Optimising Ergonomic and Acoustic Design of Hand-held Sound Level Meters

Julian Simpson, Douglas Manvell, Lars T Kroman, Helge Larsen, Erling S Olsen

Brüel & Kjær Sound & Vibration Measurement A/S, Nærum, Denmark

Introduction

Hand-held instruments are, by their very nature, used in the hand by humans. Genetic mechanisms make sure that all humans and their hands are different; not an ideal situation for a hand-held instrument designer who would prefer clones; users with identical hands. However, in recognition of the fact that individuality does exist, a research group investigated the expectations of potential and current hand-held instrument users, and the findings were used to construct a new form of sound level meter (SLM).

Directional Response

If a measuring instrument is to be labelled “Sound Level Meter” it must conform to IEC 61672. To retain freedom in form design, the standard does not expressly give mechanical details. However, paragraph 5.3, Directional Response, specifies a set of frequency related tolerances for the maximum absolute difference in displayed sound levels at any two sound-incidence angles within ± θ degrees from the reference direction [1]. In other words, you can have any shape of case you want, so long as its acoustic effect on a measurement is within limits. This is a neat solution from a metrology point of view, but in practice the constraints all too often lead to SLMs with either long necks (to divorce the case from the microphone) or that are pear-shaped (acoustically slippery). Would it be possible to make a new shape of SLM? And do users want new shapes, or are they happy with long-necked or pear-shaped instruments? Nobody knew for sure, so we asked them.

Panel of Experts

In order to ascertain what users wanted, we approached a number people worldwide and asked them to become members of a panel of experts.

A panel of experts is a group of people that USE products – as opposed to an R&D team who DESIGN products [2]. They are generally acknowledged as being experts in their field, can and will share their expertise, and are likely to find new solutions and ideas. A panel of experts will tell the designers what they want, rather than the designers guessing what is needed (long necks or pear shapes).

From those accepting the invitation, it was possible to create seven panels of experts, each consisting of about a dozen people. Each panel was convened for one day at one of seven different locations around the world, and the day was run using the predominant local language.

The panel members represented a cross-section of experts from the community comfort and occupational health fields, and they had different levels of experience when making measurements using hand-held sound and vibration instruments from different manufacturers. Some were employed in the public sector, and there was a good mix of technicians and consultants.

For each panel, the same five different tasks were given to all members. The results of the tasks were collated into one large report running to several hundred pages, which gave a very good idea of what should and should not be included in a hand-held instrument destined for national and international markets. Several hundred pages of results may seem an insurmountable amount to digest, but when the number crunching and correlations had been done, a simple pattern emerged that summed up the design features of a new hand-held instrument; it had to be easy, safe, and clever [3].

From Panel of Experts to Industrial Designer

Having obtained a very good idea of what users wanted using the panels of experts, it was a simple step to draw up a set of specifications for the appointed Industrial Designer:

- Single unit, small size and low weight
- Fits your hand
- Fulfils acoustical standards
- Rugged - all weather proof – rain, cold, heat, dust, mud (sets material constraints)
- Clear display – indoor, outdoor, day, night
- Keys – operate one-handed by feel and with gloves on
- Detachable transducer

However, these specifications gave the designer some dilemmas:

- Small size and weight: battery life vs. performance
- Fits your hand: instrument size vs. key
- Fulfil acoustical standards: size vs. shape

After a couple of iterations producing models that satisfied the size requirements of the electronics (see Figure 1), attention was then turned to how the instrument fitted into people’s hands.

Figure 1: An existing SLM and new shape prototypes

Testing the Ergonomics

A polypropylene model of the proposed SLM shape was given to 40 test persons who were asked:

- Does it fit my hand?
- Is it convenient to hold during measurement?
- Is it easy to hold and use in one hand?
- Can I find the Start/Pause/Continue key by feel?
- Do I have a safe grip?

The result of this survey indicated that people with small hands had problems, but it didn't show why there were problems. To investigate this, the same 40 people had their hand-size measured and a photograph of how they held the instrument was recorded – see Figure 2.

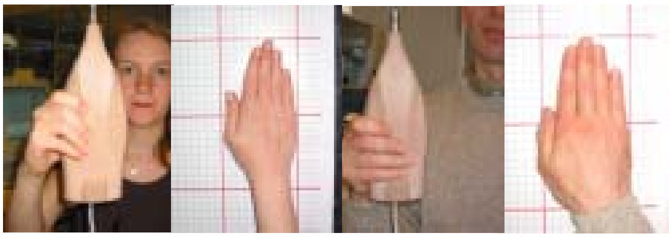

Figure 2: Examples of different hand-positions and sizes

By taking this information into account, it was then possible to produce a very ergonomic instrument shape that most people who picked it up would feel comfortable holding. But how would it be acoustically?

Getting the Acoustics Right

Despite appearing obvious, it is not necessarily the size of the SLM casing that interferes with the directional response, it is generally related to the rate of change of surface area presented to a plane wave, taking into account the frequency (wavelength). Abrupt changes cause ripples in the directional response, and small differences are most noticeable at higher frequencies. So gentle curves are the order of the day from an acoustic point of view, but this conflicts with the ergonomic requirement of having "sharp" edges to grip onto. In order to merge these two conflicting requirements, an iterative process was introduced; the designer produces a CAD-defined prototype shape, from which a surface mesh model and a polypropylene CAD-CAM "hard copy" are made. The mesh model is then subjected to boundary element calculations (BEM) and the polypropylene model is measured acoustically, both resulting in a directional response of the casing (see Figure 3). The combination of results from the calculations and measurements highlight areas that give discrepancies in the allowed directional response. The result is communicated back to the designer to incorporate in the shape and a new iteration is started.

Modelling Clay

After a number of iterations what was felt as being the final design was arrived at. A polypropylene model of this was measured as prescribed by IEC 61672 in an anechoic chamber. This showed that there were still some aberrations, particularly around the nose-cone and the underside of the casing. To fine-tune these areas, the plastic was replaced by soft modelling clay – see Figure 4 – and the design was measured again. The nose-cone shape and the underside were then altered slightly by moulding the clay as appropriate, and the model was re-measured. After a few iterations, the body influence on the directional response was found to be acceptable.

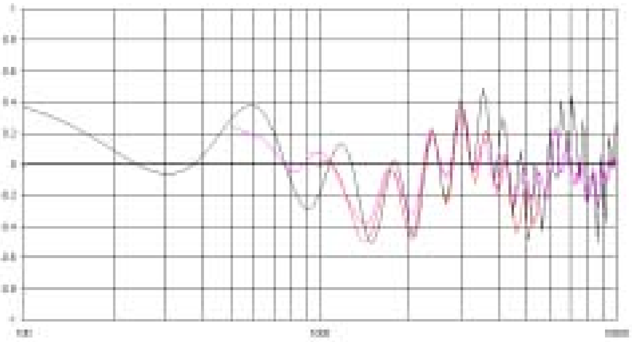

Figure 3: Intermediate body influence results for a simple mesh model (black curve), a complex mesh model with many facets (red curve), and a polypropylene model (violet curve).

Figure 4: Modifying the using modelling clay (blue/black)

Conclusion

By documenting in a non-biased way what expert users required of a hand-held instrument it was possible to create a set of requirements that could be used by a designer to produce a new SLM shape. The shape was then modified by examining how people actually hold onto it, and modified in order to fulfil the IEC 61672 directional response requirements. The result is a new shape SLM that is both highly ergonomic and satisfies the Class 1 instrumentation needs.

References

[1] IEC 61672-1 (2002-05): Electroacoustics - Sound level meters - Part 1: Specifications

[2] Brüel & Kjær Magazine, Nr. 1 2004,

[3] URL http:// www.type2250.com