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ANTERO 840CN03 RAW DATA REPORT

Document #: SSYS TR-00016

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Controlled electronic approvals are on file and available for review:
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This data is preliminary and may be subject to change as new information or test data becomes available. This data is not to be disseminated outside the distribution list. Official data will be delivered at the completion of the program

Revision History

Revision	Section	Change Description	ECO Number
01	All	Prototype Release	

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1 EXECUTIVE SUMMARY

The contents of this document summarize the mechanical properties of Stratasys Inc's (SSYS) electrostatic dissipative (ESD) material, Antero 840CN03™ as a result of a multi-site, multi-machine, and multi-phase characterization effort. The program was run in compliance with the National Institute for Aviation Research's (NIAR) National Center for Advanced Material Performance (NCAMP) procedures to generate a baseline set of qualification data – however no NCAMP representation or oversite was provided. Specimens were produced at Lockheed Martin Space Systems (LM-SS) based in Littleton, CO, and Stratasys Direct Manufacturing (SDM) in Belton, TX in accordance with industry standard methods needed for further statistical reduction in compliance with CMH-17 guidelines. The first phase of data collection and characterization was performed solely on Tension properties with the intent to expand into other properties and conditions in future phases. The data outlined in this document demonstrates the appropriate identification, characterization, and control of critical sub-systems and key processing variables as they relate to the performance parts built on a Stratasys F900™ production system. Additionally, a means of achieving proper calibration, setup, and configuration control was established in the form of a jointly developed process control document (PCD) to configure multiple systems at multiple locations to yield consistent and repeatable results.

The test methods and data provided in this report are meant to provide the groundwork for analysis against industry standard statistical reduction methods in order to generate a set of b-basis allowables. This report contains material property data only. Statistical analysis of the data including the calculations of b-basis values is given in a separate report.

2 INTRODUCTION

Antero 840CN03 is a blended and functionalized polyether ketone, ketone (PEKK) high-performance thermoplastic composite material that meets ESD performance requirements while also having flame, smoke, and toxicity (FST) characteristics consistent with FAR requirements. This material is often used in aviation and space applications where high thermal, high chemical resistance, and ESD properties are needed. This high-performance thermoplastic composite material was processed on a F900 production system.

2.1 Purpose and Scope

A fully developed test matrix, including detail on test conditions, coupon quantities, process parameters, material traceability, and coupon management was developed based on properties and conditioned prioritized by the space industry, building off of previous qualification efforts performed on other additively manufactured materials. Tension properties were prioritized for this initial dataset. Test coupons were fabricated and tested according to the test matrix provided below. Additional properties and test conditions may be added in future phases and revisions to this document to increase the application opportunities for this material.

The use of Stratasys material and process specifications do not guarantee material or structural performance. Material users should be actively involved in evaluating material performance and quality including, but not limited to, performing regular purchaser quality control tests, performing periodic machine qualifications and/or additional testing, participating in material change management activities, conducting statistical process control, and conducting regular supplier audits. The applicability of this material property database and specifications must be evaluated on case-by-case basis by aircraft companies and certifying agencies. Stratasys assumes no liability whatsoever, expressed, or implied, related to the use of the material property data, material allowables, and specifications.

Part fabricators that wish to utilize the material property data, allowables, and specifications may be able to do so by demonstrating the capability to reproduce the original material properties; a process known as equivalency. More information about this equivalency process including the test statistics and its limitations can be found in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17. The applicability of equivalency process must be evaluated on program-by-program basis by the applicant and certifying agency. The applicant and certifying agency must agree that the equivalency test plan along with the equivalency process described in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17 are adequate for the given program.

2.2 Background

Additive manufacturing (AM) represents a set of processes that build components directly from 3D CAD data by placing materials selectively, usually in layer-by-layer fashion, without the use of traditional tooling. As such, AM technologies provoke new approaches to design and manufacturing that can significantly reduce lead times and can, in some cases, build parts that cannot be built any other way.

This effort builds upon previous initiatives that sought to test and characterize the behavior of materials through the FDM™ process. Optimization of build strategy, specification development, and testing setup were applied based on best practices and lessons learned from previous, high temperature, AM material qualification efforts. However, a concentrated design of experiments was performed prior to the start of the characterization to validate the processing windows of user controllable parameters specific to Antero 840CN03. The limits for those select parameters are captured in the process specification used throughout this program.

3 PROJECT OBJECTIVES

The main objective is to have this dataset to be publicly available to enable broad dissemination of the collective knowledge for future part design. The approach for this program enables industry adopters to use their own design allowable methodologies for statistical data analysis but was created with reference to draft versions of CMH-17 guidelines to leverage STAT-17 methods.

A series of tasks were completed leading up to and including the fabrication of an available dataset for industry adoption. Following a newly developed framework for establishing a fixed process and reliable database a set of material dedicated control and specification documents were created. These documents included a Process Specification Document, a Material Specification Document, and a Process Control Document (PCD).

A test matrix was developed that includes a standard set of mechanical property test methods that accounts for differing orientations, environmental temperatures, and test conditions. This test matrix was developed to align to the performance requirements of the space industry and should be built upon for other industry specific applications. This test matrix was the result of the evolution of qualification efforts previously performed on material extrusion AM technologies and leverages traditional continuous fiber reinforced composites and traditional thermoplastic material characterization methods.

4 METHODOLOGY AND PROCEDURE

4.1 Machine Process Control Evaluation, Documentation & Design Requirement Development

A process control evaluation was performed via a variability study within the system and applicable sub-systems. From these findings, a process control specification and document were developed. Once the documentation had been finalized, the three batches of certified material were procured and inventoried in compliance with the material specification.

4.1.1 Machine Process Control Evaluation

A study of machine parameters during test builds to identify variability root causes, conduct testing and failure analysis to identify variability drivers, correlate inter-machine and machine-to-machine data trends to monitor machine parameters, analyze current process variability and identify variability contributors, and control data variability through machine and build parameters. The F900 was the platform identified as it is an updated version of the Fortus 900 line and has already undergone material characterization efforts of this nature. The process control evaluation focused on machine and material variability and not optimized parameter sets.

4.1.2 Process Control Specification and Documentation

The process control document that was developed from the process control evaluation is the document that controls the setup of the machine. This controls the amount of variability within the system and will reduce the overall coefficient of variance (CV). The process control document will be a required set of instructions that needs to be followed to achieve the specified CV.

The process specification is the document highlighting the overall process followed by both sites used to fabricate the outlined specimens. Topics covered include environmental control, equipment control, software control, material control, and the build process. The purpose of this document is to provide a new user the steps required to replicate the specimen fabrication process.

4.2 Material Allowable Test Plan Creation & Approval

The following excerpt was taken from document TPAM-840CN03; developed and released for distribution by SSYS covering only the material mechanical properties.

4.2.1 Test Methods

All testing was in accordance with nationally recognized standards, methods, and procedures. Specific mechanical property test methods applicable to the test program in this document include:

- ASTM D638 – Standard Test Method for Tensile Properties of Plastics
- ASTM D790 – Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
- ASTM D5766/D5766M-11 – Standard Test Method for Open Hole Tensile Strength of Polymer Matrix Composite Laminates
- ASTM D5961/D5961M-10 – Standard Test Method for Bearing Response of Polymer Matrix Composite Laminates
- ASTM D6641/D6641M- 16e1 – Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture
- ASTM D6742/D6742M-07 – Standard Practice for Filled-Hole Tension and Compression Testing of Polymer Matrix Composite Laminates

For filled hole and bearing tests, the hole diameter will be 0.25 in -0.000 +0.003 in. The following fasteners should be used:

1) NASM21296 bolts with MS21085 nuts and MS21299 washers,
2) NASM21297 bolts with MS21084 nuts and MS21206 washers,
3) NASM14181 bolts with MS14182 nuts and MS14183 washers, or equivalent

Unless otherwise specified, a tolerance of ±5°F was applied to all temperature conditions specified in this document.

4.2.2 Specimen identification

All specimens shall be uniquely identified by a 14-code reference system, cross referenced with descriptive identification information as follows:

This Document Number − Specimen ID: Document Number − AM Material Manufacturer ID − Material Code-Fabricator ID − Fabricator ID − Batch ID − Machine ID − Run – Fill – Print Number − Build Orientation − Actual Test Types ID − Specimen Build Location ID − Test Condition − Specimen Number

For example,

TPAM840CN03 -	SSYS -	ACN03 -	LMSS -	A -	M1 -	R1 -	RF -	P1001 -	XY -	T -	BR -	RTD -	3 -
Document Number	AM Material Manufacturer ID	Material Code	Fabricator Code	Batch ID	Machine ID	Run	Fill	Job Number	Build Orientation	Test Type ID	Specimen Build Location ID	Test Condition	Specimen Number

The testing lab may assign a separate identification code but must reference the 14-code reference system and uniquely identify the specimens. To ensure machine traceability, the Stratasys Process Specification (SPS) will contain the machine(s) serial number or some other unique identifier.

AM Material Manufacturer ID
Company Name: SSYS

AM Material Code	AM Material Name
ACN03	Antero 840CN03

Fabricator ID (Company that builds the coupons)
Company Name: LMSS & SDM

Actual Test Types	
T: Tension	OHT: Open-Hole Tension
C: Compression	FHT: Filled-Hole Tension
F: Flex	SSB: Single Shear Bearing
CLC: Combined Loading Compression	

Specimen Build Location ID	Build Platform Location of Specimen
BL	Back Left Corner
BR	Back Right Corner

FR	Front Right Corner
FL	Front Left Corner
MID	Middle / Center

(Note: See Figure 2 for details)

Batch ID: A, B, C, D, E, F etc. to be cross referenced with raw resin batches and filament lots.

Machine ID : M1, M2, …, matches machine number used.

Run Run 1 – initial fabrication, Run 2 – first reprint

Fill RF – remnant fill, SF – standard fill

Build Orientation: XY, XZ, ZX

Test Condition: CTD, RTD, ETD1, ETW1, etc. (test conditions as defined in section 6)
TFS11RT, TFS12RT, TFS13RT, etc. (fluid sensitivity test - see Table 5)
D, W (dry, wet conditions for DMA)

Specimen Number: 1,2,3,4,5,6,7,8,9, A, B, C…. etc.

4.2.3 FDM AM Material Mechanical Property testing

The Material Test Lab performed the following tests under the specified conditions. Specimen dimensions were taken before moisture conditioning.

Test environments are defined as:

CTD = -65±5°F, dry (drying per section 4.2.3.2)
RTD = 70±10°F, room temperature dry (drying per section 4.2.3.2)
RTA = 70 ±10°F, room temperature ambient (drying at RH<60%)
ETD = 180±5°F, dry (drying per section 4.2.3.2)

4.2.3.1 Failure Modes

All failure modes were identified. Testing was required to achieve appropriate failure modes. Within each test method and test environment, test engineer evaluated the failure mode immediately after each test. Obvious improper failure modes were logged. Samples were retained until data review was complete and the test report finalized. All tested specimens were digitally photographed after each test in order to pictorially document failure modes. Specimens with failures that deviated from the standard were still included unless the data was deemed invalid by two additional sources (test lab manager, third party consultant, and/or material and process engineer).

4.2.3.2 Environmental Conditioning

For dry testing, specimens were dried at 250°F±5°F for 24 hours minimum. After drying, specimens were kept in a desiccator until mechanical testing. Ambient laboratory condition is defined as 70°F±10°F. Since moisture absorption and desorption rate for polymers is very slow at ambient temperature, there is no requirement to maintain relative humidity levels.

Wet conditioning was not performed during this effort.

4.2.3.3 Non-Ambient Testing

For elevated temperature testing, the temperature chamber, test fixture, and grips were preheated to the specified temperature. Each specimen was heated to the required test temperature as verified by a thermocouple in direct contact with and taped to the specimen gage section. The heat-up time of the specimen did not exceed 5 minutes. The test started within minutes after the specimen had reached the test temperature. During the test, the temperature, as measured on the specimen, was within +/-5°F of the required test temperature.

For subzero temperature testing, each specimen was cooled to the required test temperature as verified by a thermocouple in direct contact with and taped to the specimen gage section. The test within minutes of the specimen reaching the test temperature. During the test, the temperature, as measured on the specimen, was within +/-5°F of the required test temperature.

4.2.4 Test Matrix

For each combination of test, lot, and condition, the specimens were selected from a minimum of two machines run separately as shown in Figure 1 unless otherwise specified. The term "machine" means a single AM machine running a designed and specific process with a selected AM raw material through which mechanical test coupons were built with a +/-45 raster pattern. There were two build methods that were evaluated during the characterization to capture representative fill strategies as defined by SPS 840C03, Section 6.3, Toolpath Variability: standard fill (SF) and remnant fill (RF). Standard fill is defined per the specification and is used on a majority of parts with features over a given thickness. In order to maximize material placement with the intent to have increased performance, an option that is available is the use of remnant fill. Remnant fill is defined in the process specification and is used when thin-walled features result in no or minimal material placement within the feature resulting in potentially reduced performance. The use of remnant fill allows for a partial bead of material to be placed between two contours filling in gaps. An extra specimen was added for every orientation, condition, and batch in the MID location (depicted in Figure 1 as |*) and is intended to show that RF programming did not negatively influence performance at the coupon level.

The specimen selection methodology in Figure 1 is presented in “Number of Batches x Number of Machines x Number of Specimens” format throughout this document. Specifically, Figure 1 depicts a 3x2x4 specimen selection methodology. If more than 2 machines are required to obtain the minimum specimens, the additional machine(s) shall be labeled accordingly (see section 4.2.2) and approximately equal number of specimens should be tested from each machine.

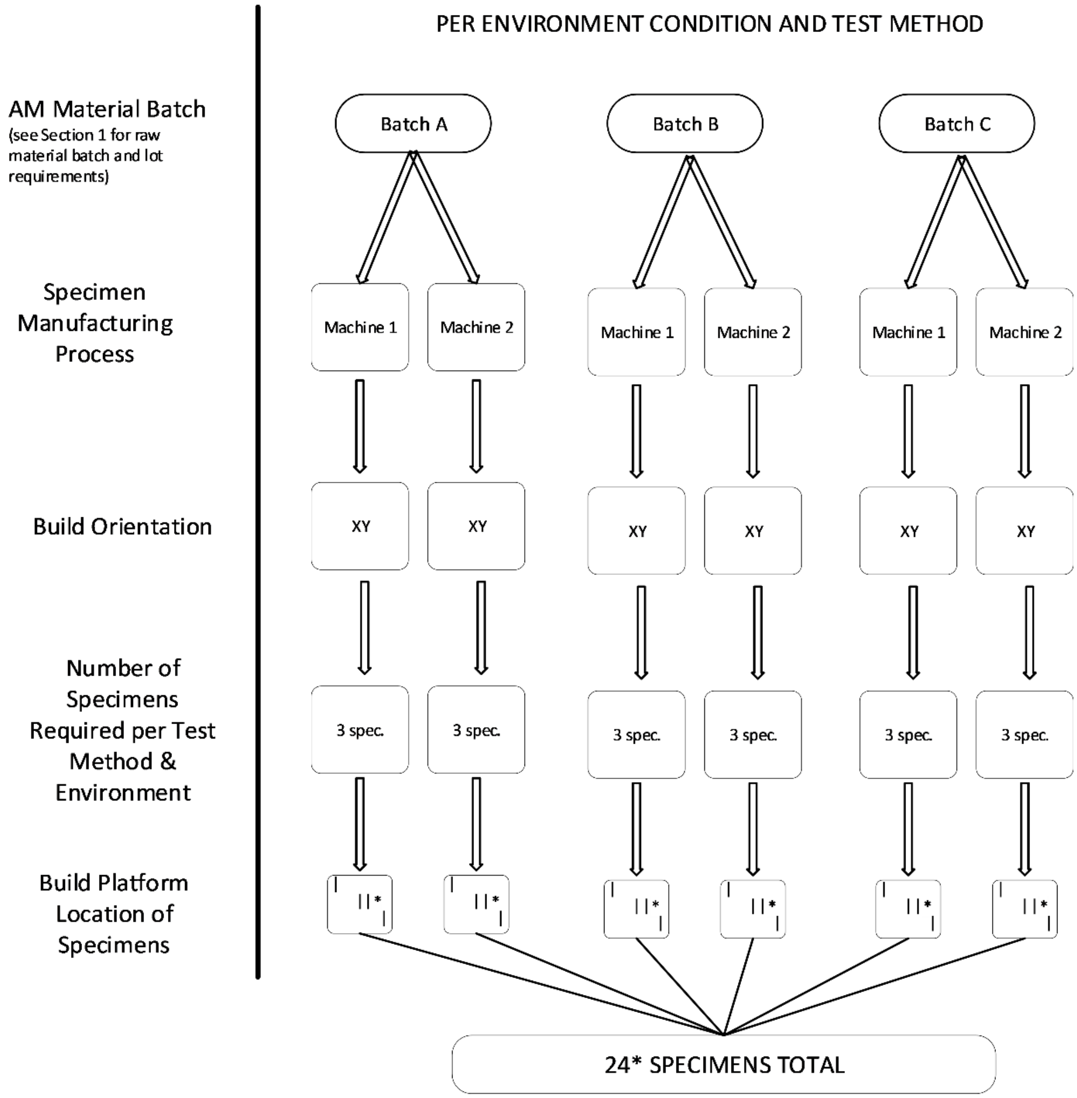


Figure 1 Specimen Selection Methodology

4.2.5 FDM AM Material Mechanical Tests

Table 1 summarizes the mechanical level testing performed.

Table 1 FDM AM Material Mechanical Tests

Build Orientation	Test Type (3)	Property	Number of Batches x Number of Machines x Number of Specimens (6)				
			Test Temperature / Moisture Condition				
			CTD (-65°F)	RTD (70°F)	RTA (70°F) (4)	ETD (160°F)	ETW (160°F)
ZX	Tension ASTM D638 Type 1 (5)	Strength and Modulus	3x2x4	3x2x4	1x2x4	3x2x4	-

XY	Tension ASTM D638 Type 1 (5)	Strength and Modulus	3x2x4	3x2x4	1x2x4	3x2x4	-
XZ	Tension ASTM D638 Type 1 (5)	Strength and Modulus	3x2x4	3x2x4	1x2x4	3x2x4	-
ZX	Compression ASTM D6641 (1)	Strength and Modulus	3x2x4	3x2x4	-	-	-
XY	Compression ASTM D6641 (1)	Strength and Modulus	3x2x4	3x2x4	-	-	-
XZ	Compression ASTM D6641 (1)	Strength and Modulus	3x2x4	3x2x4	-	-	-
ZX	Flex ASTM D790 (2)	Strength and Modulus	3x2x4	3x2x4	-	-	-
XY	Flex ASTM D790 (2)	Strength and Modulus	3x2x4	3x2x4	-	-	-
XZ	Flex ASTM D790 (2)	Strength and Modulus	3x2x4	3x2x4	-	-	-

Notes:

(1) Back-back strain gauges may be used on the first two specimens. If no buckling is observed, the remaining modulus specimens will require a strain gauge on one side of the specimens only. An appropriate extensometer may be used in place of the strain gauges if the test fixture does not allow strain gauge use. Buckling may not be identifiable when using extensometer. Strength offset values at 0.2% and 1.0% shall be reported. Strain range of 2000με-6000με shall be used for all data including modulus. standard combined loading compression WTF-EL-129 grip fixturing between two platen surfaces.

(2) ASTM D790 Flex Procedure B. Support Span to Depth ratio = 16:1.

(3) All Specimens need to be printed WITHOUT Tabs

(4) For informational testing only, specimens to be produced from material Batch C.

(5) Strain range of 5000με-20000με shall be used. Upper universal joint, steel wedge grips and laser extensometer. Grips are installed as tight as possible by hand.

(6) An additional specimen will be tested from the MID location and processed with a remnant fill per SPS 840C03, Section 6.3: Toolpath Variability

(7) Red entries were printed but not tested.

4.2.6 FDM AM Material Mechanical Tests (Design Guidance Properties)

Table 2 summarizes the as-built level tests to be carried out. The three build orientations are XY, XZ, and ZX. The build orientations in this program are not specific to any design. Therefore, careful consideration was given to the validity of properties derived from this program based on the design specific orientations in a structure to be certified.

For the single shear bearing tests, the ASTM D5961-10 One-Piece Single-Shear Test Set-Up (Procedure C) is intended to be followed.

Table 2 FDM AM Material Mechanical Tests (Design Guidance Properties)

Build Orientation	Test Type (5)	Property	Number of Batches x Number of Machines x Number of Specimens (6)			
			Test Temperature / Moisture Condition			
			CTD (-65°F)	RTD (70°F)	RTA (70°F)	ETD (160°F)
ZX	Open-Hole Tension (1)(4) ASTM D5766	Strength	3x2x4	3x2x4	-	-
XY	Open-Hole Tension (1)(4) ASTM D5766	Strength	3x2x4	3x2x4	-	-
XZ	Open-Hole Tension (1)(4) ASTM D5766	Strength	3x2x4	3x2x4	-	-
ZX	Filled-Hole Tension (2)(4) ASTM D6742	Strength	3x2x4	3x2x4	-	-
XY	Filled-Hole Tension (2)(4) ASTM D6742	Strength	3x2x4	3x2x4	-	-
XZ	Filled-Hole Tension (2)(4) ASTM D6742	Strength	3x2x4	3x2x4	-	-
ZX	Single Shear Bearing (3) ASTM D5961	Strength & Deformation	3x2x4	3x2x4	-	-
XY	Single Shear Bearing (3) ASTM D5961	Strength & Deformation	3x2x4	3x2x4	-	-
XZ	Single Shear Bearing (3) ASTM D5961	Strength & Deformation	3x2x4	3x2x4	-	-

Notes:

(1) Open-hole test configuration: 0.25 inch hole diameter, 1.5 inch width.

(2) Filled-hole test configuration: 0.25 inch hole diameter, 1.5 inch width, see section 2 for fastener callout.

(3) Single shear bearing test configuration: 0.25 inch hole diameter, 1.5 inch width, e/D = 3, ASTM D5961 Procedure C, see section 2 for fastener callout. All holes will be as-printed but undersized by 0.X" and produced with three contours for all applicable orientations.

(4) Specimen with holes will be drilled/ reamed by machine to final dimensions and ASTM requirements.

(5) All Specimens need to be printed WITHOUT tabs.

(6) An additional specimen will be tested from the MID location and processed with a remnant fill per SPS 840C03, Section 6.3: Toolpath Variability

(7) Red entries were printed but not tested.

The following drawings show the as-printed dimensions for the open-holed / filled hole tension specimen (D5766) as well as single shear bearing (D5961). Machining is required prior to testing.

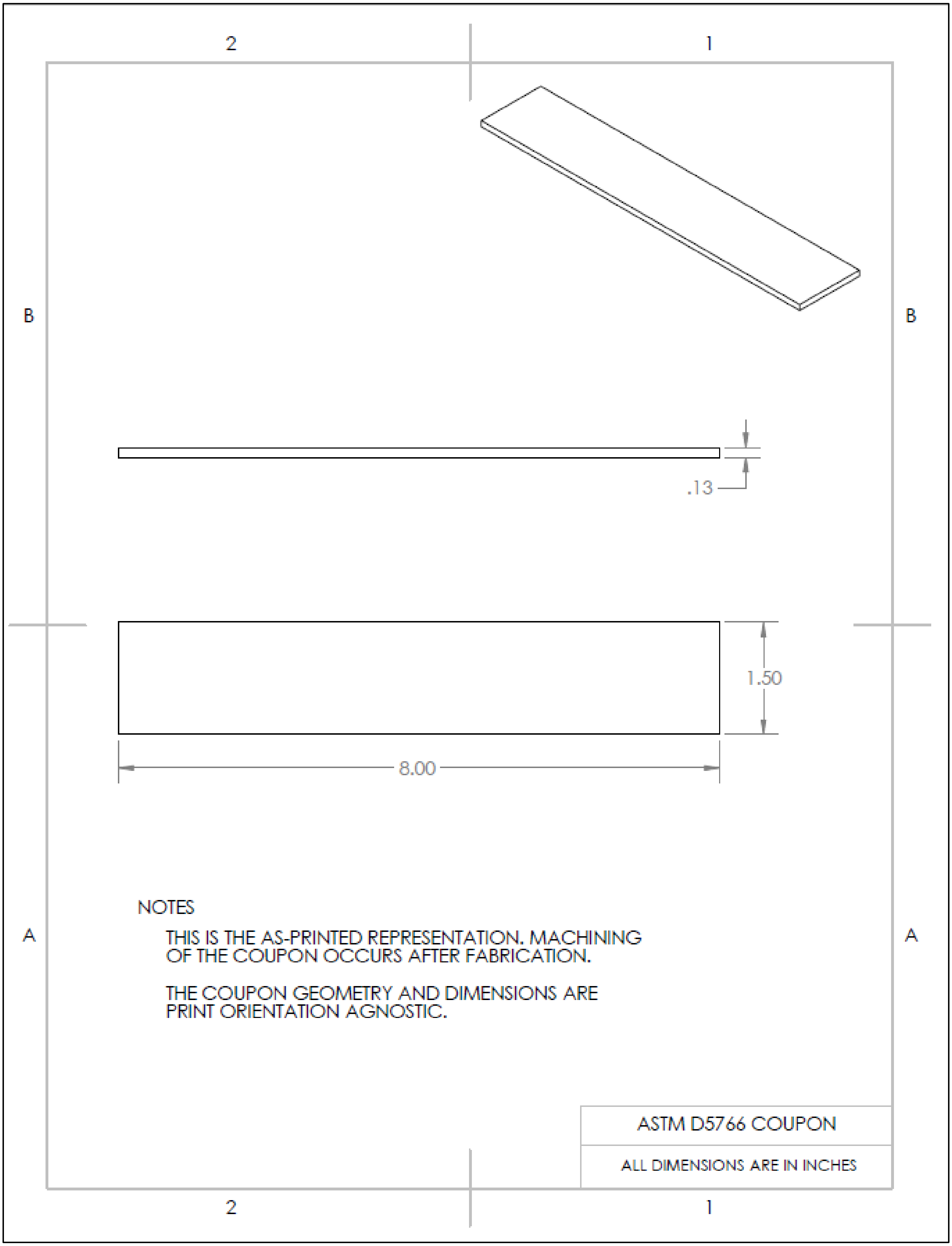


Figure 2. As-printed drawings used to develop the CAD model for open and filled hole tension specimens.

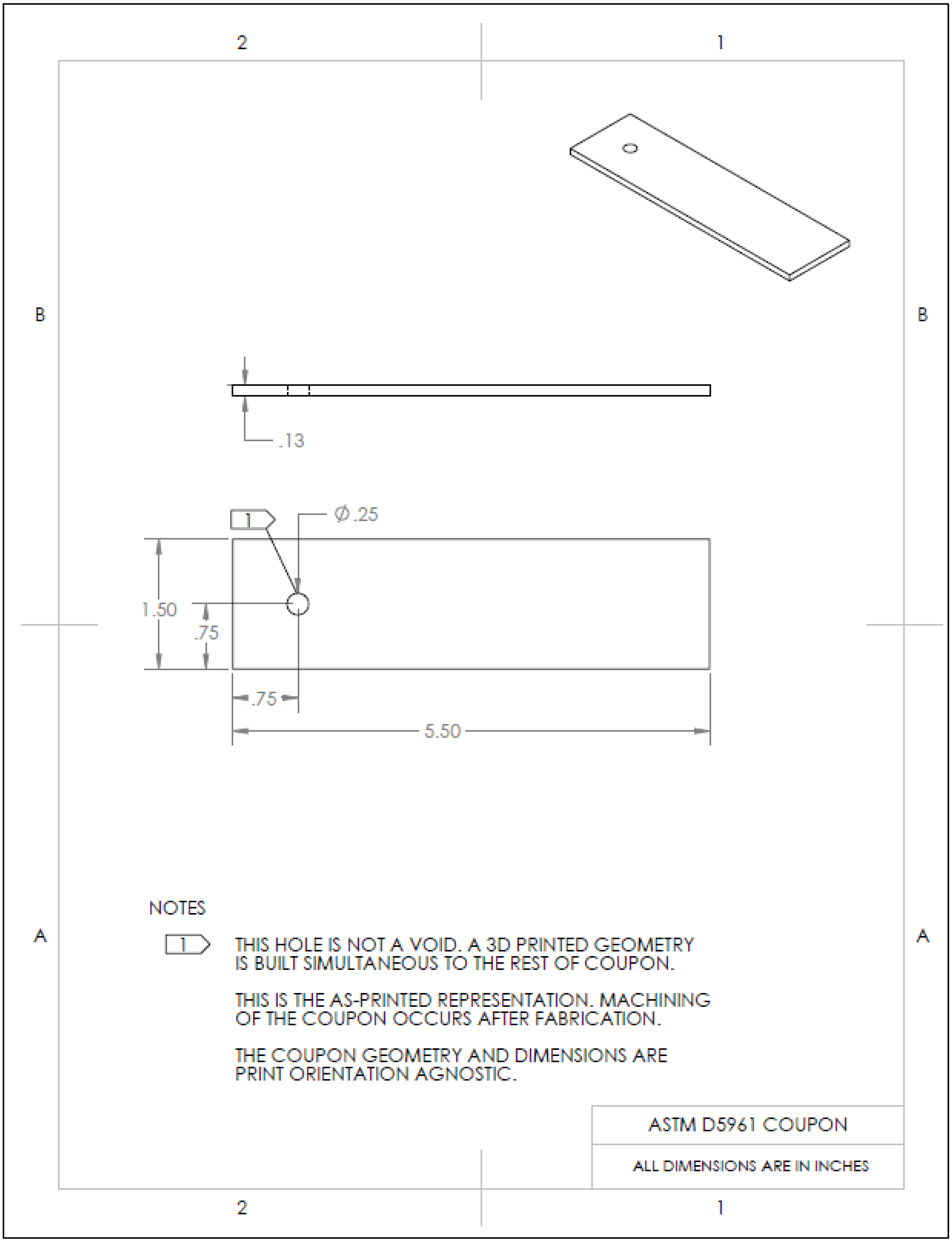


Figure 3. As-printed drawings used to develop the CAD model for single shear bearing specimens.

5 AUDITS OF DOCUMENTATION AND BUILD SITES

The fabrication sites were audited by an independent third party for quality assurance, prior to the completion of coupon fabrication once the specifications were approved by all participating entities. The material fabrication was audited at the Stratasys Inc compounding facility in River Falls, WI where the batches of material from the raw material provider used to create the intermediate form factor prior to filamentization. The Process Specification and Process Control Documentation were audited at LM-SS's operation facility in Littleton, CO and at SDM's production facility in Belton, TX where the coupons would be fabricated.

5.1 Controlled Build Files

A large problem stemming from previous attempts at material characterization, was a wide variance in the machine files that were used to control the machines. Users of varying skill developed different files which resulted in a diverse range of data. In order to avoid making the same error, the intermediary files were standardized before issuing the files to the two locations. After the test methods were decided upon, the team at Stratasys created the CAD files that would be used to create the intermediary files from. These CAD files were created based on the specification outlined by ASTM documentation.

Once the CAD files were finalized, they were then converted into the intermediary files that would be uploaded into the F900 machines. By using version 15.7 or later (please reference the latest version of the process specification for most up-to-date approved version) of Stratasys Insight software, each test method was programmed to be printed in the Antero 840CN03 material and T20F tips. Each test method was positioned in three orientations; XY (Flat), XZ (On Edge), and ZX (Upright).

There were a few constraints placed on the packing of these files. The first being the need to build coupons in three locations within the build chamber which included the back left, front right, and the center. These three locations were chosen because there is a known temperature gradient within the build chamber with the back left being the hottest and front right being the coldest. Because of this, each pack file would contain coupons in three distinct locations. This insured that all differing locations would supply coupons while also evaluating the effects of the temperature gradient within the build chamber.

Pack files were designed to be built as day and night builds, with the day builds running anywhere for 6-8 hours and the night builds running 9-15 hours in length.

A total of 45 build pack files were developed for the fabrication build sites, with the intent to capture machine to machine, batch to batch, but most importantly build to build variations.

5.2 Test Coupon Manufacturing

Three batches of material were used to complete to the qualification coupon fabrication for the qualification test matrix at two different facilities.

5.3 Test Coupon Inspection

Each individual coupon labeled for tracking purposes when removed from the build chamber. Each coupon was inspected by a designated quality representative for anomalies, both acceptable and unacceptable. If an acceptable anomaly was identified, it was documented, and the coupon was not removed from the testing samples. If an unacceptable anomaly was identified however, it was documented and removed from the acceptable coupons. The Process Specification Document outlines the acceptable or unacceptable anomalies. The coupons were also weighed and measured to verify the coupons were built to the ASTM specifications.

6 TEST RESULTS

6.1 AM Built Test Summary

Table 3. Average Values for Each Test by Orientation and Condition

PROCESSING:	SPS 840C03			
As-printed Properties				
		Batch A	**Batch B**	**Batch C**
Date of Compounding		March 2021	Jan. 2021	Sept. 2020
Date of filament manufacture		Sept. 2021	Sept. 2021	Oct. 2021
	Print Orientation:	**XY**	**XZ**	**ZX**
Tension UTS Strength (ksi)	CTD	14.95	15.54	8.88
	RTD	11.49	14.01	8.81
	RTA	11.54	14.02	8.73
	ETD	8.70	11.18	8.63
Tension Yield Strength (ksi)	CTD	N/A[1]	N/A[1]	8.62
	RTD	9.08	10.71	8.58
	RTA	9.15	10.72	8.64
	ETD	7.63	9.67	8.25
Modulus (ksi)	CTD	534.04	583.24	529.85
	RTD	409.89	452.66	402.21
	RTA	534.77	536.87	473.15
	ETD	425.60	521.93	484.80
Elongation at Break (%)	CTD	0.58	0.37	1.18
	RTD	4.21	4.45	2.24
	RTA	3.62	4.11	2.00
	ETD	3.94	2.95	2.05

Notes:

(1) For CTD - Yield stress and strain were projected due to gages falling off prior to max load being reached and was not reported.

6.2 Individual Test Summaries

6.2.1 Tensile Properties

This section contains all of the mean, range, and coefficient of variance property data extracted and summarized within the tension test configuration. ASTM D638 (Type 1) was used to execute the tensile configuration testing. Extracted data prepared in this section includes ultimate tension strength, tension strength at yield, tension modulus, elongation at break.

Table 4. Summary Data for Tension Properties

Tension: D638		CTD*			RTD			RTA			ETD		
Test Temperature [F]		-65ºF			70ºF			70ºF			180ºF		
Print Orientation:		XY	XZ	ZX	XY	XZ	ZX	XY	XZ	ZX	XY	XZ	ZX
Tensile Strength (ksi)	Mean	14.95	15.54	8.88	11.49	14.01	8.81	11.54	14.02	8.73	8.70	11.18	8.63
	Minimum	13.34	11.20	7.60	10.61	13.46	7.44	10.88	13.62	7.37	8.27	10.86	6.34
	Maximum	15.80	18.20	9.96	12.14	14.39	10.20	11.99	14.37	10.18	8.99	11.46	9.44
	CV(%)	3.98	13.12	7.44	3.40	1.61	8.27	2.96	1.52	8.15	3.01	1.49	9.68
	No. Specimens	24	24	20	25	23	23	24	21	26	23	24	24
	No. Batches	3	3	3	3	3	3	3	3	3	3	3	3
Tensile Strength At Yield (ksi)	Mean	N/A	N/A	8.62	9.08	10.71	8.58	9.15	10.72	8.64	7.63	9.67	8.25
	Minimum	0.00	0.00	7.60	8.26	9.87	7.44	7.50	9.51	7.37	6.65	8.69	6.34
	Maximum	0.00	0.00	9.50	9.69	14.08	9.52	9.98	14.00	9.94	8.22	10.67	9.14
	CV(%)	N/A	N/A	6.33	4.38	7.49	6.49	5.55	9.35	7.28	5.70	5.63	8.13
	No. Specimens	0	0	12	25	23	23	24	21	26	23	24	24
	No. Batches	3	3	3	3	3	3	3	3	3	3	3	3
Tensile Modulus (ksi)	Mean	534.04	583.24	529.85	409.89	452.66	402.21	534.77	536.87	473.15	425.60	521.93	484.80
	Minimum	489.00	490.53	460.24	369.59	412.19	373.47	389.92	443.48	391.17	206.00	368.81	290.39
	Maximum	588.97	725.00	810.20	439.93	484.03	441.49	922.17	967.89	862.47	770.34	969.63	786.37
	CV(%)	4.75	8.83	13.85	5.00	4.41	4.14	35.31	31.46	33.08	39.35	39.31	30.96
	No. Specimens	24	24	20	25	23	23	24	21	26	23	24	24
	No. Batches	3	3	3	3	3	3	3	3	3	3	3	3
Elonga-tion at Break (%)	Mean	0.58	0.37	1.18	4.21	4.45	2.24	3.62	4.11	2.00	3.94	2.95	2.05
	Minimum	0.10	0.00	0.20	3.80	3.90	1.80	2.00	2.10	0.90	1.60	1.50	1.10
	Maximum	2.90	2.90	2.10	4.71	4.90	2.80	4.50	4.60	2.50	8.50	3.60	3.10
	CV(%)	44.03	63.13	25.38	6.10	5.24	13.29	23.05	19.86	20.83	43.06	24.59	27.43

Tension: D638		CTD*			RTD			RTA			ETD		
	No. Specimens	24	23	20	25	23	23	24	21	26	23	24	24
	No. Batches	3	3	3	3	3	3	3	3	3	3	3	3

Notes:

(*) For CTD - Yield stress and strain were projected due to gages falling off prior to max load being reached and was not reported.

7 INDIVIDUAL TEST CHARTS

The subsequent charts provide a combined view of all material batches, plotting the minimum, maximum and average values based on each environmental condition performed for that respective test. Graph axis' ranges change per overall range of the test results.

7.1 Tensile Property Charts

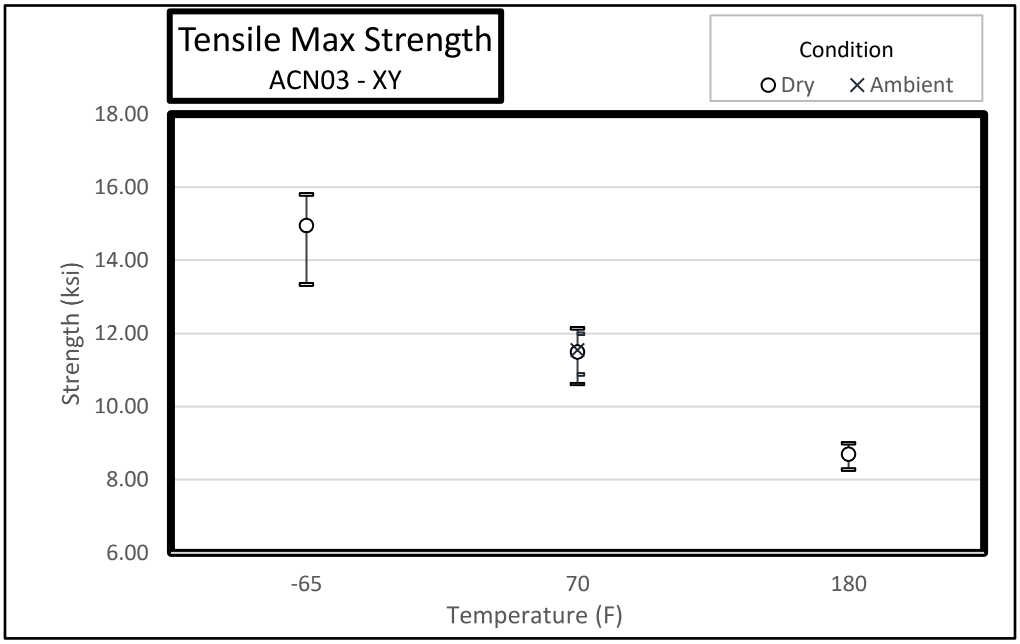


Figure 4. Tensile Strength XY

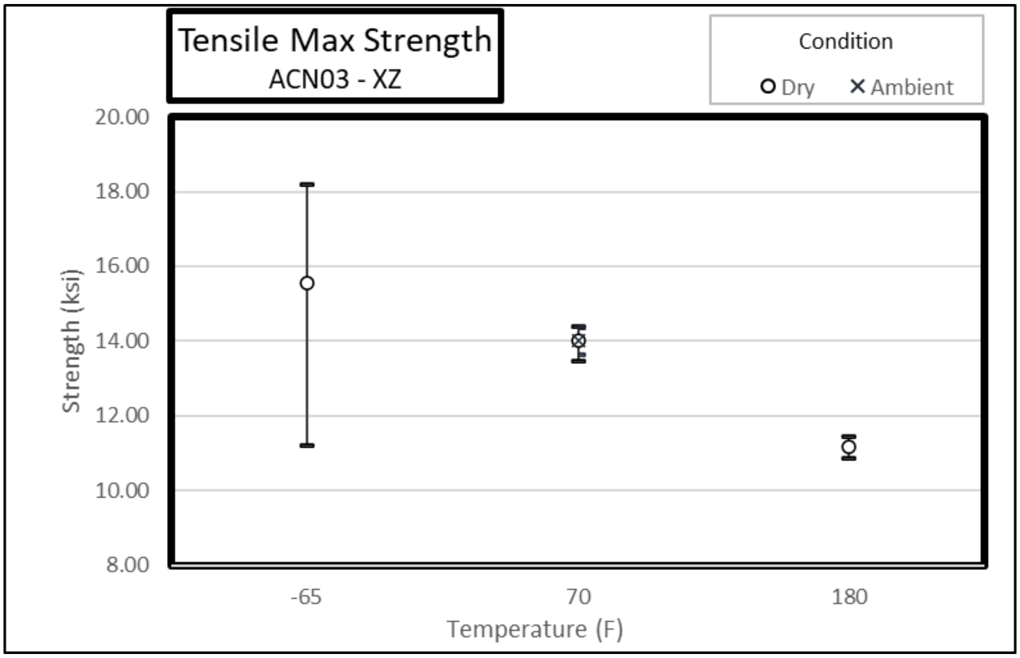


Figure 5. Tensile Strength XZ

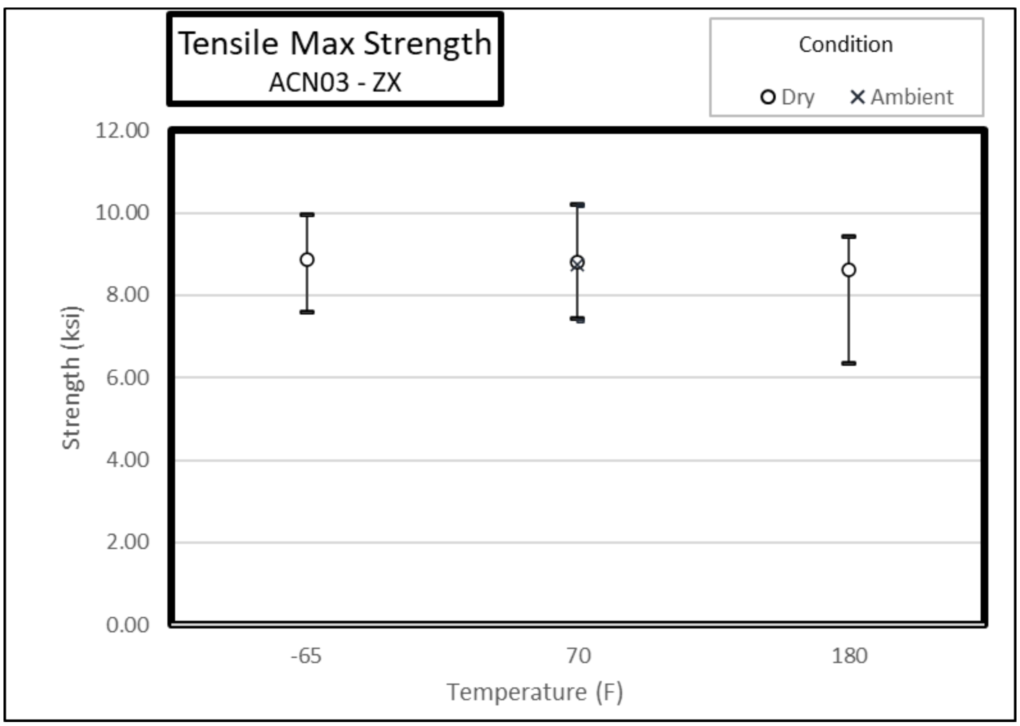


Figure 6. Tensile Strength ZX

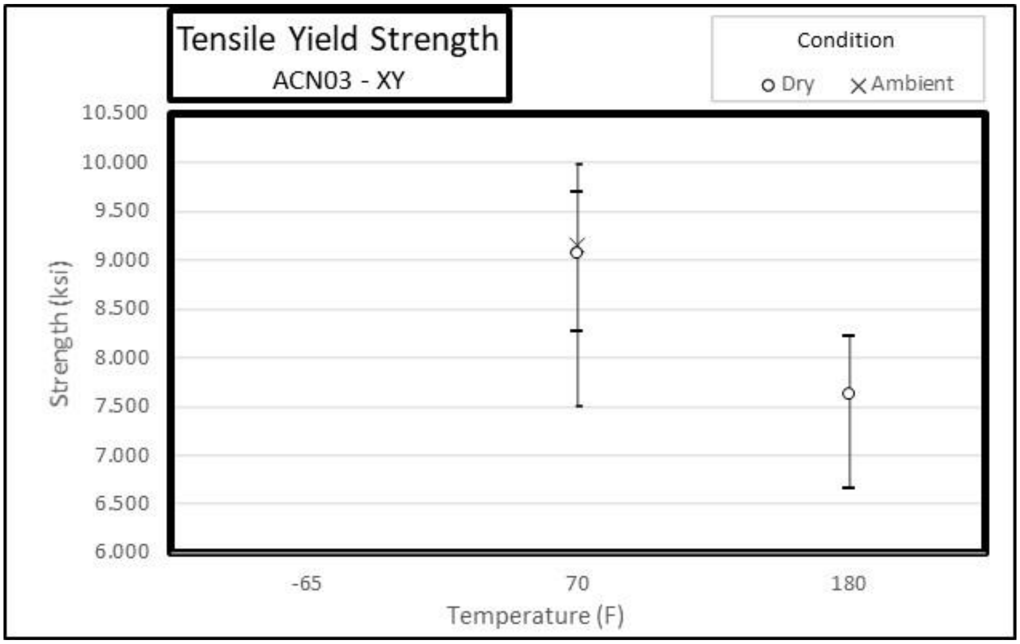


Figure 7. Tensile Strength at Yield XY

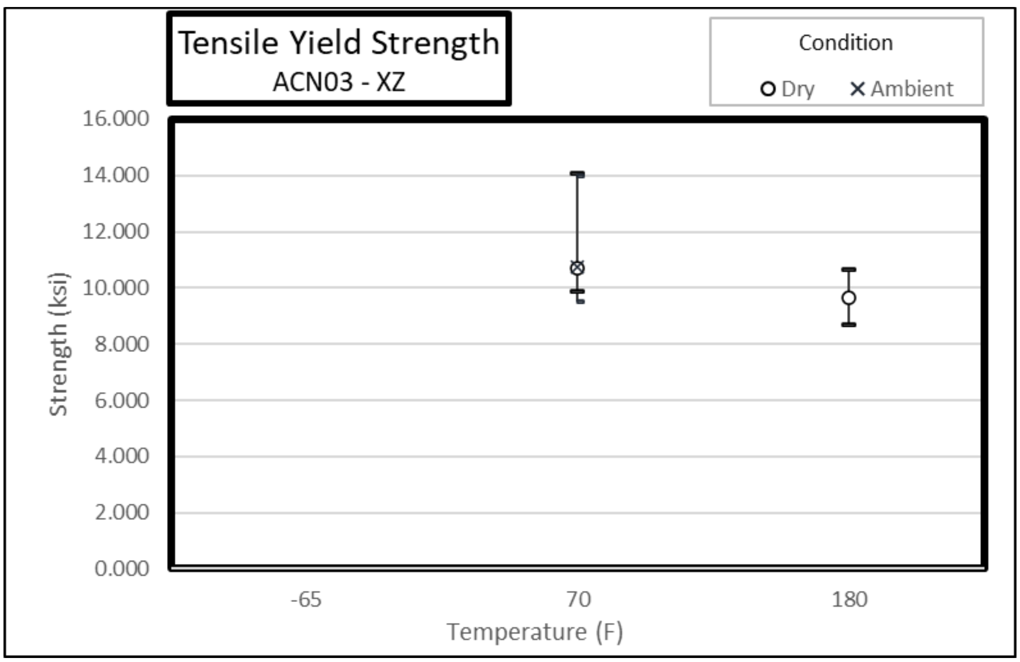


Figure 8. Tensile Strength at Yield XZ

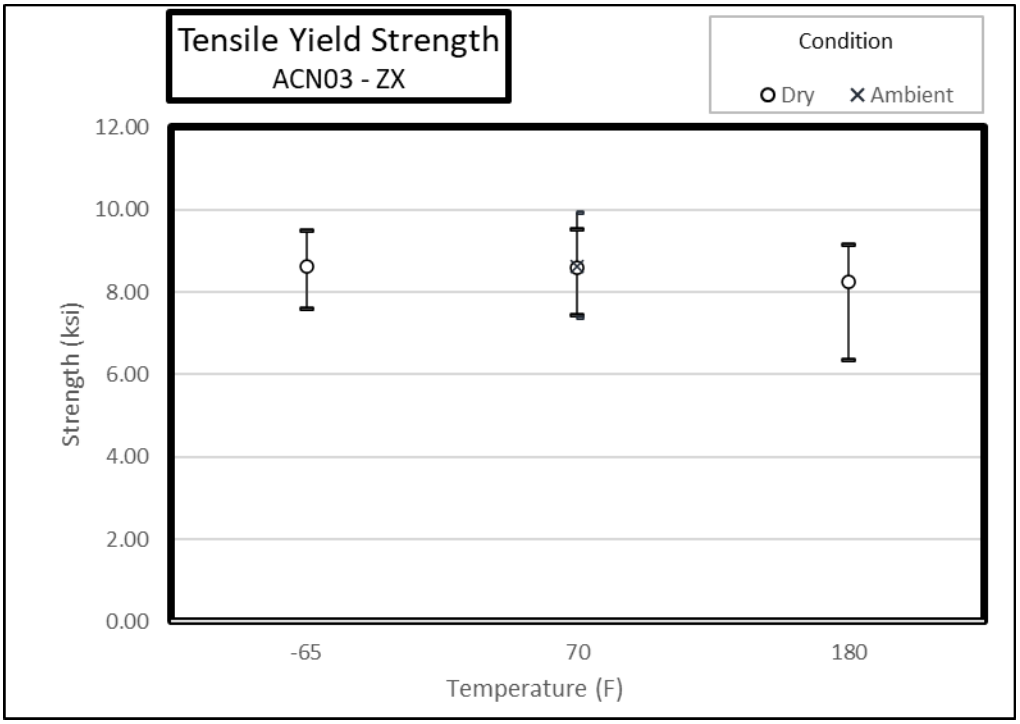


Figure 9. Tensile Strength at Yield ZX

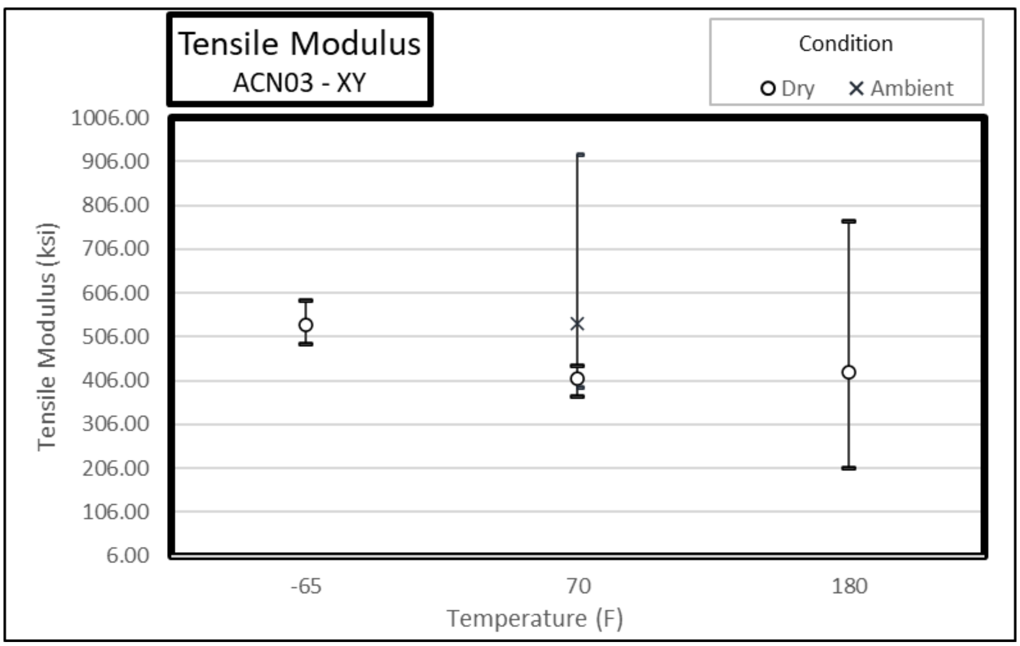


Figure 10. Tensile Modulus XY

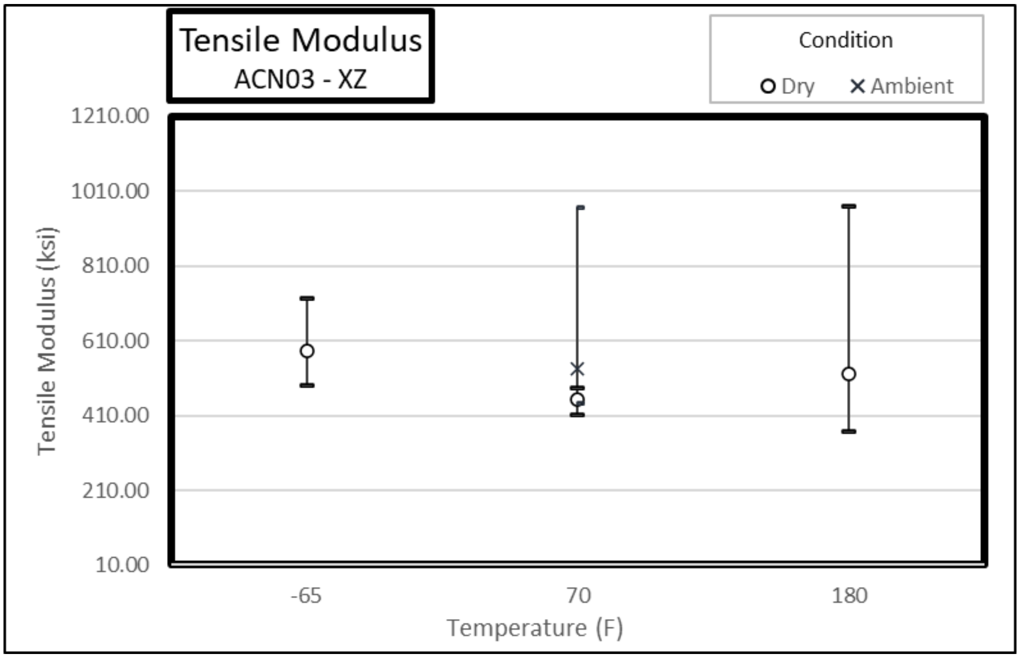


Figure 11. Tensile Modulus XZ

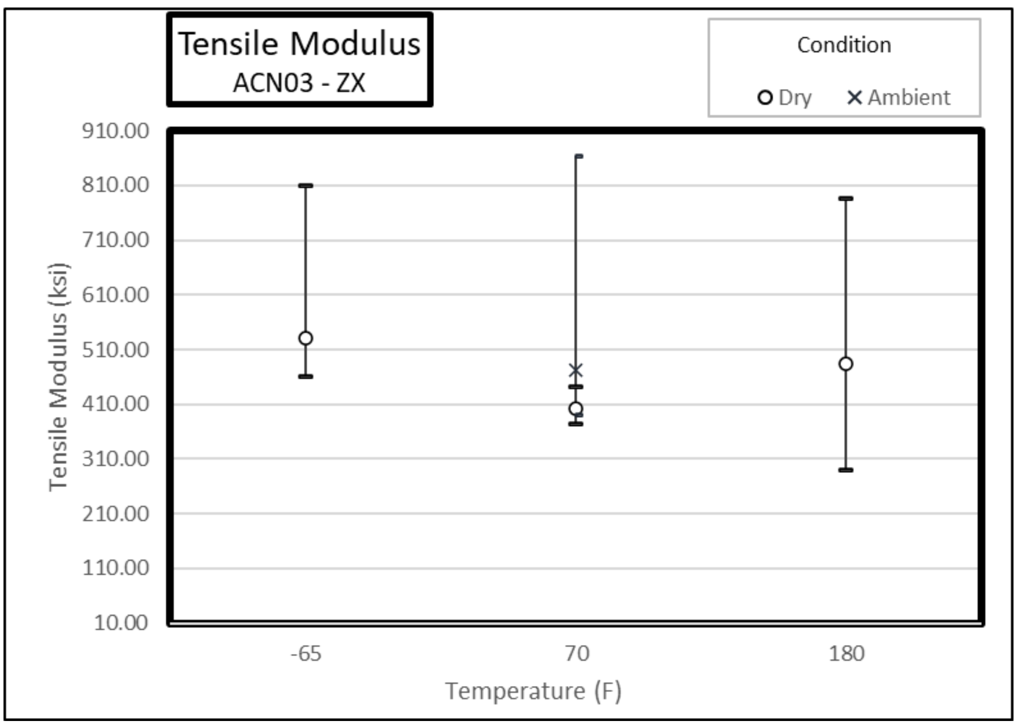


Figure 12. Tensile Modulus ZX

8 ENSEMBLE DATA

8.1 CTD Tension Properties

Table 5. Tensile CTD Ensemble Data

Tension - CTD	**Strength & Modulus**					**As Built, -45/+45**				
SPECIMEN NAME	BATCH	MACHINE	ORIENTATION	LOCATION	FILL	TENSILE STRENGTH [ksi]	STRENGTH AT YIELD [ksi]	TENSILE MODULUS [ksi]	ELONGATION AT BREAK [%]	FAILURE MODE
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-11-XY-T-BL-CTD-4	A	M1	XY	BL	SF	15.8	*15.8*	519.8	0.1	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-RF-11-XY-T-MID-CTD-25	A	M1	XY	MID	RF	15.7	*15.7*	561.3	0.1	Gage, Radius, Grip
TPAMACN03-SSYS-ACN03-M1-A-RUN1-SF-10-XY-T-MID-CTD-4	A	M1	XY	MID	SF	15.8	*9.3*	546.8	2.9	Gage, Radius, Grip
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-12-XY-T-FR-CTD-1	A	M1	XY	FR	SF	15.8	*10*	553.7	0.8	Gage, Radius
TPAMACN03-SSYS-ACN03-M2-A-RUN1-SF-2-XY-T-MID-CTD-4	A	M2	XY	MID	SF	14.44	*14.4*	528.16	0.7	Gage, Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-3-XY-T-BL-CTD-4	A	M2	XY	BL	SF	14.61	*10*	516.28	0.4	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-RF-3-XY-T-MID-CTD-25	A	M2	XY	MID	RF	14.5	*9.4*	550.6	1.3	Gage, Grip
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-4-XY-T-FR-CTD-1	A	M2	XY	FR	SF	14.45	*14.5*	526.15	0.2	Gage, Radius, Grip
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-11-XZ-T-BL-CTD-13	A	M1	XZ	BL	SF	17	*17*	542.5	0.2	Gage, Radius
TPAMCN03-SSYS-ACN03-M1-A-RUN1-RF-11-XZ-T-MID-CTD-15	A	M1	XZ	MID	RF	17.6	*17.6*	553.8	0.1	Radius, Grip
TPAMACN03-SSYS-ACN03-M1-A-RUN1-SF-10-XZ-T-MID-CTD-8	A	M1	XZ	MID	SF	18.2	*10*	583.6	0.9	Gage, Radius
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-12-XZ-T-FR-CTD-9	A	M1	XZ	FR	SF	11.2	10.1	576	1.6	Gage Section
TPAMACN03-SSYS-ACN03-M2-A-RUN1-SF-2-XZ-T-MID-CTD-8	A	M2	XZ	MID	SF	17.43	*17.4*	608.52	0.2	Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-3-XZ-T-BL-CTD-13	A	M2	XZ	BL	SF	17.34	*17.3*	697.6	0.4	Gage, Radius, Grip
TPAMCN03-SSYS-ACN03-M2-A-RUN1-RF-3-XZ-T-MID-CTD-15	A	M2	XZ	MID	RF	14.18	*14.2*	490.53	*-0.1*	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-4-XZ-T-FR-CTD-9	A	M2	XZ	FR	SF	17.31	*17.3*	592.64	0.1	Gage, Radius, Grip
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-11-ZX-T-BL-CTD-19	A	M1	ZX	BL	SF	7.6	7.6	498.9	0.9	Gage
TPAMACN03-SSYS-ACN03-M1-A-RUN1-SF-10-ZX-T-MID-CTD-12	A	M1	ZX	MID	SF	8.5	8.5	529.8	1.7	Gage

Tension - CTD	Strength & Modulus									As Built, -45/+45
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-12-ZX-T-FR-CTD-21	A	M1	ZX	FR	SF	8	8	520.6	1.6	Gage
TPAMACN03-SSYS-ACN03-M2-A-RUN1-SF-2-ZX-T-MID-CTD-12	A	M2	ZX	MID	SF	7.99	8	534.63	1.5	Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-3-ZX-T-BL-CTD-19	A	M2	ZX	BL	SF	9.51	9.1	476.76	2.1	Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-RF-3-ZX-T-MID-CTD-23	A	M2	ZX	MID	RF	9.56	8.6	534.54	2	Radius, Grip
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-4-ZX-T-FR-CTD-21	A	M2	ZX	FR	SF	8.94	8.9	500.66	1.9	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-5-XY-T-BL-CTD-4	B	M1	XY	BL	SF	15	*15*	489	0.2	Gage, Radius, Grip
TPAMCN03-SSYS-ACN03-M1-B-RUN1-RF-5-XY-T-MID-CTD-25	B	M1	XY	MID	RF	15.2	*15.2*	503.3	0.2	Gage, Radius, Grip
TPAMACN03-SSYS-ACN03-M1-B-RUN1-SF-7-XY-T-MID-CTD-4	B	M1	XY	MID	SF	14.9	*14.9*	499.9	0.2	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-8-XY-T-FR-CTD-1	B	M1	XY	FR	SF	14.7	*14.7*	567.2	0.1	Radius, Grip
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-5-XY-T-BL-CTD-4	B	M2	XY	BL	SF	14.95	*15*	512.21	0.1	Radius
TPAMCN03-SSYS-ACN03-M2-B-RUN1-RF-5-XY-T-MID-CTD-25	B	M2	XY	MID	RF	14.81	*14.8*	510.56	0.1	Radius
TPAMACN03-SSYS-ACN03-M2-B-RUN1-SF-7-XY-T-MID-CTD-4	B	M2	XY	MID	SF	14.69	*14.7*	531.92	0.1	Gage, Radius
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-8-XY-T-FR-CTD-1	B	M2	XY	FR	SF	13.34	*13.3*	529.24	0.1	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-5-XZ-T-BL-CTD-13	B	M1	XZ	BL	SF	17	*17*	548	0.1	Gage, Radius, Grip
TPAMCN03-SSYS-ACN03-M1-B-RUN1-RF-5-XZ-T-MID-CTD-15	B	M1	XZ	MID	RF	15.8	*15.8*	725	0.1	Gage
TPAMACN03-SSYS-ACN03-M1-B-RUN1-SF-7-XZ-T-MID-CTD-8	B	M1	XZ	MID	SF	16.1	*16.1*	549.9	0.2	Gage, Radius
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-8-XZ-T-FR-CTD-9	B	M1	XZ	FR	SF	11.3	*11.3*	538.8	0.2	Gage Section
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-5-XZ-T-BL-CTD-13	B	M2	XZ	BL	SF	14.79	*14.8*	561.23	0.1	Radius
TPAMCN03-SSYS-ACN03-M2-B-RUN1-RF-5-XZ-T-MID-CTD-15	B	M2	XZ	MID	RF	17.18	*17.2*	608.58	0.1	Gage, Radius, Grip
TPAMACN03-SSYS-ACN03-M2-B-RUN1-SF-7-XZ-T-MID-CTD-8	B	M2	XZ	MID	SF	17.28	*17.3*	572.19	0.1	Gage, Radius, Grip
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-8-XZ-T-FR-CTD-9	B	M2	XZ	FR	SF	16.54	*16.5*	651.34	0.1	Gage, Grip
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-5-ZX-T-BL-CTD-19	B	M1	ZX	BL	SF	8.5	*8.5*	495.4	0.6	Gage, Grip
TPAMACN03-SSYS-ACN03-M1-B-RUN1-SF-7-ZX-T-MID-CTD-12	B	M1	ZX	MID	SF	8.3	*8.3*	511.9	0.9	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-8-ZX-T-FR-CTD-21	B	M1	ZX	FR	SF	9	9	493.6	1.2	Gage

Tension - CTD	Strength & Modulus					As Built, -45/+45				
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-5-ZX-T-BL-CTD-19	B	M2	ZX	BL	SF	9.4	*9.4*	470.22	1.5	Radius, Grip
TPAMACN03-SSYS-ACN03-M2-B-RUN1-SF-7-ZX-T-MID-CTD-12	B	M2	ZX	MID	SF	9.96	*10*	460.24	0.8	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-8-ZX-T-FR-CTD-21	B	M2	ZX	FR	SF	8.78	8.8	484.68	1.8	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-4-XY-T-FR-CTD-1	C	M1	XY	FR	SF	15.1	*9.6*	530.1	2.9	Gage, Grip
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-3-XY-T-BL-CTD-4	C	M1	XY	BL	SF	14.3	*14.3*	556.3	0.1	Radius, Grip
TPAMCN03-SSYS-ACN03-M1-C-RUN1-RF-3-XY-T-MID-CTD-25	C	M1	XY	MID	RF	15.6	*15.6*	533.4	0.2	Radius
TPAMACN03-SSYS-ACN03-M1-C-RUN1-SF-2-XY-T-MID-CTD-4	C	M1	XY	MID	SF	15.3	*9.7*	539.6	2.8	Gage, Grip
TPAMACN03-SSYS-ACN03-M2-C-RUN1-SF-10-XY-T-MID-CTD-4	C	M2	XY	MID	SF	15.39	*15.4*	510.85	0.1	Radius
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-11-XY-T-BL-CTD-4	C	M2	XY	BL	SF	14.74	*14.7*	581.14	0.1	Radius, Grip
TPAMCN03-SSYS-ACN03-M2-C-RUN1-RF-11-XY-T-MID-CTD-25	C	M2	XY	MID	RF	15.32	*15.3*	530.36	0.1	Gage, Radius
TPAMCNO3-SSYS-ACN03-M2-C-RUN1-SF-12-XY-T-FR-CTD-1	C	M2	XY	FR	SF	14.32	*14.3*	588.97	0.1	Gage, Radius
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-4-XZ-T-FR-CTD-9	C	M1	XZ	FR	SF	16.1	*16.1*	585.6	0.2	Gage, Radius, Grip
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-3-XZ-T-BL-CTD-13	C	M1	XZ	BL	SF	15.70	*15.7*	537.5	0.2	Gage, Radius, Grip
TPAMCN03-SSYS-ACN03-M1-C-RUN1-RF-3-XZ-T-MID-CTD-15	C	M1	XZ	MID	RF	13.9	*13.9*	543.3	0	Gage
TPAMACN03-SSYS-ACN03-M1-C-RUN1-SF-2-XZ-T-MID-CTD-8	C	M1	XZ	MID	SF	16.6	*10*	585.9	2.9	Gage, Radius
TPAMACN03-SSYS-ACN03-M2-C-RUN1-SF-10-XZ-T-MID-CTD-8	C	M2	XZ	MID	SF	13.5	*13.5*	596.67	0	Gage, Grip
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-11-XZ-T-BL-CTD-13	C	M2	XZ	BL	SF	14.2	*14.2*	551.63	0.3	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-12-XZ-T-FR-CTD-9	C	M2	XZ	FR	SF	14.65	*14.6*	585.56	0.4	Slipped in Grip
TPAMCN03-SSYS-ACN03-M2-C-RUN1-RF-11-XZ-T-MID-CTD-15	C	M2	XZ	MID	RF	11.97	*12*	611.38	0	Gage, Grip
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-4-ZX-T-FR-CTD-21	C	M1	ZX	FR	SF	9	9	553.5	1.7	Gage, Grip
TPAMCN03-SSYS-ACN03-M1-C-RUN1-RF-3-ZX-T-MID-CTD-23	C	M1	ZX	MID	RF	8.3	*8.3*	580.9	0.5	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-RF-3-ZX-T-MID-CTD-23	C	M1	ZX	MID	RF	9.7	*9.7*	810.2	0.2	Gage
TPAMACN03-SSYS-ACN03-M2-C-RUN1-SF-10-ZX-T-MID-CTD-12	C	M2	ZX	MID	SF	8.38	8.4	515.42	0.3	Gage

Tension - CTD	Strength & Modulus					As Built, -45/+45				
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-11-ZX-T-BL-CTD-19	C	M2	ZX	BL	SF	9.09	*9.1*	558.5	0.3	Gage[1]

[1] "*" Indicates that the strain gages fell off during test, invalidating the data for these property and conditions. Values were left for informational reference only.

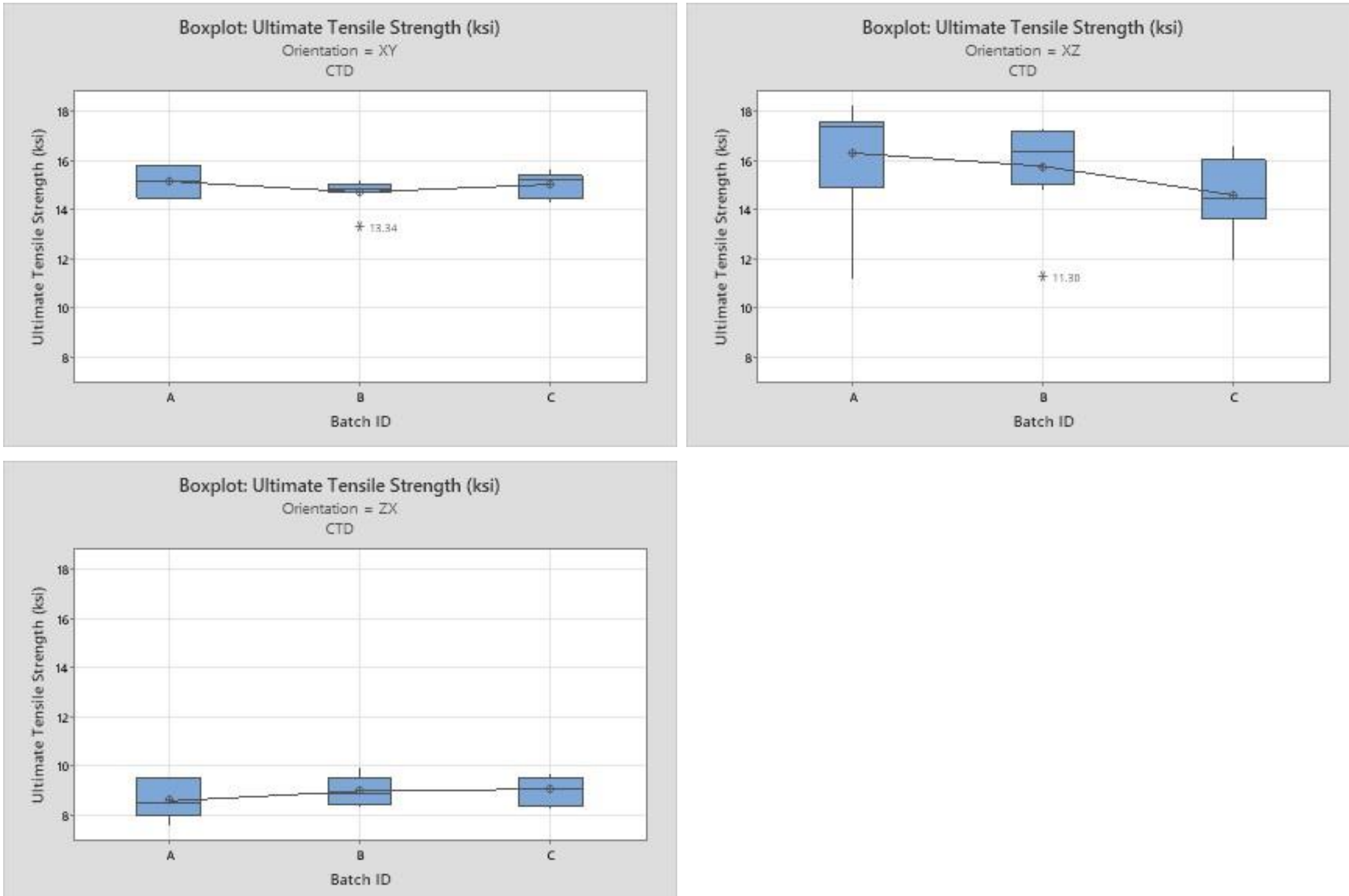


Figure 13. Plot of tensile strength by batch, per orientation for CTD.

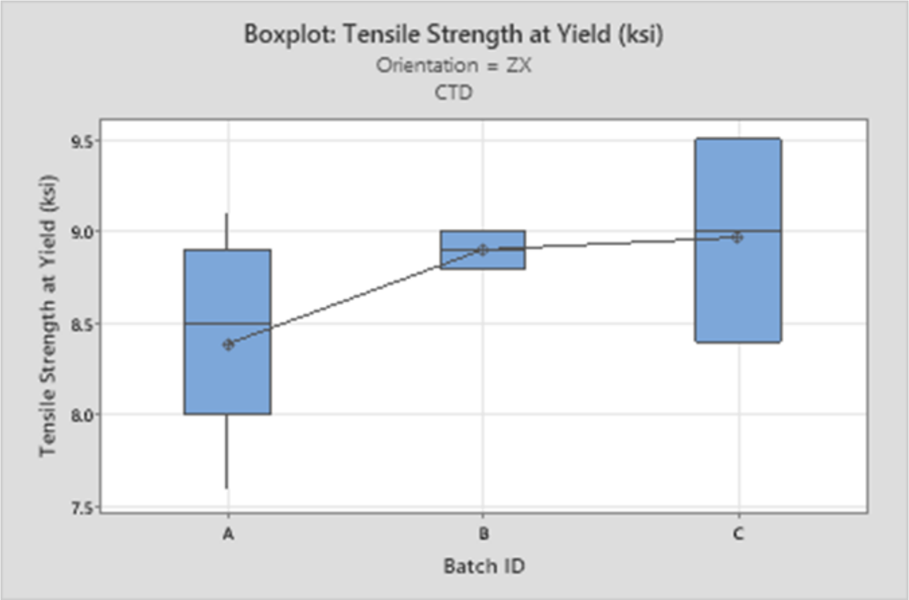


Figure 14. Plot of tensile yield strength by batch, per orientation for CTD.

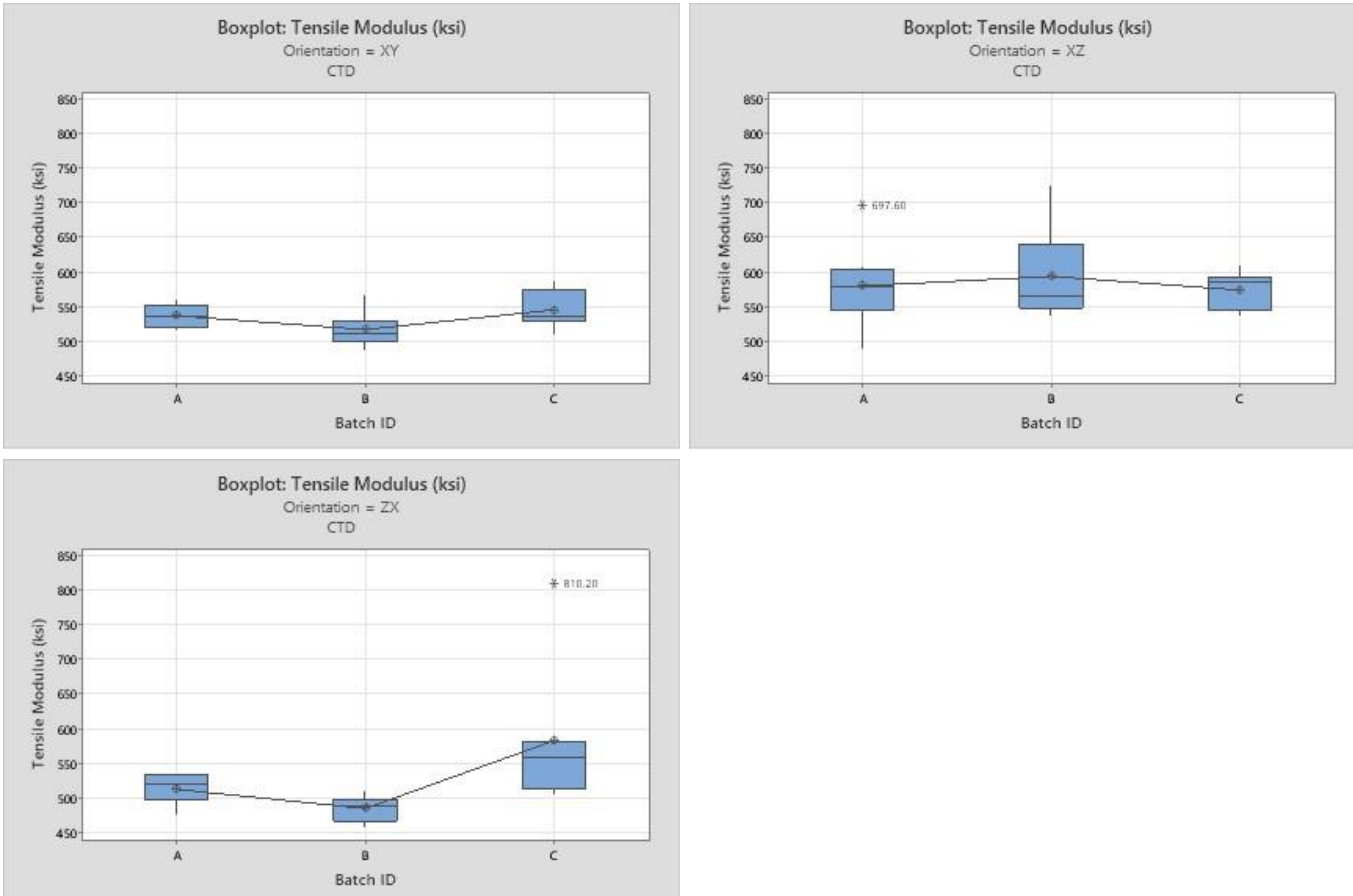


Figure 15. Plot of tensile modulus by batch, per orientation for CTD

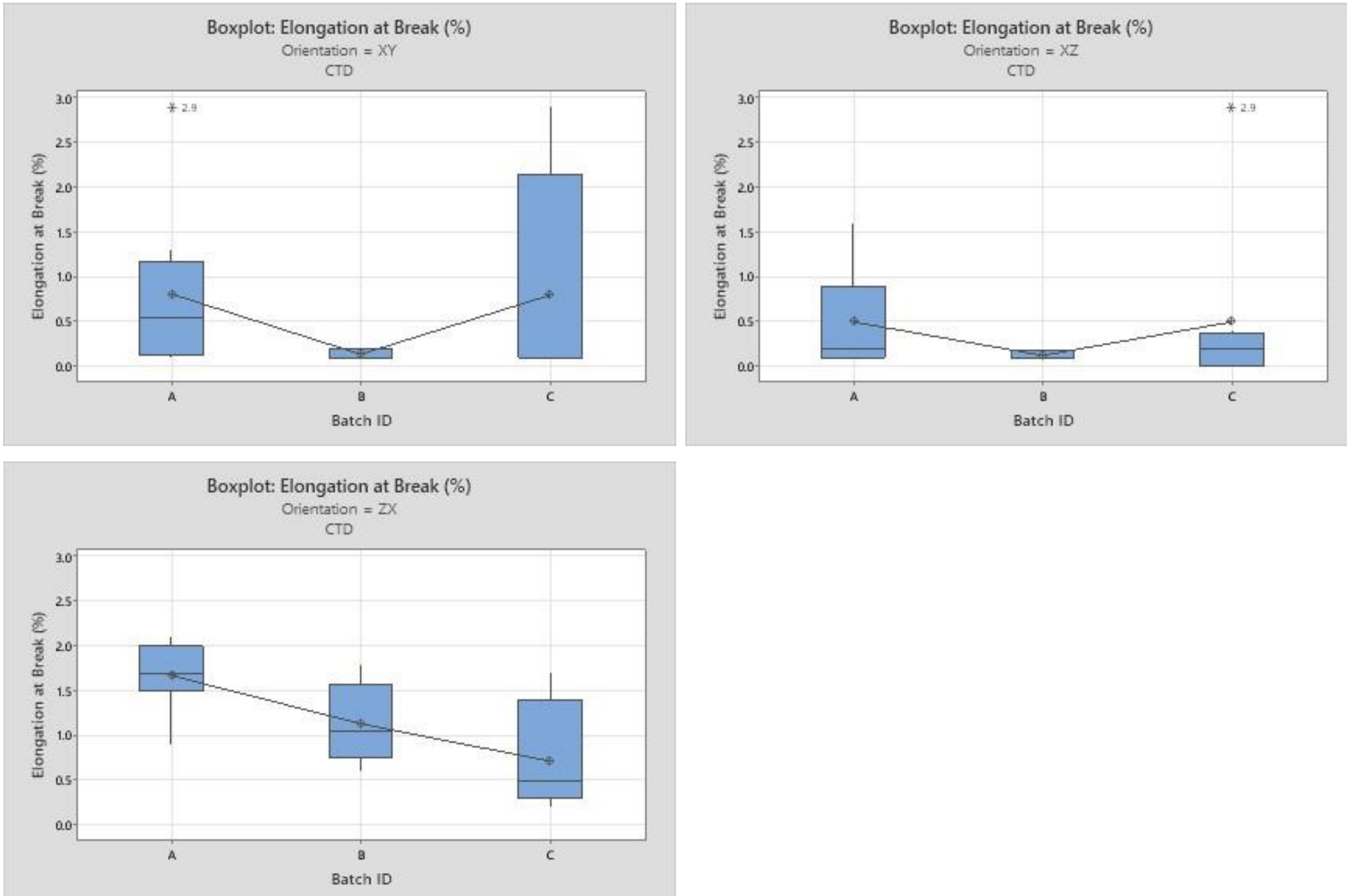


Figure 16. Plot of elongation at break by batch, per orientation for CTD.

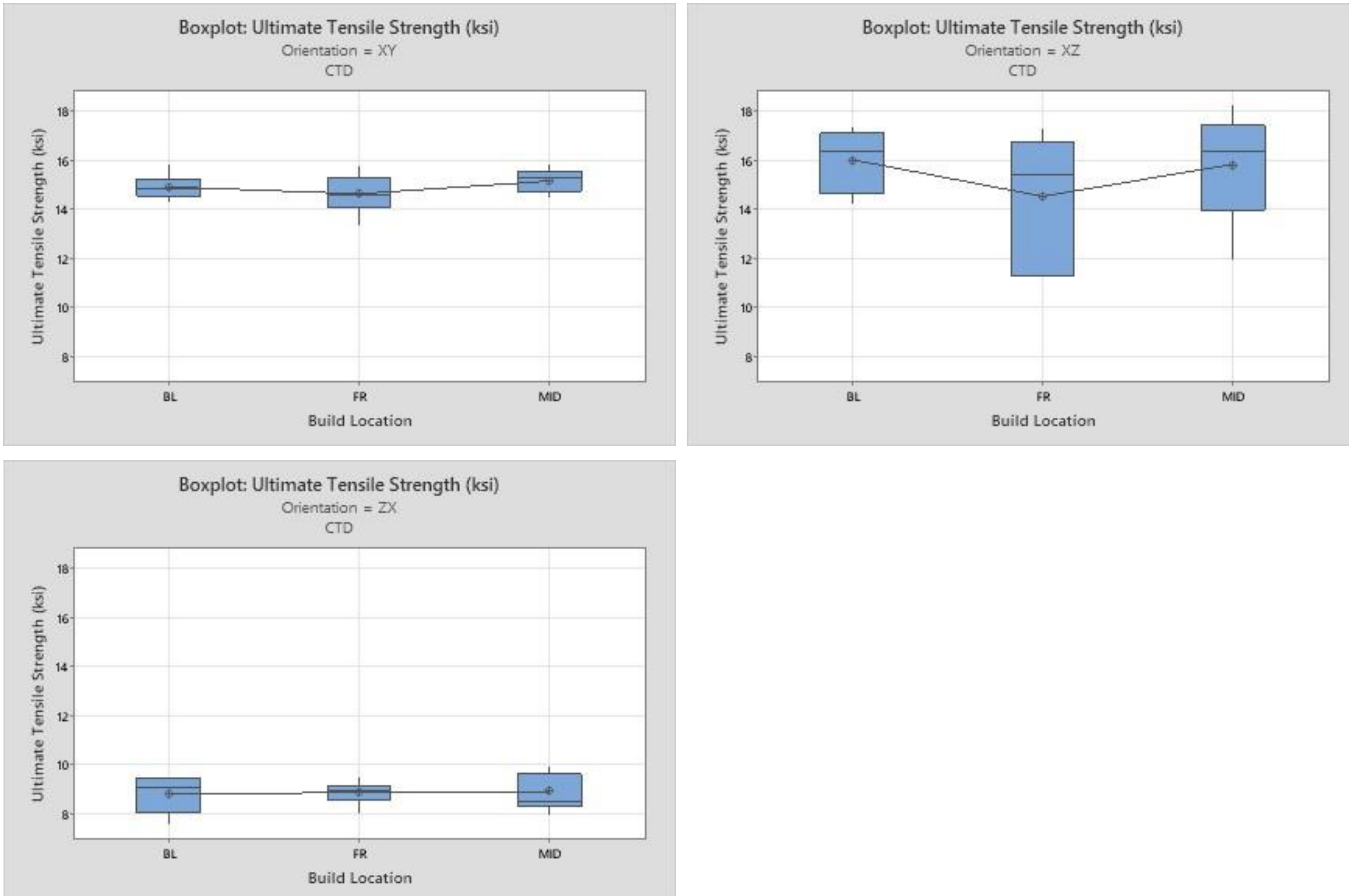


Figure 17. Plot of tensile strength by chamber location, per orientation for CTD.

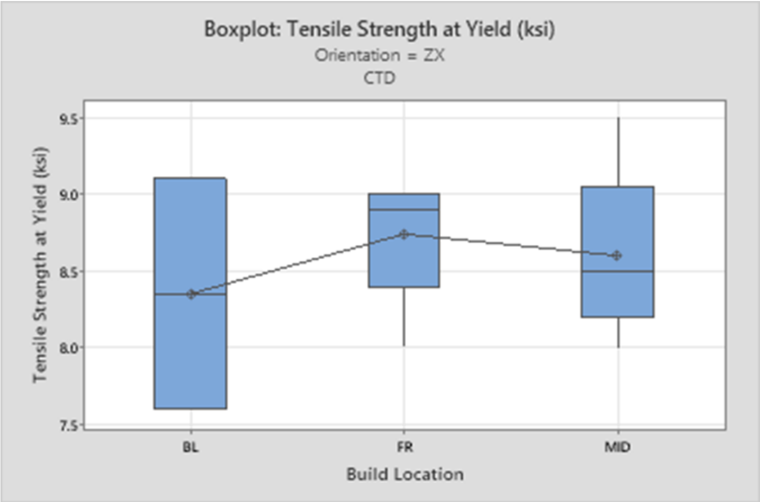


Figure 18. Plot of tensile yield strength by chamber location, per orientation for CTD.

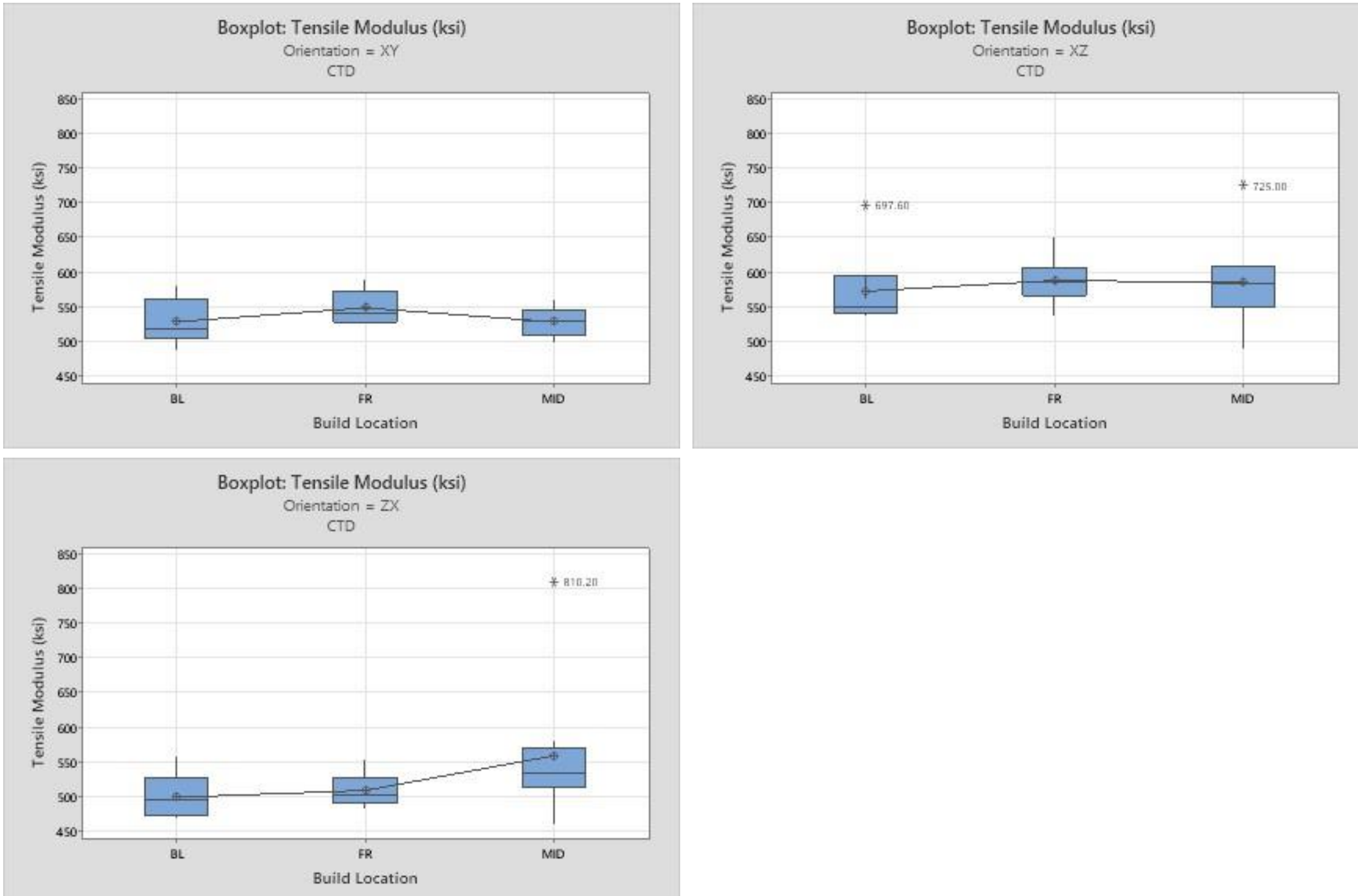


Figure 19. Plot of tensile modulus by chamber location, per orientation for CTD.

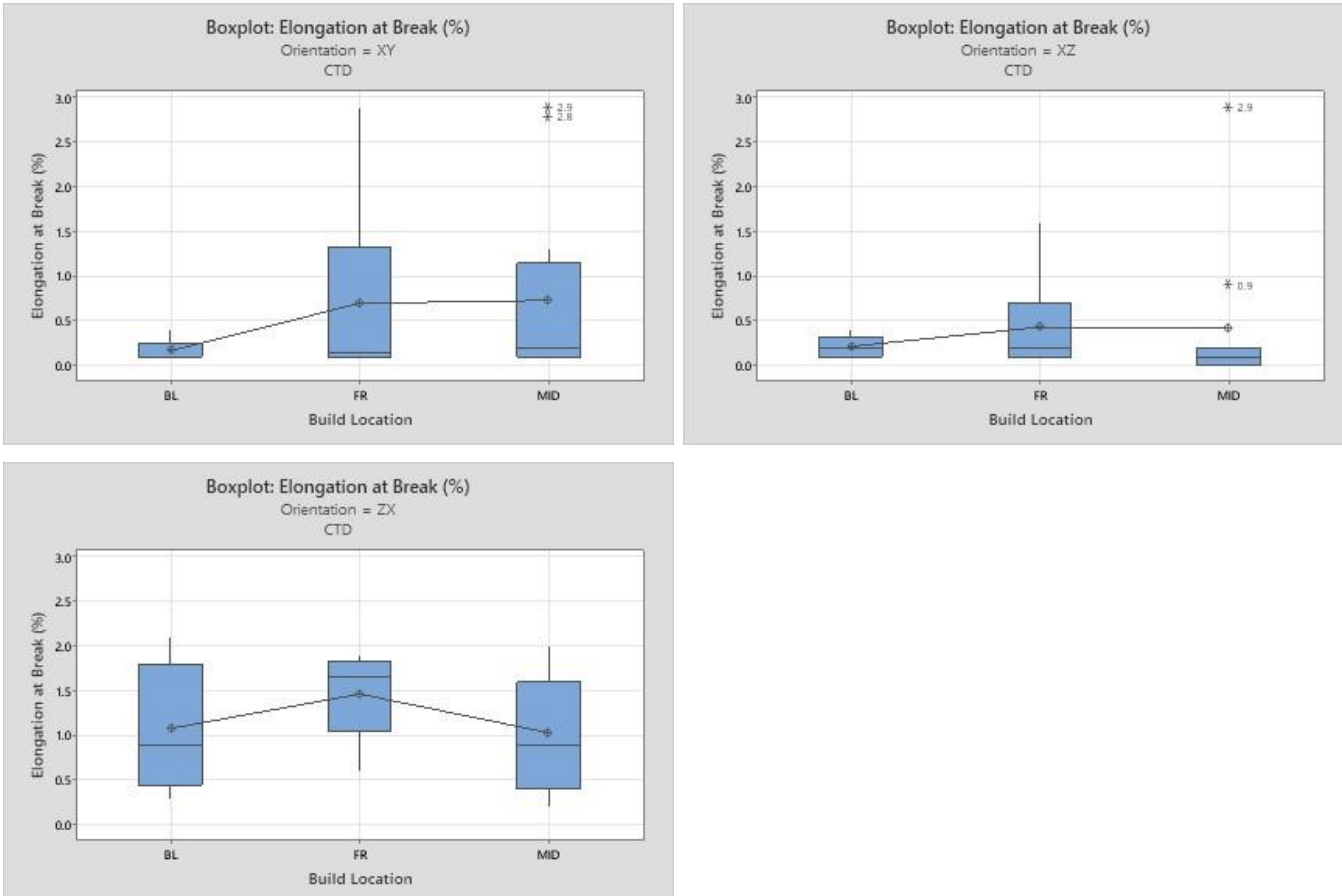


Figure 20. Plot of elongation at break by chamber location, per orientation for CTD.

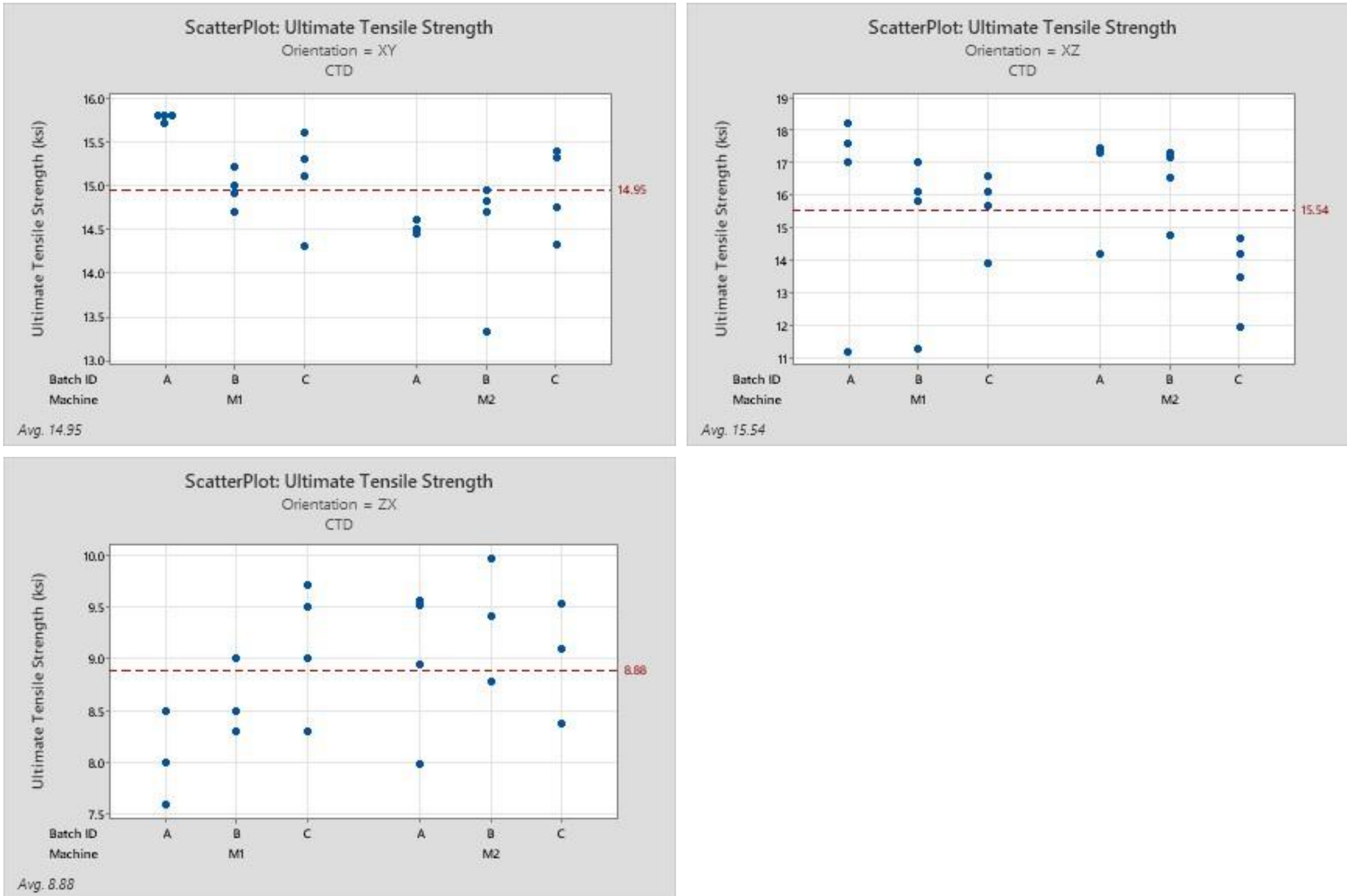


Figure 21. Plot of tensile strength by machine and batch, per orientation for CTD.

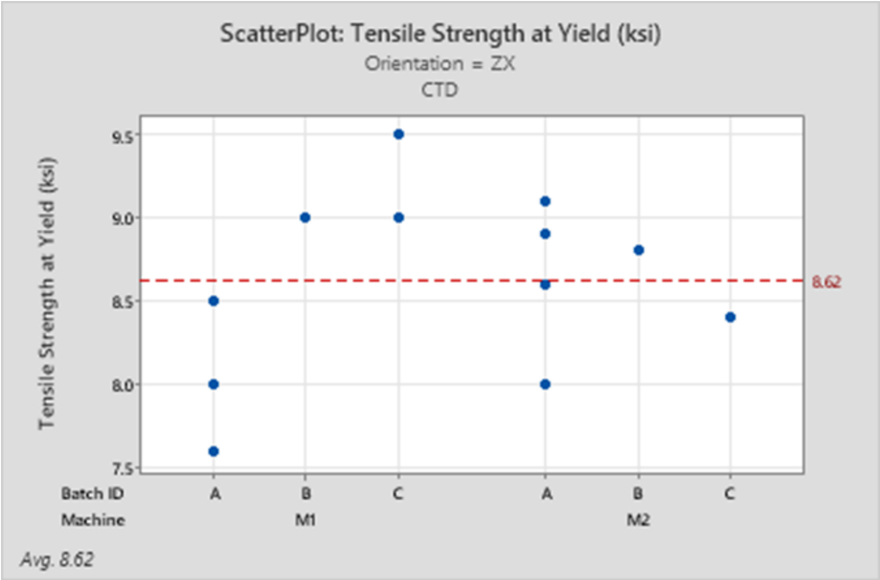


Figure 22. Plot of tensile yield strength by machine and batch, per orientation for CTD

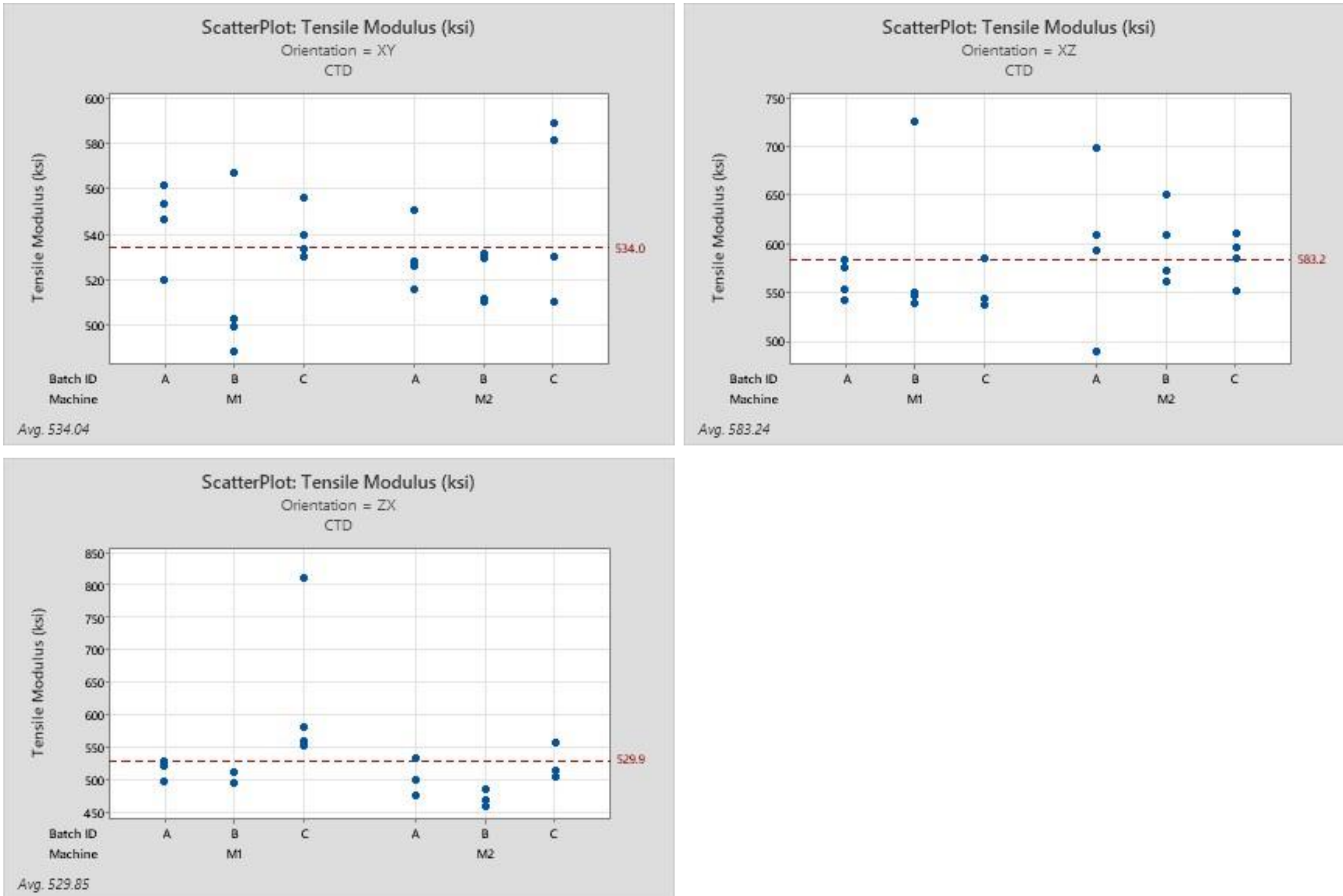


Figure 23. Plot of tensile modulus by machine and batch, per orientation for CTD.

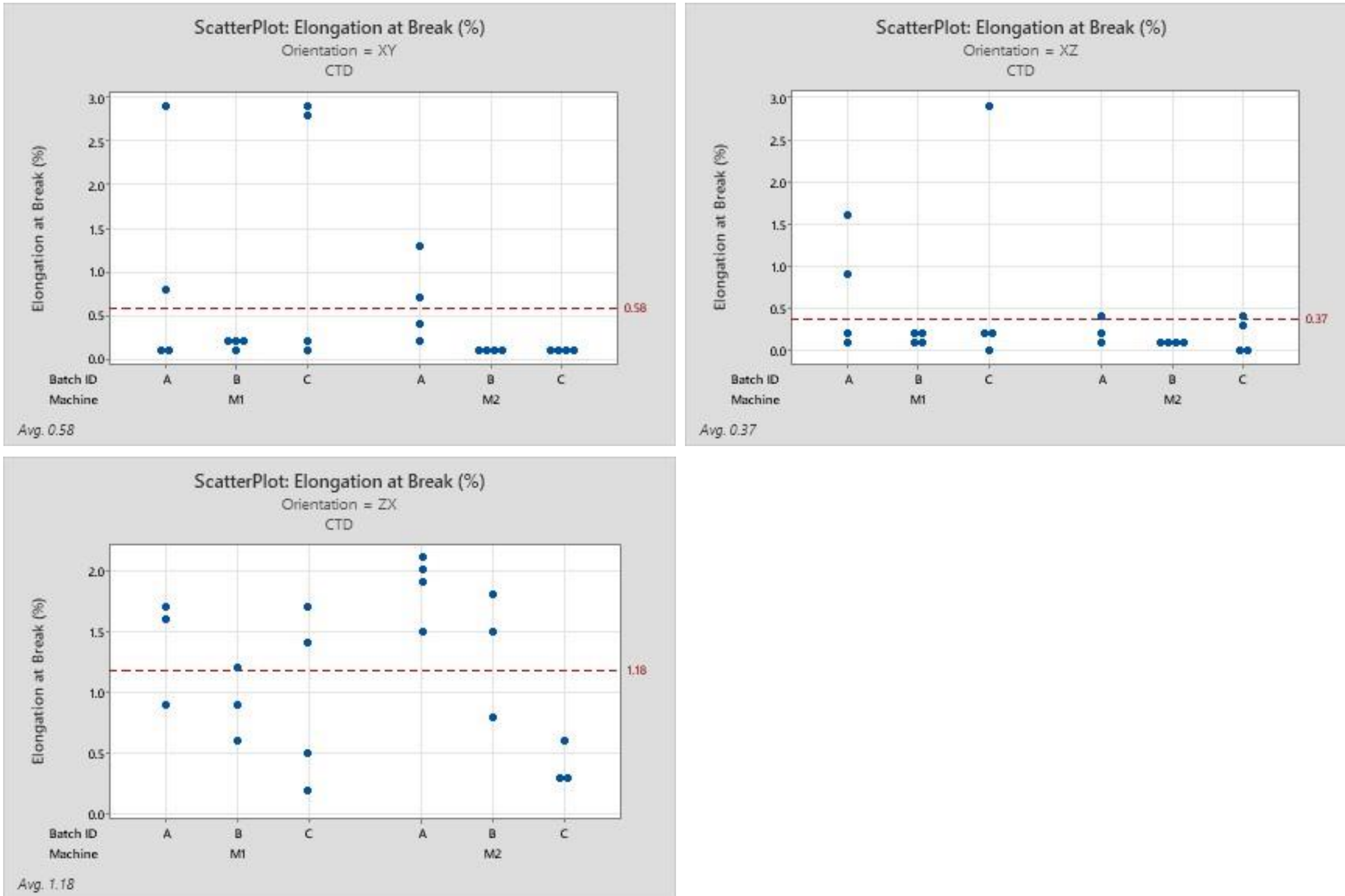


Figure 24. Plot of elongation at break by machine and batch, per orientation for CTD.

8.2 RTD Tension Properties

Table 6. Tensile RTD Ensemble Data

Tension - RTD	**Strength & Modulus**									**As Built, -45/+45**
SPECIMEN NAME	BATCH	MACHINE	ORIENTATION	LOCATION	FILL	TENSILE STRENGTH [ksi]	STRENGTH AT YIELD [ksi]	TENSILE MODULUS [ksi]	ELONGATION AT BREAK [%]	FAILURE MODE
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-10-XY-T-FR-RTD-1	A	M1	XY	Front Rt.	SF	11.74	8.92	435.91	4.2	Radius
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-11-XY-T-MID-RTD-3	A	M1	XY	MID	SF	11.76	9.01	439.93	4.1	Radius
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-12-XY-T-BL-RTD-4	A	M1	XY	Back Left	SF	11.75	9.06	429.71	4.2	Radius
TPAMCN03-SSYS-ACN03-M1-A-RUN1-RF-12-XY-T-MID-RTD-7	A	M1	XY	MID	RF	11.89	9.08	426.71	4.3	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-10-XZ-T-FR-RTD-6	A	M1	XZ	Front Rt.	SF	14.14	10.67	448.44	4.6	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-11-XZ-T-MID-RTD-12	A	M1	XZ	MID	SF	14.21	10.74	484.03	4.3	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-12-XZ-T-BL-RTD-13	A	M1	XZ	Back Left	SF	14.29	11.05	463.73	4.5	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-RF-12-XZ-T-MID-RTD-28	A	M1	XZ	MID	RF	14.39	11.15	459.86	4.5	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-10-ZX-T-FR-RTD-10	A	M1	ZX	Front Rt.	SF	8.23	8.23	413.43	1.9	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-11-ZX-T-MID-RTD-21	A	M1	ZX	MID	SF	8.14	8.14	402.32	2	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-12-ZX-T-BL-RTD-19	A	M1	ZX	Back Left	SF	8.28	8.28	408.19	2	Gage, Grips
TPAMCN03-SSYS-ACN03-M1-A-RUN1-RF-12-ZX-T-MID-RTD-23	A	M1	ZX	MID	RF	8.9	8.9	390.88	2.3	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-2-XY-T-FR-RTD-1	A	M2	XY	Front Rt.	SF	10.80	8.35	412.48	4.3	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-3-XY-T-MID-RTD-3	A	M2	XY	MID	SF	10.61	8.91	369.59	4.3	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-4-XY-T-BL-RTD-4	A	M2	XY	Back Left	SF	11.19	8.78	413.51	4.5	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-RF-4-XY-T-MID-RTD-7	A	M2	XY	MID	RF	10.95	8.26	425.49	4.4	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-2-XZ-T-FR-RTD-6	A	M2	XZ	Front Rt.	SF	13.75	10.26	440.66	4.4	Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-3-XZ-T-MID-RTD-12	A	M2	XZ	MID	SF	13.86	10.33	436.71	4.5	Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-4-XZ-T-BL-RTD-13	A	M2	XZ	Back Left	SF	14.08	14.08	475.22	4.3	Gage

Tension - RTD	Strength & Modulus					As Built, -45/+45				
TPAMCN03-SSYS-ACN03-M2-A-RUN1-RF-4-XZ-T-MID-RTD-28	A	M2	XZ	MID	RF	13.46	9.87	456.52	4.1	Gage
TPAMCNO3-SSYS-ACN03-M2-A-RUN1-SF-2-ZX-T-FR-RTD-10	A	M2	ZX	Front Rt.	SF	8.52	8.52	409.12	2.1	At Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-3-ZX-T-MID-RTD-21	A	M2	ZX	MID	SF	8.73	8.28	419.15	2.2	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-4-ZX-T-BL-RTD-19	A	M2	ZX	Back Left	SF	9.6	8.05	441.49	2.5	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-RF-4-ZX-T-MID-RTD-23	A	M2	ZX	MID	RF	10.2	8.7	409.49	2.8	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-5-XY-T-MID-RTD-3	B	M1	XY	MID	SF	11.65	9.49	405.72	4	Radius
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-7-XY-T-FR-RTD-1	B	M1	XY	Front Rt.	SF	11.52	9.23	410.69	4.1	Radius
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-8-XY-T-BL-RTD-4	B	M1	XY	Back Left	SF	11.62	8.84	430.45	4.1	Radius
TPAMCN03-SSYS-ACN03-M1-B-RUN1-RF-8-XY-T-MID-RTD-7	B	M1	XY	MID	RF	11.52	9.44	409.9	4	Radius
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-5-XZ-T-MID-RTD-12	B	M1	XZ	MID	SF	14.18	10.73	476.34	4.3	Gage, Radius
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-7-XZ-T-FR-RTD-6	B	M1	XZ	Front Rt.	SF	13.94	10	475.21	4.5	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-R1-8-XZ-T-BL-RTD-13	B	M1	XZ	Back Left	R1	13.9	10.59	456.49	4.4	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-RF-8-XZ-T-MID-RTD-28	B	M1	XZ	MID	RF	13.89	10.5	465.89	4.4	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-5-ZX-T-MID-RTD-21	B	M1	ZX	MID	SF	8.25	8.25	406.8	2	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-7-ZX-T-FR-RTD-10	B	M1	ZX	Front Rt.	SF	9.42	9.42	408.49	2.3	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-8-ZX-T-BL-RTD-19	B	M1	ZX	Back Left	SF	7.8	7.8	406.06	1.9	Gage, Grips
TPAMCN03-SSYS-ACN03-M1-B-RUN1-RF-8-ZX-T-MID-RTD-23	B	M1	ZX	MID	RF	7.44	7.44	415.53	1.8	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-5-XY-T-MID-RTD-3	B	M2	XY	MID	SF	11.33	9.06	382.3	4.5	Gage, Radius
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-7-XY-T-FR-RTD-1	B	M2	XY	Front Rt.	SF	10.8	8.48	373.77	4.6	Gage, Radius
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-8-XY-T-BL-RTD-4	B	M2	XY	Back Left	SF	11.32	8.71	381.97	4.705	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-RF-8-XY-T-MID-RTD-7	B	M2	XY	MID	RF	11.24	8.67	377.28	4.7	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-5-XZ-T-MID-RTD-12	B	M2	XZ	MID	SF	13.81	10.32	439.26	4.7	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-7-XZ-T-FR-RTD-6	B	M2	XZ	Front Rt.	SF	13.69	10.48	443.34	4.5	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-8-XZ-T-BL-RTD-13	B	M2	XZ	Back Left	SF	13.87	11.03	412.19	4.6	Radius

Tension - RTD	Strength & Modulus									As Built, -45/+45
TPAMCN03-SSYS-ACN03-M2-B-RUN1-RF-8-XZ-T-MID-RTD-28	B	M2	XZ	MID	RF	14.02	10.34	413	4.9	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-5-ZX-T-MID-RTD-21	B	M2	ZX	MID	SF	9.53	8.8	386.51	2.6	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-7-ZX-T-FR-RTD-10	B	M2	ZX	Front Rt.	SF	8.65	8.65	378.42	2.3	Radius, Grip
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-8-ZX-T-BL-RTD-19	B	M2	ZX	Back Left	SF	8.96	8.96	373.47	2.4	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-4-XY-T-BL-RTD-4	C	M1	XY	Back Left	SF	12	9.32	429.56	3.9	Radius
TPAMCN03-SSYS-ACN03-M1-C-RUN1-RF-4-XY-T-MID-RTD-7	C	M1	XY	MID	RF	11.6	9.64	438.36	3.8	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-2-XY-T-FR-RTD-1	C	M1	XY	Front Rt.	SF	11.78	9.51	407.01	4.1	Radius
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-3-XY-T-MID-RTD-3	C	M1	XY	MID	SF	11.47	9.41	418.29	3.8	Radius
TPAMCN03-SSYS-ACN03-M1-C-RUN1-RF-1-XY-T-MID-RTD-1	C	M1	XY	MID	RF	11.43	9.12	419.49	4	Gage, Radius
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-4-XZ-T-BL-RTD-13	C	M1	XZ	Back Left	SF	14.1	10.77	469.65	4.1	Radius
TPAMCN03-SSYS-ACN03-M1-C-RUN1-RF-4-XZ-T-MID-RTD-28	C	M1	XZ	MID	RF	14.15	10.9	457.39	4.4	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-2-XZ-T-FR-RTD-6	C	M1	XZ	Front Rt.	SF	14.14	10.5	470.24	4.4	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-3-XZ-T-MID-RTD-12	C	M1	XZ	MID	SF	13.78	10.86	459.88	3.9	Gage, Grips
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-4-ZX-T-BL-RTD-19	C	M1	ZX	Back Left	SF	8.74	8.74	404.48	2.1	Gage, Radius
TPAMCN03-SSYS-ACN03-M1-C-RUN1-RF-4-ZX-T-MID-RTD-23	C	M1	ZX	MID	RF	8.59	8.59	427.15	2	Gage, Grips
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-2-ZX-T-FR-RTD-10	C	M1	ZX	Front Rt.	SF	8.36	8.36	400.36	2.1	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-3-ZX-T-MID-RTD-21	C	M1	ZX	MID	SF	9.36	9.35	408.17	2.4	Gage, Radius, Grips
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-10-XY-T-FR-RTD-1	C	M2	XY	Front Rt.	SF	11.42	9.13	404.08	3.9	Radius
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-11-XY-T-MID-RTD-3	C	M2	XY	MID	SF	11.72	9.19	401.98	4.2	Gage, Radius
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-12-XY-T-BL-RTD-4	C	M2	XY	Back Left	SF	12.14	9.66	400.61	4.3	Radius
TPAMCN03-SSYS-ACN03-M2-C-RUN1-RF-12-XY-T-MID-RTD-7	C	M2	XY	MID	RF	11.93	9.69	402.57	4.2	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-10-XZ-T-FR-RTD-6	C	M2	XZ	Front Rt.	SF	14.2	10.63	446.93	4.6	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-11-XZ-T-MID-RTD-12	C	M2	XZ	MID	SF	14.24	10.32	419.84	4.9	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-12-XZ-T-BL-RTD-13	C	M2	XZ	Back Left	SF	14.19	10.31	440.25	4.6	Gage

Tension - RTD	Strength & Modulus					As Built, -45/+45				
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-10-ZX-T-FR-RTD-10	C	M2	ZX	Front Rt.	SF	7.89	7.89	394.46	1.9	Gage, Grips
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-11-ZX-T-MID-RTD-21	C	M2	ZX	MID	SF	9.89	9.29	388.19	2.7	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-12-ZX-T-BL-RTD-19	C	M2	ZX	Back Left	SF	9.58	9.27	383.2	2.6	Gage, Grips
TPAMCN03-SSYS-ACN03-M2-C-RUN1-RF-12-ZX-T-MID-RTD-23	C	M2	ZX	MID	RF	9.62	9.52	375.43	2.7	Gage, Radius

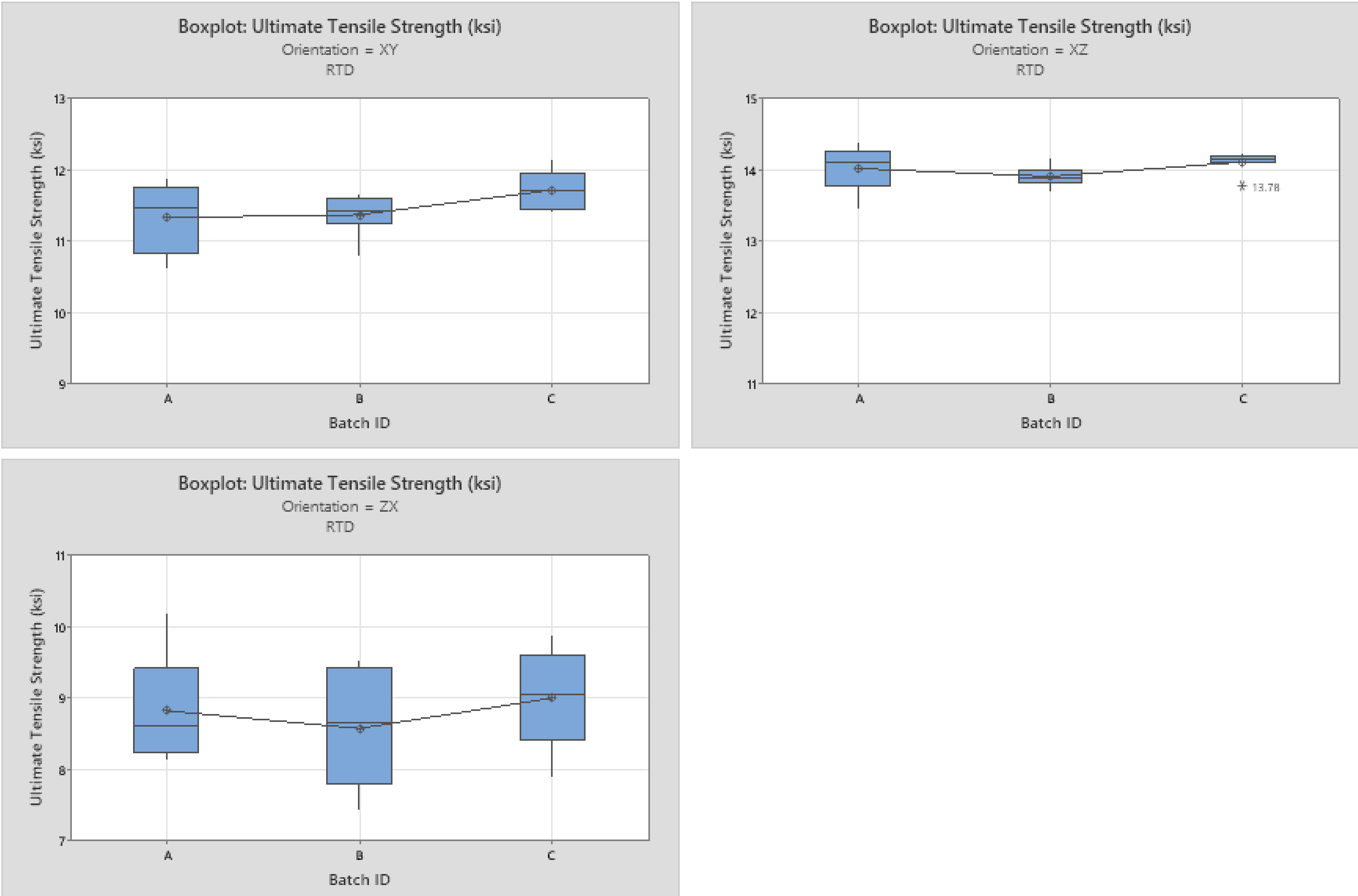


Figure 25. Plot of tensile strength by batch, per orientation for RTD.

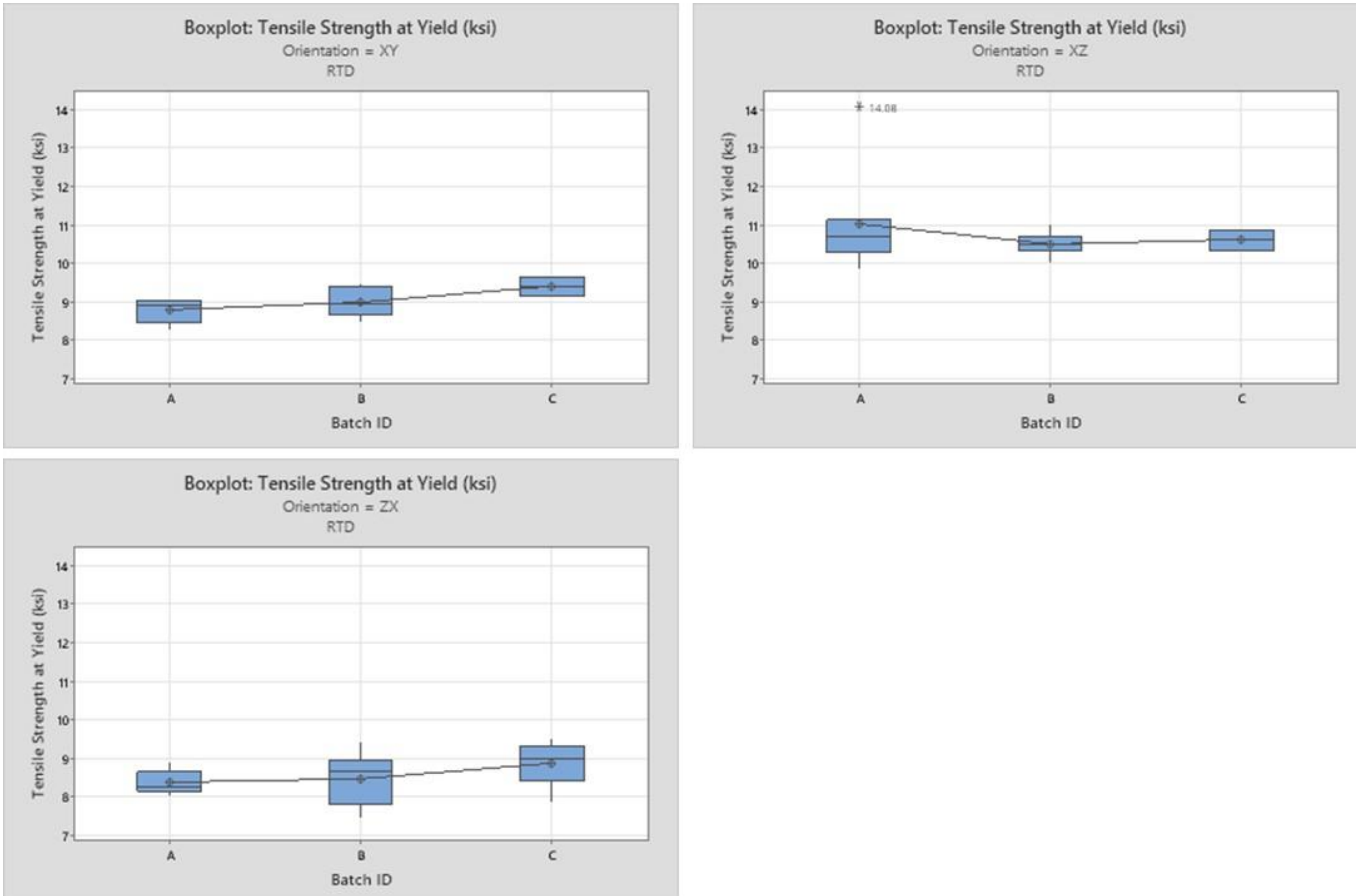
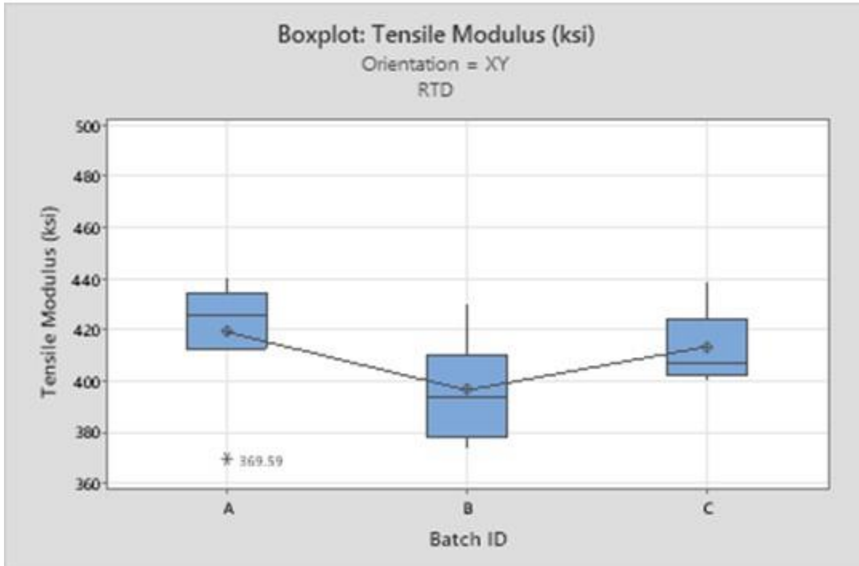
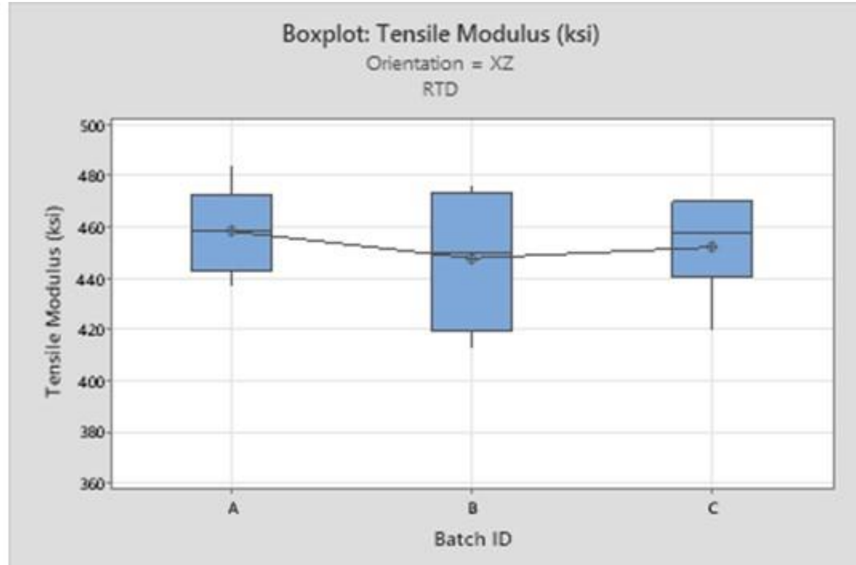


Figure 26. Plot of tensile yield strength by batch, per orientation for RTD.





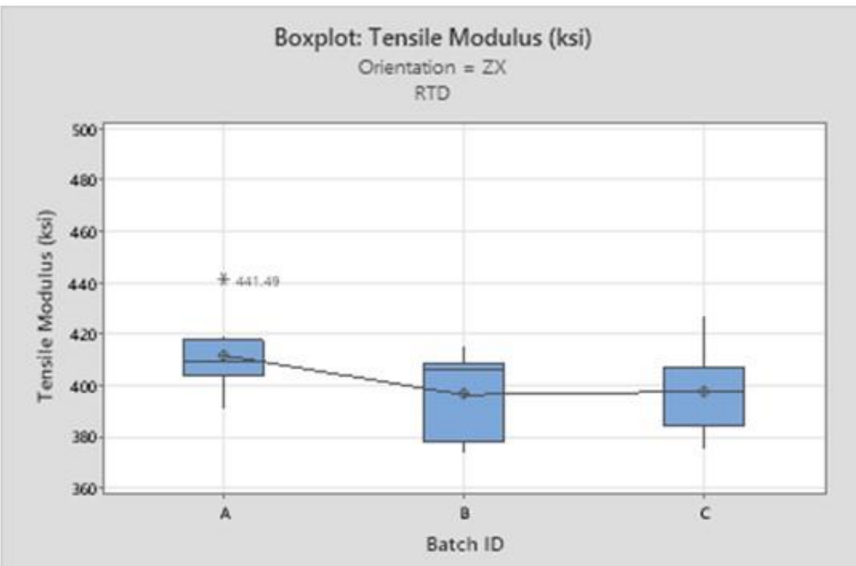


Figure 27. Plot of tensile modulus by batch, per orientation for RTD

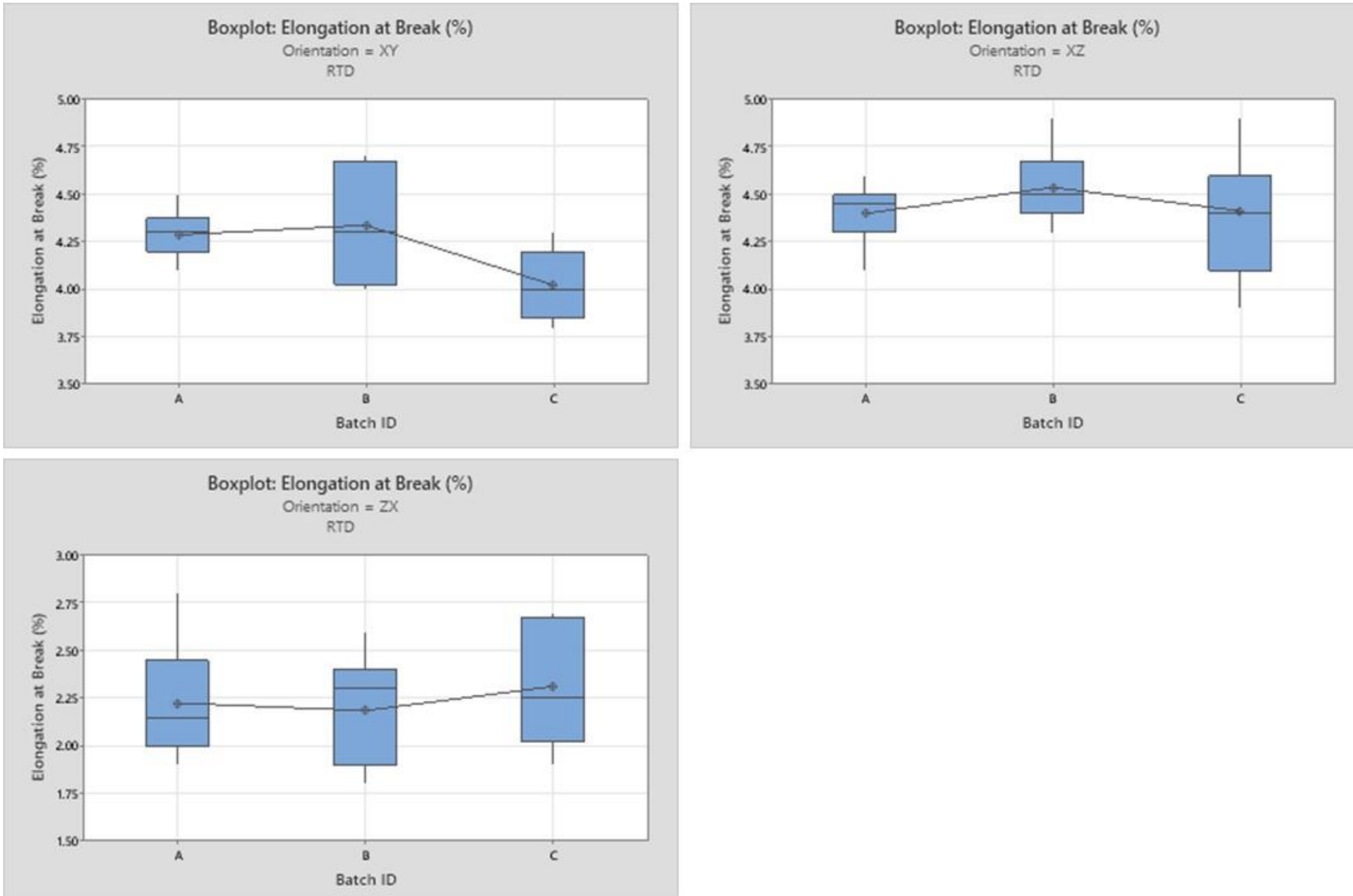


Figure 28. Plot of elongation at break by batch, per orientation for RTD.

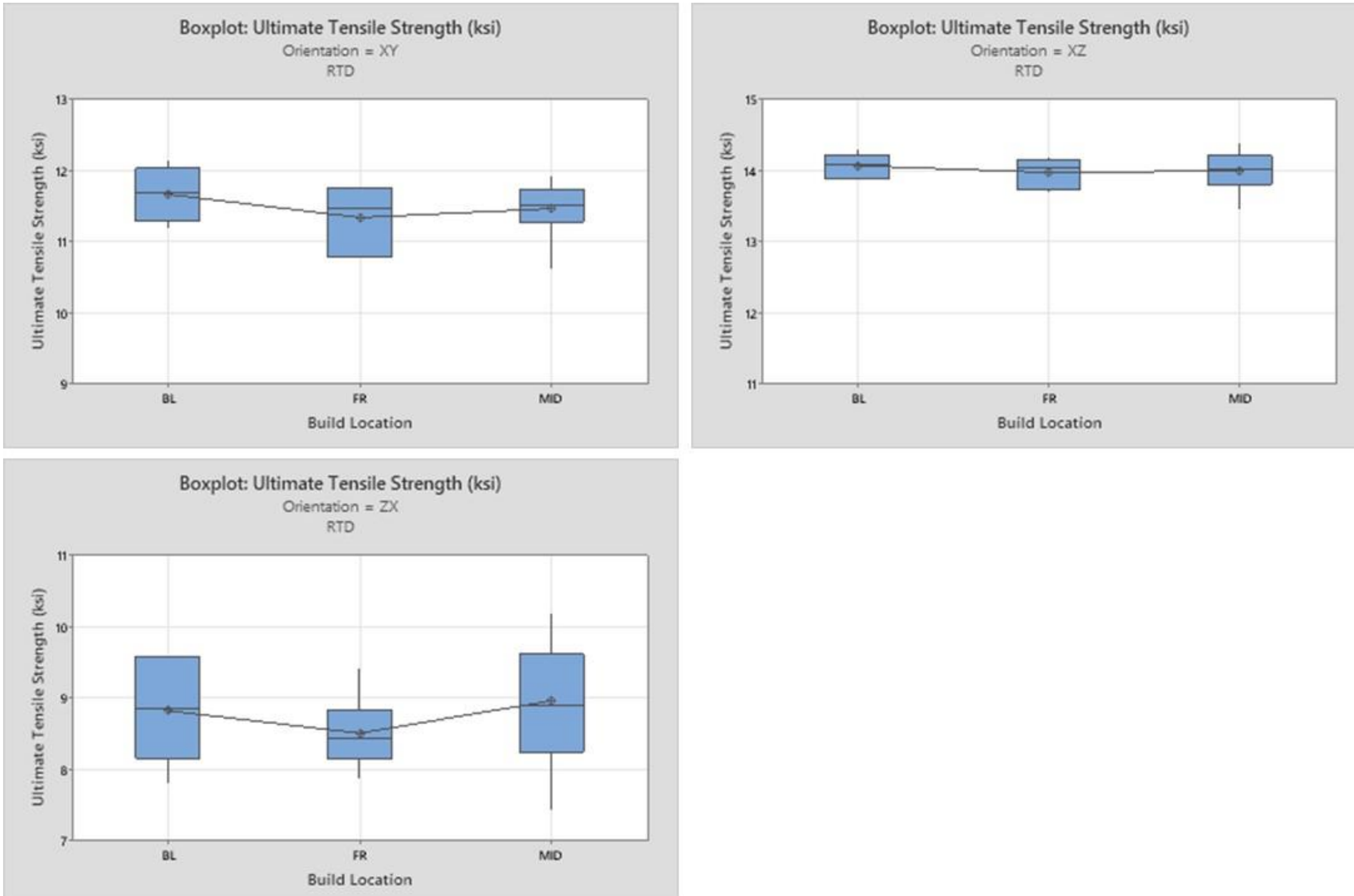


Figure 29. Plot of tensile strength by chamber location, per orientation for RTD.

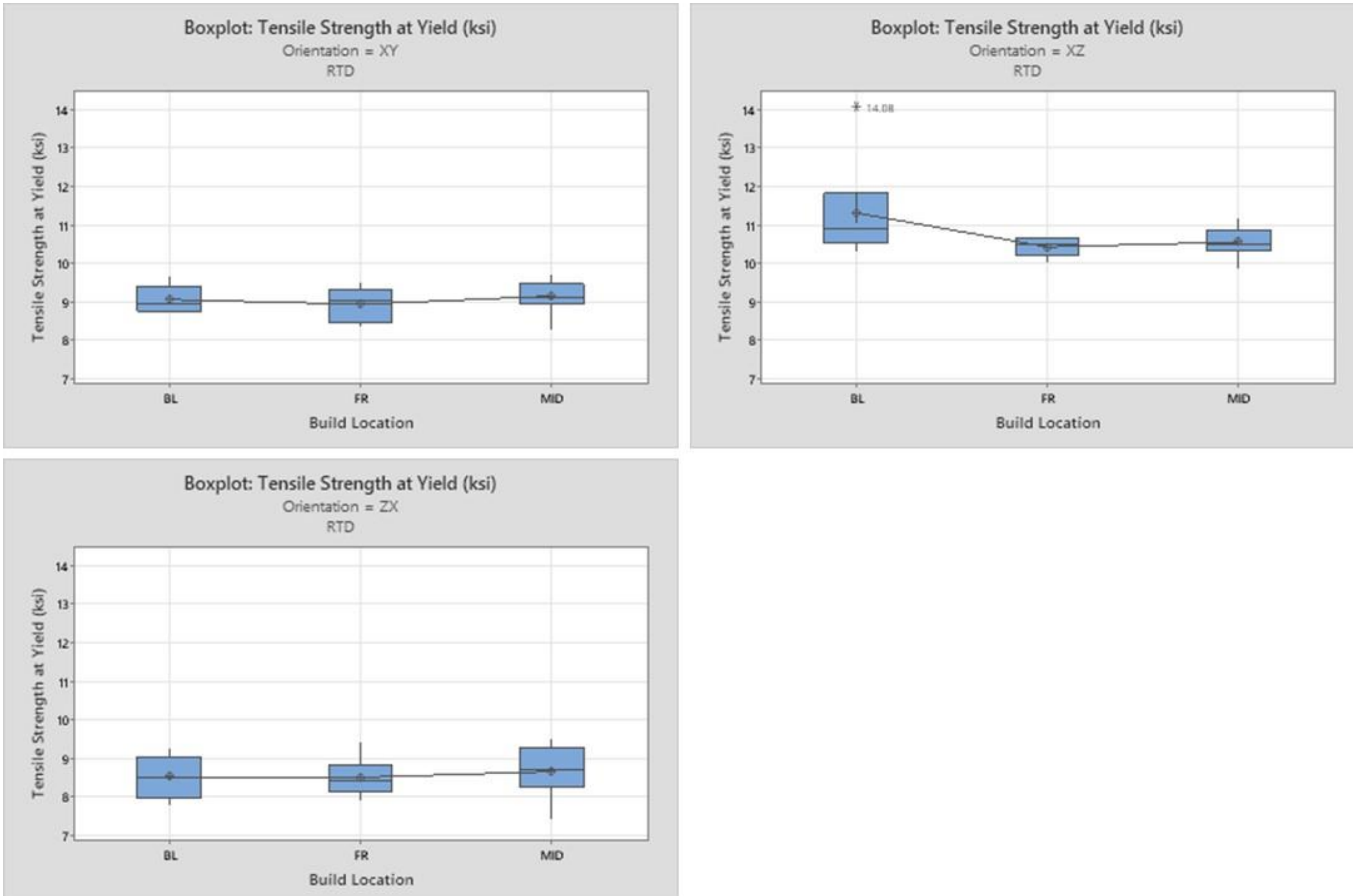


Figure 30. Plot of tensile yield strength by chamber location, per orientation for RTD.

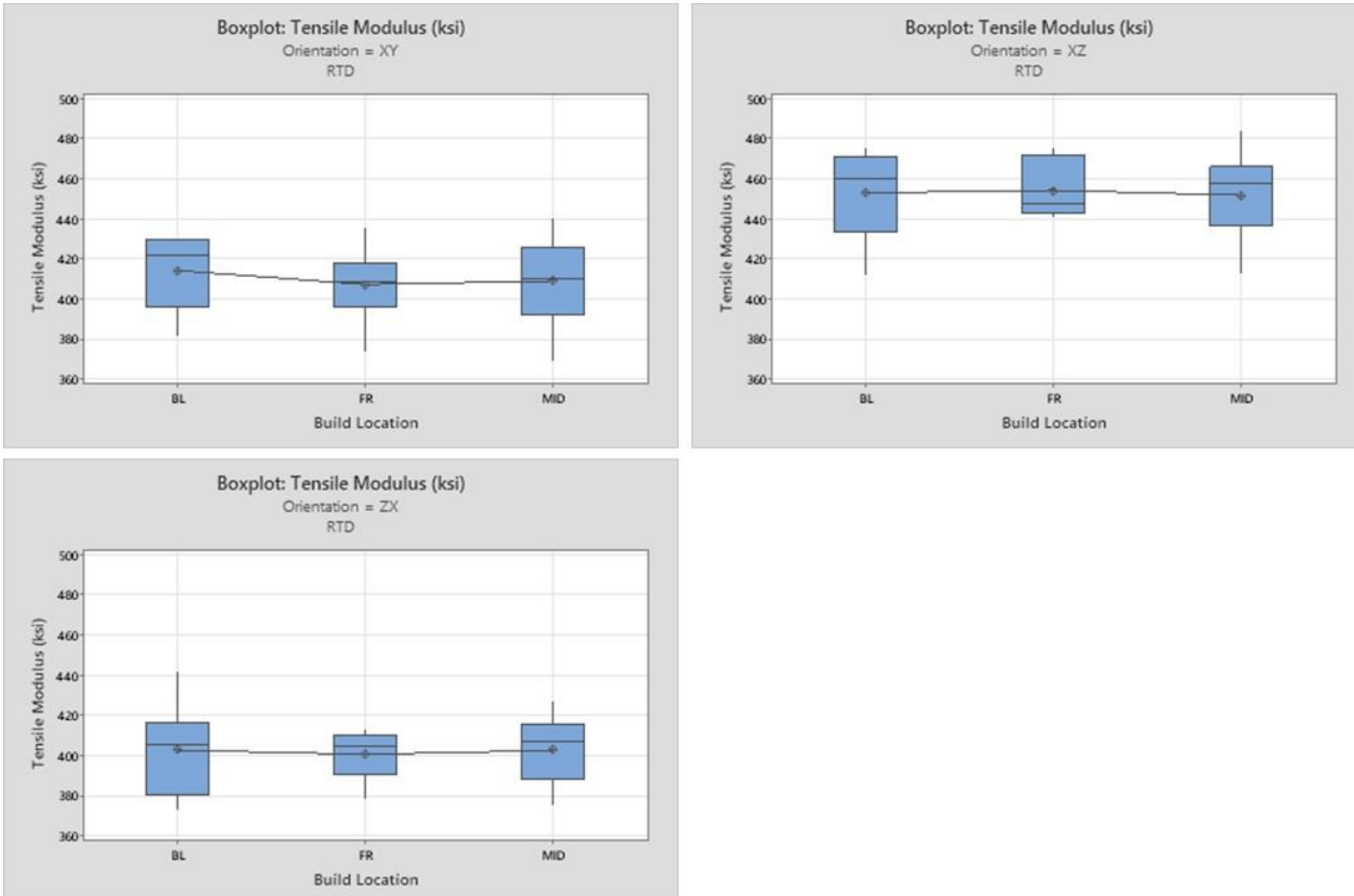


Figure 31. Plot of tensile modulus by chamber location, per orientation for RTD.

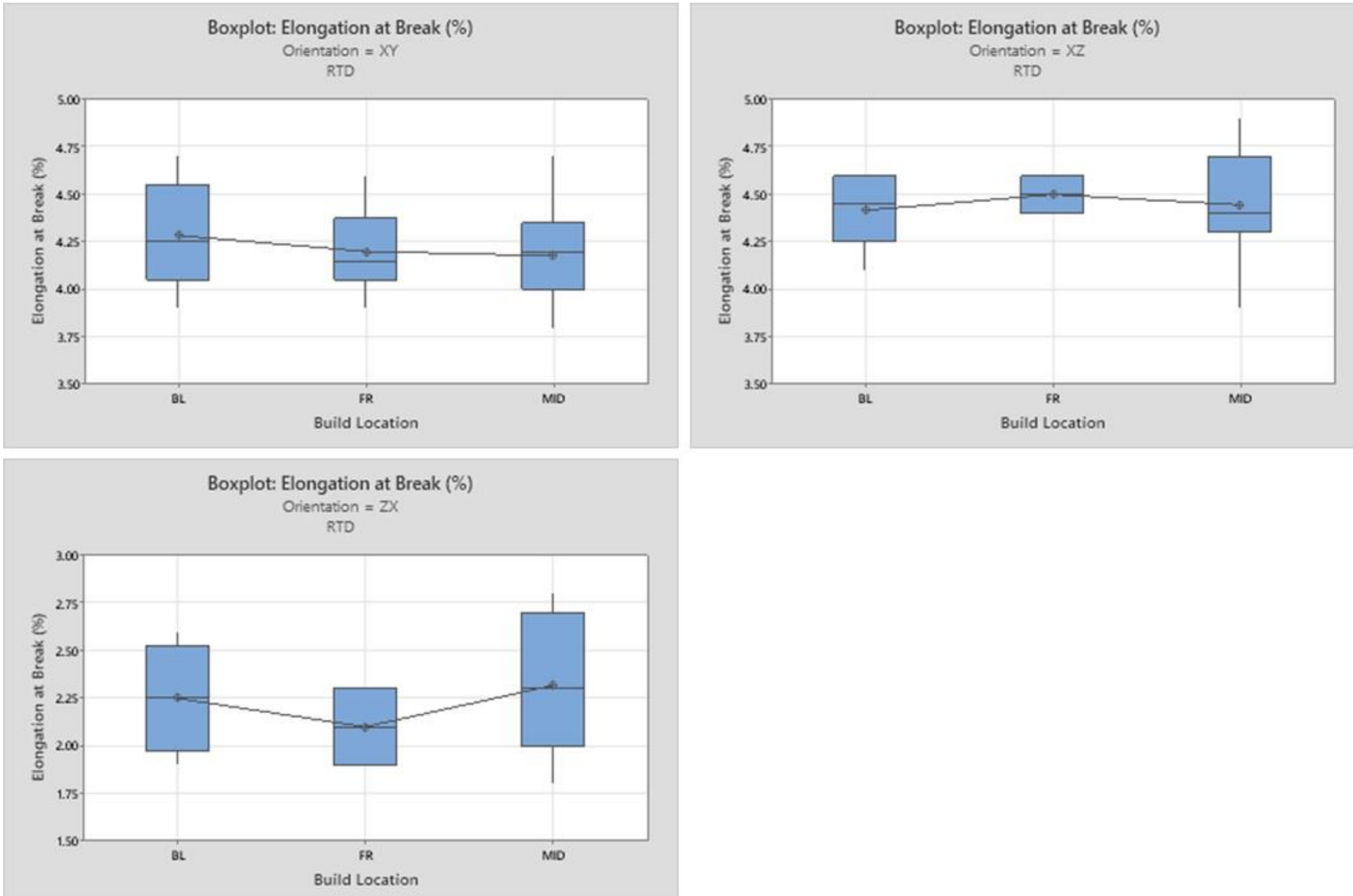


Figure 32. Plot of elongation at break by chamber location, per orientation for RTD.

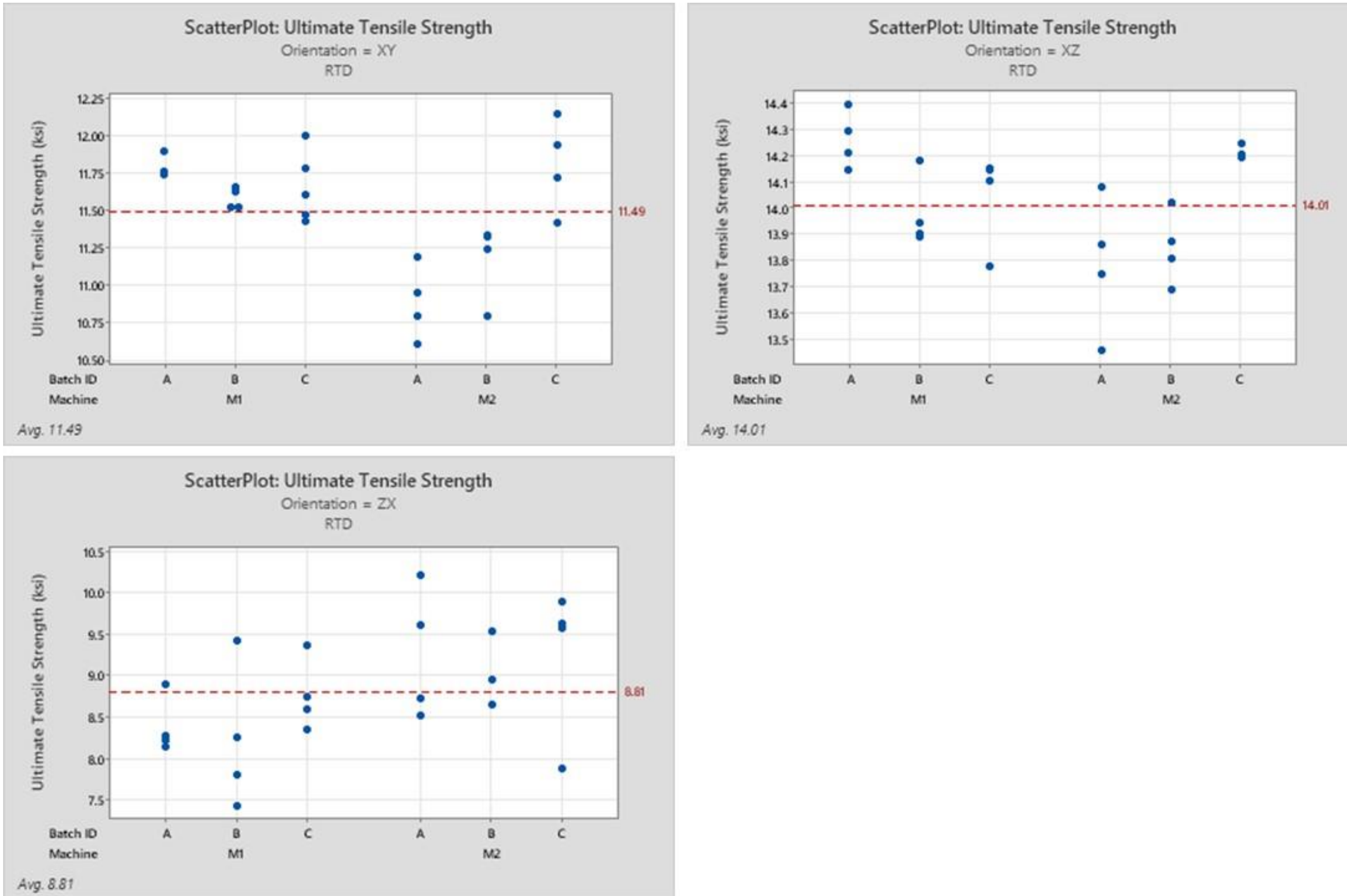


Figure 33. Plot of tensile strength by machine and batch, per orientation for RTD.

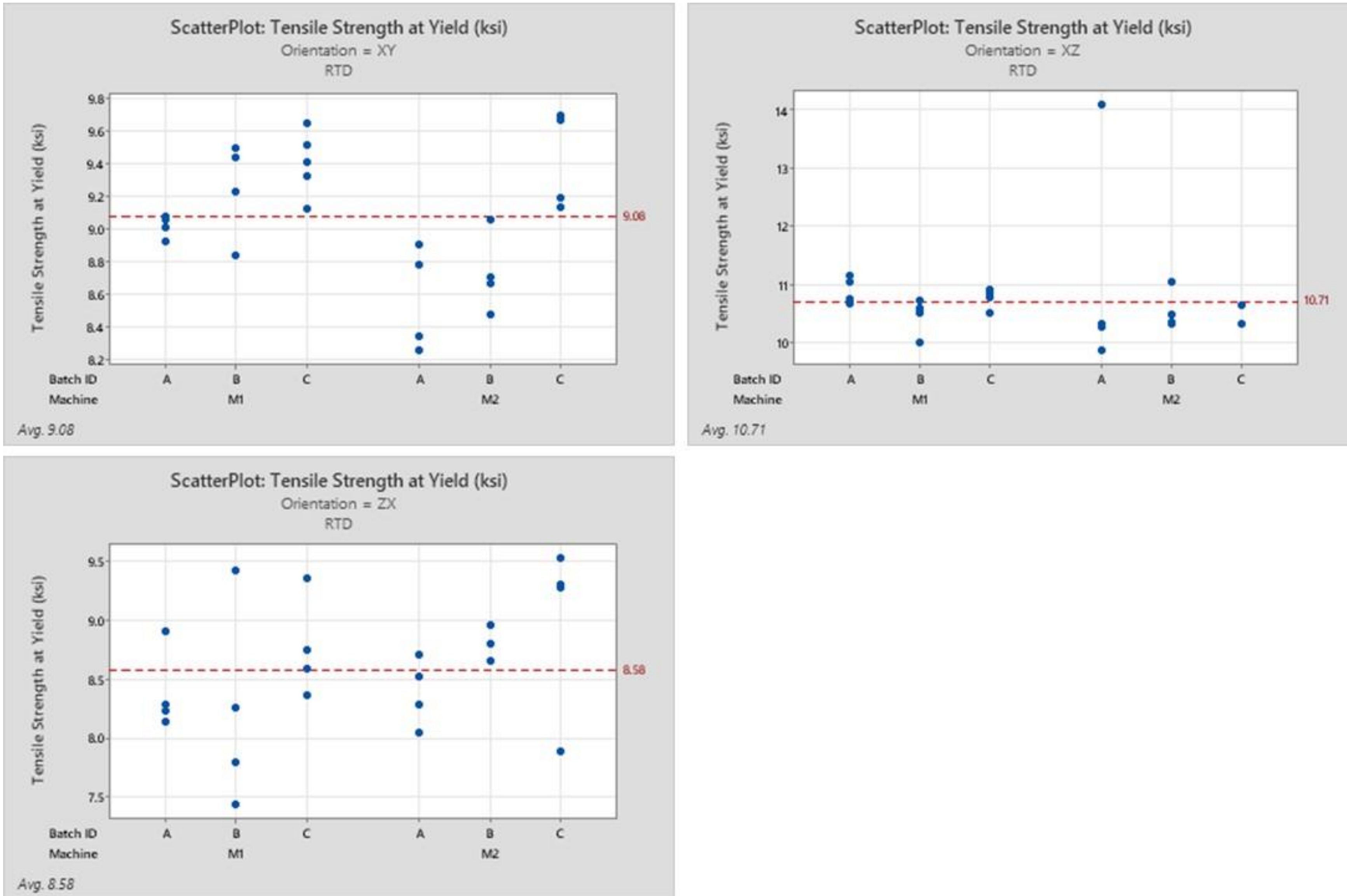


Figure 34. Plot of tensile yield strength by machine and batch, per orientation for RTD

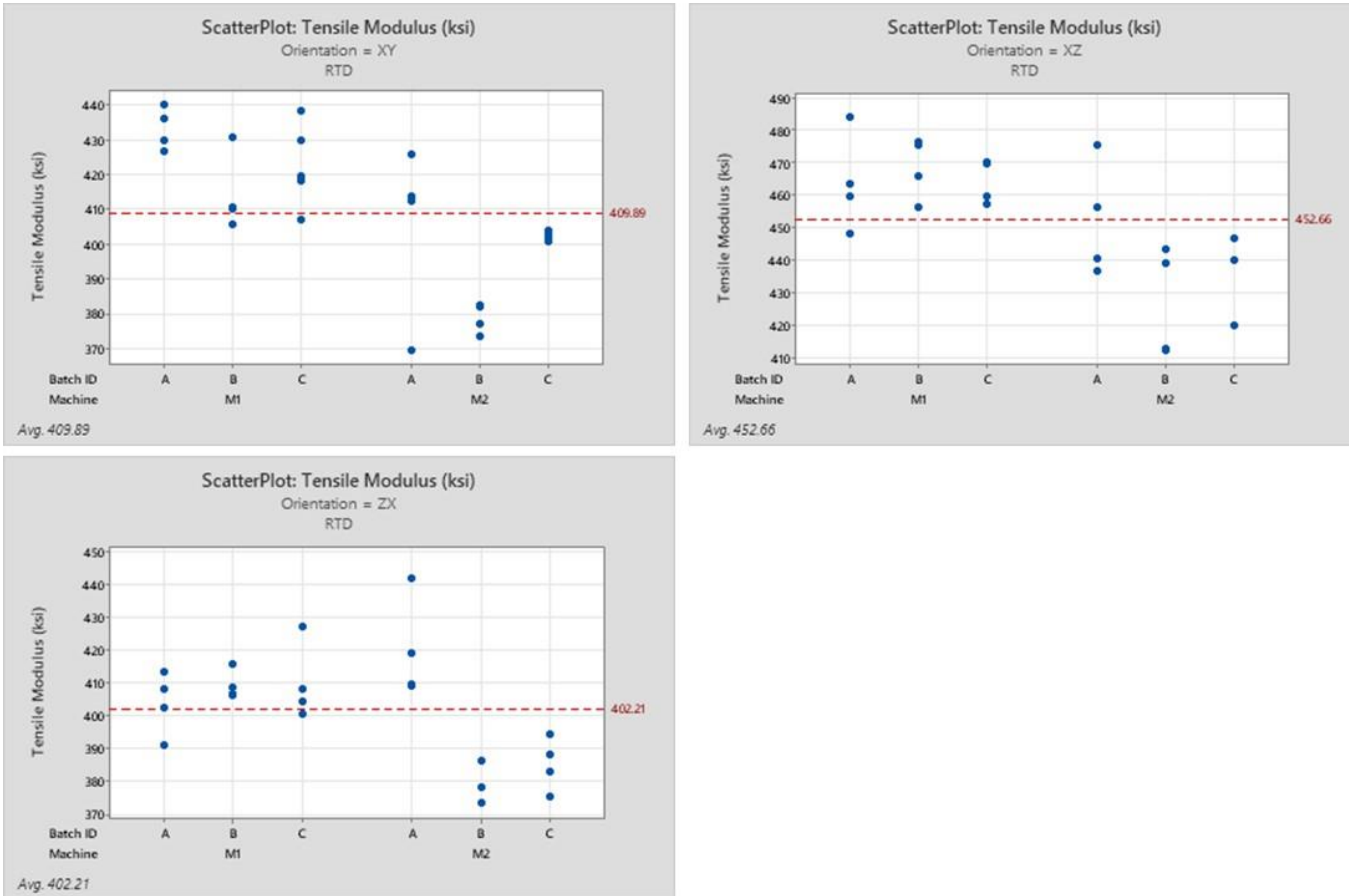


Figure 35. Plot of tensile modulus by machine and batch, per orientation for RTD.

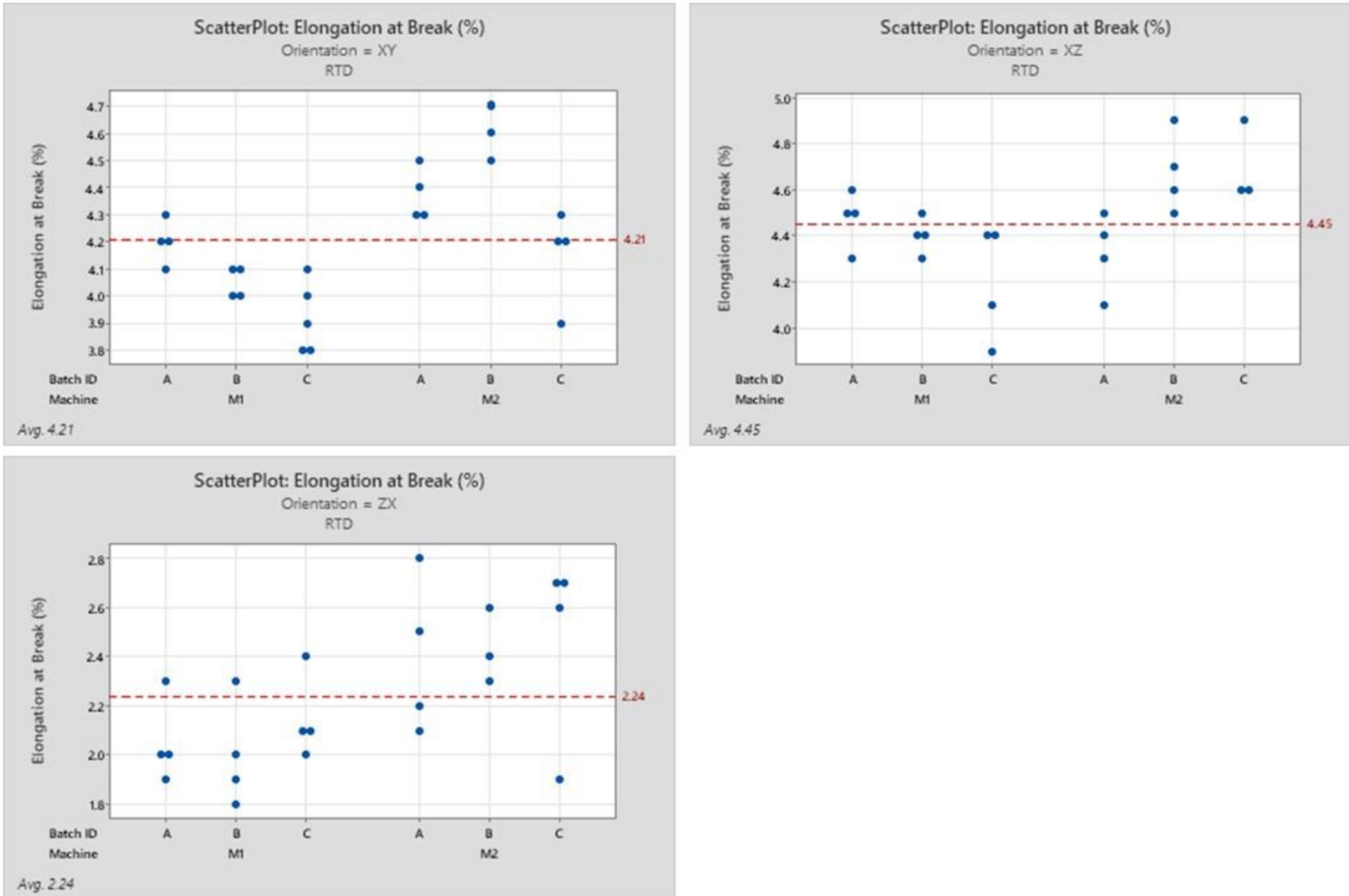


Figure 36. Plot of elongation at break by machine and batch, per orientation for RTD.

8.3 RTA Tension Properties

Table 7. Tensile RTA Ensemble Data

Tension – RTA	**Strength & Modulus**									**As Built -45/+45**
SPECIMEN NAME	BATCH	MACHINE	ORIENTATION	LOCATION	FILL	TENSILE STRENGTH [ksi]	STRENGTH AT YIELD [ksi]	TENSILE MODULUS [ksi]	ELONGATION AT BREAK [%]	FAILURE MODE
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-10-XY-T-FR-RTA-3	A	M1	XY	Front Rt.	SF	11.78	9.24	426.47	4.2	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-11-XY-T-MID-RTA-5	A	M1	XY	MID	SF	11.84	9.2	446.37	4	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-RF-11-XY-T-MID-RTA-7	A	M1	XY	MID	RF	11.75	9.19	429.78	4.2	Radius
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-12-XY-T-BL-RTA-5	A	M1	XY	Back Left	SF	11.91	9.23	429.3	4.3	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-9-XZ-T-BL-RTA-5	A	M1	XZ	Back Left	SF	13.74	9.84	479.61	4.5	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-11-XZ-T-FR-RTA-11	A	M1	XZ	Front Rt.	SF	14.17	10.86	469.73	4.4	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-12-XZ-T-MID-RTA-12	A	M1	XZ	MID	SF	14.24	10.68	458.18	4.5	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-RF-12-XZ-T-MID-RTA-15	A	M1	XZ	MID	RF	14.2	11.02	459.2	4.5	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-10-ZX-T-MID-RTA-13	A	M1	ZX	MID	SF	9.04	8.86	391.17	2.4	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-RF-10-ZX-T-MID-RTA-15	A	M1	ZX	MID	RF	9.29	9.04	394.27	2.5	Gage, Grips
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-11-ZX-T-BL-RTA-20	A	M1	ZX	Back Left	SF	7.44	7.44	406.57	1.8	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-RF-11-ZX-T-MID-RTA-23	A	M1	ZX	MID	RF	8.62	8.62	402.56	2.1	Radius
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-12-ZX-T-FR-RTA-17	A	M1	ZX	Front Rt.	SF	7.37	7.37	403.16	1.8	Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-2-XY-T-FR-RTA-3	A	M2	XY	Front Rt.	SF	11.05	9.48	823.68	2.2	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-3-XY-T-MID-RTA-5	A	M2	XY	MID	SF	10.88	9.47	796.57	2.3	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-RF-3-XY-T-MID-RTA-7	A	M2	XY	MID	RF	10.94	9.3	820.29	2.4	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-4-XY-T-BL-RTA-5	A	M2	XY	Back Left	SF	11.19	8.62	874.06	2.4	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-3-XZ-T-FR-RTA-11	A	M2	XZ	Front Rt.	SF	13.81	11.54	967.89	2.2	Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-4-XZ-T-MID-RTA-12	A	M2	XZ	MID	SF	13.87	11.95	910.08	2.2	Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-RF-4-XZ-T-MID-RTA-15	A	M2	XZ	MID	RF	13.88	12.11	933.79	2.1	Radius

Tension – RTA	Strength & Modulus									As Built -45/+45
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-2-ZX-T-MID-RTA-13	A	M2	ZX	MID	SF	7.41	7.41	862.47	0.9	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-RF-2-ZX-T-MID-RTA-15	A	M2	ZX	MID	RF	9.81	9.81	823.98	1.3	Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-3-ZX-T-BL-RTA-20	A	M2	ZX	Back Left	SF	8.76	8.76	818.92	1.1	Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-4-ZX-T-FR-RTA-17	A	M2	ZX	Front Rt.	SF	10.18	9.94	821.74	1.4	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-5-XY-T-MID-RTA-5	B	M1	XY	MID	SF	11.56	9.31	421.22	4.1	Radius
TPAMCN03-SSYS-ACN03-M1-B-RUN1-RF-5-XY-T-MID-RTA-7	B	M1	XY	MID	RF	11.54	9.24	417.27	3.9	Radius
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-7-XY-T-FR-RTA-3	B	M1	XY	Front Rt.	SF	11.59	9.15	421.34	3.9	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-8-XY-T-BL-RTA-5	B	M1	XY	Back Left	SF	11.5	8.9	416.48	4.1	Radius
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-5-XZ-T-FR-RTA-11	B	M1	XZ	Front Rt.	SF	14.22	10.48	482.56	4.4	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-6-XZ-T-BL-RTA-5	B	M1	XZ	Back Left	SF	13.62	10.28	451.56	4.6	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-8-XZ-T-MID-RTA-12	B	M1	XZ	MID	SF	13.72	10.22	443.48	4.4	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-RF-8-XZ-T-MID-RTA-15	B	M1	XZ	MID	RF	13.86	10.62	445.81	4.4	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-5-ZX-T-BL-RTA-20	B	M1	ZX	Back Left	SF	9.6	8.96	435.11	2.4	Gage, Grips
TPAMCN03-SSYS-ACN03-M1-B-RUN1-RF-5-ZX-T-MID-RTA-23	B	M1	ZX	MID	RF	8.58	8.58	412.87	2.1	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-7-ZX-T-MID-RTA-13	B	M1	ZX	MID	SF	9.55	9.28	408.1	2.5	Gage, Grips
TPAMCN03-SSYS-ACN03-M1-B-RUN1-RF-7-ZX-T-MID-RTA-15	B	M1	ZX	MID	RF	8.14	8.14	400.93	2	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-8-ZX-T-FR-RTA-17	B	M1	ZX	Front Rt.	SF	8.29	8.29	393.62	2	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-5-XY-T-MID-RTA-5	B	M2	XY	MID	SF	11.13	9.91	922.17	2.1	Radius
TPAMCN03-SSYS-ACN03-M2-B-RUN1-RF-5-XY-T-MID-RTA-7	B	M2	XY	MID	RF	11.34	9.98	874.18	2	Radius
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-7-XY-T-FR-RTA-3	B	M2	XY	Front Rt.	SF	10.97	7.5	471.4	4.3	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-8-XY-T-BL-RTA-5	B	M2	XY	Back Left	SF	11.59	8.64	431.25	4.5	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-RF-8-XZ-T-MID-RTA-15	B	M2	XZ	MID	RF	13.96	10.67	449.78	4.5	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-8-XZ-T-MID-RTA-12	B	M2	XZ	MID	SF	14	9.91	461.74	4.5	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-7-ZX-T-MID-RTA-13	B	M2	ZX	MID	SF	8.87	8.87	403.13	2.2	Gage

Tension – RTA	Strength & Modulus									As Built -45/+45
TPAMCN03-SSYS-ACN03-M2-B-RUN1-RF-7-ZX-T-MID-RTA-15	B	M2	ZX	MID	RF	8.83	8.77	401.19	2.2	Radius
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-8-ZX-T-FR-RTA-17	B	M2	ZX	Front Rt.	SF	8.52	8.52	404.86	2.1	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-2-XY-T-FR-RTA-3	C	M1	XY	Front Rt.	SF	11.75	9.41	418.08	4	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-3-XY-T-MID-RTA-5	C	M1	XY	MID	SF	11.67	9.29	415.16	4	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-RF-3-XY-T-MID-RTA-7	C	M1	XY	MID	RF	11.73	9.23	431.5	3.9	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-4-XY-T-BL-RTA-5	C	M1	XY	Back Left	SF	11.9	9.38	424.62	3.9	Radius
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-1-XZ-T-BL-RTA-5	C	M1	XZ	Back Left	SF	14.26	10.28	491.721	4.3	Radius
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-3-XZ-T-FR-RTA-11	C	M1	XZ	Front Rt.	SF	14.17	10.65	460.96	4.4	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-4-XZ-T-MID-RTA-12	C	M1	XZ	MID	SF	14	14	455.63	4.4	Gage, Radius
TPAMCN03-SSYS-ACN03-M1-A-RUN1-RF-4-XZ-T-MID-RTA-15	C	M1	XZ	MID	RF	14.05	10.26	478.12	4.5	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-2-ZX-T-MID-RTA-13	C	M1	ZX	MID	SF	8.43	8.43	410.96	2	Gage, Grips
TPAMCN03-SSYS-ACN03-M1-C-RUN1-RF-2-ZX-T-MID-RTA-15	C	M1	ZX	MID	RF	9.04	9.04	411.44	2.2	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-3-ZX-T-BL-RTA-20	C	M1	ZX	Back Left	SF	9.1	9.1	428.25	2.2	Gage, Grips
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-4-ZX-T-FR-RTA-17	C	M1	ZX	Front Rt.	SF	8.66	8.66	428.27	2	Gage, Grips
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-10-XY-T-FR-RTA-3	C	M2	XY	Front Rt.	SF	11.82	8.96	448.31	4	Radius
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-11-XY-T-MID-RTA-5	C	M2	XY	MID	SF	11.81	9.72	389.92	4.2	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-RF-11-XY-T-MID-RTA-7	C	M2	XY	MID	RF	11.83	8.45	453.43	4	Radius
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-12-XY-T-BL-RTA-5	C	M2	XY	Back Left	SF	11.99	8.89	431.71	4	Radius
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-9-XZ-T-BL-RTA-5	C	M2	XZ	Back Left	SF	14	9.51	473.42	4.4	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-11-XZ-T-FR-RTA-11	C	M2	XZ	Front Rt.	SF	13.98	9.9	525.78	4.4	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-12-XZ-T-MID-RTA-12	C	M2	XZ	MID	SF	14.36	9.99	505.94	4.3	Radius
TPAMCN03-SSYS-ACN03-M2-C-RUN1-RF-12-XZ-T-MID-RTA-15	C	M2	XZ	MID	RF	14.37	10.44	469.35	4.4	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-10-ZX-T-MID-RTA-13	C	M2	ZX	MID	SF	7.93	7.93	428.06	1.8	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-RF-10-ZX-T-MID-RTA-15	C	M2	ZX	MID	RF	8.48	8.48	395.68	2.1	Gage

Tension – RTA	Strength & Modulus					As Built -45/+45				
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-11-ZX-T-BL-RTA-20	C	M2	ZX	Back Left	SF	9.26	8.95	401.8	2.4	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-RF-11-ZX-T-MID-RTA-23	C	M2	ZX	MID	RF	9.25	8.78	406.14	2.4	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-12-ZX-T-FR-RTA-17	C	M2	ZX	Front Rt.	SF	8.52	8.52	406.55	2.1	Gage

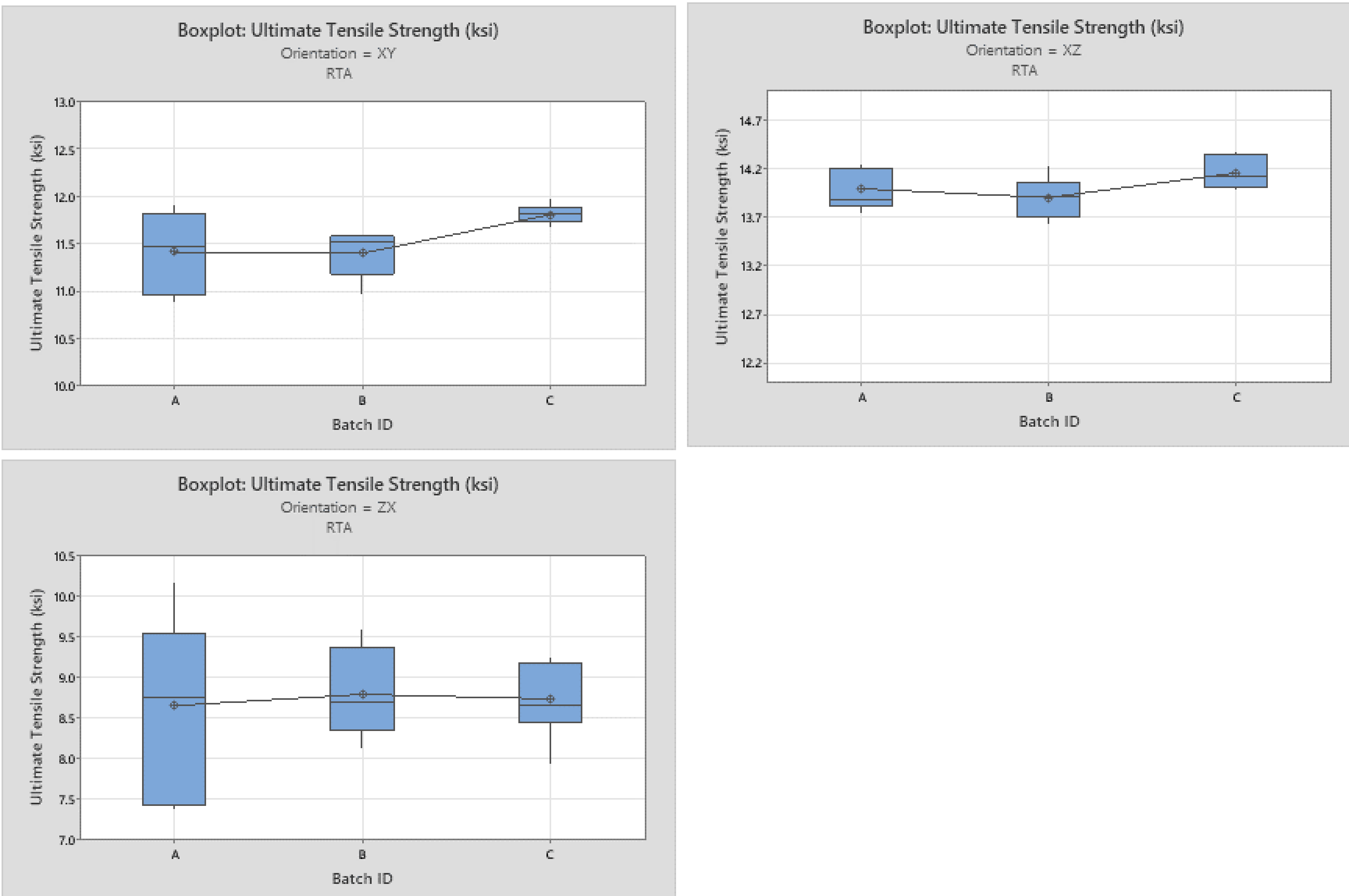


Figure 37. Plot of tensile strength by batch, per orientation for RTA.

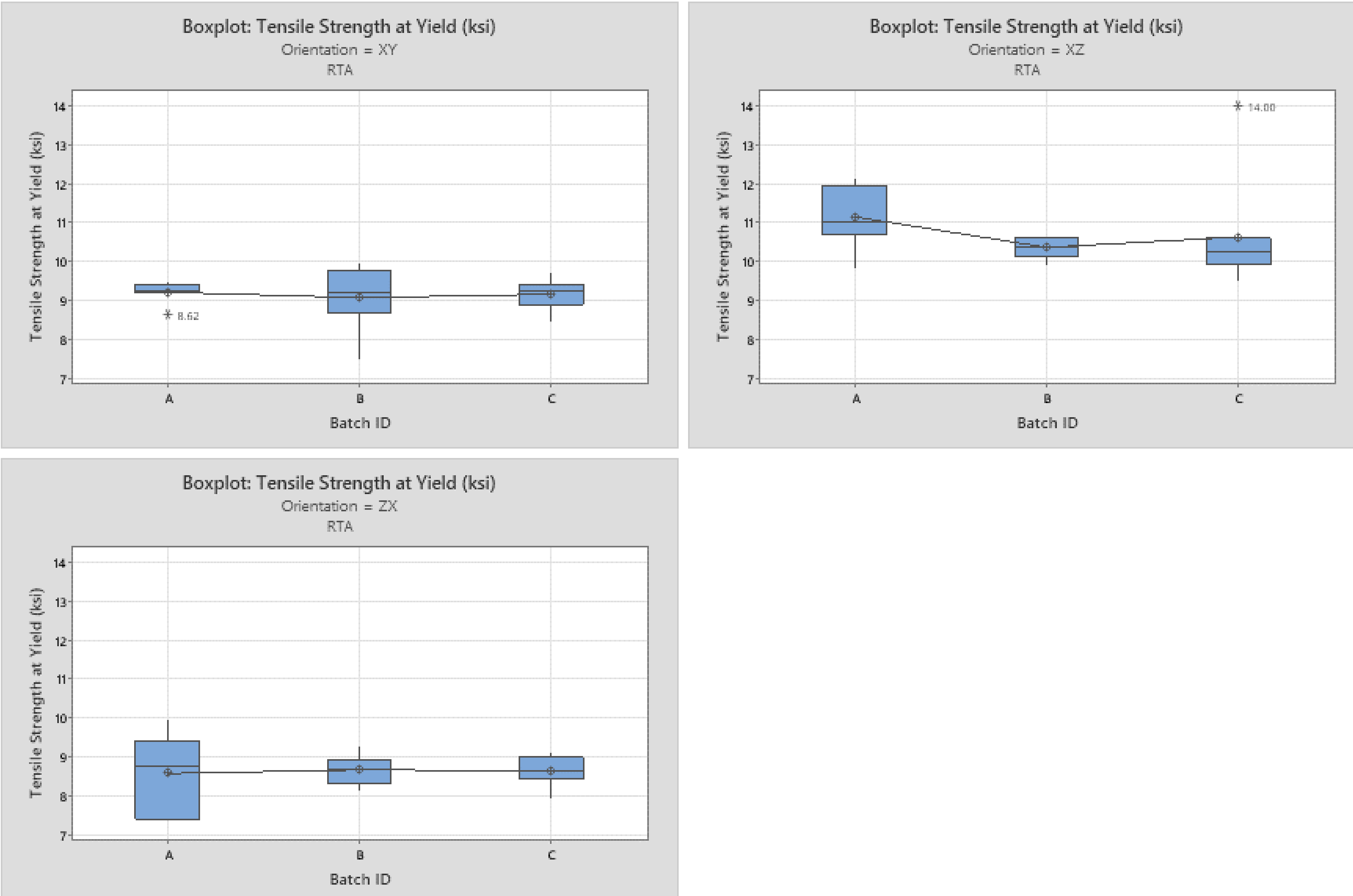


Figure 38. Plot of yield strength by batch, per orientation at RTA.

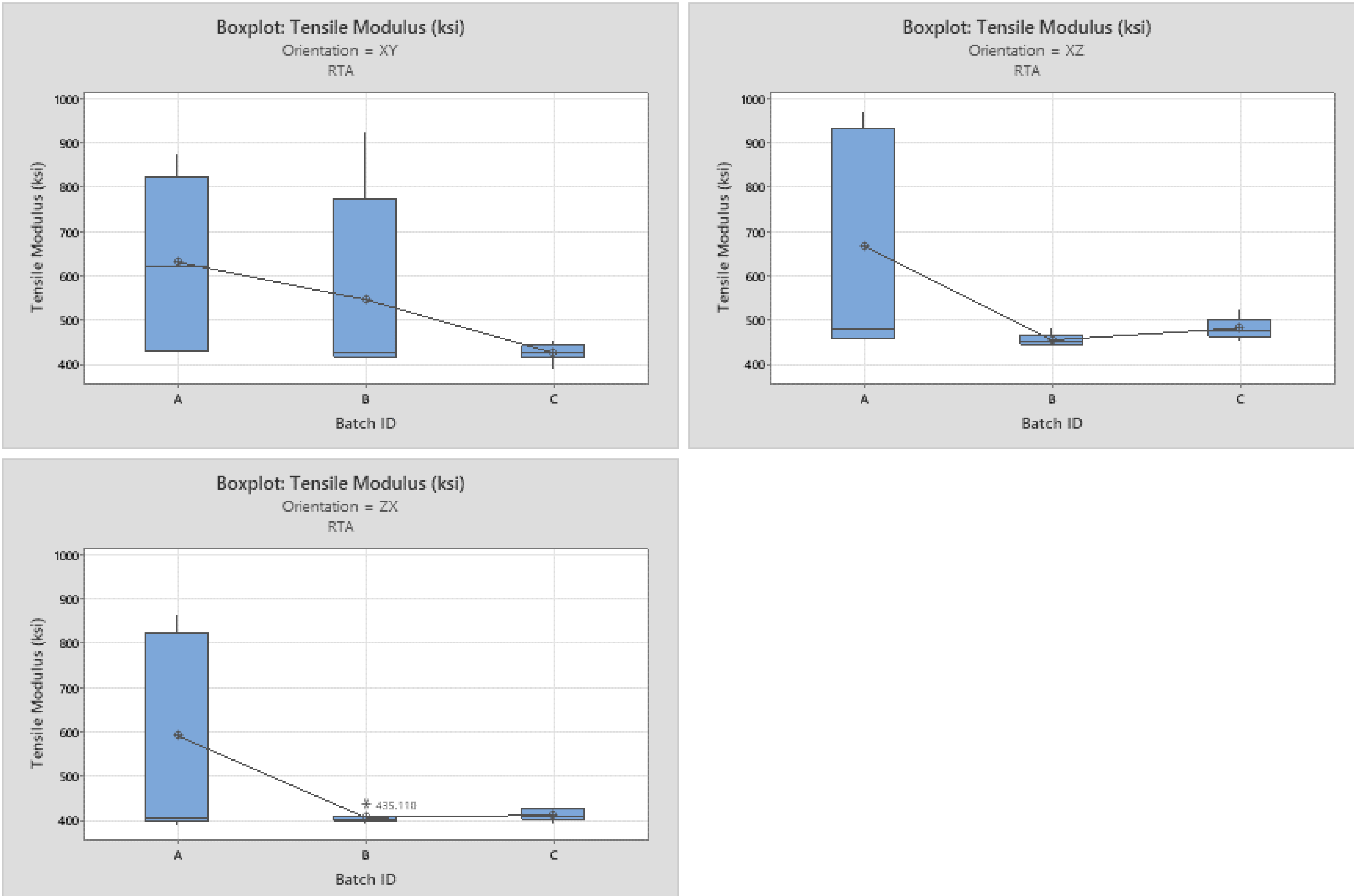
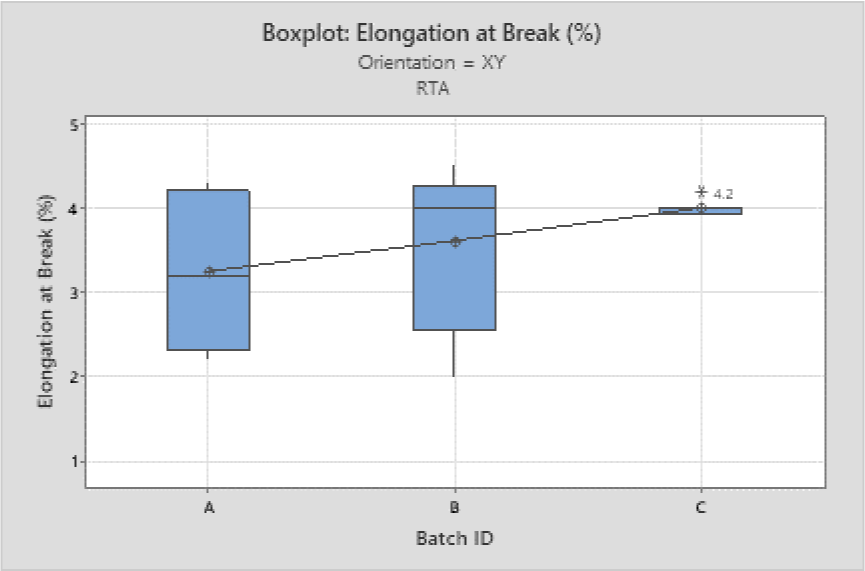
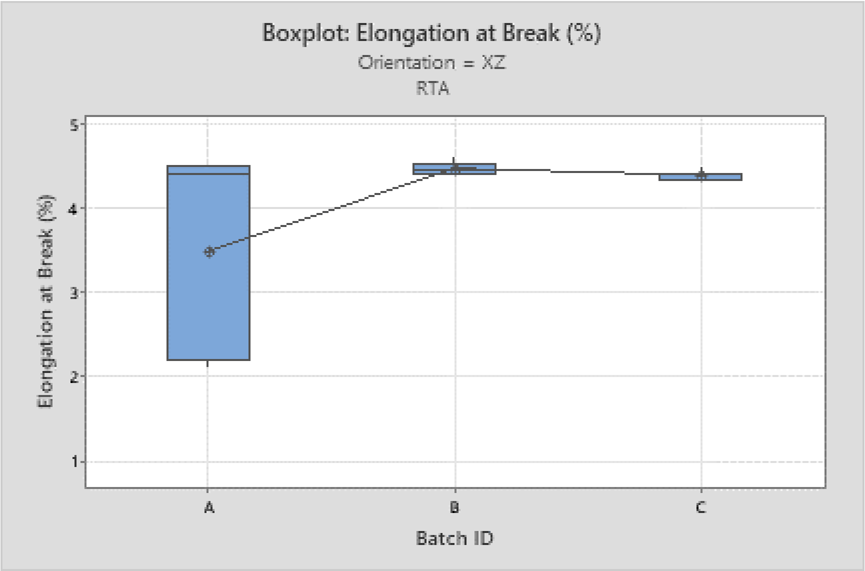


Figure 39. Plot of tensile modulus by batch, per orientation by RTA.





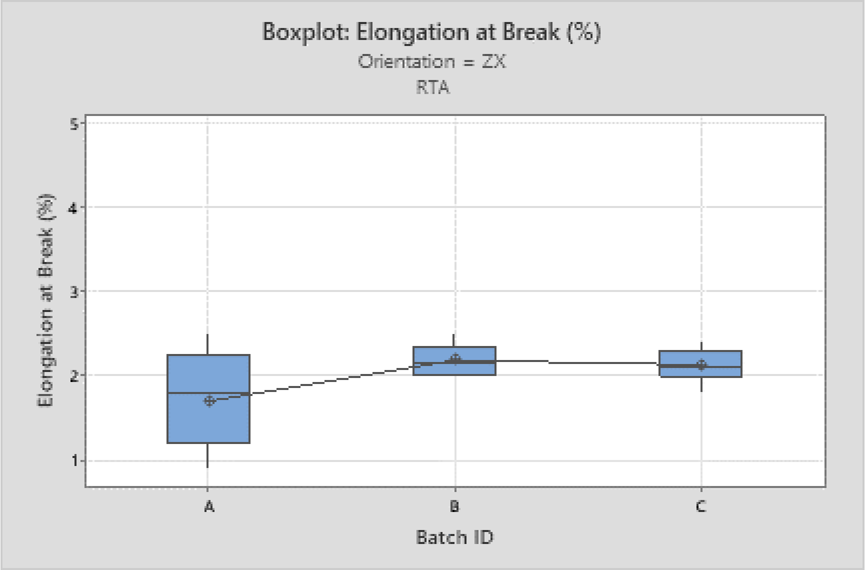


Figure 40. Plot of elongation at break by batch, per orientation for RTA.

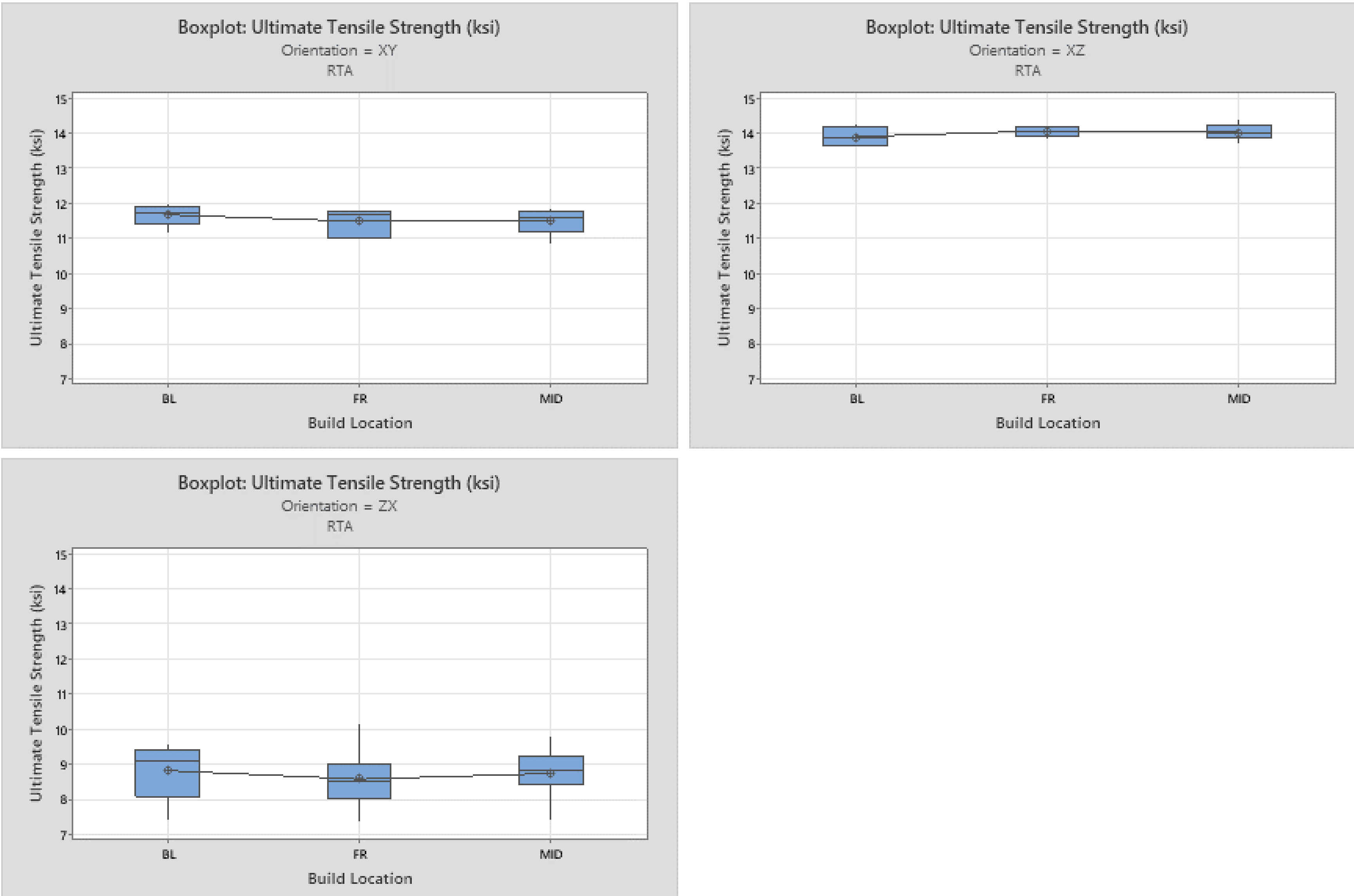


Figure 41. Plot of tensile strength by chamber location, per orientation for RTA.

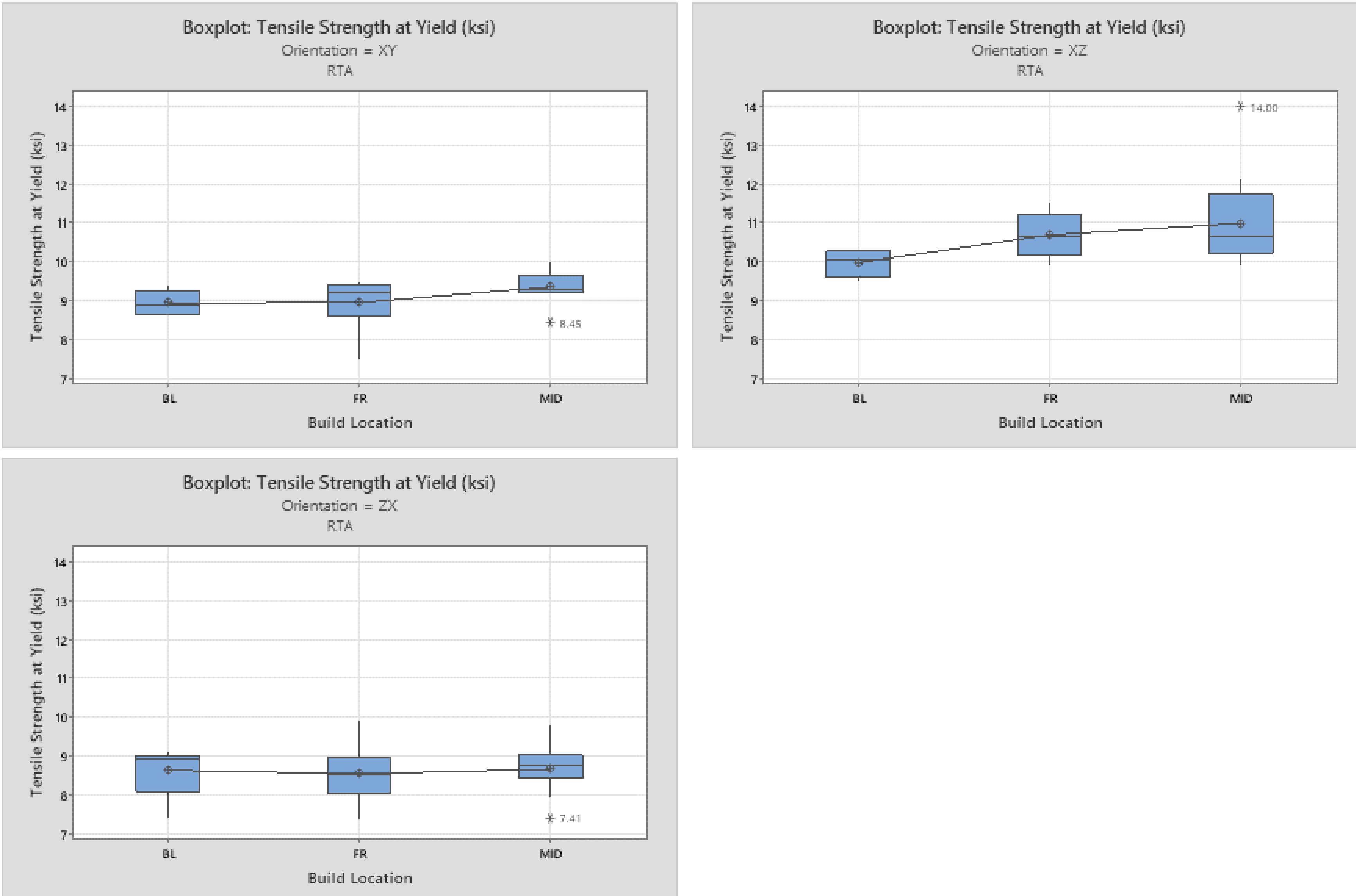


Figure 42. Plot of yield strength by location, per orientation for RTA.

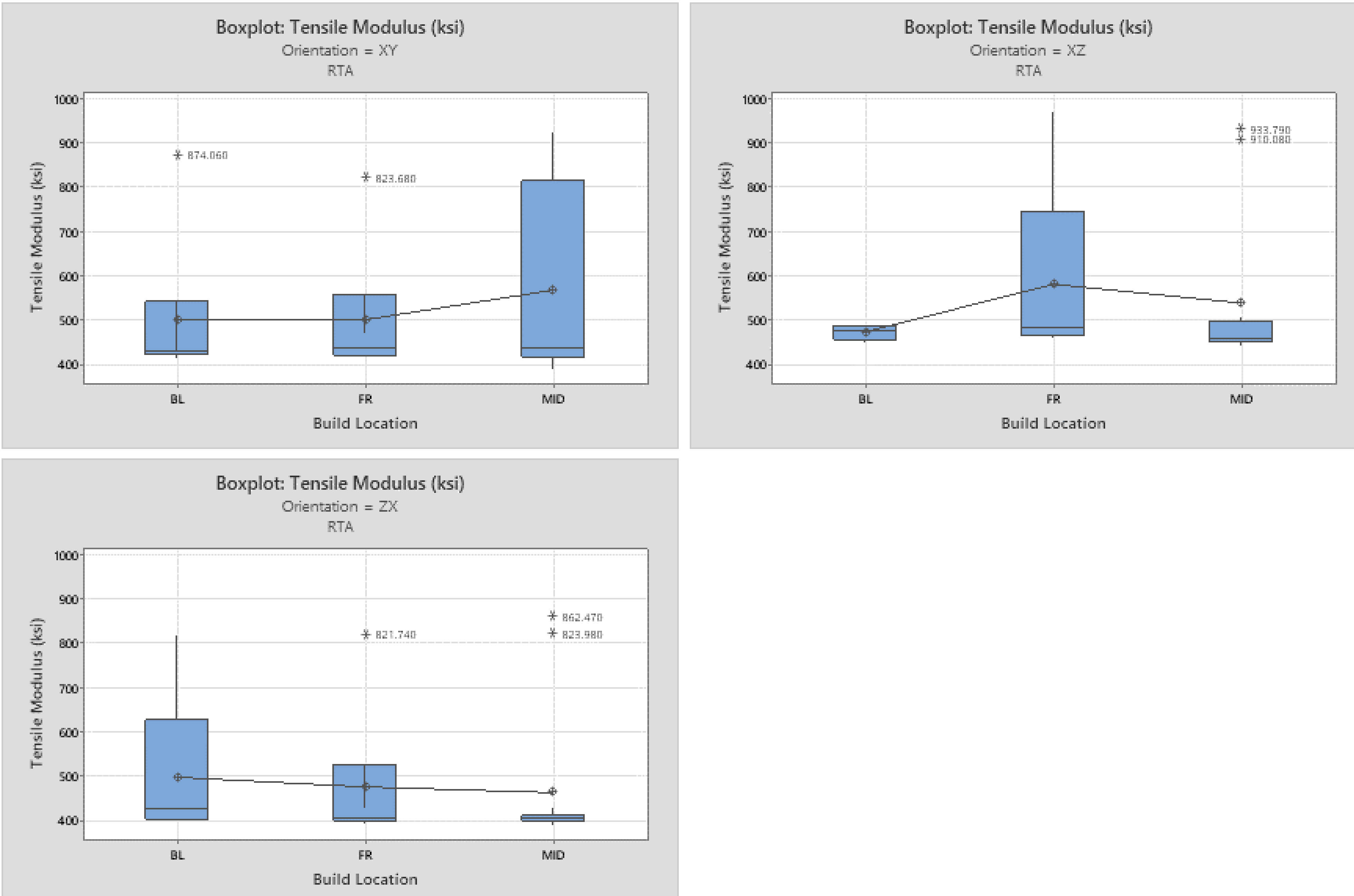


Figure 43. Plot of tensile modulus by chamber location, per orientation for RTA.

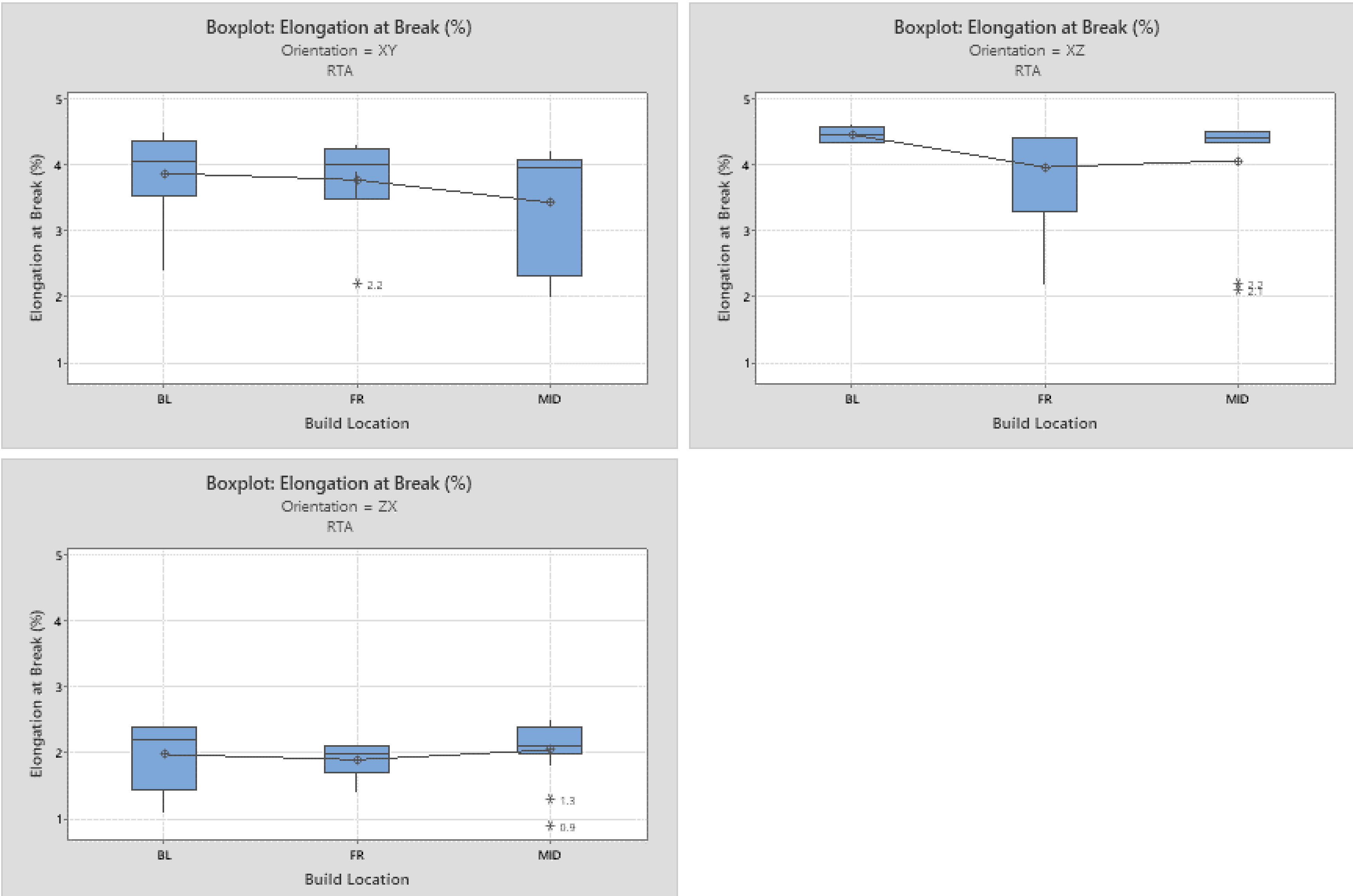


Figure 44. Plot of elongation at break by chamber location, per orientation for RTA.

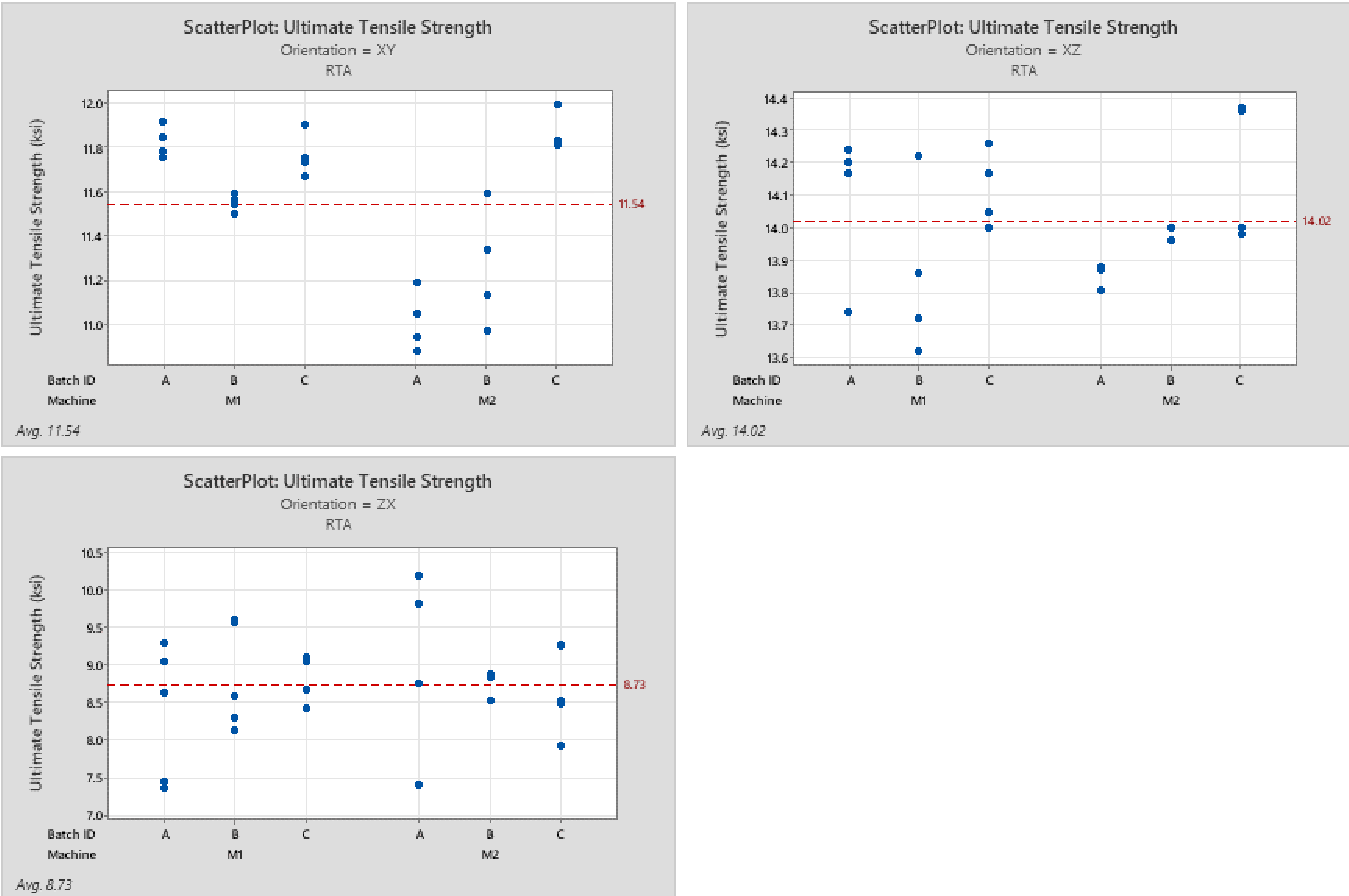


Figure 45. Plot of tensile strength by machine and batch, per orientation for RTA.

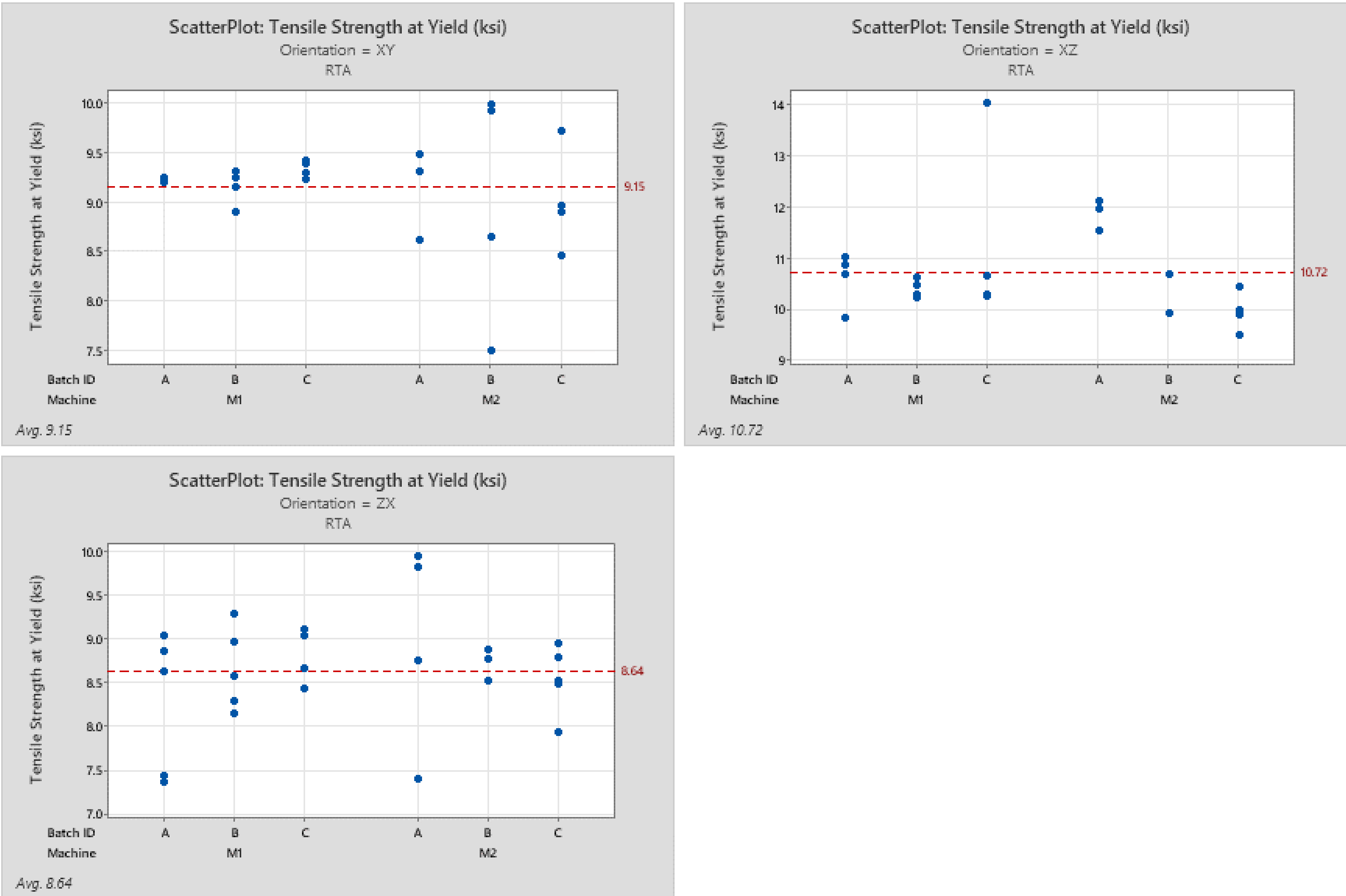


Figure 46. Plot of yield strength by machine and batch, per orientation for RTA.

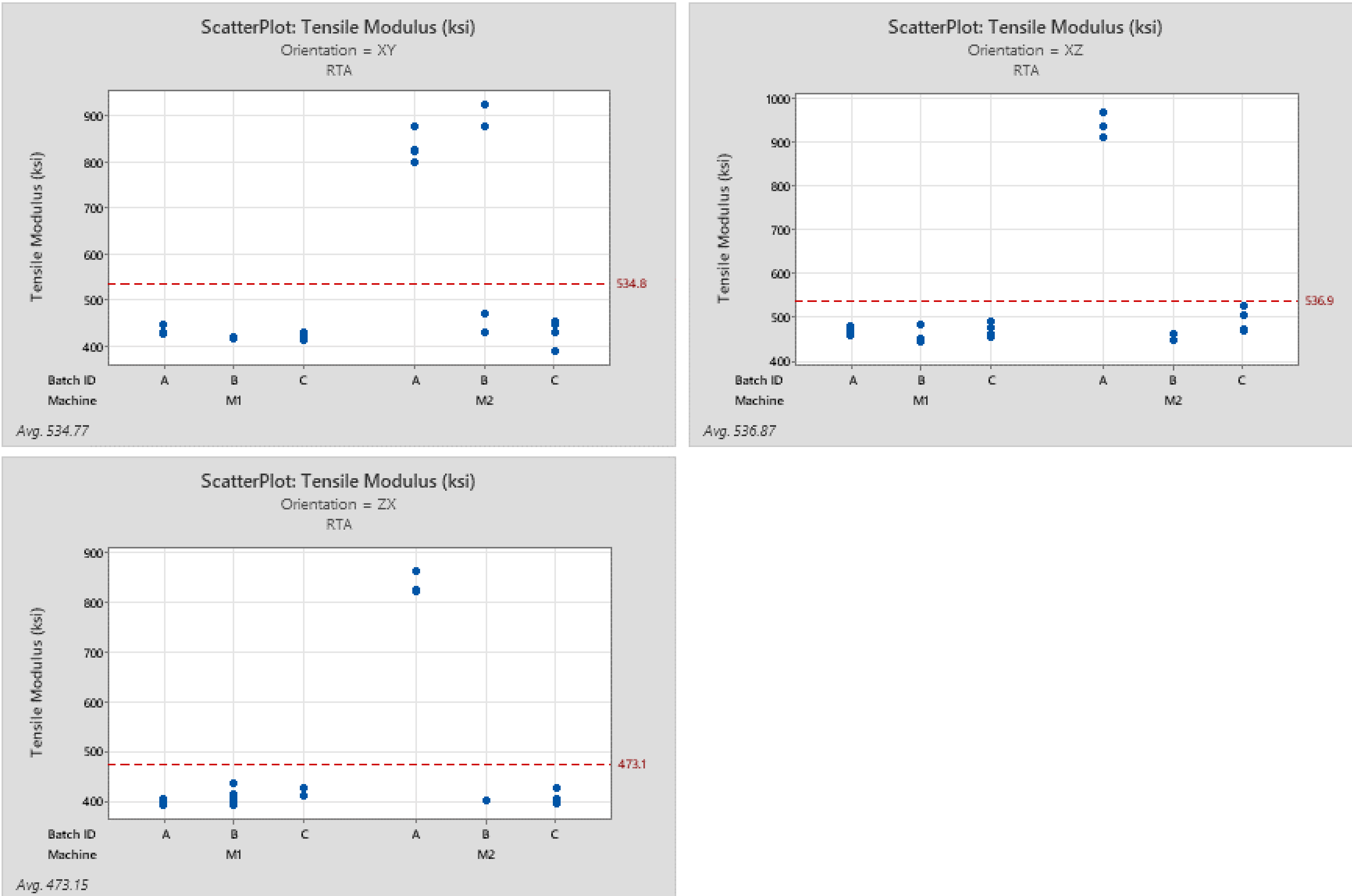


Figure 47. Plot of tensile modulus by machine and batch, per orientation for RTA.

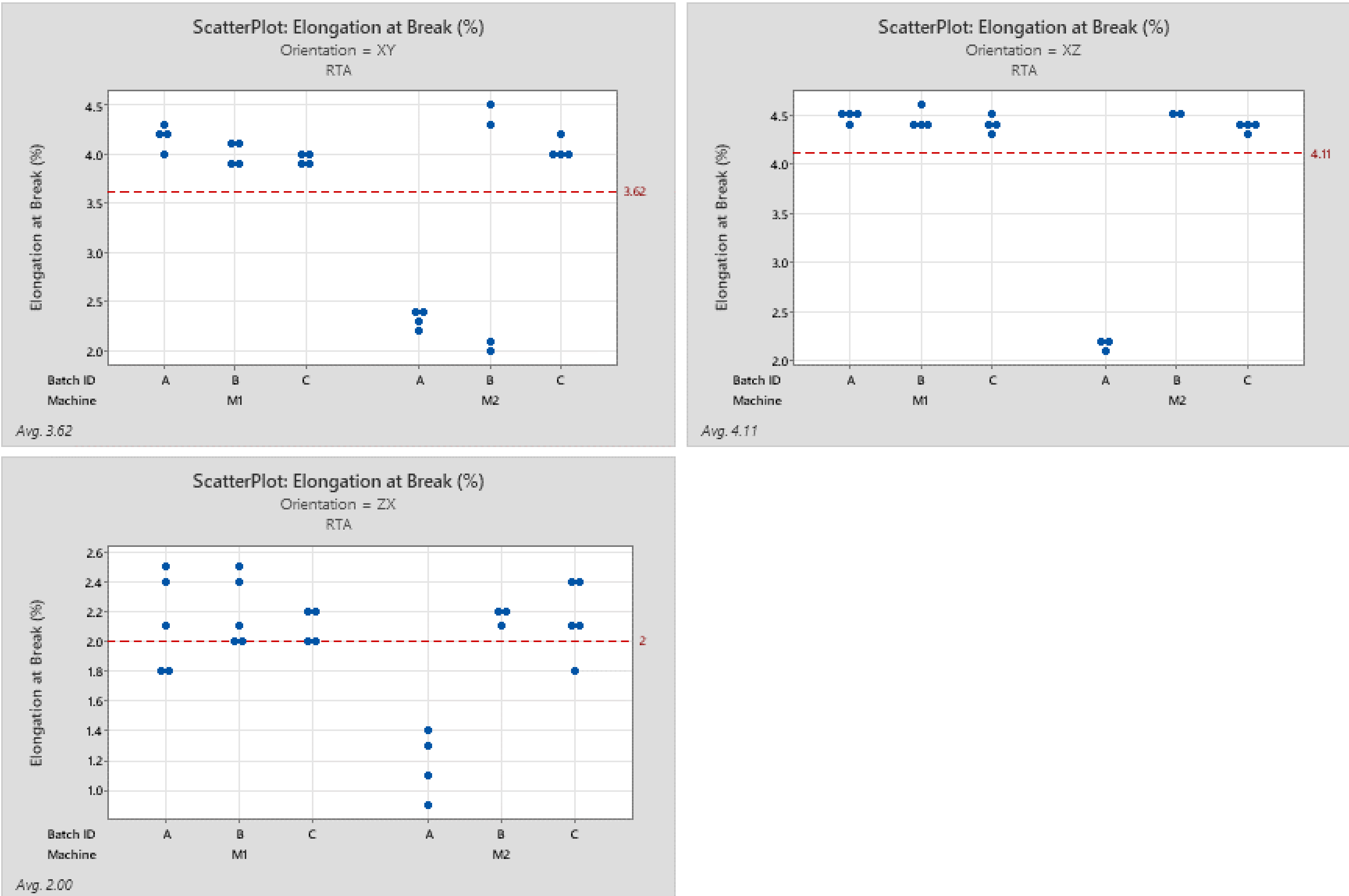


Figure 48. Plot of elongation at break by machine and batch, per orientation for RTA.

8.4 ETD Tension Properties

Table 8. Tensile ETD Ensemble Data

Tension – ETD	**Strength & Modulus**						**As Build -45/+45**			
SPECIMEN NAME	BATCH	MACHINE	ORIENTATION	LOCATION	FILL	TENSILE STRENGTH [ksi]	STRENGTH AT YIELD [ksi]	TENSILE MODULUS [ksi]	ELONGATION AT BREAK [%]	FAILURE MODE
TPAMACN03-SSYS-ACN03-M1-A-RUN1-RF-9-XY-T-MID-ETD-1	A	M1	XY	MID	RF	8.91	7.62	345.74	3.5	Gage
TPAMACN03-SSYS-ACN03-M1-A-RUN1-SF-9-XY-T-BL-ETD-3	A	M1	XY	Back Left	SF	8.96	6.7	206	5	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-11-XY-T-FR-ETD-1	A	M1	XY	Front Rt.	SF	8.97	7.99	345.83	3.4	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-12-XY-T-MID-ETD-3	A	M1	XY	MID	SF	8.9	7.75	373.77	3.3	Gage
TPAMACN03-SSYS-ACN03-M1-A-RUN1-SF-9-XZ-T-BL-ETD-7	A	M1	XZ	Back Left	SF	11.29	8.69	424.56	3	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-11-XZ-T-FR-ETD-9	A	M1	XZ	Front Rt.	SF	11.27	9.65	432.13	3.3	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-12-XZ-T-MID-ETD-11	A	M1	XZ	MID	SF	11.32	9.84	430.96	3.2	Gage
TPAMACN03-SSYS-ACN03-M1-A-RUN1-RF-9-ZX-T-MID-ETD-11	A	M1	ZX	MID	RF	7.38	7.38	405.31	1.8	Gage
TPAMACN03-SSYS-ACN03-M1-A-RUN1-SF-9-ZX-T-BL-ETD-13	A	M1	ZX	Back Left	SF	6.34	6.34	437.75	1.4	Gage
TPAMCN03-SSYS-ACN03-M1-A-RUN1-SF-11-ZX-T-FR-ETD-17	A	M1	ZX	Front Rt.	SF	8.02	8.02	387.67	2	Gage, Grips
TPAMACN03-SSYS-ACN03-M1-A-RUN1-SF-12-ZX-T-MID-ETD-20	A	M1	ZX	MID	SF	8.25	8.14	398.23	2.1	Gage
TPAMACN03-SSYS-ACN03-M2-A-RUN1-RF-1-XY-T-MID-ETD-1	A	M2	XY	MID	RF	8.27	7.04	354.99	7.4	Gage
TPAMACN03-SSYS-ACN03-M2-A-RUN1-SF-1-XY-T-BL-ETD-3	A	M2	XY	Back Left	SF	8.41	7.08	313.07	7.5	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-3-XY-T-FR-ETD-1	A	M2	XY	Front Rt.	SF	8.44	7.03	349.35	8.5	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-4-XY-T-MID-ETD-3	A	M2	XY	MID	SF	8.49	8.02	770.34	1.6	Radius
TPAMACN03-SSYS-ACN03-M2-A-RUN1-SF-1-XZ-T-BL-ETD-9	A	M2	XZ	Back Left	SF	10.86	8.72	449	3.2	Gage
TPAMACN03-SSYS-ACN03-M2-A-RUN1-SF-1-XZ-T-BL-ETD-7	A	M2	XZ	Back Left	SF	11.06	9.36	447.62	3.2	Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-3-XZ-T-FR-ETD-9	A	M2	XZ	Front Rt.	SF	11.37	10.07	439.61	3.3	Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-4-XZ-T-MID-ETD-11	A	M2	XZ	MID	SF	11.15	10.08	969.63	1.5	Gage

Tension – ETD	Strength & Modulus									As Build -45/+45
TPAMACN03-SSYS-ACN03-M2-A-RUN1-SF-1-ZX-T-BL-ETD-13	A	M2	ZX	Back Left	SF	9.44	8.74	408.08	2.6	Radius
TPAMACN03-SSYS-ACN03-M2-A-RUN1-RF-1-ZX-T-MID-ETD-11	A	M2	ZX	MID	RF	8.85	8.08	445.78	2.3	Gage
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-3-ZX-T-FR-ETD-17	A	M2	ZX	Front Rt.	SF	9.1	9.1	290.39	2.9	Radius
TPAMCN03-SSYS-ACN03-M2-A-RUN1-SF-4-ZX-T-MID-ETD-20	A	M2	ZX	MID	SF	8.97	8.62	786.37	1.5	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-5-XY-T-FR-ETD-1	B	M1	XY	Front Rt.	SF	8.76	7.77	349.57	3.4	Gage
TPAMACN03-SSYS-ACN03-M1-B-RUN1-RF-6-XY-T-MID-ETD-1	B	M1	XY	MID	RF	8.73	7.83	314.54	3.5	Gage
TPAMACN03-SSYS-ACN03-M1-B-RUN1-SF-6-XY-T-BL-ETD-3	B	M1	XY	Back Left	SF	8.94	7.95	340.86	3.4	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-8-XY-T-MID-ETD-3	B	M1	XY	MID	SF	8.81	7.69	358.61	3.3	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-5-XZ-T-FR-ETD-9	B	M1	XZ	Front Rt.	SF	11.31	9.99	401.25	3.4	Gage
TPAMACN03-SSYS-ACN03-M1-B-RUN1-SF-6-XZ-T-BL-ETD-7	B	M1	XZ	Back Left	SF	10.99	9.5	400.82	3.4	Gage
TPAMACN03-SSYS-ACN03-M1-B-RUN1-RF-6-XZ-T-MID-ETD-9	B	M1	XZ	MID	RF	10.9	9.26	386.77	3.5	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-8-XZ-T-MID-ETD-11	B	M1	XZ	MID	SF	11.13	9.64	417.45	3.2	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-5-ZX-T-FR-ETD-17	B	M1	ZX	Front Rt.	SF	9.33	8.85	388.36	2.5	Gage
TPAMACN03-SSYS-ACN03-M1-B-RUN1-RF-6-ZX-T-MID-ETD-11	B	M1	ZX	MID	RF	7.08	7.08	428.6	1.5	Gage
TPAMACN03-SSYS-ACN03-M1-B-RUN1-SF-6-ZX-T-BL-ETD-13	B	M1	ZX	Back Left	SF	7.87	7.87	428.2	1.8	Gage
TPAMCN03-SSYS-ACN03-M1-B-RUN1-SF-8-ZX-T-MID-ETD-20	B	M1	ZX	MID	SF	9.37	8.25	383.21	3.1	Gage, Grips
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-5-XY-T-FR-ETD-1	B	M2	XY	Front Rt.	SF	8.34	7.97	718.93	3.7	Radius
TPAMACN03-SSYS-ACN03-M2-B-RUN1-SF-6-XY-T-MID-ETD-1	B	M2	XY	MID	SF	8.27	7.69	756.91	4.1	Gage
TPAMACN03-SSYS-ACN03-M2-B-RUN1-SF-6-XY-T-BL-ETD-3	B	M2	XY	Back Left	SF	8.29	7.91	686.37	4.5	Radius
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-8-XY-T-MID-ETD-3	B	M2	XY	MID	SF	8.54	8.22	709.98	1.6	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-5-XZ-T-FR-ETD-9	B	M2	XZ	Front Rt.	SF	10.93	10.66	827.31	1.7	Gage
TPAMACN03-SSYS-ACN03-M2-B-RUN1-RF-6-XZ-T-MID-ETD-9	B	M2	XZ	MID	RF	11.08	9.95	967.49	1.6	Gage
TPAMACN03-SSYS-ACN03-M2-B-RUN1-SF-6-XZ-T-BL-ETD-7	B	M2	XZ	Back Left	SF	11.24	10.67	894.93	1.6	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-8-XZ-T-MID-ETD-11	B	M2	XZ	MID	SF	11.06	10.35	882.45	1.6	Gage

Tension – ETD	Strength & Modulus						As Build -45/+45			
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-5-ZX-T-FR-ETD-17	B	M2	ZX	Front Rt.	SF	8.3	8.3	729.13	1.1	Gage
TPAMACN03-SSYS-ACN03-M2-B-RUN1-RF-6-ZX-T-MID-ETD-11	B	M2	ZX	MID	RF	9.09	9.01	771.58	1.3	Gage
TPAMACN03-SSYS-ACN03-M2-B-RUN1-SF-6-ZX-T-BL-ETD-13	B	M2	ZX	Back Left	SF	9.4	9.14	756.44	1.5	Gage
TPAMCN03-SSYS-ACN03-M2-B-RUN1-SF-8-ZX-T-MID-ETD-20	B	M2	ZX	MID	SF	9.03	8.73	728.58	1.5	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-4-XY-T-MID-ETD-3	C	M1	XY	MID	SF	8.74	7.9	362.84	3.1	Gage
TPAMACN03-SSYS-ACN03-M1-C-RUN1-SF-1-XY-T-BL-ETD-3	C	M1	XY	Back Left	SF	8.97	7.65	375.25	3.2	Radius
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-3-XY-T-FR-ETD-1	C	M1	XY	Front Rt.	SF	8.82	6.65	367.31	3.3	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-4-XZ-T-MID-ETD-11	C	M1	XZ	MID	SF	11	9.61	432.05	3	Radius
TPAMACN03-SSYS-ACN03-M1-C-RUN1-SF-1-XZ-T-BL-ETD-7	C	M1	XZ	Back Left	SF	11.23	9.48	423.03	3.4	Gage
TPAMACN03-SSYS-ACN03-M1-C-RUN1-RF-1-XZ-T-MID-ETD-9	C	M1	XZ	MID	RF	11.27	9.69	418.01	3.3	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-3-XZ-T-FR-ETD-9	C	M1	XZ	Front Rt.	SF	11.25	9.19	443.96	3.2	Gage
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-4-ZX-T-MID-ETD-20	C	M1	ZX	MID	SF	9.21	9.04	336	2.7	Gage, Grips
TPAMACN03-SSYS-ACN03-M1-C-RUN1-RF-1-ZX-T-MID-ETD-11	C	M1	ZX	MID	RF	7.84	7.84	430.34	1.8	Gage, Grips
TAPMACN03-SSYS-ACN03-M1-C-RUN1-SF-1-ZX-T-BL-ETD-13	C	M1	ZX	Back Left	SF	8.44	8.44	547.33	1.6	Gage, Grips
TPAMCN03-SSYS-ACN03-M1-C-RUN1-SF-3-ZX-T-FR-ETD-17	C	M1	ZX	Front Rt.	SF	9.31	8.47	406.49	2.6	Gage, Radius, Grips
TPAMACN03-SSYS-ACN03-M2-C-RUN1-RF-9-XY-T-MID-ETD-1	C	M2	XY	MID	RF	8.59	7.52	328.22	3.5	Gage
TPAMACN03-SSYS-ACN03-M2-C-RUN1-SF-9-XY-T-BL-ETD-3	C	M2	XY	Back Left	SF	8.97	7.99	327.49	3.5	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-11-XY-T-FR-ETD-1	C	M2	XY	Front Rt.	SF	8.95	7.95	346.79	3.2	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-12-XY-T-MID-ETD-3	C	M2	XY	MID	SF	8.99	7.63	386.09	3.1	Radius
TPAMACN03-SSYS-ACN03-M2-C-RUN1-SF-9-XZ-T-BL-ETD-7	C	M2	XZ	Back Left	SF	11.39	9.34	399.69	3.6	Gage
TPAMACN03-SSYS-ACN03-M2-C-RUN1-RF-9-XZ-T-MID-ETD-9	C	M2	XZ	MID	RF	11.15	10.03	368.81	3.6	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-11-XZ-T-FR-ETD-9	C	M2	XZ	Front Rt.	SF	11.3	9.22	406.61	3.5	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-12-XZ-T-MID-ETD-11	C	M2	XZ	MID	SF	11.37	8.83	462.47	3.2	Gage
TPAMCN03-SSYS-ACN03-M2-C-RUN1-RF-12-XZ-T-MID-ETD-28	C	M2	XZ	MID	RF	11.46	10.19	399.81	3.4	Gage

Tension – ETD	Strength & Modulus									As Build -45/+45
TAPMACN03-SSYS-ACN03-M2-C-RUN1-RF-9-ZX-T-MID-ETD-11	C	M2	ZX	MID	RF	8.94	8.3	443.36	2.2	Gage
TPAMACN03-SSYS-ACN03-M2-C-RUN1-SF-9-ZX-T-BL-ETD-13	C	M2	ZX	Back Left	SF	9.33	8.08	419.31	2.6	Gage, Grips
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-11-ZX-T-FR-ETD-17	C	M2	ZX	Front Rt.	SF	9.1	8.52	368.72	2.6	Gage, Radius, Grips
TPAMCN03-SSYS-ACN03-M2-C-RUN1-SF-12-ZX-T-MID-ETD-20	C	M2	ZX	MID	SF	9.2	7.71	509.92	2.3	Gage

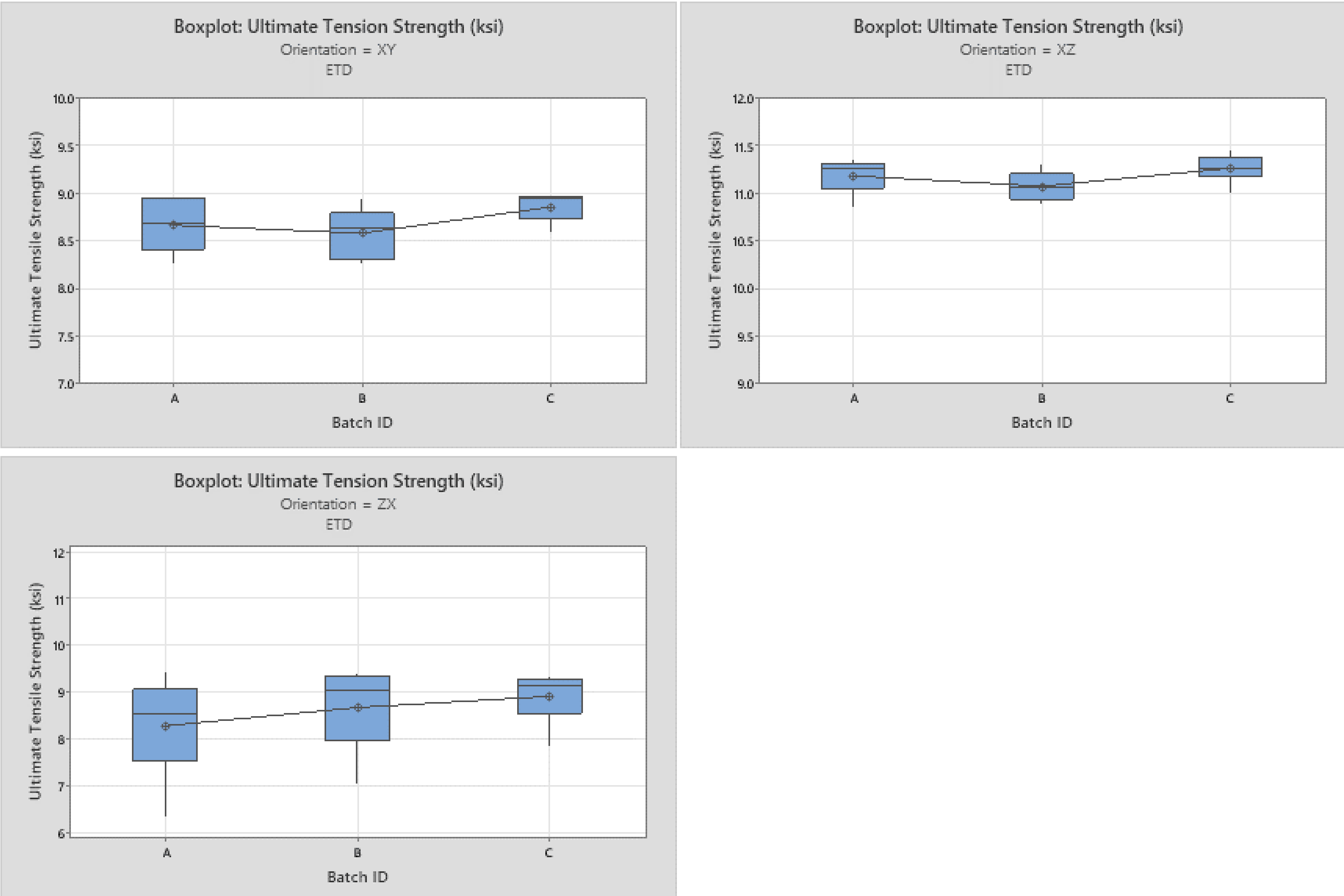


Figure 49. Plot of tensile strength by batch, per orientation for ETD.

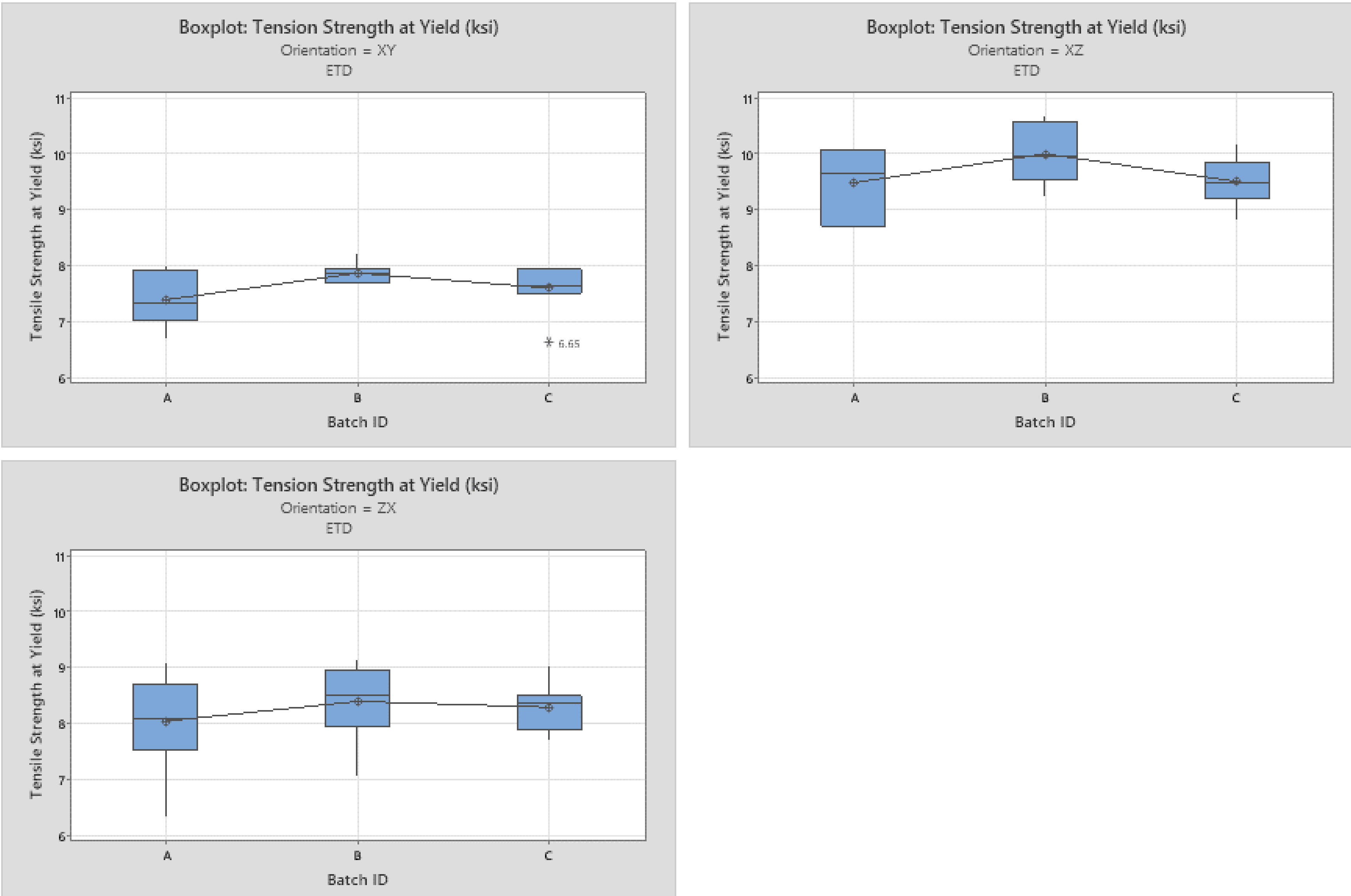


Figure 50. Plot of yield strength by batch, per orientation for ETD.

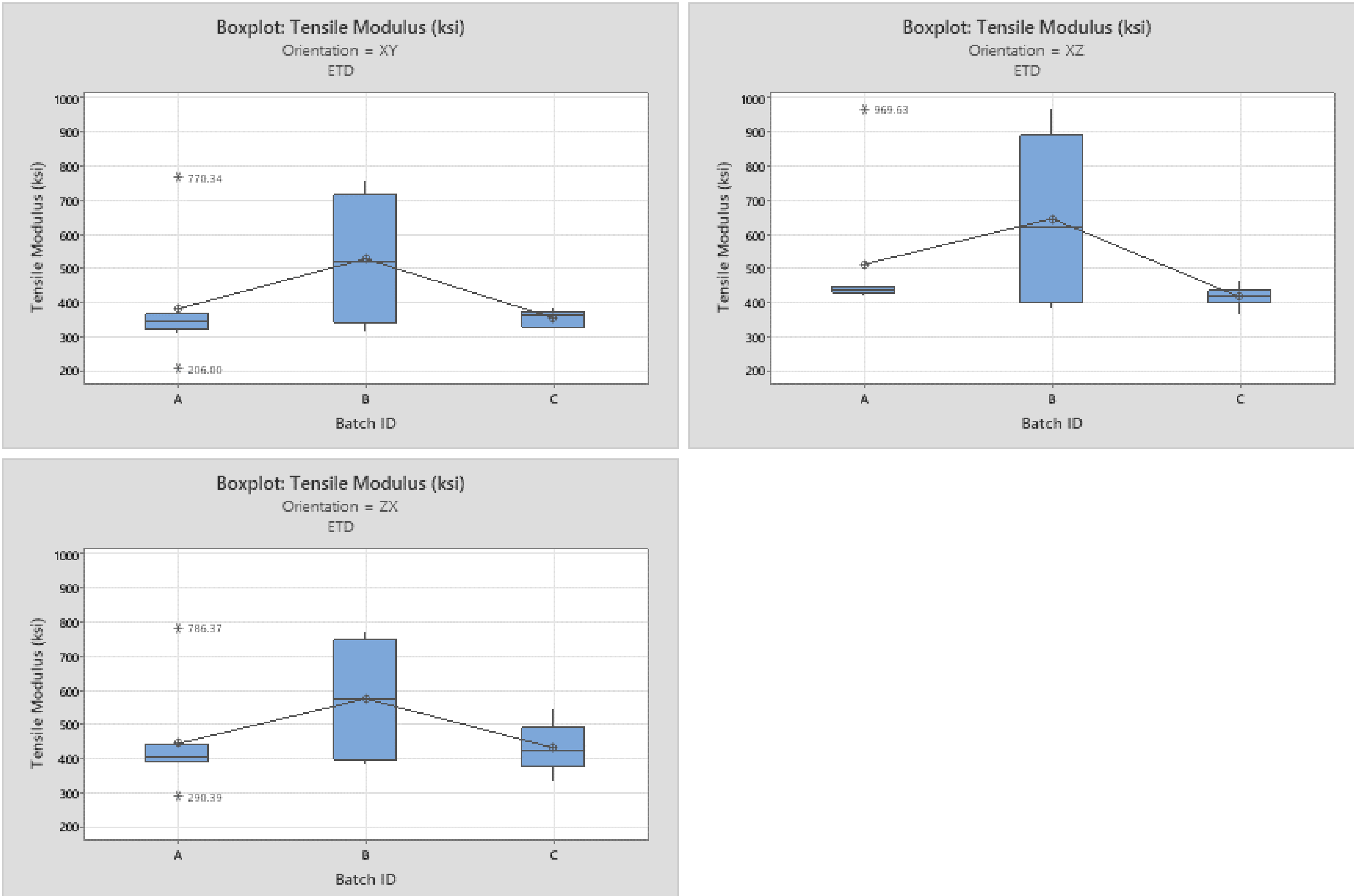


Figure 51. Plot of tensile modulus by batch, per orientation for ETD.

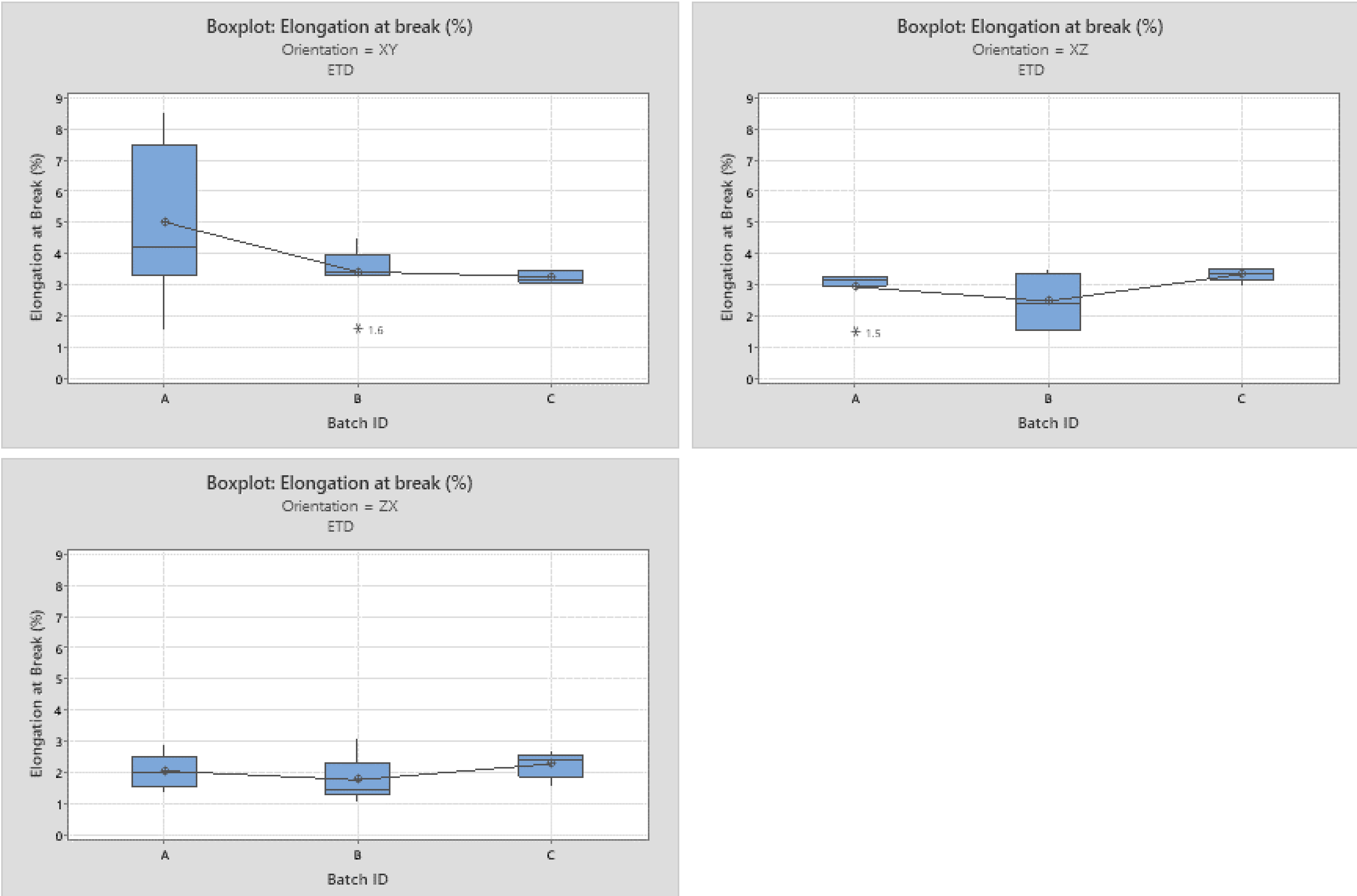


Figure 52. Plot of elongation at break by batch, per orientation for ETD.

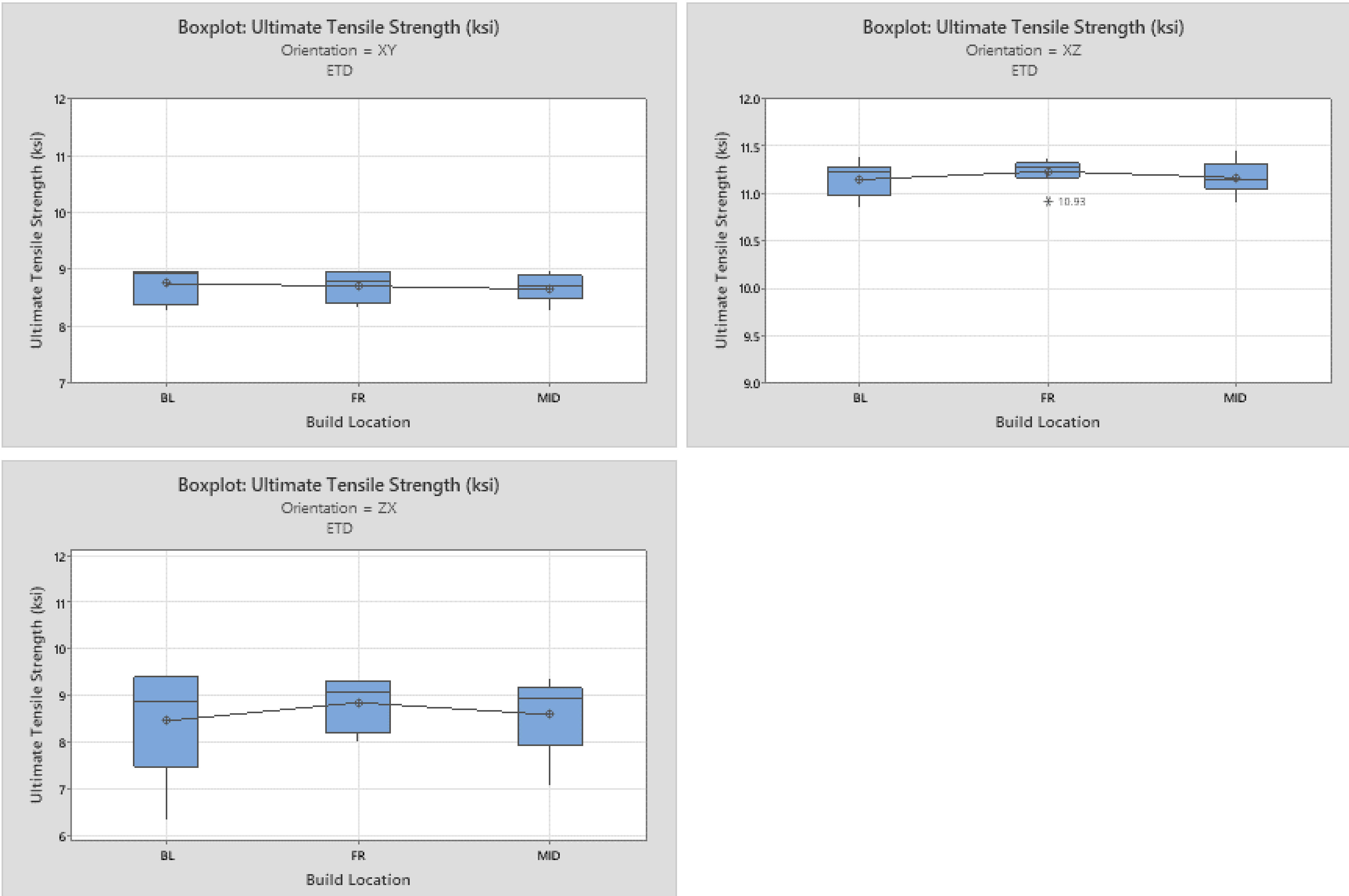


Figure 53. Plot of tensile strength by location, per orientation for ETD.

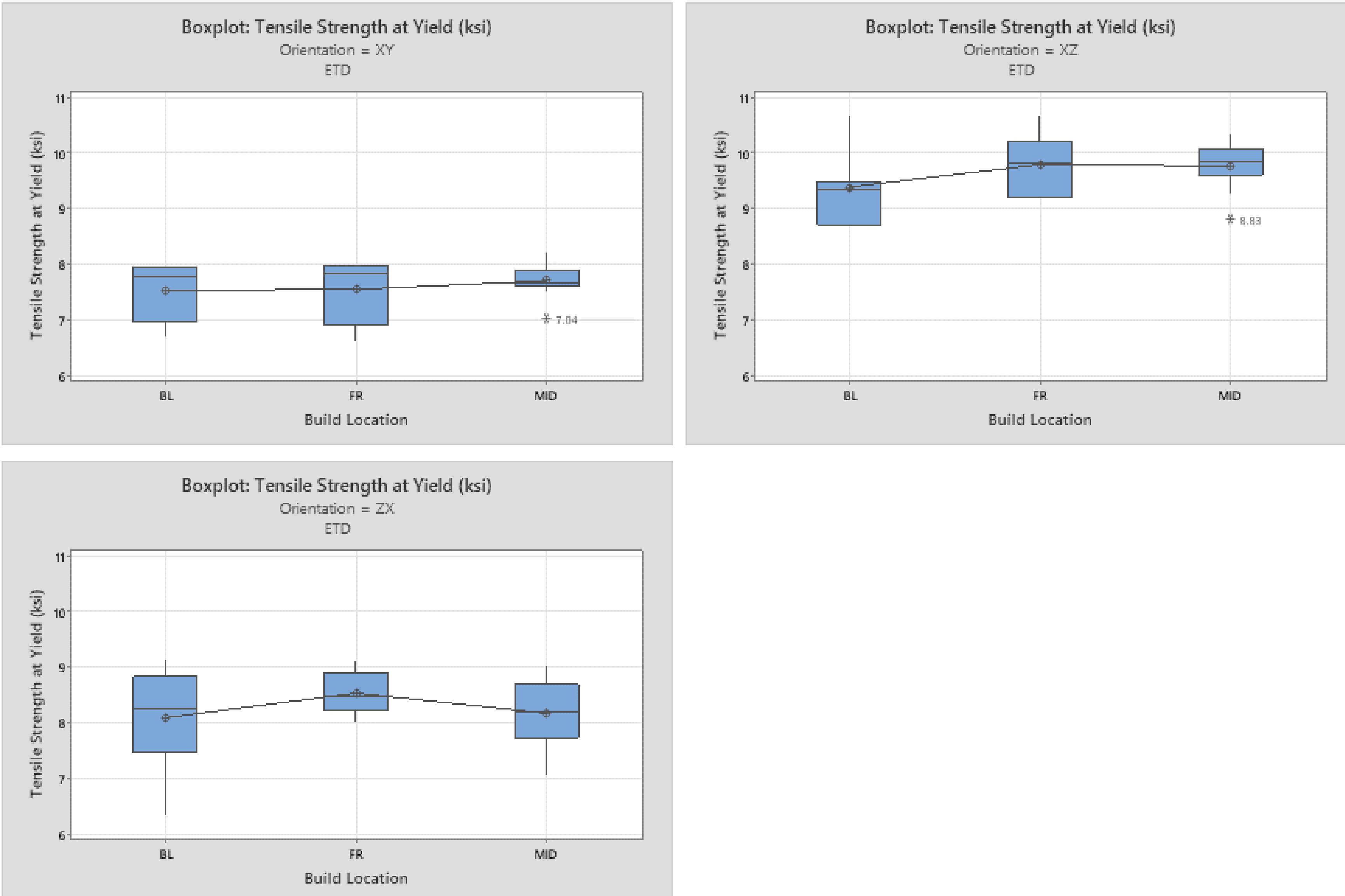


Figure 54. Plot of yield strength by location, per orientation for ETD.

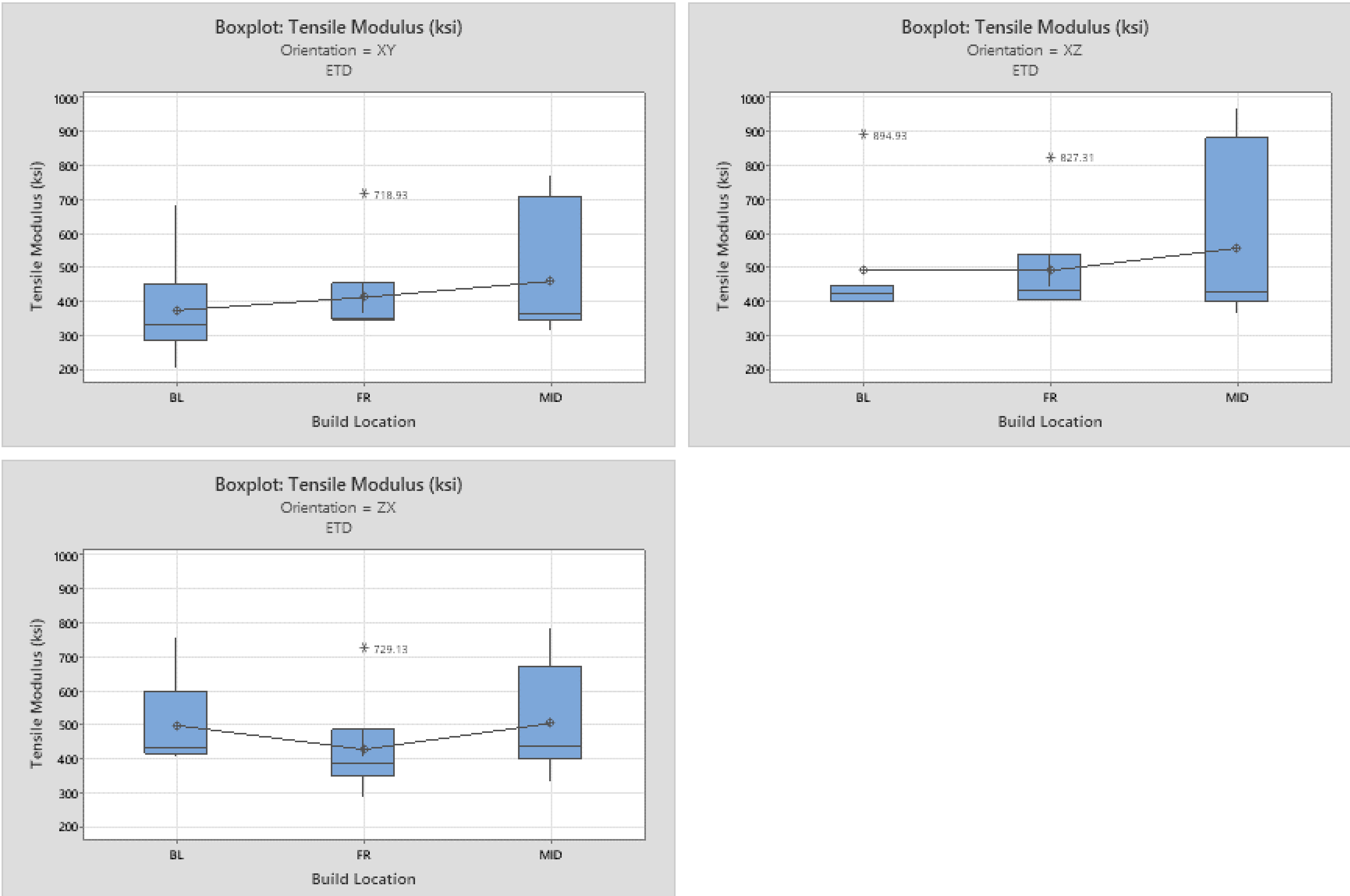


Figure 55. Plot of tensile modulus by location, per orientation for ETD.

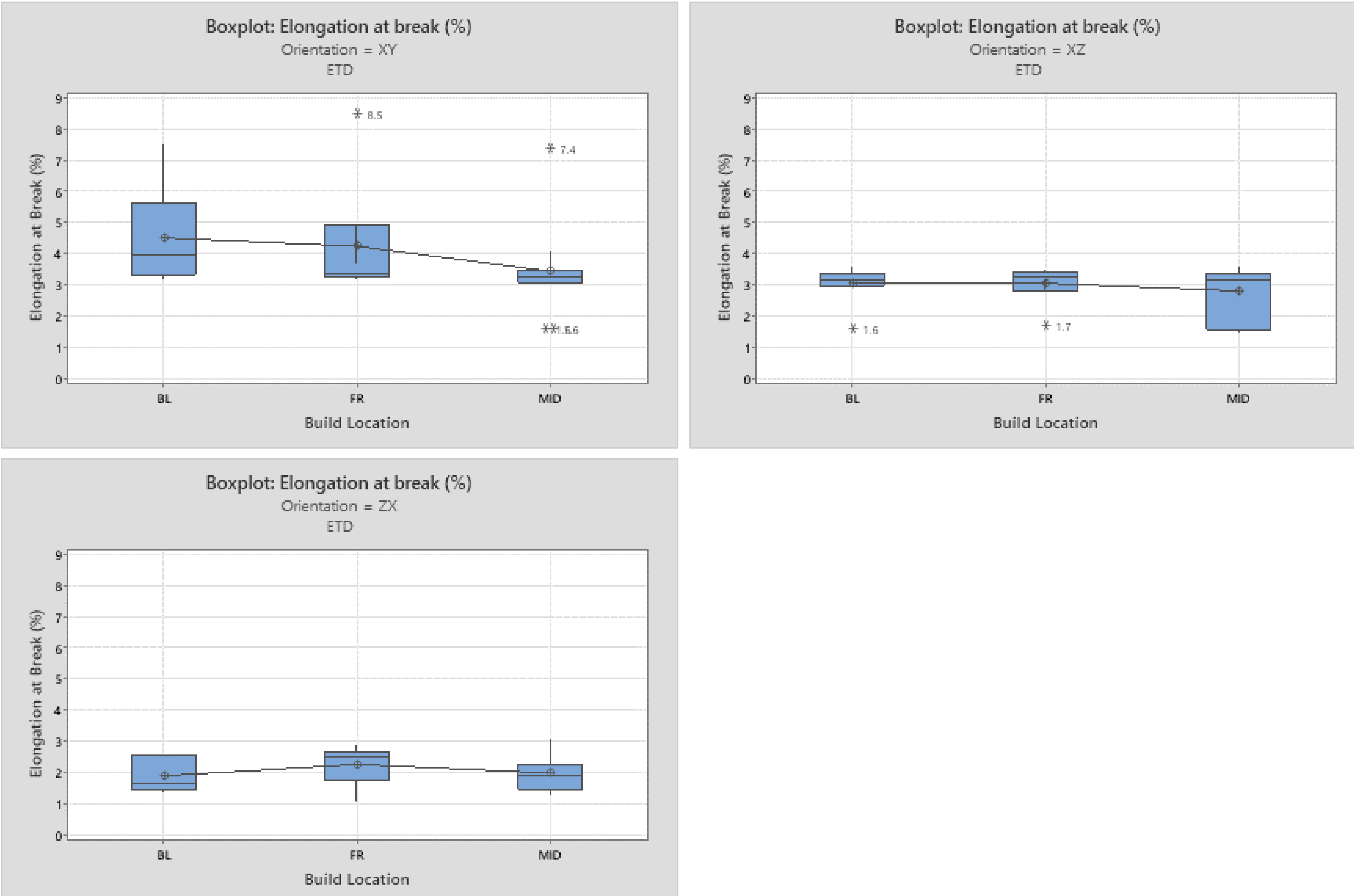


Figure 56. Plot of elongation at break by location, per orientation for ETD.

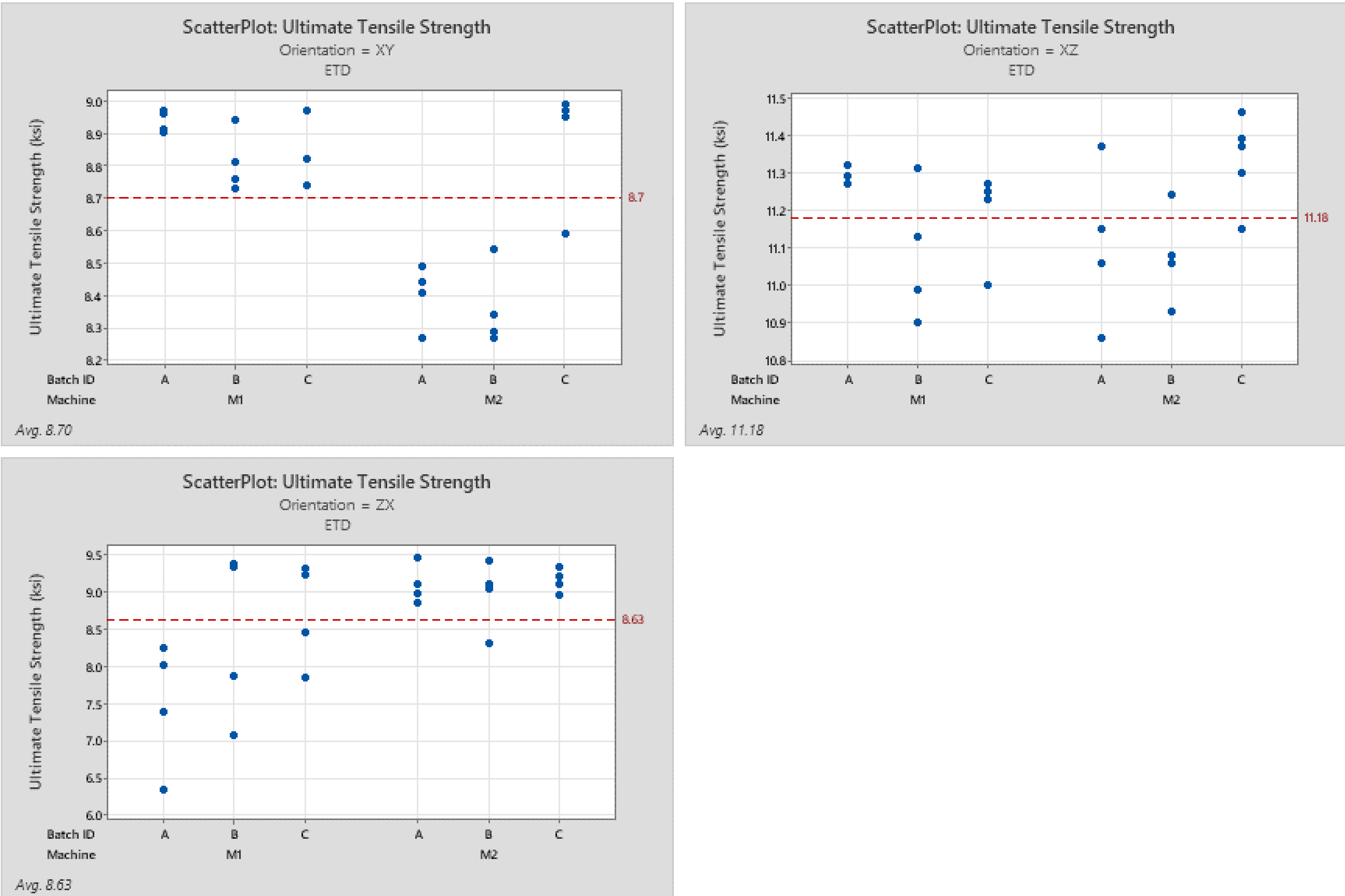
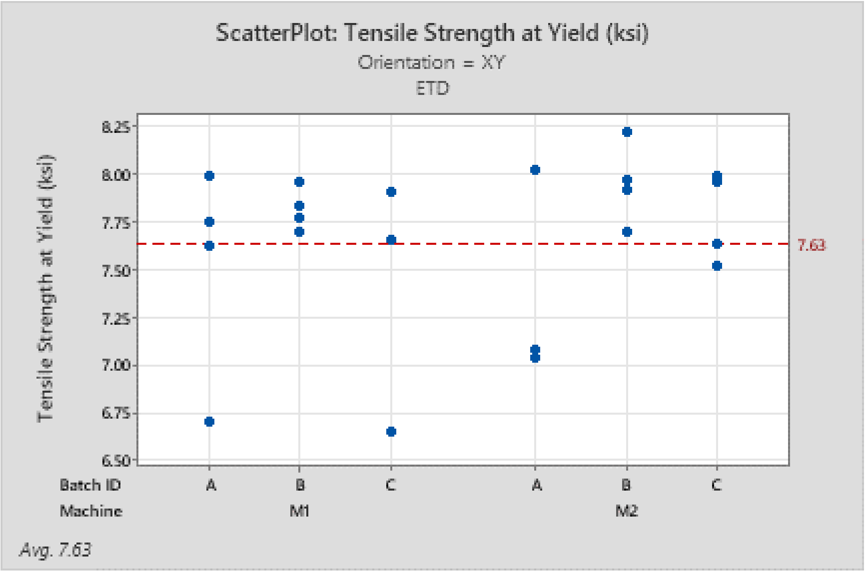
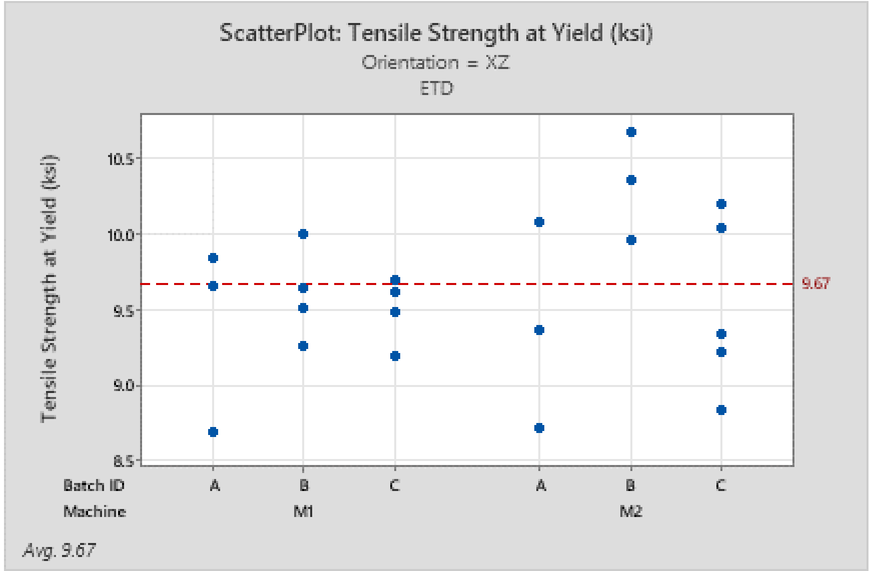


Figure 57. Plot of tensile strength by machine and batch, per orientation for ETD.





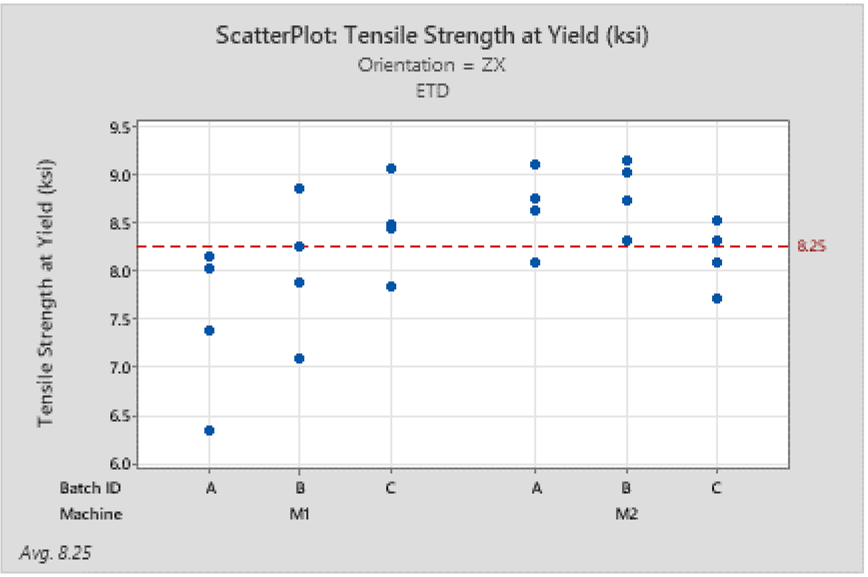


Figure 58. Plot of yield strength by machine and batch, per orientation for ETD.

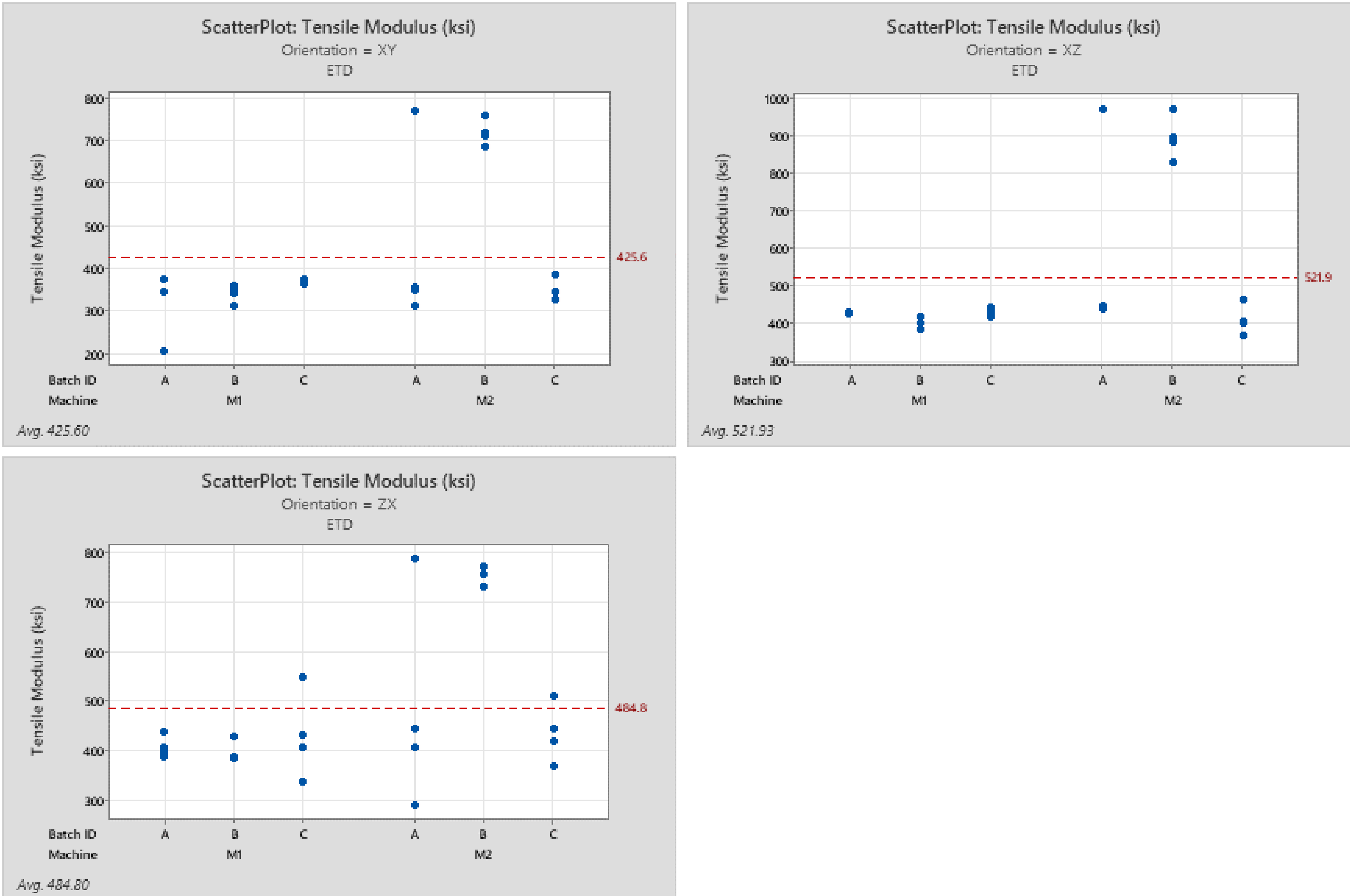


Figure 59. Plot of tensile modulus by machine and batch, per orientation for ETD.

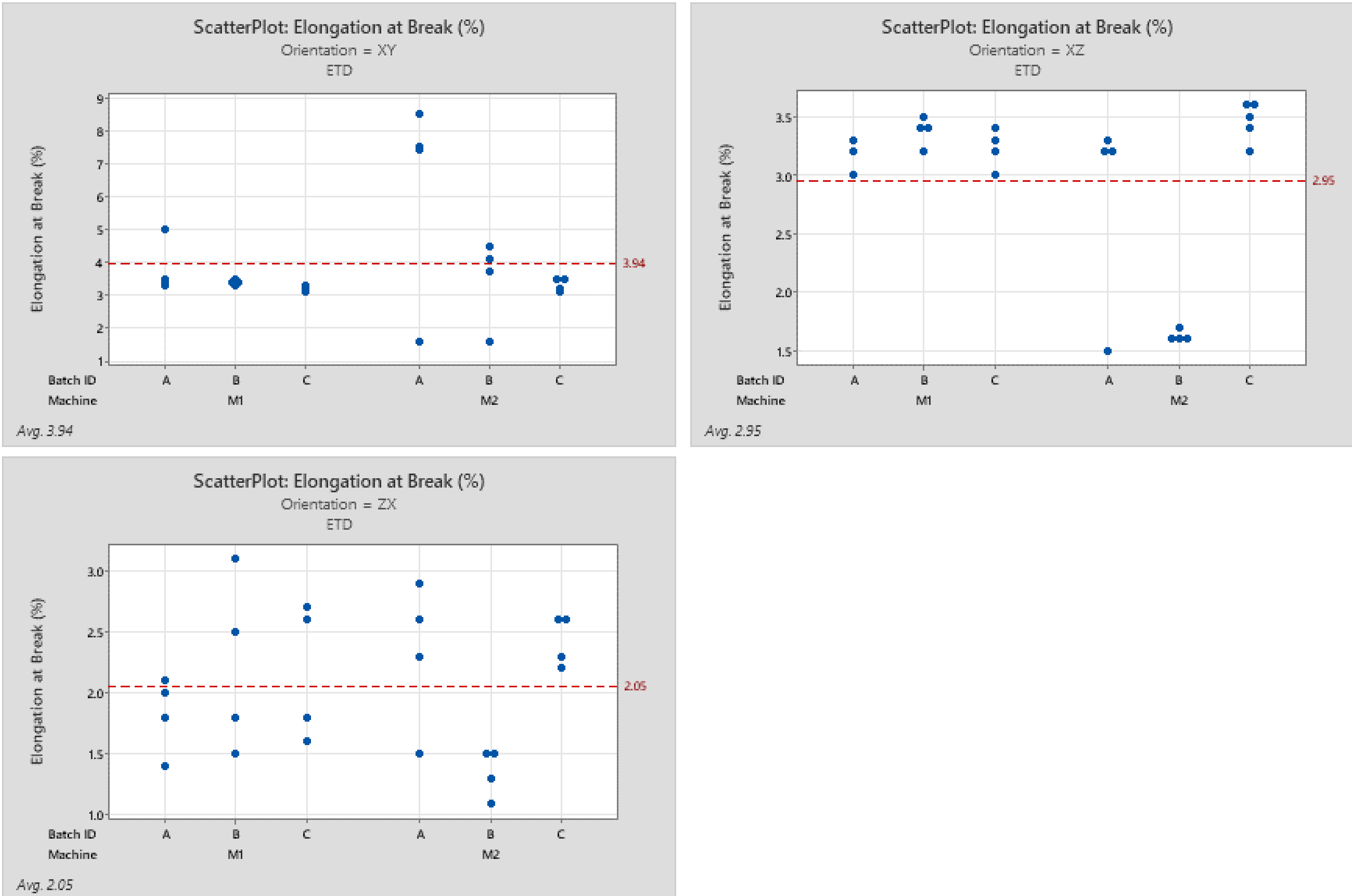


Figure 60. Plot of elongation at break by machine, per orientation for ETD.

9 SPECIMEN TEST CURVES

The following are representative examples of stress vs. strain curves for a selection of tests to understand material behavior. Full stress/strain curves for each specimen can be made available upon request.

9.1 Stress vs. Strain Examples

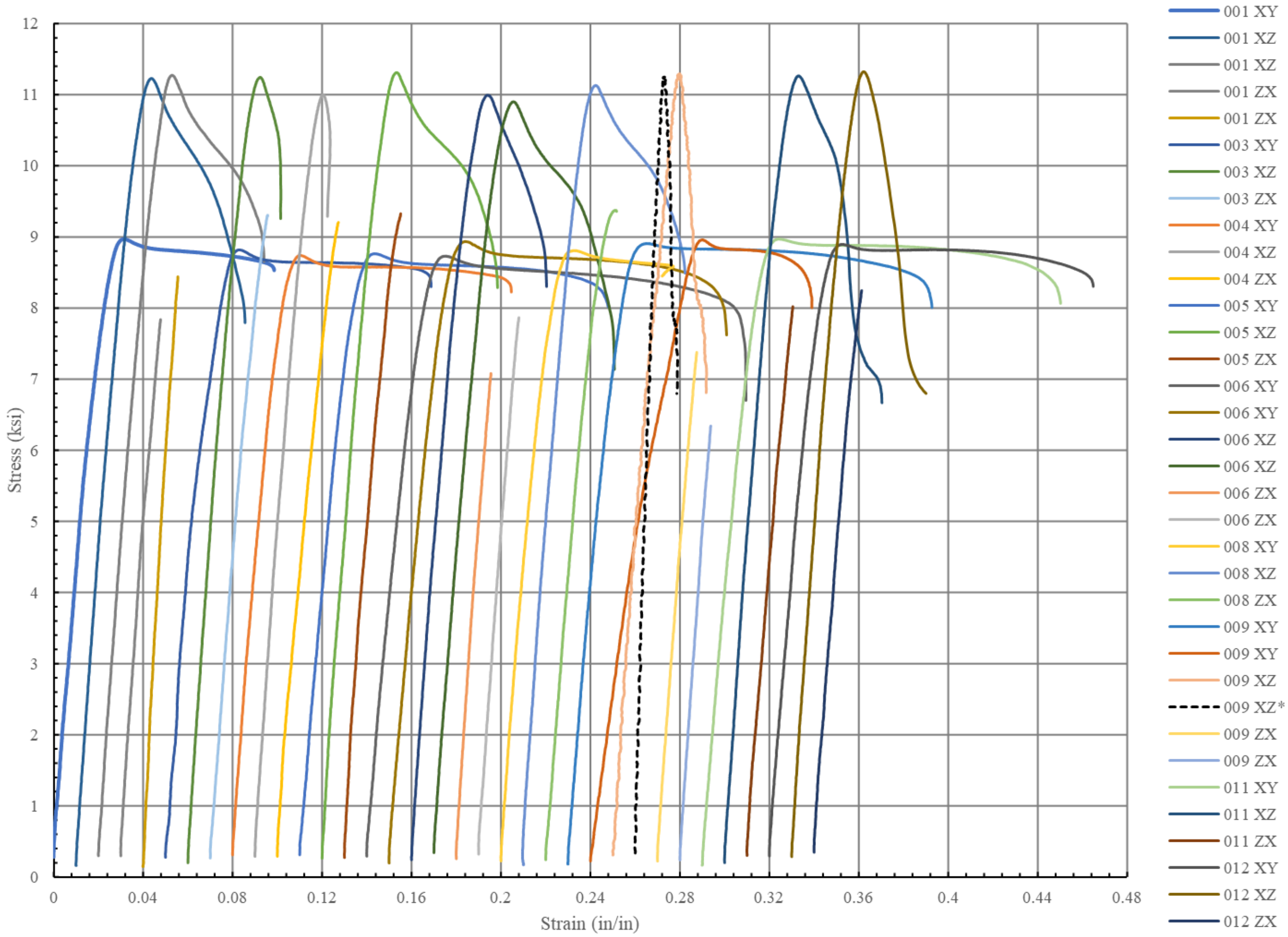


Figure 61. A combined set of representative stress vs. strain curves from D638 tension specimens across all orientations.

List of Acronyms

Acronym	Definition
AM	Additive Manufacturing
ASTM	American Society for Testing and Materials
CAD	Computer Aided Drawing
CMH-17	Composites Material Handbook for Polymer Matrix Composites
CTD	Cold Temperature Dry
CV	Coefficient of Variance
DOT	Department of Transportation
ETD	Elevated Temperature Dry
ETW1	Elevated Temperature Wet version 1
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FHC	Filled Hole Compression
FHT	Filled Hole Tension
FMEA	Failure Mode Effects Analysis
FST	Flame, Smoke, and Toxicity
GD&T	Geometric Dimensioning and Tolerances
LM-SS	Lockheed Martin Space Systems
NCAMP	National Center for Advanced Materials Performance
NIAR	National Institute of Aviation Research
OHT	Open-Hole Tension
PCD	Process Control Document
RTA	Room Temperature Ambient
RTD	Room Temperature Dry
RTW	Room Temperature Wet
SDM	Stratasys Direct Manufacturing
SSB	Single Shear Bearing
SSYS	Stratasys Inc.

Appendix A