

Mechanical Properties of Steel Bolts and Screws

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1. Scope of Application

This Standard specifies the mechanical properties and the testing, inspection, and marking of steel bolts and machine screws at ambient temperature⁽²⁾ which satisfy the conditions of Table 1⁽¹⁾.
The mechanical properties of bolts and machine screws in strength classes 4 T to 7 shall be in accordance with the Annex.

- Notes⁽¹⁾ External threaded fasteners shall be used as a general term for steel bolts and machine screws applicable to this standard.
- ⁽²⁾ The mechanical properties of bolts and machine screws in strength classes 4T to 7T are those in strength classes column I of KS B 0233-1981(mechanical properties for steel bolts and screws)
- Remarks In this standard, units and values given in { } are in accordance with the conventional units, and are provided for informative reference. (1 N/mm²=1MPa)

Table 1. External Threaded Fasteners Applicable to This Standard

Item	Applicable external thread fastener
Types of external threaded fastener	External threaded fasteners such as bolts, machine screws, etc., for which minimum mechanical properties are required, whether or not there is a head, and regardless of the shape. However, set screws are excluded.
Screw thread shape	Screw thread with the standard shape, nominal diameter, and pitch of KS B 0201 and KS B 0204.
Range of the nominal diameter of screw threads	1.6 to 39mm
Materials	Carbon steel and alloy steel

- Remarks 1. This standard does not apply to external threaded fasteners for which weldability, corrosion resistance, heat resistance against temperature of not lower than 300 ℃, and cold resistance against temperature of not higher than -50 ℃ are required.
2. The body of this Standard is in accordance with ISO 898-1:1978 (Mechanical properties of fasteners-Part 1:Bolts, screws and studs.)
3. This Standard may be applied to external threaded fasteners with a size beyond the range of this standard (for example, a size exceeding 39mm in nominal diameter of the screw thread) if the requirements for the strength classes specified in this Standard are satisfied.

2. Mechanical Properties

- 2.1 Indicating method of strength division
- The strength division of external threaded fasteners, based on the mechanical properties, shall be indicated by a two or three digit number which contains a decimal point, as shown in Table 2.

The X-axis indicates the designated tensile strength(N/mm²), and the Y-axis indicates the rupture elongation(%). The digits before the decimal point indicate 1/100 of the designated tensile strength (N/mm²)^(*), and the lower yield point^(*) or the designated proof stress^(*) to the designated tensile strength ($\frac{\text{designated yield point or designated proof stress}}{\text{designated tensile strength}}$) N/mm²(See Informative Reference Table 1).

Therefore, the value obtained by multiplying the product of the digits before the decimal point and the digits after the decimal point by 10 yields the designated yield point or the designated proof stress (N/mm²).

Note^(*) The designated tensile strength, designated yield point, and designated proof stress have been set for convenience in the strength divisions, and the minimum values of the tensile strength and yield point(or proof stress) as applied to external threaded fasteners shall be equal to or larger than these designated values(See Table 3).

Table 2. Strength division system

Designated Tensile Strength N/mm ²		300	400	500	600	700	800	900	1000	1200	1400
Minimum of Rupture Elongation %	7										
	8										
	9				6.8					12.9	
	10							10.9			
	12			5.8			9.8 ^(*)				
	14						8.8				
	16			4.8							
	18										
	20										
	22			5.6							
	25	3.6									
	30										

Note^(*) Applies to external threaded fasteners of a maximum 16mm in designated diameter of screw thread.

Informative Reference Table 1. Ratio of the Yield Point(or Proof Stress) to the Tensile Strength

Digit after the decimal point in the strength division	.6	.8	.9
Nominal lower yield point (or nominal proof stress) × 100% Nominal tensile stress	60	80	90

2.2 Mechanical properties for each strength division

The mechanical properties for each strength division of external threaded fasteners shall comply with Table 3 when subjected to the tests of Clause 4.

Table 3. Mechanical Properties

Mechanical Properties			Strength Division											
			3.6	4.6	4.8	5.6	5.8	6.8	8.8		9.8(⁶)	10.9	12.9	
									d≤16	φ>16(⁶)				
Tensile Strength(⁷) N/mm2 {kgf/mm2}			nominal	300	400		500		600	800	800	900	1000	1200
			minimum	330 {33.7}	400 {40.8}	420 {42.8}	500 {51.0}	520 {53.0}	600 {61.2}	800 {81.6}	830 {84.6}	900 {91.8}	1040 {106}	1220 {124}
Hard- ness of the Core	Vickers Hardness HV		minimum	95	120	130	155	160	190	230	255	280	310	372
			maximum	220						250	300	336	360	382
	Brinell Hardness HB		minimum	90	114	124	147	152	181	219	242	266	295	353
			maximum	209						238	285	319	342	363
	Rockwell Hardness	HRB	minimum	52	67	71	79	82	89	-	-	-	-	-
			maximum	95						99	-	-	-	-
		HRC	minimum	-	-	-	-	-	-	20	23	27	31	38
			maximum	-						30	34	36	39	44
		Surface Hardness HV			maximum	-						320	356	380
Yielding Point or Yielding Strength(⁸) N/mm ² {kgf/mm ² }			nominal	180	240	320	300	400	480	640	640	720	900	1080
			minimum	190 {19.4}	240 {24.5}	340 {34.7}	300 {30.6}	420 {42.8}	480 {48.9}	640 {65.3}	660 {67.3}	720 {73.4}	940 {95.9}	1100 {112}
Proof Load Stress			stress rate(⁹)	0.94	0.94	0.91	0.94	0.91	0.91	0.91	0.91	0.91	0.88	0.88
			N/mm ² (¹⁰)	180	225	310	280	380	440	580	600	650	830	970
			{kgf/mm ² }	{18.4}	{22.9}	{31.6}	{28.6}	{38.7}	{44.0}	{59.1}	{61.2}	{66.3}	{84.6}	{98.9}
Elongation After Rupture(%)			minimum	25	22	14	20	10	8	12	12	10	9	8
Wedge Tensile Strength			Same as minimum of Tensile Strength(¹¹)											
Impact Energy J {kgf · m}			minimum				25 {2.55}	-		30 {3.06}	30 {3.06}	25 {2.55}	20 {2.04}	15 {1.53}
Hammering Strength of the Head			There shall be no cracks on the edge between the head and the body (¹²)											
Decarburization of the Threaded Portion	Height of the Undecarburized Part E	minimum	-						$\frac{1}{2} H$		$\frac{2}{3} H$	$\frac{3}{4} H$		
	Depth of the Ferrite Decarburized Layer	maximum	-						0.015					

Notes^(*) Applies to bolts and machine screws of a minimum 12mm in nominal diameter of screw thread for bolts for steel structures.

(*) Applies to external threaded fasteners of a maximum 16mm in nominal diameter of screw thread.

(*) The minimum of the tensile strength applies to test products. Also, the rupture in the product should occur in the threaded portion or the body, and not on the edge between the head and the body.

(*) The yield point shall be used where it is distinct. Where the yield point is not distinct, the proof stress at a 0.2% permanent elongation shall be used.

(*) Ratio of the proof load stress and the minimum yield point (or the minimum proof stress)

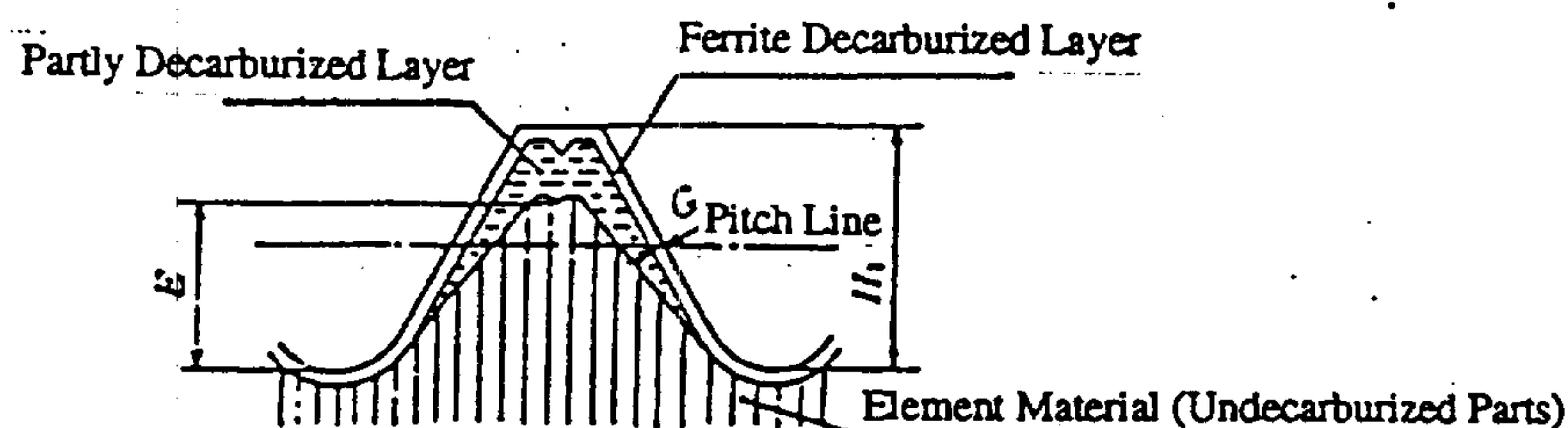
(*) For the proof load stress test, the permanent elongation shall be below 12.5%.

(*) For the minimum wedge tensile strength, the minimum tensile loads in Attached Tables 2 and 3 apply.

The tensile rupture shall be produced at the threaded portion or the body, but it shall not be produced at the joint of the head and body. Cracks of complete screw threads which are produced at the free threaded portion may develop into a rupture after enlarging into the underhead fillet or into the head.

(2) Cracks of complete screw threads may be produced at the first thread ridge of the head side, as long as the head is not wrested away.

(*) See Fig 1.



H : Height of the mountain of the maximum physically of the external threaded fasteners.

[Refer to Table 6 for the values of H and E (minimum)]

Fig 1. Decarburization of the Threaded Portion

3. Materials and Heat Treatment

The materials and heat treatment for the different strength classes of external threaded fasteners shall be as specified in Table 4. The minimum tempering temperatures of this table shall apply to materials in strength classes 8.8 to 12.9, and the limit of chemical components shall apply to materials for which the tension test can not be performed due to short length.

Table 4. Materials and Heat Treatment

Strength Division	Steel Element & Heat Treatment	Chemical Component(%)				Tempering Temperature $^{\circ}\text{C}$ (^o)
		C		P	S	
		minimum	maximum	maximum	maximum	minimum
3.6(¹⁴)	low carbon steel	-	0.02	0.05	0.06	-
4.6(¹⁴)	low or medium carbon steel	-	0.55	0.05	0.06	-
4.8(¹⁴)						
5.6	low or medium carbon steel	-	0.55	0.05	0.06	-
5.8(¹⁴)						
6.8(¹⁴)						
8.8(¹⁴)	low carbon steel with additives (B, Mn or Cr), quenching, tempering	0.15	0.35	0.04	0.05	425
8.8(¹⁵)	medium carbon steel, quenching, tempering	0.25	0.55	0.04	0.05	450(²⁰)
9.8(¹⁵)	low carbon steel with additives (B, Mn or Cr), quenching, tempering	0.15	0.35	0.04	0.05	410
9.8	medium carbon steel, quenching, tempering	0.25	0.55	0.04	0.05	410
10.9(¹⁵)	low carbon steel with additives (B, Mn or Cr), quenching, tempering	0.15	0.35	0.04	0.05	340
10.9(¹⁷)	medium carbon steel, quenching, tempering	0.25	0.55	0.04	0.05	425
	low carbon steel with additives (B, Mn or Cr), quenching, tempering	0.20	0.55			
	alloyed steel, quenching, tempering	0.20	0.55			
12.9(¹⁷)	alloyed steel, quenching, tempering	0.20	0.50	0.035	0.035	380

Notes(¹⁴) Free-cutting steel may be used for these strength classes.

The maximum contents of S, P, and Pb shall be as follows:

S : 0.34%

P : 0.11%

Pb : 0.35%

- (15) External threaded fasteners of this strength division shall be identified by underlining the strength division (Refer to 8.8).
- (16) Where sufficient hardenability is required for external threaded fasteners of more than 20mm in nominal diameter, the material for strength division 10.9 should be used.
- (17) For the materials of these property classes, it is intended that there should be a sufficient hardenability to ensure a structure consisting of approximately 90% martensite in the core of threaded sections for the fasteners in the "as-hardened" condition before tempering.
- (18) This alloy shall include at least one of the following elements :
chromium, nickel, molybdenum, and vanadium.
- (19) When external threaded fasteners of strength division 8.8 to 12.9 are tested in accordance with 4.3, the difference in average values of hardness shall be less than a Vickers hardness of 20.
- (20) If the nominal diameter of the screw exceeds 20mm, it is possible to set the lowest tempering temperature to 425 °C.

4. Testing

4.1 Types of test

The tests to determine the mechanical properties of external threaded fasteners shall be as given in Table 5.

Table 5. Types of Test

Types of Test	Mechanical Properties to be Tested	Normal Items in the Testing Method
Tensile test on test piece	Tensile strength, yielding point or yielding strength, elongation after rupture	4.2.1
Tensile test of products	Tensile strength	4.2.2
Tensile test of wedge	Wedge tensile strength	4.2.3
Tensile test of proof load	Long-term elongation of proof load stress	4.2.4
Hardness test	Hardness of the core, hardness of the surface	4.2.5
Hammering test of the head	Hammering strength of the head	4.2.6
Impact test	Impact energy	4.2.7
Decarburization test	Height of the undecarburized part of the threaded portion, depth of the ferrite decarburized layer	4.2.8
Retempering test	Hardness before and after retempering	4.3

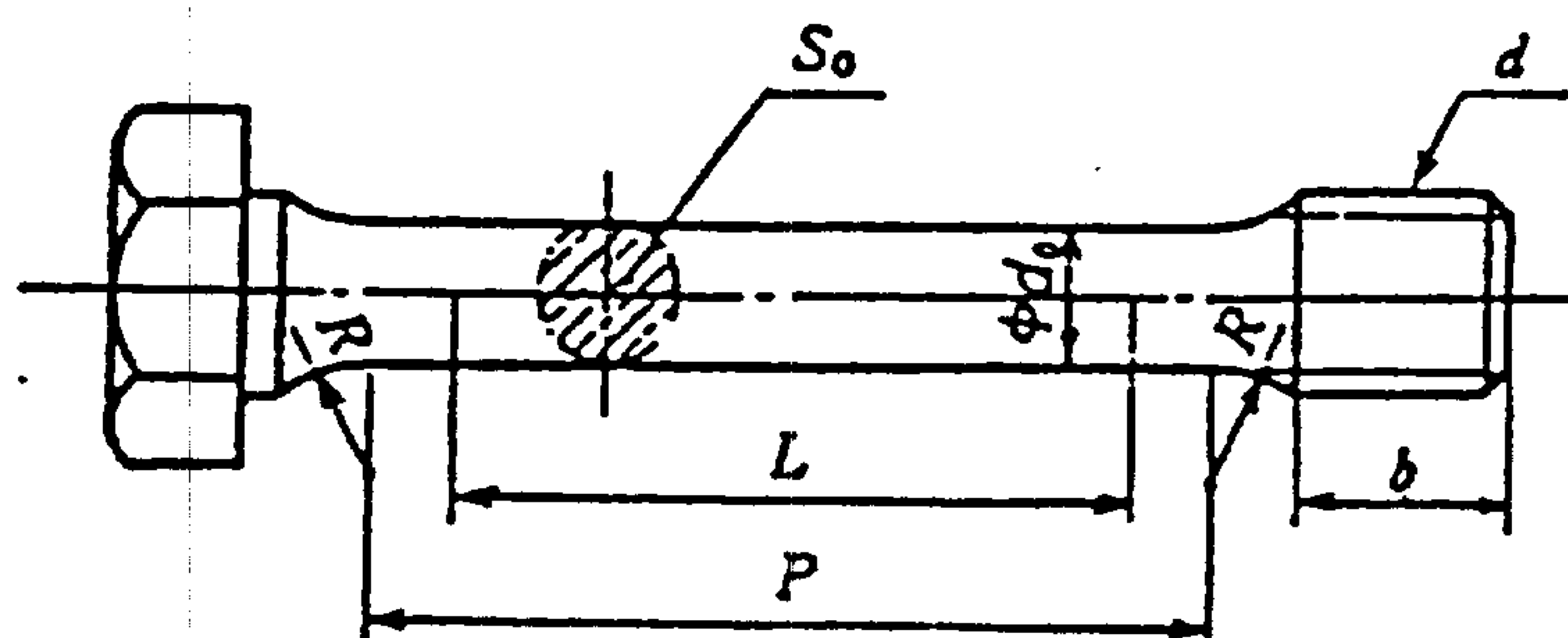
4.2 Testing of mechanical properties

4.2.1 Tensile test of a test piece

Prepare a test piece (see Fig. 2) in accordance with No. 14 A of KES T-L005, and examine the tensile strength, yield point (or proof stress), and rupture elongation.

The diameter of the parallel part of a test piece taken from an external threaded fastener of more than 16mm in nominal diameter which has been heat treated shall not be less than the original diameter by 25% or more⁽²⁷⁾.

Note⁽²¹⁾ If the diameter is reduced by 25%, the sectional area of the parallel part becomes approx. 44% of the sectional area of the original diameter.



d : nominal diameter of the screw thread

d_0 : diameter of the parallel part (make smaller than the minor diameter of the screw thread)

b : length of the threaded portion ($b \geq d$)

L : distance between marks $5 d_0$ (or $5.65 \sqrt{S_0}$)

P : length of the parallel part $L + d_0 \approx 6 d_0$

R : radius of the neck, not less than 4mm

S_0 : sectional area of the parallel part

Fig. 2. Tensile Test Piece

4.2.2 Tensile test of a product

As shown in Fig. 3, engage a nut or a suitable jig so that the complete threaded portion of a minimum of 1 d (d is the nominal diameter) remains at the head side of the external threaded fastener, increase the tensile load slowly in the axial direction of the screw thread until the product ruptures, and determine the location of the rupture and the maximum tensile load⁽²⁸⁾ at the time of rupture. The clamp part of the specimen shall be a self-aligning type so that the force in the horizontal has no effect and the speed of the cross head with no load does not exceed 25mm/min.

Note⁽²²⁾ Tensile strength is calculated by dividing tensile load by effective sectional area(A_s) as in the following equation:

where A_s : effective sectional area of the threaded portion

d_2 : basic measurement of effective diameter(mm)

d_3 : value of basic measurement of root circle 1/6 of height of basic threaded portion
($H=0.866025 P$) (mm)

Also, in attached tables 1 and 2 are the effective area and minimum tensile load of threaded portion of metric coarse screw thread and metric fine screw thread.

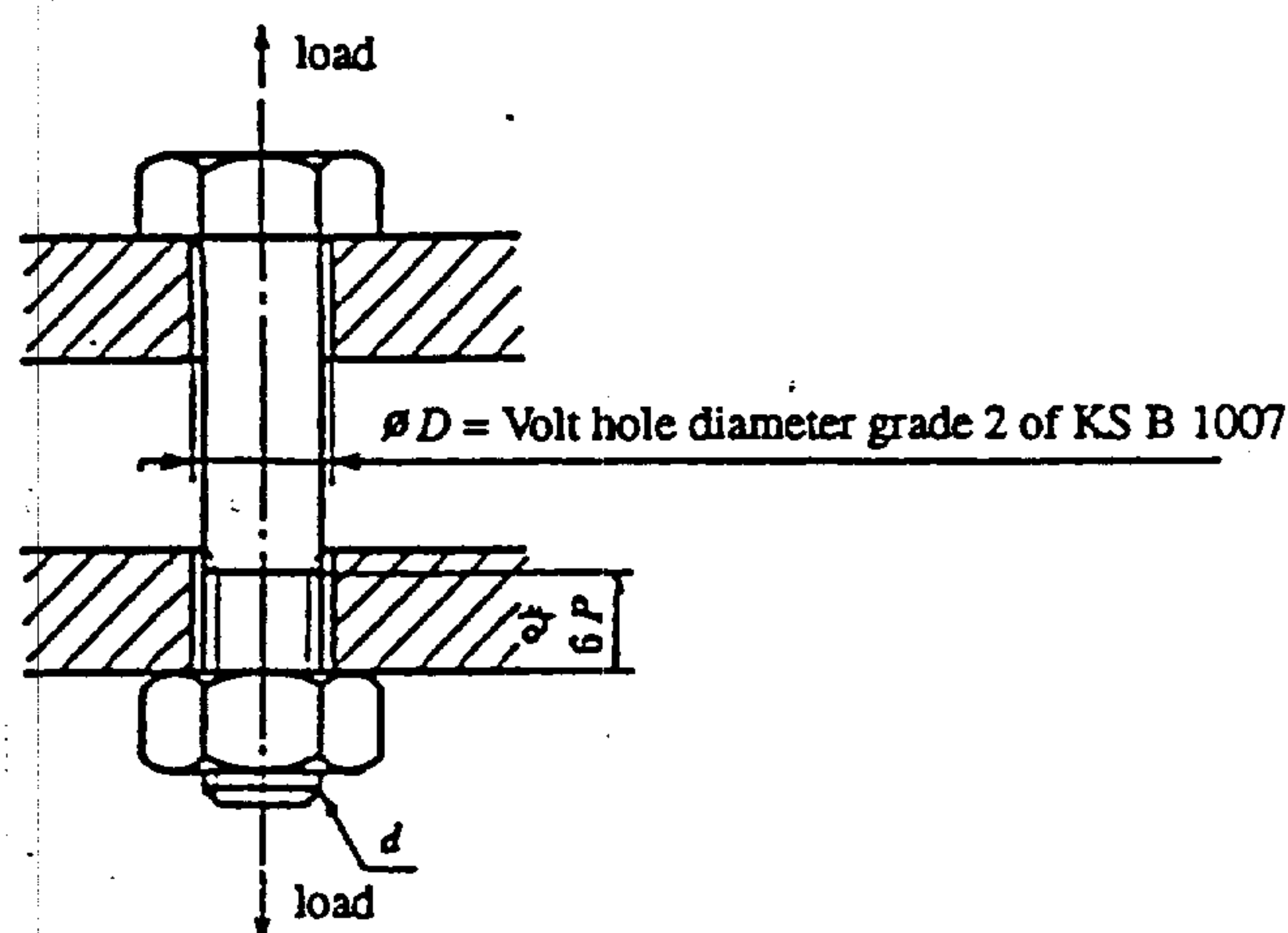


Fig.3. Tensile Test of a Product

4.2.3 Wedge tensile test

Wedge tensile test applies to products other than stud bolts. As shown in Fig. 4, piece a hardened wedge of angle α on the bearing surface of the head of the external threaded fastener so that one side of the head makes contact with the inclined plane of the wedge. Engage a nut or a suitable jig so that the complete threaded portion of a minimum of $1 d$ (d is nominal diameter) remains at the head side of the other threaded portion, increase the tensile load slowly in the axial direction of the screw thread until the products ruptures, and determine the location of the rupture and the maximum tensile load at the time of rupture.

For products for which the head diameter exceeds $1.7d$ which did not pass the wedge tensile test, the head diameter can be trimmed to $1.7d$ and the product can be retested at the wedge angle shown in Fig.4.

For products for which the wedge diameter exceeds $1.9d$, a 6° wedge may be used in place of the 10° edge.

Note⁽²⁾ Calculation of tensile strength conforms to 4.2.2.

Also, tensile strength calculated from this test is called "wedge tensile strength".

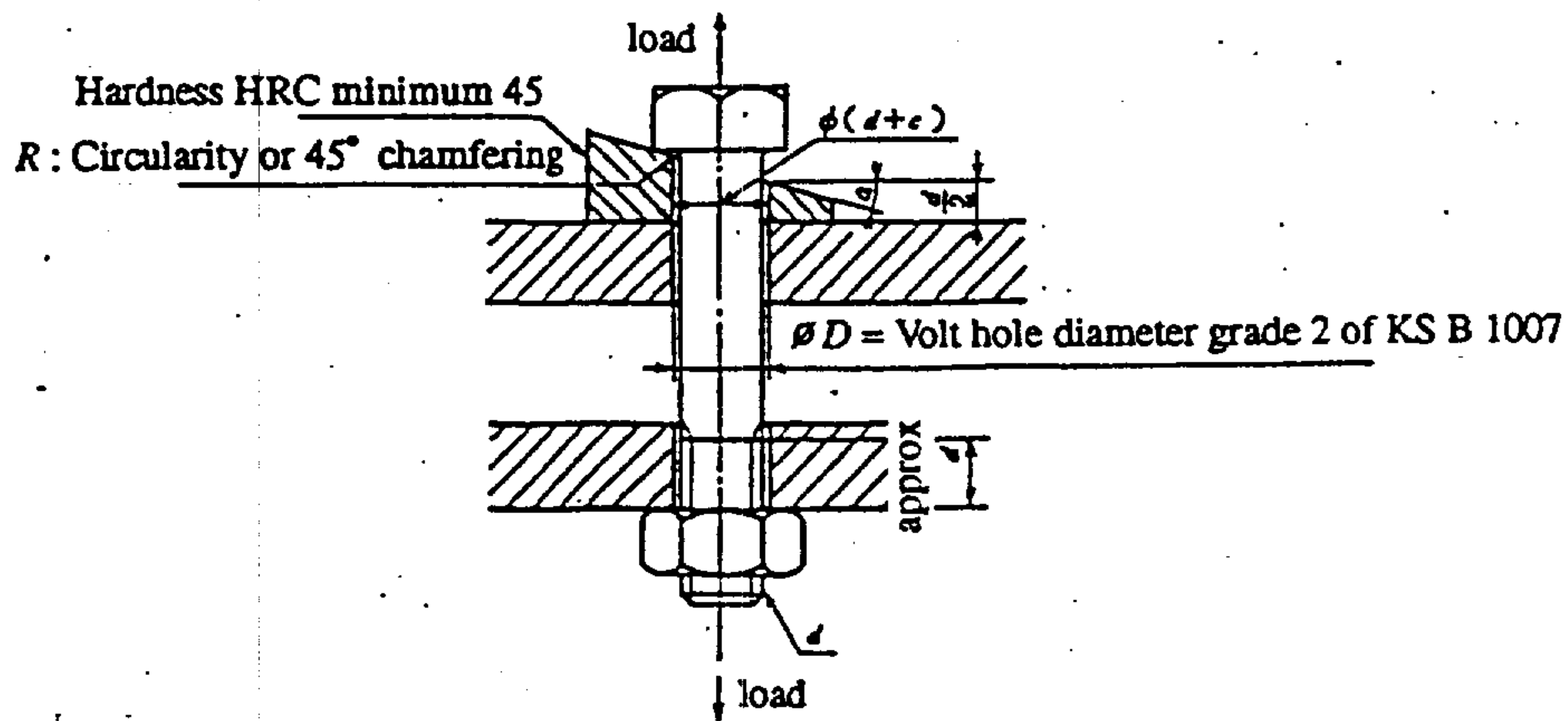


Fig.4. Wedge Tensile Test

Nominal diameter of threaded portion d mm		R ⁽²⁾ mm	C mm	Angle $\alpha \pm 30^\circ$			
				Threaded portion with body length of $2d$ or above		Threaded portion with whole or body length $2d$ or below	
				Strength divisions to be applied		Strength divisions to be applied	
above	below			3.6, 4.6, 4.8 5.6, 5.8, 8.8 9.8, 10.9	6.8, 12.9	3.6, 4.6, 4.8 5.6, 5.8, 8.8 9.8, 10.9	6.8, 12.9
-	6	0.5	0.7	10°	6°	6°	4°
6	12	0.8	0.8				
12	20	1.6	1.3				
20	39	3.2	1.6	6°	4°	4°	4°

Note⁽²⁾ R for parts of Grade C(see KS B 0238) shall be obtained from the following formula :

$$R = \frac{d_{\text{max}} - d_{\text{min}}}{2} + 0.2(\text{mm})$$

where, d_{max} : maximum diameter of the circle which has shifted from the radius under the head(mm)

d_{min} : minimum diameter of the body(mm)

4.2.4 Proof load test

As shown in Fig.5, engage a nut or a suitable jig so that about $6P$ of the complete threaded portion (P is the pitch of the screw thread) remains at the head side of the external threaded fastener.

Apply the proof load indicated in Attached Table 4 or 5 in the axial direction of the screw thread for 15 sec, remove the load, and determine the permanent elongation of the external threaded fastener. The clamp part of the specimen shall be a self-aligning type so that the force in the horizontal direction has no effect and the speed of the cross head with no load shall not exceed 3mm / min.

The measurement of permanent elongation shall be as follow : As shown in Fig. 5, make conical holes of angle 60° at both ends of the external threaded fastener using a drill, apply the spherical terminal of a measuring instrument, the difference in the length of the external threaded fastener before and after the proof load. The precision in the measurement of the length shall be $\pm .5\mu$ m. Measurement may be in accordance with other method if this precision is maintained.

If, at the beginning of application of the proof load, there is apparent permanent elongation in the product due to straightness of the shaft perpendicularity of the head, increase the proof load specified in Attached Table 4 or 5 by 3% to retest.

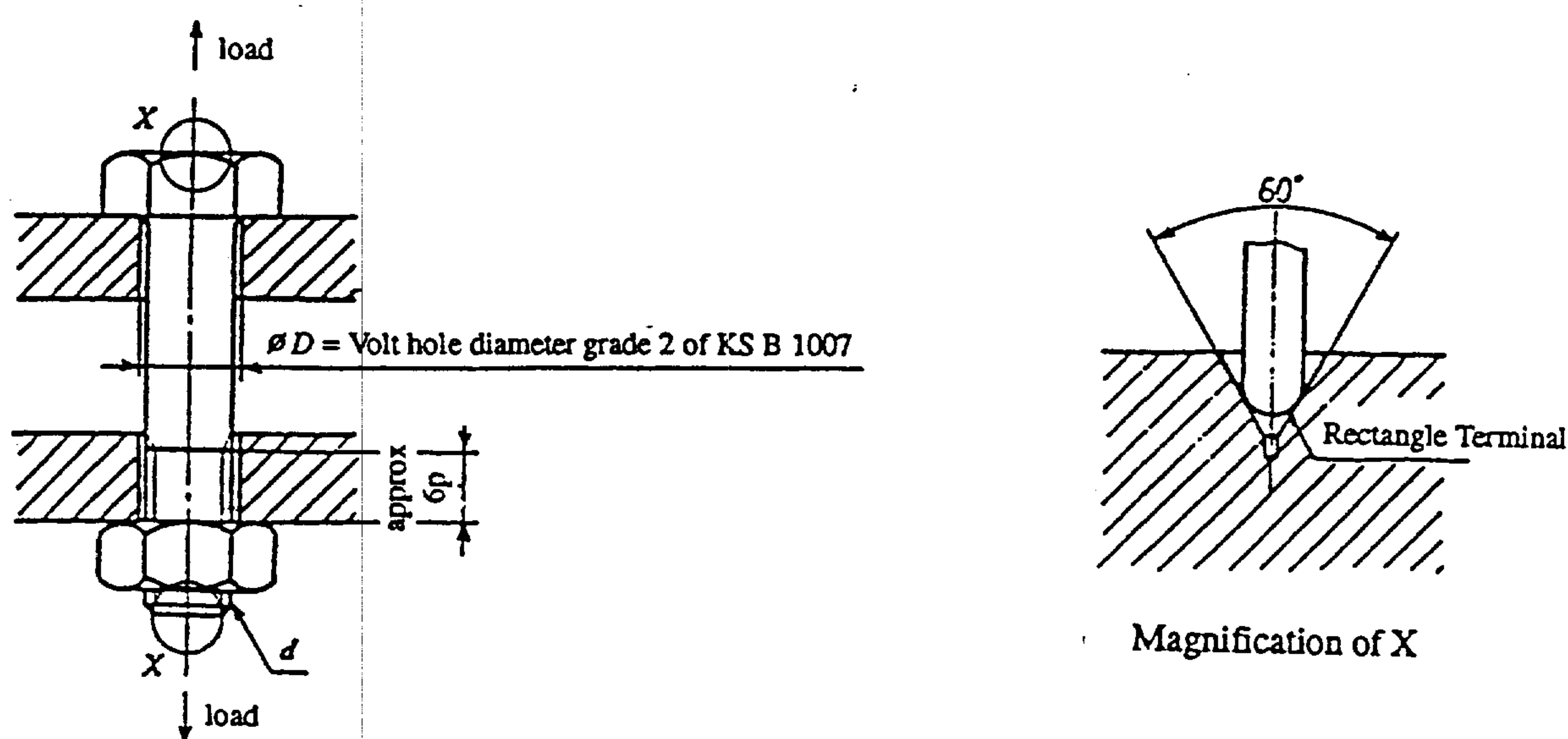


Fig.5. Proof Load Test

4.2.5 Hardness test

The tests for hardness and surface hardness shall be as follows :

(1) Hardness test

Determine the hardness at the head of the external threaded fastener, tip of the threaded portion, or body in accordance with the test method specified in.