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Market Share Bottom Line on Appliance Sound Quality

Can you hear it?

The sound an appliance makes can contribute to a consumer's overall evaluation of that product in terms of its acceptability, function, and perceived quality or workmanship. Sound may enhance as well as detract from the pleasure using an appliance. Sound may also indicate how well the appliance is working, and can play a role in unnecessary warranty service calls.

Manufacturers are often faced with negative reactions to the sound quality (SQ) of their products, and may be uncertain or confused as to how to go about "improving" this subjective attribute – simply decreasing the overall noise level can be expensive, and may not even be necessary in order to increase customer satisfaction. All of these issues, coupled with the need for manufacturers to develop high-end and international markets, have made SQ an important product attribute.

Just because sound quality is a subjective attribute doesn't mean there aren't ways of dealing with it. Engineering procedures exist for objectively determining, quantifying and optimizing the quality of sound an appliance produces, as defined by a given consumer market. Furthermore, these methods for "engineered sound quality" can be applied to readily evaluate the trade-offs between a given degree of SQ improvement and the corresponding anticipated product engineering effort needed to achieve such improvements. The process can thus provide specific design goals for the sound of an appliance in terms that product planners can specify (such as purchase preference or perceived effectiveness, for example) and engineers can deal with (a reduction in motor sound or a change in flow noise, for example).

Misleading Measurements

In much work concerning product sound, the inclination is to just examine the overall A-weighted sound pressure levels of similar devices measured in comparable situations, and declare that the device with the lowest dBA level is superior. This approach can be misleading, however, because consumers react to more than just overall sound level. Achieving a desired sound for an appliance shares some similarities with achieving the right color, surface texture, or shape, in that sound involves peoples' reactions, and the more favorable sound can be determined to only a very limited degree by physical measurements since the overall favorability of a sound is generally product specific (e.g., a refrigerator should not sound like a vacuum cleaner, and vice-versa).

However, while design aspects such as color and texture are generally independent of other aspects, sound is affected by many of the basic features and functionality of the appliance. The sources of motion (motors, actuators, solenoids, etc.), their interconnections, and the structures that hold them in place all participate in determining the sound that is generated. The design has to somehow connect the choices for these physical components to the perceptual reactions of existing or potential consumers of the appliance.

Jury studies that correlate SQ to design modifications are appealing to a designer since they can support the incremental changes that are normally made in the design process. For example, how many pulses should be applied to the piezoelectric lighter of a gas stove to give confidence that the burner will light but not so many that it is annoying? Or, is the pulse width modulation applied to the drive motor of a washing machine preferable (or at least equally acceptable) to a PSC motor drive in terms of the sound it produces? Or is it better to focus on reducing the broadband airflow noise in a vacuum cleaner or that narrowband tone associated with the suction fan blades, in terms of reducing annoyance while still maintaining a sense of power and cleaning efficiency?

In each case, the designer may be thoroughly comfortable with the mechanical aspects of these design alternatives, but the perceptual aspects of the sound may be daunting. Properly designed and carried out, SQ jury studies are an applicable tool to dealing with these questions and issues. Analysis of the jury data enables one to determine just how much sound an appliance “should make,” what the character of that sound “should” or “should not” be from a consumer/user perspective, and how that sound can be achieved.

Keeping Up with Changes

Two concerns about jury studies are often raised: their cost and the time they require. Product managers might feel that every time a design is changed (which may be often during development), they have to undertake a new jury study to see if an improvement in SQ has been achieved. Also, the turnaround time for a jury study may be several weeks. Naturally one asks, “Why can’t we just have an SQ button on the sound level meter?” Many meters now have a loudness output, why not “acceptability,” “perceived reliability,” or “annoyance”? Isn’t that what “SQ metrics” are all about?

The answer to this is that metrics do have their place, but because people have different expectations regarding product sounds depending on the nature of the product (e.g., unlike metrics, their reactions to product sounds are product specific), a jury test with actual product users is usually needed if the goal is to truly optimize sound quality to gain market share. The jury thus serves as a kind of “SQ meter,” customized for a particular type of product. A jury test also enables topics such as purchase likelihood based on sound to be addressed. Once a jury study has been carried out there is usually no need to hold another one, since a properly designed study will generate a model that enables the designer to predict the effects on SQ of specific design changes. Furthermore, it is often possible to form a correlation between a combination of a relevant subset of SQ metrics and the SQ jury test results, which can then be used to broaden the product class on which predictions of SQ can be made.

By mixing together altered versions of the actual sounds of the various noise-producing components that exist within an appliance (e.g., the sounds of the major physical parts and/or mechanisms contributing to the total sound), configurations of “virtual” versions of that appliance can be created. By listening to and rating the sounds of these virtual products, it can be determined which modifications will maximize, in some predefined sense, the sound quality as perceived by actual users/buyers of the appliance.

Steps Taken

The procedure for carrying out this type of jury testing will generally involve the following steps: First, identifying the particular sound quality attributes of interest and the sound-producing components or mechanisms of interest; and second using design-of-experiments methodology and other statistical considerations to design

the jury tests according to the number of components, operating modes and attributes of interest. Third, recording, synthesizing or otherwise generating the sounds of the identified components or mechanisms of interest, and then mixing modified versions of these component sounds together according to the test design to create the sound stimuli sets; and fourth, presenting the sounds of the resulting virtual products to selected juries representing a cross-section of the desired consumer base, and recording their responses in terms of rating values (or preferred choice if the jury test is of the paired comparison type). Fifth, analyzing the jury results with the goal of forming a regression model for quantitatively relating the SQ attribute ratings to changes in component sounds; and sixth, forming a customized set of SQ metrics by correlating the jury test results with relevant SQ metrics computed on the sounds presented to the jury (with “relevancy” being determined with statistical procedures such as Principal Components Analysis or Partial Least Squares).

Typical outcomes from a sound quality analysis such as described above are given in the figures on the opening article page. One illustrates the basic form of information obtained from a regression analysis performed on jury ratings of the “acceptability” of sound produced during the fill cycle of a front-loading washing machine, as the sound levels of flow noise and of a valve closure are varied (exploring the space with increased sound levels is also included, since SQ attribute ratings can sometimes increase with increasing levels). The figure clearly shows that the overall level of flow noise has a much larger influence on acceptability than does the level of valve closure sound. In this case, since there are only two components that were varied, a three-dimensional plot serves to convey the entire behavior of the regression model. Visualizing models with more than two sound producing components is not as easy, since there are then more than three dimensions to deal with. One approach is to examine slices or contours through the response surfaces generated by varying two components at a time, while holding the remaining components at some fixed value such as 0 dB change from their baseline values.

An example of such a contour plot is also on the opening page and shows how the rating values for “perceived quality of workmanship” for an air tool device change as a function of the sound levels of two components: the exhaust pulsation and the turbulent air flow. In this case, a maximum value for perceived quality would be obtained if the pulsation noise could be decreased by 6 dB and the turbulent air noise allowed to actually increase by about 2 dB. However, if it appears that these changes are not feasible to implement, then one can come off the maximum somewhat and settle for a smaller but still significant degree of rating improvement, as represented by any point along one of the contours. Some of these combinations may be easier to implement than others.

The output as represented by contour diagram resulting from an SQ jury study and its subsequent analysis thus offer a powerful tool for evaluating and optimizing the trade-offs between engineering effort and increasing the SQ of the product.

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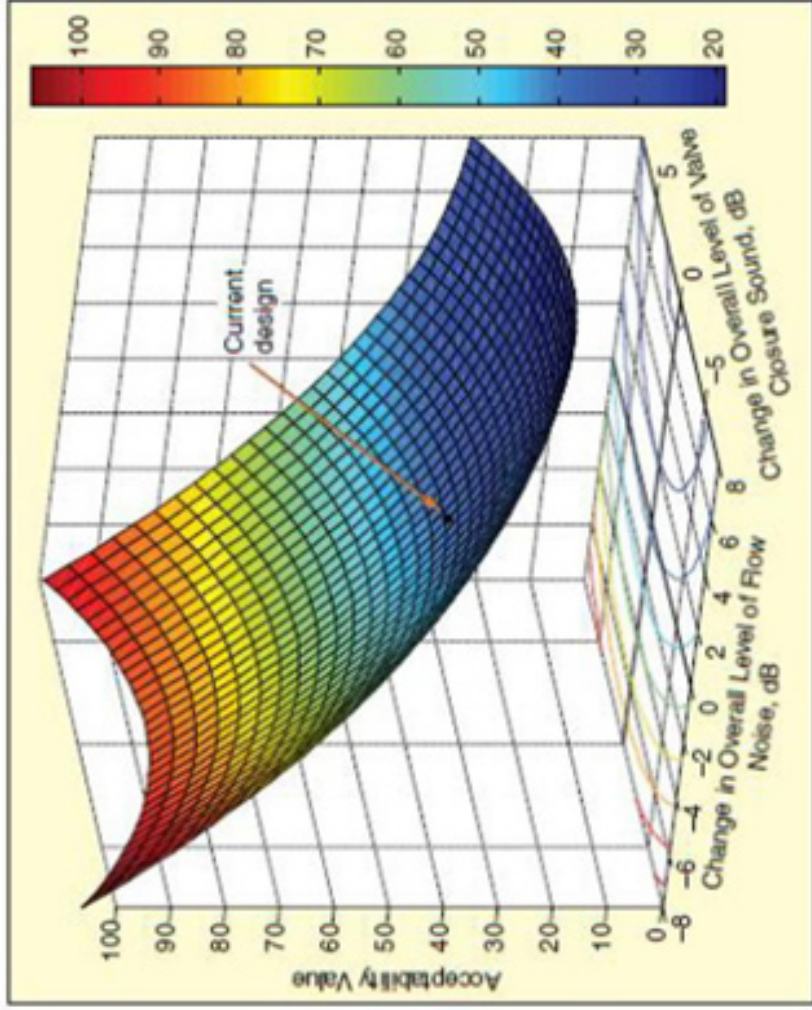


Figure 1.

Regression model response surface for 'acceptability' of the sound of the fill cycle in a front loading washing machine, showing how the value of this attribute, as rated by a jury of consumers on a scale of 0 to 100, changes as the sound levels of flow and valve closure change from their present values.

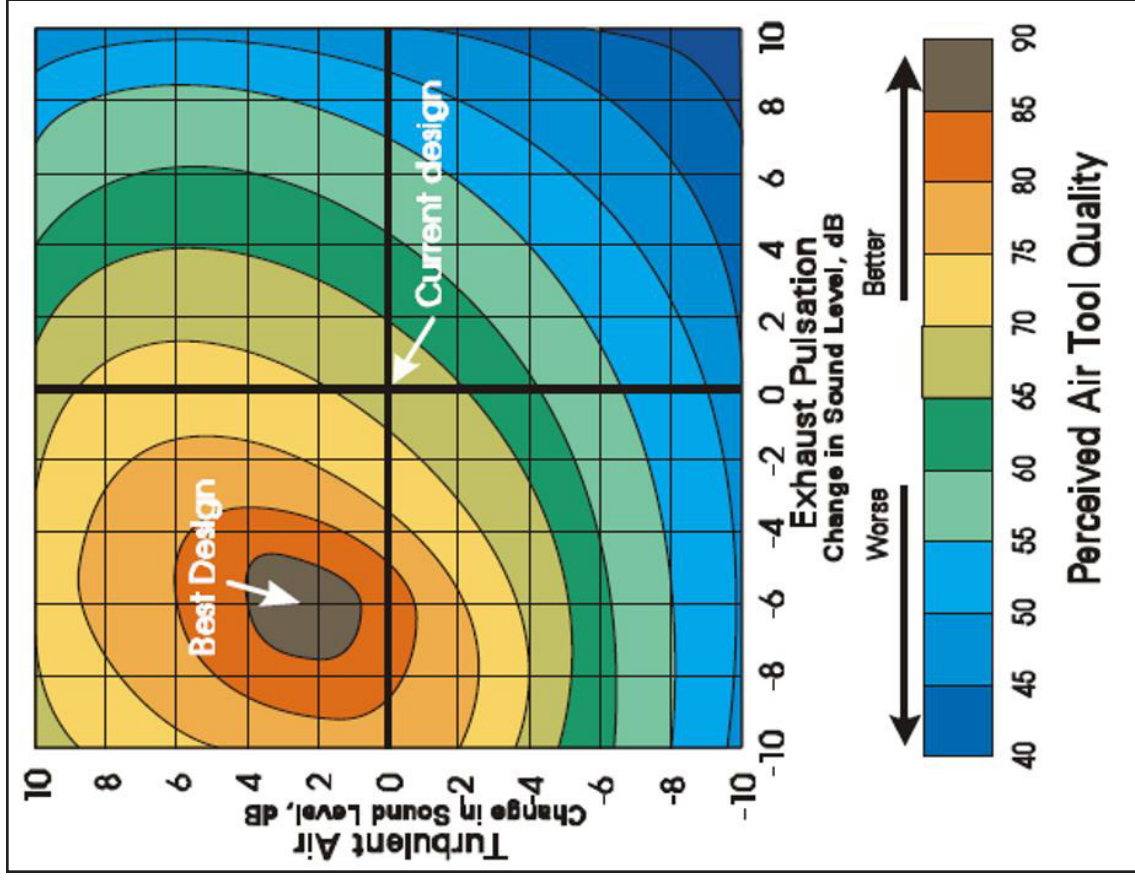


Figure 2.

Contour diagram for the perceived workmanship quality of an air tool device, as a function of the sound levels of two of its major sound producing mechanisms.