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A SIMPLE IMPULSE SOURCE FOR MUSICAL INSTRUMENT MEASUREMENT

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1. Introduction

The relation between the internal bore shape of a brass instrument and the impulse reflection response play an important role in the assessment of brass instrument quality. Early reflections indicate the presence of bore discontinuities which may have significant effects in the initial transient of a played note. By means of the Fourier transform, eigenfrequencies which correspond closely to the input impedance peak frequencies have been measured.

Conventional impulse sources such as the Ionophone (9) are ideal for such measurements, but are expensive, delicate, and require stable EHT sources.

The method developed at Surrey University is robust and cheap, and uses an ordinary electronic ignition system, with a slightly modified spark plug which is inserted into the instrument mouthpiece cup to introduce the impulse into the instrument. Pulse widths down to 0.4 msec., with peak sound pressure levels in excess of 30 Pa. are readily obtained.

The transducer, a horn-coupled probe microphone, is positioned in the smallest dimension of the mouthpiece throat. The signal recorded is not the conventional impulse response, $h(t)$, but the impulse reflection response, denoted $h'(t)$ (10). This is equivalent to the inverse Fourier transform of the input reflection coefficient.

Pulse synchronisation and data acquisition is via a Data General NOVA 4 computer, which facilitates signal-to-noise ratio improvement by averaging many records.

2. Background

The acoustic characteristics of a brass wind instrument have been shown to have some correlation with the subjectively perceived quality judged by a player (1,2). Previous methods of measurement have concentrated mainly on the input impedance (3,4,5) for the reason that the impedance peak frequencies are important in assessing the steady state played note.

The Fourier transform of the input impedance gives the pressure seen at the input due to a unit impulse of volume velocity, and has been calculated, for example, by Pratt (1) and Elliott (6). Certain features of this signal can be seen to be empirically related to positions of discontinuities in the instrument bore.

Such a measurement would possibly be of use to a manufacturer to enable detection of faults inside instruments such as blobs of solder of ill-fitting joints, without total dissassembly.

3. Present Measurement Devices

The impedance measuring device built at Surrey University (4) was not designed to measure above 2kHz, as no peaks are present in the input impedance curves above this frequency for most brass instruments. This bandwidth limits the time (and hence spatial) resolution of the Fourier transformed result, so that detail smaller than about 9cm. in size cannot be seen. If detail of 1cm. in size is to be resolved, a simple calculation shows that the bandwidth must be greater than 17kHz. This is not feasible with the impedance measuring device due to limitations on the loudspeaker driver, so an alternative approach was sought. Plane wave propagation is maintained only if the excitation does not have significant energy in the frequency region higher than the first mode frequency normal to the tube axis.

Previous experiments by Fransson (7) on flutes and Kruger (8) on brass instruments, using the Ionophone (9) as a pulse source have given results which have been encouraging, though due to differences in measuring conditions cannot be compared to results from the impedance measuring device.

4. Description of New Device

A simple impulse source was investigated, which eliminated the need for the stabilized modulated EHT source required by the Ionophone. To achieve good bandwidth characteristics, the pulse must be short. A spark discharge meets this criterion ideally. Control and repeatability are then important factors, and these are met by the present system which employs an automotive electronic ingition circuit, modified to give variable pulse width (0.1 to 1 msec.), and variable pulse delay (1 to 5 msec), relative to a TTL trigger pulse.

The EHT is fed to a car spark plug, which has the curved electrode removed to increase the spark length. Hence the acoustic output is increased, and the pulse width reduced. The cavity between the central electrode and outer body is filled with insulating sealant to prevent pulse degradation from cavity reflections and compliance.

The system is controlled by the minicomputer, which controls triggering of the device as well as data acquisition and subsequent processing (Fig. 1).

Calibration of the measurement chain is simply effected by means of a pistonphone and a small subroutine which calculates the true RMS voltage seen at the ADC.

As the impulse and data recording are synchronised, a simple running average of many normalised data records is sufficient to improve the signal to noise ratio. A typical measuring run averages about 100 to 200 pulse records.

5. Results

The performance of the device is presented graphically. The pulse alone has an amplitude of 40.96.Pa. and approximate width 1.0 msec. (Fig. 2).

The trace of the input reflection response of an instrument, (Fig. 3), in this case a French Horn, is more interesting in that the principal reflection is not the same shape as the input pulse. This is due to the characteristics of a horn shape, which tend to radiate high frequencies better than low, and hence lowpass filter the impulse. Fine structure at times before the principal reflection indicates presence of bore discontinuities. The pressure amplitude is not directly related to the bore shape, however, as multiple reflections between discontinuities give rise to an additional contribution to the pressure signal.

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6. References

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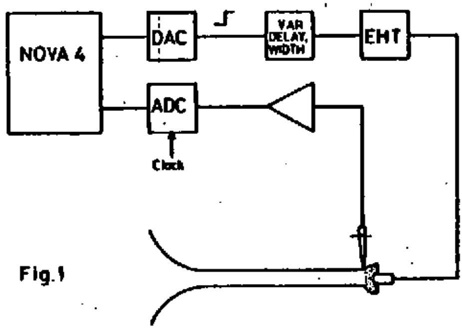

Fig. 1

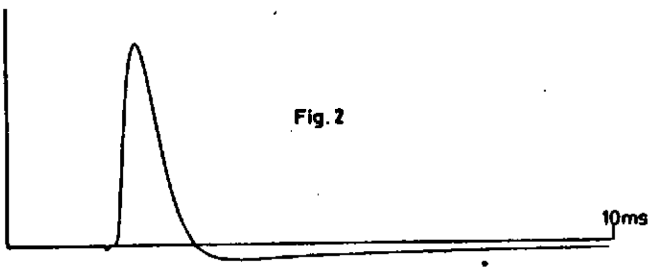

Fig. 2

100 averages

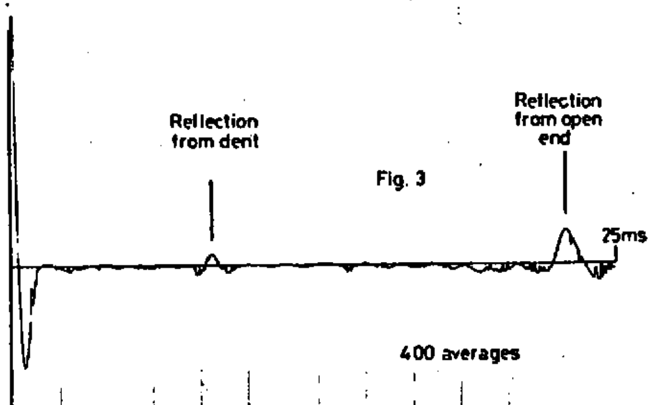

Fig. 3

400 averages