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**Methods for determining average
grain size of magnesium alloy sheets**

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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 in accordance with the Industrial Standardization Law.

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Methods for determining average grain size of magnesium alloy sheets

1 Scope

This Japanese Industrial Standard specifies the methods for determining the average grain size of magnesium alloy sheets (hereafter referred to as “product”) to be used for the forming such as bending, stretching, and deep drawing.

2 Terms and definitions

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

2.1 grain

one of many micro crystals composed of metal

The granular region surrounded by the boundary (hereafter referred to as “grain boundary”) which appears on the observed surface of sample ground and prepared for the microscopic measurement. The twin as shown in figure 1 is not regarded as grain.

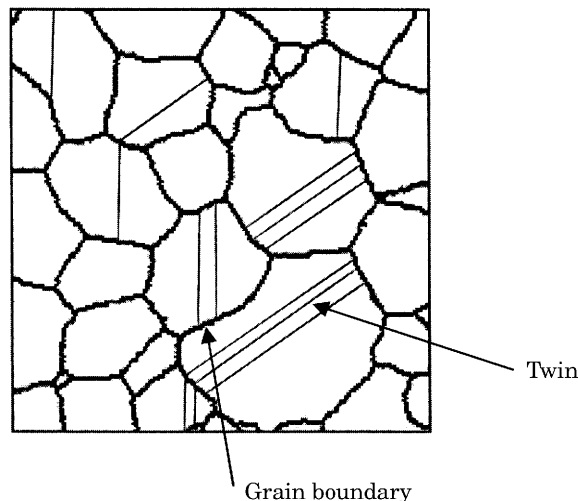


Figure 1 Definition of grain

2.2 grain size

the average size of grain

It is expressed by the average value of grain size numbers.

2.3 grain size number

the value of G , whose relation to the average number of grains per 1 mm^2 of observed surface of sample, m , satisfies $m = 8 \times 2^G$

It can be a positive number, zero or negative number.

2.4 mixed grain

the condition in which, grains whose size deviation from the maximum grain is equivalent to 3 or more in grain size number are unequally distributed within one visual field

of observation occupying approximately 20 % of the area, or the condition in which the grain size difference of 3 or more in grain size number, between any two different visual fields of observation, is present

2.5 rolling direction

the last rolling direction in the rolling process of sheet material

3 Classification

The measuring method shall be in accordance with any one of the following, most typically the comparison method. In case of any doubts arising in the measured results, however, either the quadrature method or the intercept method shall be used. Which one of the two is to be applied shall be subjected to the agreement between the parties concerned with delivery.

- a) Comparison method
- b) Quadrature method
- c) Intercept method

NOTE : The measured value by intercept method tends to be smaller than the measured value by quadrature method.

4 Sampling and preparation of sample

4.1 Sampling

The sample shall be taken from the representative part of the product while avoiding severely deformed parts such as those found at the edge of product or in products which have been given shearing process for the purpose of sampling. For the number of samples to be taken, two or more is desirable, the detailed requirements of number of samples and the sampling position shall be in accordance with the agreement between the parties concerned with delivery.

4.2 Observed surface of sample

For the observed surface of sample, there are three basic directions, namely, the rolling direction, thickness direction and width direction and three basic surfaces. The three basic directions and basic observed surfaces are shown in figure 2. The most typically observed surface is the surface vertical to the width direction (A in figure 2). However, when the grain boundary is made to appear on this surface, if the grains are not equiaxial¹⁾, the surface vertical to the rolling direction (B in figure 2) shall be observed.

Note ¹⁾ “Not equiaxial” refers to a state of grains elongated in a certain direction (for example, in observation of A, elongation of grains in the rolling direction).

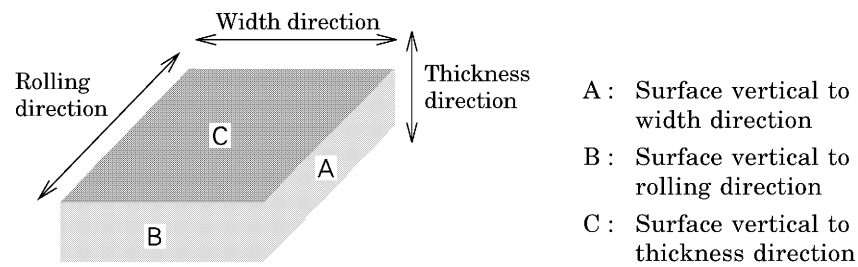


Figure 2 Three basic directions and basic observed surfaces of sample

4.3 Appearance of grain boundary

After the observed surface decided in 4.2 is ground by appropriate method, the grain boundary shall be made to appear by using an adequate corrosive liquid. When the grain boundary is hard to determine because the observed surface shows a processed structure, it is allowed to sample from the product which has been annealed to straighten.

4.4 Visual field of observation

The visual field of observation shall be selected from the observed surface at random. The number of visual fields of observation shall be at least three (five to ten are desirable) for the observed surface of one sample.

Moreover, for microscope, a metallurgical microscope shall be used. When the grain size is measured by quadrature method and intercept method, the metallurgical microscope is required to have the function to monitor the microscopic image by photography or CCD camera.

5 Measurement

5.1 Measurement according to comparison method

5.1.1 Principle

The grain size number is obtained by contrasting a microscopic image (a visible image obtained by looking into a viewfinder), the microscopic photograph, the image on monitor or prints of these (hereafter generically referred to as "microscopic image") to the grain size standard graph, and the obtained numerical value is taken as the grain size at visual field of observation.

5.1.2 Measuring procedures

The measuring procedures shall be as follows.

When the image magnification can optionally be adjusted on a computer, measurement may be according to the method specified in Annex B.

- a) The microscopic image is compared with the grain size standard graphs specified in Annex A (hereafter referred to as "standard graph A") and the grain size number based on comparison with the standard graph A is obtained according to the following 1), 2) and 3).

- 1) When the visual field of observation is a microscopic image, the grain size number of one of the standard graphs A, the circle of which is judged to contain the number of grains closest to that observed in the visual field of observation, is recorded as the grain size number obtained based on contrast to the standard graph A.
 - 2) When the visual field of observation is a microscopic photograph, an image on monitor or the print of the image on monitor, the grain size number of one of the standard graphs A, in which the size of grain is visually most similar to that observed in the visual field of observation, is taken as the grain size number obtained by contrast to the standard graph A.
 - 3) When, in 1) and 2), the grain size number is judged to be in the middle of the two graphs of standard graph A, 0.5 is added to the smaller grain size number of the two and is taken as the grain size number obtained by contrast to the standard graph A.
- b) The grain size number in the visual field of observation is calculated according to formula (1) from the grain size number obtained by the contrast to standard graph A obtained in a) and the image magnification, and the resultant value is rounded such that, for the fraction from 0.0 to 0.5, the figure over 0.3 is counted as 0.5, the others as 0.0, and for the fraction from 0.5 to 1.0, the figure over 0.8 is counted as 1.0 and the others as 0.5 by taking the rounding range as 0.5 [for example, when the value of G calculated according to formula (1) is 10.78, it is taken as 10.5].

$$G = M + 2 \left(\frac{\log \frac{g}{100}}{\log 2} \right) \dots\dots\dots (1)$$

where, G : the grain size number in visual field of observation
 M : the grain size number obtained by contrast to the standard graph A
 g : the magnification of microscopic image

NOTE : It shall be paid attention that the magnification of image of the microscopic photograph, the image on monitor and the prints of image on monitor do not necessarily coincide with the magnification of microscope. The magnification of image can be obtained, for example, from the scalebar recorded in a microscopic image. However, since there are various systems besides this, it is recommended to refer to the instruction manual for input system of microscopic image to be used.

5.2 Measurement according to quadrature method

5.2.1 Principle

A circle, rectangle or square of 5 000 mm² area is drawn on a microscopic image as the measurement region, and the grain size number is calculated from the number of grains in the region. The resultant numerical value is taken as the grain size in the visual field of observation.

5.2.2 Measuring procedures

The measuring procedures shall be as follows.

- a) A circle, rectangle or square of 5 000 mm² area is drawn²⁾ on a microscopic image as the measurement region and the magnification of microscope is adjusted so that the number of grains present in the region becomes 50 or more.

Moreover, the precision of area of measurement region shall be $\pm 1\%$ of 5 000 mm² (for example, a circle of 80.0 mm diameter being 5 027 mm² area may be made to be the measurement region).

- b) The number of grains that are entirely within the measurement region and the number of grains that are divided by the boundary line of measurement region are counted (see figure 3 and figure 4), and the number of grains in measurement region is calculated according to formula (2).

$$n = n_A + 0.5 \times n_B \quad \dots\dots\dots (2)$$

where, n : the number of grains in measurement region
 n_A : the number of grains entirely within the measurement region
 n_B : the number of grains divided by the boundary line of measurement region

- c) The number of grains per 1 mm² of the observed surface of sample is calculated according to formula (3).

$$m = \frac{g^2 n}{5\,000} \quad \dots\dots\dots (3)$$

where, m : the number of grains per 1 mm² of observed surface (mm⁻²)
 g : the magnification of microscopic image
 n : the number of grains in measured region calculated according to formula (2)

- d) The grain size number in visual field of observation is calculated according to formula (4) and the resultant value is rounded to one decimal place.

$$G = \frac{\log m}{\log 2} - 3 \quad \dots\dots\dots (4)$$

where, G : the grain size number in visual field of observation
 m : the number of grains per 1 mm² of observed surface calculated according to formula (3) (mm⁻²)

Note ²⁾ The dimensions of measurement region to be 5 000 mm² area is 79.8 mm diameter in the case of circle, 70.7 mm in one side in the case of square, and for example, 80.0 mm $\times$ 62.5 mm in the case of rectangle.

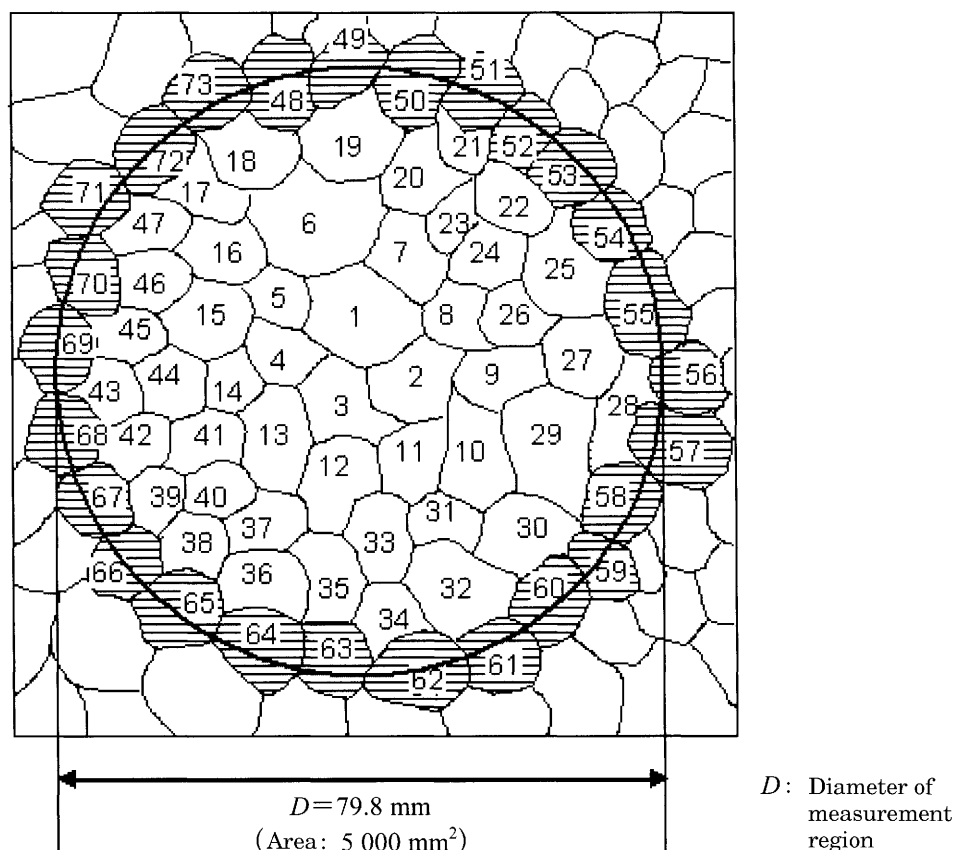


Figure 3 Example of measurement for number of grains in quadrature method
(Case in which the measurement region is taken as a circle)

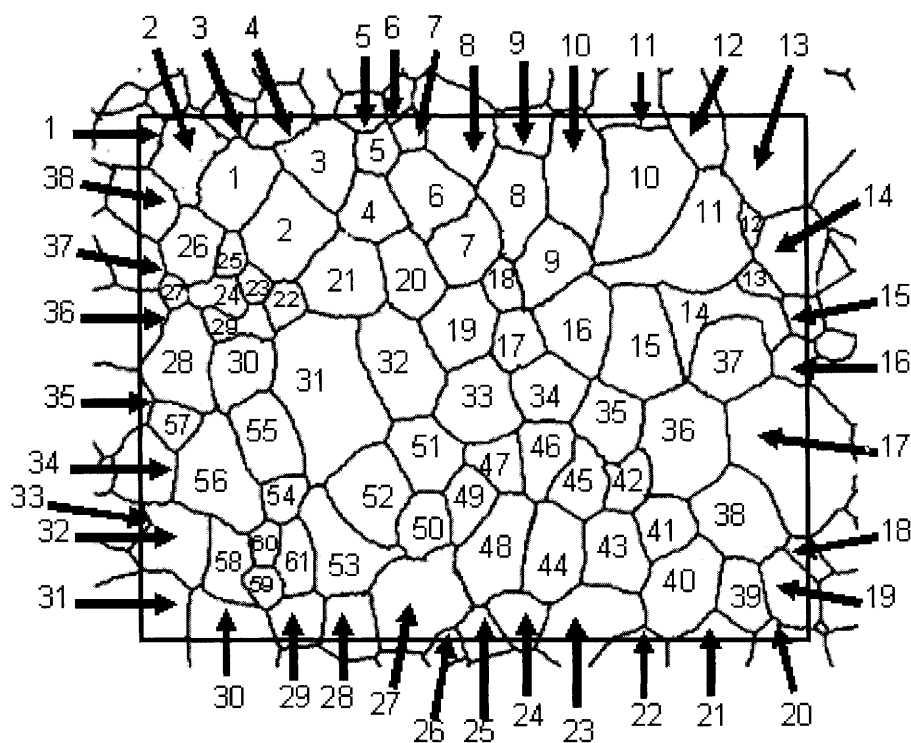


Figure 4 Example of measurement for number of grains in quadrature method
(Case in which the measurement region is taken as a rectangle)