



Tool Steel for Plastic Injection Mold Construction

1 Scope

1.1 Material Description. This material specification applies to low to medium alloy modified American Iron and Steel Institute (AISI) AISI P20 Tool Steel, as defined in ASTM A681, produced through various melting, forging, and heat treatment manufacturing processes.

1.2 Symbols. Not applicable.

1.3 Applicability. Modified AISI P20 Tool Steel is used in the construction of cavity and core tooling used for the thermoplastic injection molding. GM Tool Steel Grades in this standard are specified by surface hardness, hardenability, microstructure, chemistry, physical properties, and quality requirements to achieve a balance of machinability, thermal conductivity, fracture toughness, corrosion resistance, weldability, wear resistance, ability to polish, ability to etch, and core strength which are all critical characteristics of injection mold tools.

This standard addresses Steel Supplier and Material Requirements for modified AISI P20 Tool Steel and are part of the Steel Supplier Approval Process. After successful completion of the submission per A1 in Appendix A, and GM approval, all sections of this standard are intended to apply to production forgings used to make injection molds.

1.4 Remarks. Thermoplastic injection mold tooling design, construction, and validation requirements can be found in GMW15850. This specification is intended to support technical problem solving when considering the mill origin of tool steel, metallurgical certification data, and production processing only and will not specify tool build requirements.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

API 6A Annex M	ASTM A751	ASTM E140	ISO 643
ASNT SNT-TC-1A	ASTM D6482	ASTM E228	ISO 1302
ASTM A370	ASTM E3	ASTM E381	SPI AR-106
ASTM A388	ASTM E29	ASTM E1461	
ASTM A681	ASTM E45	ASTM E2585	

2.2 GM Standards/Specifications.

GMW3059	GMW15850	GMW17205
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2.3 Additional References.

CG5806 Steel Testing and Material Composition Requirements

3 Requirements

3.1 Requirements on Test Specimens.

3.1.1 Material. Modified AISI P20 Tool Steel will be delivered from the manufacturer in the pre-hardened condition. GM Tool Steel Grades are designed for optimum hardness and cleanliness as shown in Table 1. Hardness conversions shall be made according to ASTM E140.

Table 1 defines the various GM Tool Steel Grades defined in this standard and the required hardness. Surface finish listed in Table 1 is considered secondary to the surface hardness requirements. The Steel Supplier will develop a process that is capable of consistent through-hardening and superior cleanliness to facilitate the

achievement of the desired surface finish after secondary finishing processes for each GM Tool Steel Grade shown in Table 1. Surface finish is defined by ISO 1302 "N" value and Society of the Plastics Industry (SPI) SPI AR-106 "Mold Finish Guide" value.

Table 1: Material Identification, Steel Grade Description, Surface Finish, and Required Surface Hardness

GM Tool Steel Grade	Description	SPI AR-106 "Mold Finish Guide" Target Minimum	ISO 1302 "N" Value	Required Minimum Surface Hardness ASTM A370 Rockwell Hardness C (HRC)	Required Minimum Surface Hardness ASTM A370 Brinell Hardness, Tungsten Ball (HBW)
GM Standard	Standard grade for injection mold tool steel	B-1	N3	30 to 35	286 to 327
GM High Hard	Modified alloy addition to improve hardness, hardenability, and ability to polish over standard AISI P20 Tool Steel	A-2	N2	34 to 38	319 to 353
GM Lens Quality	Re-melted steel with high ability to polish and meet surface finish requirements	A-1	N1	37 to 43	344 to 400

3.2 Chemical Composition. The Steel Supplier shall measure chemical composition for all elements listed in Table 2. Samples will be taken from the final melt after all chemistry modifications and treatments are complete. The chemistry sample will be taken from the molten iron that is to be poured into ingot molds and will be a solidified chilled sample. The intentional addition of boron, tungsten, tantalum, lead, or cobalt as special alloys are not permitted.

3.2.1 Chemistry sampling for individual and multiple heats shall follow the procedures listed in ASTM A751.

3.2.2 Optical Emission Spectroscopy (OES) analysis of the elements listed in Table 2 shall be measured in accordance with the procedures, master, samples, and calibration defined in ASTM A751.

3.2.3 Chemistry shall be reported for each forging on the mill certificate.

Table 2: Chemical Composition of Modified AISI P20 Tool Steel ^{Note 1}

GM Tool Steel Grade	Carbon	Manganese	Phosphorus ^{Note 2}	Sulfur ^{Note 2}	Silicon	Nickel	Chromium	Molybdenum	Vanadium	Copper
GM Standard	0.20 to 0.40	0.60 to 1.80	0.030 maximum	0.006 maximum	0.20 to 0.40	0.40 minimum	1.20 to 2.05	0.30 to 0.80	0.25 maximum	0.35 maximum
GM High Hard	0.20 to 0.36	0.60 to 1.80	0.025 maximum	0.006 maximum	0.20 to 0.40	0.40 minimum	1.20 to 2.05	0.40 to 0.80	0.25 maximum	0.35 maximum
GM Lens Quality	0.20 to 0.36	0.85 to 1.80	0.015 maximum	0.003 maximum	0.20 to 0.40	0.40 minimum	1.20 to 2.05	0.40 to 0.80	0.25 maximum	0.35 maximum

Note 1: All vales are given in weight percentage.

Note 2: Phosphorous and Sulfur are critical to material cleanliness.

3.3 Hardness. Hardness is critical to machinability and shall be kept as consistent as possible throughout the cross section of the forging.

3.3.1 Hardness will be used to measure and control mechanical properties during the production process. Surface hardness checks will be reported on all shipped product as part of the mill certificate. If a shipped forging is cut from a larger parent block, the individual cut piece must be checked for surface hardness. Reporting the hardness of a parent block is not an acceptable substitute to qualify a cut steel block extracted from a larger forging.

3.3.2 Surface hardness will be checked by ASTM A370 HBW or ASTM A370 HRC on the finished forging and conform to the limits listed for each grade in Table 3.

3.3.3 In the case where hardness testing large forgings is impractical, portable hardness testing per ASTM A370 is permitted. Reporting hardness testing results shall follow the methods in ASTM A370.

3.3.4 Hardness testing locations for forgings are shown in B1.1.1 (Figure B1) and B1.1.2 (Figure B2) of Appendix B.

3.3.5 Core hardness will be reported as per A1 in Appendix A. Upon approval, core hardness is expected to meet the minimum limits shown in Table 3 through the Steel Supplier production process control system. Core hardness is expected to maintain no more than a three-point ASTM A370 HRC drop from the surface to the center of any forging that has a width > 30.5 cm (> 12 in). Forgings that have a width of ≤ 30.5 cm (≤ 12 in) must not have a hardness drop of > 2 ASTM A370 HRC points from the surface to the center. The forging width is defined in Figure A2 in Appendix A. Practicing appropriate sectioning strategies of large forgings and forging as close to net shape whenever possible will help to maintain the required ASTM A370 HRC drop from surface to center as dictated by forging width.

Table 3: Surface Hardness Range and Minimum Core Hardness by Forging Width for Modified AISI P20 Tool Steel

GM Tool Steel Grade	Surface Hardness ASTM A370 HBW (ASTM A370 HRC)	Minimum Core Hardness for Blocks > 30.5 cm (> 12 in) Width ASTM A370 HBW (ASTM A370 HRC)	Minimum Core Hardness for Blocks ≤ 30.5 cm (≤ 12 in) Width ASTM A370 HBW (ASTM A370 HRC)
GM Standard	286 to 327 (30 to 35)	264 (27)	271 (28)
GM High Hard	319 to 353 (34 to 38)	294 (31)	301 (32)
GM Lens Quality	344 to 400 (37 to 43)	319 (34)	327 (35)

3.4 Microstructure. The microstructure will consist primarily of martensite and lower (fine) bainite as shown in Figure 1. Microstructure shall be designed to have as minimal amount of non-martensitic transformation products as possible with the goal of 0% non-martensitic transformation products at any location in the forging. Unacceptable microstructure with excessive non-martensitic transformation products is shown in Figure 2.

The microstructure sample preparation shall follow the methods listed in ASTM E3. Microstructure is expected to remain consistent during production once a material grade or Steel Supplier has been approved, regardless of the Steel Supplier sampling frequency. Microstructure results will be reported per A1 in Appendix A.

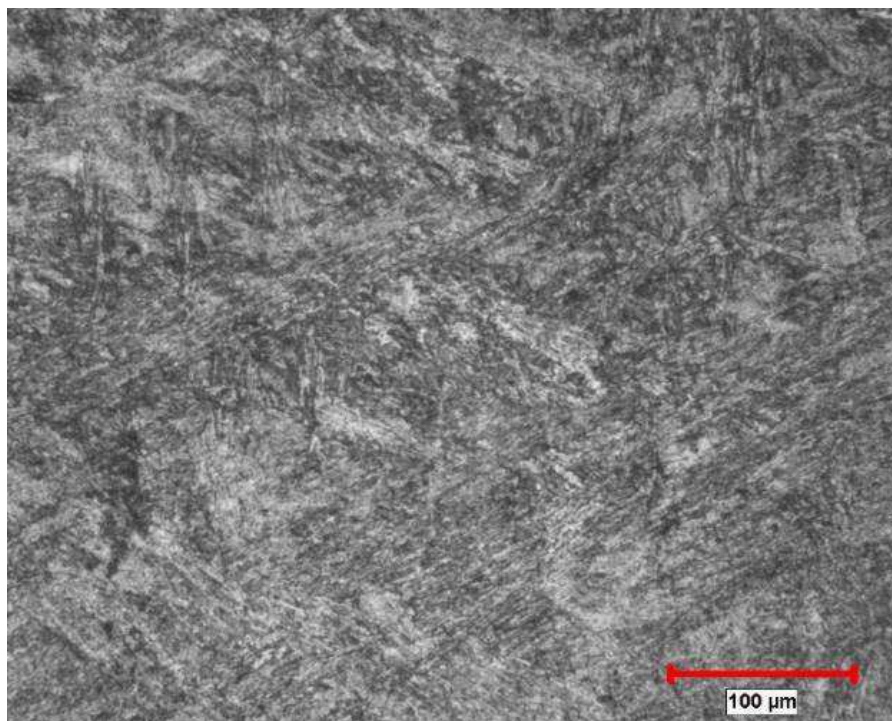


**Figure 1: Example Acceptable Martensitic and Bainitic Microstructure
200× Magnification**

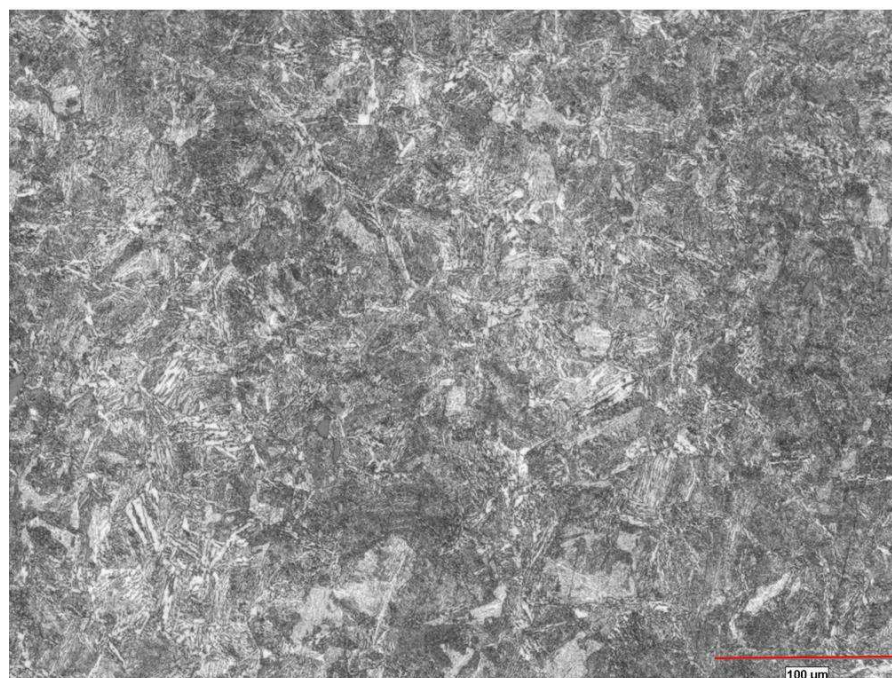


**Figure 2: Example Unacceptable Microstructure: Excessive Non-martensitic Transformation Products
200× Magnification**

3.5 Macrostructure and Grain Size. Material supplied to this specification shall be free from excessive porosity, segregation, slag, dirt, or other non-metallic inclusions, pipe, checks, cracks, and other injurious defects.