

# Situation of standardization in the field of mechanical testing and measurements

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## Abstract

Standardized mechanical test methods are referred in many materials and product standards for the characterization of quality of the materials or products. Mechanical testing is carried out on materials for three different reasons:

- For quality control purposes to ensure that a material conforms to a technical specification or that it has been correctly processed.
- To provide information which can be used in the design of a component or structure.
- As part of investigations into the reasons for failures in service.

Hence the results achieved from the mechanical testing of products that are made of / or from materials are used to help guarantee the safety and reliability of materials which in turn ensures the safety of those products.

The paper gives an overview on the standardization activities of the last ten years for the different fields of mechanical testing as uniaxial, ductility, hardness, toughness and fatigue testing .

## 1 Introduction

In order to work with comparable measured values, standards for mechanical test methods and materials testing machines have been developed. This work started between 1920 and 1930 for the different methods in the different countries. The result was that the national, European and ISO standards partly contain different specifications. Meanwhile it is generally accepted to strive for a complete alignment of standards at all standardization levels. With the application of parallel voting on new draft standards, within ISO and CEN double work will be avoided.

Problems can arise from the intensifying interlining of existing national standards and new supranational standards (ISO/EN). When adopting a supranational standard as a national standard, it must be ensured that the supranational standard adopted e.g. as DIN EN ISO in no way contradict relevant national standards. In most cases the relevant national standard will be cancelled.

However, it might happen that the new EN ISO standard covers only a part of the existing national standard. In these cases it must be decided whether the part not covered by the new EN ISO standard can be abandoned or whether this part contains specifications that must be retained due to their relevance for the national economic region. In the latter case it will be maintained as a so-called "residual standard".

A further important purpose of standardization work is to decrease the measurement uncertainty of the test methods and to give the users of standards guidelines to handle.

With the publication of DIN EN ISO/IEC 17025 "General requirements for the competency of testing and calibrating laboratories", the test or calibration certificates provided by the laboratories shall incorporate the measurement results received including the measurement uncertainty. From these data it shall be possible to gather that the metrological specifications have been fulfilled. Moreover, it shall be ensured that the measurement results are converted back to SI units using a metrological chain.

## **2 Uniaxial testing**

(ISO/TC 164/SC1, ECISS/TC 1, DIN/NMP 142, DIN/NMP 143, DIN/NMP 811)

### **2.1 General**

Among the uniaxial force tests appear the tensile test which can be considered as the most common and used mechanical test and has been applied for a long time. The properties, which can be derived from tensile tests, can be directly used for the characterisation and acceptance of metallic materials and the design of numerous structures and equipment used in different application fields for which the properties given by creep testing can also be taken into account.

It is essential to have International Standards applied all around the world for this type of testing and relevant methods of verification and calibration of corresponding testing machines in order to avoid technical barriers in trade.

The International Standards developed by ISO/TC 164/SC 1 and ECISS/TC 1 also have to take into account the evolution of technology as far as testing machines with computer assistance are concerned. The uncertainty issues must be addressed in the standards concerning test methods and testing machines to get more accurate information about the metallic materials.

### **2.2 Tensile testing (NMP 142)**

Table 1 shows the situation for the standardization of the tensile test.

For the time being we have separate standards at the ISO- and CEN level which are corresponding for about 90 %. Unfortunately the secretariat of AFNOR (France) which is responsible for the ISO and ECISS (CEN) work could not arrange a parallel work on this standard in the past. So the latest version of EN 10002-1: 2001 was revised on the basis of ISO 6892 : 1998 but contain a revised annex for the measurement uncertainty and a new annex containing recommendations for the use of computer controlled tensile testing machines.

At the European level since 1999 a working group was established with the aim to revise the existing specifications for the testing rate to reduce the tolerances for a better comparison of the test results and to apply only the strain rate as the testing rate.

These results of the European working group were also presented at the meeting of ISO/ TC 164/SC 1 in September 2001 in Torino and the delegates decided to take it into account for the next revision of ISO 6892 in 2003 and apply the parallel voting procedure in ISO and CEN. In future time there will be only one uniform standard for tensile testing.

A detailed description is given in [1].

### **2.3 Creep testing (NMP 143)**

Table 2 shows the situation for this field.

Over a long time the standardization work was under the ISO level "standstill". In Europe the committee ECISS/ TC 1 decided to combine the test method for the non-interrupted and the interrupted creep test. So EN 10291 was published in 2000. This could be the basis for the future revision of ISO 204 which shall be proceeded in 2002.

Interesting in this field is the New Work Item in ECISS/ TC 1 about the stress relaxation testing, the standards number is prEN 10319 with two parts :

- test method in testing machines and
- test method with bolt models.

### **2.4 Verification and calibration of materials testing machines (NMP 811)**

Table 3 shows the international and European situation, see also [2]. After the publication of DIN EN ISO 7500-1 in November 1999, DIN/NMP 811 prepared three national supplements to allow the withdrawal of the corresponding national standards.

With the publication of DIN EN ISO 7500-1 which replaces DIN EN 10002-2, DIN/NMP 811 decided to withdraw some German national standards and to integrate those specifications in the national Supplements to DIN EN ISO 7500-1.

For the standards for verification and calibration of testing machines table A.1 of DIN 51220 (draft 2002) gives a complete overview. This table contains the valid international and European standards, the withdrawn DIN standards and the new and necessary German supplements or national annexes.

**Table 1** – Overview on standards for the tensile test

Standard N° DIN	Title	ISO Standard N°	EN Standard N°	DIN EN ISO Standard N°
50145	Test method	6892:1988	10002-1: 2001:05 <sup>b</sup>	
50125	Test pieces <sup>a</sup>			
50114	Test method for sheets	Annexes A, C	Annexes B, D	
50140	Test method for tubes	Annex D	Annex E	
51210-1/-2	Test method for wires	Annexes B, C	Annexes C, D	
50145	Test method High Temp.	783:1999	10002-5: 1992	
	Test method Low Temp.	15579:2000	-	DIN ISO 15579
<sup>a</sup> succession edition 1991-04 <sup>b</sup> contains annex A regarding computer controlled testing machines  withdrawn edition  residual standard  valid standards				

**Table 2** – Overview on standards for creep testing

Title	ISO	ECISS	DIN
Non interrupted test method	ISO/R 204 : 1961 <sup>a</sup> ISO 204 : 1997	EURONORM 123-75 <sup>a</sup>	DIN prestandard DVMA 118 : 1937 <sup>a</sup> DIN 50118 : 1952 <sup>a</sup> DIN 50118 : 1982 <sup>a</sup>
Interrupted test method	ISO/R 203 : 1961	EN 10291 : 2000	DIN EN 10291 : 2000b
Creep testing machines	ISO 7500-2 : 1996	EN ISO 7500-2 : 1999	DIN 51226 : 1977 <sup>a</sup> DIN EN ISO 7500-2 : 1999
Tensile stress relaxation test		prEN 10319 - Part 1:2000-10 <sup>c</sup>	E DIN EN 10319:2001-01
<sup>a</sup> withdrawn standards <sup>b</sup> amended with supplement 1 „Advises for the application of the standard“ <sup>c</sup> procedure with testing machines; Part 2 : Procedure with bolt model (in preparation)			

**Table 3** – Overview on standards for verification and calibration of materials testing machines

DIN Standard-No.	ISO Standard-No.	EN Standard-No.	DIN EN ISO Standard-No.
<b>EN 10002-2 :1993-07</b>	7500-1 : 1999-09	<b>10002-2 : 1991-09</b>	7500-1 : 1999-11
			Supplement 1 <sup>a</sup> , 2 <sup>b</sup> , 3 <sup>c</sup>
<b>51301 : 1986-02</b>			
EN 10002-3 : 1994-08	376 : 1999-08	10002-3 : 1994-05	376 : 2002-... <sup>f</sup>
Supplement 1 <sup>d</sup>			
EN 10002-4 : 1995-01	9513 : 1999-04	10002-4 : 1994-11	9513 : 2002-... <sup>f</sup>
Supplement 1 <sup>e</sup>			
<sup>a</sup> Tension-, compression- and bending testing machines		<sup>d</sup> Indications for application	
<sup>b</sup> Spring testing machines		<sup>e</sup> Examples for extensometers	
<sup>c</sup> Fatigue testing machines		<sup>f</sup> in preparation	
 <b>withdrawn editions</b>			

### 3 Ductility testing

(ISO/TC 164/SC2, ECISS/TC 1, DIN/NMP 142)

The recent development of the ductility tests is orientated to more modern methods of testing, enabling more effective use of metallic materials and their assessment from the point of view of their formability and their behaviour during technological treatment. The tests are also used as technological tests for forming of metals. The standards are used by: manufacturers of products (wires, sheets, tubes etc.) materials experts, main users of metallic products, testing laboratories, research institutes and producers of testing equipment.

Most of the German national standards are replaced by European and international standards. There is only the necessity for the revision of the Erichsen Cupping Test (ISO/DIS 20482), taking into account thicker and more narrow sheets (content of DIN 50101-2 and DIN 50102). This revision is now in progress.

### 4 Hardness testing

(ISO/TC 164/SC3, ECISS/TC 1, DIN/NMP 141)

#### 4.1 General

Hardness testing methods are longest applied and well known test methods for metallic materials.

In order to work with comparable measured values, standards of hardness testing methods have been developed. This work started in the beginning of 1930. National, European and ISO standards partly contain different specifications. Another purpose of standardization work is to decrease the uncertainty of test methods. With this target in mind the department of Materials Testing of DIN took over the secretariat of the responsible ISO-Committee ISO/TC 164/SC 3 "Hardness testing of metallic materials" in 1994, aiming to achieve the identity of world-wide ISO-Standards with European and other national standards.

In 1994, at the first meeting hosted by the new DIN secretariat, the following important resolutions for the general working procedure were approved:

- SC 3 decided that in the frame of the systematic ISO-5-years revision all documents related to a specific hardness test are to be considered at the same time, i. e. the test method, the verification and calibration of testing machines and the calibration of reference blocks. This format would ensure the same revision date for all documents related to a specific hardness test (see table 4).
- SC 3 decided that for the future revisions one ISO standard number is assigned to a specific hardness test with the Part numbers 1, 2 and 3 assigned to the above mentioned three parts (see table 4).
- SC 3 decided the application of the Vienna Agreement between ISO and CEN for the future revision of all Hardness Testing Standards.

The result of the ISO standardization work over the last years under the German secretariat is now the publication of the uniform revised hardness testing standards for Vickers, Brinell and Rockwell.

#### **4.2 Vickers, Brinell and Rockwell Hardness Tests**

The essential amendments again the previous editions of the above mentioned standards, see [3].

#### **4.3 Macro Rockwell Hardness Test**

The standardization work on this item started in 1989. Because of the changing of the ISO/TC 164/SC 3 secretariat in 1994 ISO/DIS 11700 was published in 1996. During the examination of the DIS voting the discussion in ISO/TC 164/SC 3 showed that since the beginning of this standardization work the interest in Macro Rockwell Hardness Testing has been strongly decreasing.

In accordance with the principle of standardization work - is there a technical necessity for the development of a standard? - it was decided at the meeting of ISO/TC 164/SC 3 in 1997 to delete this item from the programme of work.

#### **4.4 Instrumented Indentation Test (Universal Hardness)**

This Work Item was approved in 1993 and it was decided to start this work as a Technical Report, because it was felt necessary to get more experience in this field of prenormative work. This Technical Report was published in 1995 as ISO/TR 14577. According to the ISO rules for Standardization work the responsible Technical Committee must decide three years after the publication of the TR and the transformation of this TR to a standard or if this TR should be withdrawn.

In 1997 ISO/TC 164/SC 3 decided to work on this item and to develop an International Standard. For this reason an international working group under the convenorship of Dr. K.-H. Behncke was created. The first drafts were discussed at the SC 3 meeting in June 1998 and contain the following aspects:

- New title: "Instrumented Indentation Test for Hardness and other Materials Parameters"
- Specification of the scope
- Possibilities of characterization of the materials parameters as: e.g. Universal and Indentation hardness and plastic and elastic parts of the indentation work.

In between in 2001 ISO/TC 164/SC 3 decides to change the designation "Universal hardness" into "Martens hardness"(see [4]).

The publication of ISO 14577 is scheduled until the end of 2002.

Also other technical committees as ISO/TC 107/SC 2/WG 1 "Microhardness" and CEN/ TC 184/WG 5 "Testing of ceramic coatings" are involved in this standardization work and at the meeting of ISO/TC 164/SC 3 on 17/18 September 2001 it was decided to create a part 4 of ISO 14577 "Test method for coatings".

A complete description of this standardization work is given in [5,6].

**Table 4** – Overall view on hardness testing standards for metallic materials

Test method	First		Title	Actual		Residual standard (DIN)	Actual stage of work
	Standard No.	Edition		Standard No.	Edition		
Brinell	6506	1981	Test Method	6506-1	ISO 1999-09 DIN EN ISO 1999-10		Revision is prepared beginning 2002
	156	1982	Testing machines	6506-2		Supplement 1	
	726	1982	Reference blocks	6506-3		Supplement 1	
	410	1982	Tables	Containing in 6506-1			
Vickers	6507-1	1982	Test Method HV 5 to 100	6507-1	ISO 1997-11 DIN EN ISO 1998-01		Revision is prepared beginning 2002
	6507-2	1983	Test Method HV 0,2 to < 5				
	6507-3	1989	Test Method HV 0,2				
	146	1989	Testing machines HV 0,2 to 100	6507-2		Supplement 1	
	146-2	1993	< HV 0,2				
	640	1984	Reference blocks HV 0,2 to 100	6507-3		Supplement 1	
	640-2	1993	Reference blocks < HV 0,2				
	409-1	1992	Tables HV 5 to 100	Containing in 6507-1			
409-2	1983	Tables HV 0,2 to < 0,5					
409-3		Tables HV < 0,2					
Rockwell	6508	1986	Test Method scales A-K	6508-1	ISO 1999-09 DIN EN ISO 1999-10	DIN 50103-3	Revision is prepared beginning 2002
	1024	1989	Test Method scales N/T				
	716	1986	Testing machines scales A-K	6508-2		Supplement 1	
	1079	1989	Testing machines scales N/T				
	674	1988	Reference blocks scales A-K	6508-3		Supplement 1	
1355	1989	Reference blocks scales N/T					
Knoop	4545	1993	Test Method	4545	1993		Revision is prepared as ISO 4545-1, -2, -3, -4 beginning 2002
	4546	1993	Testing machines	4546			
	4547	1993	Reference blocks	4547			
	10250	1993	Tables	10250			
Instrumented indentation test	TR 14577 DIN 50359	1995	Test Method	FDIS 14577-1	2002-....		Publication is scheduled until end of 2002  A part 4 " Test method for coatings" will be prepared
	Testing machines		FDIS 14577-2				
	Reference blocks		FDIS 14577-3				
	18265	2000	Hardness conversion (Basis DIN 50150 : 2000)	DIS 18265	2002-....		

#### **4.5 Hardness conversion**

Since 1994 there were intensive discussions in the German committee NMP 141 referring to the revision or the confirmation of DIN 50150. The question was if another publication form would be better to avoid the problems some of the users had in the past with the application of the standard taking into account all the necessary informations.

The result was to revise DIN 50150 completely and the standard was expanded as follows:

- The main part of the standard contains general for the conversion and for the application of the conversion tables, amended by the conversion tables as annexes A to F.
- The user of the standard should take into consideration the warning in clause 3 where the attention is drawn to the risk for the use of converted hardness- or strength values (see also [7]).
- The publication of DIN 50150 was in 2000.

On the basis of the English version of DIN 50150 a New Work Item was created in ISO/TC 164/SC 3 and the draft standard ISO/ DIS 18265 will be published in 2002 with the application of the parallel voting in ISO and CEN.

#### **4.6 Summary for hardness**

A review of the standardization work in the field of hardness testing over the last 10 years shows that it was reached a good success to have now world-wide uniform standards for hardness testing.

But what are the main topics for the future work?

- With the publication of DIN EN ISO/ IEC 17025 the calibration certificates shall contain also the measurement uncertainty.  
It is a future work of the committee to decide how this can be introduced in the standards.
- A further item is the increase of the reliability of hardness testing machines. First proposals for the automatic registration and evaluation of periodic checks are given in [8].

### **5 Toughness testing**

(ISO/TC 164/SC4, ECISS/TC 1, DIN/NMP 146 for "fracture toughness" and DIN/NMP 144 for "pendulum")

#### **5.1 Fracture Toughness (NMP 146)**

##### **5.1.1 General**

The essential elements of fracture toughness testing are: first, reproducible simulation of the stress and displacement fields surrounding the crack or crack-like defect presumed to be contained in the structure, second, fiducial replication of the structural loading and service environment, and third, characterisation of the crack fields in terms that can be used directly in design or remedial procedures. The discipline is called fracture mechanics and is a relatively new technical discipline having been developed entirely within the past half century.

##### **5.1.2 Situation**

In the field of fracture toughness the German responsible committee NMP 146 only take part in the ISO work. Following items are in progress:

- ISO 12737 Metallic materials – Determination of plane–strain fracture toughness published 1996, DIN EN ISO 12737: 1999-04
- ISO/DIS 12135 Metallic materials – Unified method of test for the Determination of quasistatic fracture toughness, 2002 waiting for F/DIS
- ISO/CD 15653 Metallic materials – Method of test of fracture toughness of welds, 1999
- New Work Item: Metallic materials – Method of test for the Determination of resistance to stable crack extension using specimens of low constrain, 1999.

## **5.2 Pendulum (NMP 144)**

### **5.2.1 General**

Charpy impact testing is often specified in contracts as an acceptance test for structural materials. In addition, Charpy testing is required to meet requirements such as: first, national codes such as ASME Boiler and Pressure Vessel Code in the United States, second, to insure new and repaired ships with Lloyd's of London.

The Charpy V-notch (CVN) test specimen and associated test procedure is an effective cost-saving tool for the steel industry. The specimen is relatively easy to prepare, many specimens can be prepared at one time, various specimen orientations can be tested, and relatively low cost equipment is needed to test the specimen.

A historical overview about the development of the standardization work for the Charpy test is given in [9].

### **5.2.2 Situation for the standardization of the Charpy impact test**

Based on the „Grundsätze zur Schlagprüfung“ (DVM) , in Germany DIN 50115 was published in 1937 because there were enough experiences for this test method to show the influence of deformation, heat treatment, application temperature and aging for steel.

In the United States ASTM E-23T was published in 1933 and the development of the American standardization work is detailed described in [10].

An overview about the standardization work on the different levels gives table 5.

### **5.2.3 Test Method**

In Germany in 1991 DIN 50115 was withdrawn with the publication of DIN EN 10045-1. The difference between these two standards is the number of different test piece geometries. The DVM and KLST test pieces in DIN 50115 are not content of DIN EN 10045-1. For this reason a residual standard DIN 50115 was published which contains special test piece geometries and special evaluation methods e.g. for fracture surfaces.

The comparison between the ISO standards (ISO 148 and ISO 83) and EN 10045-1 shows the correspondence for the V-notched test pieces, but for the U-notched test pieces in ISO 83 a tolerance for the right-angled test piece cross section is not specified.

Since 1966 in ISO/TC 164/SC 4 P the standardization work is focused on the combination of ISO 148 and ISO 83 as ISO/DIS 148-1 which is not published until now. This draft will be proceeded with the application of the parallel voting in ISO and CEN.

### **5.2.4 Reference test pieces**

DIN EN 10045-2 requires the indirect calibration of pendulum impact testing machines with the application of reference test pieces. This is also specified in ISO 148-3.

This procedure of the indirect calibration of the testing machines in Germany needs about 10000 reference test pieces per year. This amount of reference test pieces is not available for the time being from " Community Bureau of Reference" (BCR) and for this reason the German standardization committee NMP 811 recommended to carry out only the direct verification and calibration of pendulum impact testing machines.

### **5.2.5 Instrumented Charpy test**

Since 1950 complementary devices to carry out the instrumented Charpy test exist and are commercially available. At the international level some specifications exist, but no standards. About 20 European laboratories applied the two German specifications (see table 5) successful. For this reason Germany proposed in 1994 a New Work Item in ISO/TC 164/SC 4 P "Steel – Charpy V-notch pendulum impact test – Instrumented test method" with the application of the parallel voting in ISO and CEN.

DIN EN ISO 14556 was published in September 2000, see also table 5.

**Table 5**– Overview on ISO, EN and DIN standards for pendulum impact test

Tittle	DIN		ISO		EN	
	Number	Shape of test piece	Number	Shape of test piece	Number	Shape of test piece
Test method	50115 : 1975-02	ISO-V ISO-U DVM DVM F DVM K KLST	148 : 1983 83 : 1976	ISO-V ISO-U	10045-1 : 1991-04	ISO-V ISO-U
		DIS 148-1 : ????	ISO-V ISO-U			
	50115 : 1991-04	Special test pieces and evaluations DVM DVMK KLST				
Verification of pendulum impact machines	51306 : 1983-09		R 442-1965		10045-2 : 1993-01	
Requirements on pendulum impact machines	51222 : 1985-01		148-2 : 1998			
	51222 : 1995-06 <sup>a</sup>					
Preparation of reference test pieces			148-3 : 1998		Annex B in EN 10045-2	
Instrumented Charpy test	in Germany valid regulations: DVM 001 SEP 1315		EN ISO 14456 : 2000			
	EN ISO 14556 : 2000-09					

<sup>a</sup> only for testing machines with  $\leq 50$  J.

	Residual standards		Withdrawn standards		Now valid standards and drafts
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### 5.2.6 Summary for impact testing

The development of the standardization work for impact testing over the last 10 years shows that it was only possible for the instrumented Charpy test to apply the parallel voting in ISO and CEN to get a uniform standard all over the world.

For the future work it is important:

- to work actively at the ISO level and to transfer these ISO standards to EN standards,
- to include the measurement uncertainty into the test result and into the calibration certificates of the testing machines.

This second item should be a New Work Item in ISO/TC 164/SC 4.

## 6. Fatigue testing

(only ISO/TC 164/SC 5)

Because there is no interest of the German industry to support this field of standardization work the responsible DIN committee NMP 145 was cancelled in 1998.

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