



Shaft and Gear Steels

1 Scope

1.1 Material Description. This specification describes the requirements for steels utilized in automotive components, such as powertrain and driveline shafts and gears.

1.2 Symbols. Not applicable.

1.3 Applicability. Steel bar stock, seamless tubing, or forgings utilized in the manufacture of shafts and gears. The intent of this specification is to define metallurgical requirements for the steel from which the finished parts are made. Finished part requirements, such as final heat treated properties, are described on the specification or part drawing.

2 References

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

2.1 External Standards/Specifications.

ASTM A534	ASTM E1181	JIS G0555	QS 192700
ASTM E10	DIN 50602	JIS G4051	SAE J403
ASTM E18	EN 10083	JIS G4052	SAE J404
ASTM E45	EN 10084	JIS G4053	SAE J406
ASTM E112	EN 10247	JIS G4104	SAE J1268

2.2 GM Standards/Specifications.

GMW3059

2.3 Additional References.

- Drawing number 29544305 Through Hardening Treatment of Steel
- Drawing number 29544308 Steel Forging Normalizing Heat Treatment
- Drawing number 29544309 Nitriding of Parts made from Cast or Wrought Ferrous Materials

2.3.1 Standards Titles.

- ASTM A534 Bearing Quality Steel for Carburizing
- ASTM E10 Brinell Hardness
- ASTM E18 Hardness Testing
- ASTM E45 Inclusion rating
- ASTM E112 Determining Average Grain Size
- ASTM E381 Standard Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
- ASTM E384 Knoop and Vickers Hardness of Materials
- ASTM E1181 Characterizing Duplex Grain Sizes
- DIN 50602 Metallographic examination: microscopic examination of special steels using standard diagrams to assess the content of non-metallic inclusions.
- EN 10083 Steels for quenching and tempering
- EN 10084 Case Hardening Steels
- EN 10247 Micrographic examination of the non-metallic inclusion content of steels using standard pictures
- EN 10263-3 Steel rod, bars and wire for cold heading and cold extrusion

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- GMW3059 Restricted and Reportable Substances
- JIS G0555 Microscopic testing method for the non-metallic inclusions in steel
- JIS G4051 Carbon steels for machine structural use
- JIS G4052 Structural steels with specified hardenability bands
- JIS G4053 Low-alloyed steels for machine structural use (no title listed in IHS)
- JIS G4104 Chromium Steels (Superseded by JIS G4053)
- SAE J403 Chemical Compositions of SAE Carbon Steels
- SAE J404 Chemical Compositions of SAE Alloy Steels
- SAE J406 Hardenability of Steels
- SAE J1268 Hardenability Bands for Carbon and Alloy H Steels

3 Requirements

All materials supplied to this standard must comply with GMW3059, Restricted and Reportable Substances, including the requirement to submit a full material composition disclosure to GM via the International Material Data System (IMDS) or via a completed GMW3059 report form.

3.1 Qualification.

All steels provided to this specification including tubes, bars, or forgings shall be approved as described as follows.

3.1.1 Steel Mills.

All steel mills providing product to the requirements of this specification shall be approved by GM Materials and Product Engineering.

Prior to any steel procurement, a GM Steel Making Practice Survey (Appendix B) must be completely filled out for each grade and mill which will be used for steel manufacturing. The completed surveys shall be reviewed by the responsible Materials Engineer. The steel survey shall accurately reflect the process for all grades described in this specification. The mill survey and review for qualification shall show capability to produce bearing quality steel product, as described in this section (3.0 Requirements).

If the survey is deemed acceptable, the GM Materials Engineer and Product Engineer may define additional qualification requirements to complete the approval.

Upon a successful part qualification, the supplier shall be added to the relevant approved supplier list.

Unless otherwise specified, multiple steel supply sources for the same product are not permitted without complete validation of all steel sources.

3.1.2 Seamless Tubing.

All seamless tubing suppliers providing product to the requirements of this specification shall be approved by GM Materials and Product Engineering.

Prior to any steel procurement, a GM Steel Making Practice Survey (Appendix B) must be completely filled out for each grade and mill which will be used for the steel manufacturing of the seamless tubing. The completed surveys shall be reviewed by the responsible Materials Engineer. The steel survey shall accurately reflect the process for all grades described in this specification. The mill survey and review for qualification shall show capability to produce bearing quality steel product, as described in this section (3.0 Requirements).

If the survey is deemed acceptable, the GM Materials Engineer and Product Engineer shall define additional qualification requirements.

Upon a successful part qualification, the supplier shall be added to the relevant approved supplier list.

Unless otherwise specified, multiple steel supply sources for the same product are not permitted without complete validation of all steel sources.

3.2 Steelmaking.

The steels described by this specification require maximum molten metal stream protection from oxidation to meet all requirements described herein.

Steelmaking practice shall minimize inclusions. Slag practice shall be optimized for steel quality. This includes processes which remove slag prior to casting such as slag raking and level control in the tundish which maximizes slag separation from the molten metal.

Steel shall be fully killed/deoxidized. Aluminum fine grain practice to control grain size in subsequent heat treatment shall be used. Refer to the aluminum content limits in Appendix A, Table A1, Table A2, and Table A3. The steel shall be stirred, and refined in the ladle metallurgy station. (**Note:** Silicon killing is not allowed for steel in powertrain gears and shafts). Vacuum degassing is required. Steel shall be bottom poured from the ladle and/or tundish. The pour stream shall be protected from oxidation during teeming or casting. Ingot cast product must be bottom filled (uphill teemed).

Additions of calcium or calcium alloys for deoxidation or inclusion shape control is not permitted.

Continuous cast product shall be electromagnetically stirred in an oscillated mold during solidification.

All material shall be internally sound and free from pipe and porosity. Surfaces shall be free from seams, pits, laps, and any other imperfections that would be detrimental to the finished part functions. These materials are typically supplied in bar, tube, or forged form to the shaft blank or forging supplier.

Material shall be sufficiently reduced and homogenized such that banding meets the requirements of the Hardness Method for determining Banding in ASTM A534, Supplemental Requirements Section S5.1; or is acceptable based on photomicrographs which have been approved by GM and the Seller. Samples for ASTM A534 are to be obtained from incoming steel bar or tube stock.

Reduction ratio of the as-cast strand or ingot to the final bar or tube diameter shall be 5 to 1 minimum based on the cross-sectional area. Rolling mill practice will include conditioning to remove surface defects of detrimental size. The defect size on the bar or tube supplied to the machine source will be limited so that it is completely removed during machining.

3.3 Chemical Composition.

Compositions of steel grades are listed in Appendix A (Table A1 for Shaft Steels, Table A2 for Gear Steels, and Table A3 for Driveline Gear Steels). Steel grades not covered in this specification shall be preapproved by GM Materials Engineering and Product Engineering. Steel compositions of grades not covered in this specification shall follow ASTM, DIN, EN, ISO, JIS, or SAE standards.

The steel grade shall be specified on the Engineering Drawing, the Blank Drawing, or this GMW Shaft and Gear Steels Specification (in order of precedence).

3.4 Hardenability.

The DI of the steel is calculated per SAE J406. SAE J406 maintains accuracy up to 1.50 weight percent Nickel. For high Nickel grades, the DI range calculated using the equation in SAE J406 shall be accepted with knowledge of its limitation, or replaced by a physical Jominy test.

Ladle refining shall have appropriate controls to maintain a chemistry range which corresponds with an Ideal Diameter (DI) range of 10 mm (0.4 in) for the final product (example: DI range 2.7 - 3.1). Specific DI ranges for powertrain gears are listed in Appendix A, Table A2.

3.5 Internal Cleanliness.

Samples shall be obtained from incoming steel bar or tube stock. For SAE grades, inclusion types, shapes, and size controls shall be as specified in ASTM E45, Method A, Worst Fields. As permitted in ASTM specifications ASTM A534 and ASTM E45, inclusion ratings shall be based on 0.5 increments, not integer increments. Heat acceptance shall be based on the worst inclusion rating, not average ratings. The GMW17942 Shaft and Gear Steel specification for the component shall define which of the limits in Table 1 or Table 2 apply.

Equivalent alternative cleanliness rating methods based on local rating practices such as DIN 50602, EN 10247, or JIS G0555 may be utilized with the agreement of the GM Product Engineer and GM Materials Engineer.

Table 1 defines internal cleanliness requirements for shafts. Table 2 defines requirements for gear steels.

Table 1. Rate the worst fields to the nearest 0.5 increment and report the worst of the worst fields as well as the average of the worst field ratings.

Table 1: Inclusion Rating Limits for Shafts based on ASTM E45, Method A, Worst Fields

Category	Inclusion Type	Rating Limit			Inclusion Type Definition
		Shafts with Bearing Journal	Shafts without Bearing Journal (can include bushings)	SAE 1552 Modified	
Thin Series	A	2.5	3.0	3.0	A = Sulfides
	B	2.0	2.5	2.0	B = Aluminates
	C	0.5	1.0	2.0	C = Silicates
	D	1.0	1.0	2.0	D = Oxides
	A	1.5	2.0	1.5	A = Sulfides
Heavy Series	B	1.0	1.5	2.0	B = Aluminates
	C	0.5	1.0	2.0	C = Silicates
	D	1.0	1.0	2.0	D = Oxides

Table 2. Rate the worst fields to the nearest 0.5 increment and report the worst of the worst fields as well as the average of the worst field ratings.

**Table 2: Inclusion Rating Limits for Gears and Driveline Components
based on ASTM E45, Method A, Worst Fields**

Category	Inclusion Type	Rating Limit				Inclusion Type Definition
		All Others	SAE 1552 Modified	SAE 4130/SAE 4140 Modified	SAE 5130H	
Thin Series	A	2.5	3.0	3.0	3.5	A = Sulfides
	B	2.0	2.0	2.0	2.0	B = Aluminates
	C	0.5	2.0	2.0	0.5	C = Silicates
	D	1.0	2.0	2.0	1.0	D = Oxides
Heavy Series	A	1.5	1.5	2.0	2.0	A = Sulfides
	B	1.0	2.0	2.0	1.0	B = Aluminates
	C	0.5	2.0	2.0	0.5	C = Silicates
	D	1.0	2.0	2.0	1.0	D = Oxides

3.6 Semi Finished Shapes.

The forging flow line pattern shall be documented at validation, PPAP, and annually thereafter.

Alternative heat treatments may be specified to improve machinability. Examples include double normalize, normalize and temper and isothermal anneal. The alternative heat treatment shall be defined on the product or blank drawing, as applicable. The drawing shall include, as a minimum, a hardness specification.

Rolling mill practice shall include conditioning to remove surface defects of a detrimental size. The defect size on the bar or tube supplied to the machining source shall be so that it is completely removed during blank machining. The material is to be stress relieved after straightening during the processing.

All semi-finished shapes shall be normalized unless otherwise noted on the drawing. For furnace normalized parts, the holding time shall be 1 h minimum per 25.4 mm (1.0 in) of thickness of the largest cross-section of the part, but not < 1 h at temperature. Alternative normalizing processes, such as induction normalizing, require approval from the GM Materials Engineer and Product Engineer. The normalizing method shall not be changed after validation.

3.6.1 Shaft.

The default normalizing process is furnace normalizing. Alternative normalizing processes must be approved by the GM Materials Engineer and Product Engineer.

The microstructure of the as received hot rolled bar stock, seamless tubing, or forging must be consistent with the specified process parameters, the mass of the part, and the alloy composition. The method by which prior austenitic grain size is determined shall be approved by the GM Materials Engineer. The average prior austenite grain size per ASTM E112 shall be five (5) to ten (10). Duplex grains, per ASTM E1181, are not acceptable.

3.6.2 Gear.

The default normalizing process is furnace normalizing. Alternative normalizing processes must be approved by the GM Materials Engineer and Product Engineer. Normalize at 910 °C minimum. Normalized microstructure for

the low carbon grades will be predominately ferrite and fine to medium pearlite. The higher carbon grades shall be predominately pearlite. The method by which prior austenitic grain size is determined shall be approved by the GM Materials Engineer. The average prior austenite grain size shall be six (6) or finer per ASTM E112. Duplex grains, per ASTM E1181, are not acceptable.

3.6.2.1 Tube and Bar.

Tube or bar is normalized, straightened and stress relieved prior to separating into blanks. Tube or bar shall meet hardness requirements after stress relief. For hardness requirements, see Table 3.

Table 3: Normalized Hardness Requirements for Gears

Grade/Specification	ASTM E10	ASTM E18
SAE 1552 Modified	HBW 192 - 241	HRBW 92 - 100
SAE 5130H	HBW 163 - 225	HRBW 85 - 98
SAE 4121 Modified	HBW 174 - 225	HRBW 88 - 97
All Others	HBW 156 - 207	HRBW 83 - 95

3.6.2.2 Forgings and Blanks.

The final forged shape shall be normalized at 910 °C minimum on a continuous conveyor furnace (i.e., belt, roller hearth). Blanks must be loaded evenly spaced in a single layer. Dump loading will not be permitted. The parts shall be loaded with part axis normal to the conveyor, as shown in Figure 1 following, unless otherwise approved by the GM Materials Engineer and Product Engineer. No partial or total decarburization is allowed. For hardness requirements, see Table 3.

Refer to 3.6.3 for heat treatment loading requirements for driveline gears.



Figure 1: Example of Single Layer Loading Required for Heat Treatment of Powertrain Gears

3.6.2.3 Blanks for Nitriding.

Material shall be normalized at 871 °C to 910 °C. After normalizing and before nitriding, parted blanks and forgings shall be austenitized, quenched, and tempered prior to finish machining per 29544305, Method 1.

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Tempering temperature shall be per 29544309. (**Note:** The tempering temperature shall be at least 28 °C higher than the nitriding processing temperature. The nitriding processing temperature range is 495 °C – 577 °C). The core hardness shall be HRC 21-27 after quench and temper. Hardness is to be measured at the geometric center of the part wall per ASTM E18. The core microstructure after the austenitize, quench, and temper heat treatment shall conform to 29544309 except as follows: the microstructure shall be uniform throughout the cross-section and consist of predominantly spheroidized tempered martensite.

3.6.3 Driveline Gear.

The default normalizing process is furnace normalizing. Alternative normalizing processes must be approved by the GM Materials Engineer and Product Engineer.

Normalized microstructure will be predominately ferrite and fine to medium pearlite. Bainite, tempered martensite and acicular ferrite shall be < 10% of the total structure based upon GM visual acceptance criteria. The method by which prior austenitic grain size is determined shall be approved by the GM Materials Engineer. Prior austenite grain size shall be six (6) to nine (9) per ASTM E112. Duplex grains, per ASTM E1181, are not acceptable. Decarburization is defined as surface carbon loss. No partial or total decarburization is allowed. For SAE 4320H steel normalization, following austenization a slow cool (furnace cool or controlled cool) plus tempering is preferred.

Tube or bar is normalized, straightened and stress relieved prior to separating into blanks. Tube or bar shall meet hardness requirements after stress relief. Forgings and blanks shall be normalized on a continuous conveyor furnace (i.e., belt, roller hearth) with a controlled atmosphere. Driveline gears shall be loaded for heat treatment process as shown in Figure 1 in 3.6.2.2, unless otherwise approved by the GM Materials Engineer.

4 Manufacturing Process

See 3.1.

5 Rules and Regulations

5.1 Legal Regulations. All materials must satisfy applicable laws, rules, regulations and recommendations valid in the country of usage.

5.2 Language. In the event of conflict between the English and domestic language, the English language shall take precedence.

5.3 Inspection and Rejection. Samples of components or materials released to a GM material specification shall be tested for conformity with the requirements of this material specification and approved by the responsible Engineering department prior to commencement of delivery of bulk supplies.

A new approval must be received for any changes, e.g., properties, manufacturing process, location of manufacture, etc. If not otherwise agreed, all testing and documentation normally required for initial release must be completed.

It is the responsibility of the supplier to inform the customer in a timely manner, without solicitation, and to include documentation of all modifications of materials and/or processes and to apply for a new release.

5.4 Material Safety Data Sheets/Safety Data Sheets (MSDS/SDS). For new product submissions, or when a change in chemical composition of an existing product has occurred, a complete copy of the Material Safety Data Sheet/Safety Data Sheet must be submitted in compliance with the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) requirements or other country-specific MSDS/SDS requirements.

5.5 All materials supplied to this standard must comply with the requirements of the International Material Data System (IMDS) and GMW3059, **Restricted and Reportable Substances**.

6 Approved Sources

Materials supplied to this specification must be approved by General Motors.

The appropriate GM Materials Engineering department(s) must confirm material as meeting the requirements of this specification. Any test data sheets of material submitted to General Motors for such confirmation (e.g., during Production Part Approval Process (PPAP)) under this material specification must list all properties and must apply corresponding test methods of this material specification.

7 Notes

7.1 Glossary. Not applicable.

7.2 Acronyms, Abbreviations, and Symbols.

DI	Ideal Diameter
FNC	Ferritic Nitrocarburizing
GHS	Globally Harmonized System of Classification and Labeling of Chemicals
IMDS	International Material Data System
Max	Maximum
MSDS	Material Safety Data Sheet
N.A.	Not Applicable
PPAP	Production Part Approval Process
ppm	Part per Million
SDS	Safety Data Sheet
Wt	Weight

8 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:

Material per GMW17942 Y Z

Y – Appendix A, Table A1 Shaft steel, Table A2 gear steel, Table A3 driveline gear steel

Z – Grade

(Example: GMWXXXX Appendix A, Table A1 SAE J403 1038)

9 Release and Revisions

This standard was originated in October 2017. It was first approved by Materials - Ferrous Materials and Sheet Metal in January 2018. It was first published in January 2018.

Issue	Publication Date	Description (Organization)
1	JAN 2018	Initial publication.