INTERNATIONAL

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Standard Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement[1]

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INTRODUCTION

When atomic hydrogen enters steels and certain other metals, for example, aluminum and titanium alloys, it can cause a loss of ductility, load carrying ability, or cracking (usually as submicroscopic cracks) as well as catastrophic brittle failures at applied stresses well below the yield strength or even the normal design strength for the alloys. This phenomenon often occurs in alloys that show no significant loss in ductility, when measured by conventional tensile tests, and is referred to frequently as hydrogen-induced delayed brittle failure, hydrogen stress cracking, or hydrogen embrittlement. The hydrogen can be introduced during cleaning, pickling, phosphating, electroplating, autocatalytic processes, porcelain enameling, and in the service environment as a result of cathodic protection reactions or corrosion reactions. Hydrogen can also be introduced during fabrication, for example, during roll forming, machining, and drilling, due to the breakdown of unsuitable lubricants as well as during welding or brazing operations. Parts that have been machined, ground, cold-formed, or cold-straightened subsequent to hardening heat treatment are especially susceptible to hydrogen embrittlement damage.

The results of research work indicate that the susceptibility of any material to hydrogen embrittlement in a given test is related directly to its trap population. The time-temperature relationship of the heat treatment is therefore dependent on the composition and structure of steels as well as plating metals and plating procedures. Additionally, for most high-strength steels, the effectiveness of the heat treatment falls off rapidly with a reduction of time and temperature.

1. Scope

1.1 This specification covers procedures for reducing the susceptibility or degree of susceptibility to hydrogen embrittlement or degradation that may arise in electroplating, autocatalytic plating, porcelain enameling, chemical conversion coating, and phosphating and the associated pretreatment processes. This specification is applicable to those steels whose properties are not affected adversely by baking at 190 to 230 °C or higher (see 6.1.1).

1.2 The heat treatment procedures established herein have been shown to be effective for reducing the susceptibility of steel parts of tensile strength 1000 MPa or greater that have been machined, ground, cold-formed, or cold-straightened subsequent to heat treatment. This heat-treatment procedure is used prior to any operation capable of hydrogen charging the parts, such as the cleaning procedures prior to electroplating, autocatalytic plating, porcelain enameling, and other chemical coating operations.

NOTE 1—1 MPa = 145.1 psi.

1.3 This specification has been coordinated with ISO/DIS 9587 and is technically equivalent.

1.4 The values stated in SI units are to be regarded as the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

[1] This specification is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.02 on Pre Treatment.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

A919 Terminology Relating to Heat Treatment of Metals (Withdrawn 1999)[3]

B242 Guide for Preparation of High-Carbon Steel for Electroplating

B322 Guide for Cleaning Metals Prior to Electroplating

B374 Terminology Relating to Electroplating

B851 Specification for Automated Controlled Shot Peening of Metallic Articles Prior to Nickel, Autocatalytic Nickel, or Chromium Plating, or as Final Finish

2.2 *ISO Standards:*[4]

ISO 2080 Electroplating and Related Processes—Vocabulary

ISO/DIS 9587 Pre-Treatments of Iron or Steel for Reducing the Risk of Hydrogen Embrittlement

2.3 *Federal Standard:*[5]

QQ-C-320 Chromium Plating (Electrodeposited)

3. Terminology

3.1 *Definitions*—Many of the terms used in this specification can be found in Terminology B374, Terminology A919, or ISO 2080.

4. Requirements

4.1 Heat treatment shall be performed on basis metals to reduce the risk of hydrogen embrittlement in accordance with Table 1. The duration of heat treatment shall commence in all cases from the time at which the whole of each part attains the specified temperature.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

TABLE 1 Classes of Stress Relief Requirements for High-Strength Steels (See Sections 4 through 6 for Details on the Use of Table 1)

Class	Stress-Relief Heat-Treatment Classes for High-Strength Steels		
	Steels of Tensile Strength (R_m), MPa	Temperature, °C	Time, h
SR-0	not applicable		
SR-1	over 1800	200–230	min 24
SR-2[A]	over 1800	190–220	min 24
SR-3	1401 to 1800	200–230	min 18
SR-4[A]	1450 to 1800	190–220	min 18
SR-5[A]	1034 or greater	177–205	min 3
SR-6	1000 to 1400	200–230	min 3
SR-7[A]	1050 to 1450	190–220	min 1
SR-8	surface-hardened parts ≤ 1400	130–160	min 8

[A] Classes SR-2, SR-4, SR-5, and SR-7 are traditional treatments used in Federal Standard QQ-C-320. They do not apply to any other standard.

4.2 Parts made from steel with actual tensile strengths ≥1000 MPa (with corresponding hardness values of 300 HV_{10kgf}, 303 HB, or 31 HR_c) and surface-hardened parts shall require heat treatment unless Class SR-0 is specified. Preparation involving cathodic treatments in alkaline or acid solutions shall be avoided.

4.3 Table 1 lists the stress-relief heat-treatment classes to be specified by the purchaser to the electroplater, supplier, or processor on the part drawing or purchase order. When no stress relief treatment class is specified by the purchaser, Class SR-1 shall be applied (see Note 4).

NOTE 2—The treatment class selected is based on experience with the part, or similar parts, and the specific alloy used or with empirical test data. Because of factors such as alloy composition and structure, size, mass, or design parameters, some parts may perform satisfactorily with no stress relief treatment. Class SR-0 treatment is therefore provided for parts that the purchaser wishes to exempt from treatment.

NOTE 3—The use of inhibitors in acid pickling baths is not necessarily guaranteed to minimize hydrogen embrittlement.

NOTE 4—Class SR-1, the longest treatment, is the default when the purchaser does not specify a class. The electroplater, supplier, or processor is not normally in possession of the necessary information, such as design considerations, induced stresses from manufacturing operations, etc., that must be considered when selecting the correct stress relief treatment. It is in the purchasers' interest that their part designer, manufacturing engineer, or other technically qualified individual specify the treatment class on the part drawing or purchaser order in order to avoid the extra cost of the default treatment.

5. Categorization of Steels

5.1 With the exception of surface-hardened parts, heat treatment conditions shall be selected on the basis of actual tensile strength. When only the minimum tensile strength is specified, or if the tensile strength is not known, the heat treatment condition shall be selected by relating known or measured hardness values to equivalent actual tensile strengths. The tensile strength shall be supplied by the purchaser.

5.2 Steels that have been wholly or partly surface hardened shall be considered as being in the category appropriate to the hardness of the surface-hardened layer.

6. Stress Relief

6.1 For high-strength steels, the following conditions apply. Stress relief treatment is not essential for steels of actual tensile strength below 1000 MPa. The conditions given in Table 1 are applied for steels of actual tensile strength above 1000 MPa. The heat treatment shall be conducted before the commencement of any preparations or cleaning treatments using processes liable to cause embrittlement such as cathodic electrocleaning or acid pickling. Other cleaning processes, such as those described in Guides B242 or B322, may be used.

6.1.1 Suitable combinations of a shorter time at appropriate higher temperatures may be used if they have been shown not to be detrimental. For tempered steels, items shall not be heated above a temperature that shall be at least 50 °C below the tempering temperature.

6.1.2 If stress relief is given after shot peening in accordance with Specification B851 or other cold working processes to introduce beneficial compressive stresses, the temperature shall not exceed 230 °C.

6.1.3 Items having surface-hardened areas that would suffer an unacceptable reduction in hardness by treatment in accordance with Table 1 shall be heat-treated at a lower temperature, but not below 130 °C, for a minimum period of 8 h. This treatment is applicable for items made of steel with actual tensile strengths below 1400 MPa.

7. Keywords

7.1 delayed brittle failure; heat treatment; hydrogen embrittlement; hydrogen induced cracking; hydrogen stress cracking; pre-treatments of iron or steel; stress relief

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