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Magnetofluidic testing of rock cutting knives

Constantin Dan Buioca*, Vasile Iusan, Remus Pirlea

Department of Physics, University of Petrosani, 20 University Street, 2675 Petrosani, Romania

Abstract

The nondestructive testing of cutting knives consists in the determination of nonuniformity of a magnetic fluid layer applied on the horizontally placed surface of the magnetized cutting plate of the knife. A low constant magnetic field was applied perpendicular to the knife surface and a uniform magnetic fluid layer was applied. The defects as nonuniform brass layer, fissures or small cavities between the cutting plate and knife core determine the apparition of magnetic field gradients and therefore magnetic forces acting on the magnetic fluid which migrates to the zones with higher magnetic field intensity. After several minutes, a nonuniform layer of magnetic fluid was directly observed. Quantitative results, concerning the position and dimensions of the defect, were obtained by computer aided processing of the magnetic fluid layer image. Experimental data for several cutting knives are presented in the paper.

Keywords: Nondestructive testing; Cutting knives; Magnetic fluids

1. Introduction

Detachable rotative cutting knives are used for making holes in coal, low and medium durity rocks or materials. These tools are made from a steel core and two cutting plates of hard alloys—metallic wolfram carbures and cobalt.

The adding of the cutting plates on the knife core is obtained by brassing, using 0.2 mm thick brass plate and an electric induction method. The brass heating and melting depend on alternative current frequency and initial processing of the brassed surfaces. Defects as nonuniformities of the brass layer or small cavities can appear during this process. Small internal fissures can also appear during the knife use in the cutting process.

Nondestructive testing of the cutting knives appears to be useful, especially before their use in technological application. Several nondestructive testing methods [1], as ultrasonic, X-rays and electromagnetic defectoscopy, are available but also present are some important disadvantages. They all necessitate complex installations, difficult to use because of the cutting knife physical dimensions and shape. Dry magnetic particles inspection seems to be more useful, but the use of very small particles and special detection methods makes it difficult. A better migration of the magnetic particles is obtained if they are in suspension in a liquid medium, and an easier (optical) detection of the particles can be done. That is why we have used magnetic fluids as magnetic particles suspensions in a liquid.

Some theoretical and experimental studies have shown that the nondestructive testing of ferro- and ferrimagnetic pieces using magnetic fluids is a simple and precise method to put into evidence any nonuniformity in the pieces determining the apparition of a magnetic field gradient [2,3]. The paper presents a theoretical and experimental investigation of the possibility to use this method in the case of rock cutting knives.

2. Theoretical aspects

Fig. 1 presents a picture of some typical cutting knives. They all contain a knife core with two cutting plates, trapezoidal shaped, brassed to the core having different shapes and dimensions.

*Corresponding author. Fax: +40-54-54-2792.
E-mail address: buioca@upet.ro (C.D. Buioca).

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Fig. 1. Rock cutting knives.

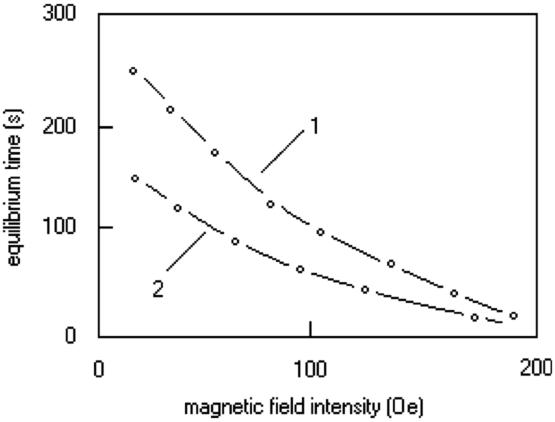

Fig. 2. Equilibrium time versus magnetic field intensity.

During the nondestructive testing, the plate's free surface is horizontally positioned and a magnetic field perpendicular to the surface is applied. The magnetic field intensity near the surface has an important gradient on the plate's boundaries and in the areas with defects.

The total force acting on a magnetic fluid particle is

$$\vec{F}_{\mathrm{M}} = V(\vec{M}_{\mathrm{MF}}\nabla)\vec{H} + V\rho_{\mathrm{MF}}\vec{g}, \tag{1}$$

where V, M_{MF} and ρ_{MF} are the volume, the magnetization and the density of the magnetic fluid particle, H is the magnetic field intensity and g is the gravitational acceleration. The magnetic fluid will migrate under the action of this force, reaching an equilibrium state in which its free surface will be perpendicular to the force.

The equilibrium time is mainly determined by the magnetic force—the first term in Eq. (1)—and magnetic fluid inertia. A high enough magnetic field intensity will determine the action of a high force and a fast migration of the magnetic fluid to the plate boundaries. Therefore, the observation of the nonuniformities determined by the defects will be very difficult. That is why a lower magnetic field must be applied to the observed plate, allowing the obtaining of a higher equilibrium time and defects observation.

A theoretical prediction of the equilibrium time is very difficult. We have determined it experimentally for a large area of magnetic fluid samples and magnetic field intensities. Fig. 2 presents the dependence of this time on the magnetic field intensity, for two magnetic fluid samples characterized by saturation magnetizations of 60 (curve 1) and 100 Gs (curve 2), respectively.

In further experiments, we have used the first magnetic fluid sample and a magnetic field intensity of 10 Oe, corresponding to an equilibrium time of about 200 s. An observation time of about 120 s, allowing to put into evidence the defects, was used in all experiments.

3. Experimental results and discussions

Experimental results were obtained for several cutting knives magnetized using a usual permanent magnet applied on the opposite side of the knife core with respect to the analyzed cutting plate. Pictures of the magnetic fluid layer after 2 min were obtained using a photo camera and were processed on a PC.

Most cutting knives did not have defects on either cutting plate. Fig. 3 presents an example. No significant variations of the magnetic fluid layer thickness (related to the gray tone of pixels in the cutting plates area), except the plate boundaries, can be observed.

Fig. 4 shows the image of a cutting knife with a defect. Two large zones with higher contrast can be seen here. One indicates a fissure or linear zone of discontinuity. This fissure, of about 0.2 mm thickness, was also directly (optically) observed by us at the plate left boundary, but its length could not be determined in this way. The

Fig. 3. Cutting knife plate without defect.

Fig. 4. Cutting knife plate with defect.

image also shows a large defect, in the left-upper part of the plate, having a nonuniform brass layer put into evidence by the strong variation of the gray tone.

A final remark must be made here. All experiments were repeated four times in order to verify the reproductivity of the results. All the obtained results, including those presented in the paper, were reproducible.

4. Conclusions

The nondestructive testing of cutting knifes using magnetic fluids is a simple, rapid and precise method to put into evidence such defects as holes, fissures or nonuniform layer of brass. Quantitative results can be obtained for holes and fissures, by processing the obtained images and determination of the dependence of gray tone as a function on pixels coordinates.

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