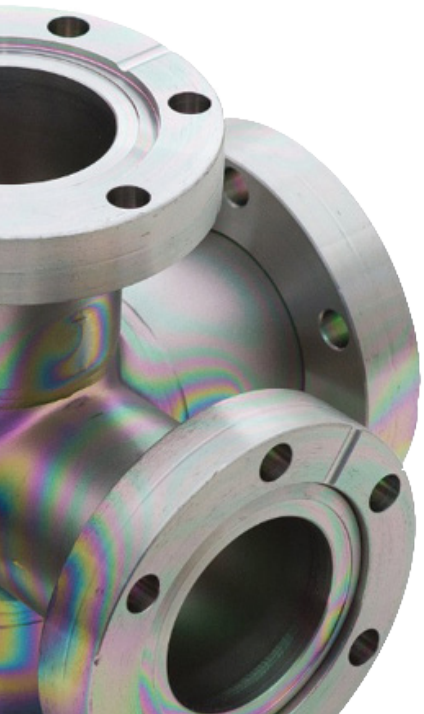
Bulk mechanical testing comparison of coated, uncoated, and thermal treated 316 stainless samples

Technical Insight

Author

David Smith,
R&D Scientist

SilcoTek® Corporation



Synopsis

In 2017, SilcoTek hired an external testing lab, Massachusetts Materials Research, Inc., to evaluate the bulk substrate properties of 316 stainless steel and the possible effects of a Dursan process on those properties. Comparative testing was performed on 316 stainless samples that were coated with Dursan, an untreated Control, and a heat treated in nitrogen control (with the same thermal deposition profile as Dursan) referred to as “Heat Sample”. Three types of material tests were performed on each sample in triplicate. The tests were Tensile Properties (at Room Temperature and 450° C), Charpy Impact, and Rockwell Hardness. In general, there was no significant variation in all tests for all three coupon types.

Background

Customers have inquired whether the Dursan process, which has a maximum process temperature of 450C, has any effect on the bulk metallurgical properties of the stainless steel substrate. Since it would be difficult to test all possible substrates, 316 stainless steel was chosen as a test substrate, which is one of the most common substrates used by SilcoTek customers. The Dursan process was also chosen as an evaluation coating since it is the SilcoTek process that applies the highest temperature profile for the longest period of time, thereby illustrating a worst-case scenario for any potential detrimental thermal effects to the bulk substrate.

Three different samples were tested: 1) an untreated raw sample of 316 stainless steel referred to as “Control”, 2) the same 316 material subjected to the exact same thermal exposure as the Dursan process, but with inert nitrogen gas as the processing atmosphere, referred to as “Heat Sample”, and 3) the same 316 material coated with the SOP Dursan process, referred to as “Dursan”. The three tests were Tensile Strength measured at room temperature and at 450C, the Charpy Impact test, and Rockwell Hardness.

Tensile Strength (ASTM E8-16a)

This test involves a “dog-bone” test piece (see Figure 1). The test piece is mounted in a device that holds the two thicker ends and applies opposing force in the directions of the red arrows as shown in Figure 1.

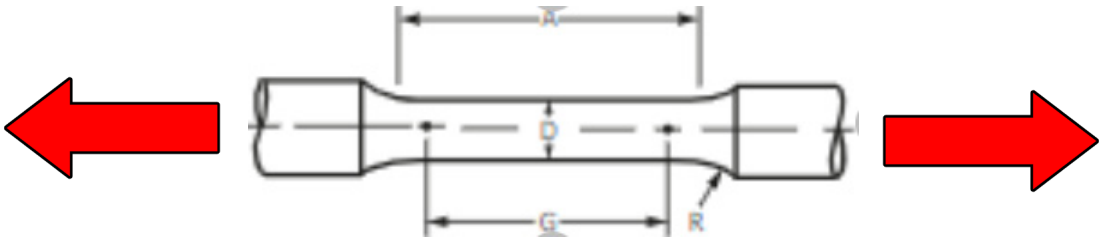


Figure 1: Illustration of Tensile Strength test coupon.

The instrument measures the Ultimate Strength in psi. This value (also known as the Tensile Strength) is calculated by dividing the maximum force carried by the specimen during the tension test by the original cross-sectional area of the specimen. The Yield Strength is measured in psi. This is the stress at which there is a 0.2% plastic elongation of the coupon. % Elongation in 4D is also reported, which is the % of elongation measured on the coupon whose gage length (G) is 4 times its gage diameter (D). The % Reduction of Area is the proportional reduction of cross-sectional area at the plane of fracture after fracture. Finally, the location of the fracture is reported. This test was performed twice: at room temperature and at 450° C for each specimen.

Charpy Impact (ASTM E23-12c)

This test involves the single beam (Charpy) impact testing of notched bar of specified dimensions (Type C). The mounted specimen is impacted by a pendulum-activated striker at a known force. The Energy of Rupture (i.e. force of the strike) is noted as well as whether or not there is visual breakage to the test piece. There were three test pieces for each specimen type (Dursan-coated, untreated, heat-exposed), for a total of 9 tests.

Rockwell Hardness

Rockwell hardness is measured pushing an indenter to generate the indentation hardness of a material. The value is dimensionless and correlates linearly with tensile strength of the bulk material. Testing was performed using a tungsten carbide ball indenter to generate RBW data.

Data

Tensile Properties (ASTM E8-16a) at Room Temp	Control	Heat Sample	Dursan Coated
Ultimate Strength (psi)	93,000	96,000	96,000
0.2% Yield Strength (psi)	49,600	52,000	52,000
% Elongation	56	54	53
% Reduction of Area	78	79	77
Break Location	Gage	Gage	Gage

Tensile Properties (ASTM E8-16a) at 450°C	Control	Heat Sample	Dursan Coated
Ultimate Strength (psi)	71,500	70,000	76,500
0.2% Yield Strength (psi)	31,500	30,800	32,600
% Elongation	37	36	40
% Reduction of Area	74	73	71
Break Location	Gage	Gage	Gage

Charpy Impact (ASTM E23-12c) Energy of Rupture (Ft/lbs)	Control	Heat Sample	Dursan Coated
Sample 1	264	264	264
Sample 2	264	264	264
Sample 3	264	264	264
Average	264	264	264
NONE OF THE SAMPLES BROKE			

Rockwell Hardness (RBW)	Control	Heat Sample	Dursan Coated
	94	93	94

Conclusion

A metallurgical testing comparison of tensile strength, impact resistance and hardness on untreated 316 stainless steel, Dursan coated 316 stainless, and 316 stainless exposed to the Dursan heat profile under a nitrogen atmosphere revealed no significant variance between all three test samples, with only slight improvements in tensile properties for the Dursan and Heat Sample test pieces.

Appendix follows on the next page.

Appendix:

Copy of the original testing report from Massachusetts Materials Research, Inc., 3/30/2017:

A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-6262 • FAX 508-835-9025

ANALYTICAL REPORT

SilcoTek® Corporation
225 PennTech Drive
Bellefonte, PA 16823

DATE March 30, 2017
P.O. NO.: 05395CM
MMR NO.: 116274
MMR ID#: 1
PAGE #: 1 of 1

ATTENTION: David Smith, Ph.D.

SAMPLE IDENTIFICATION: Routine Cutting, Machine Tensile (s/s) Tensile test, Test-ETT(450C), Hardness testing, ASTM methods per Quote 23744, ID#1: Control Sample

TENSILE PROPERTIES (ASTM E8-16a)

	Room Temp	450°C
Ultimate Strength (psi)	93,000	71,500
.2% Yield Strength (psi)	49,600	31,500
% Elongation in 4D	56	37
% Reduction of Area	78	74
Break Location	Gage	Gage

CHARPY IMPACT (ASTM E23-12c)
(Test Temperature 70°F - Full Size Specimens)

Sample I.D.	Energy of Rupture (Ft/lbs)
1	264
2	264
3	264
Average	264

All samples did not break.

HARDNESS
94 RBW

MASSACHUSETTS MATERIALS RESEARCH, INC.
Thomas W. Baxter
Manager of Testing Services

The recording of false, fictitious or fraudulent statements or entries on the certificate may be punishable as a felony under federal law.

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen performed by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

The results reported above apply only to the test sample(s) provided.

A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-6252 • FAX 508-835-9025

ANALYTICAL REPORT

SilcoTek® Corporation
225 PennTech Drive
Bellefonte, PA 16823

DATE March 30, 2017

P.O. NO.: 05395CM

MMR NO.: 116274

MMR ID#: 2

PAGE #: 1 of 1

ATTENTION: David Smith, Ph.D.

SAMPLE IDENTIFICATION Routine Cutting, Machine Tensile (s/s) Tensile test, Test-ETT(450C), Hardness testing, ASTM methods per Quote 23744, ID#2: Dursan Sample

TENSILE PROPERTIES (ASTM E8-16a)

	Room Temp	450°C
Ultimate Strength (psi)	96,000	76,500
.2% Yield Strength (psi)	52,000	32,600
% Elongation in 2"	53	40
% Reduction of Area	77	71
Break Location	Gage	Gage

CHARPY IMPACT (ASTM E23-12c)
(Test Temperature 70°F - Full Size Specimens)

Sample I.D.	Energy of Rupture (Ft/lbs)
1	264
2	264
3	264
Average	264

All samples did not break.

HARDNESS
94 RBW

MASSACHUSETTS MATERIALS RESEARCH, INC.

Thomas W. Baxter
Manager of Testing Services

Chemical analysis performed by Inductively Coupled Plasma/Optical Emission Spectrometer. Carbon, sulfur, nitrogen, hydrogen and oxygen performed by Leco Combustion. Mechanical and metallurgical testing performed per MMR Procedures.

A Subsidiary of THE MMR GROUP, INC.

Massachusetts Materials Research, Inc.

P.O. BOX 810 • 1500 CENTURY DRIVE • WEST BOYLSTON, MA 01583 • TEL. 508-835-6262 • FAX 508-835-9025

ANALYTICAL REPORT

SilcoTek® Corporation
225 PennTech Drive
Bellefonte, PA 16823

ATTENTION: David Smith, Ph.D.

DATE March 30, 2017
P.O. NO.: 05395CM
MMR NO.: 116274
MMR ID#: 3
PAGE #: 1 of 1

SAMPLE IDENTIFICATION Routine Cutting, Machine Tensile (s/s) Tensile test, Test-ETT(450C), Hardness testing, ASTM methods per Quote 23744, ID#3: Heat Sample

TENSILE PROPERTIES	(ASTM E8-16a) Room Temp	450°C
Ultimate Strength (psi)	96,000	70,000
.2% Yield Strength (psi)	52,000	30,800
% Elongation in 4D	54	36
% Reduction of Area	79	73
Break Location	Gage	Gage

CHARPY IMPACT (ASTM E23-12c)
(Test Temperature 70°F - Full Size Specimens)

Sample I.D.	Energy of Rupture (Ft/lbs)
1	264
2	264
3	264
Average	264

All samples did not break.

HARDNESS
93RBW

MASSACHUSETTS MATERIALS RESEARCH, INC.

Thomas W. Baxter
Manager of Testing Services