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Electromagnetic Radiation Induced by Percussion Drilling

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Abstract. A series of experiments detecting electromagnetic radiation (EMR) emitted during percussion drilling were carried out. The electromagnetic signals obtained could be classified into four groups. Three groups are similar to former pulse types observed during conventional uniaxial and triaxial compression experiments, while the fourth is a new one possibly emanating from conical fracturing or fragmentation of chips.

Key words: electromagnetic radiation, fracture, percussion drilling

1. Introduction. Although the drilling process has hitherto been extensively investigated, its details are still not well understood. Recently, Rossmanith et al. (1996; 1997) carried out experimental and numerical investigations in order to understand the mechanism of material damage under percussion drilling. They found that the stress applied during drilling, besides inducing elastic waves emission also resulted in a new defect series: every time a percussion occurs, existing defects grow, microcracks are formed and propagate, and a "damage zone" around the drilling tip is thus created (Rossmanith et al., 1996; 1997), a zone consisting of a network of many small and a few larger cracks. Another observed defect consists of circumferential cracks around the hole, and appears when weak regions exist in the material (Ravishankar and Murthy, 2000).

It is well known that fracturing also emits an electromagnetic radiation (EMR). This phenomenon was observed in various materials: metals, ionic crystals, glass, ice and different rocks.

During recent years, we have investigated EMR during uniaxial and triaxial compression of granite, rhyolite, chalk and glass ceramics (Rabinovitch et al., 1995; 1996; 1998; 1999; 2000; Frid et al., 2000). As the crack propagates, new bonds are severed and EMR amplitude grows (Rabinovitch et al., 1998). Hence, EMR amplitude increases with crack area (Rabinovitch et al., 1998; 1999). When the crack halts, charge oscillations decay, and the pulse amplitude decreases (Rabinovitch et al., 1998; 2000). Hence, the time from the pulse beginning to its maximum, which we call T', is proportional to the crack length. It has also been shown that the pulse frequency ω is inversely proportional to the crack width (Rabinovitch et al., 1998). Crack area is therefore proportional to T'/ω (Frid et al., 2000).

The aim of the present study is to investigate fractures that develop during percussion drilling and the EMR emitted by them.

2. Experimental arrangement and materials. We used cylindrically shaped samples 100 mm in length and 25 mm in diameter (Fig. 1) that were percussion drilled.

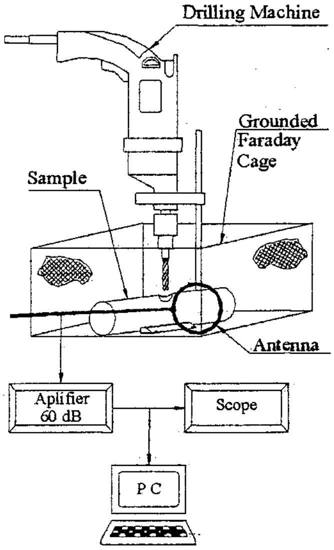

Fig. 1. Schematic diagram of experimental arrangement.

Drilling was carried out at about the mid length of the cylinder, perpendicular to the cylinder axis. EMR was measured in the frequency range 1kHz-50MHz with 1μV sensitivity throughout. Radiation is detected by a one-loop magnetic antenna 3 cm in diameter, which is electrically "small" and exhibits negligible response to foreign electric fields. The antenna was placed at a distance of 3 cm from the drilling hole. External electromagnetic disturbances were further decreased by the two following methods:

(a) The sample together with the antenna were placed in a grounded Faraday cage;

(b) The plane of the antenna was aligned perpendicular to the drilling direction, so that the influence of electromagnetic disturbances emitted by the motor of the drilling machine was minimized.

All EMR signals were electrically amplified by 60 dB, digitized and collected at a PC hard disk. The data were analyzed after test completion.

The materials used in the study were chalk from Middle Eocene layers in the Beer Sheva syncline, Eilat granite from the Nahal Shelomo area of southern Israel (Rabinovitch et al., 1999), Solenhofen limestone from Germany, PMMA and soda-lime glass.

3. Results and preliminary discussion. The 700 odd EMR signals measured during percussion drilling of all five materials were classified in the following way:

The first group: “Short single pulses” of 0.3 - 1.5 μs duration;

The second group: “Short chain of single pulses” of 2 - 15 μs duration;

The third group: “Extended chain of pulses” of 15 - 60 μs duration;

The fourth group: “Pulses along base-line voltage changes” whose duration varies between 10 and 800 μs.

Pulses of the first group (Fig.2) probably correspond to single cracks, and are characterized by a single main frequency ranging between 10 and 25 MHz.

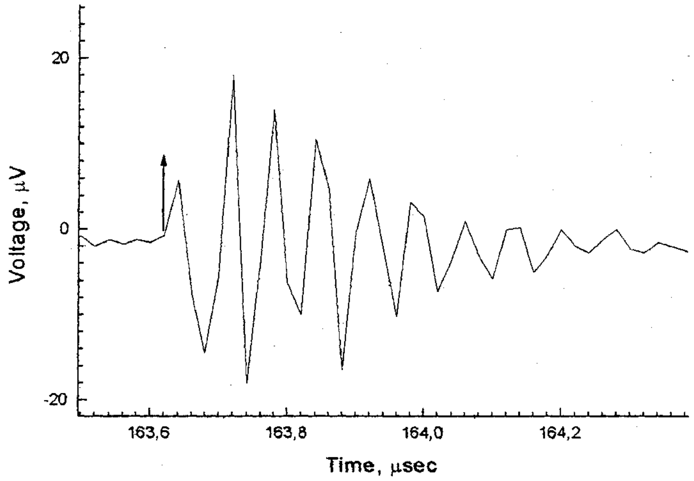

Fig. 2. An experimental EMR pulse of the first group.

It means (see above) that the corresponding cracks are very small and T’/ω values indicate that they range in area from 0.005 mm^2 up to about 0.05 mm^2.

Pulses of the second group (Fig.3) consist of several pulses of the first group type and probably correspond to several overlapping small cracks. Their frequency spectrum is, thus, a bit more complicated.

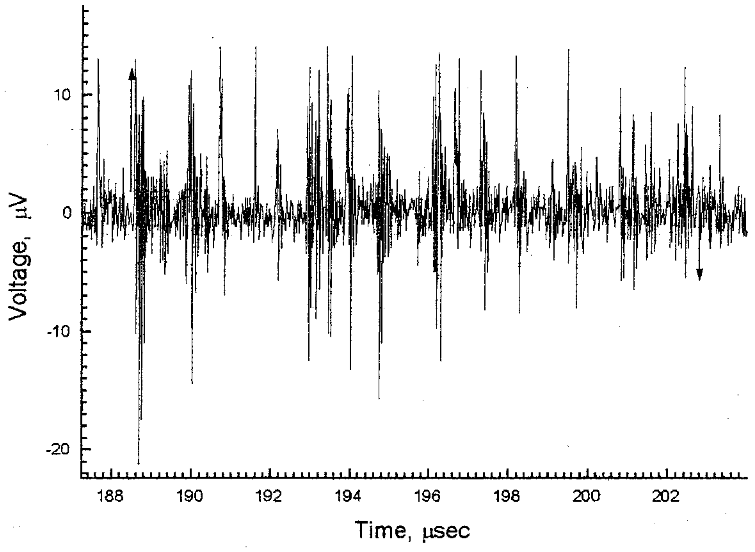

Fig. 3. An experimental EMR pulse of the second group.

Pulses of the third group consist of numerous pulses of the first two groups (Fig. 4). Hence, their frequency spectrum shows a wide range (11 – 23 MHz).

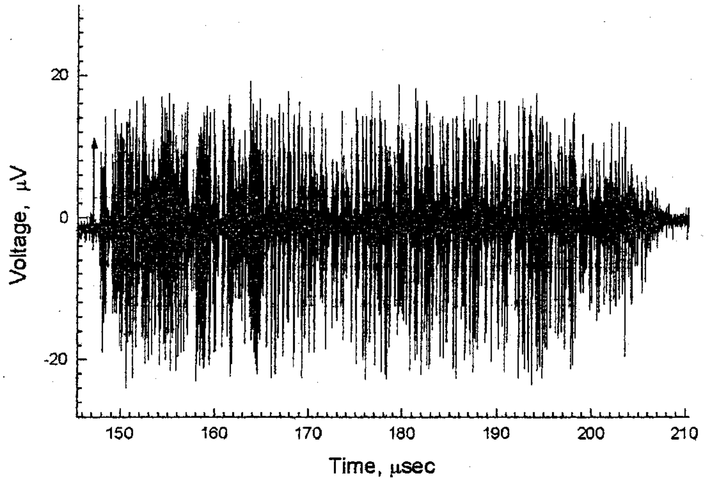

Fig. 4. An experimental EMR pulse of the third group.

These pulses are probably emitted by tiny 'powdered' particles fragmented from the walls of the drilled hole, where each particle has its own size and emits

its own frequency. Note that, like that in the first group, the area of the 'powder' particles here ranges from 0.005 mm^2 up to about 0.05 mm^2.

Signals of the novel fourth group (Fig. 5) show baseline voltage changes with very low frequencies of several kilohertz and in addition contain Lengthy groups of the third type.

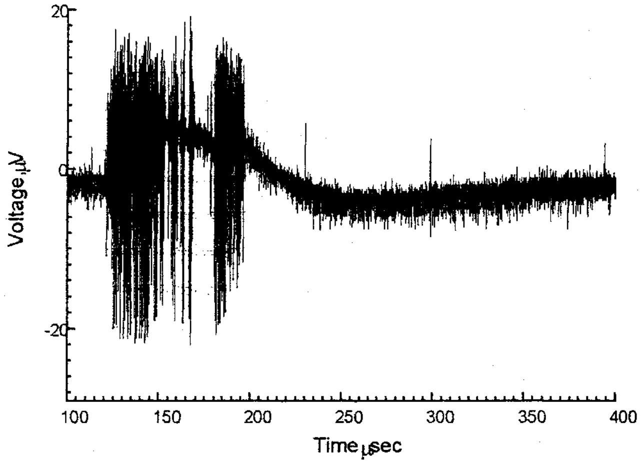

Fig. 5. An experimental EMR pulse of the fourth group, which is similar to a third group signal superimposed on a low frequency signal.

This fourth group is possibly emitted when large "chips" are fragmented. Alternatively, it rises from Herzian fractures in the material. Cracks emitting such radiation should range in area from 1 cm^2 up to 16 cm^2. The additional presence of the third group pulses indicates that 'powder' is simultaneously created.

The first three groups have earlier been observed in our compression experiments, which renders additional proof to our previous claim (Rabinovitch et al., 1998, 1999) that the EMR depends only on crack dimensions and not on its mode. Here, however pulse frequencies reached up to 25 MHz, while in our previous measurements pulse frequencies never exceeded 10 MHz (Rabinovitch et al., 2000; Frid et al., 2000). These high frequencies are caused by the separation of small particles (powder) of ~70 μm in diameter, which constitute a part of the "damage zone". The fourth group constitutes a new observation, warranting further study.

This study thus introduces a new method for a general identification by EMR profile of the wide population of "powedered" and "chipped" particles of various sizes that form by percussion drilling. It provides the basis for a future consistent (one to one) identification of all the defects involved in the process.

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