

Hardness Testing Machines

Hardness Test Methods and Guidelines for Selection of a Hardness Testing Machine

Test Method	Microhardness (Micro-Vickers)	Micro surface material characteristics	Vickers	Rockwell	Rockwell Superficial	Brinell	Shore	Portable (retracting type)	For sponge, rubber, and plastic	Rebound type portable
Material										
IC wafer	●	●								
Carbide, ceramics (cutting tool)	●	▲	●	●	▲					
Steel (heat-treated material, raw material)		▲	●	●	●		●	●		●
Non-ferrous metal		▲	●	●	●			●		●
Plastic		▲		●	●				●	
Grinding stone				●						
Casting						●				
Sponge, rubber									●	
Form										
Thin metal sheet (safety razor, metal foil)	●	●	●		●					
Thin film, plating, painting, surface layer (nitrided layer)	●	●	▲		●					
Small parts, acicular parts (clock hand, sewing-machine needle)	●	▲	▲		▲					
Large specimen (structure)						●	●	●		●
Metallic material configuration (hardness for each phase of multilayer alloy)	●	●								
Plastic plate	▲	▲		●					●	
Sponge, rubber plate									●	
Application										
Strength or physical property of materials	●	●	●	●	●	●	●	●	●	▲
Heat treatment process	●		●	●	●		▲	▲		▲
Carburized case depth	●		●							
Decarburized layer depth	●		●		●					
Flame or high-frequency hardening layer depth	●			●						
Hardenability test			●	●						
Maximum hardness of a welded spot			●							
Weld hardness			●	●						
High-temperature hardness (high-temperature characteristics, hot-workability)			●							
Fracture toughness (ceramics)	●		●							

* ●: Well-suited ▲: Reasonably suited

Methods of Hardness Measurement

(1) Vickers

Vickers hardness is a test method that has the widest application range, allowing hardness inspection with an arbitrary test force. This test has an extremely large number of application fields particularly for hardness tests conducted with a test force less than 9.807N (1kgf). As shown in the following formula, Vickers hardness is a value determined by dividing test force F (N) by contact area S (mm²) between a specimen and an indenter, which is calculated from diagonal length d (mm, mean of two directional lengths) of an indentation formed by the indenter (a diamond square pyramid, opposing face angle $\theta=136^\circ$) into the specimen using a test force F (N). k is a constant (1/g=1/9.80665).

$$HV = k \frac{F}{S} = 0.102 \frac{F}{S} = 0.102 \frac{2F \sin \frac{\theta}{2}}{d^2} = 0.1891 \frac{F}{d^2} \quad \begin{matrix} F: N \\ d: mm \end{matrix}$$

The error in the calculated Vickers hardness is given by the following formula. Here, Δd_1 , Δd_2 , and Δ represent the measurement error that is due to the microscope, an error in reading an indentation, and the length of an edge line generated by opposing faces of an indenter tip, respectively. The unit of $\Delta\theta$ is degree.

$$\frac{\Delta HV}{HV} \approx \frac{\Delta F}{F} - 2 \frac{\Delta d_1}{d} - 2 \frac{\Delta d_2}{d} - \frac{\Delta^2}{d^2} - 3.5 \times 10^{-3} \Delta\theta$$

(2) Knoop

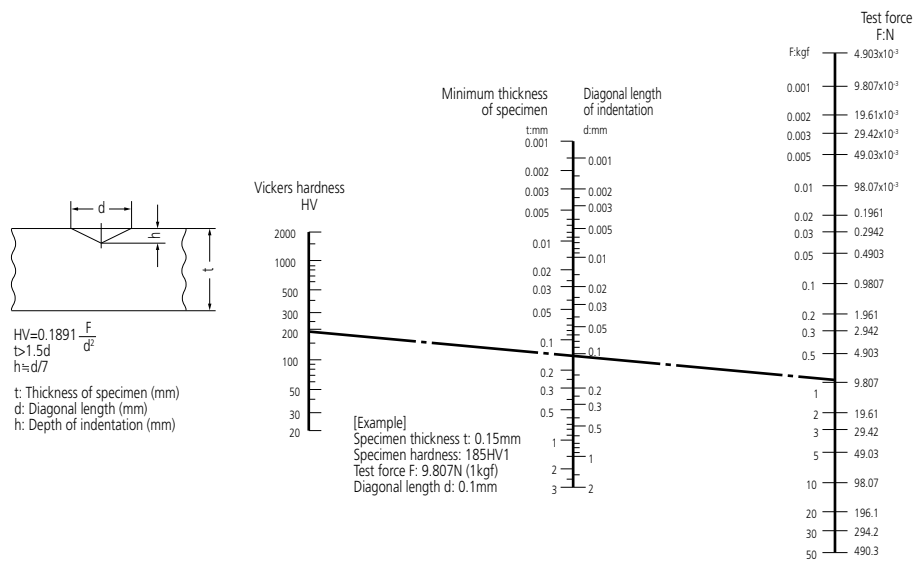
As shown in the following formula, Knoop hardness is a value obtained by dividing test force by the projected area A (mm²) of an indentation, which is calculated from the longer diagonal length d (mm) of the indentation formed by an indenter after pressing a diamond square pyramid (its cross section is rhomboidal with opposing edge angles of 172°30' and 130°) into a specimen with test force F applied. Knoop hardness can also be measured by replacing the Vickers indenter of a microhardness testing machine with a Knoop indenter.

$$HK = k \frac{F}{A} = 0.102 \frac{F}{A} = 0.102 \frac{F}{cd^2} = 1.451 \frac{F}{d^2} \quad \begin{matrix} F: N \\ d: mm \\ c: Constant \end{matrix}$$

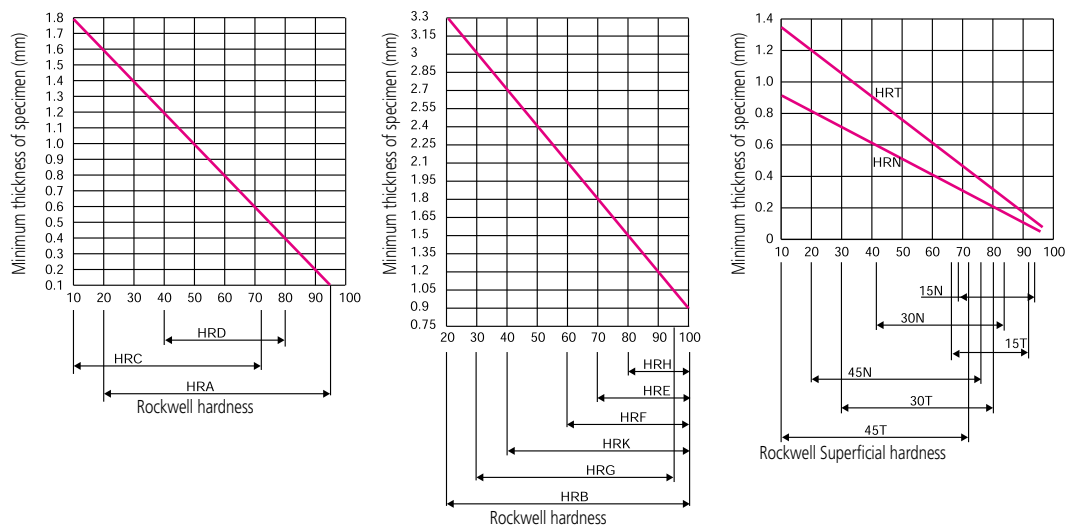
(3) Rockwell and Rockwell Superficial

To measure Rockwell or Rockwell Superficial hardness, first apply an initial test force and then a test force to a specimen and return to the initial test force using a diamond indenter (tip cone angle: 120°, tip radius: 0.2mm) or a sphere indenter (steel ball or carbide ball). This hardness is obtained from the hardness formula expressed by the difference in indentation depth of indenter h (μm) between the first and second initial test forces. Rockwell uses an initial test force of 98.07N, and Rockwell Superficial 29.42N. A specific symbol provided in combination with a type of indenter, test force, and hardness formula is known as a scale. Japanese Industrial Standards (JIS) define various scales of related hardness.

Relationship between Vickers Hardness and the Minimum Thickness of a Specimen



Relationship between Rockwell/Rockwell Superficial Hardness and the Minimum Thickness of a Specimen



Rockwell Hardness Scales

Scale	Indenter	Test force (N)	Application
A	Diamond	588.4	Carbide, thin steel sheet Case-hardening steel Steel (greater than 100HRB or less than 70HRC)
D		980.7	
C		1471	
F	Ball with a diameter of 1.5875mm	588.4	Bearing metal, annealed copper Brass Hard aluminum alloy, beryllium copper, phosphor bronze
B		980.7	
G		1471	
H	Ball with a diameter of 3.175mm	588.4	Bearing metal, grinding stone Bearing metal Bearing metal
E		980.7	
K		1471	
L	Ball with a diameter of 6.35mm	588.4	Plastic, lead
M		980.7	
P		1471	
R	Ball with a diameter of 12.7mm	588.4	Plastic
S		980.7	
V		1471	

Rockwell Superficial Hardness Scales

Scale	Indenter	Test force (N)	Application
15N	Diamond	147.1	Thin, hard layer on steel such as a carburized or nitrided layer
30N		294.2	
45N		441.3	
15T	Ball with a diameter of 1.5875mm	147.1	Thin metal sheet of soft steel, brass, bronze, etc.
30T		294.2	
45T		441.3	
15W	Ball with a diameter of 3.175mm	147.1	Plastic, zinc, bearing alloy
30W		294.2	
45W		441.3	
15X	Ball with a diameter of 6.35mm	147.1	Plastic, zinc, bearing alloy
30X		294.2	
45X		441.3	
15Y	Ball with a diameter of 12.7mm	147.1	Plastic, zinc, bearing alloy
30Y		294.2	
45Y		441.3	