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**Metallic materials — Sheet and strip —
Determination of plastic strain ratio**

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Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry based on the provision of Article 14, paragraph (1) of the Industrial Standardization Act applied mutatis mutandis pursuant to the provision of Article 16 of the said Act in response to a proposal for revision of Japanese Industrial Standard with a draft being attached, submitted by The Japan Iron and Steel Federation (JISF), an accredited standards development organization. This edition replaces the previous edition (**JIS Z 2254:2008**), which has been technically revised.

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Metallic materials — Sheet and strip — Determination of plastic strain ratio

Introduction

This Japanese Industrial Standard has been prepared based on **ISO 10113:2020**, Edition 3, with some modifications of the technical contents.

Annex JA is unique to **JIS** and not given in the corresponding International Standard. The vertical lines on both sides and dotted underlines indicate changes from the corresponding International Standard. A list of modifications with the explanations is given in Annex JB.

1 Scope

This Standard specifies a method for determining the plastic strain ratio of flat products (sheet and strip) made of metallic materials.

It also provides in Annex JA the details of the natural oscillation method that can be used for determining the plastic strain ratio of sheet or strip in coil of other metallic materials than stainless steel.

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

ISO 10113:2020 *Metallic materials — Sheet and strip — Determination of plastic strain ratio* (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

Part or all of the provisions of the following standards, 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 B 7721 *Tension/compression testing machines — Calibration and verification of the force-measuring system*

JIS B 7741 *Calibration of extensometer systems used in uniaxial testing*

JIS G 0202 *Glossary of terms used in iron and steel (Testing)*

JIS Z 2241 *Metallic materials — Tensile testing — Method of test at room temperature*

JIS Z 8401 *Rounding of numbers*

3 Terms and definitions

For the purpose of this Standard, the following terms and definitions, and those given in JIS G 0202 apply.

3.1 plastic strain ratio, r

ratio of the true plastic width strain to the true plastic thickness strain in a plate tensile test piece that has been subjected to uniaxial tensile stress

Note 1 to entry This r value is also referred to as Lankford value and defined by Formula (1):

$$r = \frac{\varepsilon_{p_b}}{\varepsilon_{p_a}} \dots\dots\dots (1)$$

where, ε_{p_a} : true plastic thickness strain
 ε_{p_b} : true plastic width strain

Note 2 to entry The above expression using a single point is only valid in the region where the plastic strain is homogeneous.

Note 3 to entry Since it is easier and more precise to measure changes in length than in thickness, the following relationship derived from the law of constancy of volume is used up to the percentage plastic extension at maximum force, A_g , to calculate the plastic strain ratio, r .

$$r = \frac{\ln\left(\frac{b_1}{b_0}\right)}{\ln\left(\frac{L_0 b_0}{L_1 b_1}\right)} \dots\dots\dots (2)$$

Note 4 to entry For some materials exhibiting a phase change during plastic deformation, the volume of the measured section cannot always be assumed to be constant. In such cases, the procedure should be defined and agreed between the parties involved.

Note 5 to entry As the value r depends on the orientation of the test piece relative to the rolling direction, as well as on the strain, the symbol r can be supplemented by the angle which characterises this orientation and the plastic (engineering) strain.

Example $r_{45/20}$ (see Table 1)

3.2 weighted average plastic strain ratio, $\bar{r}$

calculated weighted average of $r_{x/y}$ values for different test piece orientations (0°, 45° and 90° to the rolling direction)

Note 1 to entry It is calculated by Formula (3):

$$\bar{r} = \frac{r_{0/y} + 2r_{45/y} + r_{90/y}}{4} \dots\dots\dots (3)$$

Instead of the r -value measured at plastic (engineering) strain y as

shown in the above formula, the r -value measured in the plastic (engineering) strain range $\alpha - \beta$ ($r_{\alpha/\beta}$, $r_{45/\alpha - \beta}$ and $r_{90/\alpha - \beta}$) can be applied.

Note 2 to entry For some materials, other test piece orientations may be chosen, in which case formulas other than Formula (3) shall be used.

Note 3 to entry The method of r -value determination for different test piece orientations shall be consistent, i.e. the same testing method, evaluation method and plastic (engineering) strain or plastic (engineering) strain range shall be used.

3.3 degree of planar anisotropy, Δr

difference between the average of $r_{x/y}$ values for different test piece orientations (0° and 90° to the rolling direction) and the $r_{x/y}$ value for test piece orientation 45° to the rolling direction

Note 1 to entry It is calculated by Formula (4):

$$\Delta r = \frac{r_{0/y} - 2r_{45/y} + r_{90/y}}{2} \dots\dots\dots (4)$$

Instead of the $r_{x/y}$ value measured at plastic (engineering) strain y as shown in the above formula, the $r_{x/y}$ value measured in the plastic (engineering) strain range $\alpha - \beta$ ($r_{\alpha/\beta}$, $r_{45/\alpha - \beta}$ and $r_{90/\alpha - \beta}$) can be applied.

Note 2 to entry For some materials, other test piece orientations may be chosen, in which case formulas other than Formula (4) shall be used.

Note 3 to entry The method of r -value determination for different test piece orientations shall be consistent, i.e. the same testing method, evaluation method and plastic (engineering) strain or plastic (engineering) strain range shall be used.

4 Symbols

The designations of the symbols used in this Standard are given in Table 1.

Table 1 General symbols, designations, definitions and unit

Symbol	Designation	Unit
A_g	percentage of plastic extension at maximum force	%
a	thickness of the test piece after straining to a specified plastic elongation/extension	mm
a_0	original thickness of the test piece	mm
a_1	thickness of the test piece after straining and unloading	mm
b	gauge width of the test piece after straining to a specified plastic elongation/extension	mm
b_0	average original gauge width of the test piece (hereafter referred to as original gauge width of the test piece)	mm
b_1	average width of the test piece after straining and unloading	mm
d	transverse bow	mm
e	specified plastic (engineering) strain	%

ϵ_{p_a}	instantaneous plastic (engineering) thickness strain of the test piece during testing	%
ϵ_{p_b}	instantaneous plastic (engineering) width strain of the test piece during testing	%
ϵ_{p_L}	instantaneous plastic (engineering) length strain of the test piece during testing	%
F	force	N
L	gauge length after straining to a specified plastic elongation/extension	mm
L_0	original gauge length	mm
L_1	length between the marks of the original gauge length, L_0 , on the test piece after straining and unloading	mm
L_e	original extensometer gauge length	mm
m_E	slope of the elastic part of the engineering stress/percentage length extension curve	MPa
m_r	slope of the corresponding straight line of the true plastic width strain vs. true plastic length strain curve	—
r	plastic strain ratio	—
$r_{x/y}$	plastic strain ratio in x -direction (in degrees) relative to the rolling direction, and at plastic (engineering) strain, ϵ_p (y in %)	—
$r_{x/\alpha-\beta}$	plastic strain ratio in x -direction (in degrees) relative to the rolling direction, and at plastic (engineering) strain range from $\epsilon_{p\alpha}$ to $\epsilon_{p\beta}$ (α and β in %)	—
$\bar{r}^a)$	weighted average of $r_{x/y}$ values	—
R_m	tensile strength	MPa
$R_{p0.2}$	yield strength (by offset method, based on plastic elongation value of 0.2 %)	MPa
S_0	original cross-sectional area of the parallel length	mm ²
S	instantaneous cross-sectional area	mm ²
Δb	instantaneous width reduction measured with a width extensometer	mm
ΔL	instantaneous extension of the original extensometer gauge length under load	mm
Δr	degree of planar anisotropy	—
ϵ_{p_a}	true plastic thickness strain	—
ϵ_{p_b}	true plastic width strain	—
ϵ_{p_L}	true plastic length strain	—
ν	Poisson's ratio (e.g. 0.30 for copper and 0.33 for aluminium)	—
α, β, x, y	variables used as subscripts	—
NOTE 1 In the literature, the readers may encounter other symbols.		
NOTE 2 1 MPa = 1 N/mm ²		
Note a) r_m may be used instead of $\bar{r}$.		

5 Principle

The plastic strain ratio r is often used for the characterisation and qualification of materials, and for the numerical simulation of forming processes.

To determine the plastic strain ratio, a test piece is subjected to a tensile test to a specified plastic (engineering) strain and the plastic strain ratio r is calculated from measurements of the changes in width and thickness after unloading. In practice, the

plastic strain ratio r is typically derived from changes in width and gauge length of the test piece using the law of constancy of volume [see Formula (5)].

$$\varepsilon_{p_a} + \varepsilon_{p_b} + \varepsilon_{p_L} = 0 \quad \dots\dots\dots (5)$$

$$\begin{aligned} \text{where,} \quad \varepsilon_{p_a} &: \ln\left(\frac{a_1}{a_0}\right) \\ \varepsilon_{p_b} &: \ln\left(\frac{b_1}{b_0}\right) \\ \varepsilon_{p_L} &: \ln\left(\frac{L_1}{L_0}\right) \end{aligned}$$

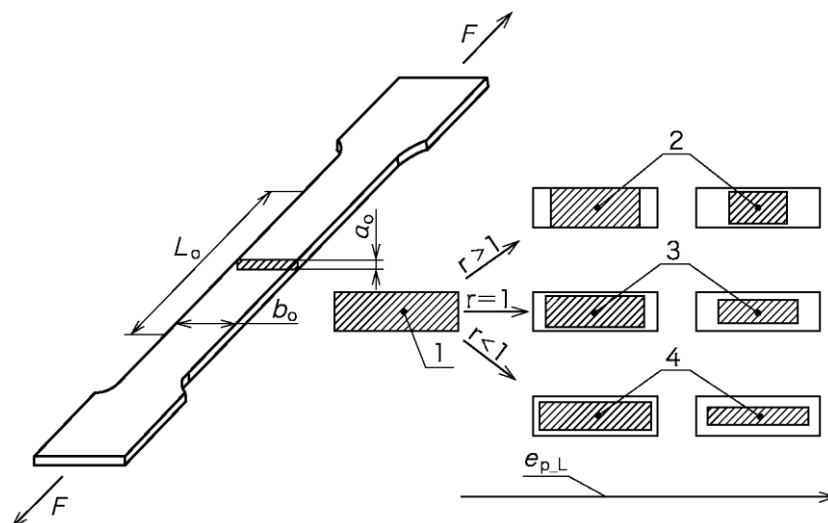
The law of constancy of volume is only applicable up to the percentage of plastic extension at maximum force, A_g because after this point local necking starts and the used mathematical approaches are no longer valid.

Several materials clearly show a slight local necking before A_g . This can lead to higher instantaneous width reduction values and results in higher r -values, especially when an extensometer ¹⁾ is used which measures the instantaneous width reduction only in the central region of the gauge length. In these cases, the following points are recommended.

Note ¹⁾ A device for measuring the dimension in width direction.

- a) Extensometers for measurement of the instantaneous width reduction which are able to measure the change of width in multiple locations ideally evenly distributed across the entire gauge length (see Clause 6) should be used.
- b) The parallel length of the test piece should be minimum six times of the original gauge width of the test piece b_0 .

An r -value value greater than one describes a behaviour where the plastic (engineering) strain of the test piece is greater in the width than in the thickness ($|\varepsilon_{p_b}| > |\varepsilon_{p_a}|$; see Figure 1). An r -value lower than one describes a behaviour where the plastic (engineering) strain of the test piece is greater in the thickness than in the width ($|\varepsilon_{p_b}| < |\varepsilon_{p_a}|$; see Figure 1). An r -value of one describe a behaviour where the plastic (engineering) strain of the test piece in the width is equal to that in the thickness, i.e., exhibiting an isotropic forming behaviour ($\varepsilon_{p_b} = \varepsilon_{p_a}$; see Figure 1).



Key

- 1: original cross-sectional area of the parallel length
 - 2: test piece with greater true plastic strain in the width than in the thickness ($|\varepsilon_{p-b}| > |\varepsilon_{p-a}|$)
 - 3: isotropic material [test piece with the same true plastic strain in width and thickness ($\varepsilon_{p-b} = \varepsilon_{p-a}$)]
 - 4: test piece with greater true plastic strain in the thickness than in the width ($|\varepsilon_{p-b}| < |\varepsilon_{p-a}|$)
- e_{pL} : increase of plastic extension

Figure 1 Illustration of the cross-section changes for different r -values

6 Test equipment

The tensile testing machine used shall comply with **JIS B 7721**, Class 1 or better.

The above requirement does not apply to testing machine for Test method 1 or 2 where the test piece length is measured after unloading.

For Test method 1 [without using any extensometer (see 8.2)], the device for the measurement of the original gauge length and the gauge length after plastic straining and unloading shall be capable of measuring with an accuracy of ± 0.01 mm. The device used for determining the original gauge width and the gauge width of the test piece after plastic straining and unloading shall be capable of measuring with an accuracy of ± 0.01 mm.

NOTE 1 **ISO 10113** specifies an accuracy of ± 0.005 mm for the device used for measurement of gauge width of the test piece for Test method 1.

For Test method 2 [only with length extensometer (see 8.3)], an extensometer for length measurement in accordance with **JIS B 7741**, of Class 1 or better in the relevant strain range, shall be used. The device used for determining the original gauge width and the gauge width of the test piece after plastic straining and unloading shall be capable of measuring with an accuracy of ± 0.01 mm.

NOTE 2 **ISO 10113** specifies an accuracy of ± 0.005 mm for the device used for measurement of gauge width of the test piece for Test method 2.

For Test method 3 [with width and length extensometer (see 8.4)], extensometers for