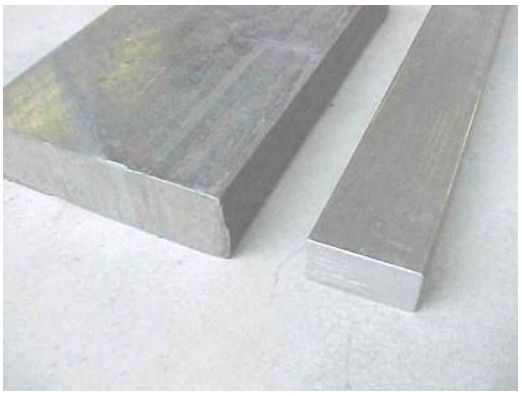
Department of Building Engineering



EXERCISE NR 9

Brinell hardness measurement of metals

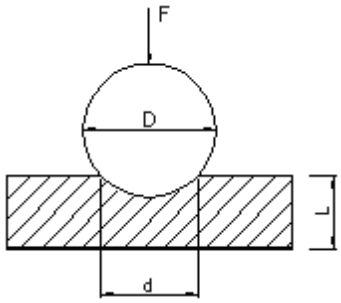
Instructions from the lab:
"Building engineering and building materials"

9 .1. Measuring the hardness of metals using the Brinell method

The Brinell hardness measurement consists of pressing a hard ball into the surface of the tested sample for a specified time. The diameter of the ball impression *d* measured after the load force *F has been removed* is used to calculate the hardness.

Brinell hardness is proportional to the quotient of the loading force and the surface area of the indentation.

The measurement diagram with basic symbols is shown in Fig. 9.1, and Fig. 9.2. shows a general view of a **Brinell hardness tester** .



Rys. 9.1. Scheme for determining the hardness of steel using the Brinell

Measuring balls. Balls made of sintered carbide are used - a material of considerable hardness, with diameters of 10; 5; 2.5 and 1 mm, in accordance with ISO 6506-2.

Sample preparation. The surface of the tested object at the place of hardness measurement should be flat and even and cleaned of scale, grease, etc. During smoothing, it is necessary to avoid changing the hardness due to heating or crushing. Traces of mechanical processing are permissible. The surface of the tested sample can be processed by grinding. For hardness testing using a ball with a diameter of *D* = 1 mm, the surface of the sample should be polished.

Fig. 9.2. Brinell hardness tester

The sample can be of any shape, provided that an appropriate hardness test table is used for measurements, ensuring:

- perpendicularity of the measuring surface to the direction of load action;
- position of the sample without elastic deformations and displacements under the influence of load.

The thickness of the sample should be at least 8 times greater than the depth of the indentation *h* calculated according to the relationship (9.1):

$$h = \frac{D}{2}\left(1 - \sqrt{1 - d^2 / D^2}\right) \qquad (9.1)$$

where: *h* – imprint depth, mm;
D - ball diameter, mm;
d – average diameter of the imprint.

The minimum thicknesses of test samples depending on the average imprint diameter are given in Table 9.3 (at the end of the instructions).

Carrying out the measurement. The test is carried out at an ambient temperature in the range from 10 °C to 35 °C. In controlled conditions, the temperature should be (23 ± 5) °C.

It is recommended to use a ball of diameter 10 mm; if the thickness of the tested sample does not allow it, a ball with a smaller diameter, but the largest possible permissible diameter, should be used.

Place the test sample on a rigid base which should be free from contamination.

The ball should be loaded evenly, without shocks, until the required force is obtained. The time from the beginning of the application of the loading force until it reaches its full nominal value should be in the range of 2 s to 8 s. The loading force should act on the sample for 10 s to 15 s.

The distance from the edge of the sample to the centre of each indentation should be at least two and a half times the average diameter of the indentation, while the distance between the centres of two adjacent indentations should be at least three times the average diameter of the indentation.

The value of the loading force according to EN ISO 6506-1: 2005 is given in Table 9.1.

Tab.9.1. Loading forces for different test conditions according to EN ISO 6506-1:2000

Symbol hardness	**Ball diameter** D mm	**Ratio force-diameter** $0.102 \times F/D^2$ N/mm^2	**Nominal value of the loading force** F
HBW 10/3000	10	30	29.42 kN
HBW 10/1500	10	15	14.71 kN
HBW 10/1000	10	10	9.807 kN
HBW 10/500	10	5	4.903 kN
HBW 10/250	10	2.5	2.452 kN
HBW 10/100	10	1	980.7 N
HBW 5/750	5	30	7.355 kN
HBW 5/250	5	10	2.452 kN
HBW 5/125	5	5	1.226 kN
HBW 5/62.5	5	2.5	612.9 N
HBW 5/25	5	1	245.2 N
HBW 2.5/187.5	2.5	30	1.839 kN
HBW 2.5/62.5	2.5	10	612.9 N
HBW 2.5/31.25	2.5	5	306.5 N
HBW 2.5/15.625	2.5	2.5	153.2 N
HBW 2.5/6.25	2.5	1	61.29 N
HBW 1/30	1	30	294.2 N
HBW 1/10	1	10	98.07 N
HBW 1/5	1	5	49.03 N
HBW 1/2.5	1	2.5	24.52 N
HBW 1/1	1	1	9,807 N

Table 9.2. Ratio $0.102 \times F/D^2$ for different metals according to EN ISO 6506-1:2005

Material	**Brinell hardness** HBW	**Ratio force-diameter** $0.102 \times F/D^2$ N/mm^2
Steel, nickel alloys, titanium alloys		30
Cast iron [a]	< 140	10
	≥ 140	30
Copper and copper alloys	<35	5
	35 to 200	10
	> 200	30
Light metals and their alloys	<35	2.5
	35 to 80	5
		10
		15
	> 80	10
		15
Lead, tin		1
Sintered metals	in accordance with ISO 4498-1	
[a] To measure the hardness of cast iron, balls with a nominal diameter of 2,5 mm, 5 mm, or 10 mm, should be used.		

The diameter of the impression is measured using a measuring microscope or other measuring device (e.g. magnifying glass). The diameter of the impression should be measured in two mutually perpendicular directions. The arithmetic mean of both measurements is used to calculate the Brinell hardness .

Calculation and determination of results. Hardness is calculated using the following relationship:

$$HBW = 0{,}102\frac{F}{S} = 0{,}102\frac{2F}{\pi D^2\left(1-\sqrt{1-d^2/D^2}\right)} \tag{9.2}$$

where: *D* - ball diameter; mm;
F - loading force; N;
d - print diameter; mm;
S - imprint surface area, mm ^{2};
0.102 – a constant equal to 1/9.80665, where 9.80665 is the conversion factor from kG to N;
HBW - Brinell hardness .

Brinell hardness unit **symbol** *HBW* is supplemented with numbers indicating: the diameter of the ball, the amount of load applied and the time of load action. Below is an example of the Brinell hardness designation , *HBW* :

600 HBW 1/30/20

Brinell hardness value ;
HBW – hardness symbol,
1 – ball diameter, mm;
30 – approximate equivalent loading force, kgf (30 kG= 294.2 N);
20 – load operation time (20 s), if not specified, then 10÷15 s;

After completing the tests, a report should be prepared containing: identification of the tested sample, diameter of the ball used, load value, nominal load action time, hardness of individual impressions, diameter of the impression and any comments regarding the measurements performed.

Table 9.3. Minimum thickness of the test sample depending on the average diameter of the impression according to EN ISO 6506-1:2005 (dimensions in millimetres)

Average print diameter d	**Minimum thickness of test sample**			
	D = 1	D = 2.5	D = 5	D = 10
0.2	0.08			
0.3	0.18			
0.4	0.33			
0.5	0.54			
0.6	0.80	0.29		
0.7		0.40		
0.8		0.53		
0.9		0.67		
1.0		0.83		
1,1		1.02		
1,2		1.23	0.58	
1.3		1.46	0.69	
1.4		1.72	0.80	
1.5		2.00	0.92	
1.6			1.05	
1.7			1.19	
1.8			1.34	
1.9			1.50	
2.0			1.67	
2,2			2.04	

Table 9.3. Minimum thickness of the test sample depending on the average diameter of the impression according to EN ISO 6506-1:2005 (dimensions in millimetres) cd

Average print diameter d	**Minimum thickness of test sample**			
	D = 1	D = 2.5	D = 5	D = 10
2.4			2.46	1.17
2.6			2.92	1.38
2.8			3.43	1.60
3.0			4.00	1.84
3.2				2.10
3,4				2.38
3.6				2.68
3.8				3.00
4.0				3.34
4.2				3.70
4.4				4.08
4.6				4.48
4.8				4.91
5.0				5.36
5.2				5.83
5.4				6.33
5,6				6.86
5.8				7.42
6.0				8.00

Group -……/team …… Date……

1. ……

2. ……

3. ……

4. ……

5. ……

Exercise 9

DETERMINATION OF STEEL HARDNESS BY BRINELL METHOD

Type of material tested	**Ball diameter D**	**The value of the pressure force *F***	**Imprint diameter**			**Imprint surface area *S***	**Hardness *HBW***
			d $_{1}$	***d*** $_{2}$	***d*** $_{wed}$		
	mm	N	mm	mm	mm	mm2	

Additional notes:

Record the Brinell value for the tested samples:

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