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characterizing the physical and chemical properties of electrical discharge machining graphite

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 2003

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CHARACTERIZING THE PHYSICAL AND CHEMICAL PROPERTIES OF ELECTRICAL DISCHARGE MACHINING GRAPHITE

Foreword

User needs have been considered in the development of this NEMA Standards Publication.

These NEMA Standards and Authorized Engineering Information for electrical discharge machining graphite were prepared by the Carbon Section of the National Electrical Manufacturers Association, and that Section will periodically review them for any revisions necessary to keep them up to date with advancing technology. Proposed revisions or comments are welcomed and should be submitted to:

Manager, Engineering Department
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, D.C. 20037

Scope

This Standards Publication defines those physical and chemical properties which are relevant to the material characterization of electrical discharge machining (EDM) graphite electrodes. No attempt is made to incorporate in these standards any application performance standards relative to EDM graphites.

It is the intent of this publication to provide both the users and producers of electric discharge machining (EDM) graphite with a common reference standard for the material characterization of this product.

The types of EDM electrode material included in these standards are:

(1) Electrographite consisting of substantially pure carbon that has been converted during manufacturing to artificial graphite.

(2) Electrographite as in (1) above, impregnated to modify the base material's physical or electrical properties, or both.

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Part 1
GENERAL

CB 2-1.01 DEFINITIONS

.01 Apparent Density.* The weight in air of a unit volume including both permeable and impermeable voids, present in the material at 25°C.

.02 Ash.† The residual product following oxidation of the base carbon as determined by prescribed methods.

.03 Carbon.† An element, atomic number 6 symbol C, molecular weight 12.01115, which exists in several allotropic forms.

.04 Electrical Discharge Machining. A metal removal process utilizing the energy of an electrical spark to remove material from a workpiece under controlled conditions.

.05 Electrical Resistivity.‡ That property of a material which determines its resistance to the flow of an electrical current.

.06 Electrode. The tool in the electrical discharge machining process. It must be made from an electrically conductive material.

.07 Flexural Strength.† A property of solid material that indicates its ability to withstand a flexural or transverse load.

.08 Grain Direction (Conventionally Molded Material)

(a) *With grain*—perpendicular to the direction of applied force.

(b) *Against grain*—parallel to the direction of applied force.

.09 Grain Direction (Extruded Material)

(a) *With grain*—in the direction of extrusion.

(b) *Against grain*—perpendicular to the direction of extrusion.

.10 Grain Direction (Isostatically Molded Material)

(a) *With grain*—the direction of the lowest linear thermal expansion.

(b) *Against grain*—the direction of the highest linear thermal expansion.

.11 Hardness.† The resistance of a material to deformation, particularly permanent deformation, indentation, or scratching.

.12 Linear Thermal Expansion.** The change in length per unit length resulting from a change in temperature of the material.

.13 Manufactured Graphite.† A bonded granular carbon body whose matrix has been subjected to a temperature typically in excess of 2400°C and whose matrix is thermally stable below that temperature.

.14 Material Grade Designation.† The designation given a material by a manufacturer such that it is always reproduced to the same specifications established by the manufacturer.

.15 Maximum Grain Size. The largest particle of the granular component as determined by its major dimension. In practice, commonly given by the nominal opening of the coarsest screen used to prepare the initial raw materials in making the product and through which substantially all initial raw material will pass, or other sophisticated measuring techniques, such as by Fisher subsieve, Coulter counter, etc.

.16 Metal Content. The weight percentage of intentionally added metallic constituents.

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CB 2-1.02 CLASSIFICATION OF GRAIN SIZE

Electrical discharge machining graphite material can be classified by grain size as follows:

Ultrafine (or micrograin graphite)—less than 10 microns maximum grain size.

Fine—maximum grain size between 10 and 100 microns.

Medium—maximum grain size greater than 100 microns.

The above classifications are commonly based on size measuring techniques of the initial raw materials. It should be noted that the measuring techniques involved are not applicable to the finished product.

Authorized Engineering Information 3-19-1980.

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* From ASTM C 559-69, *Test for Density in Air of Manufactured Carbon and Graphite Articles by Physical Measurement.* ††

† From ASTM C 709-77, *Definitions of Terms Relating to Manufactured Carbon and Graphite.* ††

‡ From ASTM C 611-69 (1976), *Test for Electrical Resistivity of Manufactured Carbon and Graphite Articles at Room Temperature.* ††

** From ASTM E 228-71 (1979), *Test for Linear Thermal Expansion of Rigid Solids with a Vitreous Silica Dilatometer.* ††

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CB 2-1.03 TEST PROCEDURES FOR MATERIAL PROPERTIES

The measurement and recording of the following information should sufficiently characterize an EDM graphite for quality control purposes. (These characteristics are not necessarily pertinent to electrode performance.)

Material grade designation
Grain direction (if known)
Flexural strength
Hardness
Electrical resistivity
Apparent density
Ash content
Metal content (for metal-impregnated EDM materials only)

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.01 Flexural Strength

The flexural strength shall be determined in accordance with ASTM C 651-70 (1977), *Test for Flexural Strength of Manufactured Carbon and Graphite Articles Using Four-Point Loading at Room Temperature,** or in accordance with the procedure specified in par. 4.7 of the *American National Standard for Brushes for Electrical Machines,* ANSI/NEMA Standards Pub. No. CB 1-1977.†

Test data derived from use of these test procedures shall identify the method used.

.02 Hardness—Nonmetal Impregnated Graphite

Nonmetal impregnated graphite shall be tested by either the scleroscope hardness method specified in par. 4.3 of CB 1-1977 or the indentation hardness method specified in par. 4.4 of CB 1. For metal-impregnated graphite, a hardness test is not meaningful.

Test data shall identify the method used.

.03 Electrical Resistivity.

The electrical resistivity of electrical discharge machining graphite shall be tested in accordance with the voltmeter-ammeter method specified in par. 4.5 of CB 1-1977.

.04 Density (Apparent)

Electrical discharge machining graphite shall be tested by using the immersion method specified in par. 4.11 of CB 1-1977, the oil-absorption method specified in par. 4.12 of CB 1, or the weight in air method given in ASTM C559-69.*

Test data shall identify the method used.

.05 Ash Content

Ash content shall be determined using the procedure specified in par. 4.16 of CB 1-1977.

.06 Metal Content

The weight percent of intentionally added metallic constituents shall be determined by the procedure shown in CB 1-1977, par. 4.16.4, modified to record the weight percent solubles in nitric acid and the metal content.

NEMA Standard 3-19-1980.

* Available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.
† Available from the National Electrical Manufacturers Association, 2101 L Street, N.W., Washington, D.C. 20037; or from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

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Part 2
GUIDANCE FOR MACHINING GRAPHITE AND IMPREGNATED GRAPHITE EDM ELECTRODES

Part 2 approved as Authorized Engineering Information 3-19-1980.

The following material is included for reference and general interest only. No representation is made as to its suitability in regard to any specific application.

CB 2-2.01 INTRODUCTION

The machining methods for specific graphite electrode materials may be furnished by the manufacturer of the material itself. Since graphite is machined quite differently from metals, a few pointers on the general machining of this material may be helpful.

As with other machining operations, much will depend upon the quantity of electrodes to be produced, and also whether the machining operation is on relatively large surfaces or small surfaces. Some specific comments related to these distinguishing factors will be mentioned later.

Whatever machining operations are used, the use of a dust extracting system of the industrial type is strongly recommended. If the dust is not properly extracted, it can interfere with proper close tolerance machining of the electrode.

In some cases, the machining can be carried out under water or other organic fluid, and in this case, the graphite sludge may be removed by filtration.

CB 2-2.02 GENERAL

In general, electrodes of simple shape are formed by common machines such as lathes, mills, grinders and drills. The power requirements for machining graphite are usually about half that required for steel. In all cases, the slides and other moving parts of the machine tool should be protected from the slightly abrasive graphite dust.

CB 2-2.03 TOOLS

It is suggested that where there are fairly large quantities of electrodes to be machined, the machine operator use tungsten carbide tipped or insert tools of a grade that would be suitable for cast iron for longer tool life. Where an EDM tool is in the form of a wheel, the shaping of the wheel can be done with high speed tool steels, or tools coated with tungsten carbide. Where large quantities of very precise electrodes are made, particularly where the graphite electrode material is hard or very dense, it is suggested that diamond wheels be used.

The following cutting angles are suggested:

Clearance—10-12°

Cutting—90°

Grinding wheels should have the following characteristics:*

Roughing—37C-36J - 5V

Finishing—37C-60J - 5V

Very fine finishing (high precision)—super porous grade 80K

CB 2-2.04 GENERAL HINTS ON THE MACHINING OF GRAPHITE

Graphite is mechanically strong and easy to machine, but is somewhat brittle due to its ceramic nature.

Two important rules should therefore be observed to obtain satisfactory results:

(1) Use good quality tools.

(2) The breaking strength of the graphite should not be exceeded.

With respect to this last point, it is recommended that the operator support the back face of the graphite from which the tools will emerge when drilling, turning, or milling.

When this method cannot be used, the first operation should be to machine about ¼ inch from the back face before starting the main operation from the front face. This effectively avoids break-out at edges.

* For explanation of grinding material grades refer to American National Standard B74.13-1970, *Markings for Identifying Grinding Wheels and Other Bonded Abrasives,* available from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

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CB 2-2.05 FIXING OR MOUNTING GRAPHITE ELECTRODES FOR USE IN EDM MACHINES

The following material is included for reference and general interest only. No representation is made as to its suitability in regard to any specific application.

Small precision electrodes can be held in clamps or special holders or may be glued to a flat plate, using an appropriate adhesive. The appropriate adhesive in this case should be one that when used as a thin film will allow the passage of current.

Blocks for large electrodes may be screwed to the baseplate of aluminum, steel, or plastic. When the electrode is made of several blocks, they should be bonded with an adhesive. Where electrodes are bonded to the base with a nonconductive cement layer, a separate electrical connection from the electrode to the base plate should be provided.

As a general rule, adhesive joints at right angles to the base plate may be electrically insulating without disturbing the passage of the electric current to the electrode, but adhesive joints parallel to the base should be either conductive or bypassed by a separate electrical connection.

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NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status are set forth in certain clauses of the NEMA Bylaws, which are quoted below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for its particular need. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

(Bylaw—Art. V, Sec. 1)

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Bylaw—Art. V, Sec. 2, Subsection A)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the standards publication may be capable of otherwise equivalent performance.

(NEMA Policy Memorandum 84-2, dated June 7, 1984)

Classes of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Bylaw—Art. V, Sec. 2, Subsection B)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design.

(Bylaw—Art. V, Sec. 6, 1st Sentence)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment and/or approval.

(Bylaw—Art. V, Sec. 4, Subsection A)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

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