DETERMINATION OF MOHS HARDNESS OF GLAZED TILES BY SCRATCHING TESTS

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ABSTRACT

The quality of ceramic coatings is closely related to the customer's satisfaction, that is, adequate design and properties according to their use. Therefore, it is necessary to think about the characteristics of the ceramic coatings that define the customer's expectations. Ceramic coatings used in paving must present, among other characteristics, high abrasion wear resistance. The determination of scratch resistance also contributes to the characterization of the ceramic product because it can be associated with abrasion resistance. The Mohs scale is normally used to measure scratch resistance. The Mohs hardness of a certain material is obtained by means of comparison of its scratching resistance with that of ten different standard minerals. This procedure can present problems because the applied force, the attack angle, the scratching velocity and the fragmentation of the standards can not be controlled during the test. In this work, a correlation between Mohs hardness measurements and the scratching hardness during the scratching test is presented. This method has eliminated the mentioned problems.

INTRODUCTION

The abrasive wear is a multiple scratching process. In this sense, the abrasive wear resistance is closely related to the scratching resistance [1,2]. Great amounts of abrasive are brought to the ceramic tiles by the feet of the users causing abrasive wear. The determination of the scratching hardness contributes to the characterization of the ceramic products.

The Mohs hardness is one of the parameters recommended by current standards [3] to evaluate ceramic tiles. However, among other problems, there is a lack of control of the applied force, the attack angle, the scratching velocity and the fragmentation of the standards, during the test. In addition, the visualization of the scratches caused by the standards is not very precise.

The sclerometric test or scratching test consists of a simulation where only one abrasive particle acts over the specimen. This technique provides the scratching hardness, specific scratching energy, dynamic brittleness index, and critical stress concentration factor, among other properties [4,5,6,7].

Figure 1 shows a scratching tester, with a diagram of the acting forces on the indentor. From this figure, some scratching parameters can be defined, especially the scratching hardness (Hr), described by the equation (1):

$$Hr = \frac{Fn}{An} = K_1 = \frac{Fn}{L^2} \qquad (1)$$

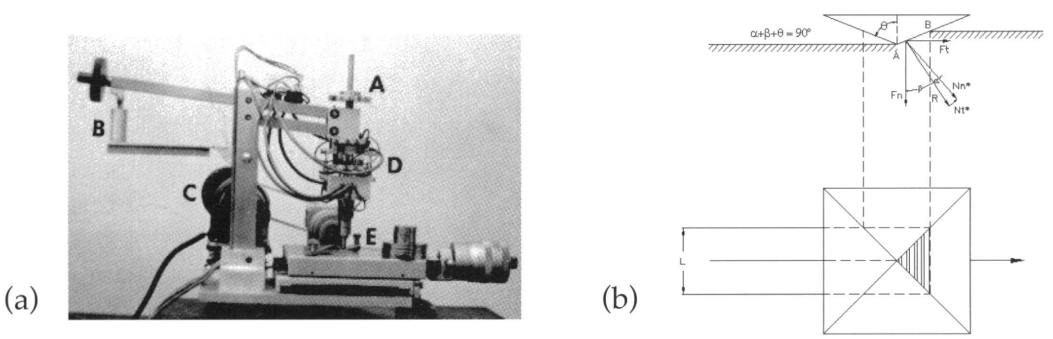


Figure 1. *(a) Scratching tester. A - Normal load, B - Shock absorber, C - Direct current motor, D - Load cell, E - Sample holding table.(b) Force diagram of the indenter.*

[1] DE MELLO, J. D. B.; *Structure Metallurgiques et Caracterization de L'abrasion des Fontes Blanches au Chrome,* Thèse de doctorat, Institute National Polytechnique de Grenoble, France, 1983.

[2] LAMY, B., *Contribution a L'etude Phenomenologique de L'enlevement de Matiere et de la Deformation des Surfaces Antagonistes dans les Processus D'abrasion,* Thèse de doctorat, Université de Haute Alsace, France, 1982.

[3] *EN 101/85 - Determinação da Dureza ao Risco de Superfície Segundo Mohs.*

[4] FEIJÃO, J. F. M., ALARCON, O. E., DE MELLO, J. D. B., DA ROSA, F. G., SILVEIRA, R. E SILVEIRA, M., *Study of Wearing Mechanism on Glazed Tiles by Scratching Tests,* Qualicer 96, Castellón, Spain, 1996.

[5] RASLAN, A. A., *Estudo da Abrasão do Silício por Esclerometria Retilínea,* Anais do I Congresso Iberoamericano de Ingenieria Mecanica, España, 1993, pp. 231-235.

[6] RASLAN, A. A., *A Dureza ao Risco de Monocristal de Silício,* Anais do X CBCIMAT, Águas de Lindóia, Brazil, 1992, pp. 1084 -1087.

Where, An is the projection of AB plane (contact plane) over the normal direction plane. L is the groove width; K_1 is a constant related to the indenter geometry. For Vickers indenter, $K_1 = 4$.

OBJETIVES

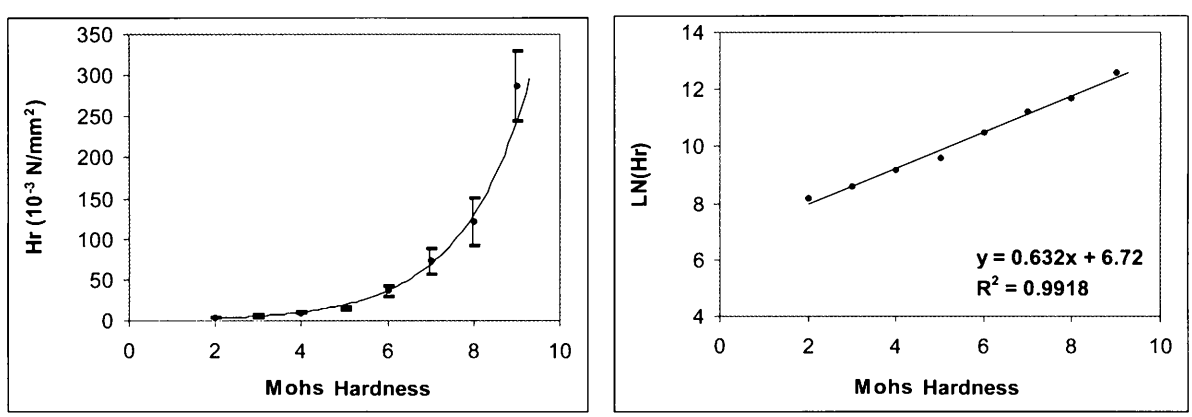
The present work aims to present a new method to measure the Mohs hardness by means of scratching tests. This method provides results that are obtained under controlled conditions, including the applied force, the scratching velocity, the attack angle and the indentor integrity.

EXPERIMENTAL PROCEDURE

The scratches were carried out in the scratching tester presented in Figure 1(a). Plates of eight different minerals were used, according to the Mohs scale standards (gypsum, calcite, fluorite, apatite, orthoclase, quartz, topaz, and corundum). The imposed conditions were: diamond scratchier (Vickers indenter in vertical position), normal load (Fn) = 1.0 N and scratching velocity of 500 μm/s.

RESULTS AND DISCUSSION

The groove widths were measured using an optical microscope. The scratch hardness values were calculated by using equation (1). The calculated values Hr were plotted in function of the corresponding Mohs hardness values, as shown in Figure 2(a). The obtained curve was linearized through the logarithms of Hr, as shown in Figure 2(b).



(a) (b)

Figure 2. *(a) Relation between scratching hardness and Mohs hardness, (b) lnHr x Mohs hardness curve.*

From Figure 2(b), the equation 2 can be obtained:

$$\text{Mohs Hardness} = \frac{\ln Hr - 6.72}{0.63} \quad (2)$$

The Mohs hardness values were measured in five commercial ceramic tiles, in order to validate the model. It were used the traditional method, that uses a comparison with standard minerals, and the scratching method. Three ceramic tiles were smooth (A, B and C) and two were rough (D and E). The experimental conditions were similar

to those used in the scratching of the Mohs standard minerals. The obtained results are presented in table 1.

Ceramic tile	A	B	C	D	E
Mohs hardness – Traditional method	4	5	5	6	8
Mohs hardness – Scratching method	4.52	5.80	5.78	5.74	5.95

***Table 1**. Mohs hardness of five commercial ceramic tiles, obtained by the traditional methods and by the scratching method (sclerometric test).*

The results presented in table 1 show that in A, B and C ceramic tiles, the Mohs hardness values are higher for the scratching method than for the traditional method. In D and E ceramic tiles, the values obtained by the scratching test are lower.

In the traditional Mohs test, if a given standard can scratch a sample, this sample is classified by the hardness of the previous standard. Considering this, the results for A, B and C ceramic tiles are expected.

The surface of D and E ceramic tiles was very rough; then, the grooves produced by the scratch tester were not clearly visible by naked eye. In these cases, during the Mohs hardness measurements using traditional method, one will need to use standards harder and harder, in order to visualize the scratches. Then, it is possible to suppose that they had just been scratched by previous standards (of lower hardness).

CONCLUSIONS

- The scratching test or sclerometric test guarantees the control of the applied force, the attack angle, the scratching velocity and the fragmentation of the standards during the test. In addition, this test does not present problems associated to the visualization of the scratches caused by the standards, as observed in the traditional Mohs tests.

- The scratching test for assessment of the Mohs hardness provides more precise values than the traditional test.