



Specification and Verification of Tensile and Fatigue Properties in Metallic Components

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. Establish robust system for mechanical property characterization and control in parts.

1.2 Applicability. This specification provides procedures for (1) specifying tensile and fatigue properties at control locations in metallic components and (2) verifying that these properties exist as specified. Control locations may be in the part, from co-cast appendages, or from separately manufactured specimens. This specification may be used in drawings, Component Technical Specifications (CTS), Vehicle Technical Specifications (VTS), Statements of Requirements (SOR), Bill of Materials (BOM)/Bill of Process (BOP)/Bill of Design (BOD), or other documents.

1.2.1 This specification may also be used to provide requirements for properties other than tensile and fatigue.

1.2.2 Except for Class 1 lot control, procedures specified herein are intended to audit capability of meeting mechanical property requirements.

1.3 Limitations.

1.3.1 This specification neither requires nor promotes the usage of mechanical property specifications. Further, this specification should not be used if mechanical property control is not needed.

1.3.2 This specification does not designate particular property levels or control locations. These are to be chosen based upon the needs of the part and the availability of an adequate volume of material from which to prepare a test specimen.

1.3.3 This specification specifically applies to properties measured in control locations for parts exiting manufacturing. Subsequent exposure of parts to environments known to affect mechanical properties, including normal use, degradation of properties does not constitute an out-of-specification condition.

1.3.4 This specification does not supplant specifications that define a given material and grades by minimum mechanical properties. Further, properties specified for parts should not be derived solely from such material specifications.

1.3.5 Warranty Disclaimer. Data submitted under this specification does not constitute any express or implied warranty, including without limitation any warranty of merchantability or fitness for a particular purpose.

1.3.6 General Disclaimer. Use of this specification does not imply that the control location represents any other region of the part.

1.3.7 Adherence to this specification does not absolve Supplier of responsibility to provide acceptable product.

2 References

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

2.1 External Standards/Specifications.

ASTM E21 IATF 16949 ISO 17025

2.2 GM Standards/Specifications.

GMW3059 GMW16705

2.3 Additional References.

- GP-11
- GP-12

3 Requirements

3.1 Responsibilities.

3.1.1 Supplier shall:

- Quote parts against this specification with an expectation that, based on experience with similar parts and processes, mechanical property requirements will be met.
- Manage costs to comply with requirements in this specification, including manufacturing additional parts required for testing.
- Obtain written agreement from **Purchaser** on any deviation from requirements in this specification.
- Provide qualified personnel to manage all operations obtaining, reporting and reacting to property data.
- Produce sufficient parts to provide required test specimens and expedite long lead-time items such as fatigue testing.
- Develop a process control plan containing procedures to satisfy requirements in this specification and a Process Failure Mode Effects Analysis (PFMEA) showing response when specified requirements are not met.
- Maintain traceability for each test sample (cast date, cast line, heat treat furnace, etc.), records of test data and statistical calculations, and make available for inspection by **Purchaser**.
- Submit complete reports at required reporting periods.
- Notify **Purchaser** when mechanical test results or statistical calculations fall below specified requirements.

3.1.2 Purchaser shall:

- Affirm lines of communication with Supplier for data reporting and notification.
- Select the property levels, control locations, test options and statistical basis governed by this specification.
- Specify property levels for which a documented need exists, and within the capability of the design of the part and the manufacturing process chosen.
- Designate sufficiently large control locations to meet minimum sample size requirements.

3.2 Classes. One of four Classes in Tables 1 through 4 is to be specified.

3.2.1 Class 1 requires tensile testing to control release of individual lots and statistical analysis of longer-term tensile and fatigue data to audit process capability.

3.2.2 Class 2 omits lot control, but requires statistical analysis of tensile and fatigue data to audit process capability.

3.2.3 Class 3 requires statistical analysis to audit tensile property capability in production, omitting both lot control and fatigue studies.

3.2.4 Class 4 requires that tensile property data be submitted at Production Part Approval Process (PPAP), but no process auditing in production.

Table 1: Test Requirements, Class 1
Control of Tensile and Fatigue Properties. Features Tensile Lot Control.

Reporting Period	Property	Sample Count/Sampling Frequency	Data Interpretation and Required Actions
Pre-Production (PPQP) Note 1, Note 2	UTS, YS and %EL	2 samples/casting run Minimum 16 samples total	Tensile lot control Min must be met. Report fatigue data to Purchaser .
	Fatigue Strength Note 3	One 16-sample Fatigue/SC study	
Production Approval (PPAP) Note 4	UTS, YS and %EL	1 sample/lot One 16-sample tensile property study	PPAP submissions must meet both Min and statistical specifications.
	Fatigue Strength	One 16-sample Fatigue/OP study	
Initial Production (GP-12)	UTS, YS and %EL	Greater of 1 sample/500 parts, or 2 samples/lot	Tensile lot control Min must be met. Maintain run chart. Report semi-annually. If statistical specifications are not met monthly, initiate notification procedure.
	Fatigue Strength	Fatigue/OP: 2 samples/month	
Regular Production	UTS, YS and %EL	Greater of 1 sample/1000 parts, or 1 sample/lot	
	Fatigue Strength	Fatigue/OP: 1 sample/month	

Min = minimum, UTS = Ultimate Tensile Strength, YS = Yield Strength, EL = Elongation, OP = Overstress-probe, SC = Staircase

Note 1: Parts sampled for tensile and fatigue studies are to be made with tooling and process representative of production.

Note 2: For Pre-production Part Quality Process (PPQP), multiple specimens may be taken from the control location in the same part.

Note 3: For PPQP fatigue, fatigue data available from similar parts already in production may be used by agreement from **Purchaser**.

Note 4: Initial PPAP only. In tooling undergoing PPAP, test samples should be distributed among each available cavity.

Table 2: Test Requirements, Class 2
Control of Tensile and Fatigue Properties. No Lot Control.

Reporting Period	Property	Sample Count/Sampling Frequency	Data Interpretation and Required Actions
Pre-Production (PPQP) Note 1, Note 2	UTS, YS and %EL	One 16-sample tensile study	Report data to Purchaser .
	Fatigue Strength Note 3	One 16-sample Fatigue/SC study	
Production Approval (PPAP) Note 4	UTS, YS and %EL	One 16-sample tensile property study	PPAP submissions must meet both Min and statistical specs. For Fatigue/OP, 16 consecutive samples must exceed Min .
	Fatigue Strength	One 30-sample Fatigue/SC study or one 16-sample Fatigue/OP study Note 5	
Initial Production (GP-12)	UTS, YS and %EL	Greater of 1 sample/1000 parts, or 2 samples/week	Maintain run chart. Report monthly. If statistical specs are not met monthly, initiate notification procedure.
	Fatigue Strength	Fatigue/SC or Fatigue/OP: 4 samples/month	
Regular Production	UTS, YS and %EL	Greater of 1 sample/5000 parts, or 1 sample/week	
	Fatigue Strength	Fatigue/SC or Fatigue/OP: 2 samples/month	

Min = minimum, UTS = Ultimate Tensile Strength, YS = Yield Strength, EL = Elongation, OP = Overstress-probe, SC = Staircase

Note 1: Parts sampled for tensile and fatigue studies are to be made with tooling and process representative of production.

Note 2: For PPQP, multiple specimens may be taken from a sufficiently large control location in parts by agreement from **Purchaser**.

Note 3: For PPQP fatigue, fatigue data available from similar parts already in production may be used by agreement from **Purchaser**.

Note 4: Initial PPAP only. In tooling undergoing PPAP, test samples should be distributed among each available cavity.

Note 5: For PPAP conduct the fatigue test type that is specified for the part.

© Copyright 2017 General Motors Company All Rights Reserved

Table 3: Test Requirements, Class 3
Control of Tensile Properties. No Fatigue, No Lot Control.

Reporting Period	Property	Sample Count/Sampling Frequency	Data Interpretation and Required Actions
Pre-Production (PPQP) Note 1, Note 2	UTS, YS and %EL	One 16-sample tensile property study	Report data to Purchaser .
Production Approval (PPAP) Note 3	UTS, YS and %EL	One 16-sample tensile property study	PPAP submissions must meet both Min and statistical specs.
Initial Production (GP-12)	UTS, YS and %EL	Greater of 1 sample/1000 parts, or 2 samples/week	Maintain run chart. Report monthly.
Regular Production	UTS, YS and %EL	Greater of 1 sample/5000 parts, or 1 sample/week	If specs are not met monthly, initiate notification procedure.

Min = minimum, UTS = Ultimate Tensile Strength, YS = Yield Strength, EL = Elongation

Note 1: Parts sampled for tensile and fatigue studies are to be made with tooling and process representative of production.

Note 2: For PPQP, multiple specimens may be taken from the control location in the same part.

Note 3: Initial PPAP only. In tooling undergoing PPAP, test samples should be distributed among each available cavity.

Table 4: Test Requirements, Class 4
Control of Tensile Properties Only at PPAP. No Fatigue, No Lot Control, No Production Testing.

Reporting Period	Property	Sample Count/Sampling Frequency	Data Interpretation and Required Actions
Pre-Production (PPQP) Note 1, Note 2	UTS, YS and %EL	One 16-sample tensile property study	Report data to Purchaser .
Production Approval (PPAP) Note 3	UTS, YS and %EL	One 16-sample tensile property study	PPAP submissions must meet both Min and statistical specs.
Initial Production (GP-12)	Not required	Not required	Not required
Regular Production	Not required	Not required	

Min = minimum, UTS = Ultimate Tensile Strength, YS = Yield Strength, EL = Elongation

Note 1: Parts sampled for tensile and fatigue studies are to be made with tooling and process representative of production.

Note 2: For PPQP, multiple specimens may be taken from the control location in the same part.

Note 3: Initial PPAP only. In tooling undergoing PPAP, test samples should be distributed among each available cavity.

3.3 Reporting Periods.

3.3.1 Tables 1 through 4 list required actions in GM design, validation and production phases – properties to be measured, sampling frequency, sample count, data interpretation and required actions. See 3.11 for data recording and reporting requirements.

3.3.2 Pre-Production. Mechanical property tests are to be performed during pre-production (prototype) to establish capability of process and design in preparation for successfully meeting specifications at PPAP.

- Lot control tensile testing is required for all Class 1 parts.
- Tensile and fatigue studies shall be made with material, tooling and process representative of production.
- Compliance with property specifications is not required at pre-production except for Class 1 tensile testing for lot control.

- By agreement from **Purchaser**, multiple samples may be extracted from a sufficiently large control location in the same part.
- By agreement from **Purchaser**, **Supplier** may submit previously established data from similar parts in production to comply with pre-production fatigue testing requirements; likewise, the required number of samples may be composed of subgroups comprising minor process variants.
- **Purchaser** may specify multiple submissions of data corresponding to different pre-production build phases (e.g., "Mule", "IVER", "Gamma", "Beta", "Pilot").

3.3.3 PPAP. Testing listed in Tables 1 through 4 applies to the initial PPAP submission. All specifications must be met for PPAP submissions.

3.3.3.1 Subsequent PPAP submissions (re-PPAP).

- Mechanical properties are not required to be documented for subsequent PPAP of replicate tooling.
- Following significant process change **Purchaser** requires submission of mechanical property data in PPAP.
- Reduced sample counts may be used if approved by **Purchaser**.

3.3.4 GP-12. Initial production data is sampled at twice the rate than for regular production.

3.3.5 Regular Production. In production, a small number of samples are to be tested on a weekly basis (plus lot-by-lot for Class 1).

3.4 Test Methods and Coding. Table 5 details coding for properties and standards covering permissible test methods.

3.4.1 Sample geometry (fatigue and tensile) and tensile test gage length for elongation measurement shall not be changed after PPAP.

3.4.2 Mandatory procedures are provided in GMW16705 for retests and replacement tests (5.4), calculating statistical measures of results (Appendix A), and determining tensile elongation (Appendix C).

3.4.3 Tensile Testing. For Class 1, tensile testing is required prior to lot release. If the first test results meet specified minimum, the lot may be released.

- If specified minimum is not met, follow procedures for retest and replacement tests, GMW16705, 5.4.
- The lot shall be reworked or scrapped if retests or replacement tests do not meet specified minimum.

3.4.4 Fatigue Strength (Classes 1 and 2) – Special Instructions.

3.4.4.1 Fatigue strength by Fatigue/SC and Fatigue/OP should be specified at either 10^6 or 10^7 .

3.4.4.2 Conduct fatigue tests under uniaxial, sinusoidal, full-reversed (load ratio, $R=-1$) loading per GMW16705, Appendix D (Fatigue/SC) or Appendix E (Fatigue/OP).

3.4.4.3 For Class 1, pre-production-level fatigue strength is to be determined by the staircase method (Fatigue/SC) per GMW16705, Appendix D.

3.4.4.4 Retesting of any Fatigue/SC and Fatigue/OP test result is forbidden (compare with, GMW16705, 5.4).

- In statistical calculations (e.g., Weibull) all test results shall be included.
- For Min requirement in Class 2, Fatigue/OP all test results shall equal or exceed the specified Min.
- Only test results subject to replacement testing per GMW16705, 5.4.4 may be excluded.

3.4.4.5 Alternative conditions may be specified at discretion of **Purchaser**.

3.4.5 Additional Mechanical Properties. This specification may be used to establish requirements for mechanical properties beyond those listed in Tables 1 through 4. Procedure:

- The property name must be noted in the material specification callout along with a reference to a **Purchaser**, national or international test standard. Any options allowed by the test standard, including specimen geometry, must be noted under Exceptions.
- The requirement may be limited to reporting reference data, where no minimum standard applies.
- Additional properties shall only be required at PPAP, unless otherwise specified.

3.4.5.1 Examples of Usage of Additional Mechanical Properties.

- Staircase fatigue study submitted at PPAP for Class 3.
- Submission of strain-controlled fatigue study per GMW16705, Appendix F.
- Submission of property data prior to establishment of minimum standard.

© Copyright 2017 General Motors Company All Rights Reserved