BUREAU OF INDIAN STANDARDS

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भारतीय मानक मसौदा

कोयला - हार्डग्रोव ग्राइंडेबिलिटी इंडेक्स का निर्धारण

(आईएस 4433 *का दूसरा पुनरीक्षण)*

Draft Indian Standard

COAL - DETERMINATION OF HARDGROVE GRINDABILITY INDEX

(*Second Revision of* IS 4433)

(ICS 73.040)

Solid Mineral Fuels and Solid Biofuels Sectional Committee, PCD 7	Last date for Comments: **01 September 2025**

FOREWORD

(*Formal Clauses will be added later*)

The grindability of coal is a measure of the ease with which it can be ground fine enough for use as a pulverized fuel, and as such it reflects some of the physical properties of coal, like hardness, strength, tenacity, and fracture. Of the two methods developed for determining grindability of coals, that developed by R. N. Hardgrove is better known and is simpler. The Hardgrove grindability test serves as a means for estimating how various coals behave in the commercial pulverizers. This method is based upon the relative ease of grinding in a batch machine where the grinding is stopped before appreciable cushioning from finely crushed material occurs. The relation between grindability and capacity of any pulverizer is a straight line if plotted on a graph provided fines are removed from the pulverizing zone before the cushioning effect becomes dominant.

A general relationship exists between grindability of coal and its rank as shown by the degree of metamorphism in the natural series from brown coals and lignites to anthracite. Coals that are easiest to grind (having highest grindability index) are those of about 14 to 30 percent volatile matter content on the dry, mineral-matter-free basis. Coals of either lower or higher volatile content (the brown coals and lignites are exception) are more difficult to grind. However, the relation between the grindability and the rank is not sufficiently precise for grindability to be estimated from the chemical analysis of a coal with acceptable accuracy. Petrographic and mineral constituents influence grindability.

The Hardgrove grindability index of coal is affected by its moisture content and thus on the relative humidity of the atmosphere in which the sample was stabilized before the test and in which the test is carried out. However, even in case of high moisture coals, the difference of Hardgrove index due to that factor is not significant.

This standard was first published in 1967 and subsequently revised in 1979. However, with the use of Hardgrove grindability machines on a wider scale, the first revision was taken up. During first revision, a standard table for ascertaining the values of Hardgrove Grindability Index (HGI) from the experimental values of mass of the coal particles over 75- micron sieve was incorporated. Minor modifications were made in the diameter of the steel balls used between the grinding bowl and ring to align the dimension with that given in DP 5074 ‘ Hard coal determination Grindability Index’ issued by the of Hardgrove International Organization for Standardization.

In this revision, the following major changes have taken up:

— The test procedure has been updated to include two options for sample selection:

  a) Volume-based sampling**,** that is using the weight equivalent to a 75 cm^3 sample, or
  b) Weight-based sampling**,** using a 50 g sample.

  The volume-based method is preferred, as it minimizes errors associated with high ash or high mineral content. Indian coals typically exhibit a wide range of ash content, and volume-based sampling yields more accurate and consistent data. This approach is particularly beneficial for samples with varying mineral compositions, such as carbonaceous coal and shaly coal**.**

— Additional apparatus, such as drying ovens and sample dividers, have been incorporated. While, improvements have also been made in balancing**,** sieving, and gross sampling processes, although the calculation method remains unchanged.

— Regarding precision, the revised terminology included a requirement probability greater than 90% in both inter-laboratory and intra-laboratory conditions. However, repeatability and reproducibility criteria may not be applicable for high-volatile coals**,** as such materials are prone to changes due to physical processes and natural degradation.

In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’.

1 SCOPE

This standard prescribes the method for determining the grindability index of all types of Indian coals using the hardgrove machine with respect to the relative grindability and ease of pulverisation.

NOTE - The sieving is mandatory for observing the pulverisation. Due to easily alteration of physical properties during handling, the high volatile and low rank coal including lignite have reduced repeatability observation.

2 REFERENCES

The following standards contain provisions which through reference in this text, constitute the provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standard indicated below:

IS No.	*Title*
IS 3810	Solid mineral fuels — Vocabulary
(Part 1) : 2002	Part 1 Terms relating to coal preparation (*second revision*)
(Part 2) : 2003	Part 2 Terms relating to sampling, testing and analysis (*first revision*)
IS 460 (Part 1) : 2020	Test Sieves — Specification: Part 1 Wire cloth test sieves (*fourth revision*)
IS 436 (Part 1/Sec 1) : 2024	Methods for sampling of coal and coke: Part 1 Sampling of coal, Section 1 Manual sampling (*second revision*)

2 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 3810 (Part 1) and IS 3810 (Part 2) shall apply.

3 PRINCIPLE

3.1 The sample is prepared by either selecting a volume based quantity that is weight of 75 cm^3 sample or by taking 50 g sample by weight. The prepared sample of coal of limited size range is then ground under defined conditions in a laboratory mill of standardized design. The grindability index is calculated from sieve analysis of the ground product and a calibration chart is prepared from standard reference coal.

NOTE - The volume based test method is preferred to avoid error for high ash or high minerals content. The Indian origin coal has wide range of ash content and selecting sample on volume base will deliver more accurate data.

4 APPARATUS

4.1 Air Drying Oven (for air-drying, 1000 g, 4.75 mm samples) - used for passing slightly heated air over the sample. It shall be capable for maintaining temperature of 10 °C to 15 °C

above ambient temperature, with a maximum temperature of 40 °C. If the ambient temperature exceeds 40 °C, then the ambient temperature shall be used.

For easily oxidized coals, the temperature should not exceed 10 °C above room temperature, unless the ambient temperature is above 37 °C**,** in which case, again, the ambient temperature shall be used**.**

4.2 Drying Pan (for air-drying, 1000 g, 4.75 mm samples)

The pan should be non-reactive and dimensions such that the spread material is of less than 25 mm thickness.

4.3 Balances

4.3.1 Capacity 1000 g, sensitivity of at least 0.5 mg;

4.3.2 Capacity 1500 g, sensitivity 1 g.

4.4 Crusher

A laboratory plate mill or a hand grinder capable of reducing 4.75 mm coal particles to 1.18 mm with the production of a minimum material finer than 600 microns. The plates shall be serrated and shall be of about 100 mm in diameter. The distance between the plates shall be adjustable and the relative speed of rotation of the plates shall not exceed 200 rev/min. External roller or impact crushers shall be avoided for sample preparation.

4.5 Sample Divider

A bounded riffle divider or a rotary divider to be used.

4.6 Sieves

4.6.1 *Metallic Frame Circular Test Sieves* - of 1.18 mm, 600 micron, 75 micron and 200 mm in diameter with cover and receiver of about conforming to IS 460 (Part 1) or equivalent.

4.6.2 *Protective Sieve* - capable of nesting in the test sieves, with round or square hole apertures in the range 16 to 19 mm. A plate sieve with round holes is recommended.

4.7 Mechanical Sieving Machine

A machine capable of accepting an assembly of vertically nested sieves along with cover and receiver pan of 200 mm in diameter and simulates the motions of hand sieving. This may be achieved by imparting a horizontal oscillatory motion of 25 to 30 mm amplitude at rate of approximately 300 cycles per assembly at a rate of approximately 150 blows per min by a mass of l.9 kg moving through a vertical distance of about 25 mm under the influence of gravity. Alternatively, the nest of sieves, cover and receiver may be vibrated by an electromagnetic device, provided the sieving performance is equivalent to the mechanically vibrated machine described. Where mechanical sieving device is not available, an equivalent amount of hand sieving is necessary to achieve the required output of mechanical sieving.

4.8 Grindability Machine

The machine is shown in Fig. 1(a) and the essential tolerances are shown in Fig. 1(b). It includes a stationary grinding bowl, of hardened iron or steel, with a horizontal track in which holds eight steel balls (polished), each of (25.40 ± 0.003) mm diameter. The balls shall be driven by an upper grinding ring rotated at 19 to 21 rev/min. The upper grinding ring of similar material to the bowl, is connected to a spindle and shall be driven by an electric motor through reduction gears. Weights shall be added to the spindle so that the total vertical force on the steel balls due to the top ring, gear, weights and spindle is (284 ± 2) N, for example, closely equivalent to a total mass of (29 ± 0.2) kg. The machine shall be fitted with a revolution counter and an automatic device for stopping the machine after 60 ± 0.25 revolutions.

NOTE — The grinding bowl, balls and top grinding ring should be protected from rusting when not in use by storing in a desiccator with silica gel.

5 SAMPLING

5.1 The collection of the gross sample and its preparation shall be in accordance with IS 436 (Part 1/Sec 1), except that the initial crushing shall be to 4.75 mm instead of 10 mm. Reduce the quantity of 4.75 mm coal to about 1 kg by using a sample divider of suitable size and capacity. Beyond 4.75 mm and 1 kg should be avoided in top sizes sample collections. It does not meet the requirement of the test procedures.

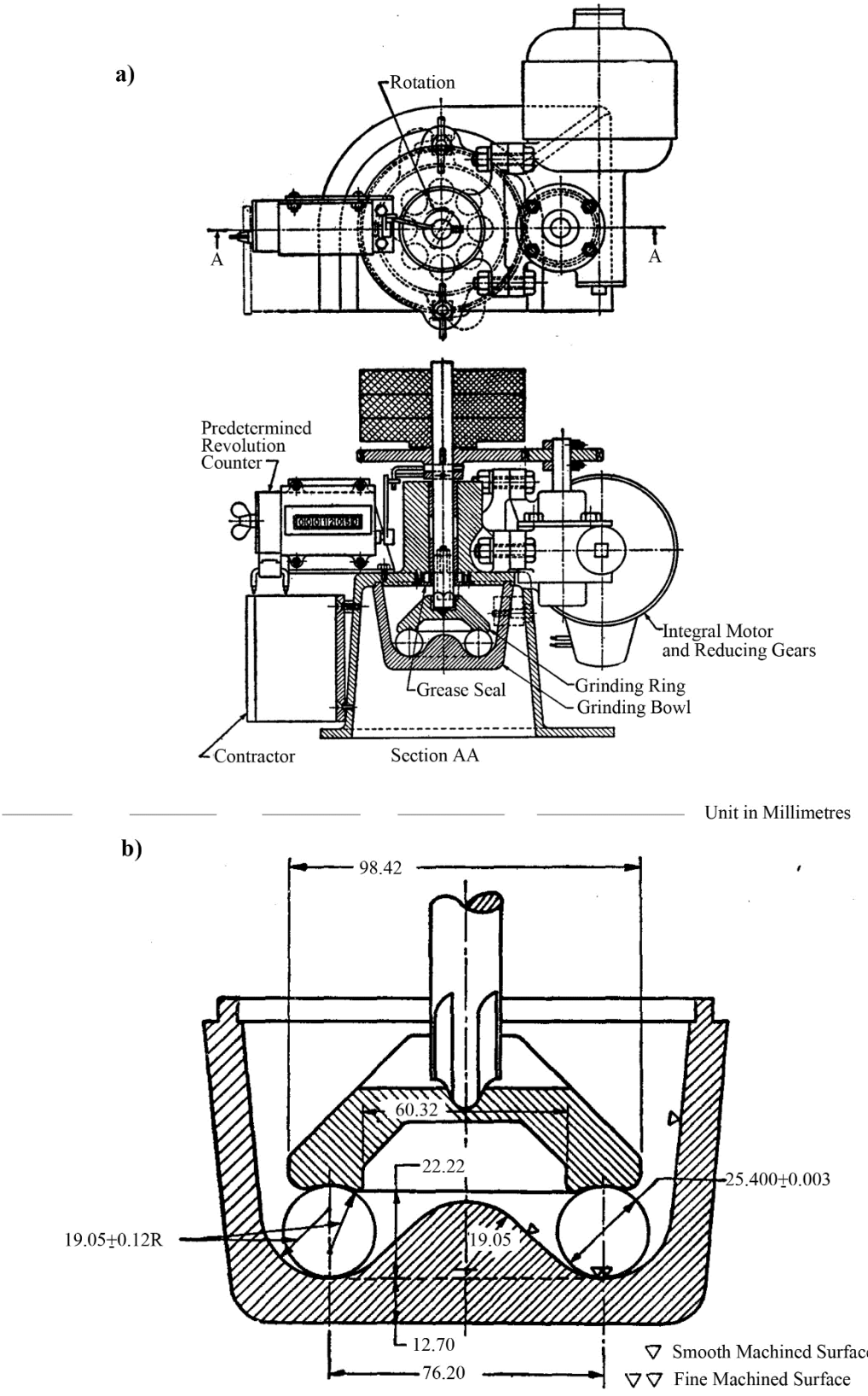

Fig. 1: a) Hardgrove Grinding Machine.
b) Details of Grinding Elements of Hardgrove Machine.

6 SAMPLE PREPARATION

6.1 Air dry (in air-drying oven) 1000 g portion of 4.75 mm coal, between 24 h and 48 h. Determine the mass of the dried portion to the nearest gram. Sieve the entire amount on a set of nested sieves consisting of a 1.18 mm IS Sieve on top of a 600 micron IS Sieve by sieving batches of about 200 g for 2 min in the sieving machine. Crush the material retained on the 1.18 mm sieve with the crusher adjusted so that only the largest particles are crushed. Sieve the crushed material for 2 min and return the oversize to the crusher, again set to crush only the largest particles. Continue crushing and sieving until all the material passes through the 1.18 mm sieve.

6.2 Discard that part of the portion passing through the 600 micron sieve. Weigh to the nearest gram the coal passing the l.18 mm sieve and retained on the 600 micron sieve. If the yield in this size range is less than 50 percent of the dried portion, the coal thus prepared shall be discarded and the sample preparation shall be repeated starting with another 1 kg portion of the 4.75 mm coal by following the procedure mentioned in **6.1**.

6.3 Mix thoroughly the 1.18 mm by 600 micron size coal. Remove about 120 g using a sample divider and de-dust by sieving for 5 min on a 600 micron sieve using the sieving machine. Reduce the de-dusted material, using a sample divider, to not less than 50 g or equivalent to weight of 75 cm^3 sample (volume based).

7 TEST PROCEDURE

7.1 Clean the grindability machine thoroughly with acetone and space the balls as evenly as possible around the grinding bowl.

7.2 Weigh 50 ± 0.01 g of the de-dusted material or take a volume-based sample equivalent to the weight of 75 cm^3, as prepared in **6**. Distribute this evenly in the grinding bowl, and smoothen the surface. Assemble the top grinding ring to the bowl, fasten the bowl in position to the driving spindle making sure that the load is evenly applied. Pre-set the counter and adjust the automatic stopping device so that the machine can operate for 60 ± 0.25 revolutions.

7.3 When the rotation has stopped, switch off the machine and dismantle the bowl assembly. Brush any adherent coal dust on to the protective sieve nested on the 75 micron sieve and receiving pan. Empty the grinding balls and ground coal on to the protective sieve (see Note). Brush any coal from the bowl and the balls into the protective sieve, setting them aside. Brush any coal and dust from the inside and under side of the protective sieve into the 75 micron sieve and set it aside.

> NOTE — The 16 micron or 20 micron sieve used to protect the 75 micron sieve may be distorted by use and become unsuitable for testing sieving purposes. It should be marked accordingly.

7.4 Replace the cover on the 75 micron sieve. Shake the assembled pan, 75 micron sieve and cover for 10 minutes. Carefully brush any coal dust from the underside of the 75 micron sieve into the pan. Repeat the sieving for two more periods of shaking, each of 5 min, cleaning the underside of the 75 micron sieve after each repetition.

7.5 Weigh separately to the nearest 0.01 g of the coal retained on the 75 micron sieve and the coal passing the 75 micron sieve. If the sum of these masses differ by more than 0.3 g from the initial mass of 50 ± 0.01 g, the test shall be rejected.

8 CALCULATION AND REPORTING OF RESULTS

8.1 Calculate the Hardgrove grindability index using the formula:

$$HGI = 13 + 6.93\ M$$

where

M = mass of the test sample passing through 75 micron sieve after grinding. In practice M is obtained by deducting from 50 g the mass of the ground sample retained on 75 micron sieve.

8.2 Carry out duplicate determinations on portions taken from the 1.18 mm by 600 micron fraction. Report the mean grindability index to the nearest whole number. Also read the Hardgrove Grindability index against the range of mass from Table 1.

Table 1 Standard Table for Ascertaining Values of HGI From The Experimental Values of Mass of the Coal Particles Over 75 Micron sieves
(*Clause* 8.2)

Range of Mass in gram		HGI	Range of Mass in Gram		HGI
39.0000 - 39.1053	:	89	42.8572 - 43.0014	:	62
39.1054 - 39.2496	:	88	43.0015 - 43.1457	:	61
39.2497 - 39.3939	:	87	43.1458 - 43.2900	:	60
39.3940 - 39.5382	:	86	43.2901 - 43.4343	:	59
39.5383 - 39.6825	:	85	43.4344 - 43.5786	:	58
39.6826 - 39.8268	:	84	43.5787 - 43.7229	:	57
39.8269 - 39.9711	:	83	43.7230 - 43.8672	:	56
39.9712 - 40.1154	:	82	43.8673 - 44.0115	:	55
40.1155 - 40.2597	:	81	44.0116 - 44.1558	:	54
40.2598 - 40.4040	:	80	44.1559 - 44.3001	:	53
40.4041 - 40.5483	:	79	44.3002 - 44.4444	:	52
40.5484 - 40.6926	:	78	44.4445 - 44.5887	:	51
40.6927 - 40.8369	:	77	44.5888 - 44.7330	:	50
40.8370 - 40.9812	:	76	44.7331 - 44.8773	:	49
40.9813 - 41.1255	:	75	44.8774 - 45.0216	:	48
41.1256 - 41.2698	:	74	45.0217 - 45.1659	:	47
41.2699 - 41.4141	:	73	45.1660 - 45.3102	:	46
41.4142 - 41.5584	:	72	45.3103 - 45.4545	:	45
41.5585 - 41.7027	:	71	45.4546 - 45.5988	:	44
41.7028 - 41.8470	:	70	45.5989 - 45.7431	:	43
41.8471 - 41.9913	:	69	45.7432 - 45.8874	:	42
41.9914 - 42.1356	:	68	45.8875 - 46.0317	:	41
42.1357 - 42.2799	:	67	46.0318 - 46.1760	:	40
42.2800 - 42.4242	:	66	46.1761 - 46.3203	:	39
42.4243 - 42.5686	:	65	46.3204 - 46.4646	:	38
42.5686 - 42.7128	:	64	46.4647 - 46.6089	:	37
42.7129 - 42.8571	:	63			

9 PRECISION

The repeatability and reproducibility may not be applied for high volatile coals. It can undergo easily change in the physical activities and natural process as well.

9.1 Repeatability — The results of duplicate determinations carried out at different times in the same laboratory by the same operator with the same apparatus, on portions of the same lot of 1.18 mm by 600 micron coal, shall not differ by more than 2 units. Two tests with separate and consecutive test determinations by the same operator with same apparatus shall be conducted. The probability should be more than 90 percent at random collection from a single quantity with homogenous material of 4.75 mm.

9.2 Reproducibility — The means of the results of duplicate determinations carried out in each of two different laboratories on portions of the same lot of 4.75 mm coal, shall not differ by more than 3 units. Two test with separate and consecutive test determination in the same operator with same apparatus. The probability should be more than 90 percent in different laboratories on riffled splits of 4.75 mm.