CONTRIBUTION TO DETERMINATION OF COAL GRINDABILITY USING HARDGROVE METHOD

PŘÍSPĚVEK KE STANOVENÍ MELITELNOSTI UHLÍ METODOU HARGROVE

František TICHÁNEK

Doc. Ing. Dr., Department of mineral raw materials, Institute of mining engineering and safety.
Faculty of Geology and Mining, Technical University of Ostrava
17. listopadu 15/2172, 708 33 Ostrava – Poruba
e-mail: frantisek.tichanek@vsb.cz

Abstract

The paper deals with determination of grindability of coal using Hardgrove method. Some non-availabilities of determination are mentioned as well as factors affecting grindability and relations for conversion of Hardgrove Grindability Index (HGI) values to Bond Work Index (Wi). Paper also provides information on utilization of Hardgrove method in Czech Republic and indicates HGI values for coal from OKD-Karvina region.

Abstrakt

Příspěvek se zabývá stanovením melitelnosti uhlí pomocí metody Hardgrove. V příspěvku jsou uvedeny některé nedostupné informace a také faktory ovlivňující melitelnost a vztahy pro konverzi hodnot indexu melitelnosti Hardgrove (HGI) na Bondův index práce (Wi). Příspěvek rovněž poskytuje informace o použití metody Hardgrove v České republice a udává hodnoty HGI u uhlí z Ostravsko-karvinského revíru.

Key words: grindability, Hardgrove grindability index, HGI, Bond Work Index, W_i

1 INTRODUCTION

Grindability, as absolutely measurable physical quality of material has not been defined yet. Practical assessment of the resistance of the raw material against grinding is performed in laboratory facilities, in which the sample is particularized in a similar manner as in the industrial grinders. The grindability is determined basically in two possible manners: It is possible either to compare the quantity of work consumed for grinding of a sample of analysed material (product constant fineness method) or the granularity composition of final products is compared with the same consumption of grinding work (constant method of useful grinding work).

Grindability determination methods based on constant fineness of grinding are labour and time demanding. Methods based on constant quantity of the delivered grinding work, which include also the specification of grindability by Hardgrove are applied more frequently. Hardgrove grindability index (HGI) is determining factor of energy consumption during grinding. The HGI value is used for more detailed coal specification and is significant also for the design of capacity of particularization equipment and grinding circuits.

The contribution specifies the discovered value of grindability HGI of black coal from mine plants in the Karvina part of the Ostrava-Karvina coal basin.

2 TESTING EQUIPMENT, TESTING PROCEDURE

Determination of grindability is performed in Hardgrove laboratory grinder pursuant to the ASTM D409 standard. The grinder consists of two main components. Lower stationary part consists of the tank with horizontal grinding track, on which 8 steel balls with a diameter of 25,40±0,13 mm move. The grinding bodies are made to move by rotating upper part of the grinder.

General view of the device is seen in figure 1, the grinding parts of the grinder are shown in figure 2. The sample of grain size below 4.75 mm is ground and subsequently screened for preparation of analytical sample of grain size of 0.6 to 1.18 mm. A charge of 50g±0,01g of coal is removed from analytical sample and poured on the grinding track. Grinding ball is inserted, the upper rotating part is loaded and the grinder drive is started up. After 60 rotations the grinder stops and the ground coal is screened for 10 minutes on the screen with square openings with eye length of 0.075 mm. After that grains caught at the bottom of the screen are removed by means of a fine brush. The coal screening and cleaning is performed twice again after 5 minutes. After the

completion of screening the grains obtained by cleaning of screening surface are added to the undersize. The undersize and oversize are weighed with accuracy of 0.01 g. The total weight of screening products can differ from the original weight at most by 0.75 g.

Fig. 1 Hardgrove Grindability Machine

Obr.1 Mlýnek Hardgrove

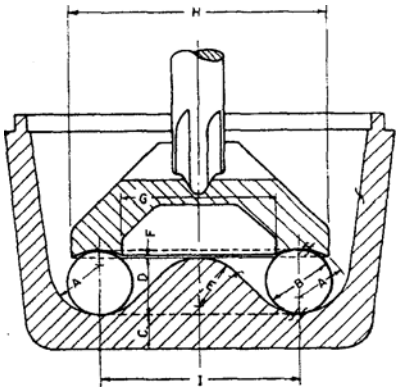

Fig. 2 Grinding Elements of Hardgrove Machine

Obr. 2 Mlecí části mlýnku Hardgrove

The HGI grindability value is calculated from the following formula:

$$HGI = 13+6{,}93(50-m)$$

The m value is the weight of oversize expressed in grams.

3 FACTORS AFFECTING THE HGI GRINDABILITY VALUES

The Hardgrove grindability index value is influenced by petrographic composition of coal. The analysis of grindability of British coal confirmed wide relation of HGI values between the quality group of coal, volatile combustible matter contents, carbon and hydrogen (Fitton, 1957).

The increase of contents of volatile combustible matter improves the grindability up to the contents of volatile combustible matter of approximately 30%, beyond which the grindability deteriorates. Similarly the HGI value increases with the growth of carbon contents. The grindability then drops rapidly with the contents of carbon exceeding approximately 92%.

The lithotypes of black coal with similar contents of volatile combustible matter include differences in the HGI values. Durite (dull coal) is a lithotype characteristic by low HGI and is generally the toughest (Temeeva, 1979). Labelling fusite as lithotype with the highest HGI value is disputable, because its extreme fragility is caused by origination of significant amount of fine fractions rather during screening that in the course of grinding in the testing device (Hower, 1988). Glittering vitrinite lithotypes in black coal have significantly higher HGI values than durites in the same coal group. The difference in grindability of individual lithotypes allows for selective grinding (Burstein, 1954 and 1971; Koshina, 1980). It is generally valid that the occurrence of vitrinite in coal increases the HGI value, whereas the micronite and liptinite macerals decrease the grindability (Hsieh, 1976; Hower, 1987).

On the basis of research of black coal from Kentucky Hower and Wild (1988) have derived that part of the HGI change can be explained by maceral composition, mainly by liptinite contents, which is the most important maceral group affecting grindability and coal class expressed in this study by the value of maximum reflectance of vitrinite. The grindability is significantly influenced also by the contents of ash in coal (Dinterová, 1976; Wang, 1996).

4 RELATION BETWEEN THE HGI GRINDABILITY VALUE AND WI WORK INDEX BY BOND

Both tests serving for determination of grindability are widely used in many industrial areas. The Hardgrove method of specification of grindability is used mostly for determination of grindability of coal, but also in determining grindability of other raw materials. Bond's method is especially used for determining rock grindability. On the basis of the results of Bond's results of determination we can to advantage empirically specify the amount of energy necessary for particularization of the given raw material. The positive of the determination of grindability using Hardgrove method consists in simple test performance.

Especially for these reasons mutual correlation between the results obtained using Hardgrove method and results of tests by Bond. For the calculation of work index W_i from HGI values Bond (1954) proposed by the following formula:

$$W_i = \frac{88}{HGI^{0,5}}$$

In 1961 Bond specifies for W_i calculation the following modified formula:

$$W_i = \frac{435}{HGI^{0,91}}$$

On the basis of research of grindability McIntyre and Plitt, 1980 recommended using of the following formula for calculation of W_i>8,5 value:

$$W_i = \frac{1622}{HGI^{1,08}}$$

For carbonates Hower et al.,1992, proposed the following formula for calculation of Wi from HGI value:

$$Wi = 14,56 - 0,10HGI$$

The Wi values obtained by calculation from HGI not always precisely correspond to the values of work index specified by sample impact testing. This is associated with the fact that in impact tests relatively large grains are ground, whereas the HGI values is discovered by grinding of fine-grain samples. Impact test is performed on impact testing device, which consists of two pendulum hammers (each with a weight of 16 kg), which is swung from the rest position and is let to impact the grain of the tested rock. The tested sample is not supposed to be visibly mechanically broken. Oval shape grain has prescribed size within the range of 50-75 mm. For determining of the index work of the given sample 25 grains is always tested.

5 HARGROVE METHOD NEGATIVES

The HGI value is an important parameter characterizing especially the coal in terms of easiness of its particularization. In spite of some negatives the HGI is used in development, design and construction of grinding circuits. The HGI value serves also to more detailed specification of coal in the international trade. Inaccuracies in determination of grindability can therefore lead to proposal of non-corresponding performance of particularization devices, which may significantly increase the costs of grinding. HGI is a non-linear quality. The difference in grinding capacity of coal with a HGI value of 40 and 50 is very sgnificant, but the difference between the value HGI 90 and HGI 100 is almost negligible (ACARP Report, 1998).

Water contents in the tested sample plays an important role in determining the HGI value (Vecci and Moore, 1978). On the basis of the performed tests of grindability of brown and lignitic coal with different water contents it is possible to expect that there is a certain water content in coal, at which the HGI value for the given

coal is minimal. It is possible to expect that the knowledge of dependence of HGI value on the content of water in a concrete type of coal can significantly contribute to optimization of the degree of drying in operating grinders in order to achieve optimum grindability.

As the methodology of HGI determination implies, the test consists in grinding of 50g sample. It is evident that the size of 50g sample volume will vary depending on the density of the tested material. Standard circular axial Hardgrove grinder is in fact a device with constant volume of grinding space. The change of thickness of the layer of ground material will bring about also the grinding conditions, which will affect the grindability value. On the basis of research (Agus and Waters, 1971, 1972), it was recommended as standard for determination of grindability sample with a volume of 75cm^3, instead of sample of 50g. Using this modified method the authors gained more concordant results, especially in testing of heterogeneous materials like for example some types of coal containing solid ash.

Heterogeneity of the sample composition influences the HGI value. In testing of the sample of mixture of coal with different grindability of individual components no values of grindability have been discovered by weighted average of the values of HGI components and they usually point to lower values of HGI grindability.

The problem of preference grinding of soft types of coal containing solid ash was dealt with by Heywood (1947). In the industrial grinders the grinding is done continuously as opposed to laboratory tests. The insufficiently ground grains of solid ash are concentrated in the recirculating material. With regard to the fact that the recirculation load can achieve a multiple of weight of charge, the material in the grinding zone will have much lower grindability than shown by the tested charge. If the grinding device was designed only on the basis of the values of grindability of charge, the capacity of the grinder may be insufficient in practical operation.

Determination of the value of HGI grindability is performed at constant pressure between the grinding elements. It is not the case in many industrial grinders and the grinding conditions differ from the laboratory Hardgrove test conditions.

Significant drawback of the Hardgrove method also consists in the fact that in the course of grinding the fine material accumulates in the coal layer and protects the non-ground particles in a better way than in the industrial, continuously operating grinders (ACARP Report, 1998).

6 GRINDABILITY OF COAL FROM OSTRAVA-KARVINA COAL BASIN

One of the first centres dealing with the research of grindability using Hardgrove method in former Czechoslovakia already in the first half of the eighties of last century was the department of mineral dressing at the faculty of geology and mining of the Technical University in Ostrava. The grindability is presently determined at the department of mineral ore processing, which makes part of the Institute of mine engineering and safety of the faculty of geology and mining of the Technical University of Ostrava. On the basis of research of crushability and grindability it was stated that the method of determination of grindability by Hardgrove is sufficiently accurate and the discovered values do not have significant spread. The reproducibility of this method allows for comparison of grindability of various types of rocks (Dinterová, 1976).

Currently the HGI value is a standard part of coal specification. Table 1 specifies the values of grindability HGI for selected samples from individual mine plants in the Karvina part of the Ostrava-Karvina coal basin (Tichánek, 1999).

Despite wide application of HGI value for closer characterization of coal there is not any unified classification scale. The grindability value of 100 HGI is considered to be a reference standard, it is however not the average value of black coal grindability.

Power plants burning ground coal usually require values of HGI > 60, coal with a value of HGI < 50 is considered heavily grindable in North America. Australian coal was in terms of HGI grindability divided into six groups (Agus and Waters, 1971). The coal types with grindability value below 40 HGI are classified as very hard, coals with HGI value from 40 to 60 are classified as hard, the coal with HGI value from 60 to 80 as medium hard, from 80 to 100 HGI as soft, and with HGI from 100 to 120 as very soft and coal with the grindability value HGI above 120 is classified as extremely soft; this group however includes only some brown types of coal.

Table 1 Values Hardgrove Grindability Index

Tabulka 1 Hodnoty melitelnosti HGI

Sample	Grindability HGI	A^d (%)	V^{daf} (%)
ČSA 0-30	70	18,4	26,5
ČSA 0-60	70	9.3	30,7
ČSM KPS	72	7,8	31,1
ČSM middlings	55	45,0	31,3
ČSM PK	60	28,5	31,0
Darkov 0-10	86	13,8	27,0
Darkov middlings	72	30,1	28,6
Darkov middlings	62	33,5	29,9
Darkov 0-30	68	24,7	28,8
Doubrava dust	59	17,7	28,6
Doubrava 0-20	57	18,6	28,9
Doubrava 0-50	53	18.1	28,7
Dukla 0-20	56	19,2	32,0
František dust	87	21,6	27,5
Lazy 0-20	64	18,7	31,4
Lazy 0-30	54	5.5	30,5
Lazy 0-50	53	5,3	29,9
Lazy Hp	63	20,3	29,5
Lazy Md	57	31,6	33,1
Lazy Cc	54	7,3	31,1

CONCLUSION

Grindability expressed as the ability of raw material to increase its surface by means of grinding is an important factor specifying the size and capacity of grinding equipment. The Hardgrove method appears to be the best from many methods of specification of the coal grindability. On the basis of the performed tests of grindability of coal from Karvina part of the Ostrava-Karvina coal basin we can state that in terms of grindability they are coals suitable for power-production use in furnaces combusting dust fuel. All the samples showed HGI values exceeding 50.

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RESUMÉ

The paper deals with grindability determination of coal by Hardgrove method. Among the coal properties specified in determining the proper coal source for a specific use, the Hardgrove grindability index (HGI) is often considered to be an important parameter. Hardgrove grindability as a complex property encompassing hardness, strength, tenacity, and fracture is a determinant of power consumption in grinding and pulverizer capacity.

The HGI is a tool developed for boiler designers and now used in a commercial manner to specify coals. Hardgrove grindability index is recognized as having some deficiencies, however it is seen to be generally effective for internationally traded coals.

Some non-availabilities of determination are mentioned as well as factors affecting grindability and relations for conversion of HGI values to Bond Work Index (Wi).

Paper also gives information about utilization of Hardgrove method in Czech Republic and indicates HGI values for coal from OKD - Karviná region. Tested coal samples belong to medium-hard even hard coals whereas all determined HGI values are higher than 50.The coal is suitable for energetic utilization in combustion chamber with pulverized fuel from the grindability viewpoint.