International Mg Society Limited (IMS)

IMS International Standards (2025)

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IMS International Standards are developed to support the production, testing, evaluation, and trade of magnesium and magnesium alloys across the global industry. They provide a shared technical foundation for stakeholders throughout the magnesium value chain, helping to harmonize requirements, facilitate communication, and streamline technical and commercial negotiations.

Drawing on extensive data and industry experience, IMS Standards distill essential technical content and introduce targeted adaptations that reflect the practical realities of the magnesium industry. They are designed to address current industrial needs while remaining open to continuous improvement.

Developed by the International Mg Society, International Mg Society Limited and expert members, these standards are made available for trial use, and feedback from all participants in the magnesium industry is actively encouraged—particularly with regard to technical content. Contributions and suggestions from researchers, engineers, manufacturers, and users are welcomed to ensure the standards remain relevant, robust, and internationally applicable.

International Mg Society (IMS) is a non-profit organization dedicated to advancing research, development, and applications of magnesium and its alloys. IMS provides a global platform for academic and industrial exchange, organizes international conferences on magnesium, and supports the dissemination of scientific knowledge. Journal of Magnesium and Alloys is the official journal of IMS.

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Foreword

The International Mg Society (IMS) is a non-profit organization. The purpose of IMS is to promote research, development, and applications of magnesium and its alloys, and to provide an academic exchange platform for all magnesium scientists and engineers. The president of IMS is Prof. Fusheng Pan. Vice presidents of IMS are Prof. Karl Ulrich Kainer (Germany), Prof. Alan Luo (USA), and Prof. Kwang Seon Shin (Korea).

IMS holds international conferences on magnesium and supports the publication and presentation of scientific results. Journal of Magnesium and Alloys is the official journal for IMS.

IMS standards are prepared by International Magnesium Alloys Advanced Materials Technology Limited (HK, China), the secretariat of the Information Committee on IMS, and prepared by IMS members.

IMS standards are published and served for all parts concerned with Magnesium in the world and are to be modified with help from anybody in the magnesium industry chain.

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This document was published by the International Mg Society Limited (IMS).

IMS Standards aim to serve the producing, testing, evaluation, and trade of the global magnesium and magnesium alloy industry, offer a standard basis for multiple parties in the industrial chain, intensified technical requirements, and simplify negotiation processes. In the preparation of the IMS standard, a number of relevant data are referred to, and the essential contents are extracted, then the targeted modifications are carried out according to the actual situation of the magnesium industry. This standard is free on trial, and any parties along the magnesium chain are sincerely invited to put forward amendments and suggestions for this standard, especially the technical contents. Please provide amendments and reasons, and attach the necessary proof of the issues, if possible.

Any feedback or questions on this document should be directed to the secretariat of the Information Committee on IMS (Email: international_Mg@163.com).

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Contents

Chapter 1

Magnesium and Magnesium Alloys – Terms and Definitions of Surface Treatment

1.1 Scope

This document specifies the terms and definitions of surface treatment of magnesium and magnesium alloys, including basic terminology, surface treatment, performance, testing, and evaluation.

It applies to the surface treatment of magnesium and magnesium alloys.

1.2 Terms and Definitions

For this document, the following terms and definitions apply.

1.2.1 Basic Terminology

1.2.1.1 Chemical Conversion

Chemical conversion is the process of forming a chemical oxide coating on magnesium in an oxidizing chemical solution, formerly known as chemical oxidation.

1.2.1.2 Anodic Oxidation/Anodizing

Anodic oxidation/anodizing is an electrochemical oxidation process. In this process, a ceramic oxide coating is formed on the surface of magnesium or magnesium alloy through electrochemical action, with magnesium or magnesium alloy serving as the anode and stainless steel or carbon serving as the cathode. The coating has protective, decorative, or other functional characteristics.

1.2.1.3 Micro-Arc Oxidation

Micro-arc oxidation (MAO) is the anodic oxidation of the high-voltage area in the plasma discharge area. The micro-arc generated on the electrode surface is used to sinter the oxide coating on the electrode surface to form a ceramic oxide coating. In the MAO treatment, the obvious arc discharge appears at the interface between the electrode and the solution. It is also called plasma electrolytic oxidation (PEO), anodic spark deposition (ASD), or Arc-anodizing deposition (AAD).

1.2.1.4 Electroplating (Electrodeposition)

Electroplating is the process of depositing a metal or alloy coating on the substrate by electrolysis to obtain the properties or dimensions that the substrate metal does not have. It is also called electrodeposition.

1.2.1.5 Electroless Plating (Chemical Plating)

Electroless plating is the process of depositing a metal or alloy coating by a chemical method rather than an electrolytic method. It is also called chemical plating.

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1.2.1.6 Painting

Painting is the process of coating paint on the substrate surface to form a protective, decorative, or specific functional coating.

1.2.1.7 Thermal Spraying

Thermal spraying is the process of forming a coating by spraying the heated spraying materials onto the surface of the pretreated magnesium and magnesium alloy substrate.

Note 1: The spraying materials can be alloy materials, ceramic materials, or alloy-ceramic composite materials.
Note 2: The spraying materials are heated to a plastic or molten state inside or outside the spraying gun.
Note 3: To obtain special coating performance, post-spraying heat treatment, mechanical treatment, or sealing treatment can be adopted.

1.2.1.8 Activation

Activation is the process of removing passivated surface conditions.

1.2.1.9 Stripping

Stripping is the process of removing anodic oxide coating, chemical conversion coating, or coating from the surface of magnesium and its alloys.

1.2.1.10 Surface Preconditioning

Surface preconditioning refers to the mechanical and chemical treatment, such as cleaning, activating, and polishing, of the substrate surface to adjust the surface state before pretreatment or coating.

1.2.1.11 Pretreatment

Pretreatment is the process of forming a thin coating layer on the substrate surface by physical, chemical, and electrochemical methods after conditioning. Generally, it can be used as a pretreatment of organic coating or used alone.

1.2.1.12 Self-Healing Coating

The self-healing coating is a coating that can heal the morphology or performance by itself once the coating is broken.

1.2.1.13 Surface Composite Treatment

Surface composite treatment is the process of combining two or more surface treatment technologies in an appropriate order and method, or manufacturing composite coatings based on a certain surface technology.

1.2.2 Surface Treatment

1.2.2.1 Degreasing

Degreasing is the process of removing grease from magnesium and its alloy surfaces by mechanical, chemical, or electrolytic methods.

1.2.2.2 Emulsion Degreasing

Emulsion degreasing is the process of removing grease from magnesium and magnesium alloys surfaces with an emulsion cleaner.

1.2.2.3 Organic Solvent Degreasing

Organic solvent degreasing is the process of degreasing magnesium and magnesium alloys surface with an organic solvent.

1.2.2.4 Mechanical Surface Treatment

Mechanical surface treatment is the process of removing foreign matter from the surface of magnesium and magnesium alloys substrate by using manual tools, power tools, or spraying, shot blasting, granulation, etc.

1.2.2.5 Chemical Surface Treatment

Chemical surface treatment is the process of removing the oxide scale and oil stain on the surface of magnesium and magnesium alloys by chemical reactions between acidic or alkaline solutions and the oxide and oil stain on the surface of magnesium and magnesium alloys.

1.2.2.6 Electrochemical Surface Treatment

Electrochemical surface treatment is the process of removing oxide and oil stains on the substrate surface or forming a conversion coating by using electrochemical methods.

1.2.2.7 Pickling

Pickling is the process of removing oxides or other compounds from magnesium and magnesium alloys surface through chemical action in an acid solution.

1.2.2.8 Desmutting

Desmutting is the process of removing the "dirty ash" attached to the magnesium and magnesium alloys surface (such as the treatment of magnesium and magnesium alloys immersed in sulfuric acid or nitric acid solution after alkali washing), also known as brightening, acid washing, or neutralization.

1.2.2.9 Deoxidizing

Deoxidizing is the process of removing oxides from the magnesium and magnesium alloys surface.

1.2.2.10 Brushing

Brushing is a method of mechanical surface treatment, usually with a rotating brush.

1.2.2.11 Grinding

Grinding is the process of removing magnesium and magnesium alloys surface materials with rigid or flexible carriers containing or attached to abrasives.

1.2.2.12 Belt Grinding

Belt grinding is a method of mechanical treatment of magnesium parts, in which the circular strip with abrasive is in contact with the surface of magnesium parts (normally including dry type and wet type).

1.2.2.13 Tumbling

Tumbling is the process of improving the smoothness of magnesium and magnesium alloys surface by batch processing of magnesium parts in a cylinder (with or without abrasive or shot).

1.2.2.14 Abrasive Blasting

Abrasive blasting is a method of mechanical surface treatment by using air flow or centrifugal force to blast abrasives such as corundum or glass sand onto the surface of objects. Fine abrasives suspended in water or other liquids can also be used for treatment (wet jet grinding or steam jet grinding).

1.2.2.15 Shot Peening

Shot peening is a method of mechanical surface treatment by spraying hard and small spherical particles (such as metal shot) onto the magnesium and magnesium alloys surface.

1.2.2.16 Glass Bead Blasting

Glass bead blasting is a method of mechanical surface treatment by spraying small spherical glass shots on the magnesium and magnesium alloys surface to make it clean or hardened.

1.2.2.17 Sand Blasting

Sand blasting is a method of mechanical surface treatment by using compressed air or centrifugal force to blast abrasive particles such as sand or magnesium oxide onto the magnesium and magnesium alloys surface.

1.2.2.18 Wet Blasting

Wet blasting is a method of mechanical surface treatment by blasting the water slurry containing abrasive onto the workpiece at high speed to clean or finish its surface.

1.2.2.19 Cleaning

Cleaning is the process of removing grease and dirt on the surface with a weak acid, a weak alkali solution, or a solvent and steam. This treatment may be chemical or electrolytic.

1.2.2.20 Rinsing

Rinsing is the process of using clean water to remove water-soluble acids, alkalis, and compounds from the surface of the workpiece.

1.2.2.21 Polishing

Polishing is the process of reducing the roughness of magnesium and magnesium alloys surface.

1.2.2.22 Mechanical Polishing

Mechanical polishing is the process of slightly cutting and grinding the surface of magnesium and magnesium alloys with a polishing wheel mounted on a polishing machine and coated with polishing paste.

1.2.2.23 Brightening

Brightening is the process of brightening the magnesium and magnesium alloys surface by mechanical, chemical, or electrochemical methods.

1.2.2.24 Satin Finishing

Satin finishing is a surface treatment process that makes the surface have uniform, discontinuous fine stripes.

1.2.2.25 Matte Finishing

Matte Finishing is a surface treatment process that uses mechanical or chemical treatment methods to form a non-directional and dull surface.

1.2.2.26 Bright Dipping

Bright dipping is the process of dipping magnesium in the proper solution to make the magnesium and magnesium alloys surface bright.

1.2.2.27 Flocculation

Flocculation is the process of polymerizing into larger aggregates that can precipitate or help to precipitate.

1.2.2.28 Surface Wire Drawing

Surface wire drawing is a surface treatment process that forms lines on the surface of magnesium and magnesium alloys by grinding products to achieve a decorative effect.

1.2.2.29 Buffing

Buffing is the process of polishing the magnesium and magnesium alloys surface with a soft rotating wheel (usually made of cotton cloth or other flexible materials). The adhesive abrasive used on the wheel is suspension, paste, or grease containing fine abrasive particles.

1.2.2.30 Chemical Polishing

Chemical polishing is a process in which magnesium and magnesium alloys are immersed in a chemical solution.

1.2.2.31 Electropolishing

Electropolishing is the polishing treatment of magnesium and magnesium alloys as the anode in a proper electrolyte.

1.2.2.32 Etching

Etching is the treatment of magnesium and magnesium alloys surface roughening due to overall or selective dissolution in the acidic medium.

1.2.2.33 Electrolytic Etching

Electrolytic etching is the etching treatment of magnesium and magnesium alloys in a proper solution by electrolysis.

1.2.2.34 Chromate Process

The chromate process is a process of chemical conversion in chromate solution.

1.2.2.35 Phosphate Process

The phosphate process is a process of chemical conversion in a phosphate solution.

1.2.2.36 Chromate Phosphate Process

The chromate phosphate process is a process of chemical conversion in a phosphate/chromate solution.

1.2.2.37 Chromium-Free Conversion

Chromium-free conversion is a process of chemical conversion in the solution without chromate.

1.2.2.38 Combined Coating

Combined coating refers to superimposing different coatings on magnesium and magnesium alloys.

1.2.2.39 Phosphoric Acid Anodizing

Phosphoric acid anodizing is a process of anodizing in a phosphoric acid solution.

1.2.2.40 DC Micro-Arc Oxidation

DC micro-arc oxidation is micro-arc oxidation conducted by the direct current.

1.2.2.41 AC Micro-Arc Oxidation

AC micro-arc oxidation is micro-arc oxidation conducted by alternating current.

1.2.2.42 Pulsed Micro-Arc Oxidation

Pulsed micro-arc oxidation is micro-arc oxidation conducted by pulse electricity.

1.2.2.43 Constant Voltage Micro-Arc Oxidation

Constant voltage micro-arc oxidation is micro-arc oxidation conducted under a constant voltage.

1.2.2.44 Constant Current Micro-Arc Oxidation

Constant current micro-arc oxidation is micro-arc oxidation conducted under a constant current.

1.2.2.45 Self-Sealing Micro-Arc Oxidation

Self-sealing micro-arc oxidation is a type of micro-arc oxidation that can seal the micro-holes of coatings in the process of micro-arc oxidation.

1.2.2.46 Anode

Anode is an electrode that generates positive ions or other oxidation reactions by discharging negative ions during electrolysis.

1.2.2.47 Cathode

A cathode is an electrode that generates negative ions or other reduction reactions by discharging positive ions during electrolysis.

1.2.2.48 Natural Oxidation

Natural oxidation is an oxidation process without artificial acceleration in the atmosphere.

1.2.2.49 Anodic Oxide Coating

Anodic oxide coating is a protective, decorative, or functional oxide coating formed on the surface of magnesium and magnesium alloys during anodic oxidation.

1.2.2.50 Combined Anodic Coating

Combined anodic coating is a combined coating formed after anodizing magnesium and magnesium alloys and then covering with organic or different coatings.

1.2.2.51 Organic Polymer Spraying Coating

Organic polymer spraying coating is an organic polymer coating formed by spraying on the surface of magnesium and magnesium alloys. Chemical conversion is usually required before spraying.

1.2.2.52 Functional Oxide Coating

Functional oxide coating is an anodic oxide coating that can significantly improve performance (*e.g.*, high hardness) or endow new functions (*e.g.*, magnetism).

1.2.2.53 Auxiliary Electrode

An auxiliary electrode is an additional anode or cathode used to evenly distribute the current during electrolysis to obtain a uniform coating.

1.2.2.54 Current Density

Current density is the current intensity per unit area passing through the electrode surface. It is generally expressed in amperes per square meter (A/m^2) or amperes per square decimeter (A/dm^2).

1.2.2.55 Critical Current Density

Critical current density is a specific current density value during electrolysis.

1.2.2.56 Current Efficiency

Current efficiency is the ratio of the effective current consumed by the formation of the oxide coating in the anodic oxidation process and the theoretical current calculated according to Faraday's law, usually expressed as a percentage.

1.2.2.57 Electrolysis

Electrolysis is a process in which a current flows through electrolytes to produce an electrochemical reaction at the electrodes.

1.2.2.58 Electrolyte

An electrolyte is a conductive liquid medium that transmits current by ions.

1.2.2.59 Throwing Power

Throwing power is the ability of the current to be evenly distributed on the irregular electrode surface during electrolysis.

1.2.2.60 Significant Surface

Significant surface is a surface that has been or is to be covered with an oxide film or coating.

1.2.2.61 Rack (Jig)

A rack (jig) is a device for suspending and carrying workpieces during surface treatment. It can be made of magnesium during anodizing and of iron parts during spraying.

1.2.2.62 Barrier Layer

Barrier layer is a very thin non-porous oxide layer close to the surface of magnesium and magnesium alloys in the porous anodic oxide coating structure, which is different from the main part of the porous anodic oxide coating.

1.2.2.63 Micro-Pore

A micro-pore is a small hole in the coating.

1.2.2.64 Color

Color is the appearance characteristic of an object determined by the composition of the incident spectrum, the reflection or transmission of light by the object, and the optical sense of the observer.

1.2.2.65 Periodic Reverse Electrolyzing

Periodic reverse electrolyzing is an electrolysis method in which the current is cyclically reversed.

1.2.2.66 Superimposed AC

Superimposed AC is the current form in which alternating current is superimposed on direct current during electrolysis.

1.2.2.67 Thief (Robber)

A thief (robber) is an auxiliary electrode placed at a specific position, which can transfer part of the current onto some parts of the workpiece to avoid excessive local current density.

1.2.2.68 Bath Voltage (Tank Voltage)

Bath voltage (tank voltage) is the voltage between the anode and cathode in the electrolytic cell.

1.2.2.69 Bus Bar

The bus bar is a rigid metal conductor that leads current into an anode or cathode (such as in an anodic oxidation tank).

1.2.2.70 Filter Aid

Filter aid is a filter medium composed of inert materials with different particle sizes. It is used to prevent excessive accumulation of filter residue on the main filter during filtration.

1.2.2.71 Air Agitation

Air stirring is a stirring and mixing process in which air passes through the solution.

1.2.2.72 Lapping

Lapping is the mechanical treatment (hard anodizing) of the coating surface. It is used mainly to achieve dimensional accuracy and improve surface quality.

1.2.2.73 Sealing

Sealing is the process of sealing the micropores in the coating to improve the coating's compactness and corrosion resistance.

1.2.2.74 Chromate (Dichromate) Sealing

Chromate (Dichromate) sealing is the sealing treatment in a solution containing dichromate, which is often used to improve the corrosion resistance of the pretreatment layer.

1.2.2.75 Passivation

Passivation is the process of making the magnesium and magnesium alloys surface, or the surface of the electroplated coating, passive.

1.2.2.76 Stripping

Stripping is a process of removing the coating from the substrate or the base coating.

1.2.2.77 Aging

Aging is the structural variation in the coating after a period of time.

1.2.2.78 Spraying

Spraying is a method of spraying paint onto the surface of magnesium and magnesium alloys parts to form a coating.

1.2.2.79 Electrostatic Spraying

Electrostatic spraying is a method for spraying charged paint onto magnesium and magnesium alloys parts to form coatings under the action of a high DC electric field. Generally, the parts to be coated are the anode, and the spraying device is the cathode.

1.2.2.80 Dip Painting

Dip painting is a method of immersing the parts to be coated in the aqueous solution or organic solution of paint to form a coating on the surface of the parts.

1.2.2.81 Powder Spraying

Powder spraying is a method of spraying dry fine powder without any water or solvent onto the substrate surface for thermal curing.

1.2.2.82 Liquid Spraying

Liquid spraying is a method of spraying solvent-containing paint resin onto metal surfaces, also known as spray painting.

1.2.2.83 Multi-Layer Spraying

Multi-layer spraying refers to the coating treatment of more than one spraying and/or curing.

1.2.2.84 Curing

Curing is a process in which the paint resin and curing agent undergo a cross-link reaction to form a polymer coating.

1.2.2.85 Roller Painting

Roller painting is a method of continuously coating organic coatings on the surface of magnesium and magnesium alloys sheet strip with paint rollers.

1.2.2.86 Heat Transfer Printing

Heat transfer printing is a process in which the ink is transferred to form a texture or pattern on the surface of the coating after heat treatment.

1.2.2.87 Blue Scale

The blue scale is an international standard scale for determining the light fastness of dyes. It is composed of eight kinds of woollen fabric with different degrees of blue, each representing a different lightfastness.

1.2.2.88 Grey Scale

The grey scale is an international standard scale with different intensities of grey on the surface, which is generally used to estimate the change of color.

1.2.2.89 PE/TGIC

PE/TGIC paints are based on saturated polyester resin and TGIC curing agent.

1.2.2.90 PE/HAA

PE/HAA paints are based on saturated polyester resin and hydroxyalkyl amide curing agent.

1.2.2.91 PU

PU paints are based on saturated polyester resin and isocyanate curing agent.

1.2.2.92 Acrylic Paints

Acrylic paints are based on acrylic resin and curing agents.

1.2.2.93 Particle Size Distribution

Particle size distribution is the size and range of powder paint, and the proportion of particles of various sizes in the total amount.

1.2.2.94 Solid Content

Solid content is the mass fraction of non-volatile matter in the paint under specified experimental conditions.

1.2.2.95 Volatile Content

Volatile content is the mass fraction of volatile matter under specified experimental conditions.

1.2.2.96 Ash Content

Ash content is the content of residue after the coating is burnt and ashed, generally expressed in mass fraction.

1.2.2.97 Levelling

Levelling is the process of reducing the surface unevenness of the coating and improving the flatness of the coating through liquid flow after coating.

1.2.2.98 Storage Stability

Storage stability refers to the ability of paint to maintain stable physical or chemical properties after storage.

1.2.3 Performance

1.2.3.1 Adhesion

The adhesion of coating refers to the bonding strength between the coating and the substrate (or intermediate coating), that is, the force required for the coating with unit surface area to detach from the substrate (or intermediate coating).

1.2.3.2 Thickness of Coating

The thickness of the coating is the thickness from the coating surface to the substrate.

1.2.3.3 Local Thickness of Coating

The local thickness of the coating is the average value of the thickness obtained through several (generally 5) single measurements within the investigated area, which is also called the coating thickness at the measurement point.

1.2.3.4 Average Thickness of Coating

The average thickness of the coating is the average coating thickness obtained from several measuring points or the thickness measured by the mass loss method.

1.2.3.5 Porosity

Porosity is the ratio of pore volume to total volume in the coating.

1.2.3.6 Appearance

Appearance refers to the visual result of the coating surface state, including the color, gloss, and appearance defects of the surface.

1.2.3.7 Hardness

Hardness is the ability of the coating to resist hard objects pressing into its surface. Hardness is an important performance to measure the hardness of the coating.

1.2.3.8 Corrosion Resistance

Corrosion resistance refers to the ability to withstand changes in various types of corrosive media, such as salt spray corrosion resistance, alkali resistance, acid resistance, etc.

1.2.3.9 Acid Resistance

Acid resistance is an accelerated corrosion test method with an acid solution of a specified concentration.

1.2.3.10 Detergent Resistance

Detergent resistance is the ability to withstand changes in detergent solutions. The test is usually carried out in a detergent solution of a specified concentration.

1.2.3.11 Weatherability

Weatherability is the ability of the coating to withstand long-term atmospheric exposure.

1.2.3.12 Self-Healing Performance

Under the action of external mechanical forces, the integrity of the structure and properties of coatings will be damaged to varying degrees. At the same time, the self-healing material in the coating could repair the defects of the crack with the help of a certain principle, and then achieve the goal of repairing without external assistance. The ability of the coating itself to identify, control, and restore the shortcomings is called self-healing performance.

1.2.3.13 Appearance Inspection

Appearance inspection refers to the visual inspection of the surface state under the specified lighting and observation conditions according to the specified requirements.

1.2.3.14 Color Difference

Color difference refers to the difference in color between a sample and a standard or between different samples.

1.2.3.15 Color Tolerance (Color Limits)

Color tolerance (Color limits) refers to the allowable color deviation of the sample compared with the standard sample under the specified lighting and observation conditions.

1.2.3.16 Brightness

Brightness is an imprecise term for the ability of an object's surface to reflect light.

1.2.3.17 Gloss

Gloss is an optical property of the coating surface characterized by the ability to reflect light, usually tested by a gloss meter.

1.2.3.18 Abrasion Resistance

Abrasion resistance is the resistance of the coating to the mechanical action of friction.

1.2.3.19 Light Fastness

Light fastness refers to the ability of the colored surface to resist light discoloration under long-term light (excluding the influence of the atmosphere).

1.2.3.20 Light Reflectivity

Light reflectivity is the ability of the surface to reflect light when an object is illuminated by light.

1.2.3.21 Reflectance

Reflectance is the ratio of reflected luminous flux to incident luminous flux.

1.2.3.22 Specular Reflectance

Specular reflectance is the ratio of the reflected light flux and the incident light flux in the specular reflection direction under the condition of a specified light source and receiver angle.

1.2.3.23 Specular Gloss

Specular gloss is the ratio of the reflected light flux in the specular reflection direction to the reflected light flux of the glass standard in the specular reflection direction under the condition of the specified angle of the light source and receiver.

1.2.3.24 Image Clarity

Image clarity refers to the surface optical performance of anodic oxide coating, expressed by the image clarity or distortion reflected from the surface.

1.2.3.25 Gloss Retention

Gloss retention is the ability of the coating to maintain its original gloss, which is usually expressed by the ratio of the gloss change before and after the test.

1.2.3.26 Sealing Quality

Sealing quality is the sealing effect of micropores of anodic oxide coating, which is usually evaluated by the phosphoric acid immersion test, stain test, and admittance test.

1.2.3.27 Biocompatibility

Biocompatibility is one of the properties that living tissues react to inactive materials.

1.2.3.28 Electromagnetic Shielding

Electromagnetic shielding is the ability to prevent or reduce electromagnetic waves from invading some parts of space and the ability to limit electromagnetic interference to a certain range.

1.2.3.29 Thermal Control Performance

Thermal control performance is the ability to achieve thermal control through the thermal absorption performance and thermal radiation performance of the coating.

1.2.3.30 Conductivity

Conductivity is the ability of the coating to conduct current.

1.2.3.31 Wettability

Wettability is the ability or tendency of a liquid to spread on a solid surface.

1.2.3.32 Resistance to Cracking by Deformation

Resistance to cracking by deformation is the ability of the coating to resist external forces and keep the coating unbroken.

1.2.3.33 Craze Resistance

Craze resistance is the ability of the coating to resist crack formation at high temperatures.

1.2.3.34 Insulation

Insulation is a general term for the ability of an insulating coating to withstand voltage impact, which is expressed by breakdown voltage, breakdown strength, and withstand voltage.

1.2.3.35 Surface Density

Surface density is the ratio of coating mass to apparent volume.

1.2.3.36 Boiling Water Resistance

Boiling water resistance is the resistance of the coating to boiling water immersion.

1.2.3.37 Solvent Resistance

Solvent resistance is the ability of the coating to resist swelling, dissolution, cracking, or deformation caused by a solvent.

1.2.3.38 Impact Resistance

Impact resistance is the ability of the coating to resist the impact load.

1.2.3.39 Cupping Resistance

Cupping resistance is the ability of the coating to resist cracking or falling off in the cupping test.

1.2.3.40 Bending Resistance

Bending resistance is the ability of the coating to withstand deformation.

1.2.3.41 Thermal Conductivity

Thermal conductivity is the performance of the coating to conduct heat.

1.2.3.42 Breakdown Potential

Breakdown potential is the minimum voltage of the conductor when the voltage is applied at a constant rate of increase in voltage, resulting in the loss of dielectric properties of the coating.

1.2.4 Testing and Evaluation

1.2.4.1 Thickness Test by Eddy Current

The thickness test by eddy current is a high-frequency induced current method used to measure the thickness of the non-conductive coating on the non-magnetic substrate.

1.2.4.2 Thickness Test by Mass-Loss Method

The thickness test by mass-loss method is to calculate the average thickness of the anodic oxide coating through the loss of mass per unit area of the sample after removing the oxide coating. This method can also be used to detect the surface density of anodic oxide coating.

1.2.4.3 Thickness Test by Split-Beam Microscope Method

The thickness test by the split-beam microscope method is a non-destructive method for measuring the thickness of a coating using a split-beam microscope.

1.2.4.4 Thickness Test by Microscopical Method

The thickness test by the microscopical method is a cross-sectional microscopic measurement of the local thickness of the coating using a metallographic microscope.

1.2.4.5 Microhardness Test

The microhardness test is a test method to obtain the coating hardness by applying a certain load to the indenter and measuring the indentation size on the cross-section of the anodic oxide coating with a microhardness tester.

1.2.4.6 Hardness Test by Pencil Scratch

Hardness test by pencil scratch is a method to test the coating hardness by using pencils of various hardness to scratch or scratch the coating.

1.2.4.7 Indentation Test

The indentation test is a method to measure the size of the indentation with an indentation tester under specified conditions, and test the coating hardness by the reciprocal of the indentation length.

1.2.4.8 Sand-Falling Test

The sand-falling test is a test method to check the abrasion resistance of the coating by using the abrasive particles to fall freely on the surface of the sample.

1.2.4.9 Abrasive Jet Test

The abrasion jet test is a test method that uses compressed air or inert gas to drive abrasive particles to shoot at the surface of the sample to inspect the coating.

1.2.4.10 Abrasive Wheel Wear Test

The abrasive wheel wear test is a test method to measure the wear resistance of the coating by using the reciprocating motion between the friction wheel under constant load and the surface of the sample.

1.2.4.11 Taber Abrasive Resistance Test

The taber abrasive resistance test is a test method for measuring the wear resistance of a coating when the flat sample is fixed on a horizontal rotating disc and the friction wheel contacts with the sample surface under a pre-set contact pressure.

1.2.4.12 Salt Spray Test

Salt spray test generally refers to the test method of accelerated corrosion in a salt spray medium of sodium chloride solution, including neutral salt spray test (NSS), acetic acid salt spray test (AASS), and copper-accelerated acetic acid salt spray test (CASS).

1.2.4.13 NSS Test

The neutral salt spray test (NSS) is an accelerated corrosion test method using a neutral sodium chloride solution spray.

1.2.4.14 AASS Test

Acetic acid salt spray test (AASS) is an accelerated corrosion test method using an acetic acid acidified sodium chloride solution spray.

1.2.4.15 CASS Test

The copper-accelerated acetic acid salt spray test (CASS) test is an accelerated corrosion test method using acetic acid, copper chloride, and sodium chloride solution spray.

1.2.4.16 Mortar Resistance Test

Mortar resistance test refers to an accelerated corrosion test method using mortar (used for the slurry group prepared in proportion with sand and lime or the slurry group prepared in proportion with sand, lime, and cement).

1.2.4.17 Acid Resistance Test

The acid resistance test is a test method for accelerated corrosion with an acid solution of a specified concentration.

1.2.4.18 Kesternich Test

The Kesternich test is an accelerated corrosion test method conducted in a high-temperature and humid atmosphere containing sulfur dioxide.

1.2.4.19 Humidity Resistance Test

A humidity resistance test is a test method for checking its resistance to humidity and heat in a constant temperature and humidity box.

1.2.4.20 FACT Test

The film anodic corrosion test (FACT) test is the anodized magnesium oxide corrosion test. This test is a corrosion test conducted by applying direct current to the oxide coating in a specific electrolytic cell.

1.2.4.21 Machu Test

The Machu test is an accelerated corrosion test conducted in the Machu solution.

1.2.4.22 Natural Weathering Test

The natural weathering test is conducted under various atmospheric conditions at the atmospheric exposure test station to study the weatherability of materials in different environments.

1.2.4.23 Accelerated Weathering Test

The accelerated weathering test is an accelerated laboratory test that simulates and strengthens the destructive effect of natural atmospheric exposure conditions on samples.

1.2.4.24 Accelerated Light Fastness Test

The accelerated light fastness test is a test method for testing the color durability of colored anodic oxide coating by irradiation of an artificial light source.

1.2.4.25 Phospho-Chrom Test

Phospho-Chrom test is a test method for determining the sealing quality by soaking in phosphoric acid/chromic acid solution. At present, there are two kinds of Phospho-Chrom tests: nitric-acid pre-immersion and nitric-acid-free pre-immersion, both of which belong to arbitration tests.

1.2.4.26 Dye Spot Test

A dye spot test is a test method to check the ability of anodic oxide coating to absorb dye under specified conditions. It is mainly used for online evaluation of the sealing quality of anodic oxide coating.

1.2.4.27 Admittance Test

The admittance test is a test method to measure the apparent admittance value of the oxide coating with an AC circuit and evaluate the sealing quality of the coating.

1.2.4.28 Bending Test

The bending test is a test method to determine the minimum bending radius (related to the thickness of the plate) of the coating without visible cracks.

1.2.4.29 Exfoliation Corrosion Test

The exfoliation corrosion test is a test method to evaluate the sensitivity of materials to exfoliation corrosion through visual inspection or metallographic observation through the full immersion test of test materials in a corrosive solution for a certain time.

1.2.4.30 Alternating Dry and Wet Test

The alternating dry and wet test is a test method to wet and dry the magnesium and magnesium alloys sample at a given frequency in a certain experimental cycle.

1.2.4.31 Tensile Shear Test

The tensile shear test is a test method to test the adhesion between the coating and the substrate by using test tools or equipment to make the sample bear the tensile force perpendicular to the coating surface until the coating peels off.

Chapter 2

Magnesium and Magnesium Alloys – Powder Coating Selection Guide for Magnesium Surface Spraying

2.1 Scope

This standard specifies the powder type and coating characteristics for magnesium surface spraying; applicable environment, product, and coating of powder; quality assurance, powder performance and test methods, quality instructions, and purchase order (or contract) contents.

This standard applies to the use and selection of powder for magnesium and magnesium alloy surface spraying.

2.2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes the requirements 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.
IMS 001 Magnesium and Magnesium Alloys – Terms and definitions of surface treatment

2.3 Powder Type and Coating Characteristics

The powder type and coating characteristics are shown in table 2.1.

2.4 Applicable Environment, Product, and Coating of Powder

2.4.1 Environment Type and Suitable Coating

The suitable powder coating shall be selected according to the environmental type with reference to table 2.2.

2.4.2 Product Field and Suitable Powder Type

The suitable powder type shall be selected according to the product field with reference to table 2.3.

2.4.3 Coating Color and Suitable Powder

(a) The suitability of the powder color shall be evaluated when selecting the coating color. Black, red, yellow, dark green, dark blue, and metal colors are suitable for high-temperature-resistant (above 300 °C) coatings. Light colors are not applicable to high-temperature-resistant coating. Metal color (excluding pearlescent color) is not applicable to anti-corrosion powder coating.
(b) The powder and color of the corresponding weathering grade shall be selected according to the weathering grade of the coating. RAL color scale or similar colors shall be selected. The use of colors other than the RAL color scale will increase the risk of unqualified weatherability of powder or coating.

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Tab. 2.1 – Powder type and coating characteristics.

Powder type			Typical coating characteristics						
Type	Code	Major component	Weatherability	Corrosion resistance	Flexibility	Leveling	Decorative nature	Hardness	Adhesion
Epoxy powder	EP	The powder is thermosetting and composed of epoxy resin, curing agent, pigment filler, additive, etc.	Bad	Excellent	Good	Good	Good	Good	Excellent
Polyester epoxy powder	PE-EP	The powder is thermosetting and mainly composed of saturated carboxyl polyester and epoxy resin.	Worse than normal	Good	Good	Good	Good	Good	Good
Polyester powder	PE	The powder is thermosetting and mainly composed of saturated carboxyl polyester and a special curing agent (mainly TGIC and HAA).	Good	Normal	Good	Normal	Normal	Good	Good
Polyurethane powder	PUR	The powder is thermosetting and mainly composed of saturated hydroxy polyester and corresponding curing agent (mainly isocyanate and amino resin).	Good	Good	Normal	Excellent	Excellent	Excellent	Good
Acrylic acid powder	AY	The powder is thermosetting and mainly composed of acrylic resin and curing agent.	Good	Normal	Normal	Good	Good	Good	Normal
FEVE powder	FEVE	The powder is thermosetting and mainly composed of FEVE resin and curing agent isocyanate.	Excellent	Excellent	Normal	Normal	Normal	Good	Normal
PVDF powder	PVDF	The powder is thermoplastic and mainly composed of PVDF resin.	Excellent	Excellent	Below normal		Below normal	Good	Below normal
Silicone resin powder	SP(SI)	The powder is thermosetting and mainly composed of silicone resin, other resins, and their corresponding curing agents.	Good	Good	Excellent	Normal	Normal	Below normal	Normal

Tab. 2.2 – Environment type and a suitable coating.

Environment type					Suitable coating
Type	Corrosion index	Ultraviolet intensity grade	Typical example		Coating code
1	C1, C2	0	Dry and clean indoor area with low ultraviolet radiation	Storage room internal structure support	PE40, PE-EP40, PE-EP10, PVDF40, FEVE40, PUR40, EP40, AY40, SO40
2	C1, C2	I		Furniture	PE40, PE-EP40, PVDF40, FEVE40, PUR40, AY40, SP40
3	C1, C2	II	Rural outdoor areas with medium ultraviolet radiation intensity and no industrial pollution		PE40 of Class II, PUR40 of Class II, PVDF40, FEVE40
4	C1, C2	III	Outdoor desert area with high ultraviolet radiation intensity		PVDF40, FEVE40
5	C3, C4	0	Damp basement		PE40, PE-EP40, PVDF40, FEVE40, PUR40, EP40, AY40, SP40
6	C3, C4	I	Indoor hot spring area		PE40, PE-EP40, PVDF40, FEVE40, PUR40, EP40, AY40, SP40
7	C3, C4	II	Outdoor areas of cities (or light marine areas) with general ultraviolet radiation intensity and general industrial pollution		PE40 of Class II, PUR40 of Class II, PVDF40, FEVE40
8	C3, C4	III	Outdoor areas of cities (or light marine areas) with high ultraviolet radiation intensity and serious industrial pollution		PVDF40, FEVE40
9	C5, C6	0	Salt mine		EP40, PE-EP60, PE60, PUR60, SP60, PVDF40, FEVE40
10	C5, C6	I	Outdoor coastal areas with general ultraviolet radiation intensity and high salinity	Indoor partition	PE40, PUR40, SP40, PVDF40, FEVE40
11	C5, C6	II		Balcony guardrail	PE40 of Class II, PUR40 of Class II, PVDF40, FEVE40
12	C5, C6	III	Outdoor coastal areas with high ultraviolet radiation intensity, such as ship superstructure		PVDF40, FEVE40

TAB. 2.3 – Product field and a suitable powder.

Typical product field	Suitable powder type	Remarks
Auto parts	Epoxy powder	It is generally used for the primer coating of wheel hubs and other parts.
	Polyester epoxy powder	It is applicable to the coating of automobile engine cooling parts, internal connecting rods, and other parts.
	Acrylic acid powder	It is applicable to the finishing paint applied to the wheel hub and the exterior coating of the vehicle body.
	Polyester powder	It is applicable to the coating of the wheel hub, exterior body trim, and other parts.
	Polyurethane powder	It is applicable to the coating of instrument panels, steering wheels, and other automobile interiors.
Rail transit	Polyester powder	It is applicable to the coating of doors, windshields, headstock opening and closing mechanisms, contactor boxes, inverter boxes, luggage racks, roof plates, subway doors, screen doors, escape doors, side walls, and other parts of bullet trains.
	Polyester epoxy powder	It is applicable to the coating of table and chair decorations in rail transit.
Pipeline anti-corrosion and other heavy anti-corrosion products	Epoxy powder	It is applicable to the coating of natural gas, oil pipelines, sewage pipelines, etc.
Ship superstructure	Polyurethane powder	It is applicable to the coating of ship superstructure decorative parts.
Furniture (furniture, cooker, sanitary ware, lamps, etc.), interior decoration (mirror frame, ceiling, etc.)	Polyester epoxy powder	It is applicable to the coating of furniture, cookers, sanitary ware, lamps, mirror frames, ceilings, and other products.
	Epoxy powder	It is applicable to the decorative texture coating of furniture, cookers, sanitary ware, lamps, mirror frames, ceilings, etc.
	Polyester powder	It is applicable to the coating of furniture, cookers, sanitary ware, lamps, frames, ceilings, and other products.
	Polyurethane powder	It is applicable to the coating of all-magnesium furniture, mirror frames, ceilings, and other products.
	Silicone resin powder	It is applicable to the coating of high-temperature parts such as ovens and grills.
Household electric appliances	Polyester epoxy powder	It is applicable to the coating of TV frames, washing machines, refrigerators, water heaters, and other products.
	Polyester powder	It is applicable to the coating of outdoor units, indoor units, and other products of air conditioners.
Radiator	Polyester epoxy powder	It is applicable to the coating of radiators, putty, heaters, and other products.
	Polyester powder	It is applicable to the coating of radiators, putty, heaters, and other products.
Electronics and electrical appliances	Polyester powder	It is applicable to the coating of instrument housing, electricity meters, computer cases, and other parts.
	Epoxy powder	It is applicable to the coating of internal components of the electric control cabinet.
	Polyester epoxy powder	It is applicable to the coating of computer cases, instrument shells, electricity meters, and other products.

Tab. 2.3 – (continued).

Typical product field	Suitable powder type	Remarks
Doors, windows, fences, outdoor sports facilities	Polyester powder	It is applicable to the coating of doors and windows, curtain walls, outdoor sports facilities, fences, and other products.
	Polyurethane powder	It is applicable to the surface coating of doors and windows, curtain walls, outdoor sports facilities, fences, and other facilities with low powder wood grain transfer printing, or products with anti-graffiti requirements.
	PEVE powder	It is applicable to the coating of doors and windows, curtain walls, outdoor sports facilities, fences, and other products.
	PVDF powder	It is applicable to the coating of doors and windows, curtain walls, outdoor sports facilities, fences, and other products.

2.5 Quality Assurance

The production process of powder and the quality of raw materials have a great impact on the performance of powder. The powder ordering party shall sign a corresponding technical agreement with the powder coating manufacturer, which indicates the requirements for the powder production process (see A.1) and the coating forming substances (see A.2). If necessary, the powder manufacturer shall be visited for inspection.

2.6 Quality Assurance Certificate

To ensure the reliability of powder coating quality (especially weatherability and corrosion resistance), the content of the quality assurance certificate shall be negotiated with the powder coating manufacturer. The quality assurance certificate shall at least include the following contents. The format of the quality certificate is shown in table 2.4.

Tab. 2.4 – Format of the quality assurance certificate.

Name of supplier (seal)					
Product name00		Implementation standard			
Color		Type of pigment		weathering grade	
Minimum coating thickness		Curing temperature		Curing time	
Curing agent system		Powder coating density		Gelatinization time	
Resin content		Glass transition temperature	T_{g1}:	T_{g2}:	
Salt spray test results			Impact resistance		
Natural exposure results of powder coating		Color difference:		Gloss:	
Resin					
Resin manufacturer name					
Resin model		Resin batch number			
Viscosity		Acid value (hydroxyl value)			
Natural exposure results	Color difference:		Gloss:		
Black-and-white board	Formula:				
	QUV		High-pressure water immersion		

(a) The serial number of the implementation standard;
(b) Product name;
(c) Production process, including curing temperature and curing time;
(d) Density of powder coating;
(e) Curing agent system;
(f) Type of pigment in powder coating;
(g) Weathering grade of powder coating, acetic acid salt spray test results, and impact resistance test results of chromium-free chemical pretreatment (except anodic oxidation pretreatment) powder-coated test panels;
(h) Resin content, acid value (or hydroxyl value), viscosity, gelatinization time (characterizing and reflecting activity), glass transition temperature, molecular weight distribution, and color of powder coating;
(i) For outdoor powder coatings, natural exposure test results shall be provided (according to formula components, including color difference value and gloss value);
(j) The resin manufacturer's name, resin batch number, and resin model, and the natural exposure test results (including color difference value and gloss value) shall be provided for the resin used for outdoor powder coating;
(k) The black and white standard plates were prepared with resin according to the standard formula, along with the QUV and high-pressure water immersion test reports of the standard plates.
(l) The standard formula for preparing black and white standard plates with resin.

2.7 Purchase Order (or Contract)

Relevant technical requirements shall be presented in the purchase order (or contract) after completing the powder coating calculation. The powder purchase order (or contract) shall indicate the following contents. Details of the purchase order are shown in table 2.5.

(a) Serial number of the implementation standard;
(b) Product name;
(c) Powder type;
(d) Color number and glosses;
(e) Mass fraction of burning residue;
(f) Particle size distribution;
(g) Hiding power;
(h) Weatherability and other coating performance grades or requirements;
(i) Net weight;
(j) Other special requirements.

TAB. 2.5 – Details of the purchase order.

<table>
<tr><td>Company name</td><td colspan="7"></td></tr>
<tr><td>Product name</td><td></td><td>Implementation standard</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Powder type</td><td></td><td>Color Number</td><td></td><td>Glasses</td><td></td><td>Order Quantity</td><td></td></tr>
<tr><td colspan="2">Mass fraction of burning residue</td><td colspan="2"></td><td colspan="2">Weathering grade</td><td colspan="2"></td></tr>
<tr><td colspan="2">Particle size distribution requirements</td><td colspan="2"></td><td colspan="2">Hiding power</td><td colspan="2"></td></tr>
<tr><td>Coating performance</td><td colspan="7"></td></tr>
<tr><td>Other requirements</td><td colspan="7"></td></tr>
</table>

Appendix A

(Normative)

Quality Requirement

A.1 Production Process Requirements

A.1.1 Typical Powder

The production process of typical powder is shown in figure A.1.

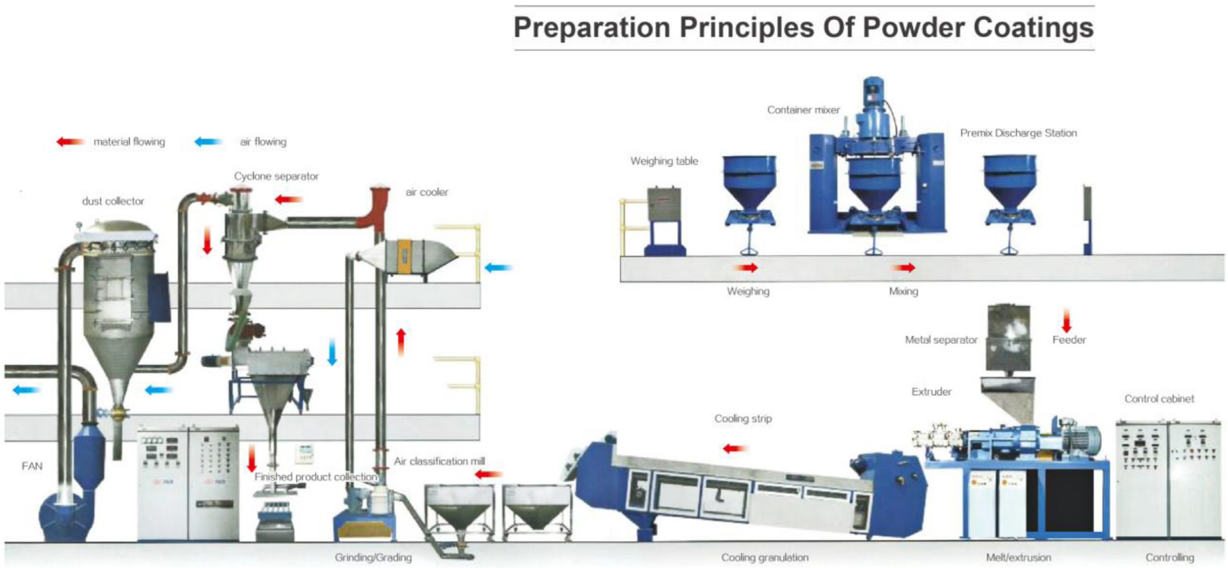

Fig. A.1 – Preparation principles of powder coatings.

A.1.1.1 Pre-Mixing and Extrusion Process Control

During the pre-mixing of raw materials, the feeding amount shall be controlled at 20% ~ 80% of the capacity of the pre-mixing cylinder. The mixing time shall be controlled at 3 min ~ 5 min. The temperature of the mixing section of the extruder shall be 10 °C ~ 20 °C higher than the softening point of the resin. The thickness of the sheets pressed by the tablet press shall be 1 mm ~ 2 mm, and the material temperature before fine crushing shall be controlled below 32 °C.

A.1.1.2 Post-Mixing Process for Special Powders

Textured powder, two-component powder, and powder with additives added later shall be mixed with the same batch of powder in a double-barrel V-type mixer to eliminate the quality difference of the same batch of products. To eliminate the quality difference of the same batch of products, the Double-barrel V-type mixer shall be used in the Later Mixing Process for three types of powders: (1) Textured powder, (2) Two-component powder, and (3) Powder with additives added later.

A.1.1.3 Environmental Control for Crushing and Storage

The ambient temperature shall be controlled below 30 °C during the fine crushing process and for the storage of finished products, and the air in the production and storage areas shall be kept dry.

A.1.2 Metallic Powder

The production process of metallic powder is shown in figure A.2.

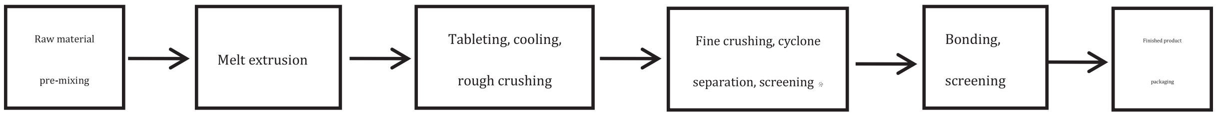

FIG. A.2 – Production process flow chart of metallic powder.

A.1.2.1 Requirement for Bonding Process

A bonding process shall be adopted for metallic powder to improve the stability of the spraying process.

A.1.2.2 Feeding and Mixing Control in Bonding

The feeding amount of bonding shall be controlled at 30%～70% of the capacity of the bonding kettle to ensure the raw materials are well-mixed and the quality of bonding powder is stable.

A.2 Quality Requirement of Coating-Forming Substances

See table A.1 for the requirements of coating-forming substances used in various powders.

TAB. A.1 – Requirements for coating-forming substances of powder.

Powder type	Requirements
Polyester powder	The acid value of the resin in the polyester powder determines the amount of curing agent. Viscosity and reactivity are the main factors affecting the surface leveling. The vitrification point affects the storage stability of the powder. Acid value or hydroxyl value, viscosity, vitrification point, and color reflect the physical and chemical characteristics of the resin batch stability. The polyols used for synthesizing polyester are usually based on neopentyl glycol. Other polyols without hydrogen can also be used. Attention should be paid to the purity of polyols. Neopentyl glycol shall be produced by the hydrogenation method. It is not recommended to use ethylene glycol, diethylene glycol, or propylene glycol.
Polyester powder	There is no requirement for indoor polyester. For the selection of outdoor polyester, the comprehensive performance, stability, and weatherability shall be considered. The comprehensive performance should be selectively evaluated based on the application environment, with a focus on some major performance. Two-component resin can be used for matting powder with durability and stability requirements. Stability requires resins with stable quality and narrow molecular weight distribution in practical use. Weatherability is evaluated mainly according to the natural exposure test and the long-term stability of the application. Accelerated aging test in the laboratory is only a reference for auxiliary evaluation. In the field of super weatherproof polyester, it will improve the wearability of the powder, if the mass fraction ratio of intermediate phthalic acid (or another diprotic acid with better weatherability than isophthalic acid) to terephthalic acid in the resin is improved. Simply adding raw materials alone cannot guarantee the performance of the resin, instead, it requires controlling the processes of resin synthesis, powder formulation, production, and operative skill. It also requires practical application results to be verified as a super weather-resistant resin Natural exposure test is the most reliable and safe method for testing super weather-resistant resin. Low-temperature curing resin can also be used on the premise of meeting performance and quality requirements.

Tab. A.1 – (continued).

Powder type	Requirements
	The curing agent of polyester powder includes HAA and TGIC systems. The HAA system is relatively environment-friendly, and the powder storage stability is good, but a small amount of water molecules occurred when the coating was solidified. Pinholes are not prone to appear on the coating of the TGIC system, but skin contact with TGIC will cause irritation and other allergic reactions. Please refer to the environmental protection label of the product for details.
Polyester epoxy powder	Requirements for epoxy resin in polyester epoxy powder: Epoxy resin shall have good storage stability, no mechanical impurities, and good flexibility. The curing agent shall have an active crosslinking reaction, such as a reaction with epoxy group in epoxy resin. The curing agent shall have high purity, less volatile matter, and less smoke. Softening point: $89\sim94$; Epoxy equivalent: $730\sim850$; Organic chlorine content ≤0.0028 mol/100 g; Inorganic chlorine content ≤0.0005 mol/100 g; BPA residue $\leq 5\times10^{-6}$; Volatile matter ≤0.3%.
Polyurethane powder	The hydroxyl value of the resin in the polyurethane powder determines the amount of curing agent. Viscosity and reactivity are the main factors affecting surface leveling. The vitrification point affects the storage stability of the powder. Acid value or hydroxyl value, viscosity, vitrification point, and color reflect the physical and chemical characteristics of the resin batch stability. To ensure the weatherability and other relevant properties of the coating, the total mass fraction of resin and curing agent in the powder shall not be less than 60%. Polyurethane resin is required to pass the natural exposure weathering test, and the curing agent is required to have less interference effects. Curing agents in polyurethane powder can be divided into externally sealed aliphatic isophorone diisocyanate or internally sealed isocyanate. The coating in such a system has good weatherability and chemical resistance, and has good ink penetration when used in wood grain transfer printing coating. Externally sealed aliphatic isophorone diisocyanate will release the sealing agent acetolactate when baking the coating.
Epoxy powder	The epoxy resin shall have good storage stability, no mechanical impurities, and good flexibility. The curing agent shall have an active crosslinking reaction, such as a reaction with epoxy group in epoxy resin. The curing agent shall have high purity, less volatile matter, and less smoke. Softening point: $89\sim94$; Epoxy equivalent: $730\sim850$; Organic chlorine content ≤0.0028 mol/100 g; Inorganic chlorine content ≤0.0005 mol/100 g; BPA residue $\leq 5\times10^{-6}$; Volatile matter ≤0.3%.
Acrylic acid powder	Acrylic resin shall have good storage stability and pass the natural exposure test.
FEVE powder	Trifluorochloroethylene vinyl ether (FEVE), theoretically with a fluorine content of 27%–29%, and FEVE fluorocarbon coating is a thermosetting powder. The curing agent shall be externally sealed aliphatic isophorone diisocyanate or internally sealed isocyanate, and the externally sealed aliphatic isophorone diisocyanate will release acid amine within the sealing agent when baking the coating. The curing agent shall be of high purity and less volatile. FEVE fluorocarbon powder is divided into fluorocarbon polyester composite powder and pure fluorocarbon powder. The resin mass fraction (excluding the curing agent) in fluorocarbon powder shall not be less than 60%. The amount of FEVE fluorocarbon resin in the composite fluorocarbon powder shall not be less than 50% of the amount of the main coating-forming resin.
FVDF powder	Fluorocarbon powder resin includes polyvinylidene fluoride (PVDF for short), and its fluorine content is 59.3% theoretically. PVDF fluorocarbon resin coating requires about 30% acrylic resin, and the baking temperature of the coating is high. PVDF fluorocarbon coating is a thermoplastic powder without a curing agent.
Silicone resin powder	Organic silicon powder is divided into three types. The coating of organic silicon graft modified polyester powder can withstand 300 °C for a short time; The coating of polyester (or silicone grafted polyester) and silicone oligomer mixed powder can withstand 300 °C for a longer time; The coating of polyester (or silicone graft modified polyester) and silicone resin powder can withstand 300 °C$\sim$500 °C. With the increase of silicone oligomer or silicone resin in the powder coating-forming substances, the temperature resistance of the powder coating is increased and the temperature resistance time is extended, but the mechanical properties of the coating are correspondingly reduced.

Chapter 3

Magnesium and Magnesium Alloys – Paint Coating Selection Guide for Magnesium Surface Spraying

3.1 Scope

This standard specifies the structure and characteristics of various coatings, applicable environment, suitable coating, coating performance, test methods, quality certificate, and contents of purchase order (or contract).

This standard applies to the application and selection of magnesium alloy surface electrophoretic and spraying coating.

3.2 Normative References

The following documents are indispensable for the application of this document. For dated references, only the dated versions apply to this document. For undated references, the latest version (including all amendments) applies to this document.

IMS 001 Magnesium and Magnesium Alloys – Terms and definitions of surface treatment

3.3 Structure and Characteristics of Various Coatings

3.3.1 Structure and Characteristics of Electrophoretic Coating

The electrophoretic coating has high hardness, good abrasion resistance, good adhesion of the coating, excellent corrosion resistance, and excellent resistance to submembrane filamentous corrosion. The electrophoretic coating on the surface of the magnesium and magnesium alloys requires the necessary pretreatment. Pretreatment before electrophoretic coating or spraying coating has an important impact on the corrosion resistance and adhesion. Pretreatment includes anodizing, oxidation, and chemical conversion treatment. The thickness of the electrophoretic coating can be controlled accurately in the production process. The thickness of the coating is not only evenly distributed, but also can cover all positions on the surface of magnesium and magnesium alloys. The coating type, main components, and typical application of electrophoretic coating are shown in table 3.1.

3.3.2 Structure and Characteristics of Spraying Coating

Spraying coating mainly includes PVDF fluorocarbon paint, epoxy paint, polyester paint, acrylic polyurethane paint, and amino acrylic paint. The spraying coating on the surface of the magnesium and magnesium alloys requires the necessary pretreatment. Pretreatment before electrophoretic coating or spraying coating has an important impact on the corrosion resistance and adhesion. Pretreatment includes anodizing, oxidation, and chemical conversion treatment. The coating type, main components, and typical application of spraying coating are shown in table 3.1.

3.4 Applicable Environment and Suitable Coating

Before selecting the coating type, the environmental conditions shall be determined. The degradation of the coating performance in the service environment shall not corrode the product or affect the appearance of the product.

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Tab. 3.1 – Coating type, main components, and typical application.

Coating type			The main components of the coating	Typical application of coating
Electrophoretic coating	Transparent electrophoresis		Acrylic resin or epoxy resin	Electronic products, rail transit decorative parts, bathroom products, solar photovoltaic products, automobile decorative parts and building profiles
	Color electrophoresis		Acrylic resin or epoxy resin, color paste	Solar photovoltaic products, auto parts, electronic products, and building profiles
Spraying coating	PVDF Fluorocarbon paint	Second coating	It's mainly composed of PVDF resin, generally with a monochromatic or pearlescent mica scintillation effect	Curtain walls, profiled plates, doors and windows, and other products with excellent weatherability requirements and atmospheric corrosion resistance
		Third coating	It's mainly composed of PVDF resin, generally with a metal effect. Ball-milled aluminium powder is used in the top coating of the coating to obtain the metal texture effect. Its metal texture is different from the pearlescent mica coating of the second coating. Because the aluminium powder is easy to oxidize or detach from, the coating surface needs to be protected by varnish to ensure comprehensive performance, which is better than the second coating	Curtain walls, profiled plates, doors and windows, and other products with excellent weatherability and atmospheric corrosion resistance
		Fourth coating	It's mainly composed of PVDF resin, generally with a metal effect and higher performance requirements. Based on the third coating, this coating is added with a UV-blocking coating	Curtain walls, profiled plates, doors and windows, and other products with excellent weatherability and atmospheric corrosion resistance
	Epoxy paint		It's mainly composed of epoxy resin	Roof structure, air compressor, mechanical equipment, food containers, and magnesium alloy products for packaging and other products with good adhesion and anti-corrosion
	Polyester paint		It's mainly composed of polyester resin	Automobile wheel hub, ceiling, profiled plate, curtain wall, packaging box, magnesium alloy products, and other products with good mechanical performance and general wearability
	Acrylic polyurethane paint		It's mainly composed of acrylic resin	Furniture, lighting, chassis, cabinet, compartment, aluminium veneer, magnesium alloy products, and other products with excellent transparency, good surface decoration, and good weatherability
	Amino acrylic paint		It's mainly composed of acrylic resin and amino resin	Furniture, lighting, chassis, cabinet, compartment, magnesium alloy products, and other products with excellent transparency, good surface decoration, and good weatherability

The atmosphere is divided into four categories, *i.e.*, industrial atmosphere, urban atmosphere, marine atmosphere, and rural atmosphere. The environment can also be divided into the wet environment, ordinary environment, and dry environment according to humidity, and the difference between indoor and outdoor corrosion in the actual environment should be considered. The suitable electrophoretic coating and spray coating shall be selected according to the environmental type, as shown in table 3.2.

TAB. 3.2 – Environment type and a suitable coating.

Corrosion grade	Corrosion degree	Environment condition		Suitable coating: Coating code – Electrophoretic coating	Suitable coating: Coating code – Spraying coating
C1	Extremely low	Outdoor	Cold or dry atmospheric environments with very low pollution and short wetting time, such as certain deserts, and Arctic and Antarctic centers	EA21, EB16 and ES21 of Class II, EA21, EB16 and ES21 of Class III, EA21, EB16 and ES21 of Class IV	LAR25, LRAR25, LF2-25, LRF2-25, LF3-34, LRF3-34, LF4-55, LRF4-55
		Indoor	Spaces with low pollution, low humidity, and heating, such as offices, shops, schools, hotels, and museums	EA2I, EB16, EC13 and ES21	LAR25, LRAR25, LF2-25, LRF2-25, LF3-34, LRF3-34, LF4-55, LRF4-55, LO15, LRO15, LA25, LA34, LRA15, LRA34, LAR25, LRAR25
C2	Lower	Outdoor	A temperate environment with low pollution ($SO_2 < 5\ \mu g/m^3$), such as rural areas and small towns; cold or dry atmospheric environment with short wetting time, such as desert	EA21, EB16 and ES21 of Class II, EA21, EB16 and ES21 of Class III, EA21, EB16 and ES21 of Class IV	LAR25, LRAR25, LF2-25, LRF2-25, LF3-34, LRF3-34, LF4-55, LRF4-55
		Indoor	Unheated spaces with large temperature and humidity changes, low pollution, and less condensation, such as warehouses and gymnasiums	EA2I, EB16, EC13 and ES21	LAR25, LRAR25, LF2-25, LRF2-25, LF3-34, LRF3-34, LF4-55, LRF4-55, LO15, LRO15, LA25
C3	Medium	Outdoor	Temperate environments with medium pollution (SO_2: $5\ \mu g/m^3 \sim 30\ \mu g/m^3$) or some areas slightly affected by chloride, such as urban areas, coastal areas with low chloride deposition, and tropical and subtropical areas with low pollution	EA21, EB16 and ES21 of Class II, EA21, EB16 and ES21 of Class III, EA21, EB16 and ES21 of Class IV	LAR25, LRAR25, LF2-25, LRF2-25, LF3-34, LRF3-34, LF4-55, LRF4-55
		Indoor	Space with moderate condensation frequency and pollution during production, such as food processing plants, laundries, breweries, and milk factories		
C4	Higher	Outdoor	Temperate environments with high pollution (SO_2: $30\ \mu g/m^3 \sim 90\ \mu g/m^3$) or some areas affected by chloride, such as polluted cities, industrial areas, coastal areas without strong impact of saline spray or deicing salt, and moderately polluted	EA21, EB16 and ES21 of Class III, EA21, EB16 and ES21 of Class IV	LF2-25, LRF2-25, LF3-34, LRF3-34, LF4-55, LRF4-55 of Class II and III

Tab. 3.2 – (continued).

Corrosion grade	Corrosion degree	Environment condition		Suitable coating	
				Coating code	
				Electrophoretic coating	Spraying coating
			tropical and subtropical areas		
		Indoor	Spaces with high condensation frequency and high pollution during production, such as chemical plants, swimming pools, seagoing ships, and shipyards		
C5	Much higher	Outdoor	Temperate or subtropical environments with very high pollution (SO_2: 90 $\mu g/m^3 \sim 250$ $\mu g/m^3$) or some areas seriously affected by chlorides, such as industrial areas, coastal areas, and coastline coverage areas	EA21, EB16 and ES21 of Class IV	LF3-34, LRF8-34, LF4-55, LRF4-55 of Class III
		Indoor	Spaces with very high condensation frequency and serious pollution during production, such as mines, industrial caves, and airtight sheds in tropical and subtropical regions	EA21, EB16 and ES21 of Class III, EA21, EB16 and ES21 of Class IV	LF2-25, LRF2-25, LF3-34, LRF3-34, LF4-55, LRF4-55 of Class II and III
C6	Extremely high	Outdoor	Tropical and subtropical (extremely long wetting time) environments with very high pollution (SO_2: > 250 $\mu g/m^3$), including some associated factors and/or areas seriously eroded by chloride, such as extreme industrial areas, coastal and offshore areas, and areas occasionally affected by salt fog	EA21, EB16 and ES21 of Class IV	LF3-34, LRF8-34, LF4-55, LRF4-55 of Class III
		Indoor	Space where condensation occurs continuously during production or is affected by high-tide humidity for a long time, and is highly polluted, such as the indoor unventilated shed in humid tropical areas, where outdoor pollutants (including chlorides in the air and particles that can accelerate corrosion) can penetrate		

3.5 Coating Performance

3.5.1 General Requirements

The performance shall be selected according to the characteristics of the coating. The performance selection of different coatings is shown in table 3.3.

TAB. 3.3 – Performance selection of different coatings.

No	Performance	Type of coating	
		Electrophoretic coating	Spraying coating
	Appearance quality	√	√
	Gloss	*	√
	Color and color difference	√	√
	Coating thickness	√	√
	Salt spray corrosion resistance	√	√
	Corrosion resistance to sulfur dioxide humid atmosphere	*	*
	Filiform corrosion resistance	*	*
	Machu corrosion resistance	×	*
	Humidity resistance	√	√
	Acid resistance	√	√
	Alkali resistance	√	*
	Mortar resistance	√	√
	Solvent resistance	√	√
	Detergent resistance	√	√
	Weatherability	√	√
	Coating hardness	√	√
	Abrasion resistance	√	√
	Impact resistance	×	√[a]
	Anti cupping	×	√[a]
	Bending resistance	×	√[a]
	Boiling water resistance	√	√

Note: "√" refers to the performance items that shall be selected, "*" refers to the performance items that shall be selected for specific purposes, "×" refers to the performance items that shall not be selected, and "a" indicates that the spray-painted film layer for anodizing pretreatment is not applicable.

3.5.2 Appearance Quality

3.5.2.1 Electrophoretic Coating

The appearance of the electrophoretic coating is uniform. The transparent electrophoretic coating has a metallic texture, and the colored electrophoretic coating has a bright color. The appearance quality of the electrophoretic coating requires that the coating after painting should be even and clean, without wrinkles, cracks, bubbles, flow marks, inclusions, stickiness, coating peeling, or other defects that affect use.

3.5.2.2 Spraying Coating

The appearance of the spraying coating is rich in color, diverse textures, and free of metal texture. The appearance quality of the spraying coating is required to be free of wrinkles, cracks, bubbles, flow marks, pockmarks, inclusions, stickiness, coating peeling, and other defects.

3.5.3 Gloss

The gloss of the coating is divided into high gloss, medium gloss, and low gloss. The use position shall be considered for the selection of gloss to avoid light pollution. As the gloss meter is not suitable for measuring the gloss of coating containing metal pigment, there is no requirement for transparent coating (such as electrophoretic coating coated with varnish), but this performance can be selected for electrophoretic coating with special requirements for coating gloss.

3.5.4 Color and Color Difference

The color and color difference of the electrophoretic coating and spraying coating with surface decoration function are important detection items. The uneven color will affect the decoration.

3.5.5 Coating Thickness

The coating thickness not only has an important impact on the corrosion resistance of the product but also has an impact on the decoration, impact resistance, cupping resistance, and bending resistance of the product. In addition, it is also an important factor in determining the production cost of magnesium alloy products.

3.5.6 Salt Spray Corrosion Resistance

Salt spray corrosion resistance is to investigate the environmental corrosion resistance of the coating, which is a common performance to evaluate the corrosion resistance of the coating. This performance is useful for investigating the corrosion situation and the service life of the coating in the marine environment.

3.5.7 Corrosion Resistance to Sulfur Dioxide Humid Atmosphere

The corrosion resistance to sulfur dioxide in the humid atmosphere is used to investigate the corrosion situation and the service life in areas with industrial pollution or acid rain. Therefore, this performance can be considered in areas with serious industrial pollution or acid rain.

3.5.8 Filiform Corrosion Resistance

The filiform corrosion resistance is to investigate the corrosion performance under the coating. Filiform corrosion often occurs under certain temperature and humidity conditions, where the coating is weak or damaged under the induction of an appropriate amount of acid, alkali, or salt. Filiform corrosion can occur in coastal or industrial environments, often starting from scratches. This performance can be considered for use in areas prone to filiform corrosion.

3.5.9 Machu Corrosion Resistance

Machu's corrosion resistance is to investigate the corrosion performance of organic polymer sprayed profiles under coating. Machu's corrosion resistance is generally not specified for the electrophoretic coating.

3.5.10 Humidity and Heat Resistance

Humidity and heat resistance are used to investigate the stability of spraying coating under high temperature and humidity environments. Humidity and heat resistance apply to both electrophoretic coating and spraying coating.

3.5.11 Acid Resistance

Acid resistance is used to investigate the resistance of the spraying coating to acid corrosion. Products with poor acid resistance may have defects that affect the use, such as serious discoloration of the coating and bubbles. The hydrochloric acid test is a commonly used evaluation method to investigate the acid resistance of the electrophoretic coating and spraying coating, while the nitric acid test is a method to evaluate the acid resistance of fluorocarbon coating.

3.5.12 Alkali Resistance

Alkali resistance is used to investigate the corrosion resistance of the sprayed coating to alkaline substances. Products with poor alkali resistance may have defects that affect the use, such as severe discoloration of the coating and bubbles. The alkali resistance test is usually conducted with sodium hydroxide solution, which is an evaluation method used to investigate the alkali corrosion resistance of the coating. The alkali resistance test can also conveniently evaluate the curing effect of the electrophoretic coating, so the alkali resistance test is required for the electrophoretic coating.

3.5.13 Mortar Resistance

Mortar resistance is used to investigate the resistance of the spraying coating to mortar erosion.

3.5.14 Solvent Resistance

The solvent resistance test is used to check whether the coating is completely cured and to investigate whether the curing conditions for the electrophoretic coating and spraying coating during production meet the curing conditions required by the coating. It shall be noted that the performance of the coating may also affect the solvent resistance.

3.5.15 Detergent Resistance

Detergent resistance is used to investigate the resistance of the coating to detergent erosion. Magnesium and magnesium alloy products for construction will be exposed to various detergents or cleaning agents, and the detergent resistance of the coating has practical significance.

3.5.16 Weatherability

Weatherability is used to investigate the ultraviolet light resistance of the coating under the action of various factors of the natural climate, which reflects the ability of the electrophoretic coating or spraying coating to resist the destruction of climatic conditions such as humidity, rain, dew, wind, frost, and maintain its original performance under the sunlight. Products with good weatherability have long service life and durable color. After the products with poor weatherability are used outdoors for some time, the surface coating may have large color changes, high gloss loss rate, and thin coating, which will affect its decorative performance, and may even have pulverization, cracking, blistering, rust, mold spots, contamination, coating peeling, and other phenomena. There are many factors affecting the weatherability of products, including the performance of coatings, production process conditions of oxidation coloring, curing temperature and time of coating, color and performance of pigments, etc.

3.5.17 Coating Hardness

Coating hardness is an important physical performance of the coating, which directly affects some important performance for coating applications, such as wearability, friction resistance, and product cleaning difficulty. Electrophoretic coating and spraying coating usually require this performance.

3.5.18 Abrasion Resistance

Abrasion resistance of the electrophoretic coating and spraying coating is closely related to the quality and use of the coatings. It can reflect the potential ability of the coating to resist abrasion and the ability to resist wind and sand. It is an important performance of electrophoretic coating and spraying coating.

3.5.19 Adhesion

The adhesion of electrophoretic coating and spraying coating is used to evaluate the adhesion between coating and substrate. Adhesion is a key performance related to service life. Adhesion of coating is closely related to the production process and production process control. At the same time, the quality of the coating may also affect adhesion.

3.5.20 Impact Resistance

Impact resistance is used to evaluate the performance of the coating against cracking or peeling off from the metal substrate using a fixed weight falling on the sample and causing deformation. The impact resistance of the coating is related to many factors, such as the pretreatment process before spraying, coating thickness, and punch diameter of the impact instrument. The impact resistance is only applicable to the spraying coating.

3.5.21 Cupping Resistance

Cupping resistance is used to evaluate the anti-cracking or anti-peeling performance of the coating by gradually deforming the sample. The cupping resistance is only applicable to the spraying coating.

3.5.22 Bending Resistance

The bending resistance test involves the process of bending a sample around a cylindrical axis and observing the changes in the film layer to evaluate its resistance to cracking or detachment from a metal substrate. The anti-bending property is only applicable to spray-painted film layers.

3.5.23 Boiling Water Resistance

Boiling water resistance is used to investigate the water resistance of the electrophoretic coating and spraying coating.

3.6 Test Methods

3.6.1 Appearance Quality Test Method

The visual inspection method shall be used to check the appearance quality. The natural light source or artificial (D65 or D50) standard light source shall be used as the light source. The viewing point shall be perpendicular to the surface of the sample or at an angle of 45° to the vertical line. The viewing distance for decorative coating shall usually be 0.5 m, and for architectural coating shall usually be 3 m.

3.6.2 Gloss Measurement Method

Gloss measurement shall be carried out with a gloss meter, which usually has 20°, 60°, and 85° geometry to measure the gloss of the coating. 20° geometry can give better resolution to the high gloss coating (*i.e.*, the coating with 60° specular gloss higher than 70 units); 85° geometry can give better resolution for low gloss coating (*i.e.*, the coating with 60° specular gloss less than 10 units); 60° geometry applies to all coatings. Because the gloss measured by different geometries is different, the geometry of the gloss meter shall be determined before the gloss measurement. 60° geometry has a wide range of applications, so it is generally selected for the gloss measurement of coatings.

3.6.3 Color and Color Difference Inspection Method

There are two main inspection methods for color and color difference: (1) the visual colorimetric method, and (2) the instrument inspection method. The visual colorimetric method applies to the inspection of color and color difference of all coatings, while the instrument inspection method is generally not applicable to the inspection of color and color difference of non-monochromatic coatings in fluorocarbon paint spraying, acrylic paint spraying, or electrophoretic coatings coated with varnish. When the visual colorimetric method is used to check the color and color difference, lighting conditions, observation angle, observation distance, and other conditions shall be considered.

3.6.4 Coating Thickness Test Method

Coating thickness shall be measured with an instrument, generally an eddy current instrument.

3.6.5 Salt Spray Corrosion Test Method

There are three main types of salt spray corrosion tests: (1) neutral salt spray test; (2) acetic acid salt spray test; and (3) copper accelerated acetic acid salt spray test. The copper-accelerated acetic acid salt spray test has an obvious accelerated corrosion effect on electrophoretic coating and can significantly shorten the salt spray corrosion test time of electrophoretic coating. However, because the conditions of the acetic acid salt spray test are closer to the natural state than those of the copper accelerated acetic acid salt spray test, the acetic acid salt spray test is also used to test the salt spray corrosion resistance of the electrophoretic coating. Fluorocarbon paint spraying coating and acrylic paint spraying coating are prone to corrosion under the coating. Therefore, a neutral salt spray test or acetic acid salt spray test can better evaluate the salt spray corrosion resistance of samples after drawing cross lines on the surface of the samples.

3.6.6 Sulfur Dioxide Humid Atmosphere Corrosion Test Method

As the corrosion rate in the sulfur dioxide humid atmosphere corrosion test mainly depends on the concentration and temperature of SO_2, this test aims to accelerate the corrosion by increasing the concentration and temperature of SO_2. Before the test, the cross lines deep into the substrate shall be drawn on the surface of the sample with a knife, then the sample shall be placed in the test chamber, 0.2 L sulfur dioxide gas shall be introduced, and the temperature in the test chamber shall be heated to 40 °C ± 3 °C within 1.5 h. 24 h is one test cycle and a total of 24 test cycles shall be conducted.

3.6.7 Filiform Corrosion Resistance Test Method

The surface of the sample shall be scratched in the specified way, and a small amount of hydrochloric acid shall be introduced to the scratch by exposing the sample to saturated hydrochloric acid vapor. Then the sample shall be placed in a test chamber with a temperature of 40 °C ± 2 °C and a relative humidity of 82% ± 3%, and taken out for result evaluation after the specified time.

3.6.8 Machu Test Method

Machu corrosion solution contains 50 g/L sodium chloride, 10 g/L glacial acetic acid, and 5 mL/L hydrogen peroxide (30%). pH value, test temperature, and test time shall be 3.0 ~ 3.3, 37 °C ± 1 °C, and 48 h, respectively. Before the test, the cross lines deep into the substrate shall be drawn on the surface of the sample with a knife, the sample shall be immersed in the test solution for 24 h, 5 mL/L hydrogen peroxide (30%) shall be added, the pH value shall be adjusted to 3.0 ~ 3.3 with sodium hydroxide or glacial acetic acid, and the test shall continue until the specified period is reached. The sample after the test shall be free of corrosion beyond a distance of 0.5 mm from the scribing line.

3.6.9 Damp Heat Test Method

The sample shall be placed in a constant temperature and humidity chamber with pre-adjusted temperature and relative humidity for the test, and taken out to check the damage to the sample surface after the specified time. When hanging the sample in the constant temperature and humidity chamber, mutual contact between the surfaces to be tested shall be avoided. When checking the sample in the test cycle, direct contact with the surface of the tested sample by hand shall be avoided.

3.6.10 Acid Resistance Test Method

3.6.10.1 Hydrochloric Acid Test Method

10 drops (1 + 9) of hydrochloric acid test solution shall be dropped on the coating surface of the sample, covered with a watch glass, and placed at an ambient temperature of 18 °C ~ 27 °C for 15 min. The change on the coating surface shall be visually inspected after taking down the watch glass and rinsing it with tap water.

3.6.10.2 Nitric Acid Test Method

100 mL of analytical pure nitric acid (ρ = 1.40 g/mL) shall be injected into a 200 mL large-mouth bottle. Then, the sample shall be covered down on the bottle mouth, kept for 30 min, taken down, rinsed with tap water, wiped dry, and inspected after placing for 1 h. The test shall be conducted in an environment with a temperature of 18 °C ~ 27 °C and a relative humidity of less than 50%.

3.6.11 Alkali Resistance Test Method

The glass (or synthetic resin) ring, with an inner diameter of 32 mm and a height of 30 mm, shall be fixed onto the coating surface of the sample with vaseline or paraffin. 5 g/L sodium hydroxide solution shall be injected into 1/2 of the ring height. The ring mouth shall be covered with a glass plate or synthetic resin plate, kept at an ambient temperature of 20 °C ± 2 °C for a specified time, cleaned with water, placed for 1 h, and a circle with a diameter of 30 mm shall be drawn concentric with the ring on the surface of the sample. The corrosion in the circle shall be observed with a 10 ∼ 15 times magnifying glass and graded according to observation.

3.6.12 Mortar Resistance Test Method

Mortar shall be mixed with 75 g of construction lime, 225 g of dry sand, and about 100 g of deionized water, placed on the surface of the sample, stacked into a cylindrical shape with a diameter of 15 mm and a thickness of 6 mm, placed in an environment with a temperature of 38 °C ± 3 °C and a relative humidity of 95% ± 5% for 24 h. The apparent condition of the sample surface shall be visually inspected by removing the mortar, wiping off the residue on the surface with a wet cloth, and drying in the air.

3.6.13 Solvent Resistance Test Method

3.6.13.1 Static Method

A cotton strip shall be dipped in the solvent (Xylene is used for electrophoretic coating, and butanone is used for fluorocarbon coating), saturated, placed on the sample, and kept for 30 s. The softening of the coating surface and other changes shall be inspected after taking off the cotton strip, washing the sample with tap water, wiping it dry, and placing it at room temperature for 2 h.

3.6.13.2 Wiping Method I

A cotton strip shall be dipped in solvent (Butanone is used as a solvent for fluorocarbon paint spraying coating), saturated, gently wiped back and forth on the surface of the sample along the same straight path 30 times within 30 s, and taken off. The coating surface shall be inspected after taking off the cotton strip, washing the sample with tap water, wiping it dry, and placing it at room temperature for 2 h. The test results shall be divided into four grades: (1) Grade 1 coating is very dark and soft; (2) Grade 2 coating is very dark and can be scratched with fingernails; (3) Grade 3 coating has a slight loss of gloss (less than 5 gloss units); (4) Grade 4 coating has no obvious change and no scratch by fingernail. Among them, Grade 3 and Grade 4 are qualified, and Grade 1 and Grade 2 are unqualified.

3.6.13.3 Wiping Method II

At room temperature, a 1 kg heavy hammer head (The contact area between the weight and the sample surface is about 150 mm^2.) wrapped with at least six layers of medical gauze shall be dipped in solvent (Xylene is used as the solvent for the electrophoretic coating and butanone is used as the solvent for the fluorocarbon paint spraying coating.), saturated, and wiped back and forth 100 times along the same straight path on the sample surface at the rate of one round trip per second (One round trip is counted as one cycle.). The gauze shall be kept wet during the test. It shall be visually inspected whether the organic polymer coating after the test is wiped off.

3.6.14 Detergent Resistance Test Method

The concentration of detergent solution used in the detergent resistance test is 30 g/L, contains 53% sodium pyrophosphate, 19% anhydrous sodium sulfate, 20% sodium dodecylbenzene carbonate, 7% sodium silicate hydrate, and 1% anhydrous sodium carbonate. The sample shall be placed in the detergent test solution for 72 h at 38 °C ± 1 °C, then taken out and wiped dry. The coating surface shall be visually inspected for bubbles, covered with adhesive tape with an adhesive force greater than 10 N/25 mm, and pressed to drain the air under the adhesive tape. The adhesive tape shall be quickly pulled up at an angle perpendicular to the coating surface, and it shall be inspected whether the coating falls off.

3.6.15 Weatherability Test Method

3.6.15.1 Natural Exposure Weathering Test Method

To objectively and fairly evaluate the weatherability of products, the exposure field shall be established in the area that can represent the most severe climate types or in the place where the tested product is used.

3.6.15.2 Manual Accelerated Weatherability Test Method

There are three kinds of artificially accelerated weatherability tests: (1) artificially accelerated weatherability test with the fluorescent ultraviolet lamp; (2) artificially accelerated weatherability test with a xenon arc lamp; (3) artificially accelerated weatherability test with a carbon arc lamp. Because the spectral distribution of xenon lamps is more similar to that of sunlight, it is also more widely used. Electrophoretic coating and fluorocarbon paint spraying coating are more often tested for weatherability by a manual accelerated weatherability test with a xenon arc lamp, while the accelerated weatherability test with a fluorescent ultraviolet lamp using a UV-B313 lamp is faster.

3.6.16 Coating Hardness Test Method

There are two kinds of coating hardness tests: (1) the indentation hardness test, and (2) the pencil hardness test. The indentation hardness test is more suitable for relatively thicker coatings, while the pencil hardness test is more suitable for relatively thinner coatings. Therefore, the pencil hardness test is usually used to detect electrophoretic coating, fluorocarbon coating, and acrylic coating with low coating thickness.

3.6.17 Abrasion Resistance Test Method

In the test, the abrasion coefficient of the coating shall be measured by the sand falling tester to evaluate the abrasion resistance of the coating. There are generally two kinds of abrasives used in this test: one is No. 80 black silicon carbide, and the other is standard sand. To ensure the accuracy of the test results, the test abrasives shall be dry, the relative humidity of the laboratory shall not be greater than 80%, and attention shall be paid to avoiding the wind. No. 80 black silicon carbide shall be used as the abrasive for electrophoretic coating, and standard sand shall be used as the abrasive for fluorocarbon coating.

3.6.18 Adhesion Test Method

An adhesion test is usually conducted with the grid cut method, which is used to evaluate the resistance of the coating to detach from the substrate when the coating penetrates the substrate with a right-angle grid pattern. The cutting spacing is related to the coating thickness. The cutting spacing is 1 mm, 2 mm, and 3 mm when the coating thickness is 0 μm ~ 60 μm, 60 μm ~ 120 μm, and 120 μm ~ 250 μm, respectively. The grid cut method does not apply to the coating with a thickness greater than 250 μm or the coating with texture.

3.6.19 Impact Resistance Test Method

There are two main types of impact resistance tests: (1) positive impact test (the weight directly impacts the inspected surface), and (2) recoil test (the weight impacts the opposite side of the inspected surface). The diameter of the punch used in the test is 16 mm, and the mass of the weight is 1000 g $\pm$ 1 g. During the test, the tested surface of the sample shall be upward for the positive impact test or downward for the recoil test. The distance between the impacted part of the sample and the edge shall not be less than 15 mm, and the distance between the edges of each impact point shall not be less than 15 mm. Then the weight shall be dropped freely at an appropriate height and directly impacted on the sample, to produce a pit with a depth of 2.5 mm $\pm$ 0.3 mm. Then the change of the pit and the surrounding coating shall be inspected.

3.6.20 Cupping Resistance Test Method

The cupping resistance test can be conducted in accordance with a specified indentation depth to assess the qualification of the coating. Alternatively, the indentation depth can be gradually increased to determine the minimum depth at which the coating first cracks or begins to detach from the substrate.

3.6.21 Bending Resistance Test Method

The bending resistance test can be conducted using a specified cylindrical shaft diameter to assess the qualification of the coating. Alternatively, the test can be carried out with cylindrical shafts (the diameter of cylindrical shafts ranges from large to small) to determine the minimum diameter at which the coating first cracks or begins to detach from the substrate.

3.6.22 Boiling Water Resistance Test Method

The duration of the boiling water resistance test and whether the test is pressurized have an impact on the test results. Generally, the 5 h normal pressure boiling water resistance test shall be adopted for the electrophoretic coating.

3.7 Quality Certificate

3.7.1 Quality Certificate of Electrophoretic Coating

Each batch of stock solution shall be accompanied by a product quality certificate that indicates the following:

(a) Supplier name;
(b) Product name;
(c) Batch number and production date;
(d) Weight or number of pieces;
(e) All analysis and inspection results (including factory inspection results and recent type inspection results of non-factory inspection items) and the seal of the supplier's quality inspection department;
(f) Number of this standard.

3.7.2 Quality Certificate of Spraying Coating

To ensure the reliability of the quality (especially weatherability and corrosion resistance) of the spraying coating, the contents of the quality certificate shall be negotiated with the coating manufacturer, and the contents of the quality certificate shall include at least the following:

(a) Executive standard number;
(b) Product name;
(c) Manufacturing technology Construction technology, including curing temperature and curing time;
(d) Density of coating paint;
(e) The fineness of coating paint;
(f) Viscosity of coating paint;
(g) Solids of coating paint;
(h) Types of pigment;
(i) Mass fraction of PVDF resin in the resin (fluorocarbon coating);
(j) Volatile organic compound content of coating paint;
(k) Neutral salt spray test results, impact resistance test, and other test results of coating paints.

3.8 Contents of Purchase Order (or Contract)

3.8.1 Contents of the Electrophoretic Coating Purchase Order (or Contract)

The purchase order (or contract) for the stock solution of this standard shall include the following contents:

(a) Product name;
(b) Type of stock solution;
(c) Viscosity and density of stock solution;
(d) Net weight;
(e) Special requirements for viscosity, density, and solids of stock solution;
(f) Weatherability, alkali resistance, grade of ultraviolet salt spray joint test of composite coating, and grade or special requirements of other composite coating performance;
(g) Special requirements for solid content, swimming force, coulomb efficiency, pH value, conductivity, amine value, and acid value of working fluid;
(h) Number of this standard;
(i) Other requirements.

3.8.2 Content of Spraying Coating Purchase Order (or Contract)

Relevant technical requirements shall be presented in the purchase order (or contract) after the selection of the spraying coating is completed. The following contents shall be indicated in the purchase order (or contract) for spraying coating.

(a) Executive standard number;
(b) Product name;
(c) Type of coating;
(d) Weatherability and other coating performance grades or requirements;
(e) Net weight;
(f) Other special requirements.

Chapter 4

Magnesium and Magnesium Alloys – Extruded Profiles for Rail Transit Equipment

4.1 Scope

This international standard specifies the chemical composition, mechanical properties, shape, and dimensional tolerance, technical conditions for inspection and delivery of magnesium and magnesium alloy extruded profiles for rail transit equipment applications.

4.2 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 documents (including any amendments) applies.
ISO 3116, *Magnesium and magnesium alloys — Wrought magnesium and magnesium alloys*
ISO 6892-1, *Metallic materials—Tensile testing—Part 1: Method of test at room temperature*

4.3 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

Profile

Wrought product of uniform cross-section along its whole length, with a cross-section other than wire, rod/bar, tube, sheet, or strip, supplied in straight lengths or in coiled form, and where the product is long in relation to its cross-sectional dimensions.

Note: According to the form of its cross-section, it is called:

(a) hollow profile: the cross-section includes either one enclosed void, provided that the cross-section is other than a tube, or more than one enclosed void;
(b) solid profile: the cross-section does not include any enclosed void.

4.4 Orders or Tenders

The order or tender shall define the product required and shall contain the following details:

(a) the type and form of product:
— designation of the magnesium or magnesium alloy;
— form of the product (profile);
(b) the metallurgical temper (degree of hardness or heat treatment condition) of the material for delivery and, if different, the metallurgical temper for use;
(c) the number of this International Standard or specification number, or, where none exists, properties agreed between the supplier and the purchaser;
(d) dimensions and shape of the product (thickness, width, length, diameter); and/or reference to a drawing defining the product;

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(e) tolerances of the dimensions and form, with reference to the appropriate International Standard;
(f) quantity;
(g) any requirements for certificates of conformity, test, and/or analysis;
(h) any special requirements agreed between the supplier and the purchaser (for example, drawings).

4.5 Requirements

4.5.1 Designation

The alloy designation and temper shall be in conformity with table 4.1. If there is any alloy not specified in table 4.1, the alloy designation and temper shall be agreed upon between the supplier and purchaser and stated in the order.

TAB. 4.1 – Alloy designation and temper of extruded profiles.

IMS designation	ISO designation	Temper
IMS-AZ31E	ISO-MgAl3Zn1(A)	F
IMS-AZ40A	ISO-MgAl4Zn	F
IMS-AZ41A	ISO-MgAl4Zn1	F
IMS-AZ61C	ISO-MgAl6Zn1	F
IMS-AZ81B	ISO-MgAl8Zn	F, T5
IMS-M2B	ISO-MgMn2	F
IMS-ZK61C	ISO-MgZn6Zr	F, T5
IMS-ZM21A	ISO-MgZn2Mn1	F
IMS-WE54B	ISO-MgY5RE4Zr	T5, T6
IMS-WE43C	ISO-MgY4RE3Zr1(B)	T5, T6
IMS-VW84A	ISO-MgGd8Y4Zn2	F, T5, T6

4.5.2 Production and Manufacturing Processes

Unless otherwise specified in the order, the production and manufacturing processes shall be left to the discretion of the producer. Unless it is explicitly stated otherwise in the order, no obligation shall be placed on the producer to use the same processes for subsequent and similar orders.

4.5.3 Quality Control

The supplier shall be responsible for the performance of all inspections and tests required by the relevant International Standard, specification, or customer requests, prior to shipment of the product. If the purchaser wishes to inspect the product at the supplier's works, he shall notify the supplier at the time of placing the order.

4.5.4 Chemical Composition

The chemical composition shall conform to the requirements for the appropriate material given in table 4.2, or comply with the requirements specified in ISO 3116.

If the purchaser requires content limits for elements not specified in table 4.2 nor in ISO 3116, these limits shall be stated in the order document.

4.5.5 Mechanical Properties

The mechanical properties of profiles shall be in conformity with those specified in table 4.3. If there is any alloy not specified in table 4.3, the mechanical properties shall be in conformity with those specified in ISO 3116 or those agreed upon between the supplier and purchaser and stated in the order.

TAB. 4.2 – Chemical composition of wrought magnesium and magnesium alloys.

Alloy group	Material designation																			
	Symbol	ISO designation	Element	Mg	Al	Zn	Mn	Gd	Y	RE	Li	Zr	Ca		Si	Fe	Cu	Ni	Others	
																			Each	Total
MgAlZn	IMS-AZ31E	ISO-MgAl3Zn1(A)	min max	Rem —	2.4 3.6	0.5 1.5	0.15 0.40	—	—	—	—	—	—	—	— 0.10	— 0.005	5	— 0.005	— 0.05	— 0.30
	IMS-AZ40A	ISO-MgAl4Zn	min max	Rem —	3.0 4.0	0.2 0.8	0.15 0.50	—	—	—	—	—	—	— 0.01B e	— 0.10	— 0.05	— 0.05	— 0.005	— 0.01	— 0.30
	IMS-AZ41A	ISO-MgAl4Zn1	min max	Rem —	3.7 4.7	0.8 1.4	0.30 0.60	—	—	—	—	—	—	— 0.01Be	— 0.10	— 0.005	— 0.05	— 0.005	— 0.01	— 0.30
	IMS-AZ61C	ISO-MgAl6Zn1	min max	Rem —	5.5 6.5	0.5 1.5	0.15 0.40	—	—	—	—	—	—	—	— 0.10	— 0.005	— 0.05	— 0.005	— 0.05	— 0.30
	IMS-AZ80C	ISO-MgAl8Zn	min max	Rem —	7.8 9.2	0.20 0.8	0.12 0.40	—	—	—	—	—	—	—	— 0.10	— 0.005	— 0.05	— 0.005	— 0.05	— 0.30
MgMn	IMS-M2B	ISO-MgMn2	min max	Rem —	—	—	1.2 20	—	—	—	—	—	—	—	— 0.10	—	— 0.05	— 0.01	— 0.05	— 0.30
MgZnZr	IMS-ZK61C	ISO-MgZn6Zr	min max	Rem —	—	4.8 6.2	—	—	—	—	—	0.45 0.8	—	—	—	—	—	—	— 0.05	— 0.30
MgZnMn	IMS-ZM21A	ISO-MgZn2Mn1	min max	Rem —	— 0.1	1.75 2.3	0.6 1.3	—	—	—	—	—	—	—	— 0.10	— 0.06	— 0.10	— 0.005	— 0.05	— 0.30
MgYREZr	IMS-WE54B	ISO-MgY5RE4Zr1	min max	Rem —	—	— 0.20	— 0.03	—	4.75 5.5	1.5 4.0	—	0.4 1.0	—	—	— 0.01	— 0.01	— 0.02	— 0.005	— 0.01	— 0.30
	IMS-WE43C	ISO-MgY4RE3Zr1 (B)	min max	Rem —	—	— 0.20	— 0.03	—	3.7 4.3	2.4 4.4	— 0.2	0.4 1.0	—	—	— 0.01	— 0.01	— 0.02	— 0.005	— 0.01	— 0.30
MgGdY	IMS-VW84A	ISO-MgGd8Y4Zn2	min max	Rem —	—	1.0 2.0	0.6 1.0	7.5 9.0	3.5 5.0	—	—	—	—	—	— 0.05	— 0.01	— 0.02	— 0.005	— 0.01	— 0.15

TAB. 4.3 – Mechanical properties of profiles.

Alloys	Type	Temper	Dimensions[a]	Tensile strength R_m (N/mm^2) min	0, 2% Proof stress $R_{P0.2}$ (N/mm^2) min	Elongation A % min
IMS-AZ31E	SP[b]	F	$t \leq 6.3$	240	145	7
			$6.3 < t \leq 40$	240	150	7
			$40 < t \leq 60$	235	150	7
			$60 < t \leq 130$	220	140	7
	HP[c]	F	All	220	110	8
IMS-AZ40A	–	F	$t \leq 130$	240	150	5.0
IMS-AZ41A	–	F	$t \leq 130$	250	150	5.0
IMS-AZ61C	SP	F	$1 \leq t \leq 10$	260	150	6.0
			$10 < t \leq 40$	270	170	9.0
			$40 < t \leq 65$	260	160	9.0
	HP	F	$1 < t \leq 10$	250	110	7.0
IMS-AZ80C	SP	F	$t \leq 6.3$	295	195	9.0
			$6.3 < t \leq 40$	295	195	8.0
			$40 < t \leq 60$	295	195	6.0
			$60 < t \leq 130$	290	185	4.0
	SP	T5	$t \leq 6.3$	325	205	4.0
			$6.3 < t \leq 60$	330	230	4.0
			$60 < t \leq 130$	310	205	2.0
	HP	F	$1 \leq t \leq 10$	280	180	3.0
IMS-M2B	SP	F	$t \leq 50$	230	120	3.0
			$50 < t \leq 100$	200	120	3.0
	HP	F	$t \leq 2$	225	165	2.0
			$T > 2$	200	145	1.5
IMS-ZK61C	SP	F	$t \leq 50$	300	210	5.0
	SP	T5	$t \leq 50$	310	230	5.0
	HP	F	All	275	195	5.0
	HP	T5	All	315	260	4.0
IMS-ZM21A	SP	F	$t \leq 10$	230	150	8.0
			$10 < t \leq 75$	245	160	10.0
IMS-WE54B	SP	T5	$10 < t \leq 50$	250	170	6.0
			$50 < t \leq 100$	250	160	6.0
	SP	T6	All	250	160	6.0
IMS-WE43C	SP	T5	$6.3 < t \leq 50$	250	160	4.0
			$50 < t \leq 130$	240	150	4.0
	SP	T6	$6.3 < t \leq 50$	250	150	4.0
			$50 < t \leq 130$	240	140	4.0
IMS-VW84A	SP	F	$t \leq 10$	400	290	8.0
			$t > 10$	350	250	11.0
	HP	F	All	350	250	11.0
	SP	T5	$t \leq 10$	500	360	6.0
			$t > 10$	430	310	3.0
	HP	T5	All	430	310	3.0
	SP	T6	$10 < t \leq 65$	500	350	8.0
			$t > 65$	450	280	8.0

[a] t (mm) = thickness of solid profile; wall thickness of hollow profile.
[b] Solid profile.
[c] Hollow profile.
Notes: The temper shall be in accordance with the symbol, definition, and meaning specified in ISO 3116.

4.5.6 Surface Finish

The products shall be free from defects detrimental to their use. While an operation designed to mask a fault is not permitted, the elimination of a superficial fault is permissible, provided that the dimensional tolerances remain.

4.5.7 Tolerances on Shape and Dimensions

The tolerances on the length, cross-sectional dimension, angularity, straightness, flatness, curved cross-section, twist, fillet radii, and surface roughness of profiles shall be as follows.

4.5.7.1 Tolerances on Length

If fixed lengths are to be supplied, this shall be stated in the order document. The tolerances on fixed length are given in table 4.4.

The length range and tolerances for the random length shall be subject to agreement between the supplier and purchaser.

TAB. 4.4 – Tolerances on fixed length. Unit: mm.

Diameter of circumscribing circle	Tolerance on fixed length L				
	$L \leq 2000$	$2000 < L \leq 5000$	$5000 < L \leq 10\,000$	$10\,000 < L \leq 15\,000$	$15\,000 < L \leq 25\,000$
$D \leq 100$	+5	+7	+10	+16	+22
$100 < D \leq 200$	+7	+9	+12	+18	+24
$200 < D \leq 450$	+8	+11	+14	+20	+28
$450 < D \leq 800$	+9	+14	+16	+22	+30

Note: If no fixed length is specified in the order document, profiles may be delivered in random lengths.

4.5.7.2 Tolerances on Cross-Sectional Dimensions

Tolerances on cross-sectional dimensions (see figures 4.1–4.3) are specified in table 4.5.

The sectional dimensions shall be A, B, C_e, C_i, and D as given in figure 4.1, and their tolerances shall be as given in table 4.5. However, as given in figure 4.2, the tolerances on the sectional dimensions, where the nominal wall thickness of one wall is equal to or greater than three times the thickness of the other wall t shall be upon the agreement between the purchaser and the manufacturer.

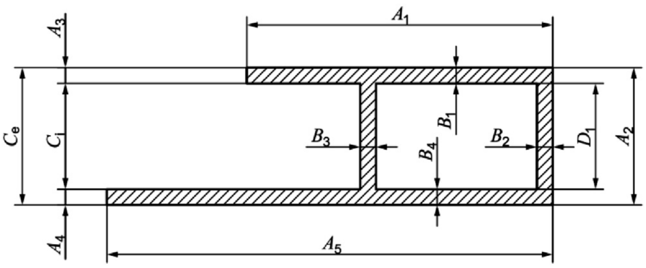


FIG. 4.1 – Basic cross-sectional dimensions of extruded profiles.

Key for figure 4.1:
A_1–A_5: dimension of metallic part, except thickness of wall surface at hollow part (B),
B_1–B_4: thickness of wall surface at hollow place,
C_e *and* C_i: dimensions of empty space at opening,
D_1: dimensions of empty space at hollow place.

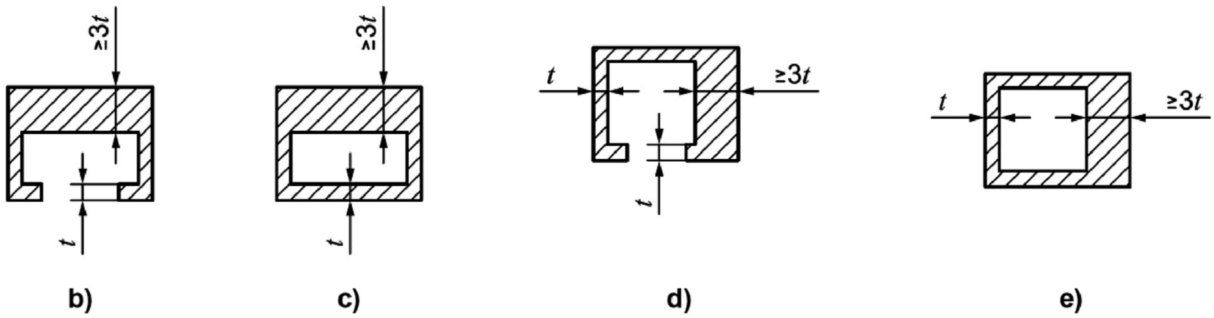


FIG. 4.2 – Cross-sectional dimensions of asymmetric wall thickness profiles.

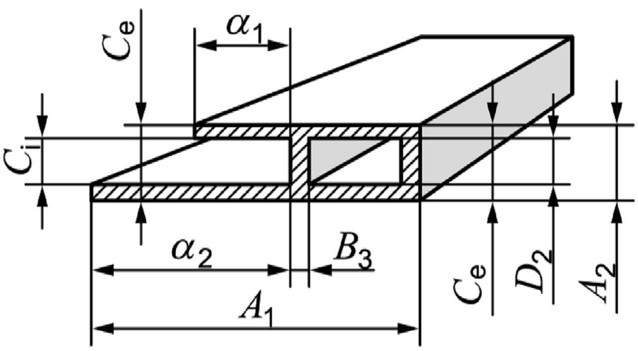


FIG. 4.3 – Cross-sectional dimensions with rib root measurement points.

Key for figure 4.3:
α_1, α_2: distance between specified point and root of let.

4.5.7.3 Tolerances on Angularity

The deviation from a specified angularity shall be measured as shown in figures 4.5 and 4.6.

The angularity tolerances for right angles shall be as specified in table 4.6 as a function of profile width W.

For profiles with a value of W that exceeds 400 mm, the tolerance shall be subject to agreement between the supplier and purchaser.

The maximum allowable deviation α in an angle other than a right angle shall be ±2°. When the tolerances are specified for the plus or the minus side only, the allowable deviation α shall be 4° or −4°.

In the case of unequal side lengths, the tolerance on angularity shall apply to the shorter side of the angle, *i.e.*, it is measured starting from the longer side.

4.5.7.4 Tolerances on Straightness

Deviations from straightness h_s and h_t shall be measured as shown in figure 4.7 with the profile placed on a horizontal base-plate so that its own mass decreases the deviation.
Key for figure 4.7:
l_t: total length,
h_t: camber of the total length,
h_s: camber at arbitrary position,
1: ruler,
2: flat table.

The tolerances on the camber of profiles shall be as given in table 4.7.

Tab. 4.5 – Tolerance on cross-sectional dimensions. Unit: mm.

Dimension at specified part	Tolerance[a]								
	Metallic part[b, c] (where 75% or more is metal)		Hollow part (where more than 25% is hollow space, *i.e.*, less then 75% is metal) C_i or C_e[d]						
	Metallic part other than that in the right column A	Thickness of wall surface at hollow part[e] B	Distance between specified point and root of let α[f]						Tolerances for empty space D
			$5 < \alpha \leq 15$	$15 < \alpha \leq 30$	$30 < \alpha \leq 60$	$60 < \alpha \leq 100$	$100 < \alpha \leq 150$	$150 < \alpha \leq 200$	
Circumscribing circle size less than 250 mm in diameter									
$A \leq 3.20$	±0.23	±15%, but ±2.30 max. and ±0.38 min	±0.33	±0.38	—	—	—	—	± 0.38
$3.20 < A \leq 6.30$	±0.27		±0.39	±0.45	±0.51	—	—	—	± 0.45
$6.30 < A \leq 12.50$	±0.30		±0.47	±0.51	±0.58	± 0.61	—	—	± 0.54
$12.50 < A \leq 20.00$	±0.35		±0.53	±0.58	±0.64	± 0.67	—	—	± 0.62
$20.00 < A \leq 25.00$	±0.38		±0.60	±0.64	±0.70	±0.77	±0.89	—	± 0.69
$25.00 < A \leq 40.00$	±0.45		±0.69	±0.73	±0.83	±0.91	±1.0	—	±0.81
$40.00 < A \leq 50.00$	±0.54		±0.79	±0.83	±0.99	±1.1	±1.2	±1.4	±0.90
$50.00 < A \leq 100.00$	±0.92		±1.1	±1.2	±1.5	±1.7	±2.0	±2.3	±1.29
$100.00 < A \leq 150.00$	±1.3		±1.5	±1.6	±2.0	±2.4	±2.8	±3.2	±1.65
$150.00 < A \leq 200.00$	±1.7		±1.8	±2.0	±2.6	±3.0	±3.6	±4.1	±2.03
$200.00 < A \leq 250.00$	±2.1		±2.1	±2.4	±3.2	±3.7	±4.3	±4.9	±2.48
Circumscribing circle size over and include 250 mm in diameter									
$A \leq 3.20$	±0.54	±20%, but ±3.40 max. and ±0.57 min	±0.64	±0.69	—	—	—	—	±0.69
$3.20 < A \leq 6.30$	±0.57		±0.67	±0.76	±0.89	—	—	—	±0.72
$6.30 < A \leq 12.50$	±0.62		±0.71	±0.82	±0.95	±1.5	—	—	±0.75
$12.50 < A \leq 20.00$	±0.65		±0.78	±0.93	±1.3	±1.7	—	—	±0.84
$20.00 < A \leq 25.00$	±0.69		±0.81	±1.0	±1.6	±2.0	±2.7	—	±0.87
$25.00 < A \leq 40.00$	±0.72		±0.85	±1.2	±1.9	±2.3	±3.0	—	±0.90
$40.00 < A \leq 50.00$	±0.92		±1.2	±1.5	±2.2	±2.6	±3.3	±4.6	±1.29
$50.00 < A \leq 100.00$	±1.3		±1.6	±1.8	±2.5	±2.9	±3.6	±4.9	±1.65
$100.00 < A \leq 150.00$	±1.7		±1.9	±2.2	±2.9	±3.2	±3.8	±5.2	±2.03
$150.00 < A \leq 200.00$	±2.1		±2.3	±2.5	±3.2	±3.5	±4.1	±5.4	±2.48
$200.00 < A \leq 250.00$	±2.4		±2.6	±2.9	±3.5	±3.8	±4.4	±5.7	±2.85
$250.00 < A \leq 300.00$	±2.8		±3.0	±3.2	±3.8	±4.1	±4.7	±6.0	±3.23
$300.00 < A \leq 350.00$	±3.2		±3.3	±3.6	±4.1	±4.4	±5.0	±6.2	±3.60
$350.00 < A \leq 400.00$	±3.6		±3.7	±3.9	±4.5	±4.7	±5.3	±6.5	±3.98
$400.00 < A \leq 450.00$	±4.0		±4.1	±4.3	±4.8	±5.0	±5.6	±6.8	±4.35
$450.00 < A \leq 500.00$	±4.4		±4.4	±4.6	±5.1	±5.3	±5.9	±7.1	±4.73

TAB. 4.5 – (continued).

Dimension at specified part	Tolerance[a]								
	Metallic part[b, c] (where 75% or more is metal)		Hollow part (where more than 25% is hollow space, *i.e.*, less then 75% is metal) C_i or C_e[d]						
	Metallic part other than that in the right column A	Thickness of wall surface at hollow part[e] B	Distance between specified point and root of let α[f]						Tolerances for empty space D
			$5 < \alpha \leq 15$	$15 < \alpha \leq 30$	$30 < \alpha \leq 60$	$60 < \alpha \leq 100$	$100 < \alpha \leq 150$	$150 < \alpha \leq 200$	
$500.00 < A \leq 550.00$	±4.7		±4.8	±4.9	±5.4	±5.6	±6.2	±7.3	±5.10
$550.00 < A \leq 800.00$	±5.1		±5.1	±5.3	±5.7	±5.8	±6.5	±7.6	±5.48

Note: The circumscribing circle is the smallest circle that encloses the cross-section of the profile entirely. However, this dimension may have to be increased when profiles are subjected to corrections of the uneven thickness or in the case of hollow profiles, for which the centre of the circumscribing circle needs to be considered, based on the void. These matters should be confirmed with the supplier beforehand as required.

Notes: [a]When the dimensional tolerance is not made equal at the plus side and minus side, determine the value in the column corresponding to the centre of the allowable range, and use this value as a standard to decide the tolerance.

[b]In the case of angled profiles as shown in figure 4.4, the tolerances shall be decided not on the base of the length of dimension X, but on the base of the angle α (see 4.5.7.3).

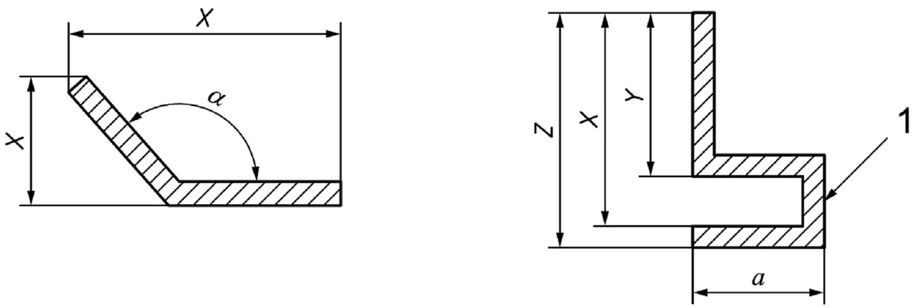


FIG. 4.4 – Cross-sectional dimensions of angled extruded profiles.

[c]Even when value Y in figure 4.4 is equal to or greater than 75% of value X, these tolerances are not applied to the dimension X or Z. The tolerances for X and Y shall conform to the column corresponding to space dimension C_i and C_e, depending on the distance a from the reference base.

[e]If the purchaser and the supplier agree, the outside dimension C_e may be specified instead of the inside dimension C_i.

[f]This is applicable when the space volume enveloped with the hollow part is 70 mm^2 or larger. If less than 70 mm^2, employ column A.

[g]If 5 mm or under, employ column A.

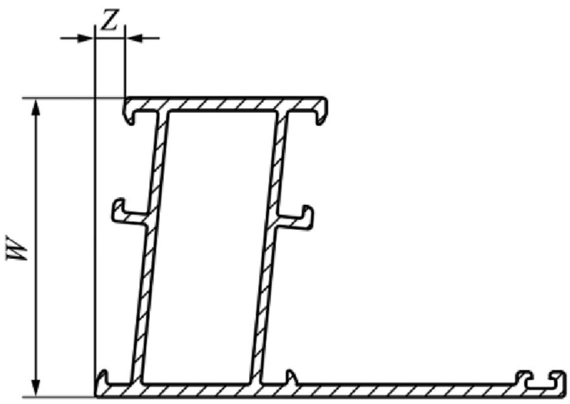


FIG. 4.5 – Measurement of angularity in a right angle.

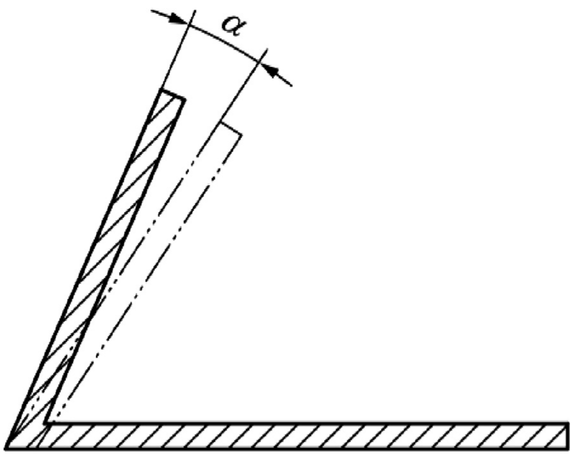


FIG. 4.6 – Measurement of angularity in an angle other than a right angle.

TAB. 4.6 – Angularity tolerance for right angles. Unit: mm.

Width W	Maximum allowable deviation from a right angle Z
$W \leq 30$	0.4
$30 < W \leq 50$	0.7
$50 < W \leq 80$	1.0
$80 < W \leq 120$	1.4
$120 < W \leq 180$	2.0
$180 < W \leq 240$	2.6
$240 < W \leq 300$	3.1
$300 < W \leq 400$	3.5

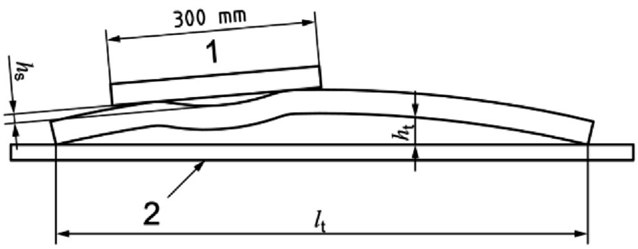
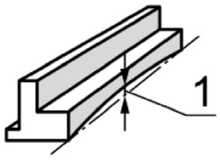


FIG. 4.7 – Measurement of straightness.

Tab. 4.7 – Tolerances on straightness. Unit: mm.

Diameter of circumscribing circle D	Minimum wall thickness t	Tolerance	
		 Key: 1: camber	
		h_s for arbitrary length of 1000	h_t for total length
$D \leq 38$	$t \leq 2.4$	$h_s \leq 6.6$	$h_t \leq 6.6 \times l_t/1000$
	$t > 2.4$	$h_s \leq 2$	$h_t \leq 2 \times l_t/1000$
$D > 38$	All	$h_s \leq 2$	$h_t \leq 2 \times l_t/1000$

Note: The tolerance value is obtained when the profile is laid on a flat plate under its own weight so that the camber is minimum.

4.5.7.5 Tolerances on Flatness

The flatness shall be measured as shown in figure 4.8.

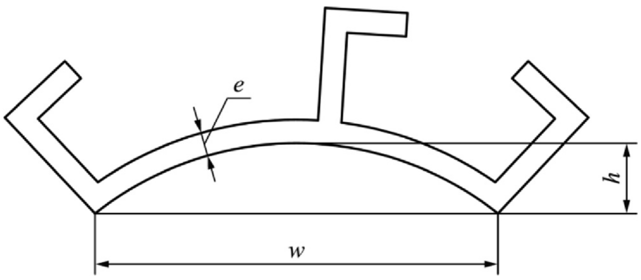
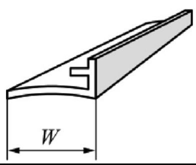
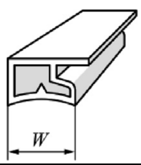


Fig. 4.8 – Measurement of flatness.

Key for figure 4.8:
w: width,
h: flatness,
e: thickness.

The maximum allowable deviation on flatness for solid and hollow profiles shall be as specified in table 4.8.

Tab. 4.8 – Tolerances on flatness. Unit: mm.

Width W	Tolerance h	
		
	For both solid profile and hollow profile	
	For arbitrary width of 25	For total width W
$W \leq 25$	—	$h \leq 0.2$
$W > 38$	$h \leq 0.2$	$h \leq 0.008 \times W$

4.5.7.6 Tolerances on Curved Cross-Section

The tolerances for the curved cross-section of profiles shall be applied only when required by the purchaser. If the purchaser does not provide the form board, this item may not be checked.

Tolerances on curved cross-section shall be examined by a form board provided by the purchaser. It shall be measured as shown in figure 4.9. The tolerance shall not be more than 1% of arc length.

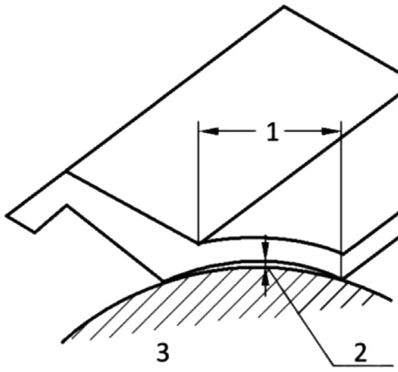


Fig. 4.9 – Measurement of tolerances on curved cross-section.

Key for figure 4.9:
1: arc,
2: tolerances on curved cross-section,
3: form board.

4.5.7.7 Tolerances on Twist

The tolerances on the twist of profiles shall be measured as shown in figure 4.10. Placing the profile on a flat base-plate, the profile resting under its own mass, and measuring the maximum distance at any point along the length between the bottom surface of the profile and the base-plate surface.

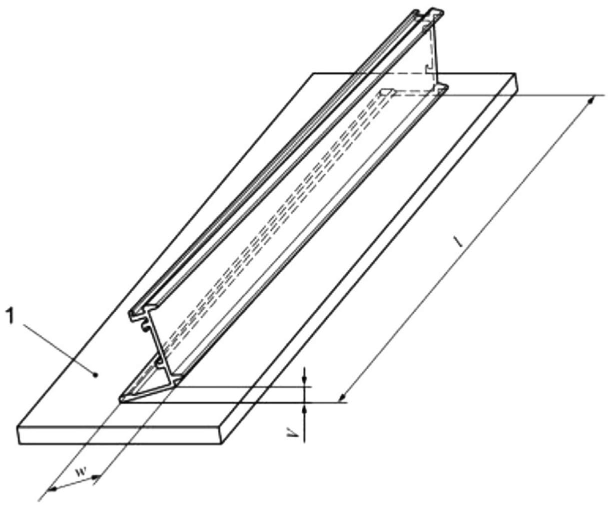


Fig. 4.10 – Measurement of twist.

Key for figure 4.10:
l: whole length,
w: width,
V: twist,
1: flat table.

The maximum allowable deviation on twist for profiles shall be as specified in table 4.9.

TAB. 4.9 – Tolerances on twist. Unit: mm.

Diameter of circumscribing circle D	Tolerance [per width (W) 1 mm]	
	Per length of 1000	Maximum value for total length
$12.5 < D \leq 40$	0.070	0.140
$40 < D \leq 80$	0.034	0.105
$80 < D \leq 250$	0.026	0.070
$D > 250$	0.017	0.058

4.5.7.8 Tolerances on Fillet Radii

The tolerances on the fillet radii of profiles shall be measured as shown in figure 4.11.

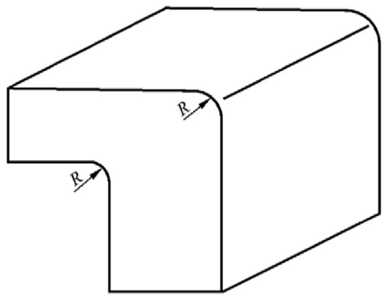


FIG. 4.11 – Measurement of fillet radii.

Key for figure 4.11:
R: fillet radii.

The maximum allowable deviation on fillet radii for profiles shall be as specified in table 4.10.

TAB. 4.10 – Tolerances on fillet radii. Unit: mm.

Fillet Radii R	Tolerance
$R \leq 1$	±0.40
$1 < R \leq 3$	±0.75
$3 < R \leq 10$	±1.50
$10 < R \leq 25$	±2.00

4.5.7.9 Tolerances on Surface Roughness

Roughness of the surface of profiles shall not exceed the amount permitted by table 4.11.

TAB. 4.11 – Tolerances on surface roughness. Unit: mm.

Wall thickness t	Tolerance [Maximum value for allowable depth of defect]
$t \leq 1.65$	0.038
$1.65 < t \leq 3.20$	0.050
$3.20 < t \leq 4.80$	0.065
$4.80 < t \leq 6.30$	0.075
$6.30 < t \leq 12.5$	0.100
$t > 12.5$	0.200

4.6 Test Procedure

4.6.1 Sampling

4.6.1.1 Specimens for Chemical Analysis

The specimens for chemical analysis shall be cast from molten metal samples taken at the time of casting. Their shape and conditions of production (mould design, cooling rate, mass, etc.) shall be so designed that their composition is homogeneous, and be suitable for the method of analysis which is agreed between the supplier and the purchaser.

4.6.1.2 Specimens for Mechanical Testing

4.6.1.2.1 Location and Size
Specimens shall be taken from samples in such a way that it is possible to orient the test pieces in relation to the product, as specified in 4.6.1.2.2.

The specimens shall be large enough to allow the manufacture of sufficient test pieces for the required tests, and for any retests which may be required.

4.6.1.2.2 Orientation of Specimens
Specimens shall generally be taken in the longitudinal direction, unless otherwise agreed upon between the supplier and purchaser and stated in the order.

4.6.1.2.3 Identification of Specimens
Each specimen shall be marked in such a manner that, after removal, it is still possible to identify the product from which it was taken and its location and orientation. If, during the course of subsequent operations, removal of the markings cannot be avoided, new markings shall be made before the originals are removed.

4.6.1.2.4 Preparation of Specimens
Specimens shall be taken from the sample after completion of all the mechanical and heat-treatments that the product has to undergo before delivery, and which may influence the mechanical properties of the metal. In cases where this is not possible, the sample or specimens may be taken at an earlier stage, but they shall be subjected to the same treatment as that to which it is intended to submit the product concerned.

NOTE: If the purchaser intends to convert the material to a final temper which is different from the ‘as supplied’ temper, then additional testing may be requested by the purchaser in order to satisfy himself that the material is capable of meeting the specified properties of the final temper. It is only necessary for the supplier to confirm that selected samples, heat-treated using supplier laboratory conditions, meet the properties specified for the final temper required by the purchaser.

Cutting shall be carried out in such a manner that it does not change the characteristics of the part prepared. Thus, the dimensions of the specimens shall provide an adequate machining allowance to permit removal of the zone affected by cutting.

Specimens shall not be machined or treated in any way that may alter their mechanical properties. Any straightening required shall be carried out with great care, preferably by hand.

4.6.1.2.5 Number of Specimens
Unless otherwise specified, the minimum number of specimens shall be as follows:

– for products having a nominal mass up to and including 1 kg per linear metre (1 kg/m), one specimen shall be taken for each lot of 1000 kg or part thereof;
– for products having a nominal mass greater than 1 kg/m up to and including 5 kg/m, one specimen shall be taken for each lot of 2000 kg or part thereof;
– for products having a nominal weight greater than 5 kg/m, one specimen shall be taken for each lot of 3000 kg or part thereof.

Not less than one representative specimen shall be taken from any given inspection or heat-treatment lot.

4.6.1.3 Test Pieces for Tensile Test

4.6.1.3.1 Identification of Test Pieces

Each test piece shall be marked in such a manner that it is possible to identify the inspection lot from which it was taken and, if required, its location and orientation in the product.

If a test piece is marked by stamping, this shall not be in a place or manner that may interfere with subsequent testing.

Where it is not convenient to mark a test piece, an identification tag may be attached. Alternative methods, such as specially designed boxes, may be used for the purpose of test piece identification.

4.6.1.3.2 Machining

Any machining necessary shall be carried out in such a manner that it does not change the characteristics of the metal in the test piece.

4.6.1.3.3 Number of Test Pieces

One test piece shall be taken from each specimen.

The recommended shapes and dimensions for test pieces are specified in ISO 6892-1.

4.6.1.3.4 Type and Location of Test Pieces

The type of test pieces shall follow table 4.12.

The location of test pieces shall be agreed upon between the supplier and the purchaser.

Tab. 4.12 – Type of test pieces. Unit: mm.

Wall thickness t	Type of test pieces
$t \leq 12.5$	Use a rectangular test piece
$t > 40$	Use a round standard 10 mm diameter test piece

Note: The test piece shall be prepared such that the fabricated surface is preserved without modification.

4.6.2 Test Methods

4.6.2.1 Chemical Composition

The determination of the chemical composition of alloys given in tables 4.2 and 4.3 shall be performed in accordance with relevant International Standards, or other standards as agreed between the supplier and the customer.

4.6.2.2 Tensile Test

Tensile tests shall be carried out in accordance with ISO 6892-1.

4.6.2.3 Surface Finish

Unless otherwise specified, examination of surface appearance shall be carried out, without the assistance of magnifying apparatus, on products before delivery.

For products intended to be anodized, it is recommended that an anodizability test be carried out by the producer on the products before delivery. The frequency and the conditions of the test may be agreed upon between the producer and customer.

4.6.2.4 Additional Tests

If any other tests are required, they shall be agreed upon between the supplier and purchaser. These tests shall be carried out in accordance with the relevant International Standards or a method agreed between the supplier and purchaser.

4.6.3 Retests

4.6.3.1 Mechanical Properties

If any one of the test pieces first selected fails to meet the requirements for the mechanical tests, the following procedure shall be applied:

— if an error is clearly identified, either in the test piece preparation or the test procedure, then the corresponding result shall be disregarded and the testing recommended as initially required;
— if this is not the case, then two further specimens shall be taken from the same inspection lot, one being from the same unit of product from which the original specimen was taken, unless that unit of product has been withdrawn by the supplier. If both test pieces from these additional specimens meet the requirements, the inspection lot that they represent shall be deemed to comply with the requirements of this International Standard.

Should one test piece fail to meet the required limits:
— the inspection lot shall be deemed not to comply with the requirements of this International Standard;
— or, where applicable, the lot may be submitted to additional mechanical or thermal treatment(s) and then retested as a new lot.

4.6.3.2 Other Properties

The retest procedure of other properties shall be agreed upon between the supplier and purchaser.

4.7 Inspection Documents

4.7.1 General

When requested by the purchaser and agreed upon by the supplier, the supplier shall provide the appropriate inspection documents.

The following documents shall be established based on inspections and tests performed by qualified personnel involved in the manufacturing process and/or belonging to the quality control department.

4.7.2 Certificate of Conformity

The certificate of conformity is a document by which the producer certifies that, according to inspections and results of representative tests, the products for delivery comply with the relevant International Standards and with the additional requirements in the order.

4.7.3 Test Report

The test report is a document by which the producer certifies that the products for delivery comply with the requirements specified in the order.

The document details the results of the current production controls carried out on identical products made using the same methods as the products for delivery, but not necessarily on the products for delivery themselves.

The test report shall include:

(a) the sample;
(b) the International Standard used (including its year of publication);
(c) the method used;
(d) the result(s), including a reference to the clause which explains how the results were calculated;
(e) any unusual features observed;
(f) the date of the test.

4.8 Marking

Marking of products is only undertaken when agreed upon between the supplier and purchaser and stated in the order. This marking shall not adversely affect the final use of the product.

4.9 Packing

Unless otherwise specified in International Standards relating to special products or specified in the order, the method of packing shall be determined by the supplier who shall take all suitable precautions to ensure that, under the usual conditions of transportation, the products are delivered in a condition suitable for use.

4.10 Transportation and Storage

During transportation, all the products shall be kept clean, dry, and away from contamination. Rain and snow shall be kept off to prevent erosion of the packing case. Chemically active substances, dampened materials, or inflammable substancse shall not be. Loading and unloading should be done with caution to avoid damage to the packing.

Immediately after receiving, the products should be preserved in a dry and clean environment, which is free of corrosive gas, chemically active substances, dampened materials, and inflammable substances, and sheltered from rain and snow. Inspection for the erosion should be done within 10 days.

4.11 Arbitration Tests

In cases of dispute concerning conformity with the requirement of this International Standard or specification cited in the order, testing shall be carried out by an arbitrator chosen by mutual agreement between the supplier and purchaser.

The arbitrator's decision shall be final.

Bibliography

[1] ISO 3116, *Magnesium and magnesium alloys — Wrought magnesium and magnesium alloys.*
[2] ISO 6892-1, *Metallic materials—Tensile testing — Part 1: Method of test at room temperature.*

Chapter 5

Magnesium and Magnesium Alloys – Soluble Magnesium Alloy Materials for Downhole Tools

5.1 Scope

This standard specifies the requirements, test methods, inspection rules, as well as marking, packaging, transportation, storage, quality certification, and order contract (or purchase contract) content for magnesium and magnesium alloys, soluble magnesium alloy materials used in downhole tools.

This standard applies to cast or extruded rod materials of soluble magnesium alloys for petroleum and natural gas industry downhole tools (*e.g.*, fracturing balls, bridge plugs, etc.).

5.2 Normative References

The following documents are essential for the application of this document. For dated references, only the dated versions apply. For undated references, the latest versions (including all amendments) apply.
ISO 6892-1, Metallic materials — Tensile testing — Part 1: Method of test at room temperature
ISO 16220:2017, Magnesium and magnesium alloys-Magnesium alloy ingots and castings
ISO 8287-2021, Magnesium and magnesium alloys — Unalloyed magnesium — Chemical composition
GB/T 20967, Non-destructive testing – Visual testing – General principles
GB/T 32792, Packing, marking, transporting, and storing of magnesium alloy wrought products
GB/T6519-2013, Ultrasonic inspection of wrought aluminium and magnesium alloy products
GB/T 4297, Inspection method for macrostructure of wrought magnesium alloy products
GB/T37596-2019, Magnesium alloy forgings for aerospace

5.3 Terms and Definitions

Soluble magnesium alloy materials for downhole tools refer to cast or extruded rod materials used in the fabrication of petroleum and natural gas industry downhole tools, which exhibit a tensile strength of no less than 150 MPa and a dissolution rate of at least 5 $mg\cdot cm^{-2}\cdot h^{-1}$ in a 93 °C 3% KCl solution.

5.4 Requirements

5.4.1 Designation

5.4.1.1 Alloy Grades and Conditions

The grade and conditions of soluble magnesium alloy materials shall conform to the requirements specified in table 5.1. When the purchaser requires other grades or conditions, such specifications shall be negotiated and agreed upon between the supplier and purchaser, and explicitly stated in the order contract (or procurement contract).

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TAB. 5.1 – Alloy grades and conditions.

Alloy Grade	Condition
IMS-WN54M	H112
IMS-VW84N	H112
IMS-VN21 M	Cast
IMS-WC54M	H112
IMS-WN74M	H112
IMS-ZN42	H112
IMS-AZ911M	T6
IMS-CN41M	Cast

5.4.1.2 Product Marking

The designation of soluble magnesium alloy materials shall be expressed in the sequence of product name, standard number, grade, conditions, and specifications. Example designations are as follows:

Example 1:
Extruded rod material with grade IMS-WN54M, H112 conditions, diameter 40 mm, and length 3500 mm shall be designated as:
Extruded Rod IMSxxxx-IMS-WN54M H112-Φ40×3500

Example 2:
Cast rod material with grade VN21M, as-cast conditions, diameter 300 mm, and length 1000 mm shall be designated as:
Cast Rod IMSxxxx-IMS-VN21M-Φ300 × 1000

5.4.2 Quality Control

Ingots used for the production of soluble magnesium alloy materials shall meet the chemical composition and macrostructure requirements specified in this standard. Other quality requirements for the ingots shall comply with the provisions of ISO 16220:2017.

5.4.3 Chemical Composition

The chemical composition of the grades of soluble magnesium alloy materials shall conform to the requirements specified in table 5.2.

5.4.4 Room-Temperature Tensile Mechanical Properties

The room temperature longitudinal tensile mechanical properties of soluble magnesium alloy materials shall conform to the requirements specified in table 5.3. Where the properties exceed those specified in table 5.3, they shall be mutually agreed upon by the supplier and purchaser and clearly stated in the purchase order (or contract).

5.4.5 Dissolution Rate

The dissolution rate of soluble magnesium alloy materials shall conform to the requirements specified in table 5.4. Where the dissolution rate exceeds that specified in table 5.4, it shall be mutually agreed upon by the supplier and purchaser and clearly stated in the purchase order (or contract).

5.4.6 Macrostructure

5.4.6.1 Ingot Macrostructure

Macrostructure specimens of ingots for soluble magnesium alloy production shall not permit defects that disrupt metallic continuity, including cracks, inclusions (containing flux slag), gas pores, primary crystal segregation, pipe shrinkage, or coarse grain rings.

Tab. 5.2 – Chemical composition.

Element	Grade	Chemical composition[a] (wt.%)														
		Mg	Al	Zn	Mn	RE	Zr	Y	Gd	Ca	Si	Fe	Cu	Ni	Other elements[b]	
															Individual	Total
MgYNi	IMS-WN54M	Rem	—	—	—	—	—	4.5 ~ 6.0	—	—	0.05	0.01	0.02	3.5 ~ 5.0	0.02	0.2
MgGdYNiMn	IMS-VW84N	Rem	—	—	0.6 ~ 1.0	—	—	3.5 ~ 5.0	7.9 ~ 9.0	—	0.05	0.01	0.02	1.0 ~ 3.0	0.02	0.2
MgGdNi	IMS-VN21 M	Rem	—	—	—	—	—	—	1.2 ~ 3.0	—	0.05	0.01	0.02	0.4 ~ 1.0	0.02	0.2
MgYCu	IMS-WC54M	Rem	—	—	—	—	—	4.5 ~ 5.0	—	—	0.02	0.02	3.5 ~ 4.8	0.05	0.01	0.1
MgYNiZrCa	IMS-WN74M	Rem	—	—	—	—	0.1 ~ 0.5	6.2 ~ 7.2	—	0.1 ~ 0.5	0.02	0.01	0.02	3.8 ~ 4.8	0.02	0.2
MgZnNi	IMS-ZN42	Rem	—	3.5 ~ 4.5	—	—	—	—	—	—	0.02	0.02	0.01	1.5 ~ 2.5	0.02	0.3
MgAlZnCuNiMn	IMS-AZ911M	Rem	9.0 ~ 10.0	1.0 ~ 2.0	0.1 ~ 1.0	—	—	—	—	—	0.05	0.01	1.0 ~ 2.0	0.3 ~ 0.5	0.01	0.1
MgCuNi	IMS-CN41M	Rem	—	—	—	—	—	—	—	—	0.02	0.02	3.5 ~ 4.5	0.5 ~ 1.0	0.02	0.2

[a]When a single value is specified for the mass fraction in the table, magnesium represents the minimum limit, while other elements represent the maximum limit.
[b]Other elements refer to those whose chemical symbols are listed in the table header, but for which no specified limit values are defined in this table.

Tab. 5.3 – Room-temperature tensile mechanical properties.

Alloy grade	Condition	Tensile strength *Rm* (MPa)	Proof strength *Rp*0.2 (MPa)	Elongation after fracture A (% %)
		No less than		
IMS-WN54M	H112	445	215	12
IMS-VW84N	H112	350	240	6
IMS-VN21 M	Cast	175	75	3
IMS-WC54M	H112	225	120	3
IMS-WN74M	H112	500	460	6
IMS-ZN42	H112	295	220	8
IMS-AZ911M	T6	360	260	4
IMS-CN41M	Cast	210	160	12

Tab. 5.4 – Degradation rate.

Alloy grade	Condition	Test temperature (°C)	Test medium	Dissolution rate $mg{\cdot}cm^{-2}{\cdot}h^{-1}$
				Not less than
IMS-WN54M	H112	93	3 wt.% KCl	60
IMS-VW84N	H112	93	3 wt.% KCl	20
IMS-VN21 M	Cast	93	3 wt.% KCl	14
IMS-WC54M	H112	93	3 wt.% KCl	21
IMS-WN74M	H112	93	3 wt.% KCl	14
IMS-ZN42	H112	93	3 wt.% KCl	36
IMS-AZ911M	T6	93	3 wt.% KCl	50
IMS-CN41M	Cast	93	3 wt.% KCl	80

5.4.6.2 Bar Macrostructure

Laps with depth not exceeding half of the diameter, negative deviation are permissible in macrostructure specimens of bars. For lap-free bars, requirements shall be mutually agreed upon by the supplier and purchaser and clearly stated in the purchase order (or contract).

5.4.6.3 Special Macrostructure Defects

If the purchaser requires specifications for macrostructure oxide films, metallic compounds, or manganese compounds, such requirements shall be mutually agreed upon and stated in the purchase order (or contract), and shall conform to section 3.6 of GB/T 37596-2019.

5.4.7 Ultrasound Flaw Detection

Ultrasonic testing of bars shall comply with Class A requirements specified in GB/T 6519-2013. If alternative testing classes are required, they shall be mutually agreed upon by the supplier and purchaser and explicitly stated in the purchase order (or contract).

5.4.8 Surface Quality

The surface of soluble magnesium alloy materials shall be clean and free from defects affecting serviceability, including cracks, corrosion, and embedded foreign matter. Surface defects with depth not exceeding the negative deviation–such as extrusion marks, compression marks, handling marks, blisters, scratches, protrusions, or depressions–are permissible.

5.5 Test Procedure

5.5.1 Chemical Composition

The chemical composition of soluble magnesium alloy materials shall be conducted in accordance with ISO 8287-2021.

5.5.2 Room-Temperature Tensile Mechanical Properties

The longitudinal room-temperature tensile mechanical properties test method of soluble magnesium alloy material is carried out according to the method specified in ISO 6892-1.

5.5.3 Dissolution Rate

Dissolution rate tests for soluble magnesium alloy materials are performed in accordance with the methods in the Appendix.

5.5.4 Macrostructure

Macrostructure testing of soluble magnesium alloy materials shall be performed according to the methods specified in GB/T 4297.

5.5.5 Ultrasound Flaw Detection

Ultrasonic test methods for rods are in accordance with the methods specified in GB/T 6519-2013.

5.5.6 Surface Quality

Soluble magnesium alloy material surface quality test according to the method specified in GB/T 20967.

5.6 Result Determination

5.6.1 Inspection and Acceptance

5.6.1.1 Supplier Inspection

Soluble magnesium alloy materials shall be inspected by the supplier to ensure that the quality of the materials conforms to the provisions of this standard and the order form (or contract), and the quality certificate shall be filled in.

5.6.1.2 Purchaser Inspection

The purchaser shall inspect the received products in accordance with this standard. If the inspection results do not comply with this standard and the order (or contract), the purchaser shall notify the supplier in writing, and the matter shall be resolved through consultation between the supplier and the purchaser. Objections regarding surface quality and dimensional tolerances shall be raised within one month of receipt of the product, while objections of other nature shall be raised within three months of receipt of the product. In case of arbitration, it shall be determined through consultation between the supplier and the purchaser.

5.6.2 Batch Formation

Soluble magnesium alloys shall be submitted for acceptance in batches. Each batch shall consist of products of the same grade, condition, specification, melt number, and heat treatment furnace, with no limit on batch weight.

5.6.3 Inspection Items

Before dispatch, each batch of soluble magnesium alloys shall be inspected for chemical composition, room-temperature tensile mechanical properties, degradation rate, macrostructure, ultrasound flaw detection, and surface quality.

5.6.4 Sampling

Sampling of soluble magnesium alloys shall comply with the provisions in table 5.5.

TAB. 5.5 – Sampling provisions.

Inspection item	Sampling provisions	Clause number for requirements	Clause number for test methods
Chemical composition	Sampling shall be conducted in accordance with ISO 8287-2021, with one sample taken per batch	4.3	5.1
Room-temperature tensile mechanical properties	Sampling shall be conducted at 10% of the batch quantity, but not less than 2 pieces. One specimen shall be cut from the front end of each selected soluble magnesium alloy material.	4.4	5.2
Dissolution rate	Sampling shall be conducted at 10% of the batch quantity, but not less than 2 pieces. One specimen shall be cut from the front end of each selected soluble magnesium alloy material.	4.5	5.3
Macrostructure	In the ingots used for the production of soluble magnesium alloy materials, 10% of the quantity of each batch, not less than 2 pieces of sampling, is extracted from each piece of the tail end of the cut 1 specimen	4.6	5.4
Ultrasound flaw detection	Each piece of soluble magnesium alloy material shall undergo 100% inspection prior to delivery.	4.7	5.5
Surface quality	Each piece of soluble magnesium alloy material shall undergo 100% inspection prior to delivery.	4.8	5.6

5.6.5 Judgment of Inspection Results

5.6.5.1 Chemical Composition Judgment

If the chemical composition of any specimen fails to meet the requirements, the entire batch shall be rejected.

5.6.5.2 Mechanical Properties Judgment

When the mechanical properties of any specimen are unsatisfactory, double the number of specimens shall be retested from the same batch. The batch shall be accepted only if all retested specimens meet the requirements. If any specimen fails during retesting, the batch shall be rejected.

5.6.5.3 Dissolution Rate Judgment

If the dissolution rate of any specimen is unsatisfactory, double the number of specimens shall be retested. The batch shall be accepted if all retested specimens comply; otherwise, the batch shall be rejected.

5.6.5.4 Macrostructure Judgment

When any specimen fails in macrostructure, it is determined as follows:

(a) When failing due to cracks, oxide film, metallic compounds, and manganese compound segregation, the lot shall be rejected.
(b) Failure due to shrinkage tail, coarse crystal ring, bright ring, into the layer, allowed to unqualified bar cut off a certain length and repeat the test, until qualified.

(c) The rest of the bar or piece-by-piece inspection, qualified delivery; or, according to the maximum cut tail length of the bar, retested to qualified cut tail delivery.
(d) When there are other defects, the batch of bars shall be dealt with by negotiation between the supply and demand sides.

5.6.5.5 Surface Quality Judgment

If the surface quality is non-compliant, the piece shall be rejected.

5.6.5.6 Ultrasonic Testing Judgment

If the ultrasonic inspection fails, the piece shall be rejected.

5.7 Marking, Packing, Transportation, and Storage

5.7.1 Marking

5.7.1.1 Marking

The following marks shall be applied to the front end of qualified soluble magnesium alloy products:

(a) Grade;
(b) Conditions;
(c) Specification;
(d) Batch number.

5.7.1.2 Packaging Markings

Soluble magnesium alloy material box marking should be consistent with the provisions of GB/T 32792.

5.7.2 Packaging, Transportation, and Storage

5.7.2.1 Packaging Requirements

Soluble magnesium alloys shall be packaged with oil coating. Special requirements, if any, shall be agreed upon by the supplier and the purchaser and noted in the order (or contract).

5.7.2.2 Other Requirements

Soluble magnesium alloy material packaging, transportation, and storage of other requirements should be consistent with the provisions of GB/T 32792.

5.7.3 Quality Certificate

Each batch of soluble magnesium alloy material shall be accompanied by a product quality certificate stating:

(a) Name, address, telephone number, and fax number of the supplier;
(b) Product name;
(c) Grade number;
(d) Conditions;
(e) Specification and accuracy level;
(f) Lot number;
(g) Net weight and number of pieces;
(h) the test results of the various analytical items;
(i) This standard number;
(j) Factory date (or packaging date).

5.8 Orders or Tenders

Orders (or contracts) for products listed in this standard shall include the following information:

(a) Product name;
(b) Grade number;
(c) Conditions;
(d) Dimensions and tolerances;
(e) Net weight or quantity;
(f) Special requirements of the purchaser:
— Special dimensional tolerance requirements;
— Special tensile mechanical property requirements;
— Special packaging requirements;
— Other special requirements;
(g) The number of this standard;
(h) Others.

Appendix

(Normative)

Determination of Dissolution Rate by Weight Loss Method

A.1 Scope

This appendix provides a method for the determination of the dissolution rate of soluble magnesium alloy materials, which is also applicable to the determination of industrial dissolution rates for dissolution purposes.

A.2 Reagents

A KCl solution with a mass fraction of 3%.

A.3 Equipment

Water bath device, temperature control accuracy ≤±1 °C.

A.4 Sample Preparation

Each specimen shall be individually placed in a glass container of sufficient size to ensure the reagent fully submerges the specimen. The ratio of reagent volume (cm^3) to the exposed surface area (cm^2) of the specimen shall be no less than 40:1. The specimen shall not contact the glass surfaces, except at line or point contact positions used to secure the specimen.

A.5 Immersion Test Procedure

First, weigh the specimen with an accuracy of 1 mg and measure its exposed surface area. Heat the reagent in the thermostatic bath to 93 ± 1 °C, then immerse the specimen in the reagent and seal the test chamber of the bath apparatus to prevent reagent evaporation. Maintain the temperature at 93 ± 1 °C throughout the test. At 1-h intervals, remove the specimen, dry it, reweigh it, and re-measure its surface area. Repeat this process for 4–10 cycles, calculating the single-cycle dissolution rate (mass loss per unit surface area per hour) after each cycle. The test is terminated when the difference between two consecutive dissolution rates is less than 10% (relative to the prior rate), indicating stabilization. Finally, report the average of the last two dissolution rates as the material's stable dissolution rate.

A.6 Result Calculation

The dissolution rate is obtained using the following formula:

$$W = \Delta m/(S_{\text{avg}} \cdot T)$$

W is the dissolution rate, in units of mg·cm^2·h;
Δm is the mass loss between two consecutive measurements, in units of mg;
S_{avg} is the average surface area between two consecutive measurements, in units of cm^2;
T is the time interval between two consecutive measurements, in units of h; The dissolution rate for each individual cycle is calculated based on a 1 h interval.

A.7 Test Report

The test report shall at least include:

(a) Detailed description of the specimen, including chemical composition, alloy grade, etc.
(b) Reagent type and concentration, test temperature;
(c) Measurement results, including the mass of the sample before and after dissolution, dissolution time, contact area with the test solution, and dissolution rate;
(d) Name of the person who made the determination;
(e) Date of determination;
(f) Signature of the person making the determination.

Chapter 6

Magnesium and Magnesium Alloys – Technical Specifications for Chemical Conversion Coatings of Magnesium Alloy Die Castings

6.1 Scope

This standard specifies the classification, requirements, and test methods for chemical conversion coatings on magnesium alloy die castings.

It applies to chemical conversion coatings formed on magnesium alloy die castings. These coatings may serve as stand-alone corrosion protection coatings or function as pre-treatments for organic coatings.

The chemical conversion coatings of other types of magnesium components can refer to this document.

6.2 Normative References

The following documents contain provisions, which through normative reference in this text, constitute indispensable clauses of this document. For dated references, only the edition corresponding to that date applies to this document. For undated references, the latest edition (including all amendments) applies.

ISO 1463 *Metallic and oxide coatings — Measurement of coating thickness — Microscopical method*
ISO 2409 *Paints and varnishes — Cross-cut test*
ISO 2810 *Paints and varnishes — Natural weathering of coatings — Exposure and assessment*
ISO 2812-1 *Paints and varnishes — Determination of resistance to liquids — Part 1: Immersion in liquids other than water*
ISO 2813 *Paints and varnishes — Determination of gloss value at 20°, 60° and 85°*
ISO 3497 *Metallic coatings — Measurement of coating thickness — X-ray spectrometric methods*
ISO 3892 *Conversion coatings on metallic materials — Determination of coating mass per unit area — Gravimetric methods*
ISO 4519 *Electrodeposited metallic coatings and related finishes — Sampling procedures for inspection by attributes*
ISO 7784-2 *Paints and varnishes — Determination of resistance to abrasion — Part 2: Method with abrasive rubber wheels and rotating test specimen*
ISO 8296 *Plastics — Film and sheeting — Determination of wetting tension*
ISO 9227 *Corrosion tests in artificial atmospheres — Salt spray tests*
ISO 10289 *Methods for corrosion testing of metallic with metallic and other inorganic coatings on metallic substrates — Rating of test specimens and manufactured articles subjected to corrosion tests*
ISO 10993-5 *Biological evaluation of medical devices — Part 5 — Tests for in vitro cytotoxicity*
ISO 15091 *Paints and varnishes — Determination of electrical conductivity and resistance*
ISO 15184 *Paints and varnishes — Determination of film hardness by pencil test*
ISO 16220 *Magnesium and magnesium alloys — Magnesium alloy ingots and castings*
ASTM D4935-18 *Standard test method for measuring the electromagnetic shielding effectiveness of planar materials*
ASTM E1461-13 *Standard test method for thermal diffusivity by the flash method*
IMS 001 *Magnesium and magnesium alloys — Terms and definitions of surface treatment*

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6.3 Terms and Definitions

For the purposes of this document, terms and definitions in IMS 001 and the following shall apply.

6.3.1 Acid Activation

Acid activation is the process of removing oxides or other compounds from magnesium alloy surfaces through chemical action in acid solutions.

6.3.2 Alkaline Cleaning

Alkaline cleaning is the process of removing greases or neutralizing acid-activated corrosion products generated in alkaline solutions from the magnesium alloy surfaces.

6.3.3 Acid Etching

Acid etching is the process of removing mould release agents on magnesium alloy surfaces left during die-casting with acidic solutions.

6.3.4 Bleaching

Bleaching is the process of using an alkaline solution to dissolve the black oxide film formed after acid etching of magnesium alloys and restore the base metal appearance.

6.4 Classification

Chemical conversion coatings can be divided into three major categories based on functions:
Type I: Stand-alone corrosion protection coatings;
Type II: Pre-coatings.

6.5 Performances

The performance of chemical conversion coatings shall be in accordance with table 6.1.

TAB. 6.1 – Performances and requirements.

Number	Performances	Requirements	
		Type I	Type II
1	Adhesion	Grade 0	
2	Appearance	Subject to mutual agreement	
3	Corrosion resistance	48 h Grade 8	/
4	Abrasion resistance	Determined through negotiation between the supply and the demand	
5	Biocompatibility		
6	Contact resistance		
7	Chemical resistance		
8	Electromagnetic shielding		
9	Gloss		
10	Hardness		
12	Thermal conductivity		
13	Thermal control performance		
14	Thickness		
15	Weatherability		
16	Wetting tension	/	>40 mN/m.

6.6 Quality Assurance Provisions

6.6.1 Surface Pre-Treatment

6.6.1.1 Substrate Requirements

All magnesium alloy die castings can undergo chemical conversion coating treatment, provided that their composition and properties comply with the requirements specified in ISO 16220.

Unless otherwise specified, chemical conversion treatment of magnesium alloy die castings shall be performed after completion of all manufacturing and thermal processing operations (*e.g.*, forming, machining, heat treatment, and welding).

6.6.1.2 Process Flows

Two process flows shown in figure 6.1 may be used, or the sequence can be adjusted based on factory conditions. However, the following rules shall apply:

(1) After acid activation, alkaline cleaning shall be performed;
(2) After acid etching, bleaching treatment shall be applied;
(3) Rinsing by deionized water (<100 μS/cm conductivity) shall be performed between two processing steps.

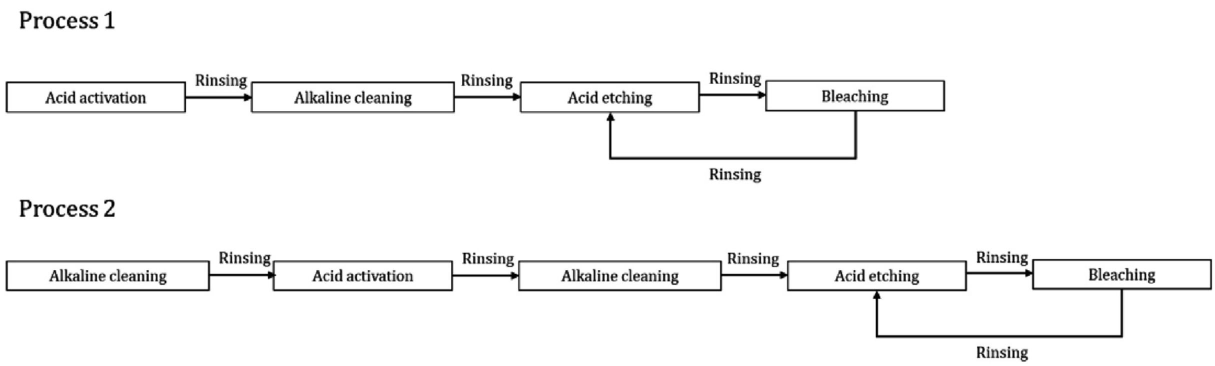

Fig. 6.1 – Process flows.

6.6.1.3 Pre-Treatment Process and Requirements

Pre-treated castings shall satisfy the following requirements:

(1) Alkaline cleaning

Alkaline cleaning can be performed using the methods specified in table 6.2.
Compressed air or an ultrasonic bath can be introduced to agitate the solution.

Tab. 6.2 – Alkaline cleaning solution and operating process.

Bath composition		Temperature, °C	pH	Cleaning time, s
Components	Content, wt.%	50–60	13–14	180–300
NaOH	5–10			
$Na_2SiO_3{\cdot}5H_2O$	3–8			
Emulsifier	5–8			
Deionized water	Balance			

(2) Acid activation

Acid activation can be performed using the methods specified in table 6.3.

Tab. 6.3 – Acid activation solution and operating process.

Bath composition		Temperature, °C	pH	Cleaning time, s
Components	Content, wt.%	20–40	0–1	30–90
NH_4HF_2	5–15			
H_3PO_4	2–5			
Deionized water	Balance			

(3) Acid etching

Acid etching can be performed using the methods specified in table 6.4.

Tab. 6.4 – Acid etching solution and operating process.

Bath composition		Temperature, °C	pH	Cleaning time, s
Components	Content, wt.%	50–60	2.5–3.5	90–150
$C_6H_8O_7$	5–10			
$C_4H_6O_5$	5–10			
Deionized water	Balance			

(4) Bleaching

Bleaching can be performed using the methods specified in table 6.5.

Tab. 6.5 – Bleaching solution and operating process.

Bath composition		Temperature, °C	pH	Cleaning time, s
Components	Content, wt.%	70–80	13–14	180–300
KOH	5–15			
$Na_3C_6H_5O_7{\cdot}2H_2O$	2–5			
Deionized water	Balance			

6.6.2 Chemical Conversion Treatment

6.6.2.1 Conversion Solutions

The conversion solutions typically contain primary salts, complexing agents, and additives.

The components can be treated by the methods listed in table 6.6.

The solution shall show no turbidity or insoluble precipitates. It shall be maintained per specifications with timely replacement of depleted baths.

Tab. 6.6 – Chemical conversion solutions and operating process.

Mass concentration and process conditions		Method 1	Method 2	Method 3
Concentration, g/L	Na_2HPO_4	20	–	–
	H_3PO_4, ml/L	7.4	50	–
	$NaNO_2$	3	–	–
	$NaNO_3$	1.84	2	–
	$Zn(NO_3)_2$	5	–	–
	NaF	1	–	–
	CaH_2PO_4	–	100	–
	$KMnO_4$	–	–	40
	KH_2PO_4	–	–	150
Process conditions	Temperature, °C	40–50	20–40	40–70
	pH	3.0–4.0	2.0–3.0	4.0–5.5
	Time, s	180–300	30–60	300–600

6.6.2.2 Application Methods

Immersion is generally used, while spray application, brushing, roll-coating, or swabbing are also allowed.

6.6.2.3 Sealing

Sealing treatment (inorganic or organic sealing) is necessary for type I, while optional for type II.

Inorganic sealing should be performed when low electrical resistance is required for the components.

The solutions and conditions for inorganic sealing are listed in table 6.7.

Sealants used for organic sealing include acrylic resin, epoxy resin, polyurethane resin, silicone, and waxes.

Tab. 6.7 – Inorganic sealing solution and operating process.

Mass concentration and process conditions		Method 4	Method 5
Concentration, g/L	Na_2SiO_4	20	–
	NH_4VO_3	–	10–30
	NaOH	1–3	–
Process conditions	Temperature, °C	50–70	45–60
	pH	13–14	6.5–7.5
	Time, min	10–20	3–5

6.6.2.4 Rinsing

Conversion coatings shall be rinsed with deionized water. Hot water rinsing is recommended to remove residual contaminants.

6.6.2.5 Drying

Coatings shall be dried immediately after rinsing. Drying temperature should be between 100 and 150 °C, and drying time between 20 and 30 min.

All relevant tests shall be conducted after the drying process.

6.7 Testing Methods

6.7.1 Alternative Specimens

When actual conversion-coated components are unsuitable for testing or cannot be submitted for destructive tests due to low quantity or high value, alternative specimens may be used to measure the adhesion, corrosion resistance, and other properties.

Specimens shall share identical alloy composition and surface condition with represented components, and undergo conversion treatment simultaneously with production parts.

The demander shall specify specimen usage methodology, including quantity, material, geometry, and dimensions.

6.7.2 Adhesion

Coatings shall adhere firmly to the substrate without powdery residue. Unless otherwise specified, paint film adhesion over conversion coatings shall be tested in accordance with ISO 2409. A cross-cut test on a flat surface of the die casting shall be conducted to assess the adhesion. If no suitable area exists on the casting itself, substitute test specimens should be prepared. Three different measurement locations shall be selected on the specimen, with both the distance between adjacent measurement points and the distance from any measurement point to the specimen edge being ≥5 mm.

6.7.3 Appearance

When examined without magnification, conversion coatings on critical surfaces shall be uniform and free from: roughness, powdering, sagging, blisters, inclusions, depressions, dark spots, pinholes, scratches, abrasions, or any substrate-exposing damage.

The coating colour may range from transparent, light gold, iridescent, grey-white to black when examined under unaided or corrected vision. Colour requirements shall be determined using reference specimens.

6.7.4 Corrosion Resistance

Corrosion resistance shall be evaluated by neutral salt spray (NSS) testing in accordance with ISO 9227. The tested specimens shall be rated in accordance with ISO 10289.

The type, quantity, shape, and dimensions of test specimens shall be selected in accordance with the relevant specifications of the material or product under evaluation. In the absence of such specifications, these parameters may be mutually agreed upon by the concerned parties. Unless otherwise stipulated or agreed, test specimens shall be processed into 150 mm × 100 mm × 1 mm.

Where no alternative requirements exist, specimens shall be cleaned before testing. Abrasives or solvents that may corrode the specimen surface shall not be used during cleaning. Post-cleaning specimens shall be protected against recontamination.

If specimens are sectioned from components, the adjacent coatings near the cut area shall remain undamaged. Unless otherwise specified, cut edges shall be protected using appropriate protective coatings such as paint, paraffin, and adhesive tape.

6.7.5 Abrasion Resistance

Abrasion resistance testing shall be in accordance with ISO 7784-2 or subject to mutual agreement.

6.7.6 Biocompatibility

Biocompatibility testing shall be in accordance with ISO 10993-5 or subject to mutual agreement.

6.7.7 Contact Resistance

Contact resistance testing shall be in accordance with ISO 7784-2 or subject to mutual agreement.

6.7.8 Chemical Resistance

Chemical resistance testing shall be in accordance with ISO 2812-1 or subject to mutual agreement.

6.7.9 Electromagnetic Shielding

Electromagnetic shielding testing shall be in accordance with ASTM D4935 or subject to mutual agreement.

6.7.10 Gloss

Gloss testing shall be in accordance with ISO 2813 or subject to mutual agreement.

6.7.11 Hardness

Hardness testing shall be in accordance with ISO 15184 or subject to mutual agreement.

6.7.12 Thermal Conductivity

Thermal conductivity testing shall be in accordance with ISO 22007-2 or subject to mutual agreement.

6.7.13 Thermal Control Performance

Thermal control performance testing shall be in accordance with ASTM E1461 or subject to mutual agreement.

6.7.14 Thickness

Thickness testing shall be in accordance with ISO 1463/ISO 3497 or subject to mutual agreement.

6.7.15 Weatherability

Weatherability testing shall be in accordance with ISO 2810 or subject to mutual agreement.

6.7.16 Wetting Tension

Wetting tension testing shall be in accordance with ISO 8296 or subject to mutual agreement.

6.8 Acceptance Rules

6.8.1 Inspection and Acceptance

The supplier shall inspect the specimens for compliance with this document and the purchase order.

The demander may inspect received products against this document and the purchase order. If results are non-compliant, both parties shall resolve the matter through negotiation.

6.8.2 Testing Lot

Products shall be inspected in lots. Each lot consists of all parts processed simultaneously in the same bath.

6.8.3 Performance Testing and Sampling

The performance testing and sampling requirements shall be in accordance with table 6.8.

Tab. 6.8 – Performance testing and sampling.

Necessity	Performances	Sampling size	Performance requirements	Testing method
Mandatory	Appearance	Piece-by-piece inspection	See table 6.1	See 6.7.3
	Adhesion	Randomly select 3–5 specimens or subject to mutual agreement		See 6.7.2
	Corrosion resistance			See 6.7.4
Non-mandatory	Abrasion resistance			See 6.7.5
	Biocompatibility			See 6.7.6
	Contact resistance			See 6.7.7
	Chemical resistance			See 6.7.8
	Electromagnetic shielding			See 6.7.9
	Gloss			See 6.7.10
	Hardness			See 6.7.11
	Thermal conductivity			See 6.7.12
	Thermal control performance			See 6.7.13
	Thickness			See 6.7.14
	Weatherability			See 6.7.15
	Wetting tension			See 6.7.16

6.8.4 Passing Criteria

If any specimen fails the appearance check, the whole lot shall be rejected. Conforming items may be delivered after individual inspection.

If any specimen fails adhesion or corrosion tests, the whole lot shall be rejected.

The passing criteria for non-mandatory performances shall be subject to mutual agreement.

6.9 Packaging and Storage

6.9.1 Packaging

Coated parts shall be packaged to ensure that the parts are protected during shipment and storage against damage due to mishandling, exposure to the weather, or any hazard.

6.9.2 Storage

Coated parts shall be stored in accordance with the following requirements:

(1) Storage in a low-humidity environment (RH ≤ 40%, 20–25 °C);
(2) Keep clear of fires, acids, alkalis, and strong oxidizers.