TECHNICAL REPORT

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Metallic materials — Strain analysis report

Matériaux métalliques — Rapport concernant l'analyse des déformations

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard (“state of the art”, for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 14936, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 2, *Ductility testing*.

This document is being issued in the Technical Report (type 2) series of publications (according to substance G 3.2.2 of part 1 ISO/IEC Directives, 1995) as a prospective standard for provisional application in the field of strain analysis of metallic sheets because there is an urgent need for guidance and unification.

This document is not to be regarded as an “International Standard“. It is proposed for provisional application so that information and experience of its use in practice may be gathered. Comments on the content of this document should be sent to the ISO Central Secretariat.

A review of this Technical Report (type 2) will be carried out not later than three years after its publication with the options of: extension for another three years, conversion into an International Standard; or withdrawal.

Annex A forms an integral part of this Technical Report. Annex B is for information only.

Metallic materials — Strain analysis report

1 Scope

This Technical Report provides information on the use of strain analysis to evaluate parts formed in sheet metal stamping presses using the method described in ISO 12004.

Strain analysis is used to determine the critical major (e_1) and minor (e_2) strains on a metallic sheet that has been formed by production stamping operations employing a die set in a stamping press. These strains are compared with the Forming Limit Curve (FLC) obtained for the same material in order to evaluate the severity of the forming process.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the edition indicated was valid. All standards are subject to revision and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent edition of the standard listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 12004:1997, *Metallic materials — Guidelines for the determination of forming-limit diagrams.*

3 Symbols

The symbols used in strain analysis are specified in table 1.

Table 1 — Symbols and their meanings

Symbol	Meaning	Unit
a	Thickness of test piece	mm
a_3	Thickness after forming the part	mm
e_1	Major strain	%
e_2	Minor strain, 90° to the direction of major strain	%
e_3	Thickness strain	%
l_0	Original gauge length of grid pattern	mm
l_1	Final length in major strain direction	mm
l_2	Final length 90° to the direction of major strain	mm
n	Strain hardening exponent (n value)	1
r_m	Plastic strain ratio, weighted average	1
FLD	Forming Limit Diagram	
FLC	Forming Limit Curve	

4 Principle

Strain analysis is a method for evaluating the localized surface strain developed on formed sheet metal parts when subjected to press stamping operations. A pattern of precise gauge lengths is applied to the surface of the flat blank of a sheet metal that is to be studied. After forming the part in the press, the pattern in critical areas is measured and the major and minor strain plotted on an FLD. An FLC for the same sheet metal is placed on the FLD. If strains are found on the part that are close to, or above the FLC, localized necking and failure are likely to occur during a production run of the part in the press.

5 Testing conditions

The testing conditions shall to be in accordance with ISO 12004.

6 Procedure

6.1 Forming Limit Diagrams (FLD)

The gridded flat blank is prepared and formed in the stamping press using the same procedures as for normal production of parts. It is recommended that the gridded blank be prepared and inserted during a regular run of the parts. When the strain analysis is done as a pre-production evaluation and adjustments made of the press, lubrication or material of blanks, another strain analysis should be subsequently made on a part formed after these adjustments, during production.

Preliminary examination of a formed part may disclose critical areas so that the grid need not be applied over the entire surface of the blank. If there is a question regarding the strain locations, the initial trial blank should be gridded over the entire surface. In some instances, grids are applied to both surfaces to ensure they have a readable pattern.

The e_1 and associated e_2 measurements for critical locations are plotted on an FLD which shall have an FLC for the material being used in the trial. The area on the formed part that is represented by specific data points must be identified on the FLD if more that one critical area is being plotted on one FLD.

An example of a Forming Limit Diagram is given in annex A.

6.2 Strain contours

The distribution of strain over a part has a strong effect on the formability. High strain gradients over a small area of a formed part can cause breakage. Strain grids are a useful way of determining strain gradients. These employ only the e_1 strain. A survey of the part is made using a set spacing of a pair of dividers to locate circles with a given level of strain. For convenience, strain increments of 10 % are used, between a low of 20 % up to the maximum on the part. For example, if the maximum strain was found to be 53 % e_1, strain contours would be traced on the grid pattern of the part at levels of 20 %, 30 %, 40 % and 50 %. This mapping of the surface is used to evaluate the effectiveness of any corrective action taken to improve performance. If the character lines of the formed panel are traced back to the flat blank, it is possible to see where the metal is moving and how adjustments of blank shape, position in the dies, lubrication or press settings change the part shape, affect thinning and reduce potential breakage. Surface imperfections due to loose metal can be effectively eliminated.

6.3 In-plane shear

Sheet metal failure is evidenced by localized thinning and breakage. The other extreme is buckling and folded metal. In either case, in-plane shear is occurring. The surface in one location is moving in one direction while a nearby location is moving in the opposite direction. Examining the shape of individual parts of the grid pattern can identify the condition. Any distortion from balanced biaxial strain should be noted. This condition does not plot on the FLD.

NOTE — Care must be taken not to confuse apparent in plane shear with uniaxial compression or biaxial tension.

6.4 Thickness strain

The thickness strain e_3 is not measured in surface strain analysis. The relationship between e_1, e_2 and e_3 is established by constancy of volume as follows:

$$e_3 = \left[\frac{1}{\left(\frac{e_1}{100}+1\right)\times\left(\frac{e_2}{100}+1\right)} - 1 \right] \times 100$$

There is a possibility of evaluating strain on a formed part by measuring the final thickness and, knowing the initial thickness, calculating e_3. The thickness can be measured:

— with micrometers — this requires cutting the formed part into pieces to get the micrometer into a position to measure;

— with electronic thickness gauges.

7 Interpretation of results

Stamping press operations used to form sheet metal into complex three dimensional shapes are subject to many variables. Assuming the press conditions are optimized and the dies are working properly, the most critical variable is the metal sheet which is being formed. By applying a grid pattern of small gauge marks to the flat blank and then forming a test part, critical areas can be identified, measurements plotted on an FLD, and comparison made with the expected forming limit for the material. The procedure is effective in defining initial conditions and then evaluating the formed part. Measurements and photographs of the part can be used later during production runs to establish whether changes in the forming process have occurred. It is sometimes found that after a part has been in production for a period of time the strains are lower and savings can be made by reducing the blank size, using thinner material in the blank or downgrading to a less formable and less expensive, grade of metal.

8 Test report

8.1 The test report shall include the following information:

a) reference to this Technical Report i.e. ISO/TR 14936;

b) identification of the test piece, or material;

c) thickness of the test piece;

d) FLC and data from the part plotted on the forming limit diagram (FLD);

e) gauge length of the grid pattern used;

f) maximum e_1 and associated e_2 found on the part;

g) strain hardening exponent n value.

8.2 The test report may include the following information:

a) mechanical properties of the material;

b) chemical composition of the material;

c) description of procedure used for the strain analysis;

d) sketch or photograph of the blank and part;

e) strain contours on a sketch of the part;

f) thinning survey over the part, with values achieved located on the sketch of the part.