



Evaluation of tensile tests

Quality of readings and repetition of readings

CONTENTS

1. Introduction	Page 1
2. Related standards and regulations	Page 2
3. Purpose of the tensile test	Page 2
4. Definition of the specific sample shape / sampling point	Page 3
5. Analysis of readings	Page 4
5.1. Evaluation of measurement quality and repetition of readings	Page 4
5.2. Statistical evaluation of readings	Page 5
6. Guidelines for the documentation of test results	Page 5

BDG reference sheet drawn up by the BDG Quality Assurance Workgroup

1 Introduction

This BDG reference sheet applies to tensile tests under EN ISO 6892-1 (Metallic materials, tensile testing part 1: Method of testing at room temperature).

This BDG reference sheet describes a practical approach to the evaluation of tensile tests. To ensure that the result of a reading can be used again and that correct conclusions can be drawn, it is important not only to identify the value of the relevant variable, but also to draw a conclusion about the quality of the result. In particular, this reference sheet specifies aspects and procedures that must be observed in the planning and evaluation of tensile tests on tensile test samples taken directly from a cast part. By analogy, the BDG reference sheet can also be applied to the testing of components.

The material-specific standards contain further guidelines, e.g. on the preparation of tensile samples, as well as on deviations and retesting. As well as describing the practical procedure in the evaluation of tensile tests, this BDG reference sheet also contains guidelines from the standard DIN EN 1706.

While taking account of material-specific guidelines, this BDG reference sheet can also be applied to other materials, such as zinc, magnesium and copper.

2 Related standards and regulations

EN ISO 6892-1	“Metallic materials, tensile testing part 1: Method of testing at room temperature”
DIN EN 1706	“Aluminium and aluminium alloys – castings – chemical composition and mechanical properties”
DIN EN 1753	“Magnesium and magnesium alloys – magnesium alloy ingots and castings”
DIN EN 12844	“Zinc and zinc alloys – castings – specifications”
DIN EN 1982	“Copper and copper alloys – ingots and castings”

3 Purpose of the tensile test

The tensile test is adequately described in the standard DIN EN ISO 6892-1 as well as in other standards associated with it.

In the castings sector tensile tests are used, among other things, as tests to support serial production, for example, to verify the efficacy of transformations to the microstructure resulting from heat treatment. A tensile test involves the use of a tensile test rod, which can be taken directly from the component, or it can be moulded into the component or cast separately. All three methods can be found in practice. In each case the purpose is to find out whether the material that is moulded into the component meets the previously specified requirements in terms of tensile strength (R_m), yield strength ($R_p 0.2$) and/or breaking elongation (A_5). Tensile test samples are often used so that the tensile test can establish a correlation with the operating loads impacting the component, either as a whole or locally.

While separately cast test rods permit a general qualitative statement about the potential strength of the material in use, test rods taken directly from the component also allow conclusions about the potential strength of the material in specific parts of the component. The type of test rod should be specified depending on the required result that the test result is intended to deliver.

Please note: A test rod cast with the component will have the same alloy composition as the component. It also has correlating process parameters and wall thicknesses and, as an element of the ventilation or foundry system, can also be designed as belonging to a specific nest.

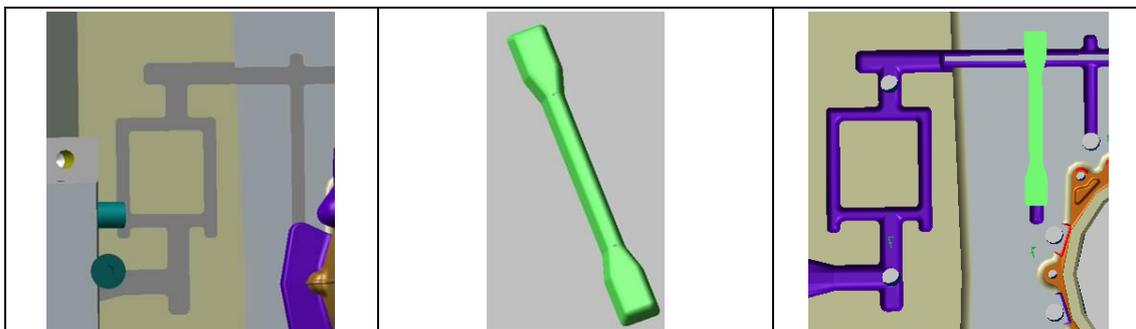


Fig. 1: Example: sample moulded into the component



4 Definition of the specific sample shape / sampling point

It needs to be borne in mind that tensile samples taken directly from a component are often significantly impacted by the quality of the as-cast microstructure available at the sampling point. Due to various causes, such as variable setting speeds, there will be non-homogeneous areas within a component. Any conclusions concerning potential mechanical and technological properties of the material based on direct sampling should always be backed up by several tensile samples from different areas within the same component. This is to prevent misleading conclusions. If tensile samples are taken from castings, it is important that the supplier and the customer agree on the dimensions and positions of the samples within the casting, as well as the testing frequency and the required characteristic values. It is possible to take either flat or cylindrical samples from a component.

Flat samples are recommended for parts of a component where cylindrical samples are rendered impossible by local geometric conditions. If at all possible, their location should be chosen so that the casting crust on the surface is largely left intact when taking samples.

If flat samples are taken from diecast components, they must not be taken from the following areas of the casting, as the quality of the as-cast microstructure would otherwise be affected negatively due to certain typical technical characteristics of castings:

- Close to the runner gate
- At and around the end of the mould cavity where there is no option of arranging adequately dimensioned overflows and/or ventilation of diecast moulds.
- At and around a highly turbulent mould filling, often accompanied by inadequate flow

Due to their geometry, cylindrical samples of the component require material thicknesses above 5 mm. According to EN 1706, section 7.3.3.2, the diameter of a cylindrical test rod should be at least 4.0 mm. When preparing the sample, the casting crust is usually taken off completely. Please take into account that tensile samples from sand-cast components require different dimensions. For example, the minimum diameter specified by EN 1706 is 12 mm. Cylindrical samples (i.e. Treated circular samples) from diecast components are not suitable for tensile testing to determine the mechanical characteristics of a diecast component, as the quickly-formed casting crust on the circular sample would be removed during treatment. If rectangular samples are taken, they should, if possible, involve sidecuts by milling.

The sampling point should be defined with a view to the conclusion required from the test result. Nodes which have thicker walls and therefore tend towards structural faults (micro/macro blowholes and gas porosity) are generally unsuitable as sampling points.

We would always recommend conducting X-rays or similar tests on a suitable number of components before the overall decision on the locations of the sampling points is taken. This is to determine the structural quality of the component that can be achieved through the process, particularly in the areas intended for sampling. Should a reading be faulty, there must be the option of repeating the test, and we therefore recommend specifying, where possible, not only an original sampling point, but also an alternative point where a reference sample can be taken.



5 Analysis of readings

Whenever samples are taken for quality assurance purposes, the analysis of the readings must be preceded by checks whether the result that has been obtained is actually usable or whether there has been a measuring error. A **measuring error** can occur if the test equipment has been set up or calibrated incorrectly, if a human error has occurred in conducting the test or if the sample was unsuitable. It must be borne in mind that identifying a **deviation in measurement** is essentially neutral with regard to functions and users and merely concerns the difference between an actual and target value. All tests involve some level of **inaccuracy**, associated with the measuring process. Subjective and one-off direct readings do not allow the mathematical identification of inaccuracies or, if they do, only with a very low level of certainty. Tensile tests, in particular, may involve inaccuracies caused by impact on the microstructure, especially the breaking elongation. These cannot be determined mathematically through several direct readings or, if so, only with a very low level of certainty. No samples are ever taken under exactly the same circumstances.

5.1. Evaluation of measurement quality and repetition of readings

Before analysing tensile test results, it must be checked whether the results that have been obtained are actually usable. This can largely be determined from the cracked tensile sample itself, or from the recorded sampling process. The standards that have been defined for tensile tests contain various guidelines for this purpose. If samples have been cracked in a way that did not comply with the relevant regulations, the results must not be used in the evaluation, but the tensile test must be repeated with different samples.

In the case of tensile tests on aluminium gravity diecasts, retesting is required under the following circumstances:

- The test rod did not crack in the expected area (e.g. head crack)
- Casting porosity on the fracture surface of the tensile sample exceeds 0.1%.
- Extent of the largest discernible single fault on the fracture surface exceeds 0.5mm.
- Notch-like defects are clearly showing on the surface of the tensile sample.

In the case of tensile tests on aluminium diecast components, retesting is required under the following circumstances:

- The test rod did not crack in the expected area (e.g. head crack)
- Casting porosity on the fracture surface of the tensile sample exceeds 5.0%.
- Extent of the largest discernible single fault on the fracture surface exceeds 0.5 mm.
- Notch-like defects are clearly showing on the surface of the tensile sample.
- Notch-like defects are clearly showing on the fracture surface (e.g. stratifications, double-oxide film defects, early setting).
- Discolouring is clearly showing on the fracture surface of the tensile sample (e.g. brown discolouring).



In the case of tensile tests on aluminium sand-cast components, retesting is required under the following circumstances:

- The test rod did not crack in the expected area (e.g. head crack)
- Casting porosity on the fracture surface of the tensile sample exceeds 1.0%.
- Extent of the largest discernible single fault on the fracture surface exceeds 1.0 mm.
- Notch-like defects are showing on the treated or untreated surface of the tensile sample.

If tensile tests are conducted to verify the efficacy of heat treatment, retesting should always involve components that have been subject to the same heat treatment conditions as the last component on which readings were taken. If retesting becomes necessary, we therefore recommend ensuring the availability of a reasonable number of components from a single heat treatment batch. If the geometric structure of the component permits it, this reference sample should be placed relatively closely to the original sample.

5.2. Statistical evaluation of readings

Experience has shown that the tensile strength values obtained in a tensile test – R_m, R_{p0.2} and A₅ – are subject to certain fluctuations, due to the above-mentioned influences on the casting process as well as how the sample is prepared. If more than 3 tensile samples are taken from a component and tested, the test evaluation for the tensile strength values R_m, R_{p0.2} and A₅ should be conducted on statistical principles.

When evaluating the compliance level of the specified values, the relevant figure will then be the average value of all the tensile samples taken from the same component. For this purpose each value must have delivered a usable outcome at least once. Individual values for clearly identifiable faulty readings must not form part of the evaluation.

EN 1706 says that neither the 0.2 tensile strength nor the tensile strength on the diecasts may drop below 70% of the specified target values.

As regards breaking elongation, the values obtained on the diecasts may be up to 50% below the values listed in the tables in EN 1706. However, neither of these two regulations apply to diecast components. The testing of a component must be considered successful if the average target values for R_m, R_{p0.2} and A₅ have been reached for that component.

The following principle should be applied to diecast components: Individual readings for the 0.2 tensile yield strength, tensile strength and breaking elongation must not fall below 70% of the specified target values. The testing of a diecast component must be considered successful if the average target values for R_m, R_{p0.2} and A₅ have been reached for that component.

6. Guidelines for the documentation of test results

The results of the tensile tests must be documented. Standard material testing machines include integrated software solutions for the purpose, allowing the documentation of both load curves and individual values. To specify the procedure and the evaluation routine for tensile tests in a way that is plausible and mandatory for testers, practical experience has shown that it is reasonable to draw up written test regulations. Please note that such test regulations are normally subject to special document control regulations concerning the drafting process, their entry into force, the implementation of changes and the archiving.



Appendix

Figs. 1 to 4 show test rods that cracked

- in the expected area (left)
- not in the expected area, but in the form of a head crack (right)

(See also section 5.1)



Fig. 1: Cylindrical test rod



Fig. 2: Cylindrical test rod with head crack



Fig. 3: Flat tensile sample



Fig. 4: Flat tensile sample with head crack



Revision note:

Replacement for version:

The following changes have been made compared with the previous version: