A BETTER WAY TO MEASURE SOUND POWER - LET THE MACHINE HANDLE THE DETAIL

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INTRODUCTION

The measurement of sound power is increasingly required to specify noise produced by machines. For some five years the sound power and radiation efficiency of prototype Lucas CAV fuel injection pumps have been measured as part of a continuing effort to reduce product noise. The measurement and analysis of large numbers of spectra was extremely time consuming and increasingly onerous.

Sound and vibration measurements are used to calculate sound power, directivity index, mean surface vibration and radiation efficiency. The complete measurement and calculation task for one prototype pump took three to four weeks, the majority of this time being occupied in data handling (ie transferring measured spectra from paper charts into mini-computer). It was decided to automate the routine measurements to increase the productivity of skilled noise control engineers. This paper describes a microcomputer-based measuring system and discusses some results from its application to sound power measurements in factories.

The requirements for this automated system are:-

- ability to measure one-third octave spectra
- ability to examine and edit data and repeat measurements
- ability to manipulate data and calculate results.
- speed - to reduce time spent by skilled engineers
- accuracy as good as an IEC 651 Type 1 Sound Level Meter
- ease of use by relatively unskilled engineers
- flexibility to cover a wide range of measurement tasks
- the ability to present results in an acceptable format.

The measuring system satisfies these requirements in the following manner.
Sound and vibration are measured and stored in one-third octave bands. This provides a reasonable compromise between the conflicting requirements of good frequency resolution and ease of numerical processing and also facilities meaningful comparisons between different products.

The measured spectra can be examined and measurements may be repeated as required. The data is stored on disk and can be modified and manipulated. Calculation is normally carried out when all the measurements have been made. The system can be left unsupervised to complete the calculations and to print out the results in report form.

Large quantities of data can be stored and manipulated. The calculation of the sound power produced by each pump typically requires measurements at twelve positions; each measurement being repeated at five different test conditions (pump speeds, fuelling etc). Thus a total of sixty one-third octave spectra (or 1800 one-third octave levels) are required to calculate the sound power spectra.

A summation average of 512 spectra each containing 31 one-third octave bands can be measured in less than 20 seconds and because of the real time capabilities the measurement period associated with each of these bands is also 20 seconds. Several such data blocks may be averaged to extend the data period.

The system uses ANSI Class III one-third octave filters together with true rms detectors with a crest factor capability of 30dB. The total measurement accuracy is better than ±0.25dB ie better than an IEC 651 Type I Sound Level Meter.

Calibration consists of fitting an acoustic calibrator to the microphone (or vibration calibrator to the accelerometer) and typing in the calibration level and the conditioning amplifier setting. The system then measures the calibration signal and calculates a 'calibration factor' to apply to all subsequent measurements.

The system is partially auto-ranging. It contains an amplifier which provides up to 10dB gain in 75 steps to regulate the signal level and maximise the dynamic range. The gain of this amplifier is controlled by software and its effect is compensated numerically. The system provides a complete series of 'prompts' for the operator for example, if gains greater than 10dB or attenuations are required then the operator is requested to change the gain of a signal conditioning amplifier.

The system produces a comprehensive printout of results which is annotated with test condition data and includes large scale, high resolution bar charts. The measured spectra and test conditions are also stored on disk to form a data-base for future comparisons and analysis.
SOUND POWER OF MACHINES IN FactORIES

The flexibility and speed of the system have been exploited in a study of the effects of microphone positions on sound power measurements of presses and machine tools.

The procedure for the measurement of sound power produced by machine tools is being discussed by the ISO Working Group ISO/TC 39/SC 6/W61. There is some concern over the specification of the required number of measurement positions and the location of these positions around large machine tools. The equipment has enabled the sound pressure to be measured at up to 85 positions around typical industrial machines. The selection of different microphone position arrays from this comprehensive data-base has expedited the development of a cost effective array. Some of the results of this study are shown in Fig 1.

![Graph showing sound power estimate (dB(A)) vs number of measurement positions](image)

Fig 1. Sound Power Estimate (dB(A)) vs No. of Measurement Positions

It is clear that the accuracy of the sound power estimate will improve as the number of measurement positions is increased. Errors of less than ±0.5dB(A) can be achieved if 8 positions are used, providing they are evenly placed around the machine. More measurement positions may be required if the machine acts as a highly directional source or if its length is very much greater than its width.
These ideas can be extended. If the measurement positions are as shown in Fig 2, then the resulting sound power estimate can be compared with the estimate obtained using other standard positions. (See Table 1).

Table 1. Sound Power Estimate (dB(A)) for several machines

<table>
<thead>
<tr>
<th>M/C</th>
<th>All Points</th>
<th>ISO 3744</th>
<th>ISO 3746</th>
<th>As in Fig 2</th>
<th>4 Corners 2 Heights</th>
</tr>
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<td></td>
<td>(70)</td>
<td>(17)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
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<tr>
<td>Compressor</td>
<td>102.1</td>
<td>102.1</td>
<td>102.4</td>
<td>102.5</td>
<td>101.9</td>
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<tr>
<td></td>
<td>(85)</td>
<td>(17)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
</tr>
<tr>
<td>Large Press</td>
<td>103.3</td>
<td>103.3</td>
<td>102.9</td>
<td>103.2</td>
<td>102.0</td>
</tr>
<tr>
<td></td>
<td>(41)</td>
<td>(9)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
</tr>
<tr>
<td>Lathe</td>
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<td>100.9</td>
<td>100.6</td>
<td>100.7</td>
<td>100.9</td>
</tr>
<tr>
<td></td>
<td>(43)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
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<tr>
<td>Small Lathe</td>
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<td>93.6</td>
<td>95.2</td>
<td>93.7</td>
<td>92.5</td>
</tr>
<tr>
<td></td>
<td>(16)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
</tr>
<tr>
<td>Pump Test</td>
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<td>104.5</td>
<td>104.4</td>
<td>104.7</td>
<td>103.1</td>
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<tr>
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<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
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</tbody>
</table>

Note: The number of measurement positions is shown in brackets.

A sufficiently accurate estimate can be obtained using the 8 positions shown in Fig 2. It should be noted that the error introduced by measuring at a small number of positions is less than the accuracy tolerance of IEC 651 Type 1 Sound Level Meters.

CONCLUSION

The introduction of this intelligent and flexible analysis system has reduced the time taken for a typical sound power measurement and calculation by a factor of 5 so that three weeks' work can now be done in three days. This has been achieved by delegating the tedious detail to the machine and leaving the engineer free to think.

The total hardware and development cost of this system was about £3000 greater than the cost of an inflexible commercially available system. The cost was repaid in the saving of engineers' time in just over one year of operation.

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