FERROUS METALS

Iron-based alloys account for a large portion of all metals production. The range of compositions and microstructures of iron-based alloys is far wider than any other system. Pure iron is soft and ductile. Development of scratch-free and deformation-free grain structures is difficult. Sheet steels present the same problem, which can be complicated by protective coatings of zinc, aluminum or Zn-Al mixtures. In general, harder alloys are much easier to prepare. Cast irons may contain graphite, which must be retained in preparation. Inclusions are frequently evaluated and quantified. Volume fractions can vary from nearly 2% in a free machining grade to levels barely detectable in a premium, double vacuum melt alloy. A wide range of inclusion, carbide and nitride phases has been identified in steels. Addition of 12 or more percent chromium dramatically reduces the corrosion rate of steels, producing a wide range of stainless steel alloys. Tool steels cover a wide range of compo sitions and can attain very high hardnesses. Preparation of ferrous metals and alloys is quite straightforward using the contemporary methods. Edge retention (see guidelines on pages 13-15) and inclusion retention are excellent, especially if automated equipment is used. The following procedures are recommended and are adequate for the vast majority of ferrous metals and alloys. Table 9 presented a variation of the method given in Table 19.

This practice is also useful for cast iron specimens including graphitic cast irons. 240 grit [P280] SiC paper can be substituted for the UltraPrep disc or another Apex Hercules H disc can be used for planar grinding with 30µm MetaDi Supreme diamond suspension. Due to their high silicon content and the potential for staining problems, it is best to use the MasterPrep alumina suspension for the final polishing step.

For softer steels, use the 30µm resin bonded UltraPrep disc, or 240 grit [P280] SiC paper, for step 1. The Apex Hercules S disc can be used in place of the

Normalized carbon steel shows coarse ferritic-pearlitic (grains with lamellar cementite) structure. Etched with 3% Nital (200X).

Table 19: 4-Step Method for Hard Steel

Sectioning	Abrasive Cutter with a wheel recommended for use on ferrous materials HRC35-60				
Mounting	Compression or Castable, typically with EpoMet or VariDur 3000				
Surface	**Abrasive / Size**	**Load - lbs [N] / Specimen**	**Base Speed [rpm]**	**Relative Rotation**	**Time [min:sec]**
Apex DGD Red	75µm Diamond water cooled	6 [27]	300		Until Plane
Apex Hercules S Rigid Grinding Disc	9µm MetaDi Supreme Diamond*	6 [27]	150		5:00
TriDent	3µm MetaDi Supreme Diamond*	6 [27]	150		3:00
MicroCloth	0.05µm MasterPrep Alumina	6 [27]	150		2:00
● = *Platen* ⊛ = *Specimen Holder*		**Plus MetaDi Fluid Extender as desired*			
Imaging & Analysis	Grain Size, Phase Area Percent, Object Measurement, Measurement & Analysis Applications				
Hardness Testing	Vickers, Knoop, Rockwell				

Table 20: 4-Step Method for Soft Steel

Sectioning	Abrasive Cutter with a wheel recommended for use on ferrous materials HRC15-35				
Mounting	Compression or Castable, typically with EpoMet or VariDur 200				
Surface	**Abrasive / Size**	**Load - lbs [N] / Specimen**	**Base Speed [rpm]**	**Relative Rotation**	**Time [min:sec]**
CarbiMet 2	320 [P400] grit SiC water cooled	6 [27]	300		Until Plane
UltraPad	9µm MetaDi Supreme Diamond*	6 [27]	150		5:00
TriDent	3µm MetaDi Supreme Diamond*	6 [27]	150		3:00
MicroCloth	0.05µm MasterPrep Alumina	6 [27]	150		2:00
= *Platen* = *Specimen Holder* **Plus MetaDi Fluid Extender as desired*					
Imaging & Analysis	Grain Size, Object Measurement, Measurement & Analysis Applications				
Hardness Testing	Vickers, Knoop				

Apex Hercules H disc but this is not usually necessary. However, with either disc, use 6µm MetaDi Supreme for the second step instead of 9µm, as shown in Table 20.

This practice is well suited for solution annealed austenitic stainless steels and for soft sheet steels. UltraPol or UltraPad cloths could be substitute for the rigid grinding discs, if desired. For perfect publication quality images, or for color etch ing, follow this practice with a brief vibratory polish using the cloths and abrasives in the last step.

Many steels, particularly the harder steels, can be prepared in three steps with excellent results. A recommended practice is given in Table 21.

For soft alloys, use 240 or 320 grit [P280 or P400] SiC paper; for harder alloys use 120 [P120], 180 [P180], or 240 grit [P280] SiC paper, depending upon the starting surface finish and the hardness of the alloy. Planar grinding can also be performed using 45µm metal-bonded or 30µm resin-bonded UltraPrep diamond discs. For softer steels, use the Apex Hercules S disc for best results. The UltraPol cloth can also be used for the second step for steels of any hardness.

The following practice is recommended for stainless steels and maraging steels. For solution annealed austenitic grades and for ferritic stainless grades and for annealed maraging grades, use the Apex Hercules S disc or the UltraPol cloth for

Table 21: 3-Step Method for Heat-Treated Steel

Sectioning	Abrasive Cutter with a wheel recommended for use on ferrous materials HRC35-60				
Mounting	Compression or Castable, typically with EpoMet or VariDur 3000				
Surface	**Abrasive / Size**	**Load - lbs [N] / Specimen**	**Base Speed [rpm]**	**Relative Rotation**	**Time [min:sec]**
Apex DGD Red	75µm Diamond water cooled	6 [27]	300		Until Plane
Apex Hercules S Rigid Grinding Disc	9µm MetaDi Supreme Diamond*	6 [27]	150		5:00
MicroFloc	3µm MetaDi Supreme Diamond*	6 [27]	150		3:00
= *Platen* = *Specimen Holder* **Plus MetaDi Fluid Extender as desired*					
Imaging & Analysis	Case Depth, Decarburization Depth Assessment, Grain Size, Phase Area Percent, Object Measurement, Measurement & Analysis Applications				
Hardness Testing	Vickers, Knoop, Rockwell				

best results. Start with 120 grit [P120] SiC paper only if it is a very hard martensitic stainless steel, such as type 440C. For the martensitic grades, planar grinding can be performed using a 4µm metal-bonded diamond UltraPrep disc. For softer stainless steels, use the 30µm resin-bonded diamond UltraPrep disc for planar grinding. Another alternative is a second Apex Hercules disc, either H or S, depending upon the hardness of the grade, and a 30µm MetaDi Supreme polycrystalline diamond suspension. The solution annealed austenitic stainless steels and the fully ferritic stainless steels are the most difficult to prepare. It may be helpful to add a 1µm diamond step on a TriDent cloth before the last step, or to follow the last step with a brief vibratory polish using colloidal silica on MicroCloth or a ChemoMet cloth, see Table 22.

Microstructure of a duplex (ferrite tan, austenite white) stainless steel held at 816° C for 48 hours which forms sigma phase (orange particles) revealed by electrolytic etching with aqueous 20% NaOH at 3 V DC, 9 seconds (500X).

Cast Iron

Cast iron is a ferrous material with high carbon content (> 2%), Silicon (> 1.5%) and other components such as manganese, chromium or nickel. In general there is a distinction between gray cast iron (carbon is in the form of graphite) and white cast iron (carbon is in the form of cementite). The simplest type of cast iron is grey cast iron (ASTM A 48), also called "GJL" according to the European Norm. Grey cast iron, or grey iron, has graphite flakes which act as notches when tensile forces are applied, so the tensile strength is relatively low. Compared to this the compressive strength is much better. Cast iron "GJS" (DIN EN 1563 cast iron, ductile iron, spherolitic graphite) has better mechanical properties, due to the spheroidal form of the graphite it contains. The graphite is in the form of spherical nodules rather than flakes, which helps prevent the creation of cracks and provides improved ductility. This form

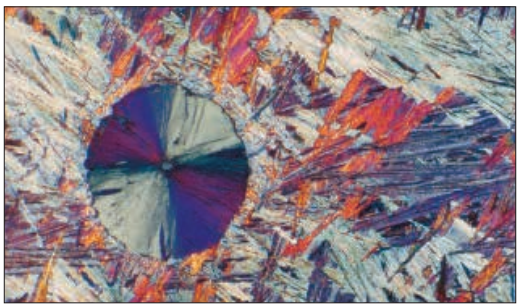
Pearlitic gray cast iron, etched with Beraha's CdS tint (1300X).

Table 22: 4-Step Method for Stainless and Maraging Steel

Sectioning	Abrasive Cutter with a wheel recommended for use on ferrous materials HRC35-50				
Mounting	Compression, typically with EpoMet				
Surface	**Abrasive / Size**	**Load - lbs [N] / Specimen**	**Base Speed [rpm]**	**Relative Rotation**	**Time [min:sec]**
CarbiMet 2	120 [P120] to 320 [P400] grit SiC water cooled	6 [27]	300		Until Plane
UltraPad	9µm MetaDi Supreme Diamond*	6 [27]	150		5:00
TriDent	3µm MetaDi Supreme Diamond*	6 [27]	150		3:00
ChemoMet	0.05µm MasterPrep Alumina	6 [27]	150		2:00
● = *Platen* ⊛ = *Specimen Holder*		**Plus MetaDi Fluid Extender as desired*			
Imaging & Analysis	Grain Size, Phase Area Percent, Object Measurement, Measurement & Analysis Applications				
Hardness Testing	Vickers, Knoop, Rockwell				

Ferrous Metals

is achieved by desulphurization of the melt and the addition of small amounts of magnesium, cerium or calcium prior to casting. Preparation artifacts can occur due to insufficient time or too low material removal rates. The effects are visible as pull outs of the graphite flakes or nodules. Table 23 shows a good practicee to prepare cast iron.



Nodular graphite, lower bainite and retained austenite in austempered ductile iron, etched with modified Beraha-martensite reagent (~1300X).

Table 23: 5-Step Method for Cast Iron

Sectioning	Abrasive cutter with a wheel recommended for use on ferrous materials HRC35-50				
Mounting	Compression or Castable				
Surface	**Abrasive / Size**	**Load - lbs [N] / Specimen**	**Base Speed [rpm]**	**Relative Rotation**	**Time [min:sec]**
CarbiMet 2	320 [P400} grit SiC water cooled	5 [22]	300		Until Plane
TexMet C	9µm MetaDi Diamond Supreme*	5 [22]	150		5:00
TriDent	9µm MetaDi Diamond Supreme*	5 [22]	150		4:00
MicroCloth	0.05µm MasterPrep Alumina	5 [22]	150		2:00
 *= Platen*  *= Specimen Holder*					
Imaging & Analysis	Graphite in Cast Iron				
Hardness Testing	Brinell				