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Standard for Coefficient of Friction Testing of Film-Insulated Magnet Wire

National Electrical Manufacturers Association

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Coefficient of Friction Testing of Film-Insulated Magnet Wire

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Foreword

NEMA MW 750-2020 was prepared by the NEMA Magnet Wire Technical Committee.

NEMA Magnet Wire publications are periodically reviewed by the NEMA Magnet Wire Section for revisions considered necessary to keep them current with technology changes. Proposed revisions should be submitted to:

NEMA Technical Operations Department
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The NEMA Magnet Wire Section approved this Standards publication. Approval of a Standard does not necessarily imply that all section Members voted affirmatively or participated in its development. At the time of approval, the Magnet Wire Section was composed of the following Members:

CONDUMEX—Mexico City, Mexico
Elektrisola, Inc.—Boscawen, NH
Essex Group, Inc.—Fort Wayne, IN
Magnekón—San Nicolas de los Garza, NL, Mexico
MWS Wire Industries—Westlake Village, CA
New England Wire Technologies Corporation—Lisbon, NH
Rea Magnet Wire Company, Inc.—Fort Wayne, IN
Rubadue Wire Company, Inc.—Loveland, CO
Virginia Insulated Products—Saltville, VA
Zeus Wire—Orangeburg, SC

Introduction

As magnet wire is transferred from its packaging to coils, the designed path takes the wire over, around, and through guides, blocks, corners, and so forth, all of which are intended to help place the wire at the designed location in the coil.

The force required to pull the wire through the designed winding path, exclusive of the bending force and between adjacent wires, is that which is necessary to overcome the friction developed between the magnet wire and the various surfaces that come in contact with the wire. This force is directly related to the surface characteristics of the film insulation, the contact surfaces, and the applied lubrication.

History

Various devices have been used to measure the coefficient of friction of magnet wire. Several were discussed in Paper #4 at the NEMA session of the 1971 Electrical/Electronic Insulation Conference.

In 1961, Parussel described a tester to measure the dynamic coefficient of friction of film insulated magnet wire. The design was subsequently standardized and incorporated in German Standards Institute (DIN) specifications. A tester similar to the Parussel design made by Excel Industries was later demonstrated to the NEMA Magnet Wire Technical Committee. At that time interest was expressed in redesigning the tester to simplify the operation.

In 1973, NEMA Engineering Bulletin No. 4 was developed by the NEMA Magnet Wire Section to describe the subject of dynamic coefficient of friction testing and provide a test method, including the final equipment description. Eventually, the original supplier of this equipment discontinued its interest in supplying equipment, and the Research Department at the Indiana Institute of Technology supplied a new design. In 1978, this test method was introduced for discussion at a meeting of the International Electrotechnical Commission (IEC) Technical Committee 55, *Winding Wires*.

One of the critical elements of the dynamic coefficient of friction test procedure was the selection of the surface that would be in contact with the wire specimen. Supplying and maintaining a prescribed steel surface ground to the applicable specifications was found to be cost-prohibitive. As a proposed solution, representatives from The Netherlands recommended the use of synthetic sapphire elements for the load block surface. Their experience indicated that these synthetic sapphires would provide excellent life at a low cost. The elements were subsequently adopted for the test surface.

Earlier versions of this dynamic coefficient of friction equipment used a dynamometer to measure the tangential force (F_d). Since the value on the dynamometer continually varies, it was necessary for the operator to estimate the average force that occurs during the test. More precision and accuracy are required so that the gage repeatability and reproducibility can be improved for this test. The dynamometer has been replaced with a force transducer selected for this work, which is a linear variable differential transformer (LVDT). The data is collected from the pressure transducer readout by a computer or microprocessor. Statistical analysis can be performed on this data set resulting in mean, min, max, and standard deviation.

Throughout this historical timeframe, there have been other methods used to characterize the coefficient of friction of magnet wire. In particular, static coefficient of friction testing methods have been used as they are more fundamental in terms of meeting the physical definition of the coefficient of friction between objects. IEC 60851 Annex B describes a static coefficient of friction test method using the inclined plane method. Static coefficient of friction can also be measured using a horizontal pull strip meter to obtain results. These alternative static C of F methods evaluate wire to wire contact and can also be used to measure the Static C of F of rectangular film insulated as well as round film insulated round magnet wire. Since Static C of F is still being used in the industry, the industry considered it appropriate that this AEI should also describe and discuss these alternative methods for obtaining the coefficient of friction of magnet wires.

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1 General

1.1 Scope

This document describes different methods and the equipment used for determining the coefficient of friction of film-insulated magnet wire.

1.2 Definitions

friction n: the resistance to relative motion between two bodies in contact

static friction (F_s): also known as limiting friction, the frictional force that is present and which must be overcome for a body to initiate movement against the surface of another body.

dynamic friction (F_d): the frictional force that is present and which must be overcome for a body to continue to be in motion against the surface of another body.

coefficient of friction (μ): the ratio of the force required to move one surface over another to the total force applied normal to those surfaces.

Static coefficient of friction (μ_s): the ratio of force required to move one surface over another to the force applied normal to those surfaces at the instant motion starts

kinetic or dynamic coefficient of friction (μ_d): the ratio of force required to move one surface over another to the force applied normal to those surfaces once the motion is in progress.

1.3 Explanation Of Friction

Friction is the resistance to motion existing when a solid object is moved tangentially over the surface of another solid object that it touches or when an attempt is made to produce such a motion. If a normal load (L) presses two surfaces together, a tangential force may be applied up to some limiting value X, and the surfaces will continue to remain at rest. Sliding only starts when the tangential force (X) exceeds the static force F_s. Almost as soon as the motion starts, the tangential force takes on a characteristic value F_d, which always acts in the direction opposite to the relative velocity of the surfaces. The value of F_s is often greater than F_d, but sometimes F_s equals F_d. The ratio F_s/L is the static coefficient of friction μ_s, while the ratio F_d/L is the dynamic coefficient of friction μ_d. The coefficients of friction are essentially a material property of the contacting surfaces and the contaminants and other films (such as lubricants) at their interface. The coefficients of friction are independent of the load and the contact area; the dynamic coefficient of friction is also independent of the sliding velocity. This last law does not apply when the presence of a lubricant creates viscous flow in the intermediate liquid layer. In this case, the dynamic coefficient of friction normally increases with increasing sliding velocity.