

Australian Standard[®]

**METHOD FOR THE
MEASUREMENT OF THE
PLASTIC STRAIN RATIO '*r*' OF
SHEET AND STRIP METALS**

The following scientific, industrial and governmental organizations and departments were officially represented on the committee entrusted with the preparation of this standard:

Aluminium Development Council
Australasian Institute of Metals
Bureau of Steel Manufacturers of Australia
Commonwealth Scientific and Industrial Research Organization
Confederation of Australian Industry
Department of Defence
Federal Chamber of Automotive Industries
Metal Trades Industry Association of Australia
National Association of Testing Authorities
Railways of Australia Committee
Society of Automotive Engineers Australasia
University of Melbourne
University of Sydney

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PREFACE

This standard was prepared by the Association's Committee on the Mechanical Testing of Metals on behalf of the Metals Standards Board in order to provide standard methods whereby the formability of sheet and strip metals may be assessed by mechanical testing.

During preparation of the standard, the committee considered information contained in the following documents:

ASTM E517-74 Plastic Strain Ratio 'r' for Sheet Metal

Recommended Procedure for the Measurement of the Plastic Anisotropy Ratio 'r'—prepared by the International Deep Drawing Research Group.

The committee also considered other methods in use which call for multisectional test pieces, e.g. the 'circle arc' and the 'sollac' methods, but decided against their inclusion because these methods are not in common use in Australia, because of problems associated with the preparation of test pieces which require unacceptably small tolerances for routine testing purposes, and further, because these methods are more sensitive to errors in parallelism and to errors caused by inhomogeneities in the metal than the method included.

In the interests of standardization the committee resolved to retain the tolerances on test piece widths as specified in AS 1391.

This standard requires reference to the following Australian standards:

AS 1391 Methods for Tensile Testing of Metals

AS 1545 Methods for the Calibration and Grading of Extensometers

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STANDARDS ASSOCIATION OF AUSTRALIA

Australian Standard

METHOD FOR THE MEASUREMENT OF THE PLASTIC STRAIN RATIO '*r*' OF SHEET AND STRIP METALS

FOREWORD

In the testing of metals for their forming properties, the plastic strain ratio '*r*', provides valuable information on the ability of sheet or strip metal to resist thinning or thickening when stressed in the plane of the metal.

The plastic strain ratio '*r*', is a measure of the plastic anisotropy resulting from preferred orientation of the constituent polycrystals. Because high '*r*', values favour the forming of deep drawn products, such as cylindrical flat bottom cups, the plastic strain ratio is particularly useful for the evaluation of metal used in deep drawing operations where a substantial portion of the metal is drawn into the die cavity.

The '*r*', value is the ratio of the true width strain to true thickness strain during a tensile test. However, thickness measurements are not used because of difficulties in readily attaining sufficient precision with such measurements. The use of length in place of thickness for calculations assumes that the volume of the metal remains unchanged.

The method described in this standard permits the measurement of '*r*', values based on changes in length and width.

The methods included in Appendix B allow for the routine determination of '*r*', where extreme accuracy is not required.

METHOD

1 SCOPE. This standard sets out the method for the measurement of the plastic strain ratio ' r ', of sheet and strip metals.

2 DEFINITIONS. For the purpose of this standard, the definitions given in AS 1391 together with the following definitions apply:

2.1 Plastic strain ratio (r)—the ratio between the true width strain and the true thickness strain for a test piece strained plastically in uniaxial tension by an amount greater than the yield elongation, if present, but less than the uniform elongation.

2.2 Normal anisotropy index (r_m)—the weighted average of ' r ', values obtained from test pieces taken at 0 degrees, 45 degrees and 90 degrees to the rolling direction.

NOTE: Some materials may show significantly different values of r for other test directions, in which case an average value may include these when special note is made and an additional symbol is used to avoid confusion with r_m or Δr as defined.

2.3 Planar anisotropy index (Δr)—the weighted average difference between the ' r ', values obtained from test pieces taken at 0 degrees, 45 degrees, and 90 degrees to the rolling direction (see Note to Clause 2.2).

2.4 Yield elongation (A_e)—the total plastic extension associated with discontinuous yielding, expressed as a percentage of the original gauge length.

2.5 Uniform elongation (A_m)—the total extension at maximum force, expressed as a percentage of the original gauge length.

3 SYMBOLS AND DESIGNATIONS. For the purpose of this standard, the following symbols and designations apply:

- a_o = initial thickness of test piece
- a_i = thickness of the test piece at any instant i
- A_e = yield elongation
- A_m = uniform elongation
- b = width of test piece
- b_o = initial gauge length (width axis)
- b_i = gauge length (width axis) at any instant i
- L_c = parallel length
- L_o = original gauge length (longitudinal axis)
- L_i = gauge length, longitudinal axis, at any instant i
- ϵ_a = true thickness strain
= $\ln(a_i/a_o)$
- ϵ_b = true width strain
= $\ln(b_i/b_o)$
- r = plastic strain ratio
= ϵ_b/ϵ_a (see Appendix A)
- r_o = plastic strain ratio of a test piece, taken parallel to the rolling direction
- r_{45} = plastic strain ratio of a test piece taken at 45 degrees to the rolling direction
- r_{90} = plastic strain ratio of a test piece taken at 90 degrees to the rolling direction
- r_m = normal anisotropy index
= $(r_o + 2r_{45} + r_{90})/4$
- Δr = planar anisotropy index
= $(r_o - 2r_{45} + r_{90})/2$

4 PRINCIPLE. Prepared test pieces of sheet or strip metal are strained in uniaxial tension to induce plastic flow.

The ratio of the true strain that occurs in the width direction, perpendicular to the direction of applied stress and in the plane of the sheet, to the true strain in the thickness direction is taken as the plastic strain ratio r .

5 EQUIPMENT.

5.1 General. The equipment shall be capable of applying an axial tensile strain to the test piece.

5.2 Measuring Devices. Measuring devices shall be capable of taking all measurements to within an accuracy of 0.1 percent.

6 PREPARATION OF TEST PIECES.

6.1 General. Test pieces shall be prepared in accordance with the requirements of AS 1391 except that L/b shall be equal to or greater than 6.

Where differences exist between the requirements of AS 1391 and the requirements of this standard, the requirements of this standard shall apply.

Test pieces shall be prepared from sheet or strip metal in the as-received condition. Surfaces shall not be ground. However, local polishing of the surface to assist in the positioning of gauge marks is permitted.

Gauge marks may be made by scribing, punching, photographic means, diamond indenter or by other similar implement.

NOTE: Care should be exercised to ensure that, when indentations are made, they do not alter significantly the strain distribution within the test piece.

6.2 Gauge Length (Width). The full width of the parallel section of the test piece shall be used as the gauge length (width).

6.3 Gauge Length (Longitudinal). Gauge marks shall be used on all test pieces. They shall be positioned so that the gauge length is parallel to the edge of the strip and approximately central, and shall be in accordance with the following:

- (a) *Reduced section test pieces*—gauge marks shall be not closer than the width of the parallel section from the ends of the reduced section.
- (b) *Parallel strip test pieces*—the distance between the length gauge marks and a machine grip shall be not less than twice the width of the test piece.

6.4 Orientation. Test pieces shall be prepared so that their longitudinal axis is within ± 5 degrees of the specified orientation to the direction of rolling.

7 TEST PROCEDURE. The plastic strain ratio r shall be determined as follows:

- (a) Suitably mark test pieces so as to permit the measurement of gauge length (longitudinal). The gauge length used shall not exceed $4b$ or be less than $2b$.
- (b) Measure the gauge length (longitudinal) and record measurements.
- (c) Take at least three gauge width measurements at evenly spaced distances not greater than b apart within the gauge length (longitudinal) and record measurements.