Testing Medical Drills for Noise Emissions

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***Abstract*— A comparative study of drills from a range of manufacturers was carried out in the laboratory. These tests were made under a variety of loading conditions to assess the characteristics of the noise likely in the dentist's surgery.**

Details of the test setup are given, and some of the issues in analysing the results considered.

Simultaneous Recordings were made of the noise on a minidisk recorder, a hand held sound meter, and a sound analyser. The results from these are considered.

These are significant for dentist's hearing, and the patient's perception of visiting the dentists. The performance of different designs of pneumatic drill varies much with type and load.

***Index Terms*—noise, dentistry, drill**

I. Introduction

NOISE emission measurements were made on a range of pneumatically driven dental handpieces from a variety of manufacturers. The purpose was to establish the characteristics of the noise produced by each handpiece in a typical dental clinic setting. The desire was to find the variation of noise with handpiece when both free running, and under a normal range of loads typically used by dentists when cutting the teeth of patients. These tests were carried out at King's College Hospital Dental School using standard lab and clinic areas free from background noise.

Figure 1 Drill handpieces tested together with the steel bar with holes in which the burr was placed during tests.

II. Requirements of the Tests

The recordings of the drill noise have been executed according to the British Standard BS EN ISO 7785-1:1999 ISO 7785-1:1997 Dental hand-pieces -Part 1: High-speed air turbine hand-pieces.
The standard describes how to measure the noise of high-speed air turbine hand-pieces. According to the standard the measurements shall be taken in a room with the following features.

- The A-weighted background noise level has to be lower than 65 dB
- Greater than 2.5 m * 2.5 m* 2.5 m
- or a chamber with a free filed radius of at least 1 m
- there shall no hard reflective surface within a 1 m envelope of the hand-piece under test

The A-weighted sound pressure level is measured at a distance of 0.45 m from the hand-piece (see Fig. 3). These test conditions were followed as closely as possible within the constraints of a clinical practice room.

III. Experimental Setups

1. Free Running test.
One test arrangement for the drills free running is shown in Figure 2. Note they were supported a standard distance from the microphone, in the same position for each handpiece and burr. Whilst this did not meet the standard sound chamber conditions, the tests were done for each drill in turn, and then returning for second tests of each drill later in the sequence.

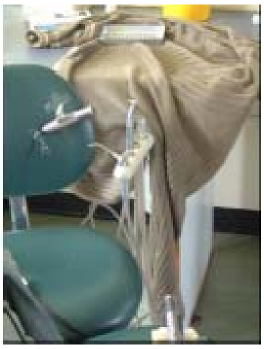

Figure 2 Free running test in dental clinic
This gave repeatable measurements with an average dBA reading for successive tests on the same handpiece with the

same supply pressure was generally within 0.5 dB, though it often fluctuated about 1 dB within a 5 second test.

The experimental set up for the free-running recording is shown in Fig. 2 and Fig.3

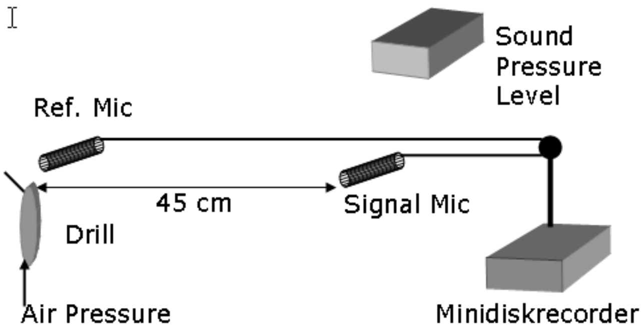

Figure 3: Experimental setup for free running drill

Drills from the following manufacturers were tested:

- Kavo Supertorque LUX 655B
- Kavo GentleSilence
- Midwest Stylus
- W&H Synea HS TA-98L
- RGN

2. Tests under load.

The steel bar test piece was suspended from a sensitive spring balance. Thus clamping the handpiece at midpoint between rubber grippers a side load was applied on the burr. By raising the suspension point of the spring the load was adjusted.

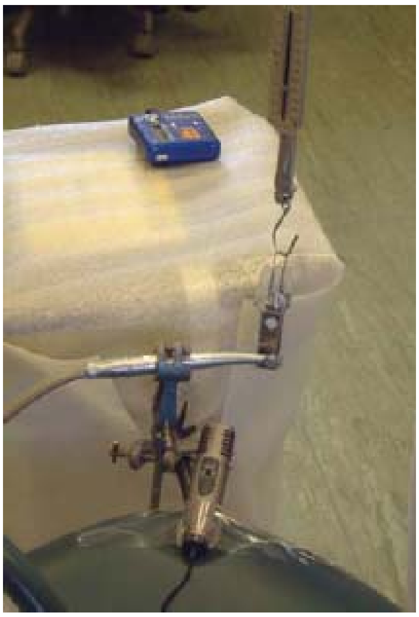

Figure 4: Handpiece under load .

Tests were carried out at side loads of 1 N, 2N and 2.5 N. These corresponded to the dentist's sense of light drilling, heavy cutting, and overloading the drill.

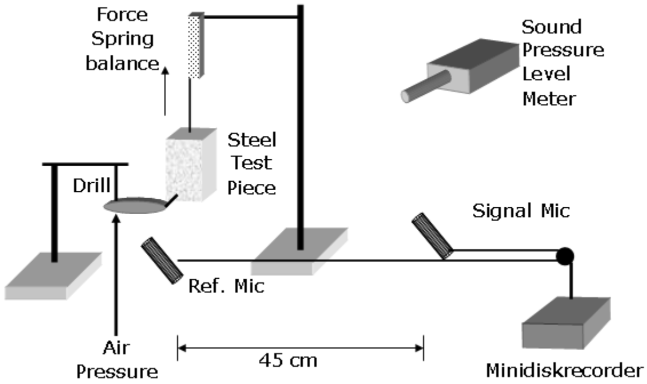

Figure 5: Experimental setup for Drill under load

Whilst the purpose of the measurements was primarily to compare the different drills the reflection of high frequency noise was reduced by cushioning nearby surfaces with foam sheeting. Tests in an anechoic chamber have illustrated the effectiveness of this.

A series of three separate sessions of testing was carried out on each drill in random order. During each test of the drill four or five separate recordings were made.

IV. Equipment Characteristics

Figure 6: Cel analyser and Sony microphones used.

The equipment used is listed below:

- Lucas CEL Sound Level Analyser CEL-593
- SONY MZ-N707 Minidisk Player (Recorder)
- 2 x Sony Microphones ECM-MS907
- B&K dual channel real-time frequency analyser type 2144

The B&K analyser, and the CEL 593 analyser were both calibrated with standard test cells.

The minidisk recordings required calibration since such recordings already process the sound. This was done in an acoustic chamber with the above equipment and a Noise Source: Bruel & Kjaer Sound Source Type 4224

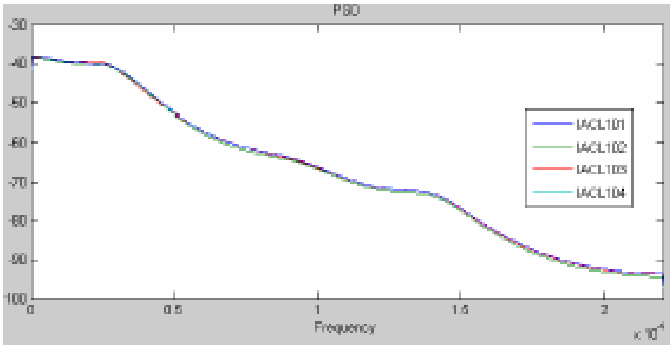

Figure 6: Frequency Response of minidisk recorder to wide band

It is evident that there is significant reduction in the response at higher frequencies, but in the principal region of interest of 3 kHz to 10 kHz the response is repeatable, and does not change significantly in a laboratory room rather than the anechoic chamber.

V. Analysing the Results

Since the Cel analyser and the B&K analyser and recorder record dBA noise levels and octave and 1/3rd octave band noise levels these are a good cross-check on the minidisk recordings. Indeed these readings gave the reference levels and the peak frequencies that are significant. Thus in the plot below it is clear that the major peak at 6 kHz is significant, followed by one at 11 kHz. Common to all these responses was that at most only two sharp frequencies dominate the noise. It is these distinct pitched noises that are so unpleasant.

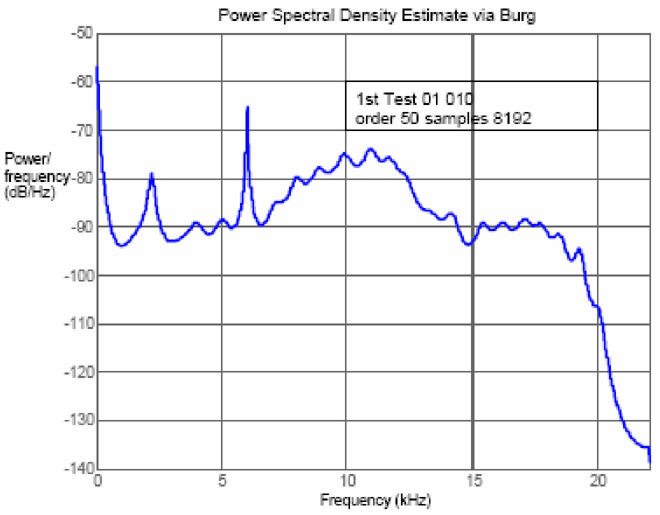

Figure 7: PSD plot of minidisk recording of a drill

The results of each test were recorded in an Excel spreadsheet. These data were then imported in Matlab for the more detailed processing and analysis. To find out the variations in noise frequency and amplitude over the course of a 5 second recording each minidisk recording was split into 0.1 seconds sections. The analysis was carried out a selection of five of these recordings for each test run. In no load conditions noise frequencies were consistent within 1 dB. With heavy side loads sometimes a lump of debris broke away and caused major changes of drill speed and noise pitch. Then the noise would change by over 3 dB. Sometimes the drill stalled. However, at normal loading the variations of frequency are less, and offer good scope for using adaptive filtering to eliminate the noise. It is noteworthy that moving a free running drill burr from open air to inside the 3 mm hole amplified the sound by 4 dB in line with the hole.

The recorded data by the Sony minidisk recorder was imported as wave files into the PC. The wave files were then imported into Matlab and were analysed by the Signal Processing Tool (SPT) as also presented in [4]. The SPT tool provides several power spectral density (PSD) estimation methods such as the FFT, Welch, Covariance, Burg etc. Here the Burg method was used with an order of 50 and an FFT length of 1024. Figure 9 shows the PSD plot of an air turbine drill via the Burg method. The distinct peak around 6 kHz can be observed very well from this plot.

Selective elimination of noise peaks is vital as acoustic insulation jump reduces all the noise levels by the same amount. Then the peak frequency still stands out above the ambient noises, and this means it can still disturb the patient.

A further problem is the change of noise frequency as the drill is loaded. Most important here is the rate of change of drill speed. These were analysed from recordings made whilst the dentist was at work. This analysis gave confidence that our choice of DSP should work to eliminate the perceived noise. This has been vindicated in demonstration tests in a dental clinic.

Undergraduate and post-graduate students have been involved in different aspects of these tests. These have proved effective projects.

One of the major difficulties with the equipment is that each instrument had to be treated independently, often with manual recording of results. This slows the analysis, and severely limits the value of the tests since the processing has to be done later. A mechatronic solution would much improve all this lengthy experimental work. In these tests several different measurement instruments are required, but they could not be centrally controlled together during the measurements. So a team of several persons is required to make measurements, where each of them controls the measurement on their device (Cel analyzer, B&K analyzer, Sony minidisk recorder), i.e. at least three persons must be present while doing this measurements, and a fourth to operate the drill. Planning mechatronically to integrate the instrumentation, software and control would much improve the tests, and require both less test time at the clinic and less people.

It is much better to use instrumentation that can directly interface to a computer, or through a Digital Signal Processor to a computer. Then the processing can be planned before going out to the clinic, and the effectiveness of the tests gauged quickly. Repeat tests, and statistically planned test routines could also be implemented more effectively.

VI. Related Work

Based on this work the team has developed active filter noise reduction. This has been demonstrated in King's Dental Hospital.

VII. Conclusion

The measurement of dental drill noise with different sound pressure meters and recording instruments were presented in this paper. To gain meaningful results the data acquired must be analysed and evaluated. This paper discussed the necessary stages, but it also highlights the need for good communication between the instruments and recorders so that they control and measure simultaneously. A mechatronic approach could lead to a better design of test rig.

Acknowledgment

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