A computerized small size fatigue testing machine for composite material experimental characterization

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Abstract: - A method of transforming a typical small size cam press into a fatigue testing machine adequate for composite material characterization, is reported in this paper. The whole machine has been equipped with measuring instruments for displacement, force and punch frequency. A data acquisition system is used for data recording and computing output results as well as controlling the whole machine via a PC.

Key Words: - composite materials, fatigue test, data acquisition, force-displacement-frequency control

1 Introduction

Composite materials have been proved to be able to replace metals in many mechanical applications, because of their cost-effectiveness. Due to their singular structure, experimental validation should always be used in order to specify their mechanical properties, since their experimental characterisation under static or dynamic loading, can optimise the material usage in structural devices [1,2]. The fatigue strength is one of the important mechanical properties that must be evaluated for these applications. Fatigue is defined as the ultimate failure of a material by the application of a varying load whose maximum amplitude, if applied continuously, is insufficient to cause failure. Fatigue behaviour of fibre-reinforced composite materials is an important consideration in most structural applications, while repeated loading of a structural component during service is common. Understanding the fatigue behaviour is, therefore, needed for reliable design of composite materials and the end structures. The main effort of fatigue research is, therefore, to establish a basis for fatigue life prediction, improvement and design of a material towards the successful structural application by fulfilling simultaneously the expected service life in a cost efficient manner [3-5]. Flexural tests have the benefits of being simple to perform and give data that are applicable to many engineering applications where bending is the primary deformation mode [6]. However, flexural fatigue tests of composite materials should follow special recommendations, mainly if the tested material will be used for aircraft component construction [7, 8].

In this paper we report on the extra-instrumentation of a typical small size cam press in order to become a testing machine capable for flexural tests (static and/or fatigue) oriented on composite material demands.

2 Measurement principle

The basic configuration of the fatigue-testing machine is shown in Fig. 1. It is a 5t capacity mechanical press of constant amplitude deflection control. Static bending loading tests as well as flexural fatigue tests could be conducted on laminated composite strip specimens. The punch load, punch deflection, punch frequency and punch velocity could be continuously controlled, whilst six different cams could provide various oscillation widths (amplitude deflection). Besides these, the testing machine has been also equipped with a load cell, an LVDT and a proximity switch in order to record the punch load, punch displacement and cycle counting during the test performance. A data acquisition system provides with continues measuring control. The data acquisition system, see Fig. 2, and the precise instrumentation construction, see Fig. 3, are reported below.

2.1 Data acquisition

The data acquisition system is based on the PCI-20428W data acquisition card provided by Intelligent Instrumentation plugged into an ISA slot of a 500MHz Pentium personal computer. The main features provided by the PCI-20428W card are 16 single ended or 8 differential 12-bit analogue inputs, two analogue outputs, 8 digital inputs, 8 digital outputs, two 8MHz rate generators and a 16-

bit counter. The maximum sampling rate is 100 K-samples per second using DMA.

The data acquisition software is developed using the Visual Designer, a Window's based software also provided by Intelligent Instrumentation, and Microsoft Visual Basic-6.0.

2.2 Instrumentation

The force measurement was conducted via a 2-kN load cell with 1mV/V sensitivity, which is mechanically coupled on the punch. The load cell used is the U9B from HBM. The output of the load cell is connected on the PCI-20428W data acquisition card via the MVD-2510 measurement amplifier from HBM. The amplifier is configured to produce at its output 2.5V per 1KN. The output of the amplifier is connected to the analogue input (Channel 1) of the data acquisition card.

A 100mm linear displacement LVDT with 80mV/V sensitivity that is mechanically coupled on the punch provides the punch displacement data. The LVDT used is the WA from HBM. The output of the LVDT is connected on the PCI-20428W data acquisition card via the AE-301 measurement amplifier from HBM. The amplifier is configured to produce 8mV per 1mm at its output. The output of the amplifier is connected to the analogue input (Channel 2) of the data acquisition card.

A proximity switch is mounted on the body of the machine, that produces one pulse for each revolution of the punch. The output of the proximity switch is connected to a digital counter that displays the number of cycles of the punch. The output of the proximity switch is also connected to the counter input of the PCI-20428W data acquisition card, thus the number of cycles of the punch is also available to the computer.

A three-phase motor is used as a punch movement supplier. The operation of the motor is controlled by a 0-50Hz frequency inverter. The computer controls the operation of the frequency inverter. Thus the computer controls the speed of the motor. The motor is also switched on or off by the computer.

3 Typical test procedure

In order to execute a typical fatigue test the following five steps should be followed:

Step 1. Set the appropriate speed of the motor on the frequency inverter and start it.

Step 2. Get a reading of the force and the displacement every 10 ms and store it in a circular buffer. This buffer will always contain the last 500 readings. For the first set of 500 readings, record the maximum value (F_{max}).

Step 3. Every 1000 cycles (of the punch), copy the readings from the circular buffer to an Excell format file.

Step 4. Repeat step 3 until the maximum value for the force (for the last 500 readings) is below 60% of F_{max}, or until a sharp drop in the peak value of the force to below 60% of F_{max} is detected, see Fig. 3 (d). In this case the frequency inverter is signalled by the computer to stop the motor.

Step 5. The file created in Step 3 above is further processed using a programme developed in Visual Basic embedded in Excel. The output of this program are the bending load vs. time diagrams, see Fig.2(a) and (b). Finally, the fatigue diagram is produced.

4 Results and Discussion

A number of flexural fatigue tests were performed on a glass fibre-reinforced composite material using the reported machine. All tests were carried out at room temperature in a three-point bending rig (consisting of two supports and a load anvil) according to DOLN 419 specification [8] as shown in Fig. 3(a) and (c). For most specimens a frequency level of 2.36 Hz (25 Hz on the motor), was used to avoid significant heating of the material, see Fig. 2(b), and a zero stress ratio (R=0) with sinusoidal waveform. In some cases a 4.72 Hz frequency (50 Hz on the motor) was used for comparison purposes, see Fig. 2(a). All samples were simply supported and loaded at their mid-span. A support distance/thickness ratio equal to 40:1 and a maximum center point deflection of 15 mm were kept constant for all tests.

Every 1000 cycles the diagram of the bending load vs. time was automatically recorded and the corresponding maximum value of the load was determined. The test completed until the maximum value of the applied load was below 60% of the initial maximum recorded bending load or until a sharp drop in the peak value of the force (below 60% of F_{max}) was detected, see Fig. 3(d).

Initiation of the first cracking at the outer tensile surface of the specimens was recorded with respect to the corresponding loading cycles. Failure resulted by the growth of a single dominant crack or several directionally different cracks into the sample exterior. The cracking development leading to a through-thickness fracture of the laminate was very difficult to be observed. This cracking development was easily observed by monitoring the progress of the recorded bending load throughout the experimental procedure.

5 Conclusions

A computerized small size fatigue-testing machine for composite material experimental characterization is presented in the present paper. The results of the experiments carried out have shown that this low-cost machine can replace existing expensive machines with accurate and reliable results. The easiness of operation as well as the ability of monitoring the behavior of the specimen throughout the testing process adds to the usefulness of the proposed machine. Furthermore, the machine can be used for static bending tests according to the international standards.

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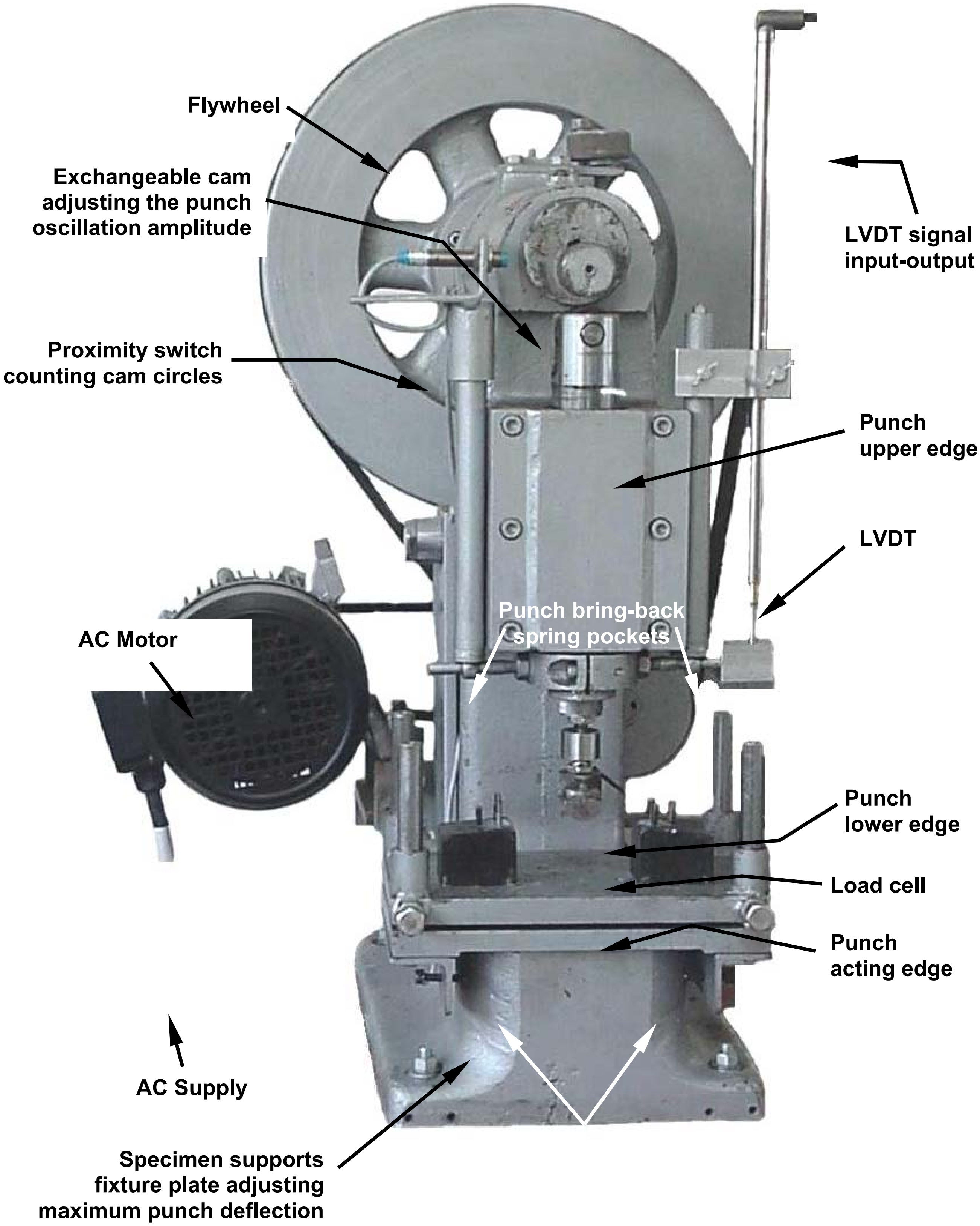
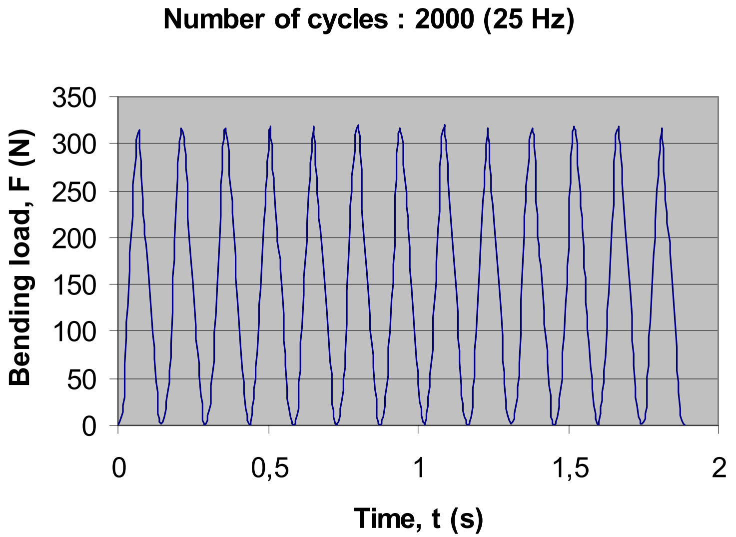
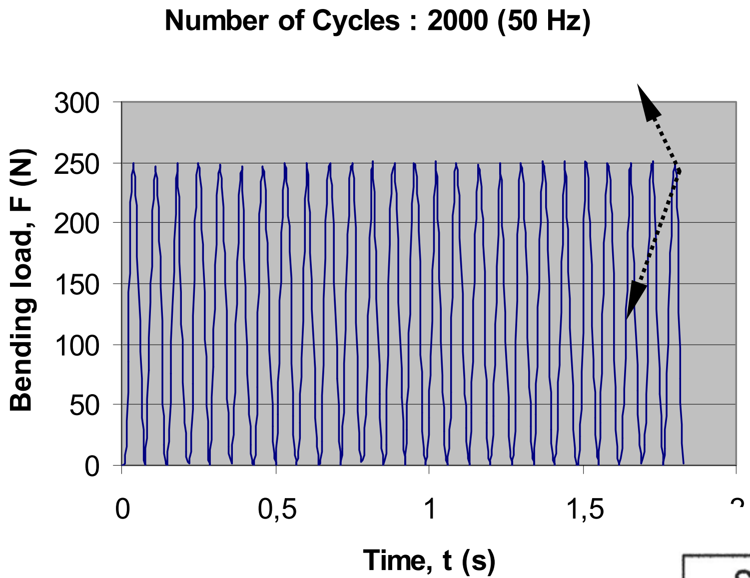


Fig. 1 The fatigue testing machine





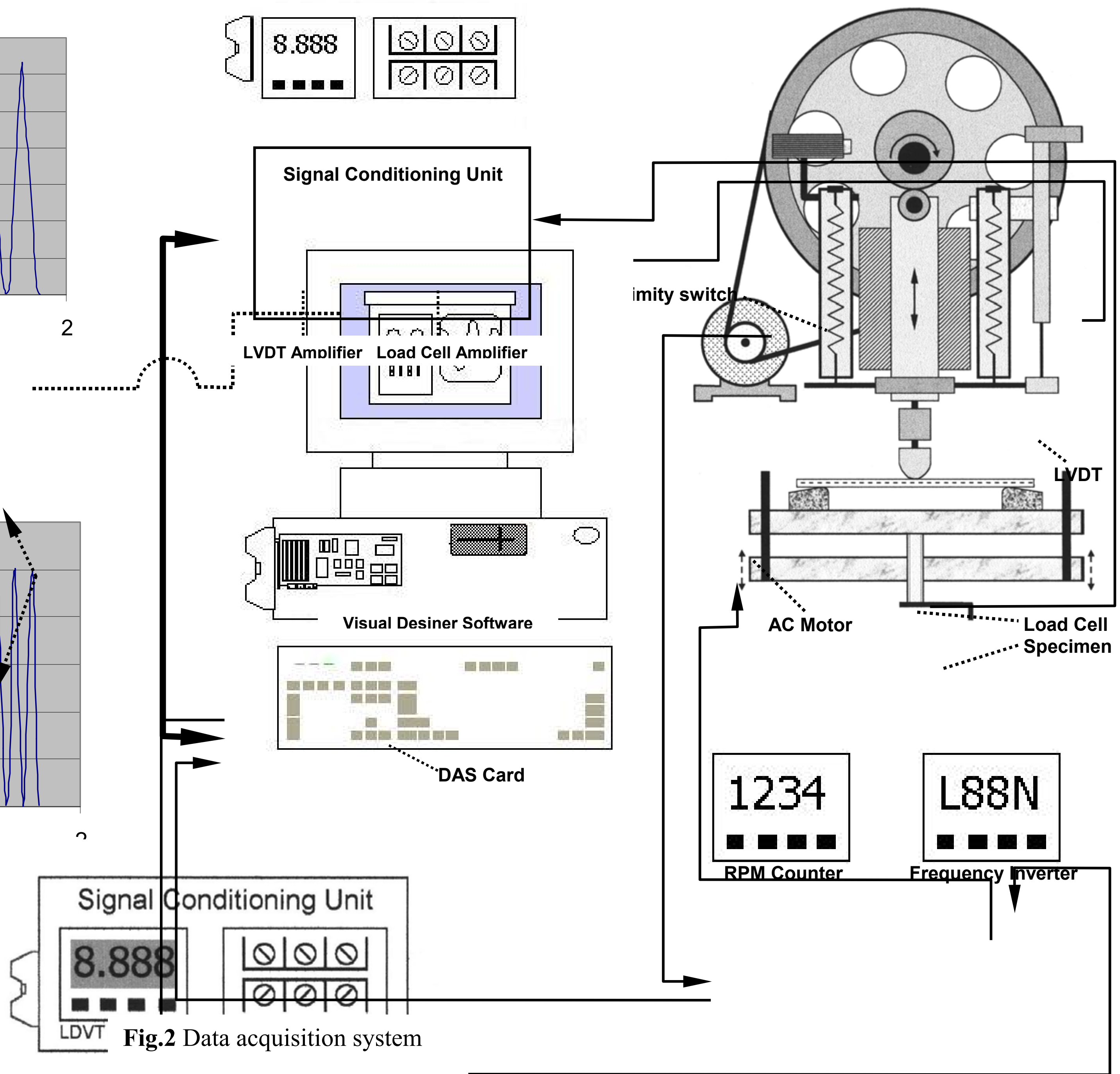


Fig.2 Data acquisition system

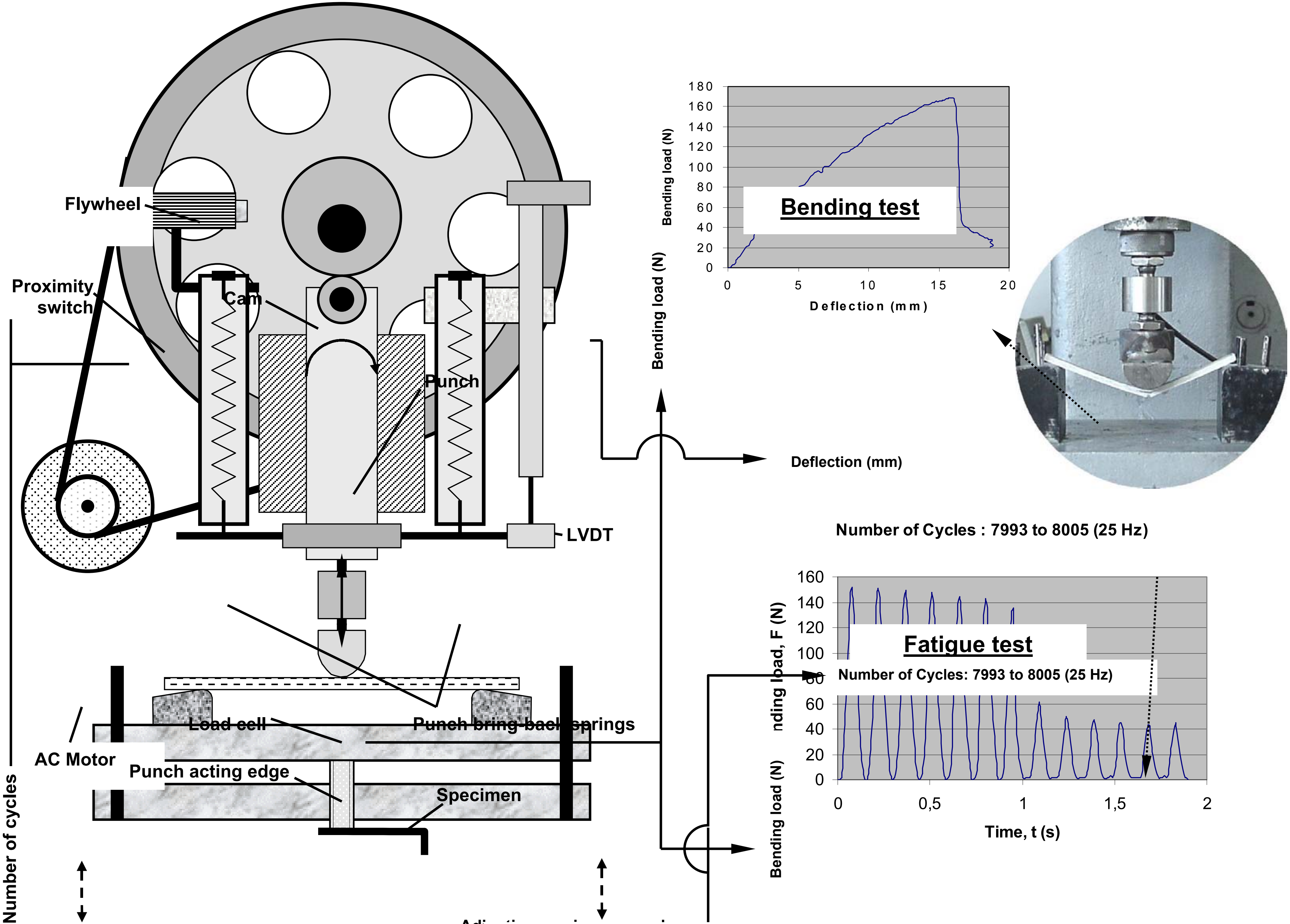


Fig. 3 Instrumentation construction