indicate a high carbon content (Fig. 11.23).

X1149-4

Macrostructure: Possible clench nail, made from high-carbon steel. This clench nail was most likely heated to a very high temperature followed by a fast cooling, most likely by quenching in water.

Microstructure: This sample was made from hypo-eutectoid, high-carbon steel, with intergranular pearlite and ferritic grains in the middle of the sample, which are visible as finely grained ferrite (Fig. 11.24). Towards the edges of the sample, the carbon content seems to rise; here, martensite is visible, and Widmanstätten structures seem to have begun to form (Fig. 11.25).

X1149-5

Macrostructure: This sample was cut from a rectangular plate and seems to be made from mid-carbon steel. It seems to have been folded when the iron was worked and shaped. The carbon content is relatively high, which might be the result of quenching in either oil or water.

Microstructure: The hypo-eutectoid structure of this sample shows lamellar pearlite and spherical cementite in areas (Fig. 11.26). Towards one edge, more ferritic areas in the middle with large hexaglomerate grains slims towards the edge (cutting edge), with ferrite and pearlite towards the edges (Fig. 11.27).

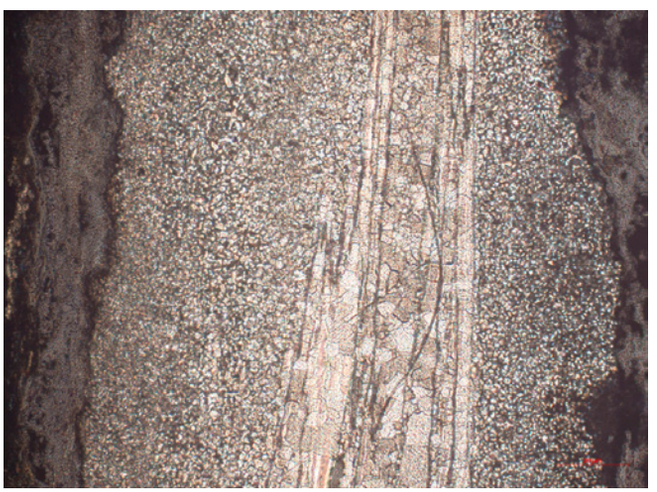

Figure 11.24. *X1149-4 microstructure.*

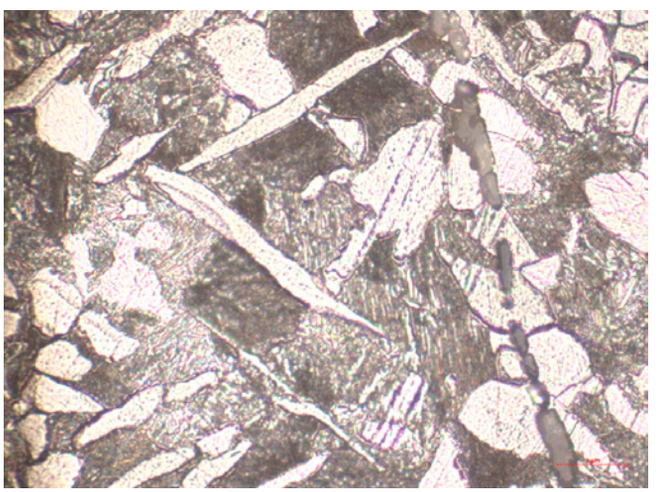

Figure 11.25. *X1149-4 microstructure.*

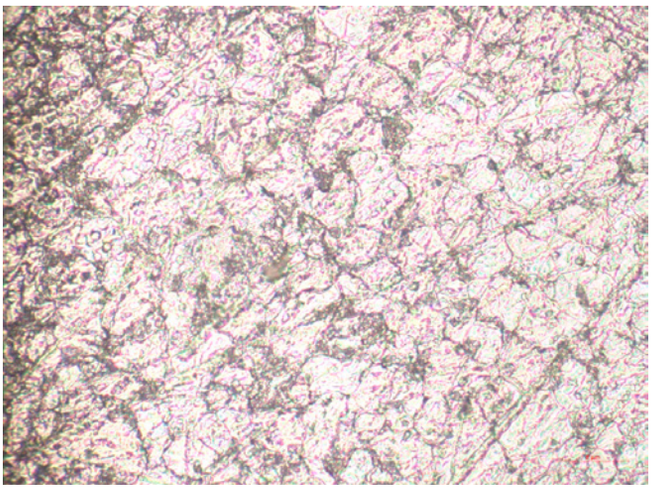

Figure 11.26. *X1149-5 microstructure.*

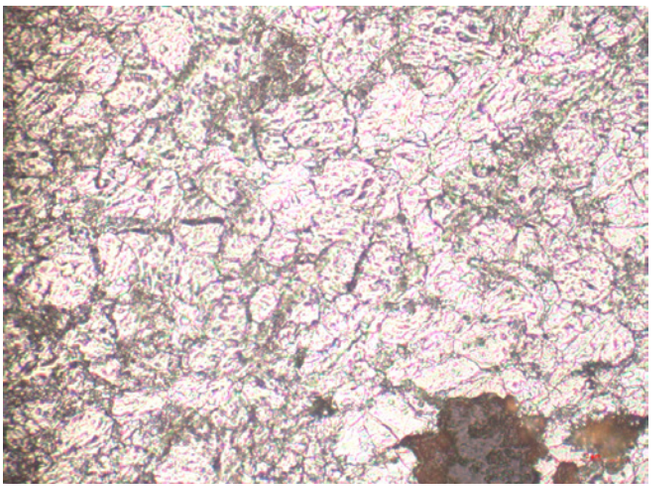

Figure 11.27. *X1149-5 microstructure.*

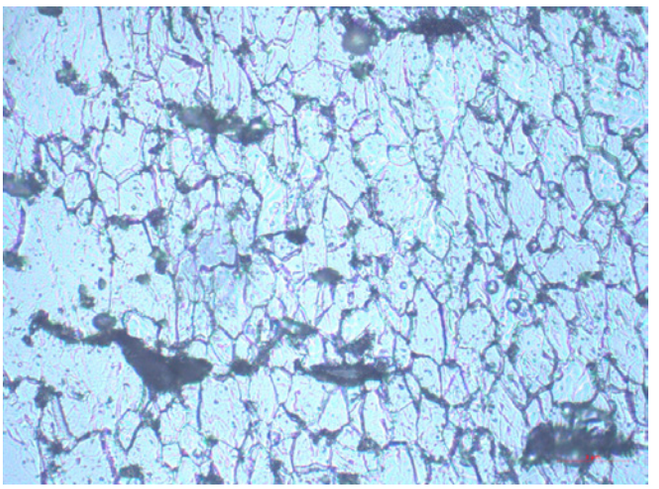

Figure 11.28. *X1149-6 microstructure.*

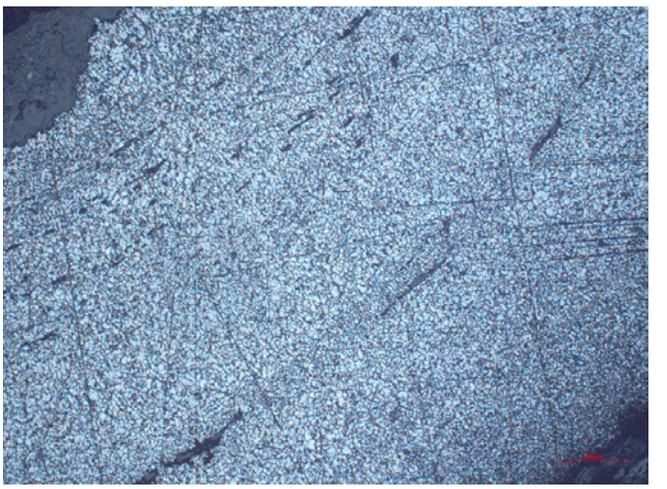

Figure 11.29. *X1149-6 microstructure.*

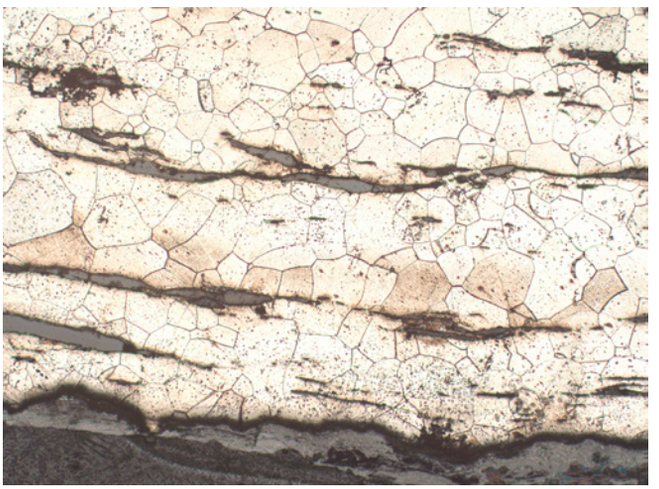

Figure 11.30. *X799 microstructure.*

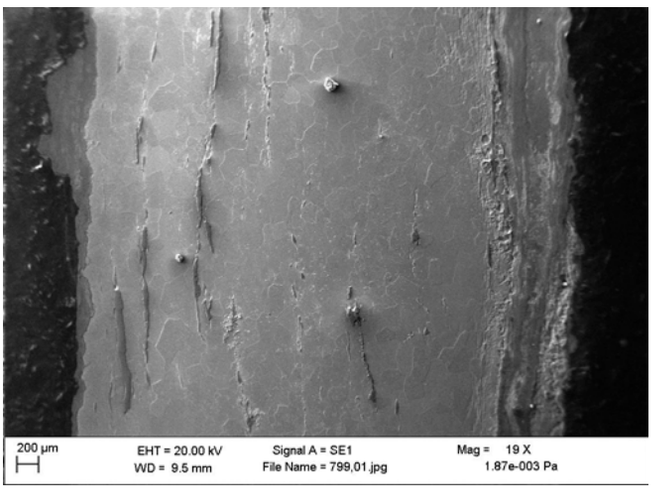

Figure 11.31. *X799 microstructure.*

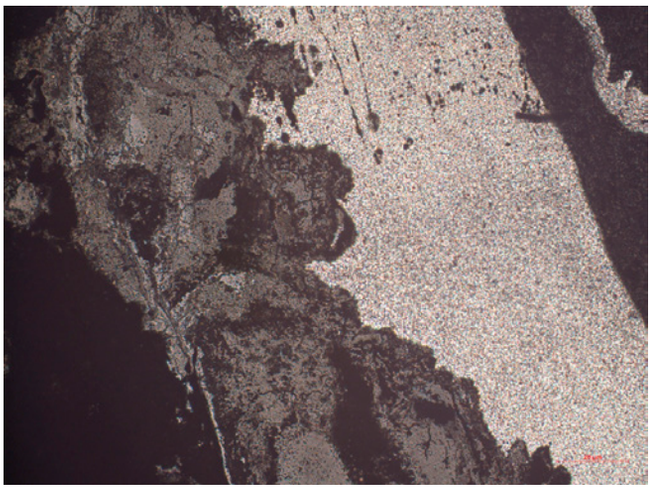

Figure 11.32. *X811 microstructure.*

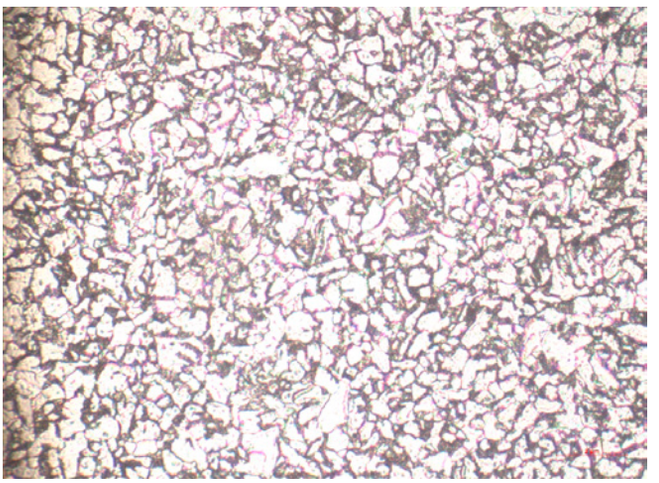

Figure 11.33. *X811 microstructure.*

X1149-6

Macrostructure: This sample was cut from a nail or a small iron rod, which was made from low- to mid-carbon steel, possibly the result of carbon diffusion.

Microstructure: The dominating structure of this sample is a hypo-eutectoid, fine-grained ferritic structure, with coarse pearlite present. The carbon content is low- to mid-carbon steel. The amount of carbon is slightly higher at one side (Fig. 11.28). The slags in the sample are presented as elongated and stretched (Fig. 11.29).

X799

Macrostructure: Iron rod. This object was cut longitudinally; besides its identification as a rod, there is no further information about its use.

Microstructure: The microstructure of this piece is predominantly ferritic or phosphoric, with large heterogeneous grain sizes (Fig. 11.30). Large slag inclusions are present in the piece; they seem elongated and have been drawn in the same direction as the object (Fig. 11.31). Towards the surface of the rod, it seems that another layer of iron was present. This was visible to the naked eye when sampling, but upon etching and polishing, this piece showed discolouration shortly after etching.

X811

Macrostructure: Small, slender nail, made from one stock of heterogeneous iron. The object most likely underwent carburization during forging.

Microstructure: The structure of this sample is predominantly hypo-eutectoid, with very fine-grained ferrite and coarse interstitial pearlite (Fig. 11.32). This structure is almost the same throughout the entire sample, but towards the lower end, the carbon content increases, and the pearlite is more dominant (Fig. 11.33).

X833

Macrostructure: This sample was cut from an iron rod. The grains are heterogeneous in size and vary between two distinct phases: one consists of large ferritic grains, and the other a more pearlitic phase with interstitial pearlite.

Microstructure: This piece of iron is predominantly ferritic, with hexagonal grain sizes (Fig. 11.34). Signs of a higher carbon content are visible. The slag inclusions do not seem to follow any direction and are small and not elongated. Between the grains, small new grains had begun to form (Fig. 11.35).

X846

Macrostructure: Folded iron rod. This sample is most likely made from a folded iron piece, although before sampling it looked more like a small iron rod.

Microstructure: The microstructure of this sample is ferritic with heterogeneous grain sizes, changing from predominantly ferritic in the middle to an increase of carbon content towards the outer edges (Fig. 11.36). From the centre towards the outer edges, the interstitial pearlite increases slightly with coarse pearlite growing. Bands of pearlite is visible in the ferritic area towards the high-carbon area (Fig. 11.37). In the outermost area, the microstructure is dominated by martensite, which might be caused by a rather long heating at temperatures above the austenization area, and possibly from quenching in water.

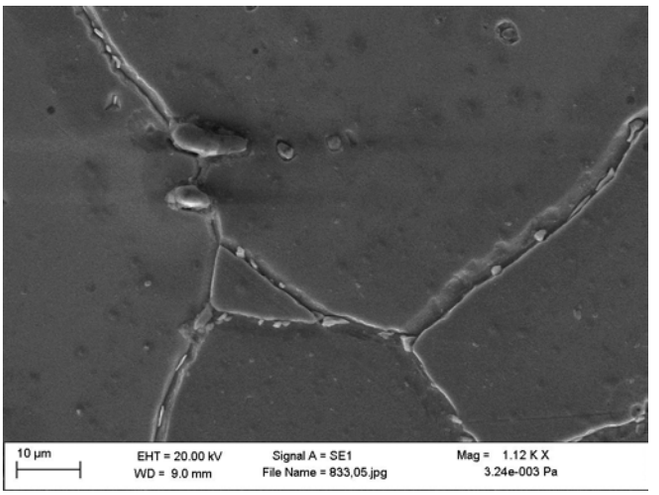

Figure 11.34. *X833 microstructure.*

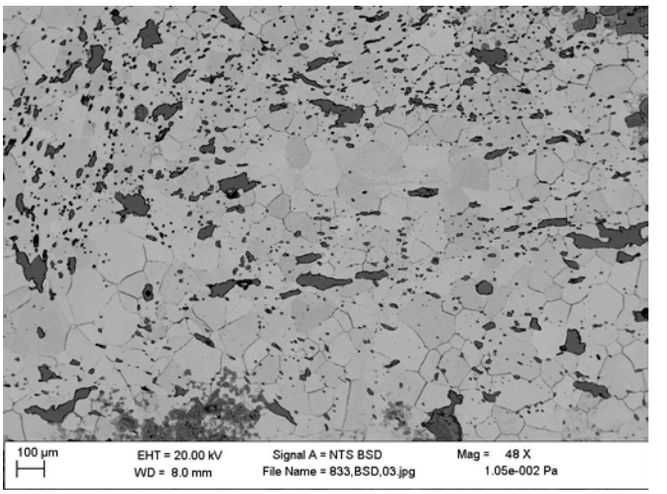

Figure 11.35. *X833 microstructure.*

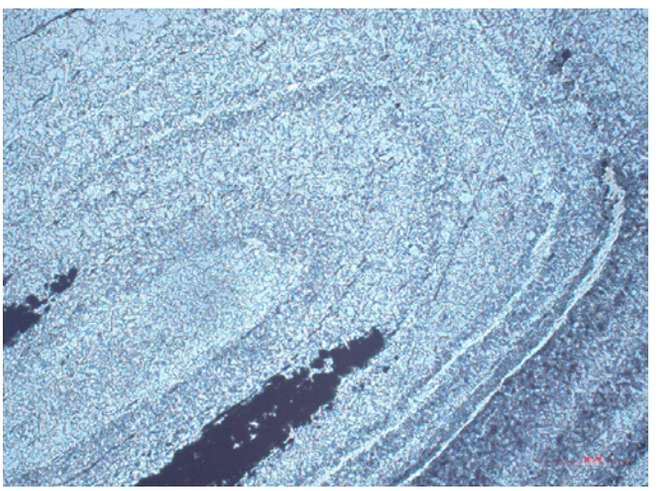

Figure 11.36. *X846 microstructure.*

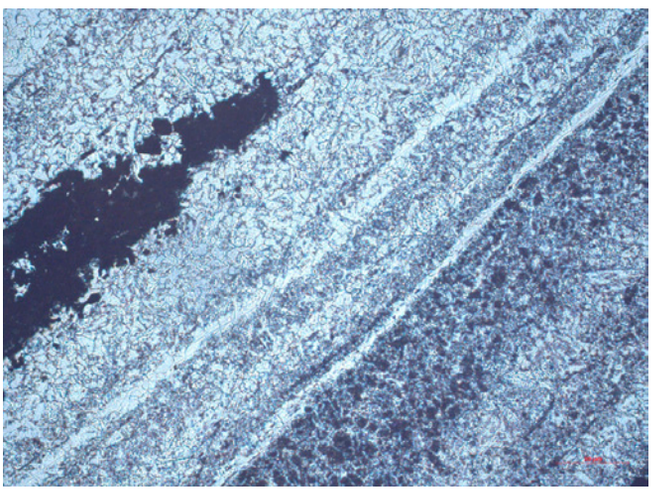

Figure 11.37. *X846 microstructure.*

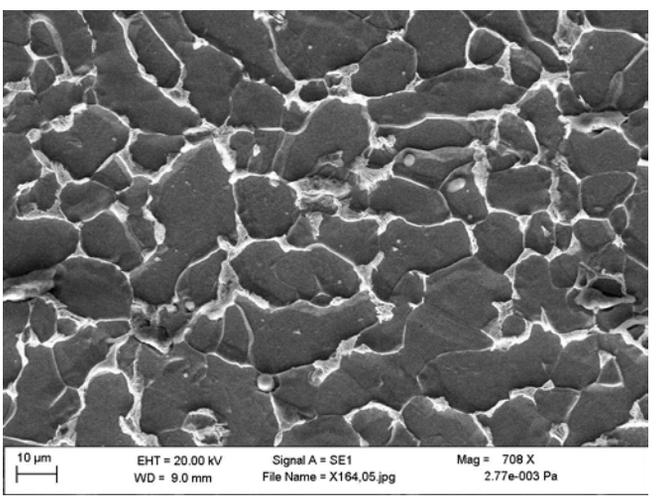

Figure 11.38. *X614-1 microstructure.*

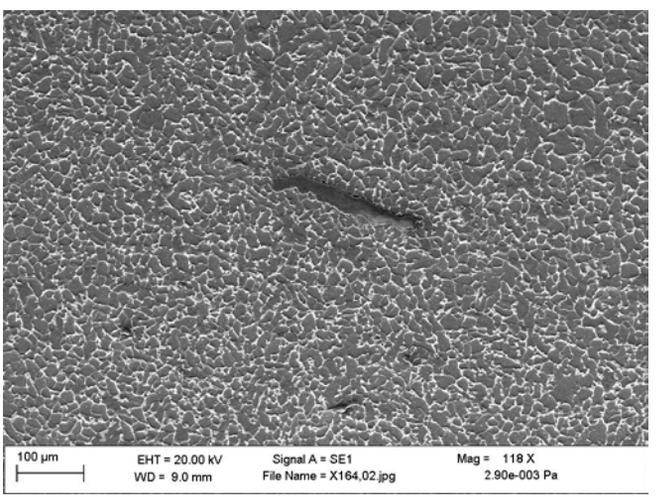

Figure 11.39. *X614-1 microstructure.*

X614-1

Macrostructure: This nail was not cut longitudinally but just below the head, due to corrosion in the topmost part of the nail. The structure alternates between phosphoric iron and very fine hypoeutectoid structures (Fig. 11.38).

Microstructure: The structure is predominantly hypo-eutectoid, low- to mid-carbon steel with interstitial pearlite present (Fig. 11.39). This is most dominant towards the broadest side of the nail. A more ferritic/phosphoric structure is visible towards the top of the iron. This object was made from one stock of iron but consists of very well-made steel.

X614-2

Macrostructure: This sample has a very high amount of carbon with Widmanstätten ferrite (Fig. 11.40), which might be a result of working at very high temperatures followed by a quenching.

Microstructure: The dominant structure of this sample is a hyper-eutectoid structure: high-carbon steel. In the more ferritic areas, however, the structure is hypo-eutectoid. In the areas with a high content of carbon, Widmanstätten ferrite can be observed in the outer edges. The amount of pearlite decreases towards the middle (Fig. 11.41), where fine interstitial pearlite is present. The lamellar pearlite with martensite and ferrite is due to an insufficient cooling from austenite area.

X614-3

Macrostructure: Bent iron rod of low- to mid-carbon steel (Fig. 11.42).

Microstructure: The structure of this sample is hyper-eutectoid and almost entirely ferritic, with heterogeneous, semi-small grains (Fig. 11.43). A slight amount of interstitial pearlite can be observed.

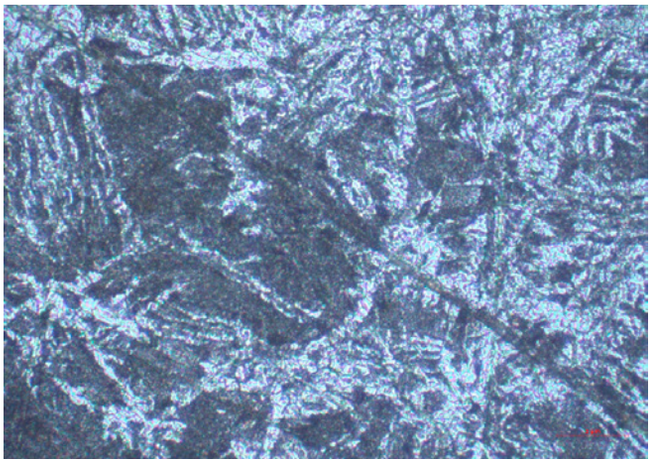

Figure 11.40. *X614-2 microstructure.*

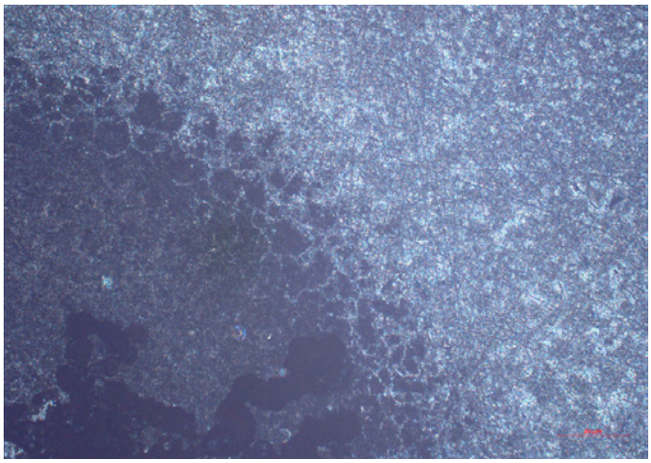

Figure 11.41. *X614-2 microstructure.*

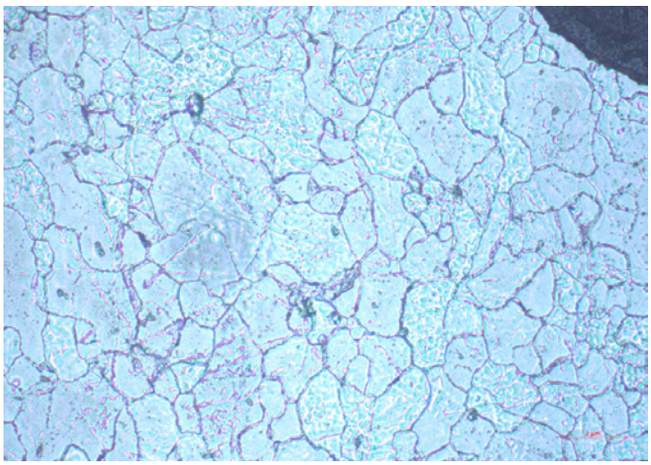

Figure 11.42. *X614-3 microstructure.*

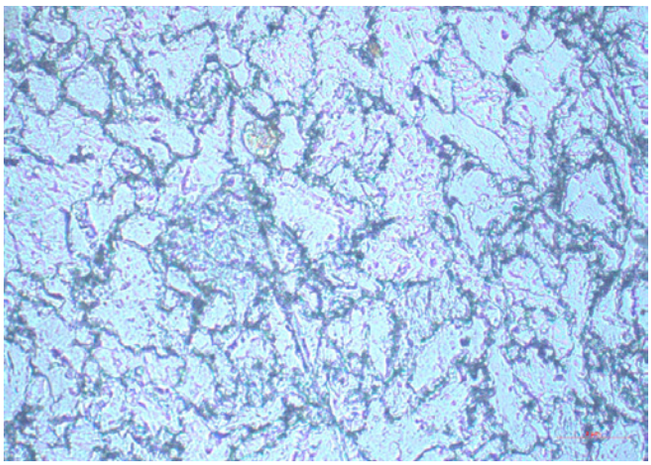

Figure 11.43. *X614-3 microstructure.*

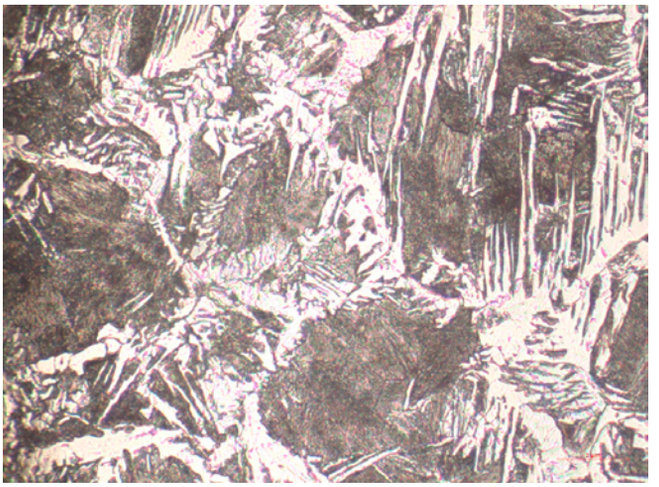

Figure 11.44. *X614-4 microstructure.*

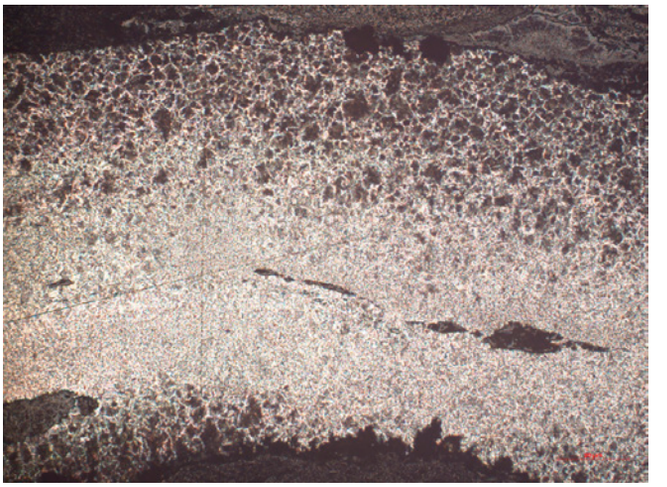

Figure 11.45. *X614-4 microstructure.*

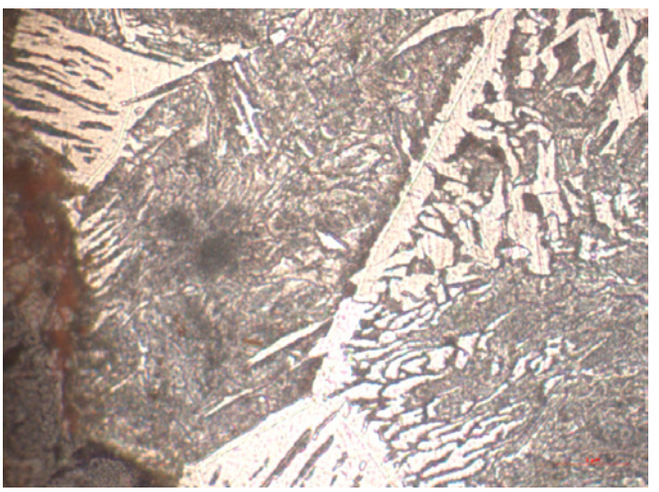

Figure 11.46. *X632 microstructure.*

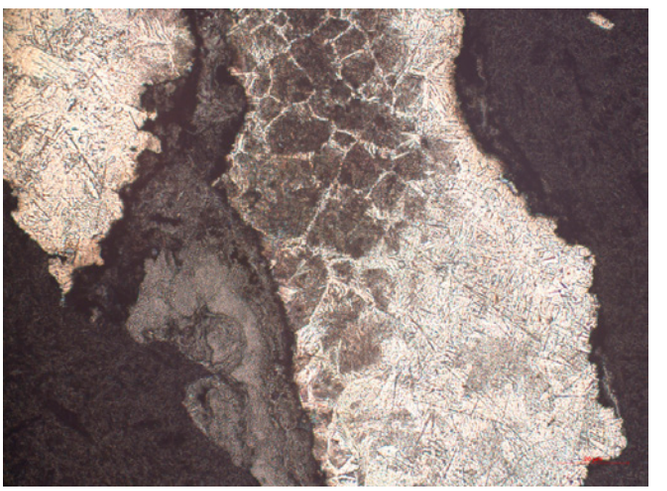

Figure 11.47. *X632 microstructure.*

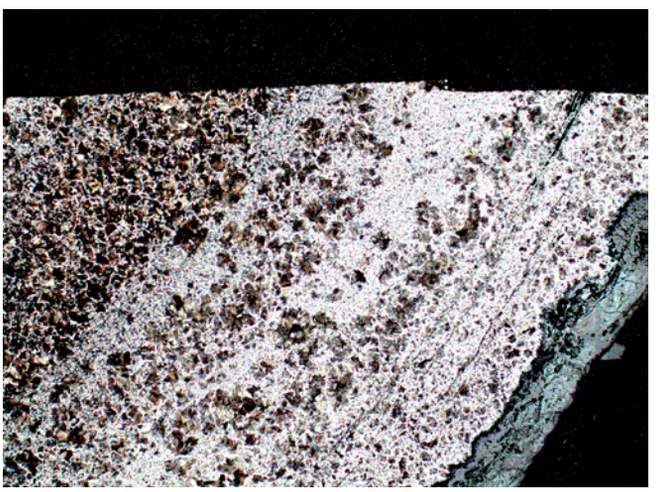

Figure 11.48. *X640 microstructure.*

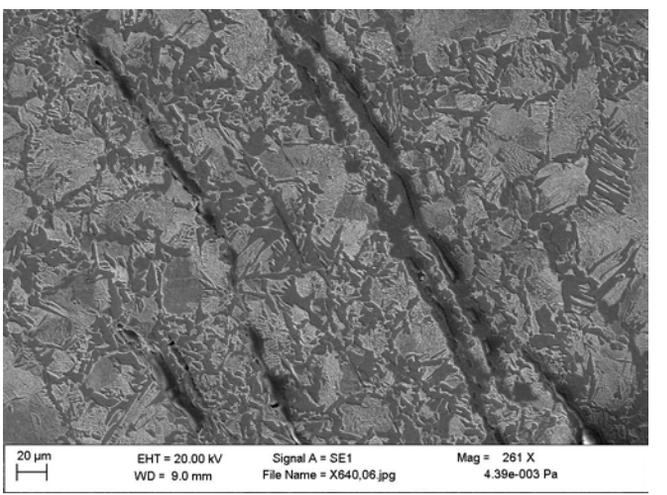

Figure 11.49. *X640 microstructure.*

X614-4

Macrostructure: This nail is made from very high-carbon steel, with Widmanstätten ferrite (Fig. 11.44), indicating that this nail was constructed at very high temperatures followed by quenching in water.

Microstructure: This nail has two structural phases, where one is more ferritic and the other has a very high carbon content. In the ferritic phase, the following can be observed; small and heterogeneous ferritic grain sizes, with interstitial pearlite forming between the grains. In the other phase, the structure slightly changes to a more pearlitic structure with needle-like grain formations forming, indicating Widmanstätten ferrite. The second phase has a very high amount of carbon, with pearlite almost entirely dominating (Fig. 11.45).

X632

Macrostructure: Small nail or iron rod. The sample has a core of high-carbon steel that is also visible to the naked eye. The edges have very prominent Widmanstätten ferrite with coarse pearlite. Widmanstätten structures are usually a result of heating an iron-carbon alloy in the austenite temperature range for long enough to allow for austenite grains, followed by a rather slow cooling, for instance in air.

Microstructure: This sample is dominated by a very heterogeneous grain structure, ranging from areas with ferritic grains to those with Widmanstätten ferrite and coarse pearlite (Fig. 11.46). In the middle is a rather large weld line, which is not visible throughout the sample, but is most likely a fold. The middle of the sample is dominated by a martensitic structure with a very high carbon content, possibly indicating that the core was cooled more quickly than the surfaces (Fig. 11.47).

X640

Macrostructure: Bent nail. This nail did not have a head, so the middle part was taken for sampling. The iron in this nail is made from very high-carbon steel.

Microstructure: The most obvious feature is the carbon banding throughout the section (Fig. 11.48). At the outer edges of the section, the microstructure is slightly more ferritic than towards the centre. The iron is ultra-high-carbon steel. The slag inclusions are few, although these seem to be elongated and drawn along the smithing direction (Fig. 11.49). The pearlite alternates with a Widmanstätten ferrite net. This nail was most likely made from one stock of iron.

X163-1

Macrostructure: Small iron rod. This sample was cut from an unknown piece of iron. There are no visible signs of welding, and it is not possible to draw any further conclusions about the object's function. However, the main part of the piece consists of pearlitic structures with a carbon banding throughout the surface.

Microstructure: The dominating structure of this piece is hypo-eutectoid, pearlitic phase (Fig. 11.50), alternating towards one side to a more ferritic structure, in which the carbon content is lesser (<0.08%; Fig. 11.51). The slags do not seem stretched.

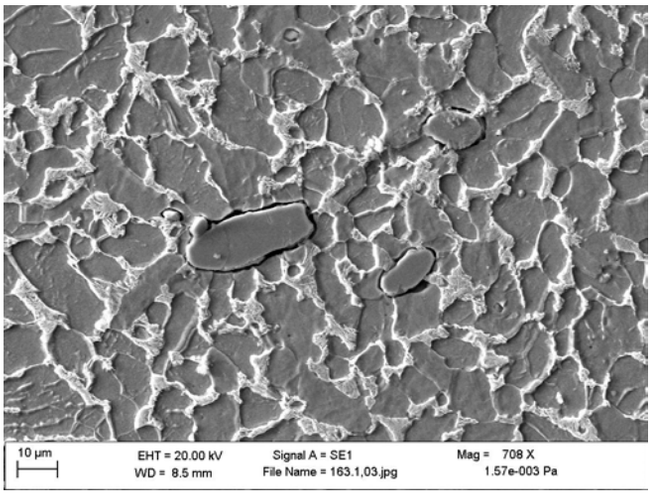

Figure 11.50. *X163-1 microstructure.*

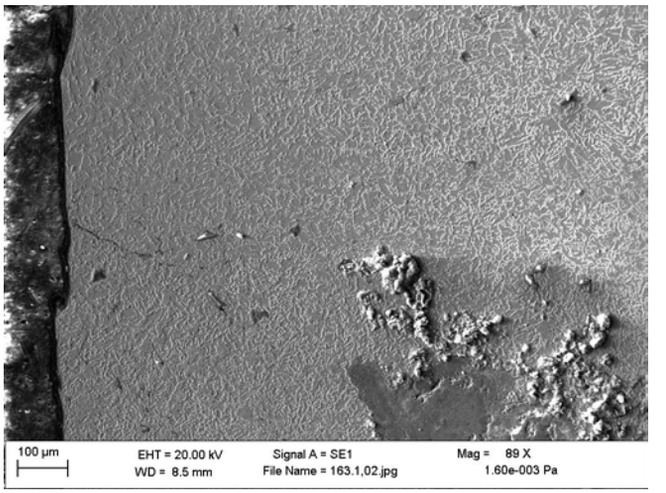

Figure 11.51. *X163-1 microstructure.*

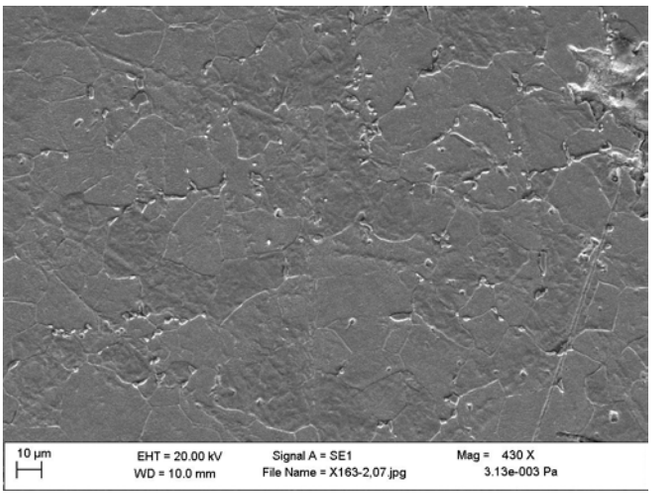

Figure 11.52. *X163-2 microstructure.*

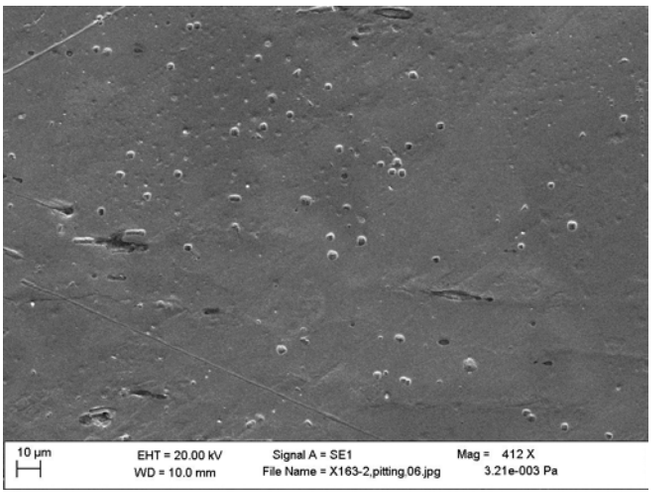

Figure 11.53. *X163-2 microstructure.*

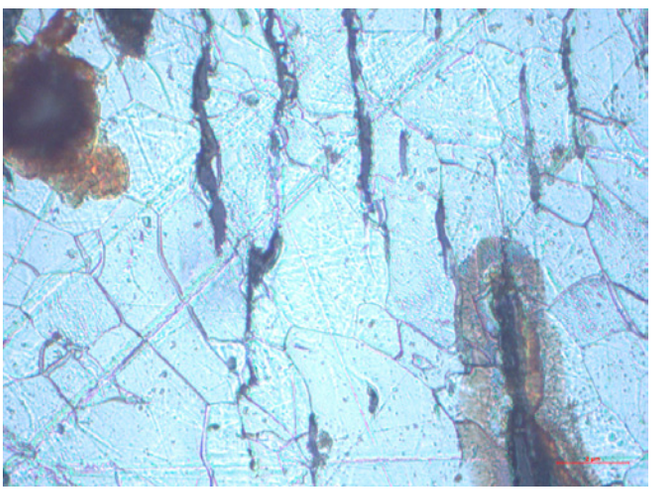

Figure 11.54. *X133-1 microstructure.*

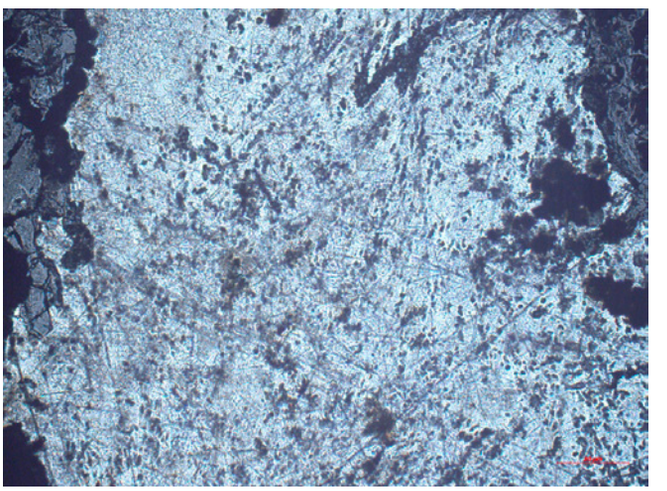

Figure 11.55. *X133-1 microstructure.*

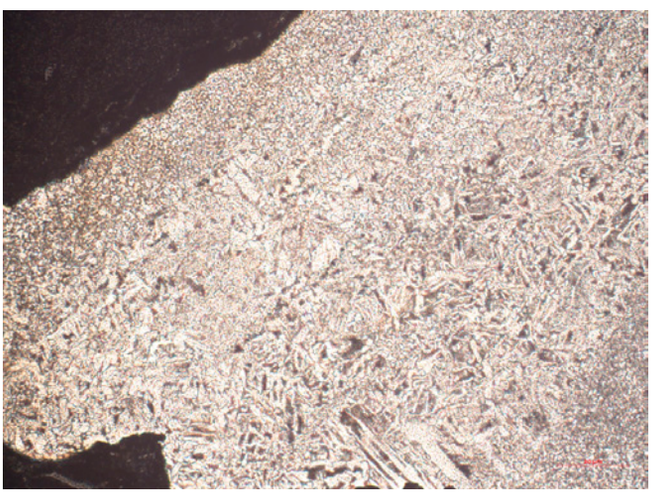

Figure 11.56. *X133-2 microstructure.*

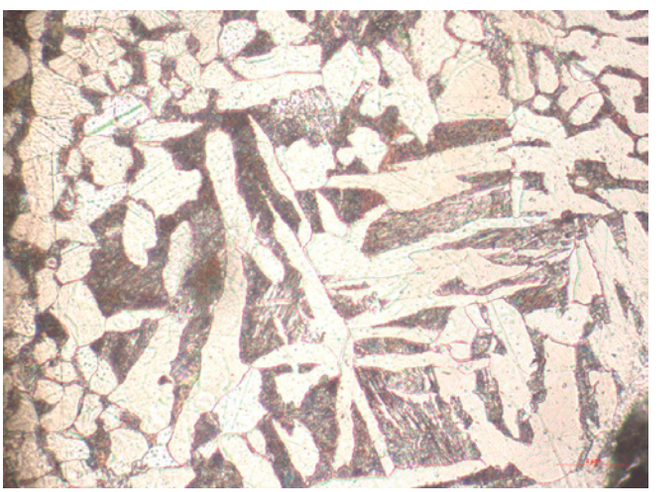

Figure 11.57. *X133-2 microstructure.*

X163-2

Macrostructure: Staple or bracket. This sample was cut from a small bracket or a staple of a sort. The iron was thin but had a well-preserved core fit for sampling. Upon sampling, however, the iron quickly became discoloured shortly after polishing and etching. The iron is most likely phosphoric with heterogeneous SI.

Microstructure: The microstructure is predominantly ferrite with heterogeneous grain sizes changing from rather large phosphoric iron to smaller hypoeutectoid grain structures with interstitial pearlite; the amount of this last, however, is not dominating (Fig. 11.52). Sporadic pits are visible, most likely the result of damage from the etching (Fig. 11.53).

X133-1

Macrostructure: This sample was cut from a nail head. The sample was made of low-carbon steel with hypo-eutectoid grain structures. The microstructure of this nail indicates that the iron was bent or rolled as a part of the production process. The slags, however, do not appear particularly elongated in all areas.

Microstructure: The microstructure contains pearlite and ferrite, although some areas are dominated by an entirely ferritic phase, displaying heterogeneous grains without any or very little grain boundaries (Fig. 11.54). Slags are numerous and elongated. Corrosion is visible as dark pitted spots. In the middle of the sample, a large slag inclusion is visible (Fig. 11.55).

X133-2

Macrostructure: Nail. Very little of the head was preserved, so the sample was cut from the neck. This sample was heated to a very high temperature and most likely cooled by quenching. The outer edges might have signs of being normalized (Fig. 11.56).

Microstructure: This microstructure of this nail is a hypo-eutectoid, heterogeneous grain structure, with different grain structures running in bands throughout the sample. These range in carbon content, with small grains in the middle and the outer edges and with needle-like structures forming in between these bands as Widmanstätten ferrite with coarse pearlite (Fig. 11.57).

X133-3

Macrostructure: Rectangular iron fragment, possibly a clench nail. This sample is most likely made from two stocks of iron, as weld lines are present in the sample. The structure alternates between large phosphoric grains and more hypo-eutectoid structures.

Microstructure: This sample is predominantly ferritic with large heterogeneous phosphorus grains (Fig. 11.58), almost without any grain boundaries, as the dominant structure. The microstructure changes towards the surface to smaller grains with interstitial pearlite in the grain boundaries (Fig. 11.59). These are also found close to the weld line.

X137

Macrostructure: The sample is cut from a nail and seem to be made of primarily low-carbon steel, with an area with less carbon and large phosphorus ferritic grains (Fig. 11.60).

Microstructure: The dominating structure of this sample is hypo-eutectoid, low- to mid-carbon steel, with pearlite present. Towards the neck of the nail on one side, larger ferritic grains replace the pearlitic structure (Fig. 11.61). The grain size is small with interstitial pearlite. The pearlite is more dominant in bands throughout the nail.

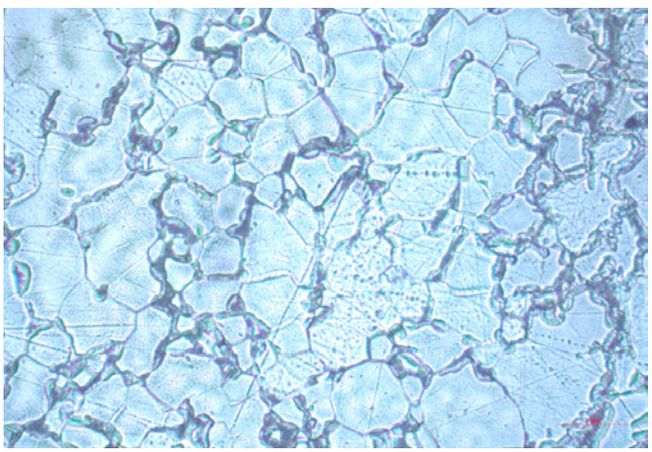

Figure 11.58. *X133-3 microstructure.*

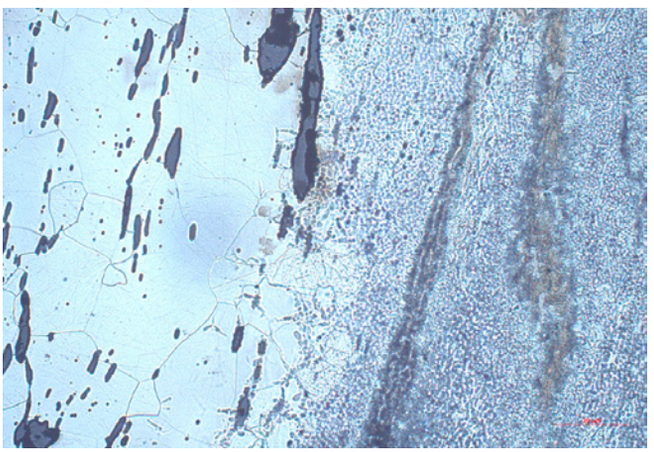

Figure 11.59. *X133-3 microstructure.*

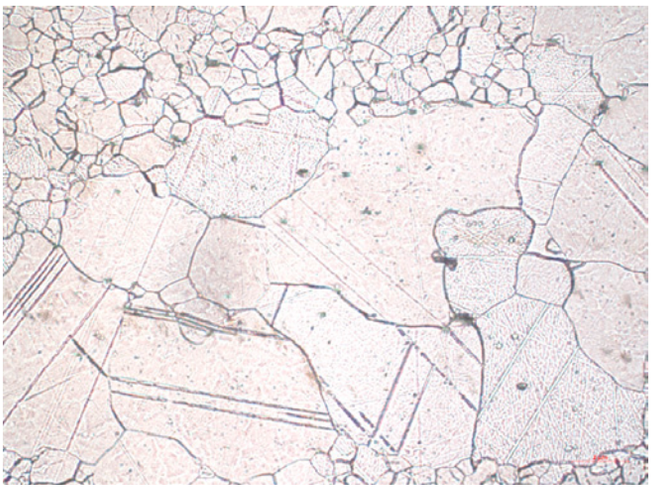

Figure 11.60. *X137 microstructure.*

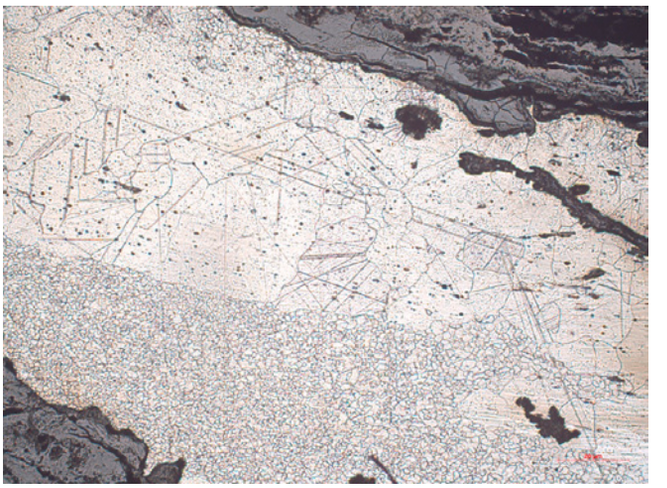

Figure 11.61. *X137 microstructure.*

Figure 11.62. *X143-1 microstructure.*

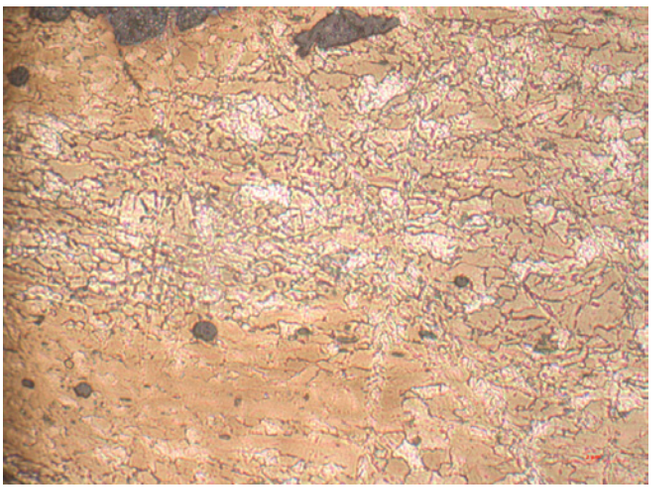

Figure 11.63. *X143-1 microstructure.*

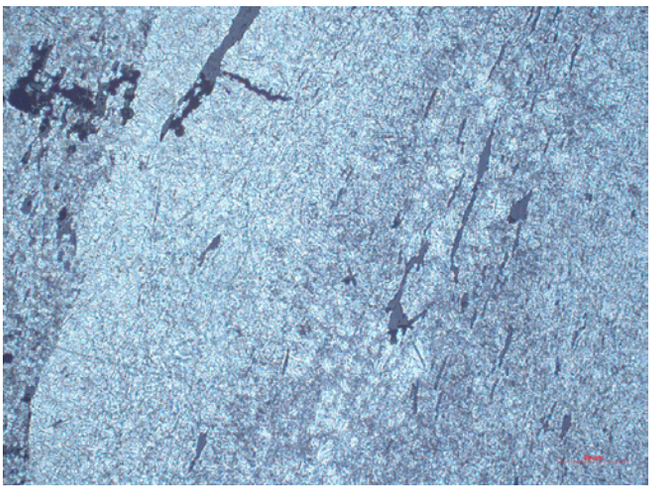

Figure 11.64. *X143-2 microstructure.*

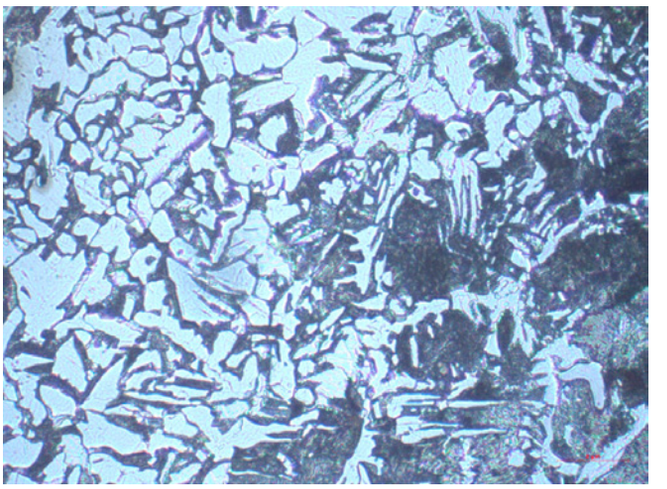

Figure 11.65. *X143-2 microstructure.*

X143-1

Macrostructure: This nail is constructed from low-carbon steel and ferritic iron with heterogeneous grain sizes (Fig. 11.62). Furthermore, the sample was made from two stocks of iron, identified by a weld line in the top middle part of the nail. The microstructure in the steel is mid-carbon steel, with visible grain structure changes throughout the sample.

Microstructure: The different phases are made of hypo-eutectoid, low- to mid-carbon steel with few pearlitic structures. The carbon seems more concentrated towards the left side with bands of pearlite going through, but the main structure is ferritic (Fig. 11.63).

X143-2

Macrostructure: A nail with low-carbon steel and ferrite. This nail was most likely constructed of one stock, as there are no visible weld lines. The nail still has two phases, however, a pearlitic and a ferritic phase. The nail might have been case-hardened, given the very hypo-eutectoid surface at the surfaces of the neck.

Microstructure: The structure of this nail is constructed from very high-carbon steel, with heterogeneous grain sizes and with pearlitic structures forming in the grains. Furthermore, pearlite is more present towards the left side of the neck of the nail (Fig. 11.64). In the more pearlitic phase, the structure has been normalized but changed and includes Widmanstätten structures (Fig. 11.65). In the ferritic areas, the grains change to larger ferritic grains with interstitial pearlite. The slags are placed as clusters scattered all over the sample and are slightly elongated.

X143-3

Macrostructure: This clench nail was made from almost pure ferrite, and the iron used for the two different pieces has similar macrostructures.

Microstructure: The structure of this nail is predominantly ferrite with slight intergranular pearlite. The grains are large and heterogeneous in structure (Fig. 11.66). The slags are mainly elongated, but some are scattered as dots throughout the sample. Based upon the lack of visible grain boundaries, it is presumed that the iron has a high content of phosphorus (Fig. 11.67). There are no obvious phase changes present, although there is a slight alteration in grain size.

X143-4

Macrostructure: This iron rod is made from ultra-high-carbon steel and has structural similarities to cast iron, resulting from the iron being worked at very high temperatures in an oxygen-reduced environment and then quenched in oil or water following a tempering.

Microstructure: The structures in this sample are hyper-eutectoid, with ultra-high-carbon steel (carbon content of c. 0.8–1.5%; Fig. 11.68). The ferrite had been saturated in carbon, so the pearlite colonies could no longer form. The grain boundaries are cementite and can be identified as white forms around the carbon. The dark patterns are martensite formations (Fig. 11.69).

X143-5

Macrostructure: This nail was made with high-carbon steel and has been heated to a very high temperature followed by a fast cooling, possibly by quenching in water.

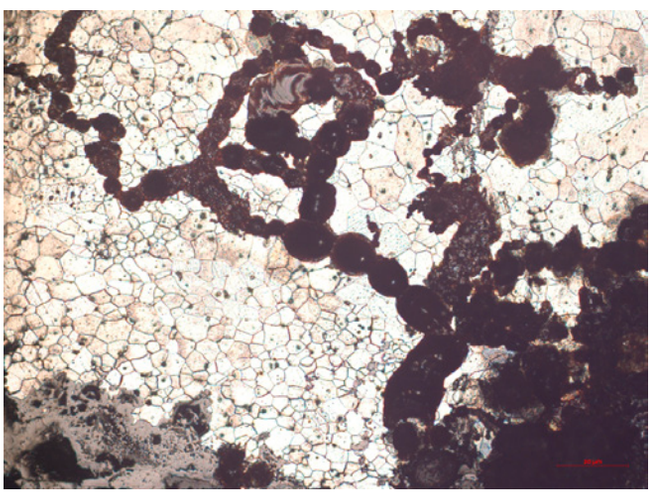

Figure 11.66. *X143-3 microstructure.*

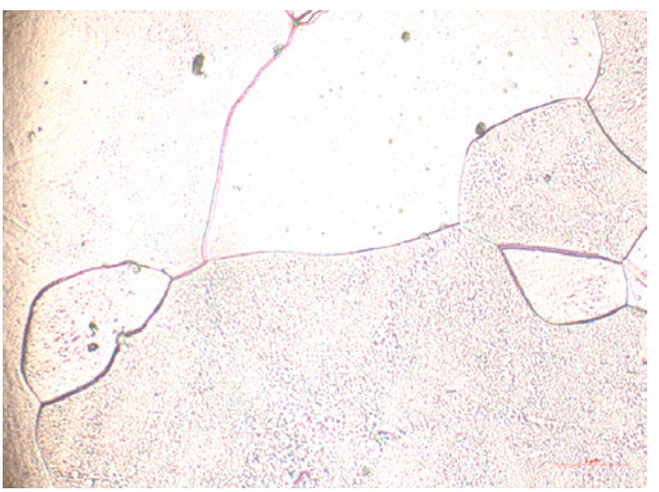

Figure 11.67. *X143-3 microstructure.*

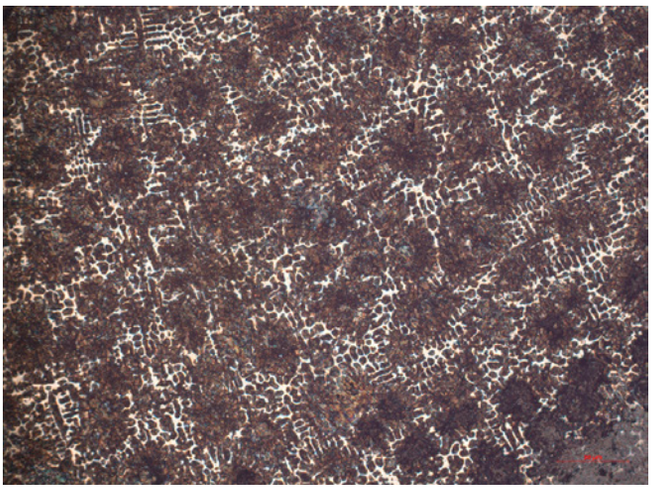

Figure 11.68. *X143-4 microstructure.*

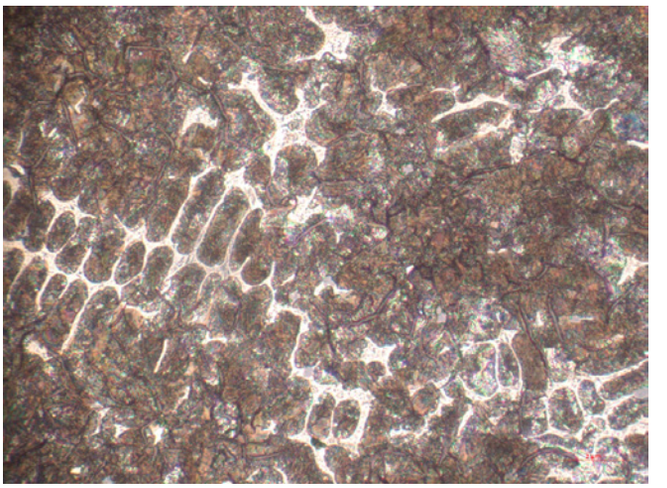

Figure 11.69. *X143-4 microstructure.*

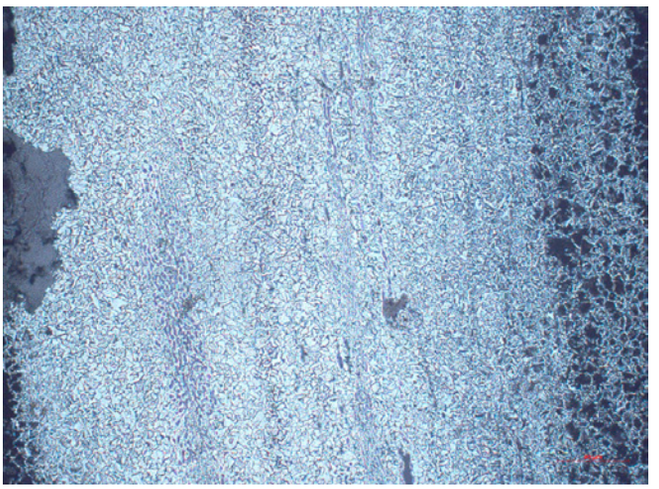

Figure 11.70. *X143-5 microstructure.*

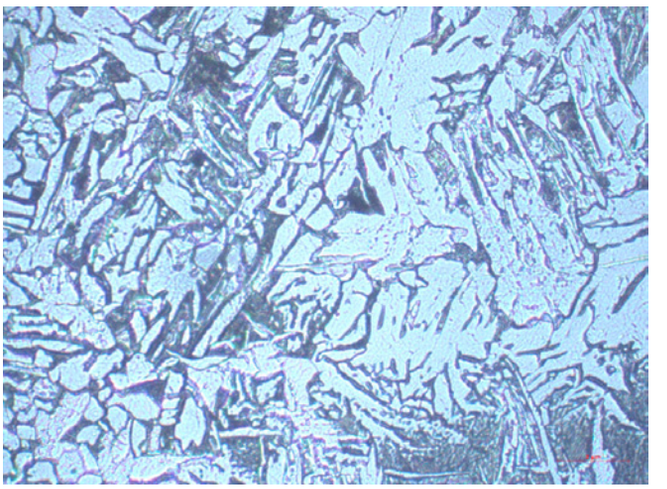

Figure 11.71. *X143-5 microstructure.*

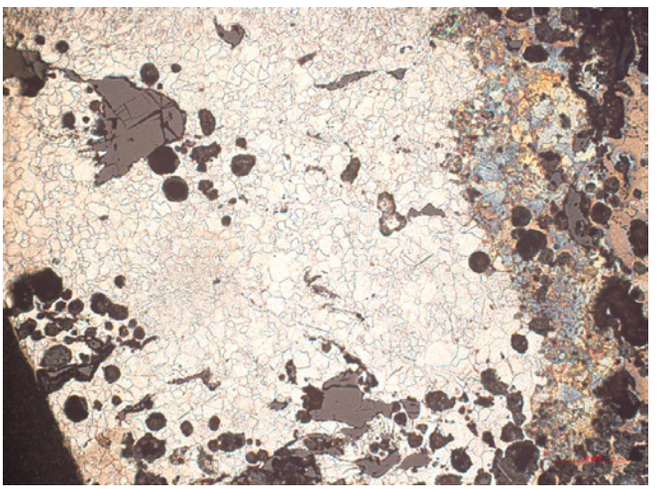

Figure 11.72. *X146-1 microstructure.*

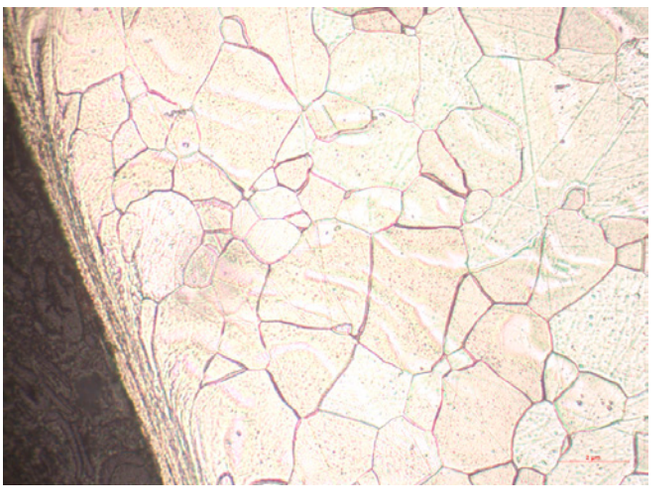

Figure 11.73. *X146-1 microstructure.*

Microstructure: Hypo-eutectoid grain structures, with variations in distribution of grain size and carbon content (Fig. 11.70). A concentration of carbon can be found close to the head of the nail. Furthermore, there are Widmanstätten structures in the areas with the highest concentration of carbon, and ferrite grain size is small but varying (Fig. 11.71). Slight banding throughout but not very pronounced.

X146-1

Macrostructure: Large nail head with very slim body. This sample was made from one stock of iron and contains hardly any carbon (Fig. 11.72).

Microstructure: This sample is almost entirely ferritic, containing barely any carbon. The microstructure shows a low carbon steel structure as a result of carbon diffusion. The sample has a high content of phosphorus, which is based upon the lack of visible grain boundaries (Fig. 11.73). There are no obvious phase changes present, although a slight alteration of grain size can be identified, as the grains seem to grow slightly towards the lower part of the sample.

X146-2

Macrostructure: Small iron rod. This rod was most likely made from one stock of iron, and the object might have been heated at low temperatures, allowing for a carburization of the outer edges without affecting the core too much.

Microstructure: The structure of this sample is mainly ferritic, with a very small amount of carbon that increases towards the outer edges (Fig. 11.74). Throughout the middle, the slags seem focused and more numerous compared to the outer edges. Furthermore, the slags seem stretched and elongated. The grain structure is heterogeneous and ferritic, without dominating grain boundaries (Fig. 11.75).

X146-3

Macrostructure: Nail. This sample was cut from a rather slender nail, and the iron used to produce it was almost entirely carbon free and was allowed to cool normally after production.

Microstructure: This sample consists almost entirely of regular polyhedral ferrite grains of slightly heterogeneous size (Fig. 11.76). The structure is uniform throughout the sample, with very fine pearlite forming (Fig. 11.77).

X146-4

Macrostructure: Nail. This sample shows a nail with a medium level of carbon, which is most likely the result of mid to high temperatures during forging followed by a relatively slow cool (not in the forge).

Microstructure: The structure of this sample is hypo-eutectoid, mid- to high-carbon steel, with large hexaglomerate, phosphorus ferritic grains in the middle part of the nail (Fig. 11.78). The nail seems to have been bent, which is shown by stretches of the slags and the general direction of the grains. The slags are larger towards the middle of the sample and slenderer in the outer areas. The carbon is not equally dispersed but can be found in areas of fine interstitial pearlitic structures (Fig. 11.79).

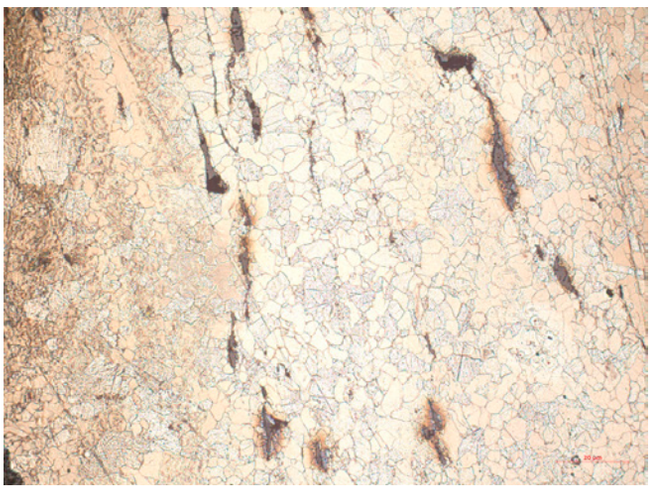

Figure 11.74. *X146-2 microstructure.*

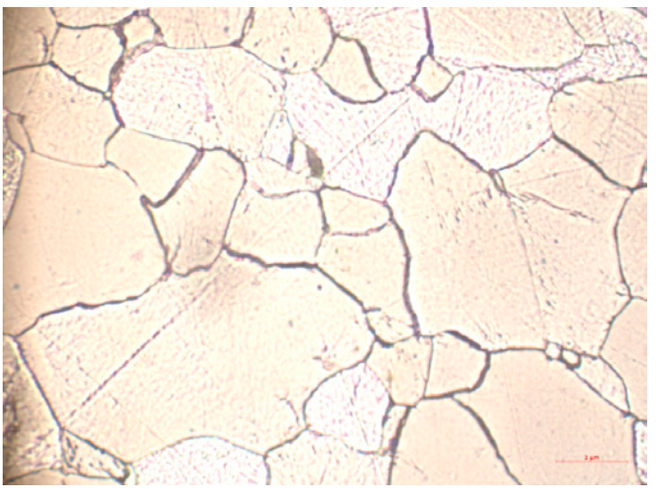

Figure 11.75. *X146-2 microstructure.*

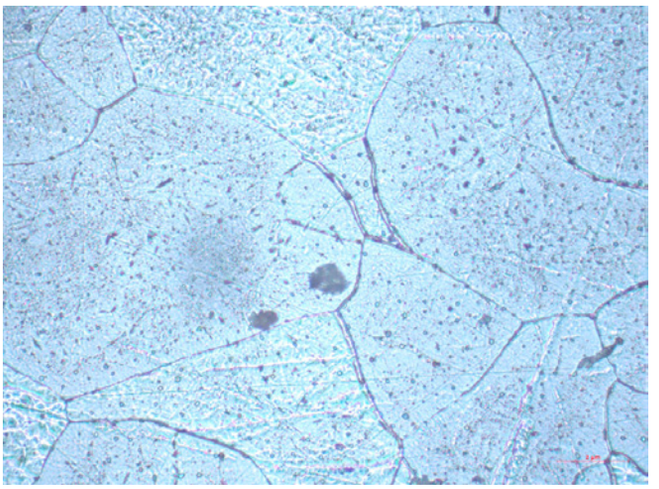

Figure 11.76. *X146-3 microstructure.*

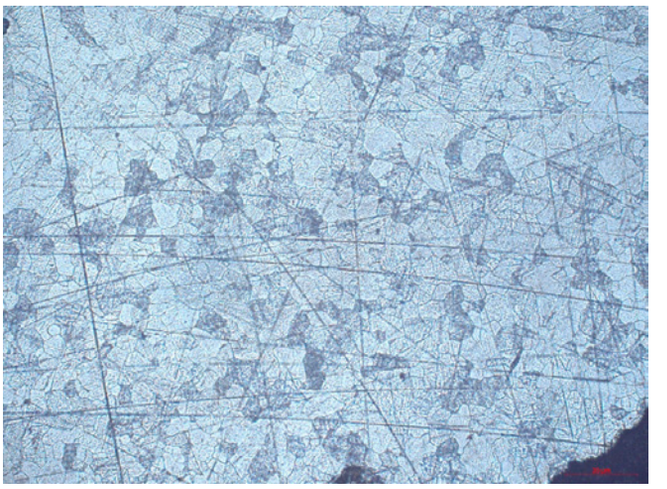

Figure 11.77. *X146-3 microstructure.*

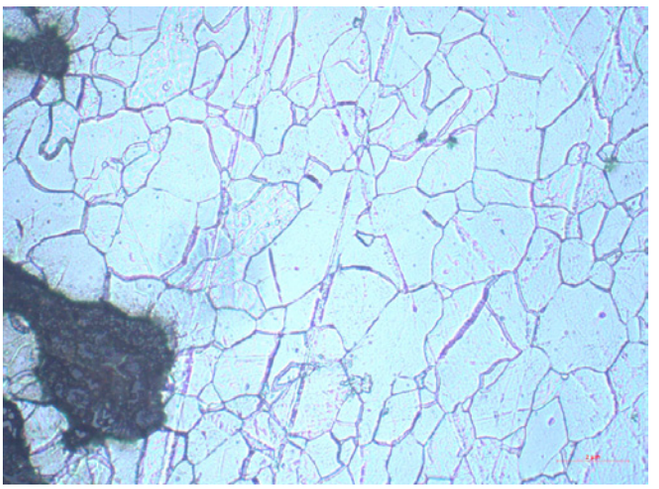

Figure 11.78. *X146-4 microstructure.*

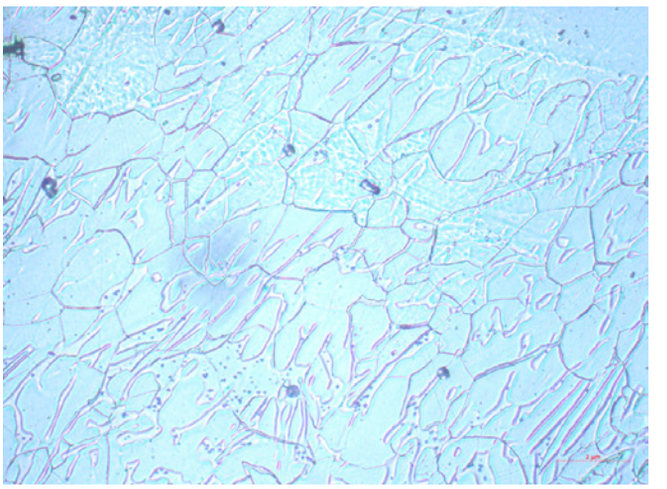

Figure 11.79. *X146-4 microstructure.*

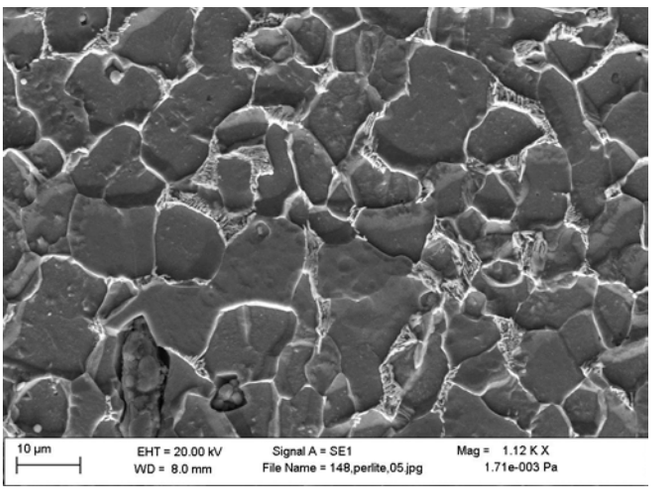

Figure 11.80. *X148 microstructure.*

Figure 11.81. *X148 microstructure.*

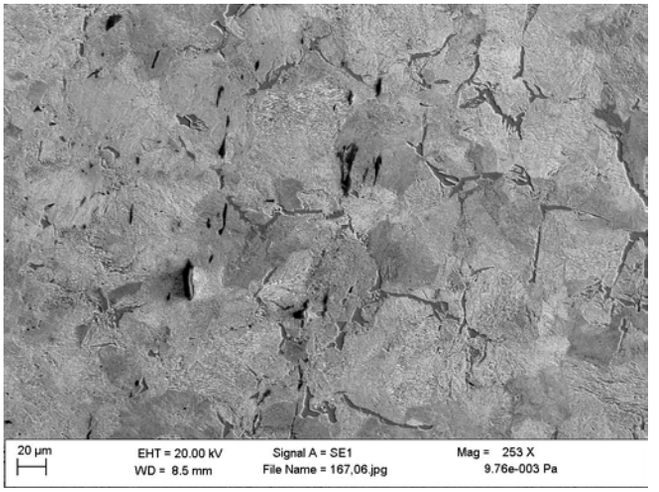

Figure 11.82. *X167 microstructure.*

Figure 11.83. *X167 microstructure.*

X148

Macrostructure: Iron rod, cut longitudinally. This iron rod was constructed from mid- to low-carbon steel, with homogenous grain sizes, although in the small range of the scale. Pearlite is visible between the grains, as interstitial pearlite spread as bands across the piece. The rod was made from one stock of iron, with very long slag inclusions embedded in the middle of the piece.

Microstructure: The dominating microstructure in this iron rod is finely grained ferrite, with hypoeutectoid-structured low-to mid-carbon steel, with coarse interstitial pearlite (Fig. 11.80). Throughout the section, bands of carbon can be seen (Fig. 11.81), which also indicates a mid-carbon steel object. The slag inclusions have been drawn from top to bottom and seem elongated.

X167

Macrostructure: Nail, cut longitudinally. The nail was made from one stock of iron, as there are no visible weld lines. The structure has two phases: a pearlitic and a ferritic phase. This nail was most likely made from very high-quality steel.

Microstructure: The microstructure of this nail is dominated by a hypo-eutectoid pearlitic phase, with beginning martensitic structures towards the outer edge of the nail-body. This is an indication of quenching, which makes the metal very hard. The transformation is not complete and pearlite is more present than bainite (Fig. 11.82). Towards the other side of the nail, large heterogeneous grains dominate the structure (Fig. 11.83). The nail is generally well preserved, although some corrosion is visible, especially in the head of the nail, which is most likely because the structure of the artefact is thinner in this part. The SI are elongated, possibly from the formation of the nail.