TENSION TEST

This test measuresthe load, applied by mechanical or hydraulic test equipment, necessary to rapture a specimen. The test is performed at room temperature.
The specimen properties and the procedures for testing are defined in the "standard" EN 10002-1and ASTM A370. After testing, the relevant results are recorded.
Specimens are obtained by machining specific sample shapes from product to be tested, or in case of bar up to certain diameters and wire testing is carried out without machining.
Generally the specimen has a round cross section, but hexagon and square profiles not machined are tested in their section as produced.
The proportional specimen have a starting lenght L_0 according to the European norm, proportional to starting section S_0:

$$L_0 = 5.65\,S_0$$

For diameters lower than 4 mm ($L_0 < 20$ mm) 100 mm length no proportional specimens are used, independently by starting section area.

BY TENSION TEST IS POSSIBLE TO DETERMINATE THE FOLLOWING MACHANICAL PROPERTIES:

Magnitude	Symbol	Measurement unit	Description
Tensile strength	R_m	MPa (N/mm^2)	it is the ratio between the maximum applied force and the original cross-sectional area of the specimen
Upper yield strength	R_s	MPa (N/mm^2)	it is detectable only when the material has the yield phenomenon (it doesn't exist for the cold drawn and the stainless steels)
Yield point	R_p	MPa (N/mm^2)	it is detectable on cold drawn and stainless steel, in place of R_S
	$R_{p(0,2)}$	MPa (N/mm^2)	load corresponding to a no proportional charge equal to a 0,2% of length L_0
	$R_{p(1,0)}$	MPa (N/mm^2)	load corresponding to a no proportional charge equal to a 1% of length L_0
Elongation	A	%	permanent elongation of length L_0, expressed in per cent of length L_0
	A_5	%	permanent elongation for proportional specimens with length L_0 equal to 5 times diameter
	A_4	%	permanent elongation for proportional specimens with length L_0 equal to 4 times diameter
	A_0	%	permanent elongation for proportional specimens with length L_0 equal to 100 mm (used for diameter lower than 4mm)
Reduction area	Z	%	Ratio between the maximum variation of area of transverse section and area of initial section S_0, expressed in per cent

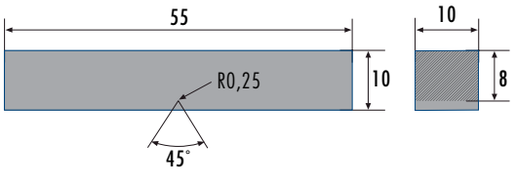
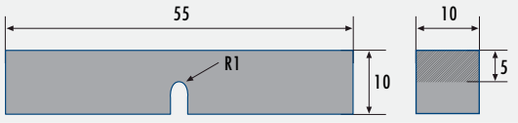
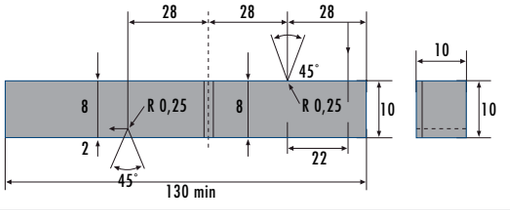
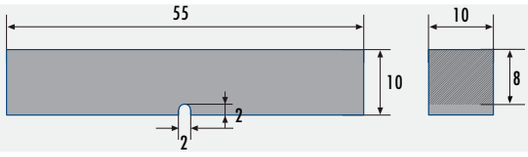
HARDNESS TEST

The hardness can be definied like the resistance opposed bu material to penetration of a body. The hardness tests are different in the shape of penetrator, the applied loads and the procedures of measurement: the details are descrbed on the relevant standards.
The hardness tests are carried out on a float specimen surface, after appropiate surface preparation. The indentations shall have a minimum distance from the edge of the specimen and between them.

Hardness test and reference standard	Symbol and examples	Description
Brinell UNI EN ISO 6506-1	HB	a penetrator (carbide ball with diameter "D") is pressed into the surface of a specimen under a load "F" (in Newtons). After removal of the load , the diameter "d" of the indentation is measured. The hardness is proportional to the ratio between indentation surface (spherical cap pressed area) and applied load according to formula: $HB = 0{,}102 \cdot \frac{2F}{\pi D\,(D-\sqrt{D^2-d^2})}$ in case of steels, the ratio between load and sphere diameter shall satisfy the following condition: $0{,}102\,\frac{F}{D} = HB$ the depth indentations "h" is also proportional to its diameter: $h = \frac{D-\sqrt{D^2-d^2}}{2}$
	HB 10/3000	Brinell hardness measured with 10 mm diameter ball and with load of 29,42 kN (equal to 3000 kgf)
	HB 2,5/187,5	Brinell hardness measured with 2,5 mm diameter ball and with load of 1,839 kN (equal to 187,5 kgf)
Vickers UNI EN ISO 6507-1: 99	HV	a pyramidal diamond penetrator (square base & vertex angle of 136°) is pressed into the surface of a specimen under a load "F" (in Newton). After removal of the load, the diagonal dimension "d" of the indentation is measured. The hardness is proportional to the ratio between indentation surface (spherical cap pressed area) and applied load according to formula: $HV = 0{,}1891\,\frac{P}{d^2}$ it's possible to apply a very low load on surface polished, up to measure the hardness of single constituents of structures
	HV30	Vickers hardness measured by load of 294,3 N (equal to 30 kgf)
	HV1	Vickers hardness measured by load of 9,81 N (equal to 1 kgf)
	HV 0,1	Vickers hardness measured by load of 0,98 N (equal to 0,1 kgf)
Rockwell UNI EN ISO 6508-1: 99	HR	a penetrator (diamond cone of 120° or steel ball of 1,5875 mm diameter) is pressed in two stages of into the surface of a specimen under a total load (preload F_0 and final load F_1) of "F" (in Newtons). The depth difference "h" between the penetration under the preload to the depth under the final load is measured. The hardness is proportional to the difference between a costant number "N" (depending on scale used) and the difference "h" following to formula: $HR = N \cdot \frac{h}{0{,}02}$
	HRC	Rockwell hardness made with diamond cone and total load "F" of 1471 N (150 kgf). Used from 20 to 70 HRC
	HRB	Rockwell hardness made with diamond cone and total load "F" of 980,7 N (100 kgf). Used from 20 to 100 HRB
	HRA	Rockwell hardness made with diamond cone and total load "F" of 588,4 N (60 kgf). Used from 20 to 88 HRA

CHARPY IMPACT TEST

The impact strength is the material's capability to resist impacts. The test is a dynamic test in which a notched specimen (see table below) is struck and broken by a single blow of a freely swinging pendulum. The pendulum is standardized (most are used in accordance to European - EN - and American - ASTM - standard) able to generate an energy generally equal to 300 J. The test is made at room temperature or often at low temperature to verify if in that condition the material has brittle behavior. The test result is expressed as absorbed energy (J) during the stroke to break the specimen.

SYMBOL	Name	Specimen geometry	L (mm)	T (mm)	H (mm)	B	C	R	D
KV	Charpy V		55	10	10	8	0,8	0,25	45
KCU	Charpy U		55	10	10	5	0,5	1	-
IZOD	Izod V		75 (1 notch) 100 (2 notches) 130 (3 notches)	10	10	8	0,8	0,25	45
-	Mesnager		55	10	10	8	0,8	1	-

KEY:
L = length - **T** = thickness - **H** = height - **B** = height section no notched - **C** = nominal test section (cm^2) - **R** = notch radius - **D** = notch angle

IMPACT TEST VALUES CONVERSION

Due to considerable effect of test parameters on impact strength, the values conversion obtained by several kind of specimen is very empirical (it is supposed that fracture behavior is the same) and is used only for qualitative analysis.

KV	KCU	Izod	Mesnager
9	21	35	47
30	20	50	67
51	39	65	87
72	48	80	107
93	57	95	127
114	66	110	147
135	75	125	167
156	84	140	187

KV	KCU	Izod	Mesnager
177	93	155	207
198	102	170	227
219	111	185	247
240	120	200	267
261	129	215	287
282	138	230	307
303	147	245	327
-	-	-	-

values expressed in Joule (J)

COMPARISON AMONG HARDNESS VALUES OBTAINED FROM DIFFERENT SYSTEM

Among the different hardness scales it is possible to establish only a rough and empirical comparison, except for a connection between Brinell and Vickers hardness. Also the comparisons between hardness and tensile strength are rough.
In any case, the table below reports these comparisons, as result of various historical tables and of tests made in our laboratory.

ATTENTION: this table is not applicable to austenitic stainless steels

CONVERSION TABLE

∅ (mm)	HB_{3000}	HV	HRB	HRC	R_m (MPa)
6,67	75	79	-	-	250
6,63	76	80	-	-	255
6,56	78	82	-	-	260
6,52	79	84	-	-	265
6,45	81	85	41	-	270
6,42	82	87	-	-	275
6,35	84	88	45	-	280
6,32	85	90	48	-	285
6,25	87	91	49	-	290
6,22	88	93	-	-	295
6,16	90	94	51	-	300
6,13	91	96	52	-	305
6,07	93	97	54	-	310
6,04	94	99	-	-	315
5,99	96	101	56	-	320
5,96	97	102	-	-	325
5,91	99	104	58	-	330
5,88	100	105	59	-	335
5,85	101	107	60	-	340
5,80	103	108	-	-	345
5,78	104	110	62	-	350
5,73	106	111	-	-	355
5,70	107	113	63,5	-	360
5,66	109	114	-	-	365
5,63	110	116	64,5	-	370
5,59	112	118	-	-	375
5,56	113	119	66	-	380
5,52	115	121	67	-	385
5,50	116	122	67,5	-	390
5,46	118	124	-	-	395
5,44	119	125	69	-	400
5,39	121	127	-	-	405
5,37	122	128	70	-	410
5,33	124	130	71	-	415
5,31	125	131	72	-	420
5.30	126	133	-	-	425
5,26	128	135	73	-	430
5,24	129	136	-	-	435

∅ (mm)	HB_{3000}	HV	HRB	HRC	R_m (MPa)
5,20	131	138	74	-	440
5,18	132	139	-	-	445
5,15	134	141	75	-	450
5,13	135	142	-	-	455
5,09	137	144	76,5	-	460
5,08	138	145	77	-	465
5,04	140	147	77,5	-	470
5,03	141	149	-	-	475
4,99	143	150	78,5	-	480
4,98	144	152	-	-	485
4,95	146	153	79,5	-	490
4,93	147	155	80	-	495
4,92	148	156	81	-	500
4,88	150	158	-	-	505
4,87	151	159	81,5	-	510
4,84	153	161	-	-	515
4,83	154	162	82,5	-	520
4,80	156	164	-	-	525
4,78	157	166	83	-	530
4,75	159	167	-	-	535
4,74	160	169	84,5	-	540
4,71	162	170	85	-	545
4,70	163	172	85,5	-	550
4,67	165	173	-	-	555
4,66	166	175	86	-	560
4,63	168	176	-	-	565
4,62	169	178	86,5	-	570
4,59	171	179	87	-	575
4,58	172	181	-	-	580
4,57	173	183	-	-	585
4,54	175	184	88	-	590
4,53	176	186	-	-	595
4,51	178	187	89	-	600
4,50	179	189	-	-	605
4,47	181	190	89,5	-	610
4,46	182	192	-	-	615
4,44	184	193	90	-	620
4,43	185	195	-	-	625

CONVERSION TABLE

∅ (mm)	HB_{3000}	HV	HRB	HRC	R_m (MPa)
4,40	187	196	91	-	630
4,39	188	198	-	-	635
4,37	190	200	91,5	-	640
4,36	191	201	-	-	645
4,34	193	203	92	-	650
4,33	194	204	-	-	655
4,31	196	206	92,5	-	660
4,30	197	207	-	-	665
4,29	198	209	93	-	670
4,27	200	210	93,5	-	675
4,26	201	212	-	-	680
4,24	203	213	-	-	685
4,23	204	215	94	-	690
4,21	206	217	-	-	695
4,20	207	218	-	-	700
4,18	209	220	95	-	705
4,17	210	221	95,5	-	710
4,15	212	223	-	-	715
4,14	213	224	96	-	720
4,12	215	226	-	-	725
4,11	216	227	-	-	730
4,09	218	229	-	-	735
4,09	219	231	96,5	-	740
4,07	221	232	-	-	745
4,06	222	234	97	-	750
4,05	223	235	-	-	755
4,03	225	237	97,5	-	760
4,02	226	238	-	-	765
4,01	228	240	98	20	770
4,00	229	241	-	-	775
3,98	231	243	-	21	780
3,97	232	244	-	-	785
3,96	234	246	99	-	790
3,95	235	248	-	-	795
3,93	237	249	99,5	22	800
3,93	238	251	-	-	805
3,91	240	252	-	-	810
3,90	241	254	-	-	815
3,89	243	255	-	23	820
3,88	244	257	-	-	825
3,86	246	258	-	-	830
3,86	247	260	-	24	835
3,85	248	261	-	-	840
3,83	250	263	-	-	845

∅ (mm)	HB_{3000}	HV	HRB	HRC	R_m (MPa)
3,83	251	265	-	-	850
3,81	253	266	-	-	855
3,81	254	268	-	25	860
3,79	256	269	-	-	865
3,78	257	271	-	26	870
3,77	259	272	-	-	875
3,76	260	274	-	-	880
3,75	262	275	-	-	885
3,74	263	277	-	-	890
3,73	265	278	-	-	895
3,72	266	280	-	27	900
3,71	268	282	-	-	905
3,70	269	283	-	-	910
3,69	271	285	-	-	915
3,68	272	286	-	28	920
3,68	273	288	-	-	925
3,66	275	289	-	-	930
3,66	276	291	-	-	935
3,64	278	292	-	29	940
3,64	279	294	-	-	945
3,63	281	295	-	-	950
3,62	282	297	-	-	955
3,61	284	299	-	-	960
3,60	285	300	-	-	965
3,59	287	302	-	30	970
3,58	288	303	-	-	975
3,57	290	305	-	-	980
3,56	291	306	-	-	985
3,55	293	308	-	-	990
3,55	294	309	-	31	995
3,54	295	311	-	-	1000
3,53	297	312	-	-	1005
3,52	298	314	-	-	1010
3,51	300	316	-	-	1015
3,51	301	317	-	32	1020
3,50	303	319	-	-	1025
3,49	304	320	-	-	1030
3,48	306	322	-	-	1035
3,47	307	323	-	-	1040
3,46	309	325	-	-	1045
3,46	310	326	-	33	1050
3,45	312	328	-	-	1055
3,44	313	330	-	-	1060
3,43	315	331	-	-	1065

CONVERSION TABLE

∅ (mm)	HB_{3000}	HV	HRB	HRC	R_m (MPa)
3,43	316	333	-	-	1070
3,41	318	334	-	-	1075
3,41	319	336	-	34	1080
3,40	320	337	-	-	1085
3,39	322	339	-	-	1090
3,39	323	340	-	-	1095
3,38	325	342	-	-	1100
3,37	326	343	-	-	1105
3,36	328	345	-	35	1110
3,36	329	347	-	-	1115
3,35	331	348	-	-	1120
3,34	332	350	-	-	1125
3,33	334	351	-	-	1130
3,33	335	353	-	-	1135
3,32	337	354	-	36	1140
3,32	338	356	-	-	1145
3,31	340	357	-	-	1150
3,30	341	359	-	-	1155
3,29	343	360	-	-	1160
3,29	344	362	-	-	1165
3,28	345	364	-	37	1170
3,27	347	365	-	-	1175
3,27	348	367	-	-	1180
3,26	350	368	-	-	1185
3,25	351	370	-	-	1190
3,25	353	371	-	-	1195
3,24	354	373	-	38	1200
3,23	357	376	-	-	1210
3,22	360	379	-	-	1220
3,20	363	382	-	39	1230
3,19	366	385	-	-	1240
3,18	369	388	-	-	1250
3,16	372	391	-	40	1260
3,15	374	394	-	-	1270
3,14	377	397	-	-	1280
3,13	380	400	-	-	1290
3,12	383	403	-	41	1300
3,10	387	407	-	-	1310
3,09	390	410	-	-	1320
3,08	393	413	-	-	1330
3,07	395	416	-	-	1340
3,06	398	419	-	-	1350
3,05	401	422	-	43	1360
3,04	404	425	-	-	1370

∅ (mm)	HB_{3000}	HV	HRB	HRC	R_m (MPa)
3,03	407	429	-	-	1380
3,02	410	432	-	-	1390
3,01	413	435	-	44	1400
3,00	416	438	-	-	1410
2,99	418	440	-	-	1420
2,98	421	443	-	-	1430
2,97	424	446	-	45	1440
2,96	427	449	-	-	1450
2,95	429	452	-	-	1460
2,94	432	455	-	-	1470
2,93	435	458	-	46	1480
2,92	438	461	-	-	1490
2,91	441	464	-	-	1500
2,90	444	467	-	-	1510
2,89	447	470	-	-	1520
-	449	473	-	47	1530
2,88	452	476	-	-	1540
2,87	455	479	-	-	1550
2,86	(457)	481	-	-	1560
2,85	(460)	484	-	48	1570
-	(462)	486	-	-	1580
2,84	(465)	489	-	-	1590
-	(467)	491	-	-	1600
2,82	(470)	494	-	-	1610
-	(472)	497	-	49	1620
-	(475)	500	-	-	1630
2,80	(478)	503	-	-	1640
2,79	(481)	506	-	-	1650
-	(483)	509	-	-	1660
-	(486)	511	-	-	1670
2,77	(488)	514	-	50	1680
2,76	(491)	517	-	-	1690
2,75	(494)	520	-	-	1700
-	(496)	522	-	-	1710
2,74	(499)	525	-	-	1720
-	(501)	527	-	51	1730
2,73	(504)	530	-	-	1740
-	(506)	533	-	-	1750
2,71	(509)	536	-	-	1760
-	(512)	539	-	-	1770
-	(514)	541	-	-	1780
2,69	(517)	544	-	52	1790
-	(520)	547	-	-	1800
2,68	(523)	550	-	-	1810

CONVERSION TABLE

∅ (mm)	HB_{3000}	HV	HRB	HRC	R_m (MPa)
2,67	(525)	553	-	-	1820
-	(528)	556	-	-	1830
2,66	(531)	559	-	-	1840
2,65	561	(533)	-	53	1850
-	564	(536)	-	-	1860
2,64	567	(539)	-	-	1870
-	570	(542)	-	-	1880
2,63	572	(543)	-	-	1890
2,62	575	(546)	-	-	1900
-	578	(549)	-	54	1910
2,61	580	(551)	-	-	1920
2,60	583	(554)	-	-	1930
-	586	(557)	-	-	1940
2,59	589	(560)	-	-	1950
-	591	(562)	-	-	1960
2,58	594	(564)	-	-	1970
-	596	(567)	-	55	1980
2,57	599	(569)	-	-	1990
2,56	602	(572)	-	-	2000
-	605	(575)	-	-	2010
2,55	607	(577)	-	-	2020
-	610	(580)	-	-	2030
2,54	613	(582)	-	-	2040
-	615	(584)	-	56	2050
2,53	618	(587)	-	-	2060

∅ (mm)	HB_{3000}	HV	HRB	HRC	R_m (MPa)
-	620	(589)	-	-	2070
2,52	623	(592)	-	-	2080
-	626	(595)	-	-	2090
2,51	629	(598)	-	-	2100
-	631	(600)	-	-	2110
2,50	634	(602)	-	-	2120
-	636	(604)	-	-	2130
2,49	639	(607)	-	57	2140
-	641	(609)	-	-	2150
2,48	644	(612)	-	-	2160
2,47	647	(615)	-	-	2170
-	650	(618)	-	-	2180
-	653	(620)	-	-	2190
2,46	655	(622)	-	58	2200
-	675	-	-	59	-
-	698	-	-	60	-
-	720	-	-	61	-
-	745	-	-	62	-
-	773	-	-	63	-
-	800	-	-	64	-
-	829	-	-	65	-
-	864	-	-	66	-
-	900	-	-	67	-
-	940	-	-	68	-
-	-	-	-	-	-