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Grinding media — Balls specification

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Foreword

Development of the East African Standards has been necessitated by the need for harmonizing requirements governing quality of products and services in the East African Community. It is envisaged that through harmonized standardization, trade barriers that are encountered when goods and services are exchanged within the Community will be removed.

The Community has established an East African Standards Committee (EASC) mandated to develop and issue East African Standards (EAS). The Committee is composed of representatives of the National Standards Bodies in Partner States, together with the representatives from the public and private sector organizations in the community.

East African Standards are developed through Technical Committees that are representative of key stakeholders including government, academia, consumer groups, private sector and other interested parties. Draft East African Standards are circulated to stakeholders through the National Standards Bodies in the Partner States. The comments received are discussed and incorporated before finalization of standards, in accordance with the principles and procedures for development of East African Standards.

East African Standards are subject to review, to keep pace with technological advances. Users of the East African Standards are therefore expected to ensure that they always have the latest versions of the standards they are implementing.

The committee responsible for this document is Technical Committee EASC/TC 035, *Steel and steel products*

Attention is drawn to the possibility that some of the elements of this document may be subject of patent rights. EAC shall not be held responsible for identifying any or all such patent rights.

Grinding media — Balls specification

1 Scope

This standard covers the requirements, sampling and test methods for grinding media made of steel and cast iron including forged steel balls and cast balls used for raw materials and materials grinding in ball mills for mining, power plants, cement plants and other materials in grinding mills. This standard does not apply for ceramic grinding media.

This standard is applied to milling balls with diameter of 15 - 120 mm.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*
ISO 6506-2, *Metallic materials — Brinell hardness test — Part 2: Verification and calibration of testing machines*
ISO 6506-3, *Metallic materials — Brinell hardness test — Part 3: Calibration of reference blocks*
ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method*
ISO 6508-2, *Metallic materials — Rockwell hardness test — Part 2: Verification and calibration of testing machines and indenters*
ISO 6508-3, *Metallic materials — Rockwell hardness test — Part 3: Calibration of reference blocks*
ISO 9013, *Thermal cutting — Classification of thermal cuts — Geometrical product specification and quality tolerances*
ISO 13385-1, *Geometrical product specifications (GPS) — Dimensional measuring equipment — Part 1: Design and metrological characteristics of callipers*
ISO 24153, *Random sampling and randomization procedures*
ISO/TR 9769, *Steel and iron — Review of available methods of analysis*
ISO 13521, *Austenitic manganese steel castings*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:
— ISO Online browsing platform: available at http://www.iso.org/obp
— IEC Electropedia: available at https://www.electropedia.org

3.1
ball mill
device with a rotating drum filled by grinding balls and material for crushing

3.2
grinding balls
products with ball form for material crushing in ball mills by abrasion, impact and crushing

3.3
grinding rollers
products with rod form for material crushing in roller mills by abrasion, impact and crushing

3.4
roller mill
device with a rotating roller filled by material for crushing

3.5
conditional ball diameter
ball diameter rounded to standard values

3.6
nominal ball diameter
limit deviations determined relative to this ball diameter

3.7
limit diameter deviation
difference between limit and nominal diameter

3.8 volumetric hardness
calculated hardness index, generalizes its value in the ball volume

3.9
lot
ten tonnes or part thereof of cast grinding media of one size, having similar composition and subjected to similar heat treatment.

4 Classification and symbols

4.1 The balls subdivided into hardness groups:

1 - balls with normal surface hardness;
2 - balls with increased surface hardness;
3 - balls with high surface hardness;
4 - balls with high surface hardness and normalized hardness at 0,5 R depth;
5 - balls with high surface hardness and normalized volumetric hardness.

4.2 Examples of balls symbols

The 60 mm balls with increased surface hardness and 2-nd hardness group:
Balls 60 - 2 EAS XXXX:
The 80 mm balls with high surface hardness and normalized volumetric hardness and 5-th hardness group:
Balls 80 - 5 EAS XXXX:

5 Supply of material

General requirement relating to supply of cast steel grinding media shall be in accordance to ISO 13521.

6 Manufacture

The steel for casting shall be made by electric arc or induction furnance or such other process as may be agreed to between the manufacturer and purchaser.

7 Freedom from defects

All grinding media shall be free from defects that affects the utility of castings. No surface condition except grinding shall be permissible. The balls surface shall not contain cracks and defects that output the balls size to marginal deviations.

8 Heat treatment

The grinding media shall be suitably heat treated according to ISO 13521 to obtain the required hardness and microstructure.

9 Microstructure

Microstructure shall be free from continuous carbide networks according to ISO 13521.

10 Dimensions

The balls dimensions and marginal deviations have given at Table 1. The balls calculation parameters are given in Table 2.

Table 1: Grinding ball dimensions and deviations

Conditional diameter, mm	Nominal diameter, mm	Limit deviations to nominal diameter , mm
15	15	± 1.0
20	20	
25	25	
30	31.5	± 2.0
35	36.5	
40	41.5	
45	46.5	
50	52.0	± 3.0
55	57.0	
60	62.0	
65	68.0	
70	73.0	
80	83.0	
90	94.0	± 4.0
100	104.0	
110	114.0	± 5.0
120	125.0	

Table 2: Calculating parameters of grinding balls

Conditional diameter of grinding ball, mm	The calculating nominal parameters			
	Surface area, cm^2	Volume, cm^3	Mass, kg	Grinding balls quantity in one ton, pieces
15	7.06	1.76	0.014	71428
20	12.56	4.18	0.033	30300
25	19.52	8.18	0.064	15625
30	31.15	16.40	0.128	7812
35	41.83	25.40	0.199	5025
40	54.00	37.40	0.294	3401
45	67.90	52.60	0.413	2421
50	84.90	74.00	0.580	1724
55	102.00	96.90	0.761	1314
60	120.70	125.00	0.980	1020
65	145.20	164.50	1.291	774
70	167.33	204.00	1.600	625
80	216.31	299.00	2.350	425
90	277.45	435.00	3.410	293
100	339.60	589.00	4.620	216
110	408.00	776.00	6.090	164
120	490.60	1023.00	8.030	124

Note 1: The calculation of grinding balls surface area and grinding balls volume performed by nominal diameters.
Note 2: The steel density is 7.85 g/cm^3 during grinding balls mass calculation.

11 Hardness

The balls hardness after heat treatment must comply with the requirements set out in Table 3 and 4. For austenitic manganese cast steels the hardness shall be according to ISO 13521.

Table 3: Ball hardness values for steel balls

Conditional diameter, mm	The balls hardness groups						
	1	2	3	4		5	
	Hardness, HRC/HB, Minimum						
	Balls surface				At 1/2 R depth	Surface	Volumetric
15 ≤ X ≤ 45	45/415	49/461	55/534	55/534	45/415	61/601	57/555
50 ≤ X ≤ 70	43/401	48/453	53/514	53/514	43/401	60/590	53/514
80 ≤ X ≤ 100	39/341	42/375	52/495	52/495	40/352	58/567	48/453
110 ≤ X ≤ 120	35/302	38/331	50/477	50/477	35/302	56/545	43/401

Note 1. Rationing upper limit the balls hardness is permissible by agreement between producer and consumer.
Note 2. The manufacturer and consumer should use one determination method during the hardness control.

Table 4: Ball hardness values for cast balls

Mechanical properties and microstructures								
Item	Type	HRC		Ak (j/cm^2)	Microstructure	Times of Falling Balls	Wear rate (g/Tn)	Breakage
		Heat Treatment	Cast					
High Cr	ZQCr20	55 - 65	≥ 50	≥ 4.0	M+C	≥ 8000	≤ 25	≤ 0.5
	ZQCr17	55 - 65	≥ 50	≥ 4.0				
	ZQCr11	55 - 65	≥ 50	≥ 4.0			≤ 30	
Low Cr	ZQCr2		≥ 45	≥ 4.0	M+C			≤ 1.0

The grinding balls the 4-th and 5-th hardness group may be supplied with impact resistance control by agreement between the manufacturer and consumer. Impact resistance control provides according to the manufacturer's methodology.

12 Chemical composition

The balls produced with the carbon content and carbon equivalents should correspond to the values in Table 5 for steel balls and Table 6 for cast balls. For austenitic manganese cast steels the chemical composition shall be according to ISO 13521.

Table 5: Chemical composition for steel balls

Conditional diameter, mm	**The balls hardness group**	**Carbon content**	**Carbon equivalents**
		%, Minimum	
15 ≤ X ≤ 55	1, 2	0.40	0.50
	3	0.60	0.70
	4, 5	0.60	0.75
60 ≤ X ≤ 70	1, 2	0.50	0.70
	3, 4	0.60	0.75
	5	0.60	0.80
80 ≤ X ≤ 120	1, 2	0.50	0.70
	3, 4	0.60	0.75
	5	0.60	0.80
Note 1: Grinding balls the 1-st and 2-nd hardness group production is permissible without taking into account the carbon equivalents requirements. **Note 2:** 60mm grinding balls the 1-st and 2-nd hardness group production is permissible with carbon content not less than 0.4%. **Note 3:** Carbon equivalent formula shown in Annex A.			

Table 6: Chemical composition for cast balls

Item	**Type**	**Chemical Composition (%)**						
		C	**Si**	**Mn**	**Cr**	**S**	**P**	**Mo**
High Cr	ZQCr20	2.0 - 3.2	≤ 1.0	≤ 1.5	19 - 22	≤ 0.08	≤ 0.06	≤ 0.1
	ZQCr17	2.0 - 3.2	≤ 1.0	≤ 1.5	15 - 18	≤ 0.08	≤ 0.06	≤ 0.1
	ZQCr11	2.0 - 3.2	≤ 1.0	≤ 1.5	10 - 13	≤ 0.08	≤ 0.06	≤ 0.1
Low Cr	ZQCr2	2.1 - 3.5	≤ 1.0	≤ 1.5	1.5 - 3.5	≤ 0.08	≤ 0.06	≤ 0.1

13 Test methods

Ball dimensions are measured by Vernier caliper in accordance with ISO 13385-1 or by other tools which provide the required accuracy.
For Rockwell hardness, balls are measured in accordance to ISO 6508-1, ISO 6508-2 and ISO 6508-3. For Brinell hardness, balls are measured in accordance to ISO 6506-1, ISO 6506-2 and ISO 6506-3. It is also possible to determine ball hardness with the help of other certified instruments. Ball surface hardness is measured on two diametrically opposite grounds.
The chemical composition of grinding media may be analyzed using any standard method listed in ISO/TR 9769.

14 Sampling

14.1 Visual and dimensional characteristics

14.1.1 The number of grinding media to be selected at random from each lot shall depend upon the size of the lot and shall be in accordance with column 1 and 3 of Table 7.

14.1.2 The sample shall be selected from the lot at random. In order to ensure the randomness of selection; procedure given in ISO 24153 may be followed.
14.1.3 Each of the items selected according to 14.2 shall be inspected for visual and dimensional requirements. Any item failing to meet either of the characteristics shall be considered as defective. The lot shall be considered as conforming to the requirements if the number of defectives found in the sample is less than or equal to the acceptance number (see Table 7, column 4) and shall be rejected if it is greater than or equal to the rejection number (see Table 7, column 5). If the number of defectives lies, between the acceptance number and the rejection number, then a second sample of the same size as the first shall be taken at random and examined. The number of defectives found in the first and second samples shall be combined and if the combined number of the defectives is less than or equal to the corresponding acceptance number of the second sample, the lot shall be declared as conforming to the requirements; otherwise not.
14.1.4 Notwithstanding anything stated above, the lot shall be deemed to be not conforming to the standard and not acceptable.

14.2 Hardness and microstructure

14.2.1 The lot which has passed the visual and dimensional requirements shall next be tested for hardness and microstructure. For this purpose, the number of cylindrical balls to be selected shall be in accordance with column 1 and 3 of Table 7.
14.2.2 The criteria for conformity for these tests are similar to those given in 14.1.3.
14.2.3 Notwithstanding anything stated above, shall be deemed to be not conforming to the standard and not acceptable.

Table 7: Scale of sampling and permissible number of defectives

Lot Weight	State	Visual and dimensional characteristics		
		Sample size	Acceptance number	Rejection number
(1)	(2)	(3)	(4)	(5)
Up to 2 tonnes	First	20	0	3
	Second	20	3	4
2 tonnes ≤ X ≤ 5 tonnes	First	32	1	4
	Second	32	4	5
5 tonnes ≤ X ≤ 10 tonnes	First	50	2	5
	Second	50	6	7
Lot Weight	**State**	**Hardness and microstructure characteristics**		
		Sample size	**Acceptance number**	**Rejection number**
(1)	(2)	(3)	(4)	(5)
Up to 2 tonnes	First	5	0	2
	Second	5	1	2
2 tonnes ≤ X ≤ 5 tonnes	First	8	0	2
	Second	8	1	2
5 tonnes ≤ X ≤ 10 tonnes	First	13	0	3
	Second	13	3	4

15 Packaging

Grinding balls: shall be packed in metal containers, big-bags, wooden boxes or other acceptable packaging of approximately 1 ton each.

16 Marking

16.1 The grinding media are not individually marked.
16.2 The package of the grinding media shall be marked with the following important information:

a) The manufacturer's name or trademark
b) The Hardness group of the grinding media
b) The size (diameter) of the grinding media

17 Transportation and storage

The grinding media blend by different sizes and hardness groups is not allowed during transportation. The transportation of grinding media shall be transported and stored in the moisture free environments to prevent rusting.

Annex A

(Informative)

Carbon Equivalence Formula

The steel carbon equivalent of C_{eq} calculates in percentage by the formula:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Si}{24} + \frac{Cr}{5} + \frac{Ni + Cu}{40} + \frac{V}{14},$$

where C, Mn, Si, Cr, Ni, Cu, V - mass fraction of carbon, manganese, silicon, chromium, nickel, copper and vanadium.

Annex B

(Informative)

Volumetric Hardness Formula

Permissible the hardness determination on the templates cut perpendicular to the technological "band", so that the controlled template surface passes through the grinding ball central part. The templates surface prepares in accordance with the requirements ISO 6508-1 and ISO 6506-1. The grinding ball cutting technology excludes its heating higher than 100 ºC to avoid distortion the hardness measurements results.

Four hardness measurements on two mutually perpendicular lines performs at 1/2 radius depth. The minimum and the maximum hardness values ignore, and the grinding balls hardness defined as arithmetic average value the other two dimensions.

The volumetric hardness determines in two mutually perpendicular directions at templates, cut in accordance with the requirements of ISO 9013.

Volumetric hardness (VH) calculated by formula:

$$VH = 0{,}289\ T_{SURF} + 0{,}436\ T_{0.25} + 0.203 T_{0.5} + 0.063 T_{0.75} + 0.009\ T_C$$

where T_{SURF}, $T_{0.25}$, $T_{0.5}$, $T_{0.75}$, Tc the hardness values the hardness values at ball surface, at a distance from the grinding ball surface in the radius parts and at ball center.

The volumetric hardness determines as arithmetic average value of volumetric hardness the control grinding balls.

Bibliography

[1] TZS 3734:2023, *Grinding media — Balls specification*
[2] DSTU 8538-2015, *Steel milling balls for ball mills — Specifications*
[3] IS 6079:1989 (Reaffirmed 2022), *Low alloy cast steel grinding media — Specification*