Impulsive neutron emissions from brittle rocks under mechanical load

Andrea Manuello Bertetto
(andrea.manuello@unica.it)

Università degli Studi di cagliari
Dip. Ing. Meccanica Chimica e dei Materiali
09123 Cagliari

The emission of neutrons from inert materials under mechanical load could be an evidence of piezonuclear reactions. In this work uniaxial load is given to specimens of granite, till failure. An experimental setup was realised and, by passive dosimeters, emissions are detected after a dosimeters calibration by reference radioactive sources. By a preliminary experiment the background level of neutrons was evaluated.
The mechanical induction of nuclear phenomena has been investigated in last century. Some authors affirmed the possibility of causing nuclear reactions by mechanical load on different materials, also in liquid and gas [1-4]. experiments with non-radioactive materials and several reactions was proposed, neutron emissions coming from piezonuclear reactions in inert liquids containing iron have been observed [5, 6]. Solutions of water with iron salts under cavitation were tested in [7]. Tests on damage coming from pressure waves on an iron bar have been performed [8]. Neutron emissions from brittle rock specimens in compression have been studied in [9 - 12].
In [12], and here, the topic was treated from an experimental point of view: specimens of Sardinia granite was loaded by a monotonic load, measuring the eventual emission through passive dosimeters.

Experimental equipment and tests
The experimental setup operates on specimens of granite. The specimens are containing iron, are fragile and the specimen must has a volume over a given threshold. All specimens were prepared with the same prismatic shape and size and are made by a granite named Rosa Beta, from the north east of Sardinia, with main mineral quartz SiO_2, feldspat, plagioclase and biotite. In table 1 and table 2 some characterisctic of the material.
Passive neutron bubble detectors were used (BTI, Ontario, Canada, 1992) [13]. These detectors are insensitive to electromagnetic noise and have zero gamma sensitivity. The dosimeters are based on superheated bubble detectors. The dosimeters are calibrated at the factory against an Americium-Beryllium source as NCRP report 38 [14].

Table 1: Granite mechanical properties [12]

Density	2,6x103 Kg/m3
Modulus of elasticity	54x109 N/m2
Coefficient of thermal linear expansion	7,3x10-9 m/m°C
Compression last breaking load	195 x106 N/m2
Knoop Micro-hardness	6,2x106 N/m2

Table 2: Granite chemical composition [12]

SiO2	71.95%
Al2O3	14.40%
K2O	4.12%
Na2O	3.68%
CaO	1.82%
FeO	1.68%
Fe2O3	1.22%
MgO	0.71%
TiO2	0.30%
P2O5	0.12%

These detectors are suitable for neutron dose measurements in the energy range of thermal neutrons (E = 0.025 eV, BDT type) and fast neutrons (E > 100 keV, BD-PND type).
To verify the dosimeters functioning, they were exposed to reference radioactive sources. The sources are one of 241Am/Be and one of Cs-137. The sources are placed in a special room with lead-lined walls, inside the Geology Laboratory in the University of Cagliari.
The bubble dosimeters used are indicated by the letters A, B and numbers as in Table 3, they can be classified as dosimeters for thermal neutrons and for fast neutron measurements.
To verify the proper functioning of the dosimeters, they were exposed to reference radioactive sources: one of 241Am/Be and one of Cs-137. The sources are in a special room with lead-lined walls.

Table 3: Identification of used dosimeters [12]

Tag	Type	Sensitivity	
		Bubbles/mrem	Bubbles/μSv
A1	BDT (for thermal neutrons)	32	2.9
B2	BD-PND (for fast neutrons)	29	2.7
B3	BD-PND (for fast neutrons)	32	2.9
A4	BDT (for thermal neutrons)	30	2.7
A5	BDT (for thermal neutrons)	31	2.8
B6	BD-PND (for fast neutrons)	32	3.0

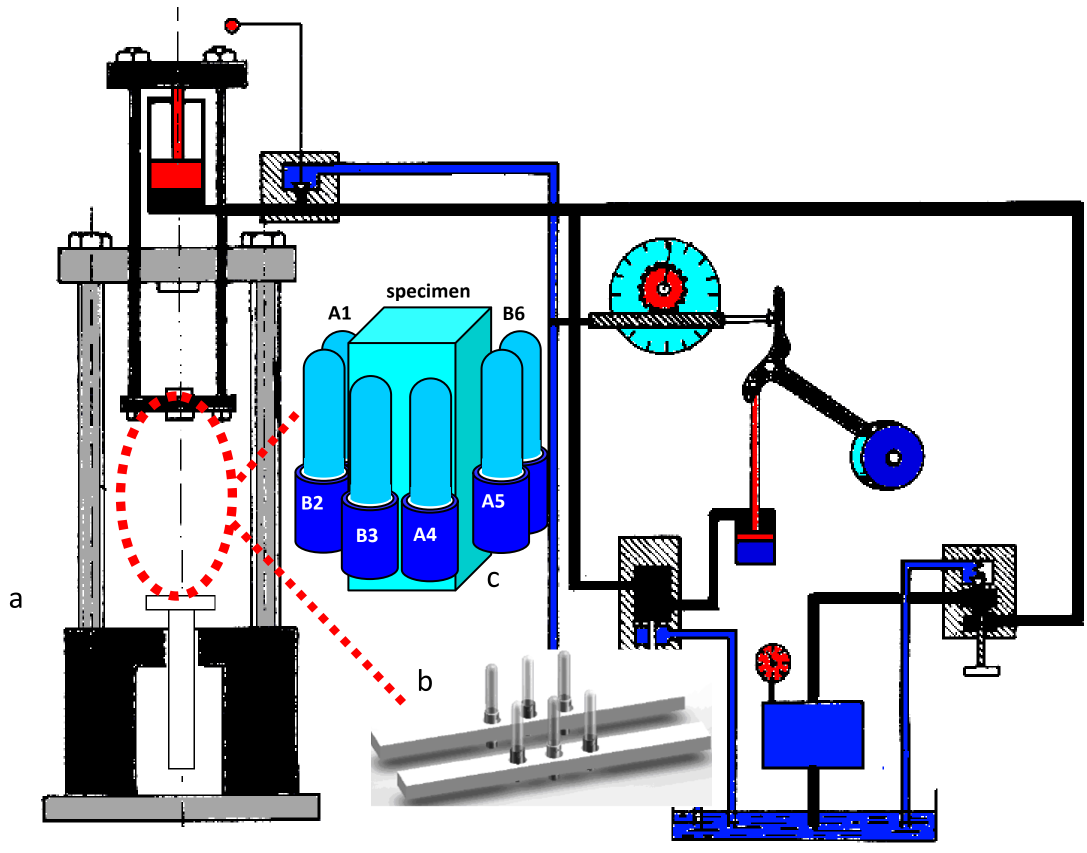

Figure 1. the test rig, the frame and strategy to position the specimen and dosimeters. In figure 1a is represented the testing machine, in figure 1b the frame supporting dosimeters is represented, in figure 1c the specimen and the dosimeter during compression tests are shown [12].

To impose the load on the specimens, a servo hydraulic testing machine was used. A scheme of the machine is in Figure 1a. An hydraulic cylinder moves a plate acting on the specimen pushed against a counterpart plate linked to the frame with a spherical joint to overcome the lack of parallelism between the plates. The cylinder stroke is 60mm. and the maximum load is 2.0 10^6 N. A frame, as shown in figure 1b, was built to hold the various dosimeters close to the specimen in the testing machine zone, during tests. The frame is mechanically and structurally independent respect to the testing machine structure: it is not connected to the body of the testing machine.
This fact avoid influence from movements or vibrations coming from the machine, during tests. In addition the material of the frame supporting the dosimeters is insensitive respect to the electromagnetic fields.
For the tests performed on the testing machine, the specimens were mounted in the tests area, between the plates, the dosimeters were positioned as close to the specimen as possible, as schematically shown in figure 1c.
Using the described test rig were performed Eight tests. a fast rate of load up to a load of 25 tons was applied. The third test gave a very significant output. This experiment was performed reaching quickly a given load and keeping the load on the sample oscillating around a value so as to start and propagate the first cracks.
In figure 2 the load increasing curve vs. time in the third test and the dosimeters positioning around the specimen are shown.

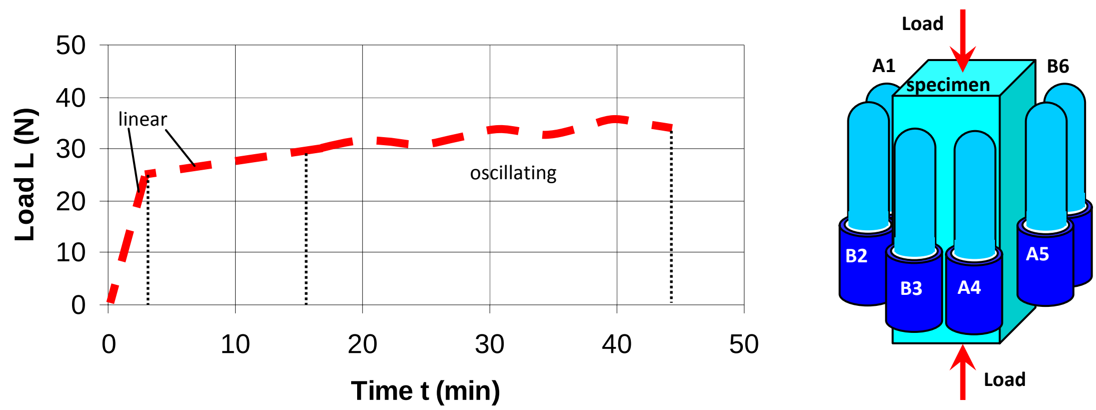

Figure 2. the load increasing curve vs. time in the third test and the dosimeters positioning around the specimen [12].

In dosimeter A4, 185 bubbles in the cylindrical part were counted. As specified in the manufacturer's data sheet the bubbles in the hemispherical area must be ignored.

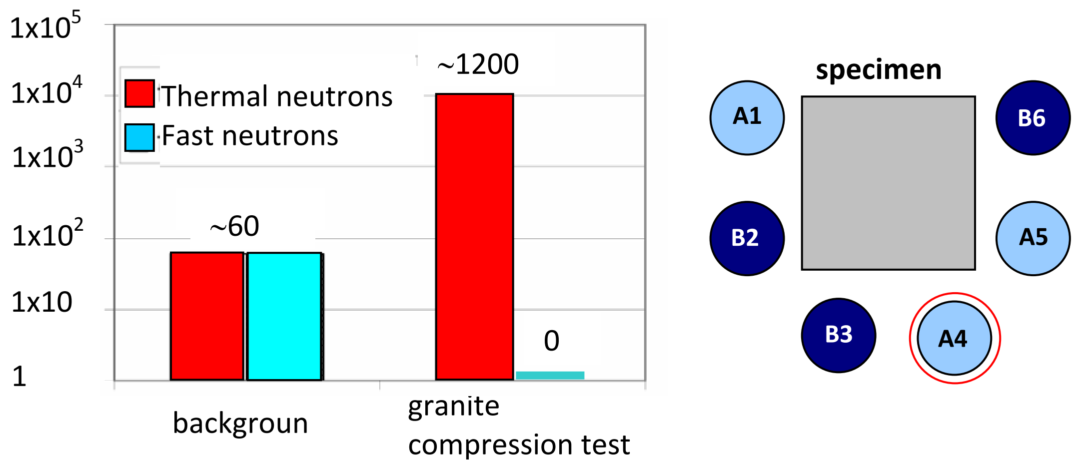

Figure 3. Dose rates for fast and thermal dosimeters for background and during the monoaxial destructive compression tests of the granite specimen [12].

Neutron emission measurements were performed. The specimens are granite from Sardinia made. The tests are mechanical compression tests. The bubble dosimeters used shown neutron fluxes of several orders of magnitude higher than the background level at the time of failure. These values correspond to a dose rate of neutrons 150 times the background level as in figure 3 [12]. The described results and the interest of the scientific community suggests further and more in-depth exploration and encourages investments of human and financial resources for new and challenging application fields, such as the neutrons applications for medical use in cancer therapy and the production of clean nuclear energy.

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