

JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS C 3216-3 : 2011

(JCMA)

**Winding wires—Test methods—
Part 3: Mechanical properties**

ICS 29.060.10

Reference number : JIS C 3216-3 : 2011 (E)

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Date of Establishment: 2011-03-22

Date of Public Notice in Official Gazette: 2011-03-22

Investigated by: Japanese Industrial Standards Committee
Standards Board

Technical Committee on Electricity Technology

JIS C 3216-3:2011, First English edition published in 2012-06

Translated and published by: Japanese Standards Association
4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440 JAPAN

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee according to the proposal for establishment of Japanese Industrial Standard submitted by the Japan Electric Wire & Cable Makers' Association (JCMA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law.

Consequently, **JIS C 3003:1999** and **JIS C 3006:1999** have been withdrawn and replaced with this Standard.

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Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public or utility model right. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public or utility model right.

This Standard has been established for the purpose of standardization of test methods of enamelled wires and fibre or paper insulated wires, and with the aim of harmonizing **JIS** test standards with relevant **IEC** standards. In deliberations carried out on harmonization of this Standard with **IEC** standard, however, it was anticipated that some of the changes from the conventionally applied **JIS** specifications, being so significant, would cause confusion in the market. Therefore, as a transitional measure, this Standard was decided to be established mainly as an **IEC** harmonized standard, but with **IEC** test specifications partially replaced with the conventional **JIS** test specifications. Establishment of this Standard is aimed at gaining consensus in the market in harmonization with the **IEC** standards. In the next revision of this Standard, efforts for a full harmonization will be made.

JIS C 3216 series consists of the following 6 parts under the general title “*Winding wires—Test methods*”:

Part 1: General

Part 2: Determination of dimensions

Part 3: Mechanical properties

Part 4: Chemical properties

Part 5: Electrical properties

Part 6: Thermal properties

Winding wires—Test methods— Part 3: Mechanical properties

Introduction

This Japanese Industrial Standard has been prepared based on the third edition of **IEC 60851-3** published in 2009. Some of the technical contents of the said International Standard, however, are modified in this Standard as a transitional measure until consensus of harmonization with **IEC** can be gained in the market.

The portions given continuous sidelines or dotted underlines are the matters in which the contents of the original International Standard have been modified. A list of modifications with the explanations is given in Annex JB. Annex JA contains matters which are not given in the corresponding International Standard.

The requirements are given in particular standards which cite this Standard.

1 Scope

This Standard specifies the methods of test for mechanical properties of enamelled copper wires, enamelled aluminium wires, fibre or paper insulated copper wires and fibre or paper insulated aluminium wires, that are used for winding wires.

The general notes on methods of test are given in **JIS C 3216-1**.

NOTE : The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

IEC 60851-3:2009 *Winding wires—Test methods—Part 3: Mechanical properties* (MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS C 3216-1 *Winding wires—Test methods—Part 1: General*

NOTE : Corresponding International Standard: IEC 60851-1 *Winding wires—Test methods—Part 1: General* (MOD)

JIS C 3216-2 *Winding wires—Test methods—Part 2: Determination of dimensions*

NOTE : Corresponding International Standard: IEC 60851-2:1996 *Winding wires—Test methods—Part 2: Determination of dimensions*, Amendment 1:1997 and Amendment 2:2003 (MOD)

JIS C 3216-5 *Winding wires—Test methods—Part 5: Electrical properties*

JIS K 7171 *Plastics—Determination of flexural properties*

NOTE : Corresponding International Standard: ISO 178:2001 *Plastics—Determination of flexural properties* and Amendment 1:2004 (IDT)

3 Elongation at fracture and tensile strength

3.1 Elongation at fracture

Elongation is the increase in length expressed as a percentage of the original length. A straight piece of wire specimen shall be elongated to the point of fracture of the conductor at a rate of $5 \text{ mm/s} \pm 1 \text{ mm/s}$ by means of an elongation test equipment or a tensile test equipment with a gauge length of between 200 mm and 250 mm. The linear increase at fracture shall be calculated as a percentage of the free measuring length. Three specimens shall be tested and the three single values of the elongation shall be reported. The mean value of the results represents the elongation at fracture.

3.2 Tensile strength

Tensile strength is the ratio of the force at fracture to initial cross-section. A straight piece of specimen wire shall be elongated to the point of fracture of the conductor at a rate of $5 \text{ mm/s} \pm 1 \text{ mm/s}$ by means of a tensile testing equipment with a free measuring length of between 200 mm and 250 mm and which records the force at fracture. Three specimens shall be tested. The initial cross-section and the three single values of the force at fracture shall be reported. The mean value of the ratio of the force at fracture and the initial cross-section represents the tensile strength.

4 Springiness

Springiness is expressed by the spring back angle of a helical coil (see 4.1), the spring elongation value (see 4.1A), or the spring back angle after bending (see 4.2).

The spring back method (see JA.4) may be applied upon agreement between the purchaser and the supplier.

4.1 Round wire with a nominal conductor diameter from 0.080 mm up to and including 1.600 mm (spring back angle of a helical coil)

4.1.1 Principle

A straight piece of specimen wire is wound five times around a mandrel with a diameter and under a tension applied to the specimen as specified in the particular standard. The reading of the angle by which the end of the five turns recoils is the measure of springiness.

4.1.2 Equipment

Figure 1 shows an example of the test equipment with details of the mandrel given in figure 2 and table 1. Figure 2 indicates a helical groove, which may be used to facilitate winding. The provision of this groove, however, is not mandatory. The dial is marked with 18 equally spaced divisions so that with five turns of the specimen the reading corresponds to the number of degrees that each turn springs back.

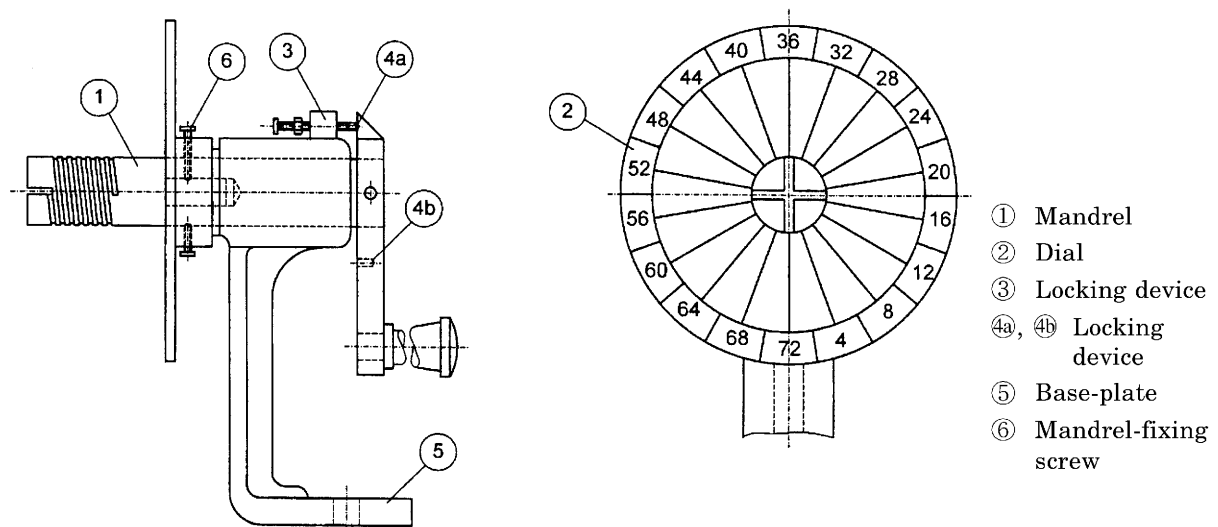


Figure 1 Test equipment to determine springiness

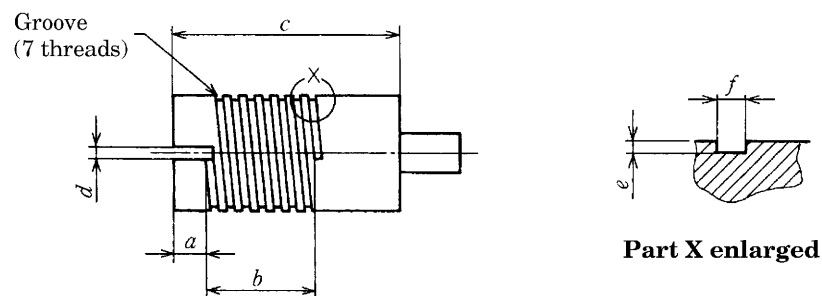


Figure 2 Mandrel

Table 1 Mandrel

Unit: mm

Mandrel diameter ^{a)}	Dimensions ^{b)}					
	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>
5	6.0	7.5	32	0.30	0.05	0.13
7	6.0	9.0	34	0.40	0.07	0.18
10	6.0	9.0	34	0.60	0.10	0.25
12.5	6.0	9.0	40	0.80	0.14	0.35
19	10.0	11.0	45	1.20	0.20	0.50
25	12.5	12.5	45	2.00	0.28	0.70
37.5	12.5	14.5	47	2.40	0.40	1.00
50	12.5	17.5	50	3.00	0.80	2.00

Notes ^{a)} At the bottom of the grove, if provided.
^{b)} See figure 2, in which *a*, *b*, *e* and *f* only apply to those with grooves.

4.1.3 Procedure

The specified mandrel shall be mounted and locked in position with its axis horizontal and with the slot or hole for fastening the specimen corresponding with the zero of the dial. The mandrel shall be dusted with powdered talc (French chalk) to prevent the specimen clinging to the mandrel. A tension shall be applied to a straight piece of specimen wire approximately 1 m in length by attaching the specified load to one end of the specimen. The handle to rotate the mandrel shall be unlatched. The other end of the specimen shall be inserted into the slot or hole so that sufficient wire projects on the other side of the mandrel and the specimen is in firm contact with the mandrel. The weight shall be slowly lowered with the specimen suspended vertically below the mandrel and with the dial zero and the slot or hole pointing downwards. With the free end of the specimen being held securely, the mandrel shall be rotated for five complete turns counter clockwise (looking at the face of the dial) and further until the zero on the dial is vertically upwards. The handle shall then be latched in this position. The load shall be removed while the specimen is held in position, and the specimen shall then be cut about 25 mm beyond the end of the fifth turn. This end of the specimen shall be bent into a vertical position in line with the dial zero to act as a pointer. A pencil or similar tool shall be placed to the left of this end of the wire to prevent any sudden spring back. The coil shall then be allowed to unwind slowly and without jerking.

NOTE : If the specimen springs back suddenly, erroneous results may be obtained.

The mandrel and the dial shall then be unlatched and rotated clockwise to bring the pointer back into a vertical position. The spring back angle is equal to the reading on the dial in line with the pointer. With very springy wires, the pointer may recoil more than one complete revolution if this is the case. 72 has to be added to the dial reading for each complete revolution of recoil. Three specimens shall be tested. The three single values shall be reported. The mean value represents springiness.

4.1A Spring elongation method

The spring elongation method is applicable to round wires of nominal conductor diameter over 0.080 mm up to and including 1.600 mm. Take three specimens approximately 1 200 mm in length from the same spool, without bending or stretching, mark the bench mark of 1 000 mm length on the central part, and then obtain the spring elongation value ΔL (mm) using the testing machine as shown in figure 2A. The operation of testing machine shall follow the procedure below.

- a) Fasten one end of the specimen to the horizontal chuck on which a winding mandrel is fixed. The diameter of mandrel is 10 times that of conductor of the specimen. Hang a weight having mass of 700 g per conductor sectional area (mm^2) from the other end of specimen.
- b) Wind the specimen between bench marks for adjacent turns by rotating the mandrel at a speed of about 50 rpm.
- c) Hold the specimen wound on the mandrel, take off the weight, and pull out the specimen from the mandrel by bringing back slowly. Measure the length l_1 (mm) of coil.

- d) Fasten one end of the test coil to the vertical chuck, fit a weight of the same mass as that specified in a) on the support so as not to elongate the test coil.
- e) Lower the support at a rate of about 50 mm/s. Hold the coil and weight as they are for 1 min after the weight is separated from the support, then remove the weight slowly from the test coil. Allow the test coil to stand for 1 min, then measure the length l_2 (mm) of coil.
- f) Obtain the spring elongation value ΔL (mm) from the following formula.

$$\Delta L = l_2 - l_1$$

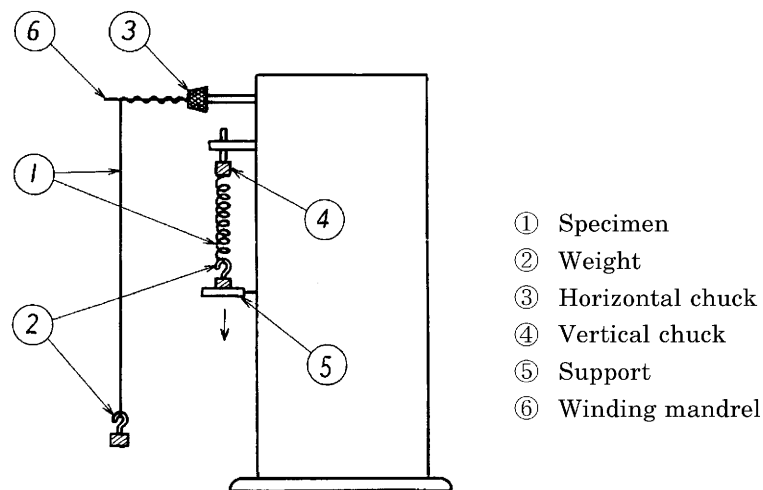


Figure 2A Spring elongation testing machine

4.2 Round wire with a nominal conductor diameter over 1.600 mm and rectangular wire (spring back angle after bending)

4.2.1 Principle

A straight piece of specimen wire shall be bent through an angle of 30°. After removing the force, the reading of the angle by which the specimen springs back is the measure of springiness.

4.2.2 Equipment

Figure 3 shows an example of the test equipment basically consisting of two clamps, one of which is fixed ② and one is movable ①, and a sector graduated in degrees ⑤ with the 0° to 10° sector of the scale graduated in 0.5° increments. The graduated sector is an arc placed in a plane at 90° to the clamp faces. Its centre is located at the outer edge of the fixed clamp ③. The lever arm with its fulcrum placed at the centre of the arc can move over the graduated sector in the vertical plane. The lever arm shall have a pointer or marker to provide a proper reading of the spring back angle. On the lever arm with approximately 305 mm length scaled off in millimetres with the origin at the centre of the arc (fulcrum of the arm), is a slider ④ with a knife edge.

4.2.3 Specimen

A specimen wire of at least 1 200 mm in length shall be removed from the spool with as little bending of the wire as possible. It shall be straightened by hand and

cut into three pieces each of 400 mm length. Elongation machine shall not be used. Unnecessary bending shall be avoided to minimize work hardening.

4.2.4 Procedure

The conductor diameter or thickness, multiplied by 40, determines the position of the slider on the lever arm. The specimen shall be tightened between the clamps with a force just sufficient to prevent slipping. The specimen shall be tightened in such a position as to allow bending the wire in the same direction as it was wound on the spool. The free end of the specimen shall exceed the slider knife edge by $12\text{ mm} \pm 2\text{ mm}$ (see figure 3). By means of the lever arm, starting at the initial position (the 30° scale mark, position 1), the specimen shall be bent for 30° (the 0° scale mark, position 2). The total bending shall take between 2 s and 5 s. The specimen shall be held in this position for less than 2 s and then returned in the reverse direction at the same angular rate at which it was bent, until the slider knife edge moves away from the specimen. The lever arm shall be raised again until the slider knife edge just contacts the specimen without bending it. In this position, the spring back angle of the specimen equals the reading on the scale of the graduated sector in line with the pointer on the lever arm (position 3).

Three specimens shall be tested. The single values shall be reported. The mean value represents springiness.

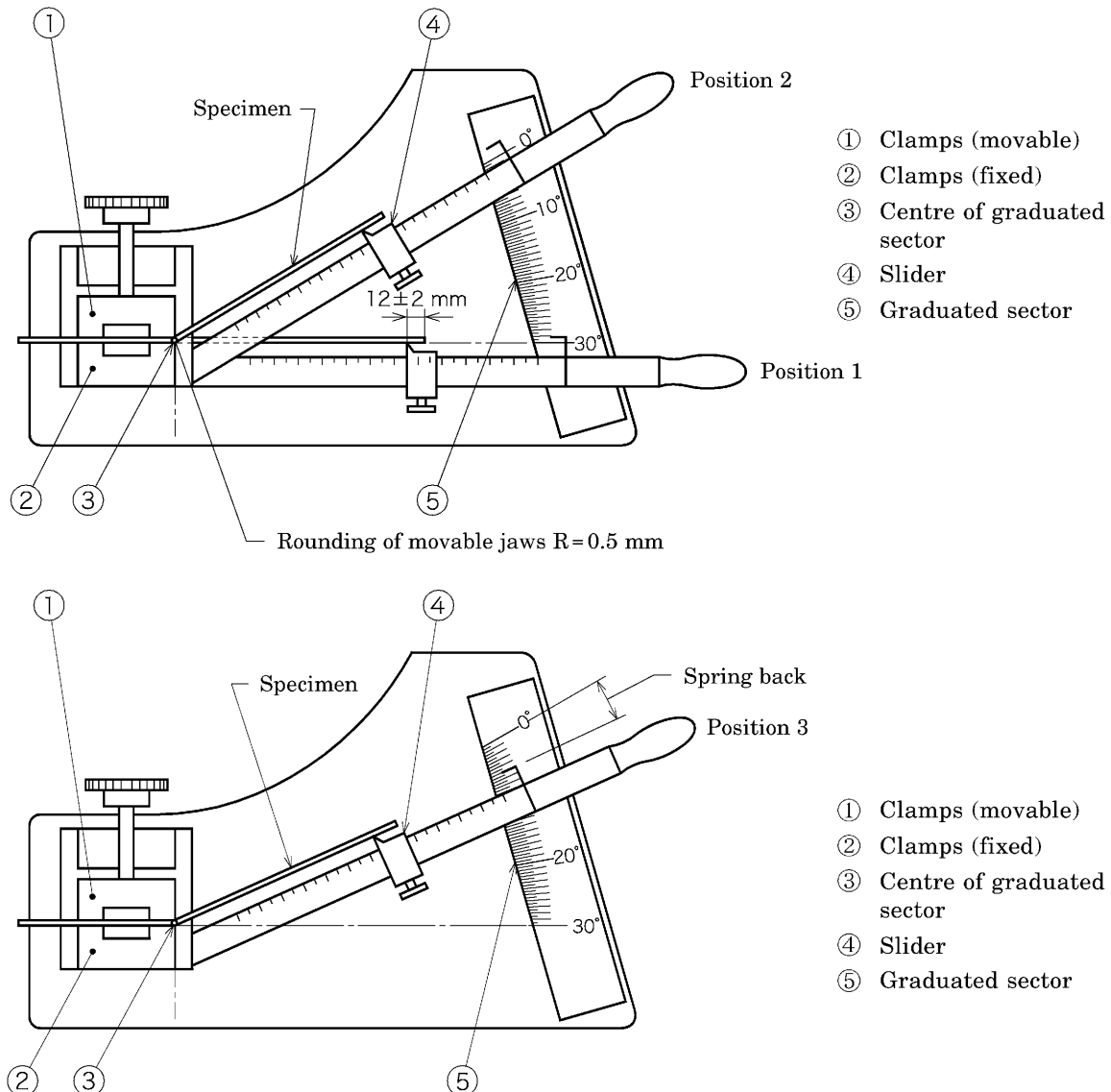


Figure 3 Test equipment to determine springiness

5 Flexibility and adherence

Flexibility and adherence reflect the potential of the wire to withstand stretching, winding, bending or twisting without showing cracks or loss of adhesion of the insulation.

The method of test in **JA.5** may be applied upon agreement between the purchaser and the supplier.

5.1 Mandrel winding test

5.1.1 Round wire

A straight piece of specimen wire shall be wound for 10 continuous and adjacent turns around a polished mandrel of the diameter given in the particular standard. The mandrel shall be rotated with a rate of 1 r/s to 3 r/s with a tension applied to the specimen that is just sufficient to keep it in contact with the mandrel. Elongating or twisting the specimen shall be avoided. Any suitable equipment shall be used.

5.1.1.1 Enamelled round wire with a nominal conductor diameter up to and including 1.600 mm

If the particular standard calls for pre-stretching before winding, the specimen shall be elongated to the specified percentage by means of an elongation test equipment or a tensile test equipment at a speed of 5 mm/s $\pm$ 1 mm/s. After winding, the specimen shall be examined for cracks with the magnification as given in table 2.

Three specimens shall be tested. Exposure of the bare conductor shall be reported.

Table 2 Magnification to detect cracks

Nominal conductor diameter mm		Magnification ^{a)}
Over	Up to and including	
—	0.040	10 to 15 times
0.040	0.500	6 to 10 times
0.500	1.600	1 to 6 times
Note ^{a)} One time expresses normal vision.		

5.1.1.2 Fibre covered round wire

After winding, the specimen shall be examined for exposure of the bare conductor with normal vision or with a magnification of up to six times. Three specimens shall be tested. Exposure of the bare conductor shall be reported.

5.1.1.3 Fibre covered enamelled round wire

After winding, the specimen shall be examined for exposure of the bare conductor or underlying coating with normal vision or with a magnification of up to six times. Three specimens shall be tested. Exposure of the bare conductor or the underlying coating shall be reported.

5.1.1.4 Tape wrapped round wire

After winding, the specimen shall be examined for exposure of the bare conductor or delamination with normal vision or with a magnification of up to six times. Three specimens shall be tested. Exposure of the bare conductor or any delamination shall be reported

5.1.2 Rectangular wire

A straight piece of specimen wire approximately 400 mm in length shall be bent through 180° round a polished mandrel of the diameter given in the particular standard in two directions to form an elongated S-shape. The straight part between the U-shape bends shall be at least 150 mm. Care should be taken to ensure that the specimen does not buckle or depart from a uniform bend. A suitable apparatus is shown in figure 4.

After bending, the insulation shall be examined for cracks in case of enamelled wire, for exposure of the bare conductor or underlying coating in case of fibre or paper insulated wire and for exposure of the bare conductor and delamination in case of tape wrapped wire under a magnification of six to ten times.

Six specimens shall be bent, three on the thickness (flatwise) and three on the width (edgewise). It shall be reported, if the wire shows cracks or delamination, exposure of the bare conductor or underlying coating, whichever is applicable.

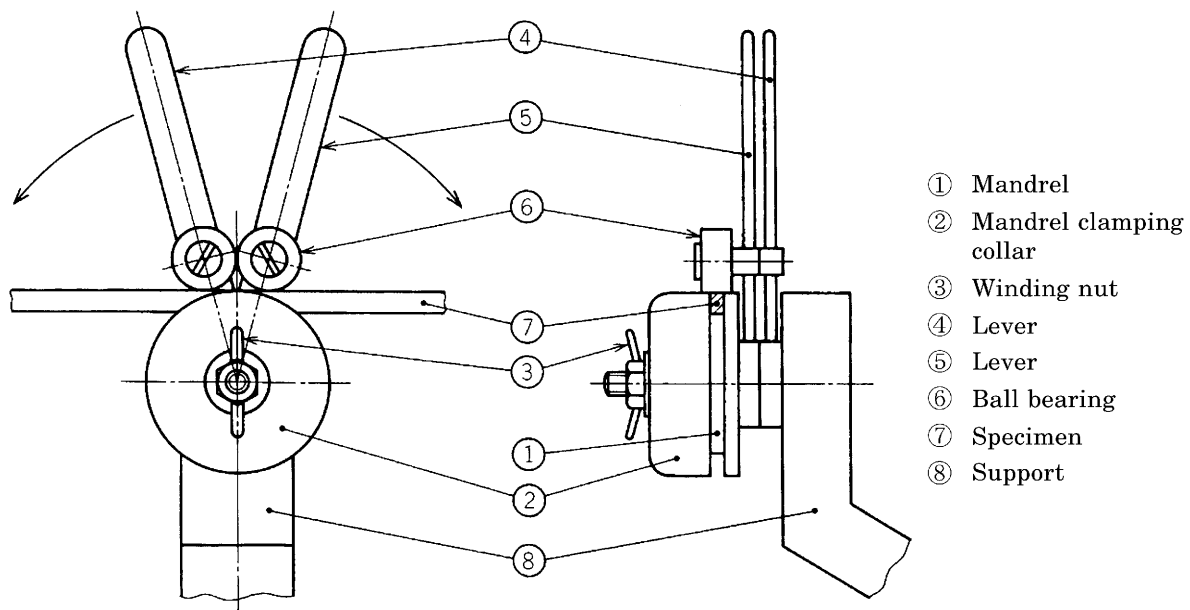


Figure 4 Test equipment for flexibility test of rectangular wire

5.1.3 Covered bunched wire

A straight piece of specimen wire shall be wound for ten continuous turns around a polished mandrel of the diameter given in the particular standard and under a tension given in 3.2.5.3 of JIS C 3216-2. Care should be taken not to twist the specimen for each revolution. After winding, the specimen shall be examined by normal vision for openings in the covering. One specimen shall be tested. It shall be reported if the specimen does not show the degree of closeness of the covering required in the particular standard.

5.2 Stretching test (applicable to enamelled round wire with a nominal conductor diameter over 1.600 mm)

A straight piece of specimen wire shall be elongated to the percentage specified in the particular standard by means of an elongation test equipment or a tensile test equipment, at a speed of $5 \text{ mm/s} \pm 1 \text{ mm/s}$. After elongation, the specimen shall be examined for cracks or loss of adhesion with normal vision or with a magnification of up to six times. Three specimens shall be tested. It shall be reported, if the specimen shows cracks and/or loss of adhesion.

5.3 Jerk test (applicable to enamelled round wire with a nominal conductor diameter up to and including 1.000 mm)

A straight piece of specimen wire shall be rapidly stretched to the breaking point or to the value specified in the particular standard by means of the test equipment as shown in figure 5 or any equipment capable of stretching at a tensile speed of about 4 m/s. A free measuring length of between 200 mm and 250 mm shall be provided. After

stretching, the specimen shall be examined for cracks or loss of adhesion under a magnification as given in table 2. A distance of 2 mm from the broken ends shall be disregarded.

Three specimens shall be tested. It shall be reported if the wire shows cracks and/or loss of adhesion.

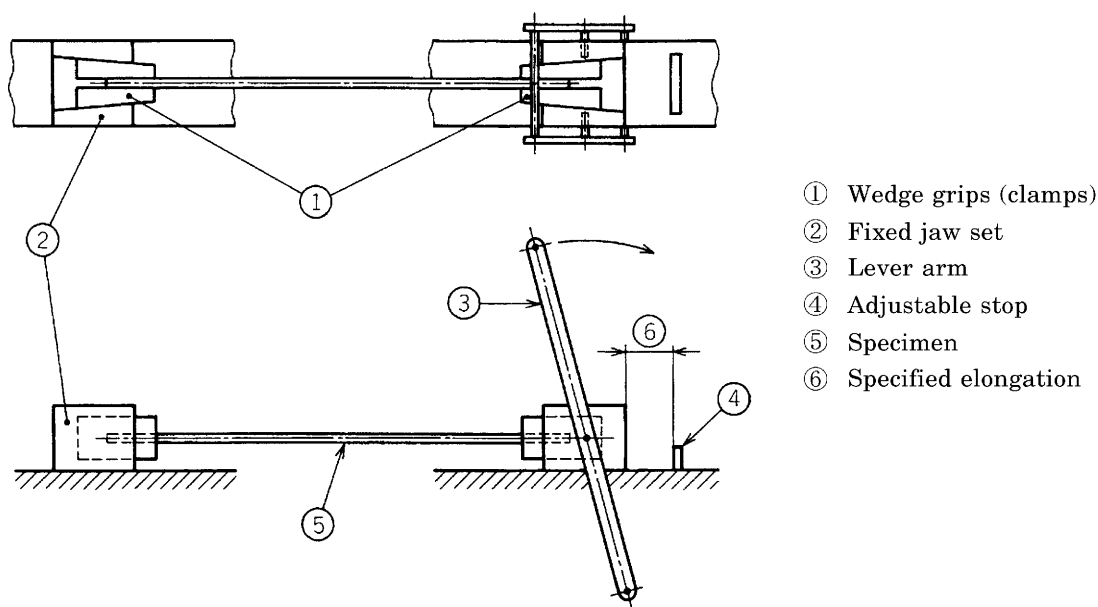


Figure 5 Test equipment for jerk test

5.4 Peel test (applicable to enamelled round wire with a nominal conductor diameter over 1.000 mm)

A straight piece of specimen wire shall be placed in the test equipment shown in figure 6 consisting of two fixing devices 500 mm apart on the same axis. One of these is free to rotate. The other is not, but can be displaced axially and is loaded according to table 3 to apply a tension to the rotating specimen.

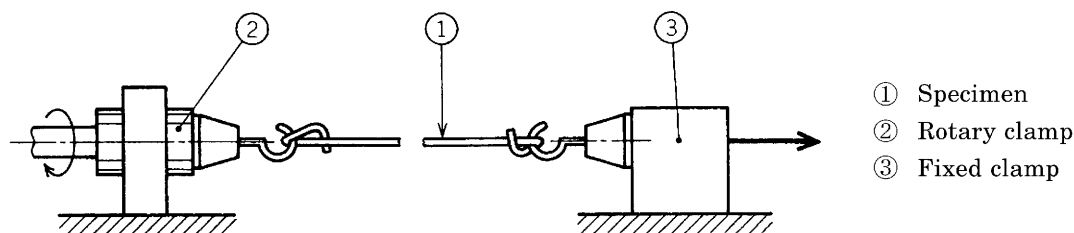


Figure 6 Test equipment for peel test