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ABSTRACT

Samples of commercially produced, poled lead zirconate titanate (PZT) piezoceramics were subject to longitudinal, compressive impact loading by a free falling striker providing a single, clean stress pulse. Samples were sandwiched in-between a Split Hopkinson Pressure Bar instrumented with miniature foil strain gauges linked to a custom built high frequency amplifier. Values of the piezoelectric charge coefficient, d_{33} were derived and compared with those obtained via the conventional low frequency (100 Hz), low stress resonance method.

The electromechanical coupling factor, k_t, was also derived by correlating the energies produced by the discharging piezoceramic and the stress wave that passed through the sample, these were then compared with values calculated from conventional resonance/anti-resonance measurements. The results obtained from the impact rig gave values for the d_{33} coefficient that are up to twice those gained from the resonance rig[1]. It is also apparent that there exists a direct relationship between the impact velocity (and therefore the impact stress) and the piezoelectric charge coefficient of the material.

Ageing of the piezoelectric device under stress was studied by means of plotting d_{33} as a function of the number of impacts suffered. Samples of all the compositions displayed a drop in the values of d_{33} of between 18 and 49% when subject to 5000 impacts of approximately 40 MPa in magnitude.

A sample of X-cut α quartz was subjected to the same tests as the PZT compositions. The quartz showed potential as a reference material for measurements of the piezoelectric response of impact loaded PZT ceramics.

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INTRODUCTION

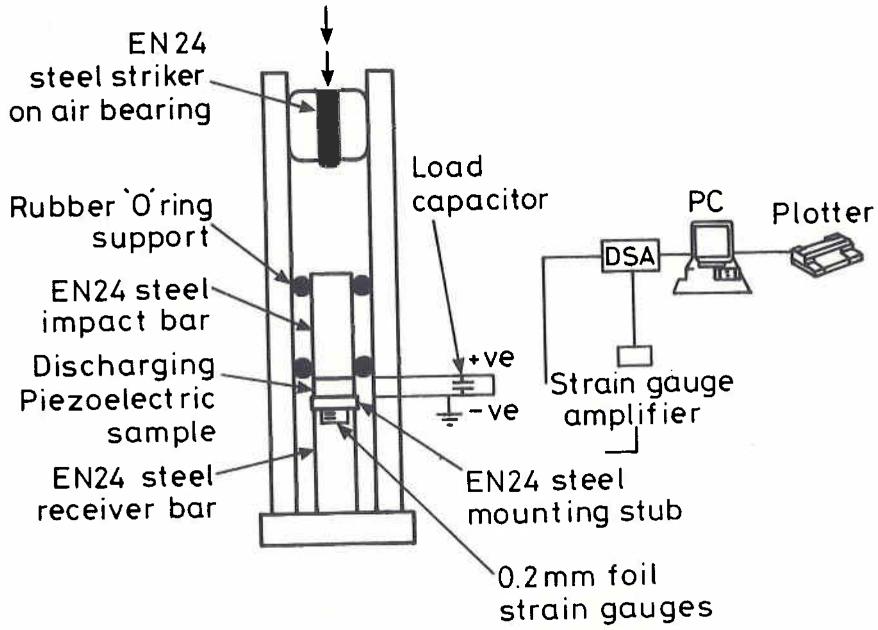
In recent years, there have arisen many new applications for piezoelectric devices; impact detonation devices requiring very rapid, large voltage pulses, high speed sensors and actuators such as those utilised in active automobile suspension systems and ignition devices for gas appliances and flash bulbs, to name but a few. In many of these applications, the piezoelectric device is subject to relatively large stresses of short duration, conditions to which conventional metrology techniques do not lend themselves. Currently, standard characterisation methods subject the piezoelectric device to cyclic stresses of very low magnitude and at low frequencies (commonly 100 Hz). Manufacturers data relating the performance of their materials are becoming less relevant as the materials are employed under conditions far removed from those under which they were characterised. It has therefore become necessary to develop a technique whereby piezoelectric device characterisation can take place under conditions relevant to today's demanding applications, but also a technique that in itself does not influence the results obtained. In doing this, new directions are set in the field of piezoelectric coefficient measurement and the limitations of these materials under immoderate conditions can be explored.

EXPERIMENTAL TECHNIQUE

The "drop weight" impact testing rig, illustrated below in Figure 1, comprises a free falling striker bar, running on an air bearing, provides a compressive impact that can be varied between 32 and 81 µs in duration and of magnitude 2 to 40 MPa, by variation of the drop height. Seven different impact durations are provided by using striker bars of lengths 13 to 104 mm.

The strikers are constructed of 12 mm diameter EN24 steel rods with hardened hemispherical ends. EN24 steel is used since it possesses excellent hardenability and is very resistant to deformation under impact. The striker bar is housed in a perspex sabot that electrically insulates it from the surrounding rig and it also serves to prevent distortion of the ensuing stress wave by virtue of it's low elastic modulus. The total mass of the striker bar and sabot is between 60 and 130 grammes, depending on the length of striker bar in use. The striker bar is held in the raised position by a small electromagnet mounted in the top of the rig and it's release is initiated by the use of a micro-switch installed adjacent to the magnet.

The piezoelectric device under test (DUT) is situated in a vertically mounted, hardened EN24 steel Split Hopkinson Pressure Bar (SHPB) that consists of a top "impact" bar and a lower "receiver" bar that is 370 mm high in total and 12 mm in diameter. The SHPB arrangement is instrumented with four miniature foil strain gauges that monitor the passage of the impact induced stress wave through the receiver bar following the impact of the striker bar on the impact bar and its passage through the DUT. The strain gauge signal received from the SHPB is sent to a custom made high frequency (approximately 2 MHz bandwidth) virtual-earth pulse amplifier. The amplifier output is then appropriated for analysis by a computer controlled digital storage adaptor (DSA).



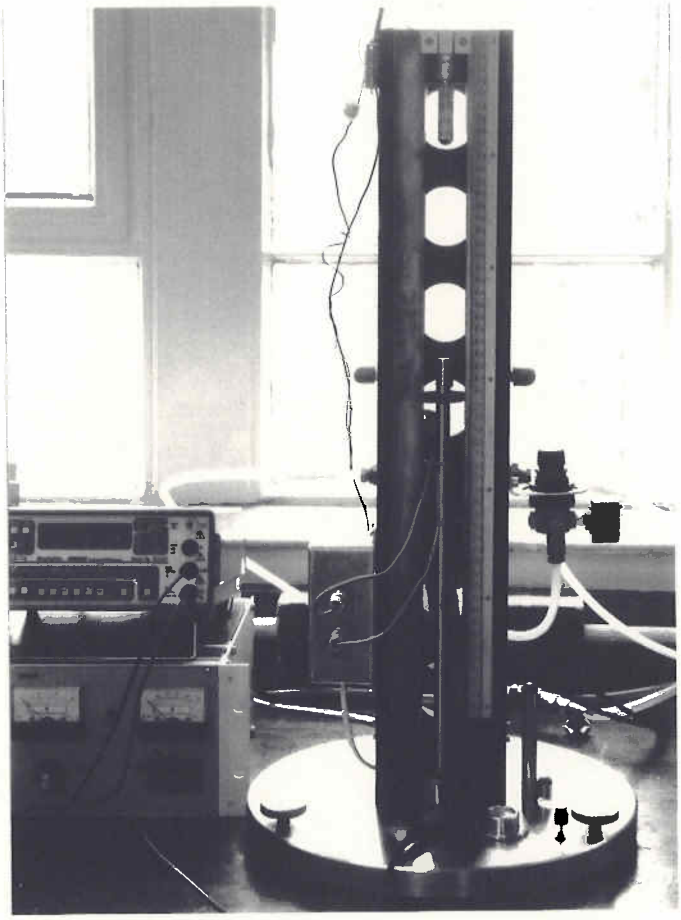


Figure 1. The Impact Testing Rig