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Metallic and other inorganic coatings — Electrodeposited coatings of chromium for engineering purposes

Revêtements métalliques et autres revêtements inorganiques — Dépôts électrolytiques de chrome pour usages industriels

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 6158 was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*, Subcommittee SC 3, *Electrodeposited coatings and related finishes*.

This third edition cancels and replaces the second edition (ISO 6158:2004), of which it constitutes a minor revision.

Introduction

Electrodeposited chromium coatings are frequently deposited from hexavalent chromium solutions similar to those used for decorative electroplating. Engineering chromium coatings, however, are generally thicker than decorative ones. Regular or conventional chromium is the type most frequently specified, but porous, cracked or specially profiled surfaces and duplex chromium are also applied to achieve oil-retaining or non-sticking surfaces, or to improve corrosion resistance.

Electrodeposited chromium coatings for engineering applications are most often applied directly to the basis metal to increase wear and abrasion resistance, to increase fretting resistance, to reduce static and kinetic friction, to reduce galling and seizing, to increase corrosion resistance, and to build up undersize or worn parts. For protection against severe corrosion, nickel or other metallic undercoats may be applied prior to the electrodeposition of chromium, or the corrosion resistance of the chromium coating may be increased by alloying, e.g. with molybdenum.

Metallic and other inorganic coatings — Electrodeposited coatings of chromium for engineering purposes

WARNING — This International Standard may not be compliant with some countries' health and safety legislations and calls for the use of substances and/or procedures that may be injurious to health if adequate safety measures are not taken. This International Standard does not address any health hazards, safety or environmental matters and legislations associated with its use. It is the responsibility of the user of this International Standard to establish appropriate health, safety and environmentally acceptable practices and take suitable actions to comply with any national and International regulations. Compliance with this International Standard does not in itself confer immunity from legal obligations.

1 Scope

This International Standard specifies requirements for electroplated coatings of hexavalent chromium, with or without undercoats, on ferrous and non-ferrous metals for engineering purposes. The coating designation provides a means of specifying the thickness of chromium appropriate for typical engineering applications.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1463, *Metallic and oxide coatings — Measurement of coating thickness — Microscopical method*

ISO 2064, *Metallic and other inorganic coatings — Definitions and conventions concerning the measurement of thickness*

ISO 2080, *Metallic and other inorganic coatings — Surface treatment, metallic and other inorganic coatings — Vocabulary*

ISO 2177, *Metallic coatings — Measurement of coating thickness — Coulometric method by anodic dissolution*

ISO 2178, *Non-magnetic coatings on magnetic substrates — Measurement of coating thickness — Magnetic method*

ISO 2819, *Metallic coatings on metallic substrates — Electrodeposited and chemically deposited coatings — Review of methods available for testing adhesion*

ISO 3497, *Metallic coatings — Measurement of coating thickness — X-ray spectrometric method*

ISO 3543, *Metallic and non-metallic coatings — Measurement of thickness — Beta backscatter method*

ISO 3882, *Metallic and other inorganic coatings — Review of methods of measurement of thickness*

ISO 4516, *Metallic and other inorganic coatings — Vickers and Knoop microhardness tests*

ISO 4519, *Electrodeposited metallic coatings and related finishes — Sampling procedures for inspection by attributes*

ISO 4526, *Metallic coatings — Electroplated coatings of nickel for engineering purposes*

ISO 9220, *Metallic coatings — Measurement of coating thickness — Scanning electron microscope method*

ISO 9587, *Metallic and other inorganic coatings — Pretreatment of iron or steel to reduce the risk of hydrogen embrittlement*

ISO 9588, *Metallic and other inorganic coatings — Post-coating treatments of iron or steel to reduce the risk of hydrogen embrittlement*

ISO 10309, *Metallic coatings — Porosity tests — Ferroxyl test*

ISO 10587, *Metallic and other inorganic coatings — Test for residual embrittlement in both metallic-coated and uncoated externally-threaded articles and rods — Inclined wedge method*

ISO 12686, *Metallic and other inorganic coatings — Automated controlled shot-peening of metallic articles prior to nickel, autocatalytic nickel or chromium plating, or as a final finish*

ISO 15724, *Metallic and other inorganic coatings — Electrochemical measurement of diffusible hydrogen in steels — Barnacle electrode method*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2064, ISO 2080, ISO 3882, ISO 9587, ISO 9588 and ISO 12686 apply.

4 Information to be supplied by the purchaser to the processor

When ordering articles to be processed in accordance with this International Standard, the purchaser shall provide the following essential information in writing, for example, in the contract or purchase order, or on the engineering drawings:

a) the designation (see Clause 5);

b) the nominal composition or specification, and metallurgical condition of the basis metal including hardness (see 5.3); in the case of reclaimed articles, it may not be possible to supply this information, and it may, therefore, be difficult to guarantee the quality of the coating;

c) the nature, condition and finish of the basis metal if they are likely to affect the serviceability and/or appearance of the coating (see 6.3);

d) the significant surface, indicated by drawings of the articles or by suitably marked samples (see 6.2);

e) the requirements for special test specimens (see 6.1);

f) the appearance and surface finish of the chromium coating, e.g. as-plated, ground or machined (see 6.2 and 6.3); alternatively, samples showing the appearance and required finish shall be supplied or approved by the purchaser, and used for comparison purposes (see 6.2);

g) the necessity for any treatment to induce compressive stress, e.g. peening before or after electroplating (see 6.10);

h) any special requirements for, or restrictions on, pretreatment, e.g. vapour blasting instead of acid pretreatment;

i) positions, where unavoidable, contact marks and the type, size and number of other defects that are acceptable (see 6.2);

j) requirements for undercoats (see 5.5 and 6.11) and stripping (see 6.12);

k) the test method to be used to measure thickness (see 6.4) and additional segment of the surface where minimum thickness requirements apply;

l) the adhesion and porosity requirements, and test methods (see 6.6 and 6.7, respectively);

m) the tensile strength of parts and the requirement for stress-relief heat treatment before electroplating (see 6.8);

n) requirements for any embrittlement-relief heat treatment after electroplating, and for hydrogen embrittlement testing (see 6.9);

o) the sampling plan and acceptance levels (see Clause 7);

p) any additional information, e.g. any special requirements for adhesion (see 6.6).

5 Designation

5.1 General

The designation shall appear on engineering drawings, in the purchase order, the contract or in the detailed product specification.

The designation specifies, in the order given, the basis metal, the specific alloy (optional), stress relief requirements, the type and thickness of undercoats, the type and thickness of the electroplated chromium coating, and post-treatments such as heat treatment to reduce susceptibility to hydrogen embrittlement.

5.2 Designation specification

The designation shall comprise the following:

a) the term “Electrodeposited coating”;

b) the number of this International Standard, i.e. ISO 6158;

c) a hyphen;

d) the chemical symbol of the basis metal (see 5.3), e.g. Fe (iron or steel);

e) a solidus (/);

f) stress relief (SR) designation, (see 5.4);

g) a solidus (/);

h) chemical symbols for the chromium coating, as well as coatings applied prior to chromium electroplating, separated by solidi for each stage in the coating sequence in the order of application; double solidi or separators (//) to be used to indicate that a step has been omitted or is not a requirement;

i) a number indicating the minimum thickness, in micrometres, of the coating(s) followed by a solidus (/);

j) hydrogen-embrittlement-relief (ER) designation (see 5.4).

See 5.6 for examples of designations.

5.3 Designation of basis metal

The basis metal shall be designated by its chemical symbol, or its principal constituent if it is an alloy.

For example:

a) Fe for iron and steel;

b) Zn for zinc alloys;

c) Cu for copper and copper alloys;

d) Al for aluminium and aluminium alloys.

To ensure proper surface preparation and hence adherence of the coating to the substrate, it is essential to identify the specific alloy and its metallurgical condition (tempered, nitrided, etc.).

It is recommended that the specific alloy be identified by its standard designation following the chemical symbol of the basis metal; for example, its UNS number, or the national or regional equivalent, may be placed between the symbols < > (see Bibliography).

EXAMPLE Fe<G43400> is the UNS designation for a high-strength steel.

5.4 Designation of heat treatment requirements

The heat treatment requirements shall be in brackets and designated as follows:

a) the letters SR, for heat treatment for stress relief purposes; the letters ER, for heat treatment for the purpose of reducing susceptibility to hydrogen embrittlement; the letters, HT, for heat treatment for other purposes;

b) in parenthesis, the minimum temperature, in degrees Celsius;

c) the duration of the heat treatment, in hours;

EXAMPLE [SR(210)1] designates stress relief heat treatment at 210 °C for 1 h.

d) when heat treatment prior to or after electrodeposition is specified, the requirements shall be included in the designation (see 5.6).

5.5 Designation of type and thickness of metal layers

The electrodeposited chromium coating shall be designated by the symbols given in Table 1 placed after a number giving the specified minimum local thickness of the coating, in micrometres. Annex A provides information on the typical thickness of chromium specified in engineering applications.

EXAMPLE Cr50hr designates a regular hard chromium coating that is 50 µm thick.

Table 1 — Symbols for different types of chromium

Type of chromium	Symbol
Regular hard chromium	hr
Hard chromium from mixed acid solutions	hm
Microcracked hard chromium	hc
Microporous hard chromium	hp
Duplex chromium	hd
Special types of chromium	hs

Nickel undercoats shall be designated in accordance with ISO 4526, i.e. the symbol sf for sulfur-free nickel coatings, sc for sulfur-containing nickel coatings, or the symbol pd for sulfur-free nickel coatings containing submicron particles dispersed throughout the nickel matrix, shall be used to designate the type of nickel undercoat by placing the appropriate symbol after the number giving the specified minimum local thickness of the coating, in micrometres.

EXAMPLE Ni10sf designates an electrodeposited nickel undercoat 10 µm thick prepared from a solution that does not introduce sulfur into the deposit.

5.6 Examples of designations

The examples of designations below describe the heat treatment and electroplating steps in the order that they are performed. The standard designation of the basis material is placed immediately after the chemical symbol for steel, Fe. It is especially important to know the standard designation of a metal or alloy that is difficult to prepare for electroplating and that is susceptible to hydrogen embrittlement.

For ordering purposes, the detailed product specification shall not only comprise the designation, but shall also include clear written statements of other requirements that are essential for the serviceability of a particular product (see Clause 4).

An example of an electrodeposited coating of regular hard chromium 50 µm thick (Cr50hr) deposited on mild steel (Fe), ignoring omission of any step (double solidi), is as follows:

Electrodeposited coating ISO 6158 – Fe/Cr50hr

An example of an electrodeposited coating of porous, electrodeposited chromium that is 250 µm thick (Cr250hp) on an aluminium alloy (Al), ignoring omission of any step (double solidi), is as follows:

Electrodeposited coating ISO 6158 – Al/Cr250hp

An example of an electrodeposited coating of regular hard chromium 50 µm thick (Cr50hr) deposited on steel (Fe) over an undercoat of sulfur-free nickel 10 µm thick (Ni10sf), ignoring omission of any step (double solidi), is as follows:

Electrodeposited coating ISO 6158 – Fe/Ni10sf/Cr50hr

An appropriate designation of an electrodeposited coating of regular hard chromium 50 µm thick (Cr50hr) deposited on steel that is stress relieved prior to electroplating at 210 °C for 2 h and heat treated after electroplating for embrittlement-relief purposes at 210 °C for 22 h is as follows:

Electrodeposited coating ISO 6158 – Fe/[SR(210)2]/Cr50hr/[ER(210)22]

6 Requirements

6.1 Special test specimens

Special test specimens are often used to measure adhesion, thickness, porosity, corrosion, hardness, and other properties when the coated articles are not suitable for the test, or if it is not practical to submit the coated articles to destructive tests because the parts are few in number or too expensive. Special test specimens shall be of the same material, shall be in the same metallurgical condition, and shall have the same surface condition as the coated articles, and shall be processed along with the coated articles that they represent.

The use of special or representative test specimens to determine that the requirements of this International Standard have been satisfied, the number of test specimens to be used, the material from which they shall be made, and their shape and size shall be specified by the purchaser [see 4 e)].

6.2 Appearance

The chromium coating on the significant surface shall be bright or lustrous and, when visually inspected, shall be free from pits, blisters, exfoliation or other defects detrimental to the final finish. Nodular growths elsewhere than at the extreme edges of coatings are not permitted on articles used in the as-plated condition, or on the surface of ground articles. Imperfections and variations that arise from surface conditions of the basis metal (scratches, pores, roll marks, inclusions) and that persist in the finish, despite the observance of good metal finishing practice, shall not be cause for rejection. The purchaser shall specify limits for the tolerable defects on the finished and unfinished product [see 4 i)].

Approved samples of artefacts shall be used for comparison purposes [see 4 f)].

Electroplated articles shall be free from cracks, visible, if needed, with corrected vision. Coatings thicker than 50 µm shall be free from macro-cracks extending to the basis metal.

If parts are electroplated and subsequently ground to size, the grinding shall never be done dry, but with the proper coolant and with a sufficiently light touch to prevent cracking. Macro-cracking, visually observed, with unaided or corrected vision, but without magnification after grinding, shall be a cause for rejection.

Blisters or cracks that are visible and that result from heat treatment or grinding procedures performed by the electroplater shall be cause for rejection.

6.3 Surface finish

This International Standard does not specify requirements for the surface condition of the basis metal prior to electroplating.

Because the appearance and serviceability of coatings depends on the surface condition of the basis metal, agreement shall be reached between the interested parties that the surface finish of the basis metal is satisfactory for electroplating, (see Bibliography), [see 4 b), 4 c) and 4 f)].

The surface finish of the chromium coating might be, for example, as-plated, ground or machined. Alternatively, samples showing the required finish shall be supplied or approved by the purchaser, and used for comparison purposes [see 4 f)].

For ground finishes, a surface roughness value, Ra, of 0,4 µm is termed a commercial finish and 0,2 µm is termed a good commercial finish.

6.4 Thickness

The coating thickness specified in the designation shall be the minimum local thickness. The minimum local thickness of an electrodeposited coating shall be measured on any point that can be touched by a ball 20 mm in diameter, unless otherwise specified by the purchaser [see 4 k)].

The minimum local thickness of electrodeposited chromium, nickel or other metallic undercoats shall be measured by one of the methods described in Annex B, unless specified otherwise by the purchaser [see 4 k)].

In cases of dispute, the coulometric method shall be used for measuring the thickness of chromium coatings less than 10 µm thick, and the microscopical method shall be used for measuring the thickness of chromium coatings and undercoats 10 µm and above [see 4 k)].

Although there are no technical limitations to the thickness of chromium that can be electroplated, there are practical limitations caused by the size and geometry of the articles that make it difficult to achieve smooth surfaces and uniformity of deposit thickness, especially as the chromium thickness is increased. The electroplating operation may have to be interrupted at intermediate stages of processing to hone or machine the coated surface so as to meet appearance and surface roughness requirements. The honed or machined surface shall be properly prepared (see 6.12) prior to resumption of electroplating to ensure adhesion between layers of chromium. Auxiliary anodes may have to be employed to achieve uniformity of deposit thickness and coverage.

6.5 Hardness

When hardness is specified, it shall be measured by the method given in ISO 4516.

6.6 Adhesion

A bend test on a representative sample, electroplated with 25 µm of chromium, is applied as a test of the effectiveness of the process. A review of methods of testing adhesion is given in ISO 2819, which includes a thermal shock test that has been found applicable in certain cases. For thick deposits of chromium (greater than 25 µm), a grinding test is useful for detecting poor adhesion [see 4 l)].

It is the responsibility of the electroplater to ensure that the method for surface preparation prior to electroplating results in coatings that are adherent to the basis metal (see 6.3). Also see 6.4 regarding the need for proper surface preparation to ensure adhesion of chromium to chromium.

6.7 Porosity

Electroplated ferrous articles (or special test specimens) shall be subjected to the ferroxyl test described in ISO 10309, or to an alternative porosity test specified by the purchaser. The part fails if more than the number of pores per part or per unit area exceeds that agreed between the purchaser and the electroplater [see 4 l)].

When porous, cracked or other types of discontinuous chromium coatings are specified, the determination of the number of pores and cracks in the chromium shall be carried out by using an optical microscope of suitable magnification, or by the method given in Annex C, when applicable [see 4 l)].

The method given in Annex C may not be applicable to thick chromium coatings where cracks or pores do not extend to the basis metal or to a nickel undercoat.

6.8 Stress relief heat treatment prior to coating

When specified by the purchaser, steel parts that have an ultimate tensile strength equal to or greater than 1 000 MPa (31 HRC) and that contain tensile stresses caused by machining, grinding, straightening or cold-forming operations shall be given a stress relief heat treatment prior to cleaning and metal deposition. The procedures and classes for stress relief heat treatment shall be according to the procedures and classes from ISO 9587 or as specified by the purchaser [see 4 m)].

Steels with oxide or scale shall be cleaned before application of the coatings. For high strength steels, non-electrolytic alkaline and anodic alkaline cleaners, as well as mechanical cleaning procedures, are preferred to avoid the risk of producing hydrogen embrittlement during cleaning operations. The possibility of overheating shall be considered in the case of mechanical cleaning of high-strength steels (tensile strength $>$ 1 400 MPa).

6.9 Hydrogen-embrittlement-relief heat treatment

Steel parts having an ultimate tensile strength equal to or greater than 1 000 MPa (31 HRC), as well as surface-hardened parts, shall receive hydrogen-embrittlement-relief heat treatment according to the procedures and classes of ISO 9588 or as specified by the purchaser [see 4 n)].

The effectiveness of the embrittlement-relief treatment shall be determined by a test method specified by the purchaser [see 4 n)] or by the test methods described in ISO 10587 and ISO 15724.

6.10 Peening of metal parts

If peening prior to or after electroplating is specified by the purchaser, it shall be performed in accordance with ISO 12686. The method of measuring shot peening intensity is also described in ISO 12686 [see 4 g)].

Shot peening prior to electroplating can minimize the reduction in fatigue strength that occurs when high-strength steels are electroplated with chromium, and is recommended for parts subjected to repeated applications of complex load patterns in service. Other factors that affect fatigue strength include thickness, which shall be kept as thin as is compatible with the expected service conditions. The compressive stresses resulting from controlled shot peening increase corrosion resistance and resistance to stress corrosion cracking.

6.11 Use of undercoats

When specified by the purchaser [see 4 j)], nickel or other metallic undercoats may be applied, and hydrogen-embrittlement-relief treatment [see 4 n) and 6.9], if required, shall be carried out after electroplating in accordance with the procedures and classes of ISO 9588. Electrolytic nickel undercoats shall comply with ISO 4526.

6.12 Stripping

Stripping and re-plating is permitted, but coatings on parts having an ultimate tensile strength equal to or greater than 1 000 MPa (31 HRC), which are stripped in acid, shall be given embrittlement-relief treatment (see 6.9) before subsequent electroplating. Embrittlement-relief treatment after stripping may not be necessary if the parts are stripped anodically in an alkaline solution [see 4 n)].

With previously electroplated parts where the chromium has been worn through, or where grinding has exposed the basis metal, or the undercoat (if present), better results are often obtained by stripping the remaining chromium completely.

When the chromium on the surface is sound however, the surface may be finished to approximate the requirements of the final product, for example, by grinding with a diamond wheel coated with aluminium oxide. After degreasing and anodically cleaning in an alkaline solution followed by thorough rinsing, the initial layer of chromium may be activated by anodic etching at 6 V in the chromium electroplating solution for 10 s to 20 s, and then making the part cathodic, initially at 3 V and then slowly increasing the voltage so that gassing and electrodeposition commence in 30 s to 60 s, and full current is reached in 5 min.

7 Sampling

The method of sampling shall be selected from the procedures specified in ISO 4519. The acceptance levels shall be as specified by the purchaser [see 4 o)].

Annex A
(informative)

Typical thickness of chromium specified in engineering applications

Typical thickness µm	Application
≥ 2 to ≤ 10	To reduce friction and for light wear resistance
> 10 to ≤ 30	For moderate wear resistance
> 30 to ≤ 60	For adhesive wear resistance
> 60 to ≤ 120	For severe wear resistance
> 120 to ≤ 250	For severe wear, abrasion and erosion resistance
> 250	For repair

Annex B
(normative)

Thickness test methods for electroplated chromium and other metallic coatings

B.1 General

ISO 3882 reviews methods of measuring the thickness of metallic and inorganic coatings.

B.2 Destructive tests

B.2.1 Microscopical method

Use the method specified in ISO 1463. The microscopical method shall be used for measuring the thickness of chromium coatings and undercoats 10 µm and above.

B.2.2 Coulometric method

The coulometric method specified in ISO 2177 may be used to measure the total thickness of the chromium deposits, as well as the thickness of a metallic under-layer, when present, at any point on the significant surface which can be touched by a ball 20 mm in diameter. In cases of dispute, the coulometric method shall be used for measuring the thickness of chromium coatings less than 10 µm thick (see 6.4).

B.2.3 Scanning electron microscope method

The scanning electron microscope method specified in ISO 9220 may be used to measure chromium thickness and the thickness of under-layers.

B.3 Non-destructive tests

B.3.1 Magnetic method

The magnetic method specified in ISO 2178 may be used when the basis metal is magnetic.

B.3.2 Beta backscatter method

Use the method specified in ISO 3543. This method is suitable for measuring the thickness of chromium coatings on aluminium and aluminium alloys, magnesium and magnesium alloys, titanium and titanium alloys, and non-metals.

B.3.3 X-ray spectrometric method

Use the method specified in ISO 3497. This method is also known as the X-ray fluorescence method.

Annex C
(normative)

Determination of cracks and pores in chromium coatings

C.1 General

Microcracking can usually be detected by direct microscopical examination without pretreatment. However, the copper deposition method (see C.3) is recommended as a means of revealing cracks in the case of a dispute, and is necessary to reveal micropores.

C.2 Microscopical examination for cracks without pretreatment

Examine the surface for cracks in reflected light under an optical microscope at a suitable magnification. Use a micrometer eyepiece or a similar device for indicating the distance over which cracks are counted. Carry out the determination over a measured length so that at least 40 cracks are counted.

C.3 Copper deposition method for cracks and pores — Copper sulfate (Dubpernell test)

C.3.1 Principle

Electrodeposition of copper from an acid sulfate solution at low current density or low voltage occurs only on the underlying nickel coating, if present, or on iron, zinc or aluminium basis metals exposed through discontinuities in the chromium. This method may be used as a rapid means of visually assessing the uniformity of cracks or pores or for counting them. In the latter case, a microscope is to be used.

C.3.2 Procedure

The test is best applied immediately on completion of the electroplating process. If there is any delay, degrease the test specimen thoroughly prior to testing, avoiding any electrolytic treatment. Using the test specimen as the cathode, deposit copper on to it for approximately 1 min in a bath containing a solution of approximately 200 g/l of copper(II) sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$) and 20 g/l of sulfuric acid (H_2SO_4, density 1,84 g/cm^3) maintained at 20 °C ± 5 °C and using an average current density of 0,3 A/dm^2 (approximately 0,2 V to 0,4 V depending on anode to cathode spacing).

It is essential before immersing them in the bath that the test specimen and the anodes are connected to the current supply.

In cases where the test is applied several days after chromium deposition, immerse the test specimen in a solution containing 10 g to 20 g of nitric acid per litre for 4 min at approximately 65 °C before the copper deposition stage in order to help reveal cracks or pores. Carry out the determination over a measured length so that at least 40 cracks or at least 200 pores are counted.

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